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The "Umbrella Effect" of the European Natura 2000 protected area network

Technical report

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'Natura 2000 - Europe's nature for you. This site is part of the European Natura 2000 Network. It has been designated because it hosts some of Europe's most threatened species and habitats. All 28 countries of the EU are working together through the Natura 2000 network to safeguard Europe's rich and diverse natural heritage for the benefit of all'.

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Theo van der Sluis, Ruud Foppen, Simon Gillings, Thomas Groen, René Henkens, Stephan Hennekens, Kim Huskens, David Noble, Fabrice Ottburg, Luca Santini, Henk Sierdsema, Andre van Kleunen, Joop Schaminee, Chris van Swaay, Bert Toxopeus, Michiel Wallis de Vries and Lawrence Jones-Walters, 2016. *How much Biodiversity is in Natura 2000?; The "Umbrella Effect" of the European Natura 2000 protected area network.* Wageningen, Alterra Wageningen UR (University & Research centre), Alterra report 2730B. 148 pp.; 82 fig.; 12 tab.; 83 ref.

Om de betekenis van het veronderstelde 'paraplu-effect' van Natura 2000 gebieden te bepalen, heeft de Europese Commissie in 2013 een onderzoek geïnitieerd met de volgende vragen: 1) Wat zijn, van de algemeen voorkomende soorten binnen de EU-28 lidstaten, de soorten die significant voordeel hebben van gebiedsbescherming onder de Vogel- en Habitat richtlijn? 2) Wat is het percentage, van alle soorten die in het wild in de EU voorkomen, dat significant profiteert van Natura 2000? 3) Hoe significant is de bijdrage van Natura 2000 aan de beleidsdoelstelling om het biodiversiteitsverlies te stoppen en om te keren? Bij onze aanpak is gebruik gemaakt van bestaande data van terrestrische zoogdieren, vogels, reptielen, amfibieën, vlinders en plantensoorten. De analyse is voornamelijk gebaseerd op statische verspreidingsmodellen en een GIS-analyse van verspreidingsgegevens met betrekking tot de aanwezigheid binnen beschermde gebieden van het Natura 2000 netwerk. De belangrijkste resultaten zijn: soorten waar niet specifiek Natura 2000 gebieden voor zijn aangewezen, komen vaker voor binnen dan buiten Natura 2000 gebieden (vooral vogels en vlinders). Vooral deze soorten profiteren daarom van het natuurbeschermingsnetwerk. Soorten waarvoor Natura 2000 gebieden zijn aangewezen, komen in het algemeen vaker voor binnen de begrenzing van Natura 2000 gebieden, dan de non-annex soorten; dit geldt vooral voor vogels en vlinders, terwijl het verschil voor amfibieën en reptielen verwaarloosbaar is. Meer specifieke conclusies en bevindingen, alsmede een discussie van de resultaten en implicaties voor vervolgstudies zijn opgenomen in het rapport.

In order to assess the significance of the presumed "umbrella effect" of Natura 2000 areas the European Commission initiated a study, in 2013, to address the following questions: 1) Which are, amongst the species regularly occurring within the European territory of the EU-28 Member States, those that significantly benefit from the site conservation under the EU Birds and Habitats Directive? 2) What is the percentage of all species occurring in the wild in the EU that benefit significantly from Natura 2000? 3) How significant is the contribution of Natura 2000 in relation to the objective of halting and reversing biodiversity loss? The approach used existing data, and covered the terrestrial mammals, birds, reptiles, amphibian, butterfly and plant species. The analysis is mostly based on statistical distribution models and GIS processing of species distribution data in relation to their presence within protected areas of the Natura 2000 network. The main findings for all species groups were: Animal species for which Natura 2000 areas were not specifically designated occur more frequently inside Natura 2000 than outside (in particular breeding birds and butterflies). These species do, therefore, gain benefit from the protected areas network. The species for which Natura 2000 areas were designated generally occur more frequently within the Natura 2000 site boundaries than the non-annex species; this is in particular the case for birds and butterflies, for amphibians and reptiles the difference is negligible. More specific conclusions and findings, as well as discussion of these results and implications for further studies are included in the report.

A summary report is available:
Lawrence Jones-Walters, Simon Gillings, Thomas Groen, Stephan Hennekens, David Noble, Luca Santini, Henk Sierdsema, Andre van Kleunen, Chris van Swaay and Theo van der Sluis (2016) *The "Umbrella Effect" of the Natura 2000 network: An assessment of species inside and outside the European Natura 2000 protected area network*. Wageningen, Alterra Wageningen UR (University & Research centre), Alterra report 2730A. 16 pp.; 30 fig.; 3 tab.; 0 ref.

Keywords: biodiversity, Natura 2000, Habitats Directive, Birds Directive, birds, mammals, reptiles, amphibians, butterflies, plants, statistical models, spatial analysis, GIS, umbrella effect, biodiversity loss.

The pdf file is free of charge and can be downloaded at http://dx.doi.org/10.18174/385797 or via the website www.wageningenUR.nl/en/alterra (scroll down to Publications - Alterra reports). Alterra does not deliver printed versions of the Alterra reports.

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Photo cover: extensive grasslands adjacent to Natura 2000 areas in South Limburg (Netherlands) (by L. Jones Walters)

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Preface

In May 2015 the European Commission published the report *The State of Nature in the European Union* an evidence base which sets out the status of and trends for habitat types and species covered by the Birds and Habitats Directives for the period 2007-2012. The report, which is based on information reported by 27 Member States, provides a basis for formally judging the success of the nature directives in relation to their original goals. However, the State of Nature report does not show the wider contribution of Natura 2000 to the conservation of species that are not listed in the annexes to the Directives.

The need to understand this contribution is driven by a general inquiry into the effectiveness of the Nature Directives and the EU strategic target, expressed within the Biodiversity Strategy to 2020, to "halt the deterioration of all species and habitats and achieve a significant and measurable improvement in their status…." It focusses in particular on the functionality of the Natura 2000 network in Europe as a key prerequisite for conserving biodiversity. In 2013 the European Commission therefore initiated this research project to assess the significance of the presumed "umbrella effect" of Natura 2000, related to its potential contribution in terms of halting and reversing the loss of species other than those for which the Natura 2000 sites have been set-up.

Furthermore, the European Commission had already announced in its Work Programme for 2010 that in order: "to keep current regulation fit for purpose, the Commission will begin reviewing ... the entire body of legislation in selected policy fields through Fitness Checks". Pilot exercises began in 2010, paving the way for further fitness checks of environmental policy instruments of which a review of the Nature Directives has been the most recent. Evidence for the Fitness Check has come from a number of sources including the recorded progress in relation to the delivery of the Directives, together with their associated (statutorily required and therefore widely available and comparative) reporting processes which are embedded in the pieces of legislation themselves. This project has also therefore been timely in being able to provide valuable evidence in relation to the effectivenes and wider contribution of the Directives to biodiversity protection and management in Europe.

This report provides the detailed results of the project *How much Biodiversity is in Natura 2000? The "Umbrella Effect" of the European protected area network.* It is a significant body of work with many interesting conclusions and recommendations for further study. These are also summarised in a shorter report that is available as a PDF for downloading. A data product that summarises the results for individual species in tabular form is also available. Together we recommend these to the community of interest around Natura 2000 and biodiversity in the European Union.

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Executive summary

Natura 2000 is a network of protected areas that now covers around 18% of the land surface of the European Union. These sites are designated under the Birds and Habitats Directives and the network includes both terrestrial and marine sites (Marine Protected Areas, MPAs). The ultimate goal of the two 'Nature Directives' is to ensure the long-term sustainability of more than 230 habitats and 1,500 species of animals and plants of 'Community Interest' and all bird species naturally occurring in the EU (Fig. 1). In May 2015 the Commission published the report *The State of Nature in the European Union* an evidence base which sets out the status of and trends for habitat types and species covered by the Birds and Habitats Directives for the period 2007-2012. The report provides a basis for formally judging the success of the nature directives in relation to their original goals.

The *State of Nature* report does not show the wider contribution of Natura 2000 to the conservation of species that are not included in the lists that make up the annexes to the Directives. The need to understand this contribution is driven by a general inquiry into the effectiveness of the Nature Directives and the EU strategic target, expressed within the Biodiversity Strategy to 2020, to "halt the deterioration of all species and habitats and achieve a significant and measurable improvement in their status…." It focusses in particular on the functionality of the Natura 2000 network in Europe as a key prerequisite for conserving biodiversity. In 2013 the European Commission therefore initiated a research project to assess the significance of the presumed "umbrella effect" of Natura 2000, related to its potential contribution in terms of halting and reversing the loss of species other than those for which the Natura 2000 sites have been set-up.

The research was focussed on terrestrial habitats and, in order to investigate the umbrella effect of Natura 2000, it addressed the general question of: *"How much biodiversity is covered by Natura 2000?"*, further specified as follows*:*

- Which are, amongst the species regularly occurring within the European territory of the EU-28 Member States (common species), those that significantly benefit from the Natura 2000-related site conservation requirements under the EU Birds and Habitats Directive?
- What is e.g. in percentage of all species occurring in the wild in the EU, the share of EU species significantly benefitting from Natura 2000?
- How significant is this contribution of Natura 2000 in relation to the objective of halting and reversing biodiversity loss?

Key considerations were the spatial distribution, the geographical range[1] of species within the EU-28 countries[2], and the presence of species within Natura 2000 and outside the network. The presence can be expressed in the form of a simple figure or percentage of the distribution of a species within Natura 2000.

Specific consideration was given to 'common' species which are the species that are not included in the annexes of either directive (for which areas were designated). However, in all cases the conservation value of species was assessed based on their position on Red Lists and endemic status. The study was accompanied by a literature review that provided context in relation to the research questions.

[1] 'Range' refers to the overall geographical envelope within the EU territory and 'distribution' is the spatial occurrence within the envelope.
[2] Some specific areas that do not form a coherent part of the EU territory were excluded because from biogeographical point of view they belong to a different zone or data was not available. These included the Macaronesian Islands, some Spanish enclaves on the African mainland and, for the birds, reptiles and amphibians, Cyprus.

The approach used existing data, for as many groups as possible and covered the terrestrial mammals, birds, reptiles, amphibian, butterfly and plant species. The analysis is mostly based on GIS processing of species distribution data in relation to their presence within protected areas of the Natura 2000 network. Statistical distribution models were used as a cross-validation tool.

In relation to the question of 'significant beneficial effect', 18% of Europe's land surface is Natura 2000. With a totally random distribution of species over the EU, on average 18% of their distributions would occur within Natura 2000. However, if the distribution of species is more than 18% in Natura 2000 (or less), this can provide the basis for considering if a benefit is being provided or whether some other effect may be being observed. 18% also provides an easily communicated baseline for judging the benefits provided by Natura 2000 to common species in the EU. For the results at country level the respective Natura 2000 coverage in each country was used as the baseline.

There is also a potential for sampling bias, particularly with the species presence data derived from the opportunistic data recording for which there may be more collection of species records within Natura 2000 sites because of their designation and the types of habitat. A spatial bias correction technique was therefore applied; this allowed for a reduction of the error by predicting a high probability of presence where many presence data are available, and predicting low probability of presence where presence data are unavailable (but the species could be present).

In summary for the animal groups:
- Common animal species and other 'non-Annex' animal species occur more frequently inside Natura 2000 than outside (in particular breeding birds and butterflies).
- Animal species for which Natura 2000 areas were not specifically designated (non-annex species) do, therefore, gain benefit from the protected areas network.
- The species of the annexes benefit more (that is, generally occur more frequently within the Natura 2000 site boundaries) than the non-annex species; this is in particular the case for birds and butterflies, for amphibians and reptiles the difference is negligible.

Natura 2000 sites do not only therefore serve their purpose in protecting the Annex 1 (Birds Directive) and Annex 2 (Habitats Directive) species but also provide significant added value to non-Annex species. A range of further conclusions for birds are that:
- Species with smaller ranges and restricted distributions have better coverage in the Natura 2000 network compared to species with large ranges and wider distributions.
- Species associated with natural habitats (as opposed to semi-natural habitats), in particular mountainous areas, have better coverage/ over-representation in the Natura 2000 network.
- The countries having highest coverage of species' distribution in Natura 2000 are the 'set' of South and East European countries: Bulgaria, Croatia, Slovakia, Hungary, Slovenia, Romania, Greece and Spain.
- In general, species for which Natura 2000 sites have been designated (Annex I species) have a larger proportion of their distribution in the network than non-Annex I species.

For butterflies it can be concluded that:
- In almost all countries butterflies are benefitting from Natura 2000.
- Threatened butterflies, either on the pan-European or on the EU-27 list, are benefitting from Natura 2000 areas.
- Endemic butterflies benefit from Natura 2000 areas.

The mammals showed similar but less strong patterns to the birds and butterflies with differences emerging for large mammals. The main conclusions are that:
- A majority of European mammal species benefit from Natura 2000.
- Large mammals are less likely to show an association with, or to derive an identifiable benefit from Natura 2000.
- Although Natura 2000 sites are not evenly distributed in EU-28, and some countries have relatively low percentages of coverage, some countries protect mammal species less than expected by the total number and area of sites.

For the amphibians and reptiles it can be concluded that:

- A majority of European species benefit from Natura 2000.
- There is little difference in the level of protection by Natura 2000 for Annex II species and non-Annex II species.
- There was a clear north south gradient in the level of coverage by Natura 2000; northern countries have fewer species that are less well covered by Natura 2000 compared to southern countries that have more species that have higher coverage by Natura 2000.
- The assessment was less accurate for marsh turtles and cave salamanders.

Based on the analyses of plant species distribution it may be concluded that:

- Red list species and some other rare species occur significantly more often inside than outside Natura 2000 sites.
- None of the plant species considered in this study showed a strong preference for areas outside Natura 2000 sites.
- Natura 2000 sites exert a strong ‘buffer zone’ effect.

The presence of a strong buffer zone effect around sites for plants suggests that, whilst future work could look at the implications of this and test with other taxonomic groups, there are other issues related to the impact of the wider countryside connected to but beyond Natura 2000. Green infrastructure has Natura 2000 and other protected areas at its heart and the approach and analysis that have been used here could be applied to questions about policy and practice in relation to connectivity through buffer zones, stepping stones and ecological corridors. This could be facilitated by the investigation and use of additional information on habitats and networks derived from Copernicus as well as other remote sensing data.

Furthermore the approaches used in this study could be applied to other drivers of biodiversity patterns such as climate change, for example modelling the impacts of temperature increase. Another policy issue of relevance, linked to the importance of high quality habitats for a range of species, and which could be modelled is that of land abandonment. This process has already had a detrimental effect on butterflies, less so potentially for large mammals and it could be valuable to assess its impact for other groups.

Finally, the role of taxa such as butterflies as indicators of the health of habitats and ecosystems within the Natura 2000 network might also be explored further as their sensitivity to both biotic and abiotic change could tell us much about species, in particular the huge array of other invertebrates, some with similar associations to habitats.

The results confirm that Natura 2000 sites provide important additional value for a range of biodiversity and among the taxonomic groups tested, butterflies and birds appear to benefit the most. The study also confirms that Natura 2000 sites are fulfilling their primary purpose of protecting the species in Annex I of the Birds Directive and Annex II of the Habitats Directive.

It is clear that the majority of species rich habitats in Europe are already in Natura 2000 sites. This emphasises the importance of policy and financial instruments and the associated management measures which are used to continue to maintain and restore habitats in Natura 2000 sites to a condition that is favourable for all of their associated species. The exceptions to this **include habitats in the** Boreal region and some areas of traditionally managed agricultural land in Eastern and Southern Europe. Whilst this conclusion could be further investigated, the results of this study suggest that more forest and traditional agricultural land should be included within Natura 2000 or, at least, should be considered for sympathetic management.

Sommaire exécutif

Le réseau Natura 2000 rassemble des zones protégées qui recouvrent actuellement le territoire de l'Union européenne à hauteur de 18%. Ces sites sont désignés dans les Directives «Oiseaux» et «Habitats» et le réseau comprend des sites à la fois terrestres et marins (Aires marines protégées /AMP). L'objectif ultime des deux «Directives Nature» est de garantir la durabilité à long terme de plus de 230 habitats et de 1500 espèces animales et végétales «d'intérêt communautaire» ainsi que de toutes les espèces d'oiseaux vivant naturellement à l'état sauvage dans l'UE (Fig. 1). En mai 2015 la Commission a publié le rapport *L'état de conservation de la nature dans l'Union européenne*, une assise factuelle qui définit le statut de et les tendances pour les types d'habitat et les espèces couvertes par les Directives «Oiseaux» et «Habitats» pour la période 2007-2012. Le rapport fournit une base d'évaluation formelle du succès des «Directives Nature» par rapport à leurs objectifs d'origine.

L'État de la nature ne montre pas l'élargissement de la contribution de Natura 2000 à la conservation des espèces non inscrites dans les listes constituant les annexes des Directives. Le besoin de comprendre cette contribution est motivé par une enquête générale sur l'efficacité des «Directives Nature» et l'objectif stratégique de l'UE, exprimée dans la Stratégie Biodiversité à l'horizon 2020, pour «enrayer la détérioration de l'ensemble des espèces et des habitats et parvenir à une amélioration significative et mesurable de leur statut...» On y met en particulier l'accent sur la fonctionnalité du réseau Natura 2000 en Europe dont on considère qu'elle est la condition sine qua non de la conservation de la biodiversité. En 2013 la Commission européenne a donc lancé un projet de recherche visant à évaluer l'importance de l'«effet parapluie» présumé de Natura 2000, par rapport à sa contribution potentielle pour stopper et inverser la perte d'espèces autres que celles pour lesquelles les sites de Natura 2000 ont été créés.

La recherche portait essentiellement sur les habitats terrestres et, pour fournir un examen spécifique de l'«effet parapluie» de Natura 2000, elle posait la question générale suivante: «*Dans quelle mesure la biodiversité est-elle couverte par Natura 2000?*», laquelle question était spécifiée comme suit*:*

- Quelles sont, parmi les espèces vivant régulièrement à l'état sauvage sur le territoire des 28 États membres de l'Union européenne (espèces communes), celles qui bénéficient de manière significative des exigences de conservation des sites liés à Natura 2000 en vertu de la Directive «Oiseaux» et «Habitats» de l'UE?
- Quelle est en pourcentage de toutes les espèces vivant à l'état sauvage dans l'UE notamment, la part des espèces de l'UE bénéficiant considérablement de Natura 2000?
- Quelle est la portée de cette contribution de Natura 2000 par rapport à l'objectif visant à stopper et à inverser la perte de biodiversité?

Les considérations clés étaient la distribution spatiale, la répartition (range[3]) géographique des espèces sur le territoire des 28 pays [4] de l'UE, ainsi que la présence des espèces à l'intérieur de Natura 2000 et à l'extérieur du réseau. La présence peut être exprimée sous la forme d'un simple chiffre ou d'un pourcentage de la distribution d'une espèce au sein de Natura 2000.

Les espèces dites «communes» ont bénéficié d'une attention particulière car il s'agit des espèces non inscrites aux annexes d'une quelconque Directive (pour laquelle des zones avaient été indiquées). Toutefois, dans tous les cas, la valeur de conservation des espèces a été évaluée en fonction de leur

[3] Le terme «range» (répartition) fait référence à l'enveloppe géographique globale à l'intérieur du territoire communautaire et la «distribution» constitue l'apparence spatiale au sein de l'enveloppe.

[4] Certaines zones spécifiques qui ne forment pas une partie cohérente du territoire de l'Union européenne ont été exclues parce qu'elles relèvent d'une zone différente d'un point de vue biogéographique ou parce que les données n'étaient pas disponibles. Ces zones comprenaient la Macaronésie, certaines enclaves espagnoles sur le continent africain et Chypre pour les oiseaux, les reptiles et les amphibiens.

position dans les Listes rouges et de leur statut d'endémisme. L'étude était accompagnée d'une revue littéraire qui fournissait le contexte lié aux questions de la recherche.

L'approche a utilisé des données existantes pour le plus grand nombre possible de groupes et elle a couvert les plantes, les mammifères (terrestres), les oiseaux, les reptiles, les espèces d'amphibiens et de papillons. L'analyse repose essentiellement sur le
système SIG de traitement de données concernant la distribution des espèces par rapport à leur présence à l'intérieur des zones de protection spéciales (ZPS) du réseau Natura 2000. Des modèles de distribution statistique ont servi d'outil de validation croisée.

En ce qui concerne la question de «l'effet bénéfique significatif», 18% de la superficie terrestre de l'Europe sont couverts par le réseau Natura 2000. Avec une distribution des espèces complètement aléatoire dans l'UE, on pourrait donc s'attendre à ce que 18% d'entre elles apparaissent dans Natura 2000. Toutefois, si la distribution des espèces est supérieure (ou inférieure) à 18% dans Natura 2000 cela peut constituer une base pour examiner si son effet est bénéfique ou si l'on observe l'apparition d'un tout autre effet. Ces 18% fournissent en outre une base de référence facilement communiquée d'évaluation des conséquences salutaires de Natura 2000 sur les espèces communes de l'UE. En ce qui concerne l'examen des pays pris individuellement, leur chiffre spécifique pour la couverture de Natura 2000 a servi de base de référence.

Il se pourrait en outre qu'on utilise le biais d'échantillonnage (parce que les données sur la présence d'espèces sont collectées sur une base opportuniste et d'autres collectes d'enregistrements d'espèces peuvent exister au sein de Natura 2000). C'est la raison pour laquelle une technique de correction du biais spatial a été appliquée; ceci a permis de réduire l'erreur en calculant une forte probabilité de présence là où de nombreuses données de présence sont disponibles et en calculant une faible probabilité de présence là où des données de présence ne sont pas disponibles (alors que les espèces pourraient être présentes).

En résumé pour les groups d'animaux:
- On rencontre des espèces animales communes ainsi que d'autres espèces animales «non-annexes» plus fréquemment à l'intérieur du réseau Natura 2000 qu'à l'extérieur (en particulier les oiseaux nicheurs et les papillons).
- Les espèces animales auxquelles on n'a pas expressément attribué des zones Natura 2000 (espèces animales «non-annexes») tirent par conséquent un avantage certain du réseau de zones de protection spéciales.
- Les espèces des annexes en profitent plus (enfin, cela se produit généralement plus fréquemment à l'intérieur des limites de la zone Natura 2000) que les «autres» espèces; c'est surtout le cas pour les oiseaux et les papillons, la différence étant négligeable pour les amphibiens et les reptiles.

Par conséquent les sites de Natura 2000 ne servent pas uniquement à protéger les espèces mentionnées à l'Annexe 1 (Directive Oiseaux) et à l'Annexe 2 (Directive Habitats) mais aussi à apporter une valeur ajoutée importante aux espèces animales «non-annexes». Vous trouverez ci-après quelques autres conclusions pertinentes pour les oiseaux:
- Les espèces aux répartitions réduites et aux distributions restreintes ont une meilleure couverture dans le réseau Natura 2000 que les espèces aux répartitions plus importantes et aux répartitions plus étendues.
- Les espèces associées à des habitats naturels (par opposition à des habitats semi-naturels), surtout dans les régions montagneuses, ont une meilleure couverture/sur-représentation dans le réseau Natura 2000.
- Les pays disposant de la plus grande couverture de distribution d'espèces dans le réseau Natura 2000 sont ceux de l'Europe orientale et méridionale: la Bulgarie, la Croatie, la Slovaquie, la Hongrie, la Slovénie, la Roumanie, la Grèce et l'Espagne.
- En général, la proportion de distribution des espèces animales auxquelles on a attribué des zones Natura 2000 (espèces Annexe I) est plus importante dans le réseau que les espèces ne relevant pas de l'Annexe I.

Quant aux papillons, on peut conclure que:
- Dans presque tous les pays les zones Natura 2000 sont bénéfiques aux papillons.
- Les zones Natura 2000 sont bénéfiques aux papillons menacés de disparition, soit sur la liste paneuropéenne soit sur la liste des 27 états membre de l'UE.
- Les zones Natura 2000 sont bénéfiques aux papillons endémiques.

Les mammifères ont montré des tendances similaires quoique moins prononcées que les oiseaux et les papillons avec l'émergence d'un modèle différent chez les grands mammifères. On peut par conséquent en conclure que:
- Les zones Natura 2000 sont bénéfiques à une majorité d'espèces de mammifères d'Europe.
- Les grands mammifères sont moins susceptibles de montrer l'existence d'un lien avec ou de tirer profit identifiable des zones Natura 2000.
- Les sites de Natura 2000 ne sont pas répartis de manière équitable sur le territoire des 28 États membres de l'UE et le pourcentage de couverture est relativement faible dans certains pays. Pourtant quelle que soit la couverture totale, certains pays protègent moins que prévu les espèces de mammifères par rapport au nombre total de zones ou de sites.

En ce qui concerne les amphibiens et les reptiles, on peut conclure que:
- Les zones Natura 2000 sont bénéfiques à une majorité d'espèces d'Europe.
- Il n'y a quasiment pas de différence entre le niveau de protection offert par Natura 2000 aux espèces inscrites à l'Annexe II et celui offert aux espèces inscrites à la non-Annexe II.
- Il existait un gradient Nord-Sud évident by Natura 2000 quant au niveau de couverture; les pays du Nord ont moins d'espèces qui sont moins bien couvertes par le réseau Natura 2000 alors que les pays du Sud ont un plus grand nombre d'espèces qui sont mieux couvertes par le réseau Natura 2000.
- L'évaluation était moins précise pour la tortue des marais et la salamandre de grotte.

Les analyses de la distribution des espèces végétales nous permettent de conclure que:
- Les espèces inscrites sur la Liste rouge ainsi que quelques autres espèces rares sont nettement plus courantes à l'intérieur des sites Natura 2000 qu'à l'extérieur.
- Aucune des espèces végétales prises en compte n´a de préférence particulière pour des zones situées à l'extérieur des sites Natura 2000.
- Les sites Natura 2000 ont un effet «zone tampon» puissant.

L'existence d'un effet *«zone tampon»* puissant autour des sites suggère, tandis que les travaux futurs pourraient en examiner les implications, qu'il existe aussi des problèmes qui touchent la vaste campagne au-delà. Natura 2000 et les autres zones de protection spéciales se trouvent au cœur de l'infrastructure verte et l'approche et l'analyse utilisées ici pourraient être appliquées à des questions concernant la politique et la pratique par rapport aux zones tampon, aux structures en pas japonais (*stepping stones*) et aux corridors écologiques. Cela pourrait être relié aux données de Copernic et à la télédétection.

Par ailleurs l'approche peut être appliquée à des problèmes tels le changement climatique et la modélisation de l'impact du réchauffement climatique. Le problème des abandons constitue ici une autre question de fond pertinente, liée à l'importance pour une variété d'espèces d'avoir des habitats de grande qualité et qui devrait être modélisée. Ce processus a déjà eu des effets néfastes sur des groupes comme les papillons, potentiellement et dans une moindre mesure pour les grands mammifères. Il est néanmoins important d'évaluer ces impacts.

Finalement, le rôle d'indicateur que jouent des groupes comme celui des papillons pourrait également être exploré car la sensibilité de ces derniers aux variations biotiques et abiotiques pourrait nous en apprendre beaucoup sur les espèces, particulièrement sur les invertébrés ayant des associations similaires aux habitats, la santé globale des habitats et des écosystèmes à l'intérieur comme à l'extérieur de Natura 2000.

Les résultats confirment que les sites Natura 2000 génèrent une valeur supplémentaire importante pour la biodiversité commune et parmi les groupes mis à l'essai les papillons et les oiseaux en profitent le plus. L'étude a également confirmé qu'ils répondent à leur vocation première, celle de protéger les espèces inscrites à l'Annexe I de la Directive Oiseaux et à l'Annexe II de la Directive Habitats.

Il est clair que la majorité des habitats exceptionnels des espèces restantes se trouve déjà sur les sites de Natura 2000. Cela souligne l'importance des instruments politiques et financiers ainsi que des mesures de gestion connexes qui continuent à restaurer ou à maintenir les habitats dans les sites de Natura 2000 dans un état favorable à l'ensemble de leurs espèces associées. Les habitats boréals et quelques zones de terres agricoles gérées traditionnellement dans l'Europe orientale et méridionale pourraient constituer l'exception à cette règle. Quoiqu'il faille approfondir cette question, les résultats laissent actuellement supposer que Natura 2000 pourrait inclure plus de forêts et de terres agricoles traditionnelles ou qu'elles devraient au moins être retenues pour gestion bienveillante.

1 Introduction

In this chapter, we describe the Natura 2000 network and summarise its development, current reporting requirements, as well as the aims and scope of this study. In Chapter 2 we provide an overview of the recent key publications related to the assessment of the network that are relevant in the context of this work. Chapter 3 presents the general analysis approach, and modifications of the approach that were made for specific taxa, largely due to differences in the data resources available for the different taxa. Chapter 4 presents the results of all sets of analyses, including those specifically for the species of the Annexes I and II of the Birds and Habitats Directive, as well as for species grouped by other criteria such as conservation status. In addition to the EU-level analyses, we also carried out country-level analyses for all groups, to provide insights into the results for particular species and to test the robustness of the method at different geographic scales. This is followed by a discussion of the results for the specific taxa (Chapter 5) and recommendations for policy (Chapter 6), as well as for further research.

The Natura 2000 network is the collective term given to the network of protected areas that are designated as part of the implementation of the Birds and Habitats Directives. We do not discuss the Directives and their different annexes in detail: for this the reader is referred to the official website of the Commision (http://ec.europa.eu/environment/nature/index_en.htm). This work only considers the terrestrial areas of the Natura 2000 network; marine reserves or aquatic species have not been evaluated in this study. The figures we use for total land area covered by Natura 2000 are based on the database from the EEA and the most recent publications of the European Commission. Appendix 1 of the report provides a glossary of terms and abbreviations used in this report.

The numbering of figures and tables is based on the chapter, e.g. Figure 4-3 is the third figure in Chapter 4. Figures or tables' number starting with A (e.g. A-3) can be found in the appendixes of the report.

1.1 The Natura 2000 network

The Natura 2000 network, as part of the Habitats (92/43/EEC) and Birds (79/409/EEC) Directives, is one of the most important tools for preventing further loss of biodiversity in the European Union, large parts of it intensively farmed, strongly urbanised and fragmented. The network should have a positive impact on the conservation of the indigenous flora and fauna.

Natura 2000 is a network of nature protection areas in the European Union (Fig. 1-1). It is made up of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the Habitats and Birds Directives (see Annex 1 for a glossary of terms used in this report). The network includes both terrestrial and marine sites (Marine Protected Areas (MPAs). The Habitats Directive requires SACs to be designated for habitats listed in Annex I and species listed in Annex II of the Directive. The Birds Directive requires SPAs to be designated for species listed in Annex 1 of the Directive, as well as for regularly occurring migratory species.

The first protected areas under the Birds and Habitats Directive were designated in 1995. Following a series of revisions and amendments, alongside augmentation of the EU, the network has grown and currently covers nearly 18%[5] of the total land area of the EU (Fig. 1-2). In 2014 the proportion of

[5] The actual figure is currently 17.88%, based on http://ec.europa.eu/environment/nature/Natura2000/barometer/index_en.htm. The figure is rounded up to18% throughout the report.

each country included into Natura 2000 varied from 8.53% (United Kingdom) to 37.85% (Slovenia). Part of this variation is due to landscape differences between countries with relatively few areas of nature conservation interest in urbanised and intensively farmed areas, such as southern England or northern France, but is also due to differences in national conservation policies (Evans 2012).

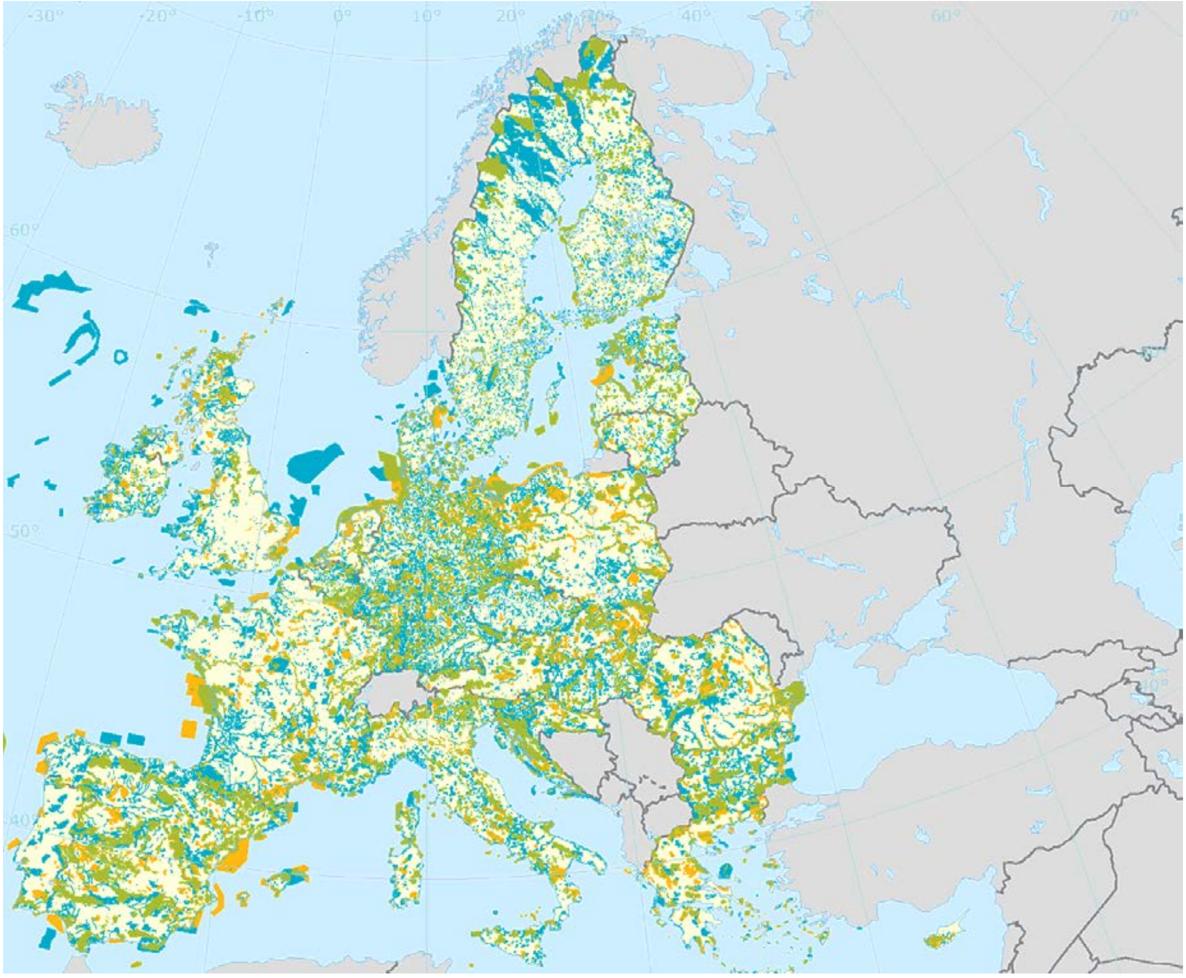


Figure 1-1 *The Natura 2000 network for the EU-28, which comprises the areas of the Birds Directive (SPAs, orange) and Habitats Directive (pSCI, SCI, SAC, blue) or both (green) (EEA 2016 http://www.eea.europa.eu/data-and-maps/figures/natura-2000).*

More than 230 habitats and 1500 species of animals and plants are listed in total in Annexes I, II, IV and IV of the Habitats Directive, and 193 birds in Annex I of the Birds Directive; and the ultimate goal is to ensure the long-term sustainability of these habitats and species. The ecological condition delivering such long-term sustainability is known as 'favourable conservation status' (FCS).

Every six years the Member States of the European Union deliver information on the Conservation Status of all species listed on the annexes of the Habitats Directive and, since 2013, on the populations and status of bird species as required by Article 12 of the Birds Directive. Based on the most recent reporting period, the EEA (2015) made an assessment, which included an overview of the importance of the Natura 2000 network for these species. Based on the detailed EEA report in May 2015 the European Commission published the report *The State of Nature in the European Union* which sets out the status of and trends for habitat types and species covered by the Birds and Habitats Directives for the period 2007-2012. The EEA report provides a basis for formally judging the success of the Nature Directives in relation to their original goals.

For species assessed as having an unfavourable conservation status, Natura 2000 coverage was significantly associated with the trend in status and with the short-term population trend. This suggests that in many situations, Natura 2000 could play a role in stabilising trends and preventing further decline. The Habitats Directive concept of conservation status is complex, involving several components. In addition to trends in range and population/area, it also incorporates distance to a target state (given by the favourable reference values) and requires considerable change before any improvement in conservation status. This could sometimes be a reason for an occasional lack of association between the observed conservation status of certain species and their coverage by Natura 2000. It may also be that many habitats and species require many years, maybe decades, to recover, even with the application of conservation measures and expansion of the Natura 2000 network (EEA 2015).

However, the *State of Nature* report does not provide any information on the wider contribution of Natura 2000 to the conservation of species that are not included in the lists that make up the annexes to the Directives. The need to understand this contribution is driven by broader interests in the value of the Nature Directives and in relation to the EU strategic target, expressed within the Biodiversity Strategy to 2020, to "halt the deterioration of all species and habitats and achieve a significant and measurable improvement in their status…." It focuses in particular on the effectiveness of the Natura 2000 network in Europe for conserving biodiversity. To address this, in 2013 the European Commission initiated a research project to assess the significance of the presumed "umbrella effect" of Natura 2000, related to its potential contribution in terms of halting and reversing the loss of species other than those for which the Natura 2000 sites have been designated.

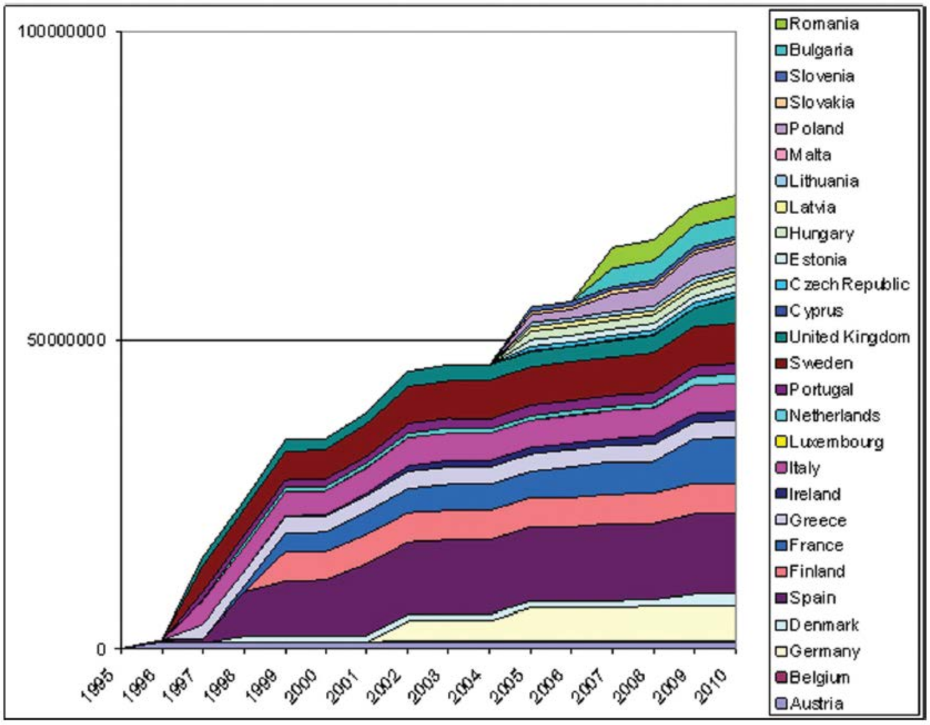


Figure 1-2 *Growth of proposed Natura 2000-area (ha) proposed per member state from 1995 to 2010. (Evans 2012)*

1.2 Aims and scope of the study

As stated above, the main objective of this report is to assess the importance of the presumed "umbrella effect" of Natura 2000, specifically to assess its potential to protect and prevent further loss and declines in 'non-target' species.

Our assessment covers a range of taxa, specifically all vertebrates except fish as well as butterflies and plants. A key aim is to identify species that are threatened but poorly protected under Natura 2000 (gap species), in order to update Annex I and Annex II species of EU Bird Directive and Habitat Directive, respectively, and to provide guidelines on Natura 2000 management and expansion.

The work has been carried out by a consortium of six organisations, with complementary taxonomic expertise. The lead of the research is with Alterra-Wageningen UR, who were also responsible for the analysis of plants. Mammal species were assessed by the IEA - Institute of Applied Ecology (Rome). Bird species were analysed jointly by the BTO - British Trust of Ornithology in cooperation with Sovon - the Dutch Centre for Field Ornithology. The ITC - University of Twente took responsibility for the analysis of reptiles and amphibians (herpetofauna). Finally the Vlinderstichting - Dutch Butterfly Conservation carried out the assessment of European butterflies.

The geographic scope of this work is the territory of all European member states, further referred to as the EU-28 (see Fig. 1-3). Some areas that do not form a contiguous part of the EU territory were excluded: these include the Macaronesian Islands (Canary Island, Madeira and Azores) which are fully part of the EU-28, but from a biogeographical point of view, belong to a different zone. The same applies to some Spanish enclaves on the African mainland (Melilla and Ceuta being the most obvious), that differ biogeographically from the Spanish mainland. For the birds and herpetofauna, Cyprus was excluded, due to lack of available data.

Figure 1-3 *The EU-28 countries covered in this analysis.*

2 Review of literature

2.1 Introduction

This chapter presents a brief overview of recent literature relevant to assessing the contribution of the Natura 2000 network to species conservation, drawing largely on the most comprehensive previous assessments. It is not therefore intended to be comprehensive. Its focus is on studies that address the effectiveness of the network in protecting species overall, whereas this work specifically addresses the question of whether Natura 2000 also provides benefits to species not listed under the relevant Annexes (the non-target species).

2.2 Importance of Natura 2000 for taxa

Gruber *et al.* (2012) devised a representation index (REX), in which he calculates the representation proportion for each species by dividing the representation of each species by the total number of Natura 2000 sites in the EU-25 countries. Comparing the REX for different species groups revealed significant differences between groups. Plants achieved the highest REX (3.51), followed by reptiles (2.41), invertebrates (2.37), fish (1.59), amphibians (1.46) and finally mammals (1.44). This ranking is a consequence of the highly uneven number of studied species per group on the Annex II list, with plants being the largest group with 464 species. However, the major finding was that the Natura 2000 network is effective in minimizing the number of gap species (see for definition the glossary of terms, Appendix 1), by providing representation for many species with a restricted range (Gruber *et al.* 2012). In total 54 gap species were identified, however only three were true gap species, others were included because of incomplete distribution data or other anomalies.

Recently an evaluation was done on the ecological effectiveness of the Natura 2000 network (McKenna *et al.* 2014). This was done on the basis of geographical comparison of data, gap analysis, to identify how well species were covered. For the Annex I habitats (HD) the study found that in particular marine habitats are not well represented in the network. Temporary freshwater habitats in the Mediterranean are also not well covered, nor are 'Lowland areas' (McKenna *et al.* 2014; Metzger *et al.* 2010). For Italy, mountainous areas seem to be overrepresented, and lowland areas underrepresented (Maiorano *et al.* 2007). It was found that in particular species depending on traditional (farmland) management) are not well covered within the current conservation network of Natura 2000. This was also found in particular country studies, e.g. for the Birds Directive (Van der Sluis *et al.* 2012a). The coverage of habitats in Denmark was highest for salt meadows, heaths, mires and lakes (greater than 80%) and poorest for streams and forests (Ejrnæs *et al.* 2014). McKenna *et al.* (2014) also identifies that a more flexible approach may be required to account for impact of global processes like climate change, e.g. using adaptive management and buffer zones to ensure that species are sufficiently well protected. Also policy coherence is considered an important factor to improve species protection through the Natura 2000 network.

The most comprehensive assessment so far is the one of Maiorano *et al.* (2015), who performed a gap analysis of the entire Natura 2000 system as well as national protected areas for all terrestrial vertebrates. Their results suggested that, at a continental level, the Natura 2000 network acts as a good complement to existing national protected areas. They concluded that the Natura 2000 is largely effective for terrestrial vertebrates but would benefit from further updating of the species lists and field management. A recent assessment focused on large mammalian carnivores in Natura 2000 concluded that Natura 2000 alone is not sufficient for ensuring their long-term persistence (Santini *et al.* 2016). Recently, the Natura 2000 network was also assessed in terms of habitat connectivity (Maiorano *et al.* 2015; Santini *et al.* 2015; Van der Sluis *et al.* 2004; Van der Sluis *et al.* 2012b). The authors concluded that the addition of Natura 2000 SACs to European protected areas had a substantial effect on connectivity, particularly for long-distance dispersers.

Sanderson *et al.* (2015) evaluated the effect of designation in Annex 1 of the Birds Directive on short and long term population trends of bird species in EU-countries. Their results showed that for both periods, Annex I species had more positive trends than non-Annex I species, particularly in countries that joined the EU earlier. Among the Annex I species, long distance migrants performed worse than the other Annex I species, suggesting that this group also needs more protection outside the breeding grounds.

Sillero *et al.* (2014) published a homogenized database, with a resolution of 50 km by 50 km, on the presence and absence of herpetofauna across 40 countries covering the whole of Europe. This database formed an updated version of the 1997 European Atlas of the Societas Europaea Herpetologica (SEH). Base on their analyses, they concluded that the centre of gravity for endemism and species richness for both amphibians and reptiles in Europe lies around the Mediterranean region, with a special focus on islands in the Mediterranean.

Abellán and Sánchez-Fernández (2015) reported on the overlap between the distribution of amphibians and reptiles and two types of protected area networks: Natura 2000 and national protected area networks. For this analysis they used the 50 km by 50 km presence and absence data from the SEH that was published in 2014. They concluded that overall, the Natura 2000 network performed better to cover assemblages of herpetofauna than the national networks, but that widespread taxa were covered by both networks, and that species with restricted ranges remained under-represented.

Although there is evidence that directed conservation effort can in some circumstances reverse a negative trend for species (e.g. Thomas *et al.* 2009; Wynhoff 2001), it is also clear that small patches supporting specialised species that are not part of a wider metapopulation are very vulnerable to local extinctions. If such sites are isolated from nearby patches supporting healthy populations, there is little chance of recolonisation from surrounding patches. This is often the case in landscape subject to intensive management or which have been abandoned. Although the Natura 2000 network is vital to the survival of many species, management must guard against losses, and this instrument must be seen in the context of the wider landscape. It is also vital that management measures within protected areas take the specific needs of species into account (Van Swaay *et al.* 2012). Conflicting management interests, e.g. targeted at birds or vegetation types, might not benefit populations of butterflies or other insects and in some cases can be detrimental (e.g. large-scale, uniform management).

Although only species listed in Annex II of the Habitats Directive are subject to the designation of Natura 2000, other species can also benefit from site designation and associated measures. Annex II species have a lower proportion of EU regional assessments as favourable (22%), and higher proportions as unfavourable-inadequate and unfavourable-bad (44% and 22%) in comparison with the non-Annex II species. However, it must be kept in mind that for more than a quarter of Annex II species, assessments are unknown. Regarding trends in conservation status, a higher proportion of Annex II species have unfavourable- improving or unfavourable-stable status, in comparison to non-Annex II species (49% compared to 44%), but also, a higher proportion of Annex II species have an unfavourable-deteriorating trend (24% compared to 17%) (EEA 2015).
The same study shows that over half of the bird species in the EU (52%) are considered to be 'secure' (no foreseeable risk of extinction), and wintering birds (mostly waterbirds) tend to show increasing populations. The study also showed that birds listed in Annex I of the Birds Directive have populations which are increasing, although often these species are not considered to have secure populations. This suggests that setting Natura 2000 sites is an effective conservation measure which also benefits non-target species (EEA 2015).

Trochet and Schmeller (2013) evaluated the coverage of 300 threatened species by the Natura 2000 network, and identified potential factors influencing the designation of sites and the structure of the network within a country (social, ecological and demographic national factors). The analysis was based on the coverage ratio between the Natura 2000 sites and distribution maps of threatened European species. They showed that the distributions of a large proportion of threatened species of the mammals, birds and reptiles considered in their study were covered well (above 90%) by the Natura 2000 network, and demonstrated that the Natura 2000 network also covers species not listed in the annexes of the Nature Directives. However, their results also showed that a large proportion of threatened species in other taxa, particularly fish (some of them listed on the European annexes), were poorly covered by the Natura 2000 network. Trochet and Schmeller (2013) included in their study results for eight butterfly species. The covering ratio for these butterflies varied considerably, but was always well below the 90% reached for mammals, birds and reptiles.

Pellissier *et al.* (2014) studied the impact of the Natura 2000 network on common bird and butterfly species populations. They found that most butterfly species were more abundant in areas with a high Natura 2000 coverage. Of the 103 most common butterfly species, 32 had higher abundances in regions with a higher Natura 2000 coverage (3 grassland specialists and 4 woodland specialists). Sixteen species had lower abundance (including three grassland specialists). The 55 remaining species exhibit little effect of Natura 2000 coverage (Fig. 4.5 in Pellissier *et al.* 2014). For birds they found evidence that half of the common bird species analysed had higher abundance when coverage of Natura 2000 sites in the landscape was higher, in particular for woodland species. Furthermore, species with narrower ecological niches were more abundant in the Natura 2000 network than generalist species. Finally they demonstrated that the decline of farmland birds in the Natura 2000 network was less steep than outside it (Pellissier *et al.* 2014).

However, results less clear for the butterfly species. Although a larger number of species respond positively rather than negatively to the presence of Natura 2000, the magnitude of the variation is limited and the abundance of a large number of species is identical whatever the contribution of Natura 2000 around the site. It is noteworthy that, as for the birds, there is a larger number of woodland butterfly specialist species - such as the White Admiral (*Limenitis camilla*) or Scotch argus (*Erebia aethiops*) - which favor Natura 2000 than of species which avoid it.

Verovnik *et al.* (2011) studied how well the Natura 2000 network in Slovenia covers areas of high butterfly diversity and/or areas with an aggregation of species of conservation concern. The diversity and distribution of Red-listed species was evaluated at a 1 km grid square level. In general the high diversity areas also hold the largest aggregation of Red-listed species with core areas concentrated in SW Slovenia. The SACs cover the majority of areas with high diversity and the distribution of all but one threatened butterfly species (*Colias myrmidone*, which has been extinct in Slovenia since 1993). Hopkins and Thacker (2016) discuss how well a number of groups of non-annex invertebrate taxa are covered by Natura 2000 areas, including a brief summary of recent studies examining overlap between assemblages and species of invertebrates and Natura 2000; they found that a high proportion of species was found within designated sites.

The Alpine Ibex (Capra ibex) is considered Least Concern by the European Red List. It covers 0.4 of European territories and 38.4% of its distribution is protected by Natura 2000. (Photographer N. Ranc)

3 Data preparation and analysis method

3.1 Introduction

The research question posed in the project specifications: *"How much biodiversity is covered by Natura 2000?"* was further specified as follows*:*

- Which are, amongst the species regularly occurring within the European territory of the EU-28 Member States (i.e. common species), those that significantly benefit from the Natura 2000-related site conservation requirements under the EU Birds and Habitats Directive?
- What is e.g. in percentage of all species occurring in the wild in the EU, the share of EU species significantly benefitting from Natura 2000?
- How significant is this contribution of Natura 2000 in relation to the objective of halting and reversing biodiversity loss?

To answer these questions, we focus on the spatial distribution, i.e. the geographical range[6] of each species within the EU-28 countries[7], and its presence within the Natura 2000 network and outside the network. This can be expressed in the form of a figure or percentage of the distribution of a species or species group covered by Natura 2000.

Specific consideration was given to species which are not included in the annexes of either directive (i.e. species other than those for which areas were designated). However, in all cases we present results in relation to the conservation value of species, based on their position on Red Lists and endemic status.

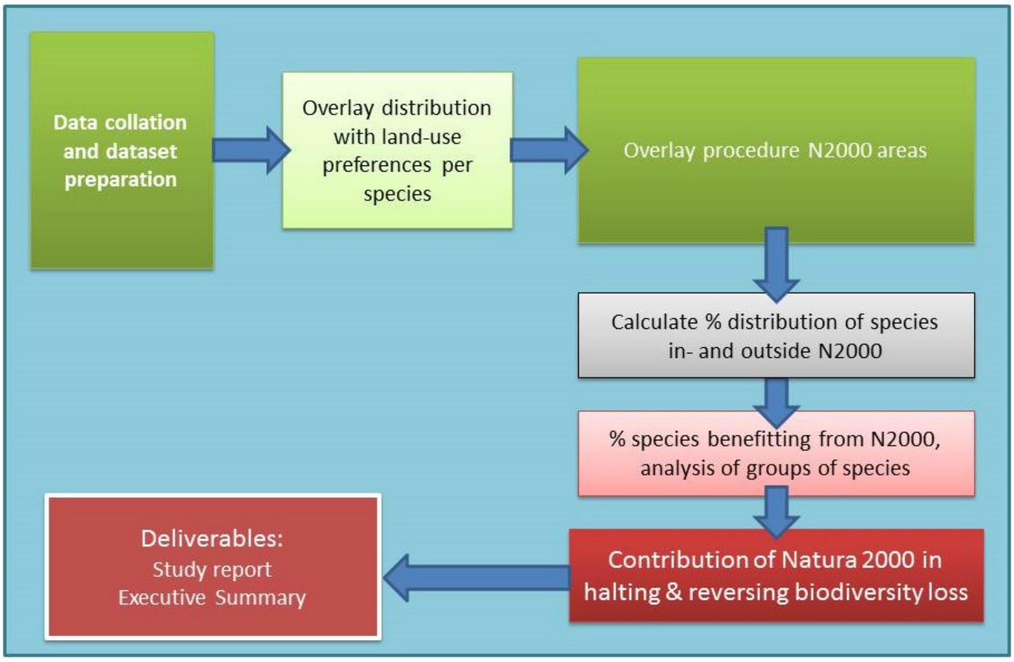


Figure 3-1 *Analytical framework of the assessment.*

[6] 'Range' refers to the overall geographical envelope within the EU territory and 'distribution' is the spatial occurrence within the envelope.

[7] Some specific areas that do not form a coherent part of the EU territory were excluded because from biogeographical point of view they belong to a different zone or data was not available. These included the Macaronesian Islands, some Spanish enclaves on the African mainland and, for the birds, reptiles and amphibians, Cyprus.

We have chosen an approach which maximises the use of existing distribution data, for as many taxonomic groups as possible. Hence, the taxa covered by this study are those which have been most widely studied and for which relatively reliable distribution data are available, including the terrestrial mammal, bird, reptile, amphibian, butterfly and plant species. The analyses are based mainly on GIS processing of species distribution data in relation to their presence within protected areas of the Natura 2000 network. In some cases, statistical distribution models were used as a cross-validation tool. The graph (Fig. 3-1 above) shows our approach, which is further elaborated in the following sections.

The data available differ among taxonomic groups (e.g. in Europe, butterflies are recorded more comprehensively than mammals), as well as within groups (i.e. per country), in some cases markedly. Available data may consist of atlas data or observation data[8]. The following situations occur:

i. Countries with good data, so at least at a resolution of 1x1 km.
ii. Countries with (partly) poor data, so with (large) gaps. If atlas data is available, most is at a scale of 10x10 km or more coarse (Note: where possible, national experts were consulted on aspects of data quality and the interpretation of the analytical results).
iii. European atlas data, often at a scale of 50x50 km. This provides a coarse distribution of the species, but is at a too low resolution in relation to use directly in relation to presence or absence in Natura 2000 areas. (Note: in some cases scaling to finer resolutions of occupied habitat data may be an option; in addition we have the capacity to model habitat suitability and provide a prediction of whether or not a given species or habitat should occur in a given Natura 2000 site).

Variation in data availability and quality among and within taxonomic groups critically determined the analytical approach used. As explained, the data differed among taxa and hence the most appropriate method of analysis also differed, but were harmonised in the integrated results and conclusions. The general approach for the analysis is described below. A more detailed description follows for all taxa, and is summarised in Table 3-1. Where differences occur, this is explained in text boxes, indicating the particular approach for e.g. taxa or species groups.

The analysis of the data for most species groups (except plants) is based on habitat masking of 50 by 50 km data with Corine Land Cover (CLC) or Global Land Cover (GLC) data (see below). This is validated by applying models at finer resolutions, first at the 5 km by 5 km scale for the whole of Europe, and using a different approach in particular for countries with more detailed data, often at the scale of 1 km by 1 km. The reason for these validation exercises is to test the robustness of the results.

In relation to the question of 'significant beneficial effect', 18% of Europe's land surface is Natura 2000. With a totally random distribution of species over the EU, on average 18% of their distributions would occur within Natura 2000. However, if the distribution of species is more than 18% in Natura 2000 (or less), this can provide the basis for considering if a benefit is being provided or whether some other effect may be being observed. 18% also provides an easily communicated baseline for judging the benefits provided by Natura 2000 to common species in the EU. For the results at country level the respective Natura 2000 coverage in each country was used as the baseline. So in our approach we compare the share of the Natura 2000 area against "% of species range inside Natura 2000".

Table 3-1

Scale levels for the different taxa that the analysis was performed at.

Taxa	50x50 km	5x5 km	2x2 km	1x1 km
Plants			×	
Mammals	×	×		
Birds	×	×		×
Herpetofauna	×	×		×
Butterflies	×	×		

8 Available data can consist of atlas data or observation data: atlas data includes published data on presence and absence of a species based on comprehensive coverage or modelling, while observational data is here defined as records compiled from a range of databases, papers and reports. These are presence records associated with spatial information, often at high accuracy but absence data are generally missing.

For spatial analysis different maps are used. CORINE land cover Level 3 (CLC-3) (EEA 2013) is often used, however, these land cover maps have for some species limitations due to their relatively coarse scale and large minimum mapping unit (25 ha). An alternative for some taxonomic groups is the ESA Global Land Cover (GLC) map, with a spatial resolution of 300 m (JRC 2009).

There is also a potential for sampling bias, particularly with the species presence data derived from the opportunistic data recording for which there may be more collection of records within Natura 2000 sites because of their designation and the types of habitat. A spatial bias correction technique was therefore applied; this allowed for a reduction of the error by predicting a high probability of presence where many presence data are available, and predicting low probability of presence where presence data are unavailable (but the species could be present).

3.2 Analysis approach for the Fauna

In the introduction (par. 3.1) three research questions were presented: which species are benefitting from Natura 2000, what is the share of species benefitting, and how significant is this for halting or reversing biodiversity loss. Ideally, these should be answered using real data of species occurrence in- and outside Natura 2000 sites. However these data are not available for most species and certainly not for the entire territory of the EU-28. So an alternative, feasible, approach was developed to assess the importance of Natura 2000 areas for all taxa, using species distribution data. This is based on modelling of real but coarse pan-EU distribution data (for mammals, breeding birds, reptiles and amphibians, butterflies), by using two types of modelled, but more detailed distribution maps and an approach using real data-based fine-grained distributions from a set of countries. The latter provides overview statistics indicating how well masking worked in each country relative to observed data and is a way of validating the methods that could be applied EU wide. These approaches are described as habitat masking and species modelling at 5x5 and 1x1 km.

The general description applies to all faunal taxonomic groups. Further details on the methods and specific additions for certain taxa can be found in Appendix 2.

Data collection
For most species groups, the original data are point or grid-based observations collected (often through national organisations) and stored in a database and used to produce atlases. This has resulted in a suite of distribution maps or range maps of species, e.g. for mammals, birds and herpetofauna in national or European-wide atlasses (Cabela *et al.* 2001; García-Barros *et al.* 2004; Gasc *et al.* 1998; Głowaciński and Rafiński 2003; Hagemeijer and Blair 1997; Kudrna 2002; Kudrna *et al.* 2011; Kudrna *et al.* 2015; Observatoire de la Faune 2004; Pleguezuelos *et al.* 2004; Sillero *et al.* 2014; Verovnik *et al.* 2012). The distribution maps are based on field observations for different periods. The proportion of coverage both within the whole EU-28 territory, and within each individual EU-28 country was calculated. Note that Cyprus and the Canary Islands, both in EU-territory, are not always included.

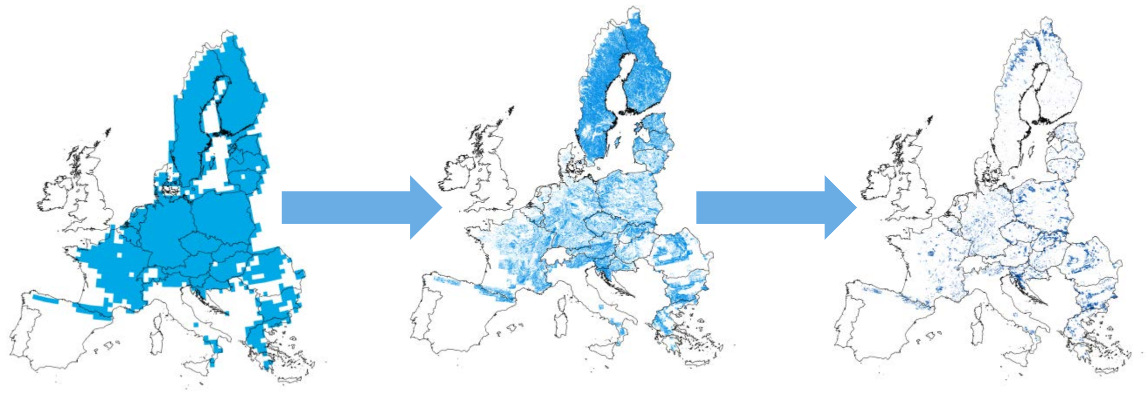
Although the species distributions in these atlases are not based on one standardized method and there are differences in the quality of field work and the relative number of observers between countries, the quality of the data when expressed as presence and absence at a 50×50 km scale is considered high. For mammals, we used predicted range maps, which we consider more reliable and up to date than the European atlas available for mammals (Mitchell-Jones *et al.* 1999). Additionally, such atlases are known to be very inaccurate proxy of the distribution of elusive animals such as some mammals, for which presence can be significantly under-estimated, especially when atlases are based on opportunistic data collection (Rondinini *et al.* 2006). Range maps were downloaded from (IUCN 2013) whereas habitat suitability models were obtained from Rondinini *et al.* (2011). This approach allowed us to assess Natura 2000 for all European wild mammal species (177 species).

Habitat masking
'Habitat masking' was carried out to estimate the fine-scale spatial distribution of suitable habitat within each 50×50 km cell occupied by a species. Species-specific habitat masks were made by assigning species to Corine Land Cover habitats - Level 3 (CLC-3), or, for mammals, the Global Land Cover map.

The CLC-3 map is based on 2012 Remote Sensing data (EEA 2013) except for Greece, where data is from 2006, and is available for the entire EU-territory with the exception of the Azores and Madeira.

Next an overlay was made between the species' 50×50 km distribution maps (Fig. 3-2a) and the Corine Land Cover types, resulting in maps showing apparently suitable Corine Land Cover types within the species known range for the EU-28 (Fig. 3-2b). These 'masked' distribution maps were validated by experts. For herpetofauna all species were retained, and in the validation section we assessed for which species the different methods deviated more than 10% from each other. For these a judgement was made which of the two methods was probably more accurate.

This validation revealed some limitations of the Corine Land Cover map. As might be expected given the sometimes complex ecological requirements of species, some land cover types distinguished in Corine do not adequately differentiate among habitat types occupied and unoccupied for all species. In these cases, the Corine map seems too coarse and some important small land cover features are absent or underrepresented in the land cover data sets, for example streams, small rivers, small lakes, fens and open areas in forests. Habitat masked maps that were obviously unsuitable for these purposes were excluded from further analysis; for the breeding birds 44 species (identified in the data tables in the annexes to this report) were therefore excluded due to the unsuitability of the CLC information and 7 additional island endemic species were excluded because these regions were not covered by CLC. The extent of each species' distribution in and outside Natura 2000 was then estimated based on a combination of atlas data and potentially suitable habitat, the latter derived from CLC (Fig. 3-2c).



A: 50×50 km distribution *B: habitat masking* *C: habitat within Natura 2000*

Figure 3-2 *An example of the habitat masking process as applied to the Black Woodpecker (Dryocopus martius). Figure 3-2a: the observed distribution of a species, Figure 3-2b: after selection of suitable habitat based on CLC-3 the area is refined, Figure 3-2c: after an intersection of habitat with the N2000 map (EEA 2015) we derive at the distribution map of habitat in Natura 2000.*

Species Modelling 5×5 km

Two approaches were used to model species distribution, the approach chosen depending on the available data and evaluation of the results of the modelling:

1. Based on the 50×50 km distribution data from the relevant taxonomic atlas. These data were downscaled to 5×5 km cells using spatial regression modelling techniques, taking into account aspects such as soil and climate data, forest management, nitrogen and sulphur deposition and the Corine Land cover types (EEA 2013), and Global Land Cover maps (JRC 2009). These resulted in modelled species distribution maps at the 5 km by 5 km scale.
2. Based on species observations available from different NGOs, data submitted to online biodiversity recording portals, count data from individual countries and the 10 km by 10 km distribution maps from the EU Birds Directive reporting in 2008–2012 (www.eea.eu). Spatial regression models were built to produce distribution maps based on these data, accounting for soil and climate data, forest management, nitrogen deposition and the Corine Land cover types (EEA 2013) and Global Land Cover maps (JRC 2009) as above.

The regression modelling was done with Boosted Regression Trees (BRT), a version of Generalized Boosting Models (GBMs). BRT is a machine-learning techniques, able to handle nonlinear relationships and to take into account synergistic effects between the different factors affecting a species' distribution (Couce *et al.* 2013). For a discussion of techniques, see Annex 2.

For the modelling of birds and butterflies we used a suite of R-scripts, called TRIMmaps (Hallmann *et al.* 2014) with BRT. TRIMmaps can be used for the spatial modelling of presence-only, presence-absence and count data and features a wide range of regression techniques. BIOMOD 2 package in R was used for herpetofauna and mammals (Thuiller *et al.* 2009), and the maxent algorithm was used to sample pseudo-absences for mammals. Within TRIMmaps, Maxent can be used to generate pseudo-absences on locations with a low habitat suitability.

For each species 10 models were fitted on different random subsets of data to get more robust models. Each subset was a random allocation of presence and absence locations to a training subset (80%) and a validation subset (20%). Reported distributions and accuracies are averages of these 10 randomized realisations of model fits. Accuracies of fitted models were assessed by looking at the True Skill Statistic (TSS is the same as HK; Allouche *et al.* 2006) which is the same as the Hanssen and Kuipers discriminant (HK) or Peirce's skill score.

TSS can only be calculated when a distribution map, giving probabilities of presence between 0 and 1, is converted into a binomial presence absence map, by setting a threshold. The TSS can be calculated with:

$$TSS = \frac{hits}{hits + misses} - \frac{\text{false alarms}}{false\ alarms + correct\ negatives}$$

A cut off was chosen, so that the proportion of correctly predicted occurrences (sensitivity) is comparable to the proportion of correctly predicted absences (specificity). For herpetofauna, the maximum TSS criterion was used as a threshold.
TSS ranges between -1 and 1, with 1 being a perfect prediction, 0 being a random prediction and -1 a perfect 'negative prediction' (i.e. predicted presences are actually absences and vice versa). The 5×5 km cells where a species is present according to the model-predictions were assigned to in-/outside Natura 2000 proportional to the ratio of area in-/outside Natura 2000.
The step-wise approach is illustrated in Figure 3-3, which shows the results of the 5x5 km modelling based on spatial modelling and atlas or spatial modelling and recent observation data. In Figure 3-4 the modelling results are shown based on the EBCC maps, with a cut-off value.

Species downscaled to 1x1 km (fine scaled national distribution)
Detailed distribution atlas projects in European countries, with distribution data at relatively fine scale (e.g. 5×5 km or 10×10 km) offer an opportunity to ground-truth estimates of species coverage by the Natura 2000 network. Such data was used for birds, mammals, herpetofauna and butterflies. The 5x5 km, 10x10 km or x,y observational data, was downscaled to 1km by 1km using GBM models, similar to the 5 km by 5 km modelling. However, here it was done a country, and not the entire EU.

The grass snake (Natrix natrix) is widespread in the European territory where it has several subspecies. (Photographer Fabrice Ottburg)

The selection of national distribution data for validation was aimed to achieve the best biogeographic coverage across Europe. Where possible we used the same countries for cross-species assessment, however this was not always possible because of taxonomic differences in the availability of regional data (Table 3-2, Fig. 3-6).

For each country, the grid on which the data were collected was intersected with the Natura 2000 network to determine the proportion of each grid cell covered (Fig. 3-5). Next, for each dataset and taking each species in turn, we calculated an area weighted sum of the data across protected and unprotected parts of grid squares. For example, if 18% of the area of an occupied grid cell was protected, a value of 0.18 contributed towards the protected total, and a value of 0.82 towards the unprotected total. Such values, when summed across squares, can be used to give an estimate of the proportion of the range overlapping the protected area network. This is a conservative approach in that it assumes species are distributed uniformly within squares with respect to protected area boundaries.

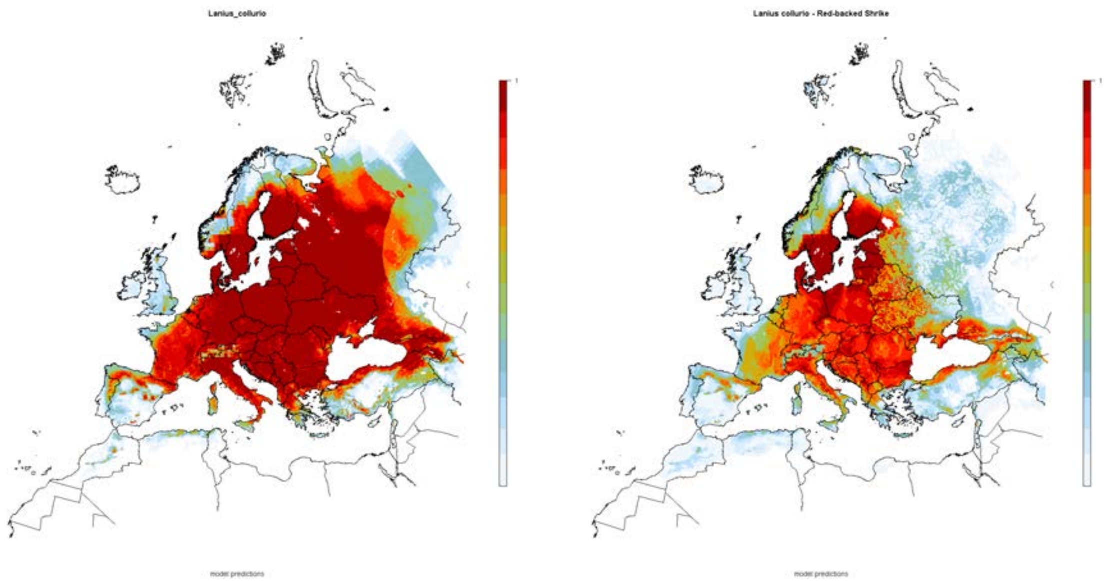


Figure 3-3 *Example of European predicted 5x5 km species modelling, showing distribution maps (probability of occurrence) based on spatial modelling, using data of a species Atlas (left) and using recent data (right). In this case the Red-backed Shrike (Lanius collurio) is shown.*

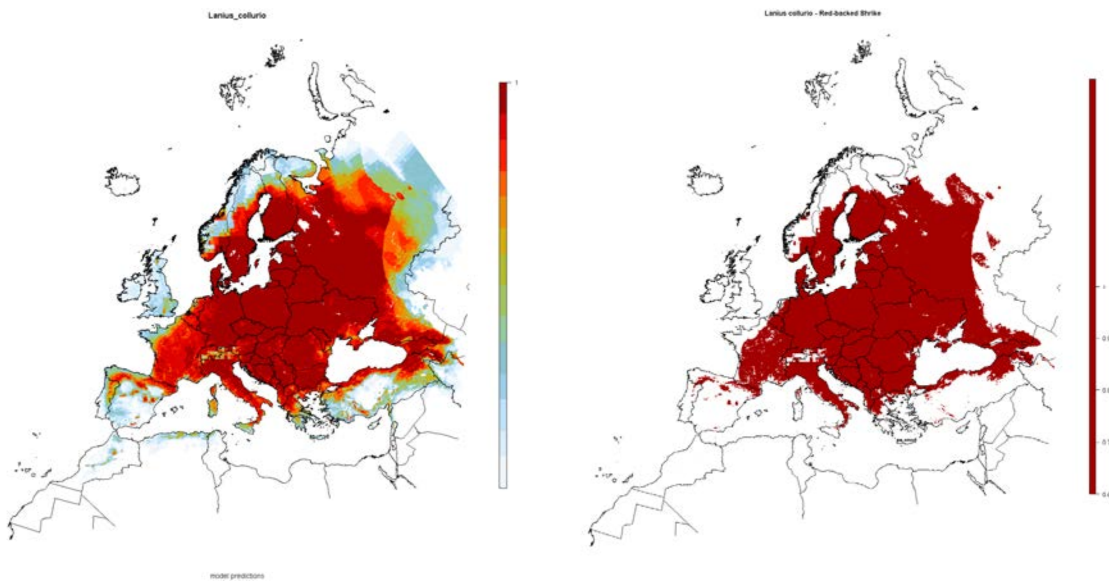


Figure 3-4 *Modelled distribution of Lanius collurio based on data of the EBCC-breeding atlas (50×50m grid data) and corresponding range based on a cutoff-value of 0.82. Predictions in Russia are unreliable due to a lack of bird data and poor data quality in some of the co-variables.*

Having derived estimates of protection status for each species in each country, we summarise these to indicate the range of protection status. These are useful for direct comparison with other methods. For comparison of the three methods we calculated a number of statistics (see Fig. 3-5 and Appendix 2 for further details).

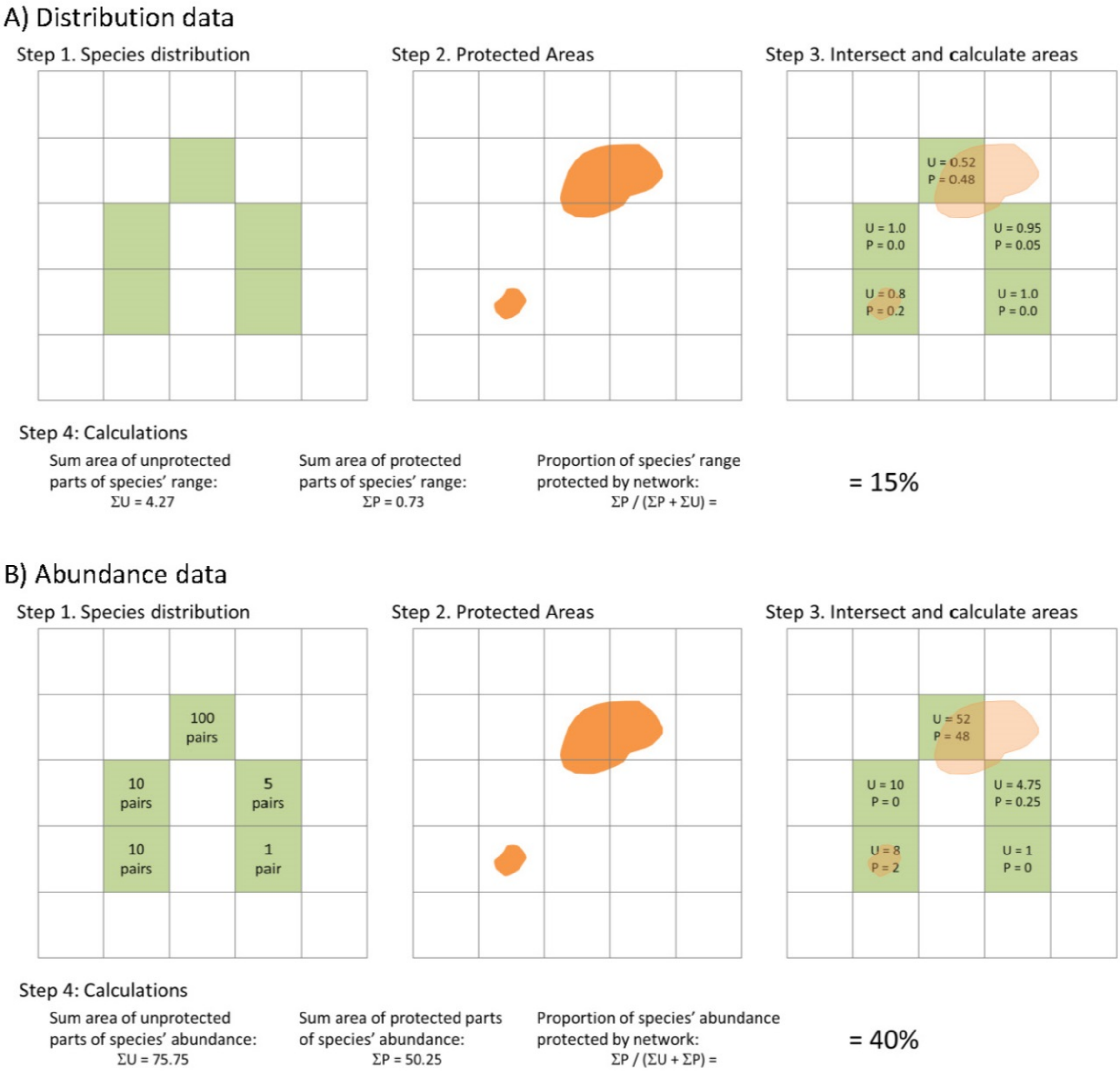


Figure 3-5 *Diagrammatic illustration of the process of calculating the percentage of a species' range (A) or abundance (B) that is protected by the network using observed species distribution and abundance information from fine-scale monitoring. We project the species distribution or spatial abundance pattern (Step 1) and Protected Area boundaries (Step 2) onto the same grid. In Step 3, the two datasets are intersected to determine the proportion of each occupied grid cell that lies inside and outside Protected Areas. For abundance data, the area fragments are multiplied by cell's abundance. These values are summed across grid squares and converted to the proportion of the range or abundance that occurs within Protected Areas. This follows a conservative assumption that for each occupied grid cell, individuals are uniformly distributed.*

Table 3-2
Countries for which detailed distribution modelling was done.

Countries	Plants	Mammals	Birds	Herpetofauna	Butterflies
Austria				×	
Belgium			×	×	
Bulgaria			×	×	
Croatia					
Cyprus					
Czech Republic	×				
Denmark					
Estonia					
Finland			×		
France			×		
Germany				×	
Greece				×	
Hungary					
Ireland	×			×	
Italy	×			×	
Latvia					
Lithuania					
Luxembourg					
Malta					
Netherlands	×		×	×	×
Poland				×	
Portugal				×	
Romania					
Slovakia	×				
Slovenia					
Spain			×	×	
Sweden	×		×	×	
United Kingdom x x x					

Figure 3-6 *Countries for which detailed distribution modelling was done.*

3.3 Analysis approach for Plants

To assess the importance of the Natura 2000 network for plants, we used the vegetation data stored in the European Vegetation Archive (EVA). The EVA database currently contains 1,122,134 vegetation plots, comprising 25,069,904 species recordings. In total, more than 50,000 taxa are represented in the database. We have restricted the assessment to vascular plants which are better represented in the database than cryptogams.

Alltogether 779,635 vegetation plots are geo-referenced, located in EU-28 countries and representing 395,499 unique locations. These unique locations in EU-28 countries have been assigned to 107,730 unique 2x2 km grid[9] cells, of which 52,695 grid cells are located within Natura 2000 sites and 55,035 grid cells outside Natura 2000 sites. In Table 3-3 the number of unique grid cells is listed for Europe and the countries on which the analysis focused and for countries for which Red Lists for vascular plants are available. Within this procedure, a grid cell has been assigned to the Natura 2000 network whenever it intersects (at least partly overlaps) with a site.

Table 3-3

Number of unique 2x2 km grid cells represented in the European Vegetation Database for the whole territory of EU-28 countries, and for countries for which Red Lists for vascular plants are available.

EU/Country	Unique 2x2 km grid cells inside Natura 2000 sites	Unique 2x2 km grid cells outside Natura 2000 sites
EU-28 countries	52,695	55,035
Czech Republic	4,387	6,637
Ireland	2,136	1,935
Italy	3,998	2,758
The Netherlands	2,276	4,723
Slovakia	2,341	2,696
United Kingdom	2,253	3,708

It was not feasible, using this approach to assess all (approximately 25,000) European vascular plants for the present study. We have therefore restricted the analyses to the **rare and diagnostic plant species**, which are those plant species that are listed in European Red List of vascular plants of the IUCN, and a number of national Red Lists. Criteria for selecting national Red List species were the availability of national Red Lists of vascular plants in digital form, as well as the availability of sufficient well located plot data in the vegetation database at national levels. Species indicated as 'Least Concern' (LC) were excluded from the analysis, as well as species from the Annex II list. The rule for LC species was applied to all Red lists including the IUCN list, not least because it was practical a problem to include these species because of the scale of the analysis that would have been required. The Annex II species were excluded as they have contributed to the designation of Natura 2000 sites. In general the Red Lists contain few Annex II species with the exception of the IUCN European Red List of vascular plants (Bilz *et al.* 2011). Even after having excluded LC and Annex II, 513 species remained for the analysis. A complete overview of all the plant species included in the analysis can be found in the data product linked to this publication. Common species were subjected to a separate analysis.

We further compiled a list of around 500 European orchid species on the basis of the European Vegetation Archive, and a list of species diagnostic for a number of Annex I habitat types. The latter is based on the project BioScore 2 (Hennekens *et al.* in prep.). The 40 Annex I habitat types that have been selected are listed in Annex 1 of this report, and represent habitats which are in most cases widely distributed in Europe. Orchid species are selected because they capture the interest of many people, but

9 The grid size of 2x2km has been chosen because of the uncertainty of the location precision of the plots. With a grid size of 1x1 km too many plots would have been excluded.

also because these species often occur in vulnerable habitats. By selecting species in this way, there was a risk that results for the plants would be skewed towards range restricted and habitat specialist species, which differs from the approach for other species groups (e.g. all bird species are considered). However, to test whether this selectivity will give a result more positive than would be the case if all species had been (could be) considered, we analysed the relationship between the number of Red list species and total number of species recorded in grid cells for the countries for which Red Lists and sufficient data were available. The results showed that, at least for those countries for which which sufficient data are available (Slovakia, Czech Republic and The Netherlands), there is a clear relationship between the number of Red List species and total number of species in grid cells (see Fig. 3-7). It seems therefore justified to use counts of Red List species as proxy for biodiversity.

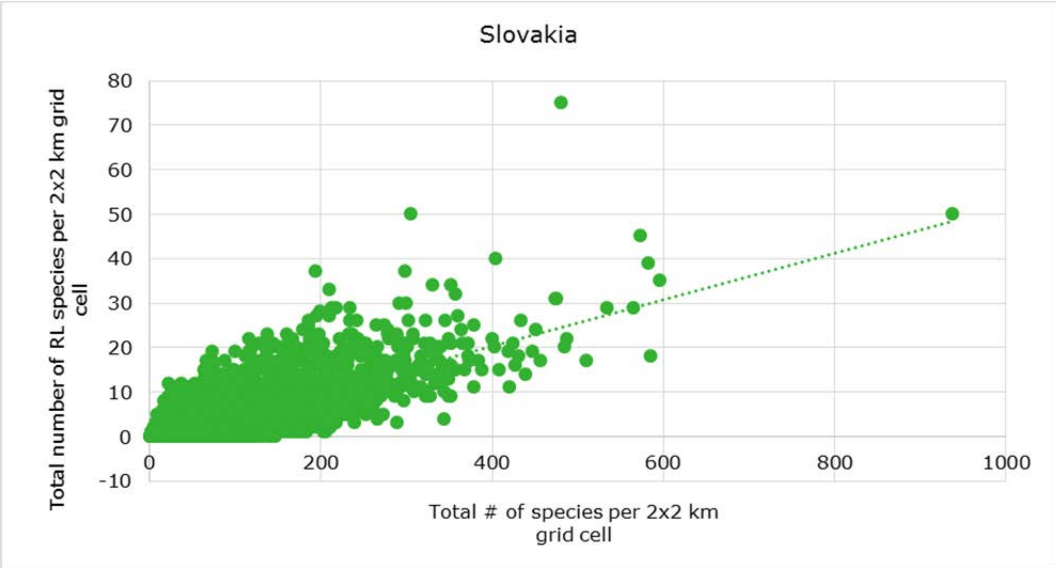


Figure 3-7 *Relation between total number of Red List plant species and total number of all species recorded in 2x2 grid cells. Other countries, like Czech Republic and The Netherlands show the same positive relation.*

Within each species group, the presence of each species was counted in random selected grid cells, inside and outside Natura 2000 sites. Based on these random selections, a ratio was defined for the selected species inside and outside Natura 2000 sites. For the first two groups (Red List of European vascular plants and orchid species), the number of random selected grid cells was set to 5,000 inside and 5,000 outside Natura 2000 sites. For the analyses on national level the number of random selected grid cells was set to 500 (500 grid cells inside and 500 grid cells outside), since the selections were only performed on the country specific grid cells. Within each group, a grid cell was selected only once. A detailed description of the method is found in Annex 3.

Yellow lady's slipper (Cypripedium calceolus) , orchid species, is considered vulnerable in most of Europe by the European Red List.).

4 Results

4.1 Introduction

We report on the percentage inside Natura 2000 for every species, grouping them to the following categories for interpretation of the results:

- is the species on Annex 1 of the EU Bird Directive or on Annex II of the Habitats or (Natura 2000 were designated to protect these species)?
- is the species on the EU Red List of threatened species?
- what is the habitat preference of the species?
- what is the range of the species in the EU?

The data product

The analysis presented in this chapter is based on the data tables, which have been compiled in this study and form an integral part of it. The data table consists of the following elements for each species presented:

- Protection status:
  - Annex II: species mentioned in Annex II of the Habitats Directive. This means that for these species, Natura 2000 areas have to be designated.
  - European Red List: the threat status of the species in the European Red Lists.
  - Red List of the EU-28 (in some cases the Red List for EU-27, before Croatia joined the EU in 2013.
- Analysis results:
  - 50x50 km distribution maps with habitat masking
  - %in: percentage of ha squares inside Natura 2000 areas in the EU-28 countries.
  - Area (km2): total area of the ha squares with the right habitat type within the distribution of the species in the EU-28 countries.
  - 5x5 km: distribution as a result of the modelling.
  - %in: percentage of the area of the 5x5 km squares, which are the result of the modelling, inside Natura 2000 areas in the EU-28 countries.
  - For some groups also 1x1 km country specific data is added.
- Distribution per country (not in Annex 2, but in accompanying excel sheet):
  - Distribution 50x50 km: percentage of ha squares inside Natura 2000 areas per country as a result of the 50x50 km distribution with habitat masking.
  - Distribution 5x5 km: percentage of ha squares inside Natura 2000 areas per country as a result of the modelling.
  - For some groups also 1km by 1km country specific data is added.

4.2 Species coverage in Natura 2000

4.2.1 Mammals

Overall we considered 169 species of mammals, following the European Red List of Mammals and excluding invasive and domestic species. Of these, 36 were listed under Annex II of Habitats Directive,18 were considered threatened (VU=12; EN=4; CR=2) and 6 Data Deficient according to the IUCN Red List. Mammal species have a mean coverage of 23.1±11.1% (mean±SD). The only species that is not covered by Natura 2000 (here referred to as gap species) is the Bavarian pine vole (*Microtus bavaricus*), a critically endangered species occurring in Austria (Fig. 4-1). According to the baseline of 18% (Natura 2000 coverage in EU-28), 55 species (32.5%) were partial gap species (i.e. species included in the Natura 2000 network but whose coverage do not reach the adopted baseline; Fig. 4-1).

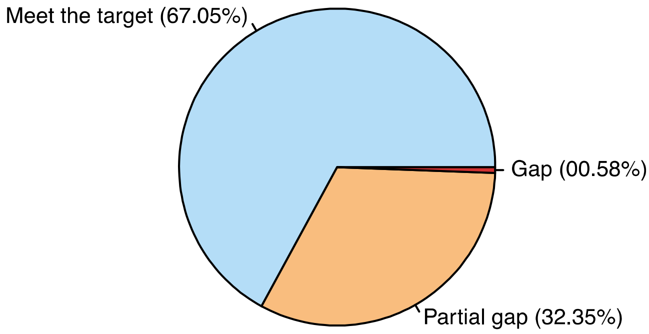


Figure 4-1 *Proportion of mammal species meeting the 18% baseline (n=169). Partial gap = species insufficiently protected by the Natura 2000 network; Gap = species entirely uncovered by Natura 2000 network.*

Protection by conservation status

Annex II species had a mean coverage of 26.5±12.2, well above the 18% baseline, and six (16.7%) were considered 'Partial Gap' species. These are the Reindeer (*Rangifer tarandus*) the Southern Birch Mouse (*Sicista subtilis*), the Steppe Polecat (*Mustela eversmanii*), the Pond Myotis (*Myotis dasycneme*), the Eurasian lynx (*Lynx lynx*) and the Geoffroy's Bat (*Myotis emarginatus*). Among these, the Reindeer is the least protected, being only covered for 3.5% of its range in the EU-28. Species not listed under Annex II had a lower level of protection, with a mean coverage 22.1±10.7 (Fig. 4-2). Some 49 species not listed under Annex II were 'Partial Gap' (36.8%) and one was entirely uncovered (Gap species). Among these, particular attention should be devoted to Azores Noctule (*Nyctalus azoreum*; 5.7% of protection) and the Bavarian pine vole (*Microtus bavaricus*; 0% of protection), which are highly threatened (EN and CR respectively according to the EU Red List) and are not listed under Annex II. The higher protection for Annex II species was consistent when analyzing the results using increasing thresholds above the baseline (Fig. 4-3).

European Red List

Non-threatened mammal species had a mean coverage 21.4±9.3, of which 51 were 'Partial Gap' species (38.3%). Threatened species were on average more protected than non-threatened species (Fig. 4-4, 4-5), with a mean coverage of 32.9±15.8. Only two species, the Azores Noctule and the Bavarian pine vole, did not meet the target. Under the European Red List there are also 5 species listed as Data Deficient, however these all met the 18% target.

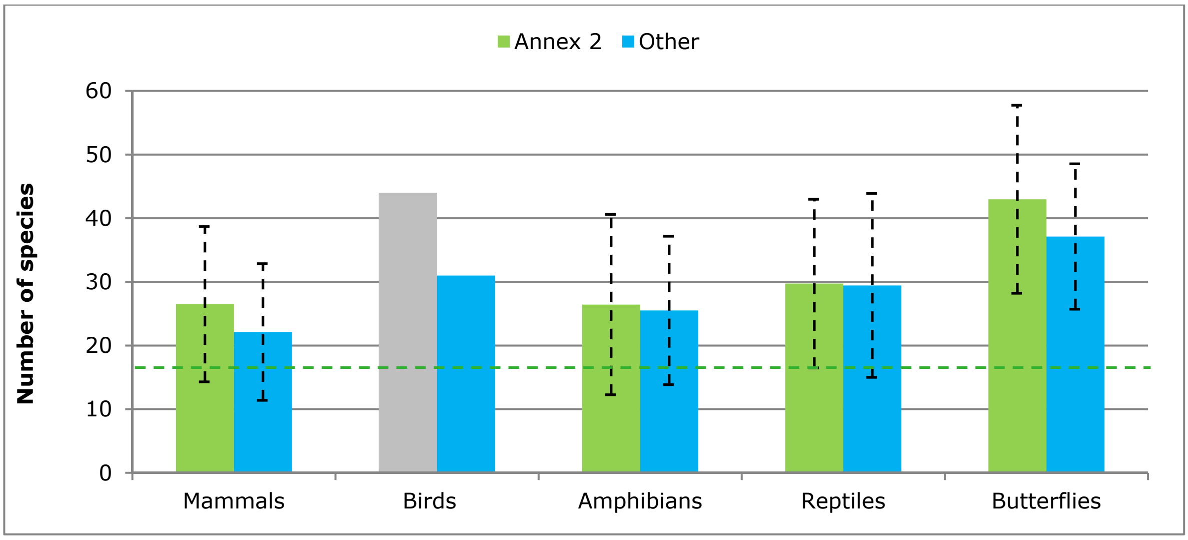


Figure 4-2 *Average share of the occurrence of annex versus non-annex species occuring inside Natura 2000 areas in the EU-28 countries. Results are based on masking analysis. Note: bird species are Annex 1. Striped line indicates the 18% baseline for Natura 2000.*

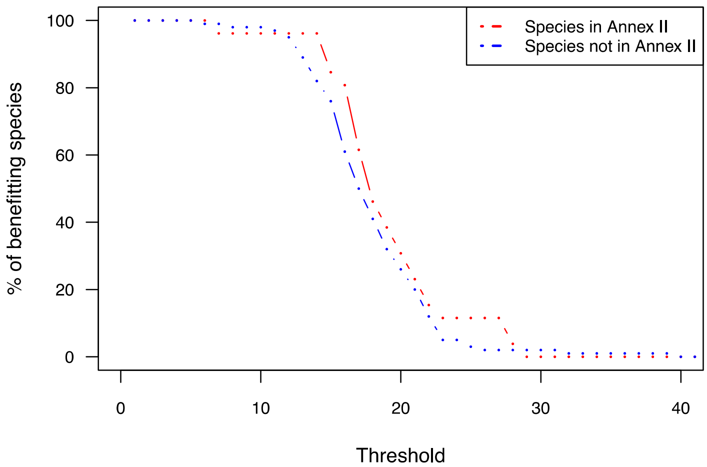


Figure 4-3 *Percentage of species meeting the 18% target at increasing target thresholds.*

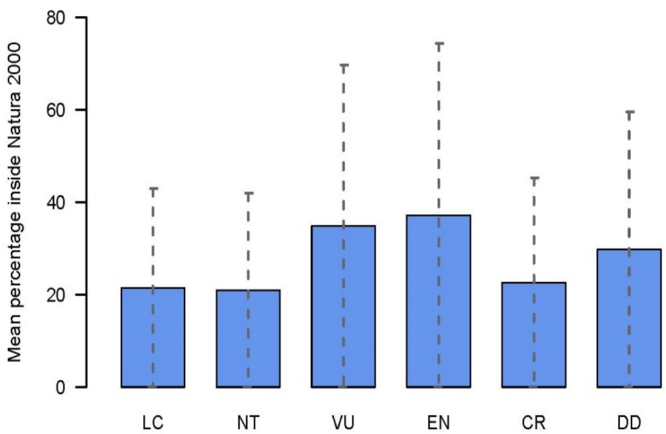


Figure 4-4 *Mean percentage of mammal range inside Natura 2000 by Red List category.*

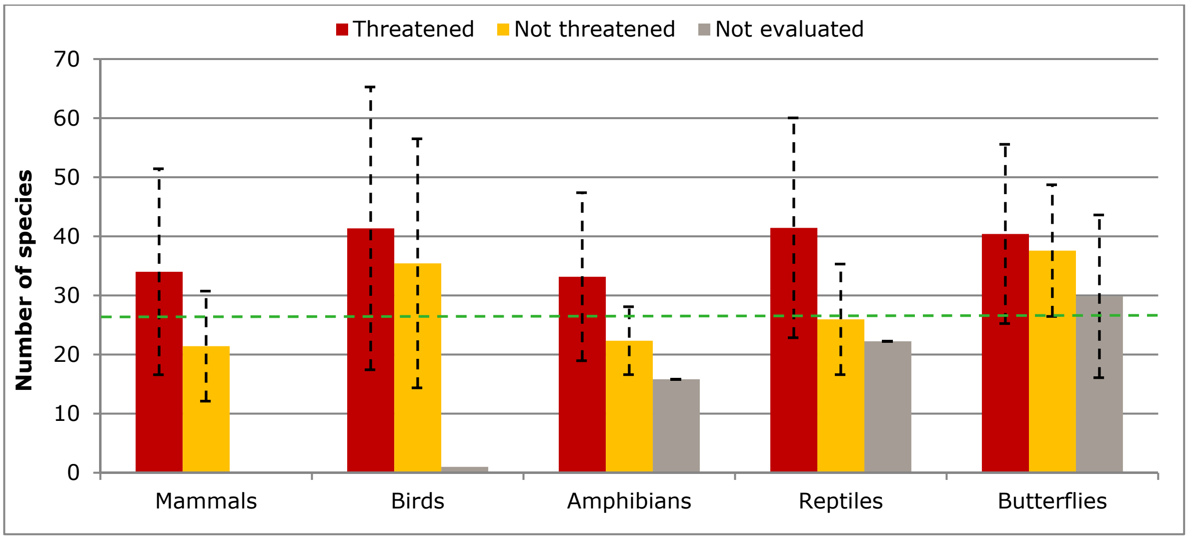


Figure 4-5 *Average share of the occurrence of threatened, non-threatened and not evaluated species occurring inside Natura 2000 areas in the EU-28 countries based on the European Red Lists. Threatened=CR, EN and VU.*

Taxonomic Order

Mammal species in EU-28 belong to 7 taxonomic Orders. The least protected mammal taxonomic order under Natura 2000 was Erinaceomorpha (i.e. Hedgehogs; 16.6±5.8%) with a proportion of 'Partial Gap' species of 66.6% (2 out of three species) (Fig. 4-6). Chiroptera (Bats) and Carnivora (Carnivores) are the two taxonomic Orders with the highest proportion of threatened species (RL: VU, EN, CR) among European mammals, 32.5% of bats and 33.3% of carnivores did not meet the target (Partial gap species).

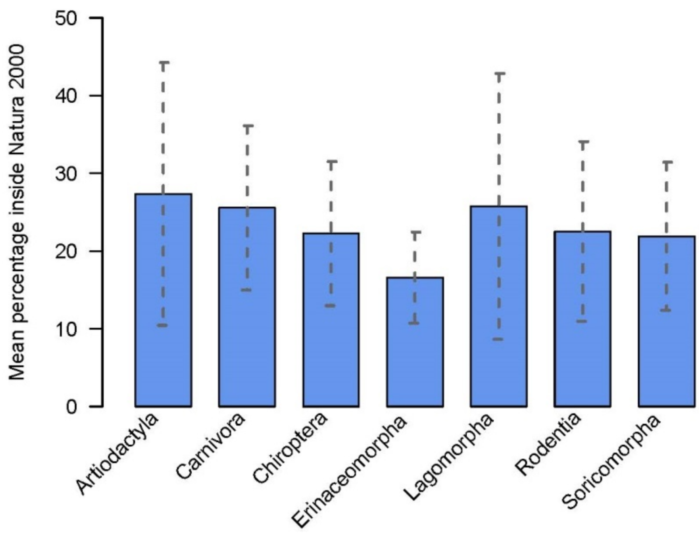


Figure 4-6 *Mean percentage of range inside Natura 2000 by taxonomic Orders.*

European endemisms

Among European mammals, 50 can be considered endemic for the EU-28. These are mostly small mammals within the Orders Soricomorpha (i.e. shrews and moles), Rodentia (i.e. rodents) and Chiroptera (i.e. bats). Endemic species are slightly more protected than non-Endemic species (25.58% vs 22.00% respectively), but the difference is negligible (Fig. 4-7).

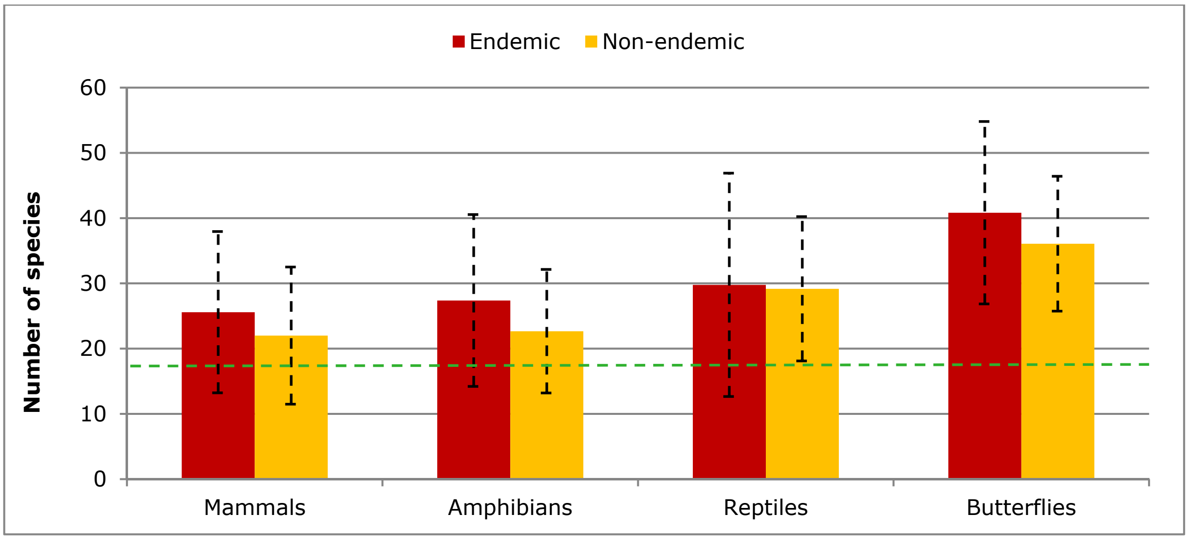


Figure 4-7 *Average share of the occurrence of endemic versus non-endemic species occurring inside Natura 2000 areas in the EU-28 countries.*

Protection by country

The coverage by Natura 2000 of European mammals differs considerably among European countries. At one extreme we find Malta, Sweden, Denmark, UK and Finland, with mean percentages below 10%; at the opposite extreme we find Bulgaria, Croatia and Slovenia with mean percentages around 35%. More interesting than coverage alone, is its value relative to the overall coverage within each country. For example, Cyprus is covered by Natura 2000 for 27.45%, more than the EU-28 average, however mammal species are only covered on average for about 23.7% (Fig. 4-8).

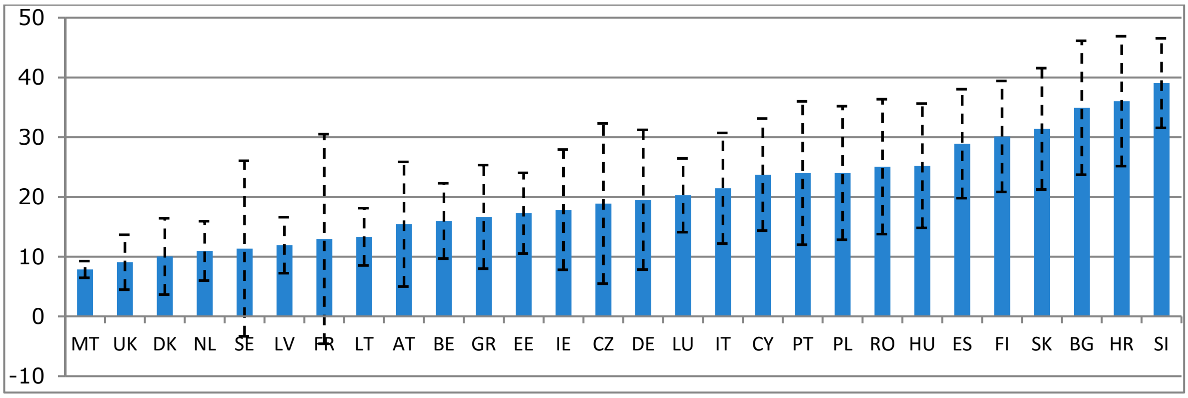


Figure 4-8 *Percentage of range inside Natura 2000 by mammal species in EU-28 countries. The error bars show the standard deviation.*

Persistence of mammal populations in Natura 2000

As described in the Methods (Appendix 2), we also assessed the number of species that could be considered to have at least one viable population at increasing viability targets, from 100 to 2000 individuals, within a Natura 2000 site. A viable population can be defined as 'a population sufficiently large to persist in the long-term'.

Given the availability of high quality population data the minimum population size necessary to persist under certain conditions and with a certain probability for a given number of years, can be estimated (e.g. "5000 individuals have 95% probability of persistence over a period of 100 years"). However, the lack of high quality population specific data limits the application of such analyses in conservation biology. In order to provide an approach that can be applied in practice, some authors have proposed that a target of a minimum of 5000 individuals per a given species should be set in order to ensure their persistence (Brook *et al.* 2011; Clements *et al.* 2011; Reed *et al.* 2003; Traill *et al.* 2010).

This estimate is far from conclusive, and this "magic number" for conservation has been widely debated. However, it is important to note here that population size is in any case a proxy for species persistence; in general "the larger population the better". In this context, viability targets can be defined as targets for the minimum population size that needs to be protected and which is "assumed" sufficient to ensure species persistence in the long-term. Expressing conservation targets as population sizes rather than distribution areas is useful as it allows the assessment of different species against the same benchmark (i.e. persistence). In fact, it is clear that a given area may have a very different value for species living at different population densities.
Based on the methodology described in Appendix 2 10 mammal species were estimated to be unable to form populations larger than 2000 individuals within the Natura 2000 network. These included rare species such as the European mink (Mustela lutreola) and the Pyrenean desman (Galemys pyrenaicus), large carnivores Wolverine (Gulo gulo), Wolf (Canis lupus), Brown bear (Ursus arctos), Iberian lynx (Lynx pardinus), Eurasian lynx (Lynx lynx); ungulates European Bison (Bison bison), Alpine Ibex (Capra ibex) and Reindeer Rangifer tarandus) (Fig. 4-9).

European mink and the Pyrenean desman are actually widely protected within their range (40.3% and 28.6% of protection respectively), however their population size is limited because of their narrow distribution. Thus, even if the entire distribution of the European mink were to be protected within Natura 2000, the protected population size would still be dangerously low.

The other species, which are all large mammals with a wide distribution, are insufficiently protected in relation to their ecological requirements. In fact, these species live at very low densities, and require larger areas than those provided by Natura 2000 sites alone in order to ensure viable populations. Based on their ecology this may therefore be expected, but it has implications for both policy and practice in relation to their conservation.

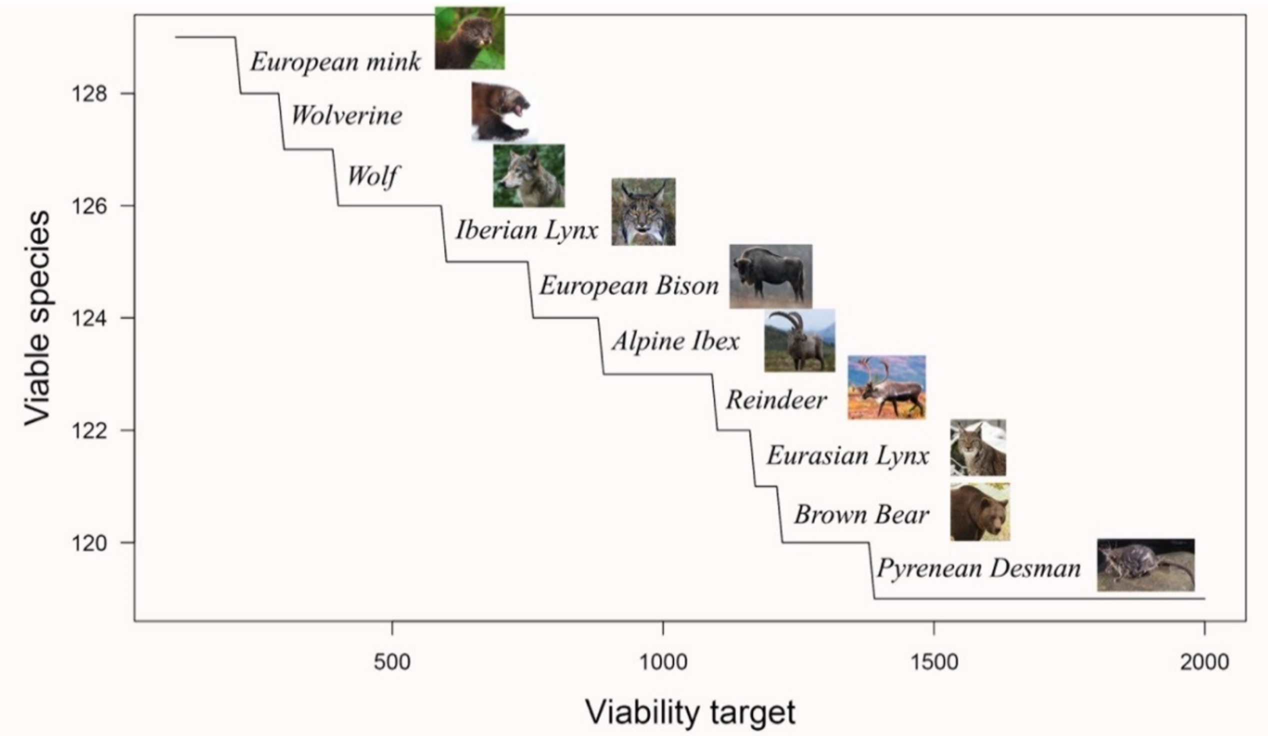


Figure 4-9 *Estimated number of mammal species able to form a viable population (y-axis) according to increasing viability target thresholds (x-axis; expressed as the minimum population size to be conserved). As the viability target increases, the number of species that can be considered to be viable decreases. Each step in the line thus represents a decrease in one species (whose largest estimated population does not reach a given target, i.e. population size) from the pool of viable species. The name and photo of the species that do not reach a given target are reported at the side of each of the steps.*

Validation by independent data points

The models representing species distribution obtained by masking IUCN geographic range maps by the habitat suitability models were validated against 981,844 independent presence points of mammal species. We performed the validation by sampling for 100 times, 1000 random points in the study area, and obtaining at each iteration a proportion of correctly predicted presences. Then we tested if the percentage of correct classification with real data fell in the upper 2.5% of the distribution (significance test) of the proportion of correctly predicted presences. The validation demonstrated that 86.7% of the distribution models performed significantly better than random (Fig. 4-10). However, the models that did not perform significantly better than random are not necessarily bad models. In fact, if the species are widely distributed in the EU-28 most random points will fall within areas of presence, and thus presence points used for validation will not perform significantly better. In other words, random points can have the same performance as presence points, because wherever they fall they are predicted to be present (same as presence points). So this validation approach works well only for species that are not widely distributed. This limitation in the validation is given by the lack of reliable absence points for many of the more elusive mammal species.

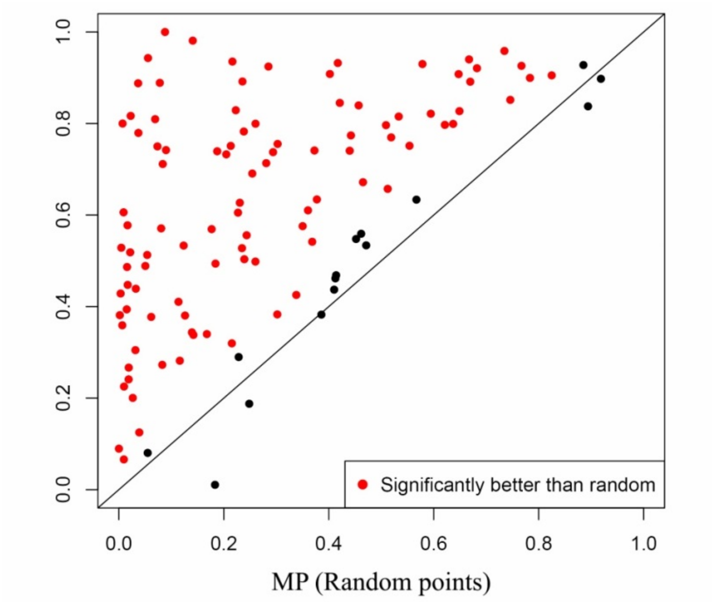


Figure 4-10 *Relationship between the MP (mean proportion of correctly predicted presences) of random points sampled within the study area (X axis), and the MP of real mammal presence points from an independent dataset (Y axis).*

Cross-Validation with statistical species distribution models

The cover percentages estimated using the statistical model predictions (BRT model), based on the 981,844 observation points, were positively correlated with those obtained by range maps and habitat masking (Pearson's rho=0.62), and showed a mean difference of 5.0±7.6% (Fig. 4-11). In general, the statistical approach tended to predict lower percentages of protection and higher percentage of 'Partial Gap' species than the approach using range maps and habitat masking. For example, mammal species were estimated to have a mean protection by Natura 2000 of 23.1±11.2% according to the range maps and habitat models, whereas only 17.8±4.5% according to the statistical models (Fig. 4-11; Data Table). As a consequence, while according to the first models the proportion of 'Partial Gap' species is 33.1%, according to the second the proportion of 'Partial Gap' species is 57.1%. This difference might be due to the over-estimation of species presence due to assuming species presence homogeneously within the suitable habitat in the geographic range. This could also be a result of under-estimation of the statistical prediction, due to the insufficient and biased sampling of presence points within the species geographic range, which leads to the under-estimation of species environmental niche. However, this difference is likely to be due to the combined effect of both effects. It is therefore important to increase the data on mammal species presence in order to build more accurate models of species distribution.

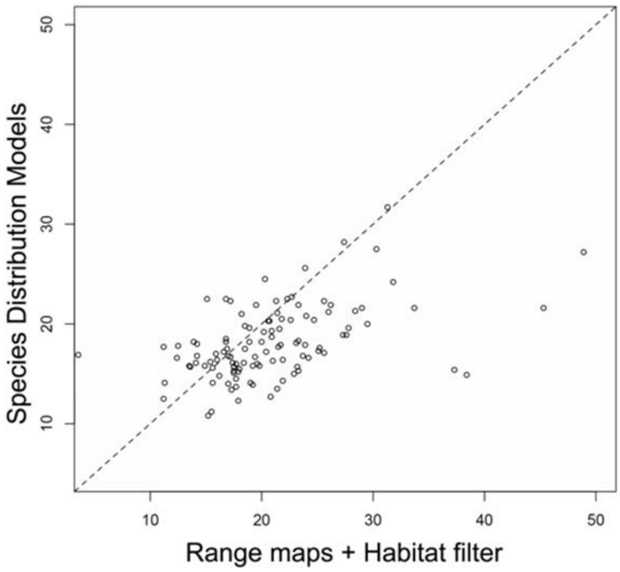


Figure 4-11 *Relationship between proportion of cover of mammal species by Natura 2000, as calculated from Range maps masked by habitat filter and statistical species distribution model. Dashed line = expected relationship if the two models were exactly concordant.*

*The red squirrel (*Sciurus vulgaris*) is considered Least Concern by the European Red List. It covers 47.2 of European territory and 20.6% of its distribution is protected by Natura 2000. This species is still abundant in Europe, but is known to be declining because of the invasion by the American Grey squirrel (Sciurus carolinensis). It is also sensitive to habitat loss and fragmentation and Natura 2000 might therefore have a role. (Photographer Leonardo Ancillotto)*

4.2.2 Birds

Below we present the results of the masking analysis using breeding bird atlas distribution maps at the 50x50 km level and two types of modelled distribution maps at the 5x5 km level. We considered the relative coverage of species' distribution by the Natura 2000 network. and present these in relation to the species' policy-status (Annex I, EU Red List), its habitat association and its distribution in the EU.

50×50 km breeding bird distribution and habitat masking

These results are based on the 50×50 km atlases with habitat masking. The percentage of habitat inside Natura 2000 sites for 355 analysed taxa is shown in Figure 4-12 and is compared to the EU-28 percentage of 18% terrestrial area covered by Natura 2000 sites. 84% of the species exceeded this baseline, indicating that the majority of species has an above average coverage in Natura 2000 sites, according to this approach. In total 16% of species were below the baseline (Partial Gap Species) and 0% species had zero coverage by the network (Gap species).

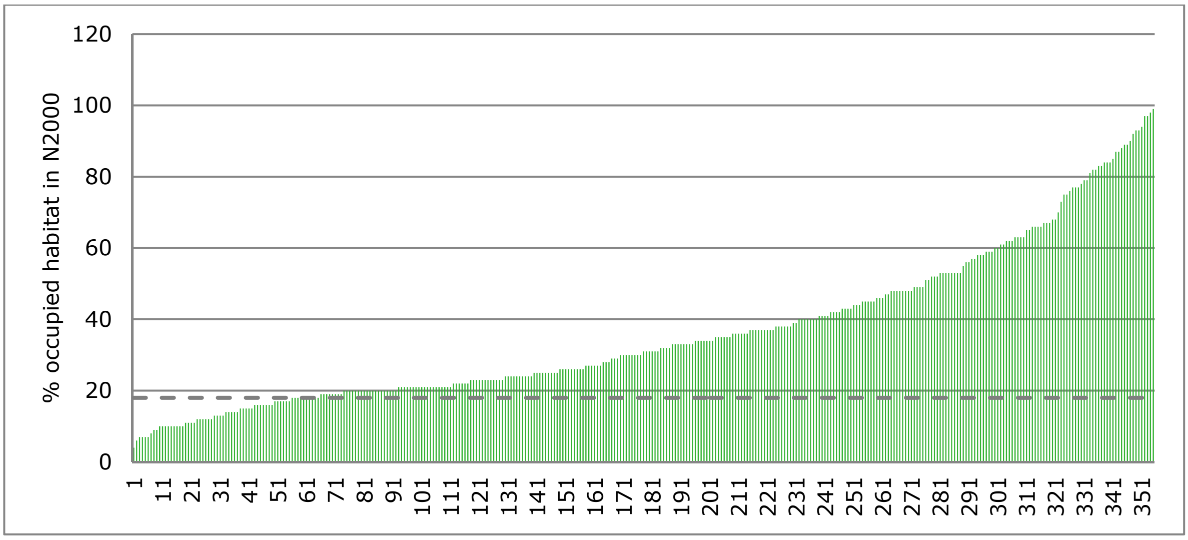


Figure 4-12 *Ranking (x-axis) of the percentages habitat inside Natura 2000 for 355 analysed bird taxa based on 50×50 km Atlas data and habitat masking. The grey line shows EU-28 percentage of 18% terrestrial area covered by Natura 2000 sites.*

Figure 4-2 and 4-5 summarise the importance of Natura 2000 sites in relation to conservation threat and habitat association categories. They show that on average, Annex I species and threatened species on the EU Red List are better covered by the Natura 2000 network than non-Annex or non-threatened species.

Concerning habitat categories the results reveal higher coverage by Natura 2000 sites for species of marshlands and wetlands, coastal/marine, and open nature habitat (Fig. 4-13). Natura 2000 coverage by generalists and species of semi-Natural terrain/ open farmland and forest/shrub also exceeds the 18% baseline but only marginally.

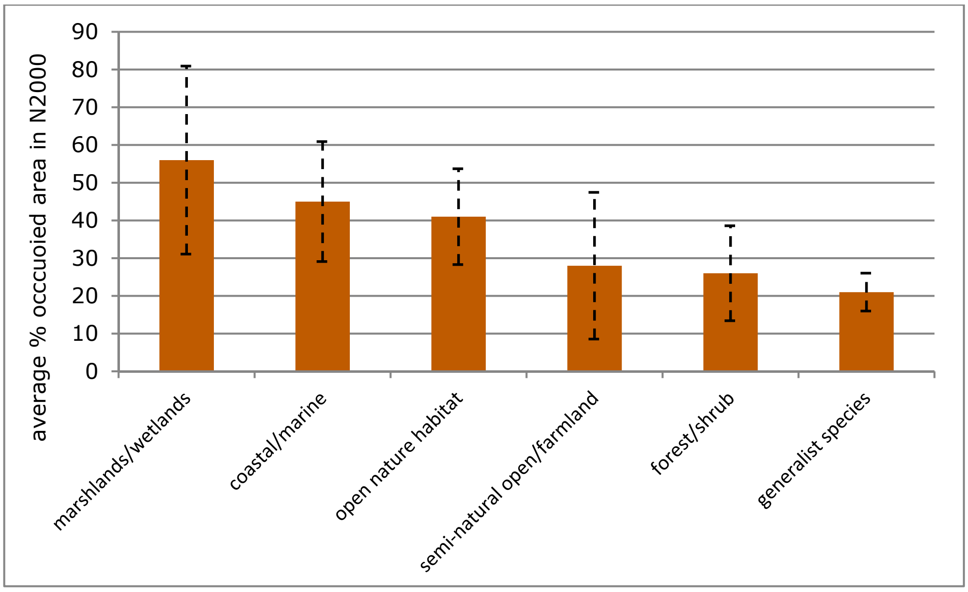


Figure 4-13 *Average percentage occupied habitat inside Natura 2000 sites for bird species by grouping them to habitat specialism based on 50 × 50 km Atlas data and habitat masking. (marshland/wetlands: n=81, coastal/marine: n=31, open nature habitat: n=42), semi Natural open/farmland: n=76, forest/shrub: n=94 and generalist species: n=31).*

Figure 4-14 shows how for very widespread species, their coverage by Natura 2000 naturally approximates the EU-28 average figure, and that rare species tend to be better covered. However, there are some rare species that are very poorly covered.

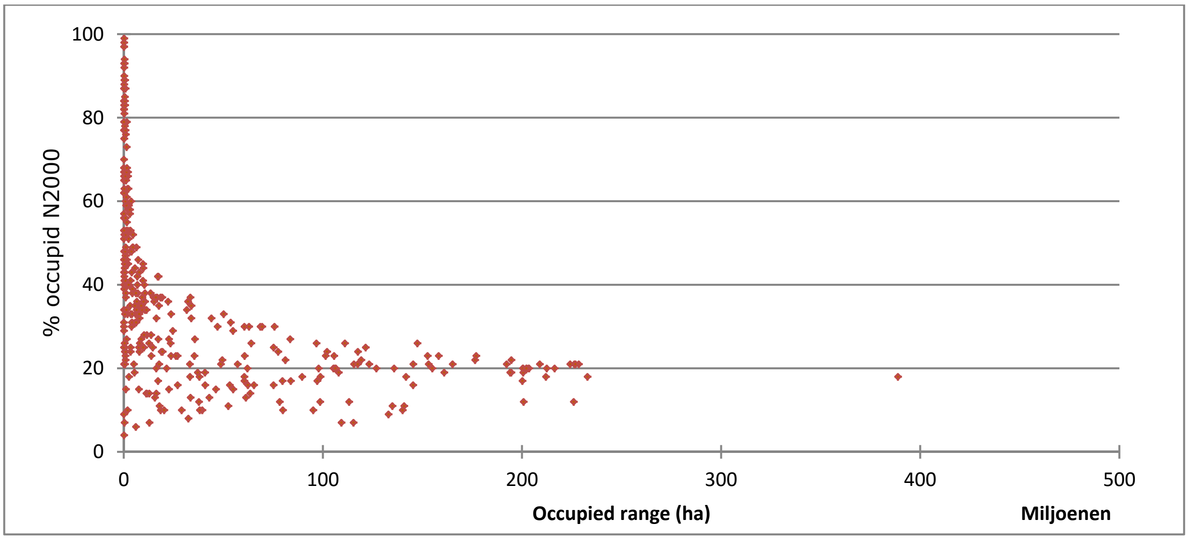


Figure 4-14 *Bird species' EU-range size (ha) versus percentage occupied area in Natura 2000. Based on 50x50 km modelling and habitat masking.*

Per country

Figure 4-15 presents the coverage of breeding bird species' distribution by Natura 2000 sites per country. Overall, southeastern European countries show the highest coverage and Malta and some northern European countries the lowest.

In the majority of the countries the proportion of the species' distribution in Natura 2000 sites is higher than expected based on the percentage surface designated as Natura 2000 site, but there is little evidence of a clear relationship between these values.

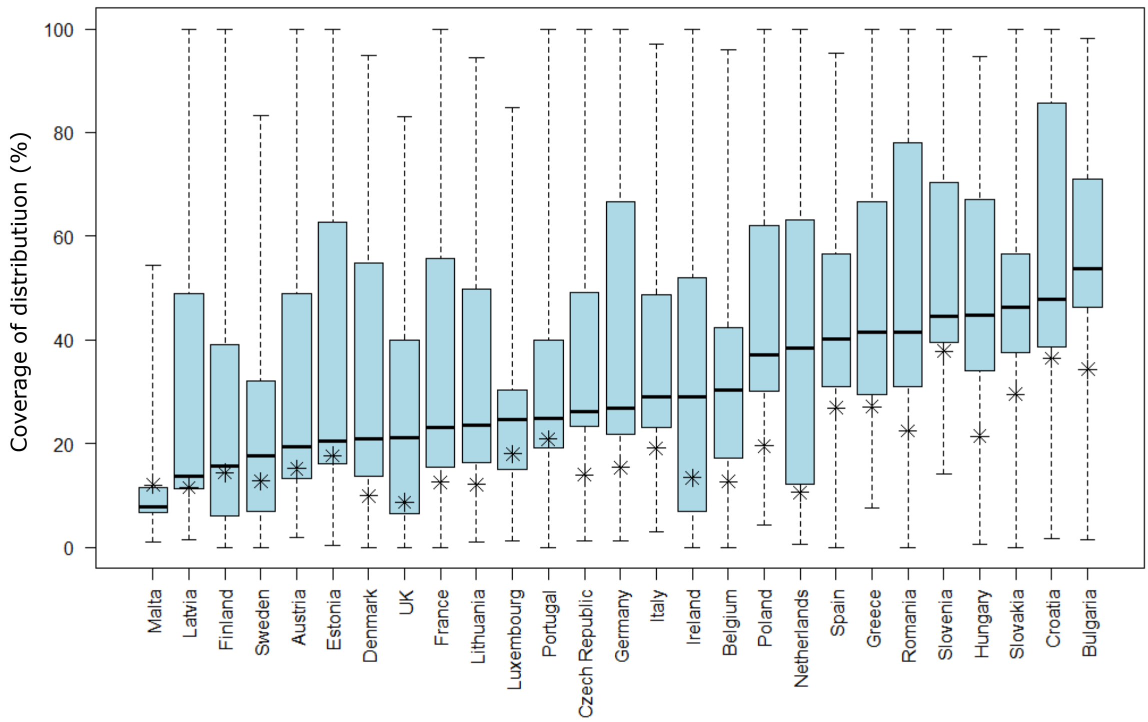


Figure 4-15 *Coverage of distribution (%) of analysed breeding birds by Natura 2000 sites per EU-country, based on 50x50 km Atlas Masking analysis. The black line shows the median value, The blue box the 25% and 75%-percentile. The bars show the interquartile range.*

Modelled 5×5 km breeding bird distribution

The 5x5 km modelling is based on down-scaled maps of the Atlas of European breeding birds (Hagemeijer and Blair 1997). The percentage of distribution coverage by Natura 2000 for 238 analysed bird species is shown in Figure 4-16. The EU-28 baseline of 18% terrestrial area covered by Natura 2000 sites is exceeded by 56% of the species, indicating that a slight majority of the species has an above average coverage in Natura 2000 sites.

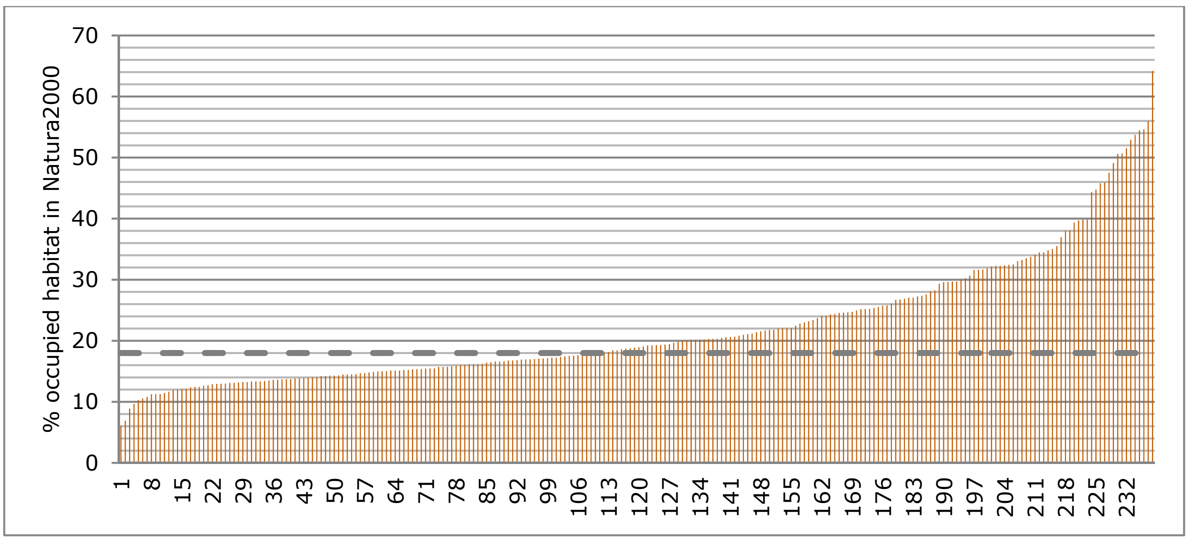


Figure 4-16 *Ranking (x-axis) of the Natura 2000 coverage for 238 analysed bird taxa based on down-scaled to 5×5 km Atlas maps. Blue line shows EU-28 percentage of 18% terrestrial area covered by Natura 2000 sites.*

Figure 4-17 and 4-18 summarise the importance of Natura 2000 sites by the same conservation threat and other categories as above. These show that the importance of Natura 2000 sites is slightly higher for species on Annex 1/ EU-28 Red List compared to species that are not. However percentages and number of species are not high when compared to the 18% baseline value as a measure for the added value of Natura 2000 sites.

Species of open nature have a relatively high presence in Natura 2000 sites compared to the 18% baseline value (Fig. 4-19). However the other habitat-groups, including semi-Natural, show an average distribution percentage in Natura 2000 close to the 18% baseline and relatively low number of species exceeding this. In particular the generalist species score relatively low.

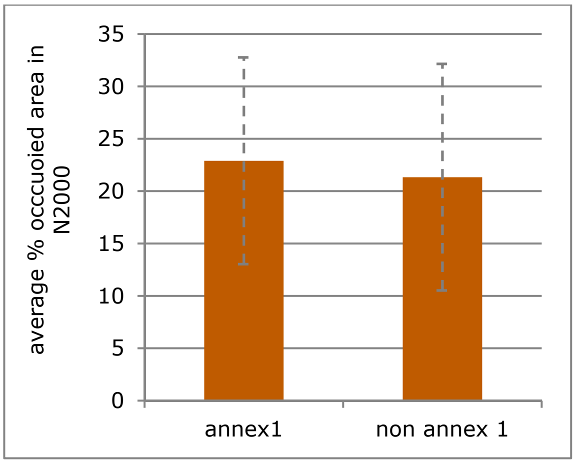


Figure 4-17 *Average percentage occupied habitat inside Natura 2000 sites for Annex 1 bird species (n=124) and non-Annex I bird species (n =114) based on down-scaled to 5x5 km Atlas maps.*

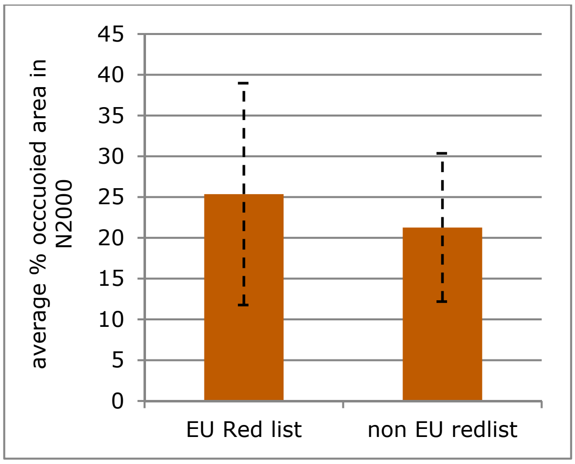


Figure 4-18 *Average percentage occupied habitat inside Natura 2000 sites for EU Red List bird species (n=51) and non-EU Red List bird species (n =187) based on down-scaled to 5×5 km Atlas maps.*

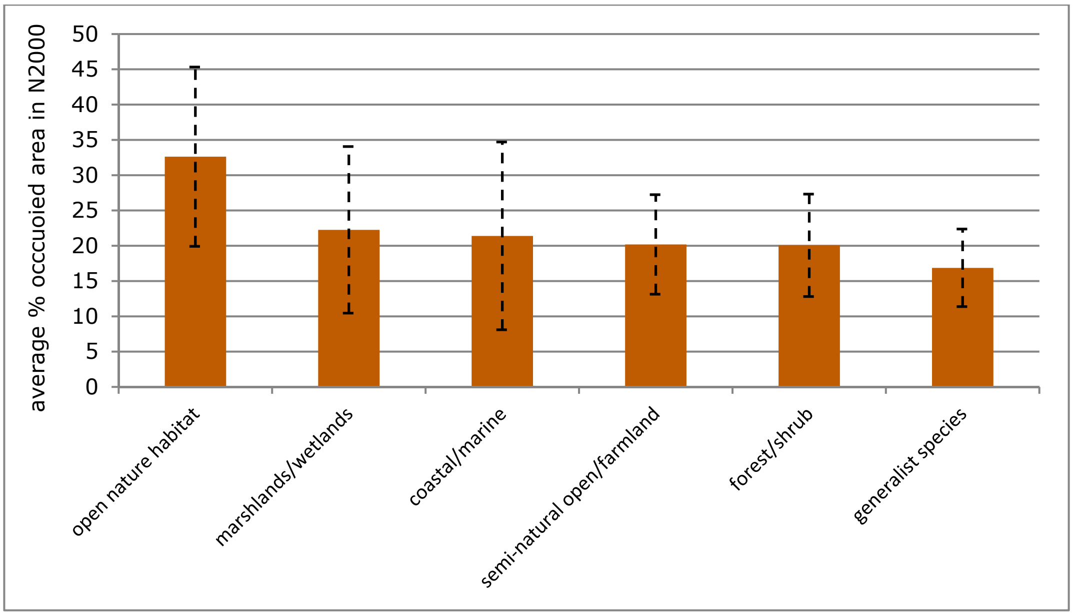


Figure 4-19 *Average percentage occupied habitat inside Natura 2000 sites for bird species by grouping them to habitat specialism based on down-scaled to 5×5 km Atlas maps. (Open nature habitat: n=31, marshland/wetlands: n=56,coastal/marine: n=8, semi Natural open/farmland: n=63, forest/shrub: n=69 and generalist species: n=11).*

Figure 4-20 illustrates that species with smaller ranges in the EU have a high proportion of their distribution in Natura 2000 sites.

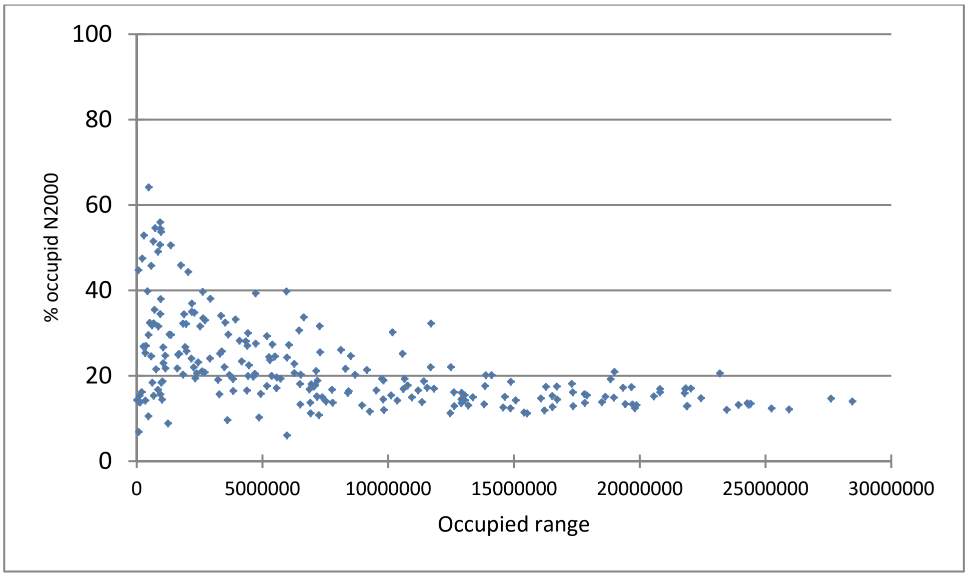


Figure 4-20 *Bird species' EU-range size (ha) versus percentage occupied area in Natura 2000. Based on 5x5 km modelling data.*

Per Country

The northwest European countries have relative low coverage values for the breeding bird species' distribution for Natura 2000 sites (Fig. 4-21). In particular, some eastern and southern countries show the highest frequency of occurrence in Natura 2000. Generally the median of species distribution coverage by Natura 2000 by country corresponds well with the relative area designated as Natura 2000 site by country.

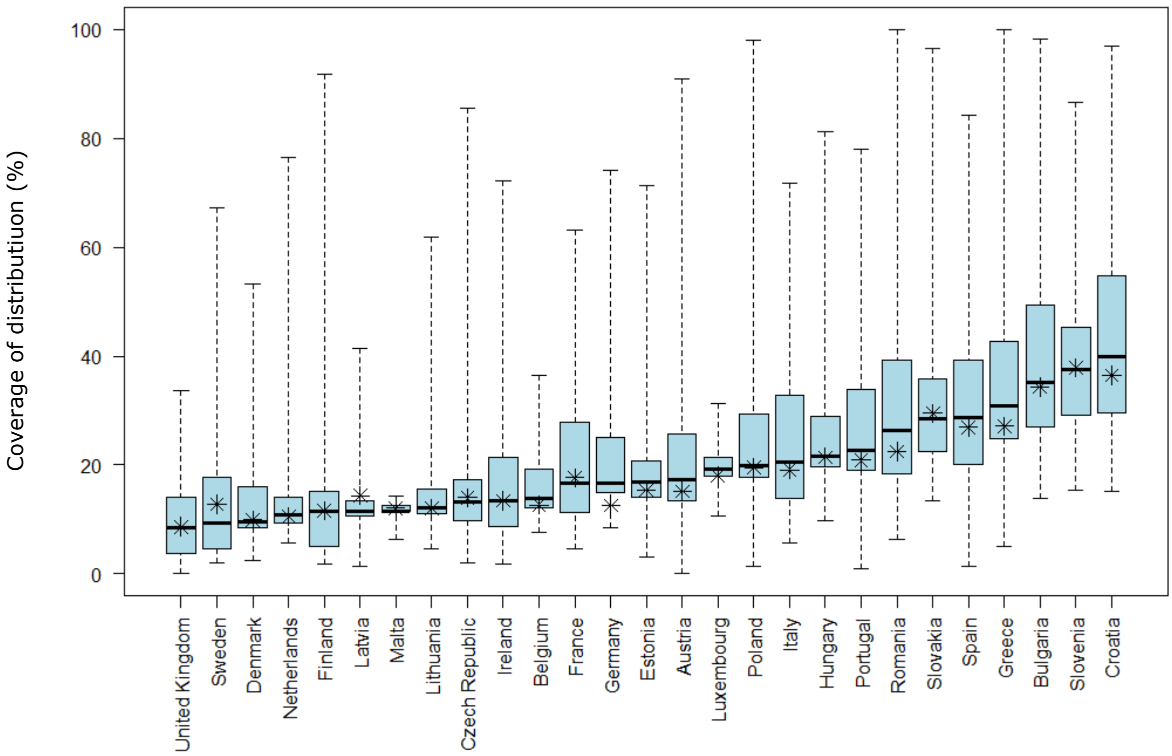


Figure 4-21 *Coverage of distribution (%) of analysed breeding birds by Natura 2000 sites per EU-country, 867 based on 5x5 km Atlas modelling analysis. The black line shows the median value, the blue box the 25% and 75%-percentile. The bars show the interquartile range.*

Modelling recent bird observations
These results are derived from species distribution models based on recent presence-only records. Based on the modelled distribution (5×5 km), the percentage habitat inside Natura 2000 sites for 252 analysed bird species is shown in Figure 4-22 and is compared to the EU-28 percentage of 18% terrestrial area covered by Natura 2000 sites. Overall, 62% of the species exceed this baseline, indicating that a majority of the species has an above average coverage in Natura 2000 sites.

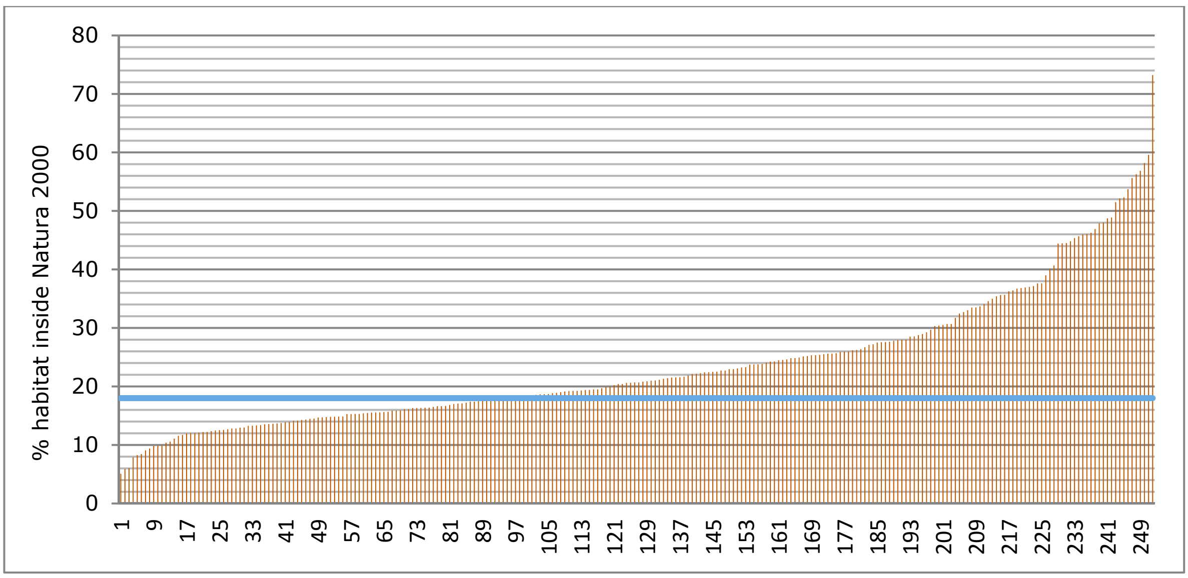


Figure 4-22 *Ranking of the percentages habitat inside Natura 2000 for 252 analysed bird species based on modelled distribution maps using various bird observation data sources. Red line shows EU-28 percentage of 18% terrestrial area covered by Natura 2000 sites.*

Figure 4-23 shows that the importance of Natura 2000 sites is slightly higher for species on Annex 1/ EU Red List compared to species that are not (Fig. 4-24). However percentages and number of species are not high with regard to the 18% baseline value as a measure for the added value of Natura 2000 sites. Regarding the habitat association groupings, Figure 4-25 show that species associated with open habitats tend to be well-covered by Natura 2000 sites, compared to the 18% baseline value. However the other habitat groups, including the semi-Natural ones, show an average coverage in Natura 2000 close to or only slightly higher than the 18% baseline and a relatively low number of species exceeding this baseline. In particular the generalist species score relatively low.

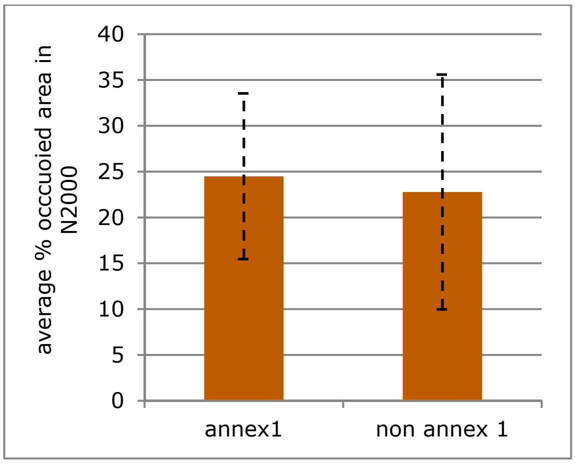


Figure 4-23 *Average percentage occupied habitat inside Natura 2000 sites for Annex 1 bird species (n=131) and non-Annex I bird species (n =121) based on modelled distribution maps using various bird observation data sources.*

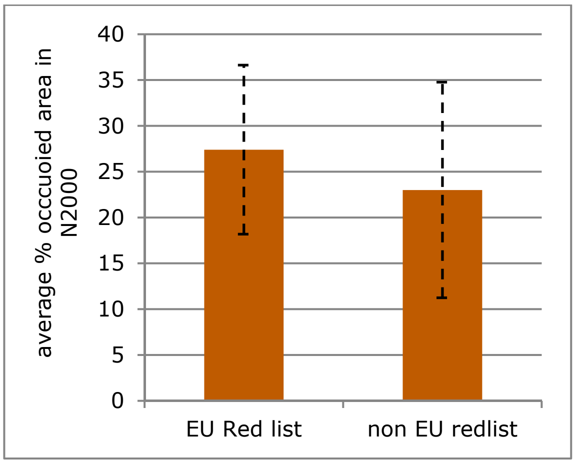


Figure 4-24 *Average percentage occupied habitat inside Natura 2000 sites for EU Red List bird species (n=67) and non-EU Red List bird species (n =195) based on modelled distribution maps using various bird observation data sources.*

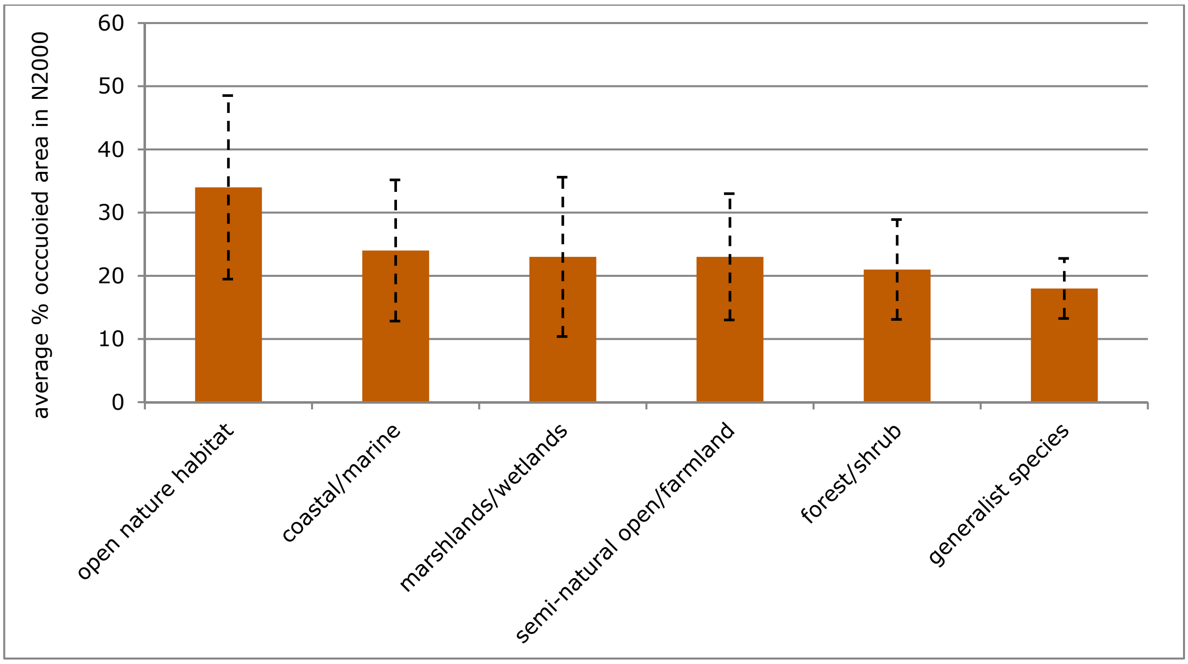


Figure 4-25 *Average percentage occupied habitat inside Natura 2000 sites for bird species by grouping them to habitat specialism based on modelled distribution maps using various bird observation data sources. (open nature habitat: n=32, marshland/wetlands: n=62,coastal/marine: n=8, semi Natural open/farmland: n=67, forest/shrub: n=71 and generalist species: n=12).*

Figure 4-26 shows that relatively many species with small range in the EU-28 have high distribution percentage in Natura 2000 sites.

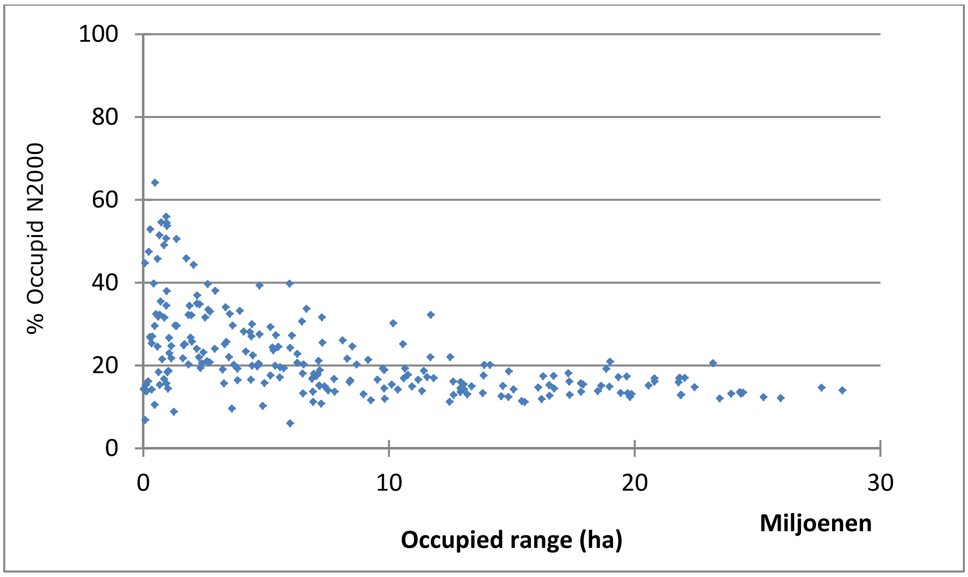


Figure 4-26 *Bird species' EU-range size (ha) versus percentage occupied area in Nature 2000. Based on 5x5 km modelling data.*

Per Country

Figure 4-27 shows the proportion of breeding bird species' distribution coverage by Natura 2000 sites per country. Here also, many northwestern European countries have relative low coverage values, whereas eastern and southern European countries tend to show higher proportions of Natura 2000 coverage. Generally the median distribution of Natura 2000 coverage per country corresponds well with the percentage of area designated as Natura 2000 site per country.

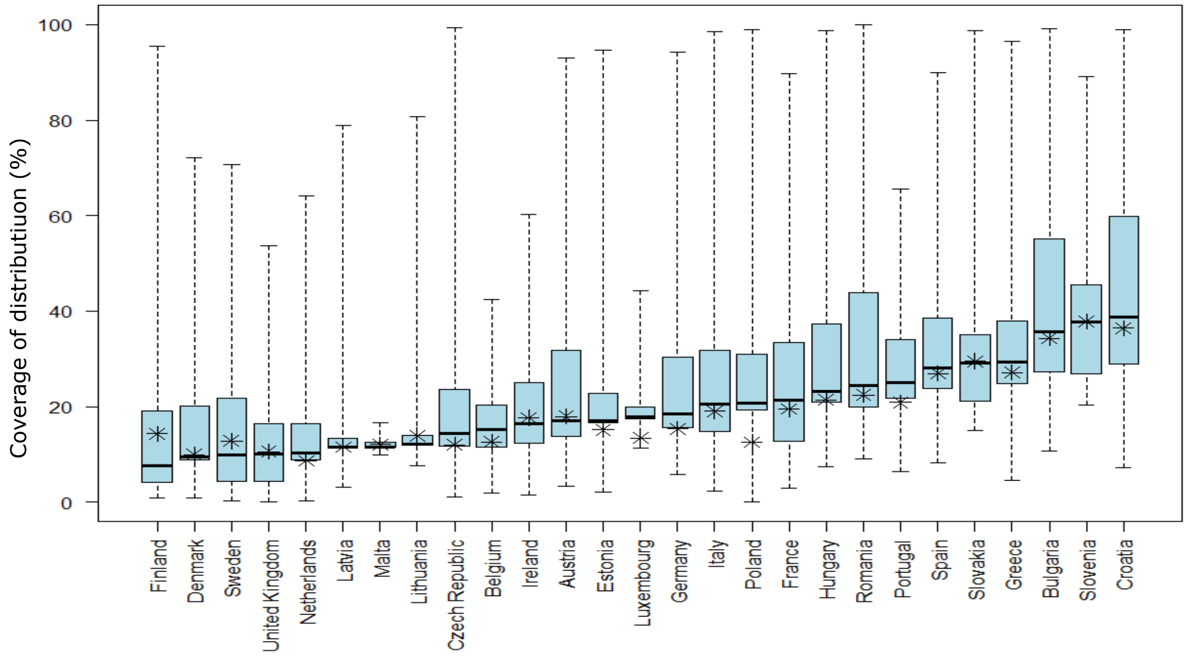


Figure 4-27 *Coverage of distribution (%) of analysed breeding birds by Natura 2000 sites per EU-country, 935 based on 5x5 km recent data modelling analysis. The black line shows the median value, The blue box the 25% and 75%-percentile. The bars show the interquartile range.*

Comparison results EU-wide masking and modelling analyses
We compared the results of the 50x50 km modelling and masking with the two alternative approaches (5x5 km downscaling and presence only data modelling) for the bird species analysed for each of the three approaches (n =231). There is a marked difference between the 50×50 km with masking analysis, which shows higher average coverage by the Natura 2000 network, compared to the other two modelling approaches that show rather similar results.

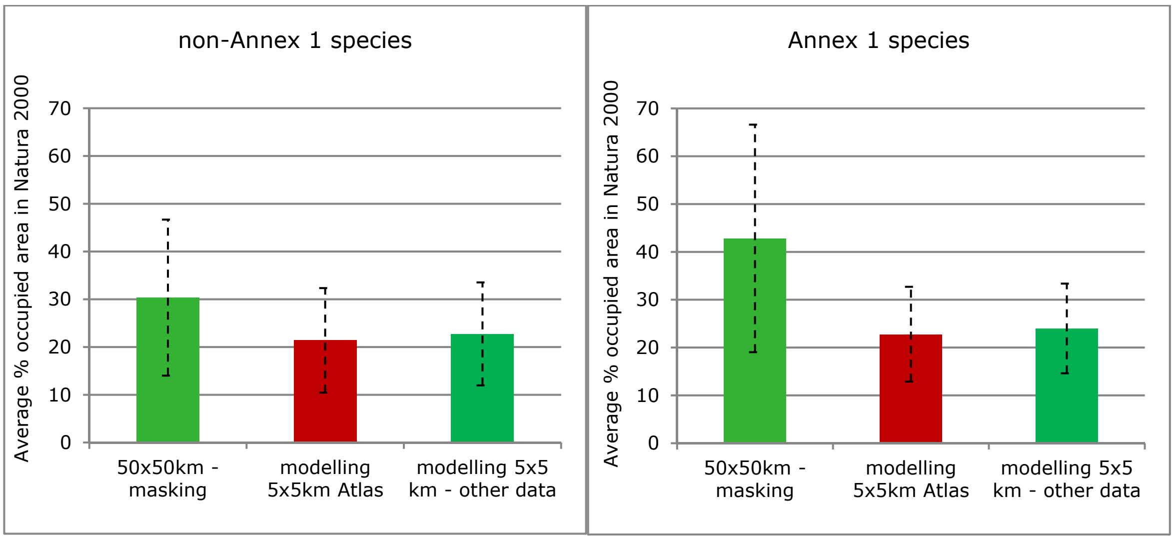


Figure 4-28 *Average % occupied area in Natura 2000 sites for the subset of 231 bird species assessed with three analytical approaches, (left) for non-Annex 1* ***s****pecies (n=109) and (right) for Annex 1 species (n=122).*

The same general pattern is visible when species are categorised by Annex 1 or EU Red List status; the 50×50 km masking analysis shows for both categorisations, considerably higher coverage by

Natura 2000 sites. When comparing Annex 1 to non-Annex 1 species the 50×50 km masking analysis shows a markedly higher average coverage by Natura 2000 sites for Annex 1 species (Fig. 4-28). This is not the case for the other two modelling approaches. The same pattern is evident for the breakdown by EU Red List species, but to a lesser extent (Fig. 4-29). All three approaches are in agreement however, that species with small ranges have higher coverage by Natura 2000 sites than species with large ranges (Fig. 4-14, 4-20, 4-26).

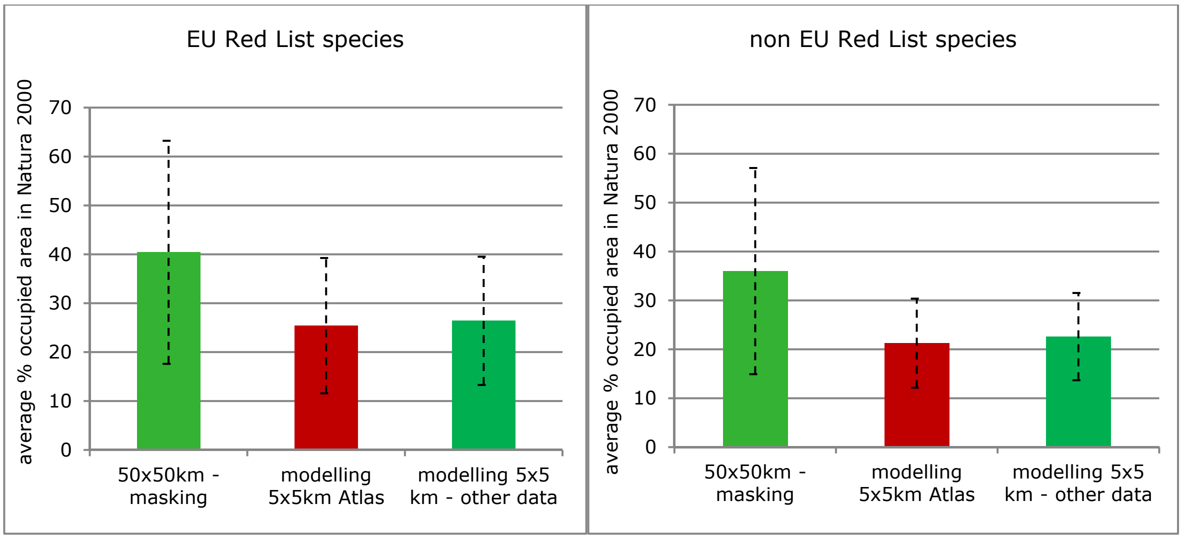


Figure 4-29 *Comparison of average % occupied area in Natura 2000 sites between the three approaches, (left) for EU Red List bird species (n=49) and (right) for non-EU Red List bird species (n=182).*

*Ptarmigan (*Lagopus mutus*) is a resident specialist of open natural mountainous habitats in Europe likely to be impacted negatively by climate change, but its relatively restricted range is currently relatively well covered by the Natura 2000 network. (Photographer Edmund Fellowes)*

4.2.3 Reptiles and Amphibians

These results are based on downscaled predictions from 50×50 km atlas data and were possible for 165 species. The 165 herpetofauna species (65 amphibians and 100 reptiles) follow the species list of the Societas Europaea Herpetologica (SEH) published in 2014 (Sillero *et al.* 2014), excluding invasive and domestic species. Also, sea turtles were excluded because all data layers available for this analysis constituted the landmass of the EU-28. Of the sea turtles only the loggerhead (Caretta cartetta) breeds on some European beaches which make them difficult to model properly. Of the included species, 23 were listed under Annex II of the Habitat directive and 31 were considered threatened (VU=21; EN=10; CR=0) according to the IUCN Red List for Europe (Fig. 4-5, 4-31).

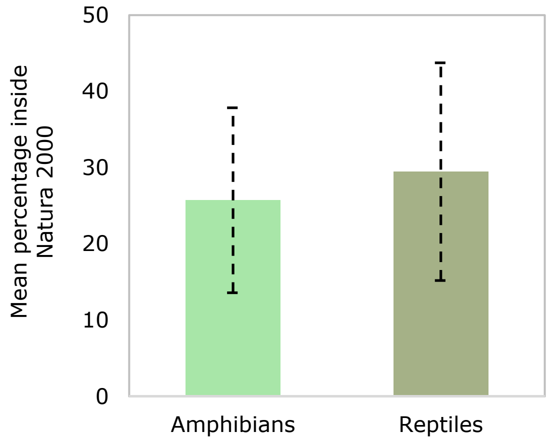


Figure 4-30 *Presence of Amphibian and reptile species within Natura 2000 areas for the EU-28.*

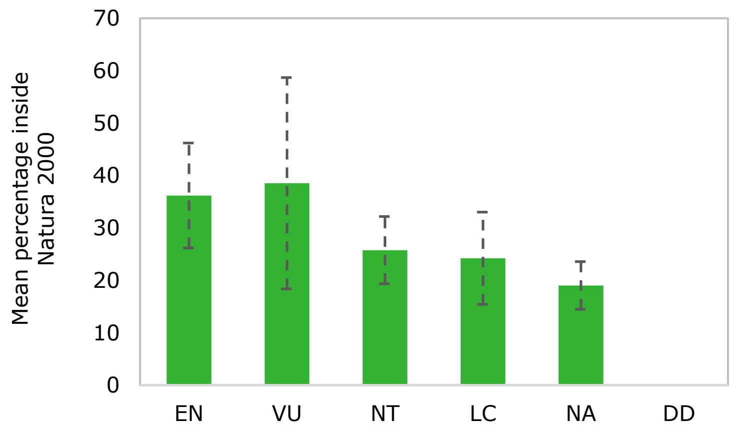


Figure 4-31 *Presence of Red Listed Amphibian and reptile species within N2000 areas for the EU-28, with a division for the threat category (EN=Endagered, VU=Vulnerable, NT= Near threatened, LC=Least concern, DD= Data deficient.*

Herpetofauna species have a mean coverage of 28.7±14.1% (25.7±12.0% for amphibians and 29.5±14.2% for reptiles; Fig. 4-30). There are no species entirely outside the Natura 2000 sites (gap species). The least protected species is the Maltese wall lizard (*Podarcis filfolensis*), a species that is labelled as 'Least Concern' by the IUCN. Using a baseline equal to 18% (Natura 2000 coverage in EU-28), 33 species (15 amphibians and 18 reptiles) were included in the Natura 2000 network for which coverage does not reach the adopted baseline (partial gaps) and 132 species (50 amphibians and 82 reptiles) were adequately protected. Annex II species had a mean coverage of 28.7±13.9% (26.4±13.7% for amphibians and 29.7±12.5% for reptiles), of which four species did not meet the target (3 amphibians and 1 reptile; see below). For comparison, species not listed under Annex II had a mean coverage 28.2±13.4% (22.5±11.5% for amphibians and 29.4±14.4% for reptiles), of which 29 species had a coverage below the baseline (Fig. 4-2). Threatened species had a mean coverage of 40.5±19.0% (36.4±18.3% for amphibians and 43.8±18.9% for reptiles) of which one species with a coverage below 18% (the Italian agile frog, *Rana latastei*). Sweden, Malta and the United Kingdom seem to cover Herpetofauna habitat the least well (Fig. 4-32), also compared to their overall coverage by Natura 2000, while Bulgaria, Croatia and Slovenia perform best for the whole group and the amphibians. Sweden is a notable positive outlier for reptiles, but only 2 species were considered (the adder, *Vipera berus*, and the common lizard, *Zootoca vivipara*) both rather common with a large range in these regions.

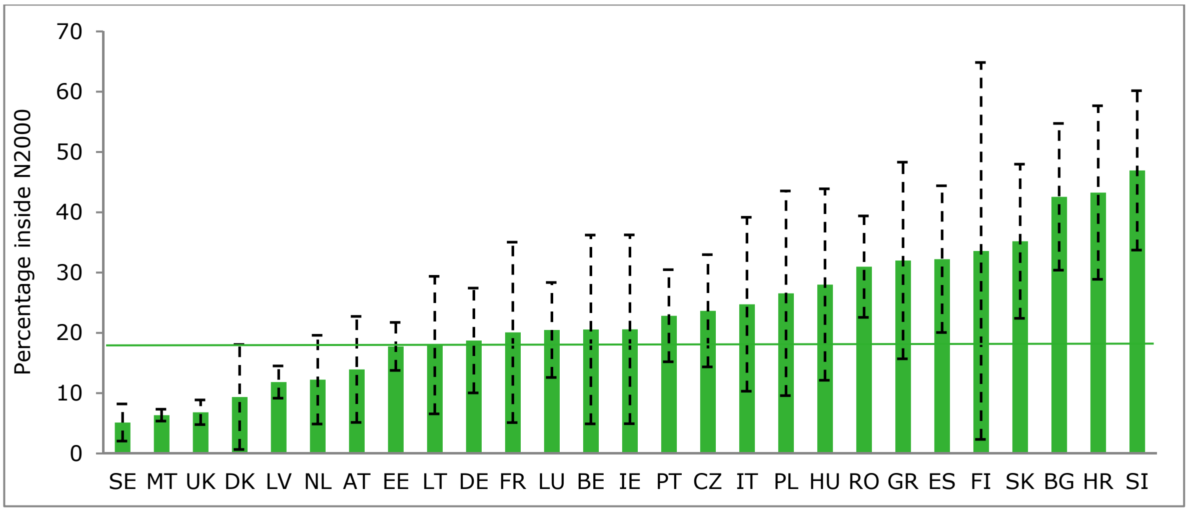


Figure 4-32 *Ranking of level of average presence of amphibian and reptile species within NATURA 2000 per country.*

It should be noted that Herpetofauna is not evenly distributed across European countries, and there is a clear north-south gradient, with more species in the southern countries than in the northern countries (Fig. 4-33). This means that in particular the analysis results reflecting the number of species are higher for southern countries than for northern countries.

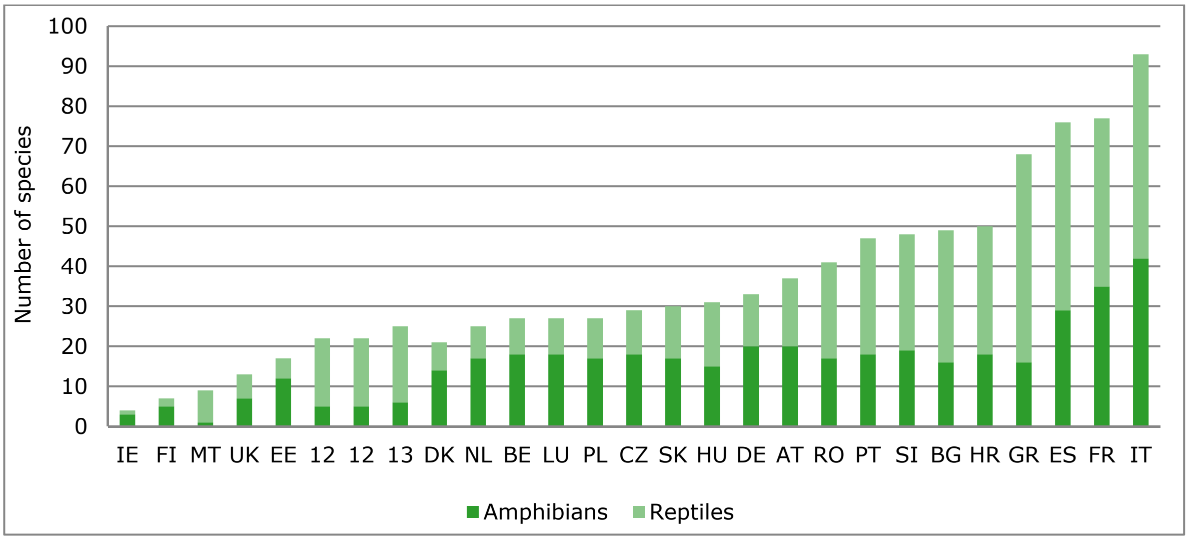


Figure 4-33 *Number of herpetofauna species that were evaluated in the habitat masking analysis per country.*

There is little difference between endemic and non-endemic species of the herpetofauna, both have a higher presence within the Natura 2000 network, approximately 28%. The amphibian endemic species do have clearly a higher presence within the protected areas network (Fig. 4-7). An explanation could be that these species are more sensitive to environmental pressures, and outside protected areas they are more exposed e.g. to pollution, water quality and dessication etc.

Annex II gap species
Figure 4-34 shows the average coverage by Natura 2000 for species as estimated with the habitat masking analysis. It shows that there are four Annex II species that are identified as Gap species. These species and their results are individually discussed in Table 4-1. We can conclude that there is essentially one notable gap species, the Italian agile frog (*Rana Latastei*) that is not well protected by Natura 2000 despite its IUCN Red List and Annex II status. In total 20% of herpefofauna species (33 out of 165) were below the baseline (Partial Gap Species).

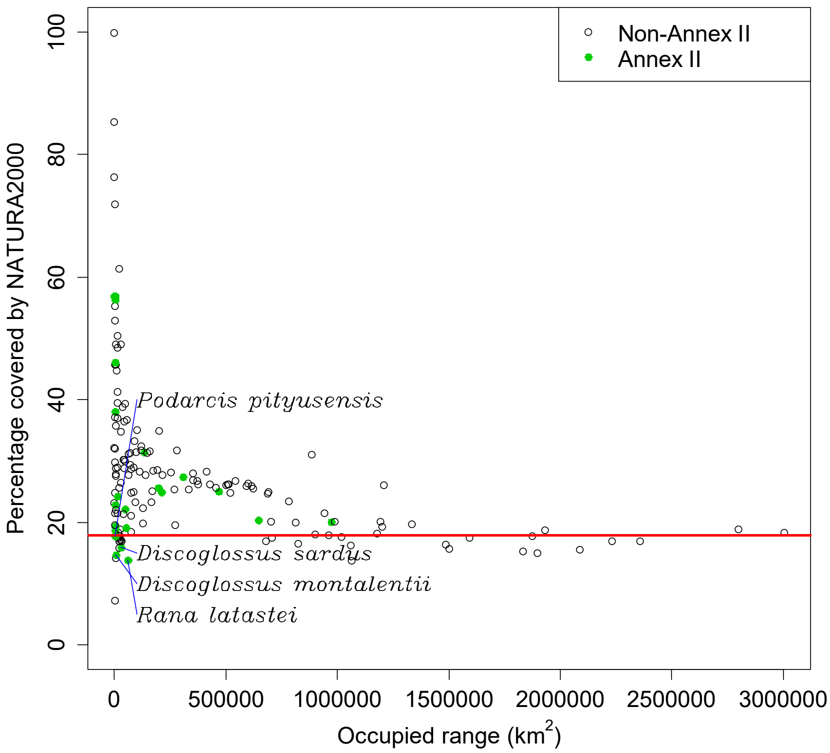


Figure 4-34 *Distribution range of herpetofauna species versus coverage by Natura 2000 as estimated by the habitat masking approach.*

Table 4-1

Annex II herpetofauna species with Natura 2000 coverage estimates based on Habitat masking that are below the EU-28 wide baseline of 18%.

Species Name	Discussion	Best estimate
Discoglossus sardus (Tyrrhenian painted frog)  © Franco Andreione	The extent of the home range of the *Discoglossus sardus* seems over estimated when using the habitat masking approach. The estimated ranges from the 5x5 km or 1x1 km modelling seem more reasonable. Also, the species is better covered by Natura 2000 at Sardinia then at Corsica. The Natura 2000 coverage according to the 5x5 km distribution mapping is 17.0%, but increases when modelled at 1km by 1km to 28.4%. The latter is only estimated for the Italian part of its distribution range, as France was not among the countries for which higher resolution data was available.	28.4%
Discoglossus montalentii (Corsican painted frog)  © Michael Linnenbach	Most likely the distribution of *Discoglossus montalentii* is overestimated by the habitat masking. There were insufficient points for the 5x5 km modelling, and as France was not among the countries for which higher resolution data was available, also modelling at 1km by 1km was not possible. It is known, however, that the frog is restricted to the more central parts of the Corsican island (Nöllert and Nöllert 1992), where also Natura 2000 areas are located. This suggests that the presented coverage in this study is an underestimation for this species.	NA
Rana latastei (Italian Agile Frog)  © Allesandro Catenazzi	*Rana latastei* occurs mainly in the Po delta, where it's Natural habitat are the swamps around the Po-river. Due to century old cultivation in this region, most swamps have been converted to agricultural lands. Also for the probably more precise estimations at 5x5 km or 1x1 km, only a small fraction is covered by Natura 2000 (11.8% and 7.6% respectively) increasing the likeliness that this is a true gap species which requires a higher coverage of the Natura 2000 network.	7.6 ~ 13.8 %
Podarcis pityusensis (Ibiza wall lizard) 	The *Podarcis pityusensis*, a typical island species, is most likely also overestimated in its extent by the habitat masking method, resulting in this case in a low Natura 2000 coverage (17.7%). The 5x5 km and 1x1 km modelling show a more realistic estimated range, and consequently higher Natura 2000 coverage (32.8% and 34.7% respectively).	32.8 ~ 34.7%

Habitat masking vs 5x5 km modelling

Figure 4-35 shows the relationship between Natura 2000 coverage according to the habitat masking and Natura 2000 coverage according to the 5x5 km modelling. Species that show more than 10% difference between the two methods are indicated by their names.

Two species groups (Speleomantes and Marsh turtles) are clustered and have a clear explanation why they show up as outliers in the plot comparing the two methods (Fig. 4-35). These species are discussed as groups below. Individual outlier species are discussed in Table 4-2. This analysis reveals that probably *Pelophylax cretensis* (the Cretan frog, listed as endangered by the IUCN Red List) should also be considered as a (partial) gap species (i.e. a Natura 2000 coverage below 18%).

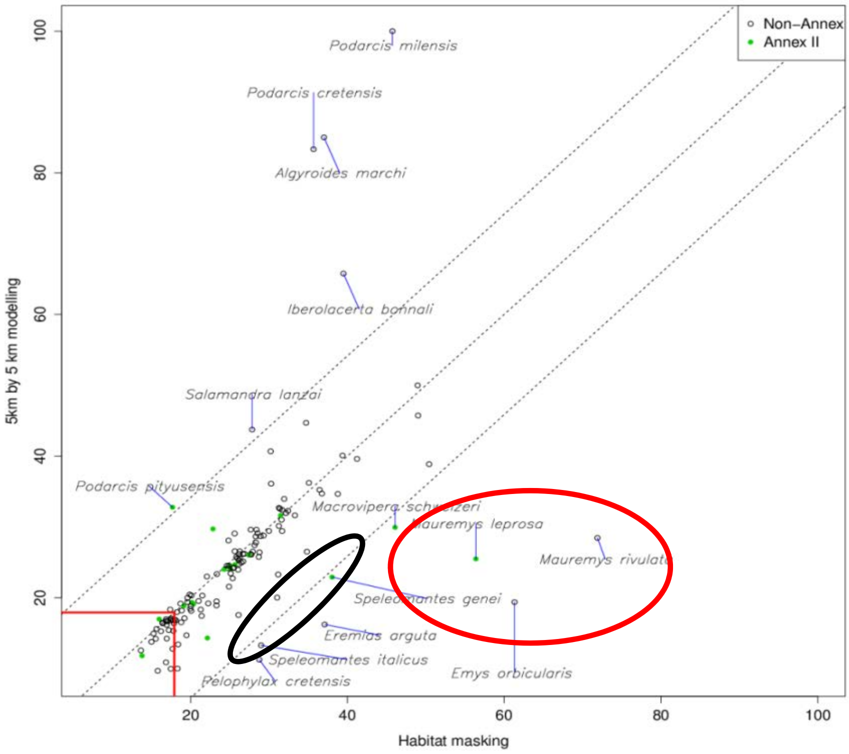


Figure 4-35 *Comparison between habitat masking and herpetofauna modelling at 5x5 km scale. Marsh turtles (red circle) and Speleomantes salamanders (black circle) are highlighted. Dashed lines indicate differences larger than 10%. Species with more than 10% difference between habitat masking and modelling at 5x5 km are indicated by their name. The red lines indicate the average EU-28 land cover under Natura 2000.*

Marshland turtles show up as a notable exception group (red circle in Fig. 4-35). For these species the main limitation is the level of detail in the Corine land cover map. The major land cover types that are associated with these species (small wetlands and marshes) seem underrepresented in the Corine land cover map, leading to an under estimation of their habitat range. This causes higher estimations of protection by Natura 2000 by the habitat masking compared to the 5x5 km modelling. The 5x5 km mapping in this case is therefore preferred to estimate the coverage by Natura 2000.

Salamanders of the genus *Speleomantes* (cave salamanders; black circle in Fig. 4-35) pose an obvious problem to model correctly, as detailed maps of the caves is not available at the extent of Europe or even country (Italy, and small part of France) where these species occur. Of the 8 *Speleomantes* species that occur on the SEH species list, only four could be modelled at the 5x5 km extent. Of these four modelled species two species show differences of more than 10% between the habitat masking result and the modelling at 5x5 km. All 8 species occur in Italy and one species also occurs in France. Five species occurring in Italy were successfully modelled at the scale of 1km by 1km. For these species differences less than 10% in coverage by Natura 2000 were estimated at 1km by 1km, suggesting that the habitat masking provided robust results for these species.

Table 4-2

Discussion of herpetofauna species and Natura 2000 coverage, based on habitat masking and based on 5x5 km modelling, that differ by more than 10% (Fig. 4-35).

Species Name	Discussion	Best estimate
Podarcis milensis (Milos wall lizard)  © Benny Trapp	The *Podarcis milensis* occurs on a few small islands in the Greek archipelago. It is highly endemic, and the small size of the islands causes obvious problems when delineating it's suitable range at a pixel size of 5x5 km. The habitat masking, using Corine data at a pixel size of 100m by 100m fits much better to delineate these small islands. For this species the habitat masking gives a better representation of its protection status than the 5x5 km or 1km by 1km modelling results.	45.8%
Algyroides marchi (Spanish algyroides)  © Benny Trapp	The percentage under Natura 2000 for *Algyroides marchi* seems an underestimation, as the extent of its range is overestimated by habitat masking. The distribution range according to the 1km by 1km and 5by 5km modelling are more precise, and so is it's estimated coverage by NATURA 2000 (81.4% and 85% respectively).	81.4~85%
Iberolacerta bonnali (Pyrenees rock lizard)  © Jeroen Speybroek	The occupied range for the *Iberolacerta bonnali* seems an overestimation if compared with the habitat masking results, but more realistic when looking at the 1km by 1km mapping (only the Spanish part of its range) and the 5x5 km mapping, with Natura 2000 coverages of 70.1% and 65.8% respectively).	65.8 ~ 70.1%
Salamandra lanzai (Lanza's Alpine salamander)  © Franco Andreone	For *Salamandra lanzai*, also habitat masking seems to overestimate it's range, and the estimated coverage by Natura 2000 by the 5x5 km mapping (43.8%) seems therefore a better estimate. There was no 1km by 1km estimate, because there were insufficient points in the higher resolution dataset.	43.8 %
Macrovipera schweizeri (Cyclades blunt-nosed viper)  © Benny Trapp	*Macrovipera schweizeri* occurs on nearly the entire territory of the small Milos islands. Like *Podarcis milensis* this species seems better represented by the habitat masking method then by the 5x5 km mapping or the 1km by 1 km mapping, Therefore, the estimated Natura 2000 coverage as estimated by the habitat masking methods seems more correct.	
Eremias arguta (Stepperunner)  © Andrew Butko	The estimated ranges of *Eremias arguta* based on the modelling at 5x5 km seem an overestimate the ranges because the small areas that are suitable are too fine to be recognized within 5x5 km blocks. Finer detailed data for 1km by 1km modelling was not available for this species. The habitat masking gives probably a more accurate estimate of its habitat covered by Natura 2000.	
Pelophylax cretensis (Cretan frog)  © Benny Trapp	The estimated range for *Pelophylax cretensis* seems overestimated by the habitat masking and 5x5 km modelling, as the species in most cases is restricted to rather small permanent water bodies. It is therefore much more accurately estimated when looking at the 1km by 1km mapping (estimated coverage of 5.3%), suggesting this is also a gap species.	

4.2.4 Butterflies

Distribution of butterflies over CLC3 types

Butterflies are not evenly distributed over Europe and its habitats. In fact, most butterflies prefer open habitats, and especially grasslands. Out of the 436 butterfly species in Europe for which information on habitat type is available, 382 (88%) occur on grasslands in at least one country in Europe, and for more than half of the species (280 species, 57%) grassland is their main habitat (Fig. 4-36; Van Swaay *et al.* 2006; Van Swaay and Warren 1999).

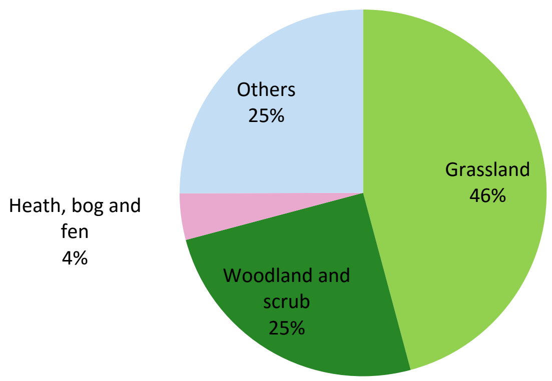


Figure 4-36 *Main habitats of European butterflies (based on Van Swaay and Warren 1999). For each habitat type the number of species is given. Grasslands are the main habitat for 57% of the species (where each species has only one main habitat).*

In this report we used the CLC3 maps for habitat masking. However, these CLC3-types are not evenly distributed over the EU. Table 4-3 shows that especially habitat types which are favoured by butterflies (like sparsely vegetated areas, CLC3 code 32 and Natural grassland, CLC3 code 26) are used by more than 380 butterfly species out of 411 analyzed. However these CLC3 types also occur much more inside Natura 2000 areas than outside. For inland marshes (CLC3 code 35) this is 70%, but also for butterflies important sparsely vegetated areas (CLC3 code 32) and Natural grasslands (code 26) occur much more inside Natura 2000 areas (48% and 39%, respectively).

Table 4-3
Distribution of butterflies in the EU-28 over CLC3 types (note: a species can be assigned to different CLC types).

CLC code	Description	Percentage in Natura 2000	Number of species assigned to this CLC type
35	inland marshes	70.0	75
31	bare rocks	57.8	101
30	beaches, sand, dunes	56.4	18
32	sparsely vegetated areas	48.2	380
27	moors and heath lands	41.2	99
26	Natural grasslands	38.5	399
28	sclerophyllous vegetation	35.1	154
36	peat bogs	34.0	23
23	broad-leaved forest	33.6	202
22	agro-forestry areas	25.8	51
29	transitional woodland-scrub	24.2	127
25	mixed forest	19.9	137
24	coniferous forest	17.6	66
21	principally agricultural land with significant Natural vegetation	14.2	62
18	pastures	13.0	4
17	olive groves	8.5	21
16	fruit trees and berry plantation	8.2	18
20	complex cultivation patterns	7.5	8
15	vineyards	7.3	10
11	port and leisure facilities	5.7	24
8	dump sites	5.6	17
10	green urban areas	4.1	58
6	airports	3.7	11
5	port areas	3.5	9
4	road and rail networks and associated land	3.2	19
2	discontinuous urban fabric	2.3	12

This is also illustrated in Figure 4-37: showing that the CLC3 types which host many butterflies, are predominantly found in Natura 2000 areas.

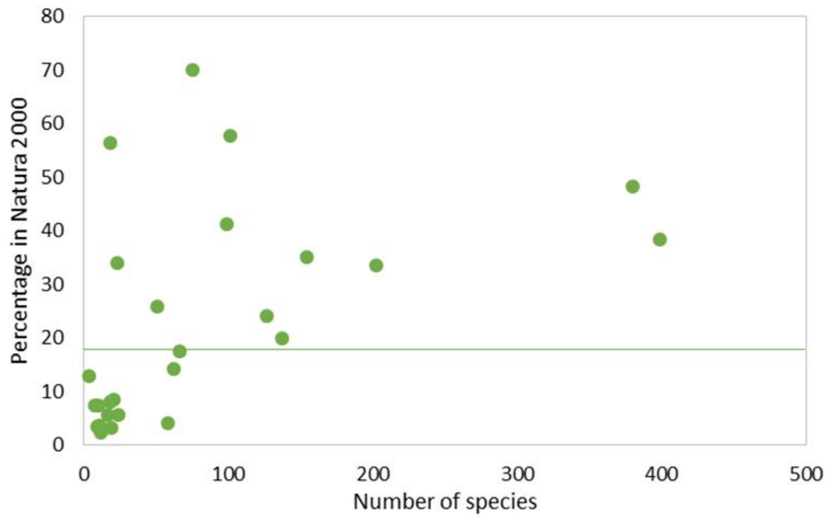


Figure 4-37 *For each CLC3 type where butterflies are assigned to in Annex 4, the relationship between the number of butterfly species and the percentage occurring in Natura 2000 is given. The line marks the baseline equal to 18% (Natura 2000 coverage in EU-28).*

Butterflies in Natura 2000: the data product

In the data table (Annex x) we used the taxonomy of the European Red List of Butterflies (Van Swaay *et al.*, 2010). The Red List status is available for the whole continent, hence including the non-EU countries up to the Ural mountains in the east, as well as for the EU-27 (Van Swaay *et al.*, 2010), produced before Croatia joined the EU in 2013 and hence only encompassing the other 27 Member States.

We calculated 5x5 km distributions for each species as a result of the modelling. This could only be done for species which have a distribution consisting of at least a few 50x50 km squares to be able to run the modelling. For this reason no results are available for rare and very localized species as *Plebejus zullichi* or *Polyommatus humedasae*.

Overall 411 species of butterflies were considered following the European Red List of Butterflies. Of these, 19 were listed under Annex II of the Habitats Directive, 24 were considered threatened (VU=16; EN=8; CR=0) according to the IUCN Red List of Europe and 22 for the EU-27 countries at the time the European Red List was made in 2010 (VU=15; EN=6; CR=1).

Butterfly species have a mean coverage of 37.4±11.6% (compared to 18% of the EU-28 countries covered by Natura 2000). This is attributable to the fact that butterflies have a preference for CLC-3 types which occur much more inside Natura 2000 areas than outside. In total 2.4% of species were below the baseline (Partial Gap Species) and no species had zero coverage by the network (Gap species).

For species listed on the Annex II of the Habitats Directive, Natura 2000 areas have to be designated. Figure 4-2 shows the percentage of squares inside Natura 2000 areas in the EU-28 countries for the nineteen species listed on the Annex II and the 392 species not on this list. Annex II species had a mean coverage of 42.9±14.7%, of which none did not meet the target. For comparison, species not listed under Annex II had a mean coverage 37.1±11.4, of which 10 species had a coverage below the baseline (Partial Gap species). The difference is significant ($F=4.627$; $p<0.05$).

The main purpose of the IUCN Red List is to catalogue and highlight those species that are facing a higher risk of extinction (i.e. those listed as Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). In Europe as a continent, 37 butterflies are considered threatened (Van Swaay *et al.* 2010). However the three Critically Endangered species either have not been reported for 25 years (*Pieris wollastoni*) or do not occur inside the EU-28 (*Coenympha phryne* occurs on pristine steppes in Ukraine and Russia, *Pseudochazara cingovskii* is only found in the Former Yugoslav Republic of Macedonia). Especially Near Threatened species have a high occurrence inside Natura 2000 areas (Fig. 4-5). The differences are significant ($F= 6.795$; $p<0.001$). Threatened species at European level (Endangered and Vulnerable) occur significantly more inside Natura 2000 areas in the EU-28 as a whole than the non-threatened species (Near Threatened and Least Concern) and the not-evaluated species, category (Not applicable and Data Deficient; Fig. 4-38; F-value 4.933, $P<0.01$), although the difference is small.

EU-27 Red List

Van Swaay *et al.* (2010) also produced a Red List for the EU-27 countries (Croatia was then not a member). Especially for Endangered species the percentage covered by Natura 2000 is relatively high. The differences are significant (F=4.565, p<0.001; Fig. 4-38). Also at EU-27 level, threatened species at (Critically Endangered, Endangered and Vulnerable) occur significantly more inside Natura 2000 areas in the EU-28 as a whole than the non-threatened species (Near Threatened and Least Concern) and the Not-Evaluated species (Data Deficient, Not Applicable and Not Evaluated) (F=5.415, p<0.01).

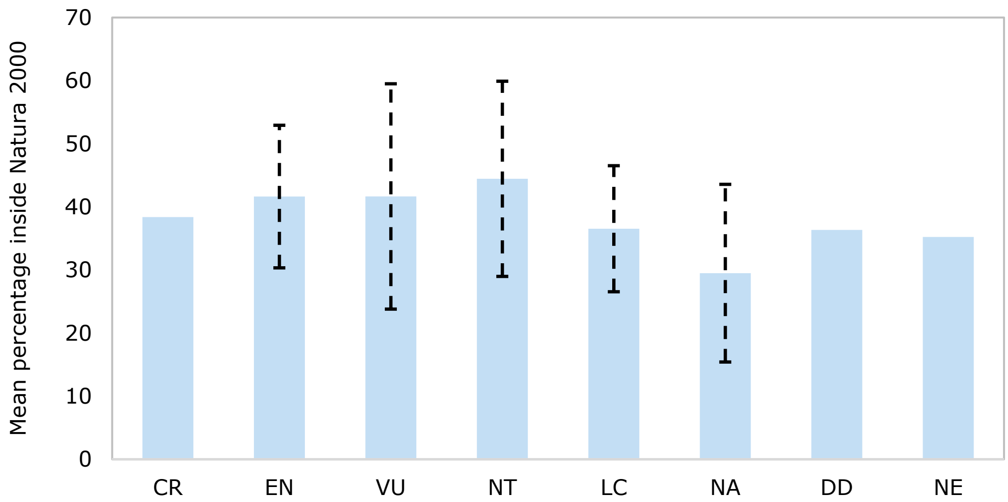


Figure 4-38 *The percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries for each of the EU-27 categories of butterflies (Van Swaay et al., 2010). Critically Endangered (n=1); Endangered (n=6); Vulnerable (n=15); Near threatened (n=47); Least concern (n=322); Not applicable (n=18); Data deficient (n=1); Not Evaluated (n=1).*

Taxonomic groups

There is no significant difference among families in the percentage of the species that occur inside Natura 2000 areas (Fig. 4-39; $F= 0.732$; $p>0.05$).

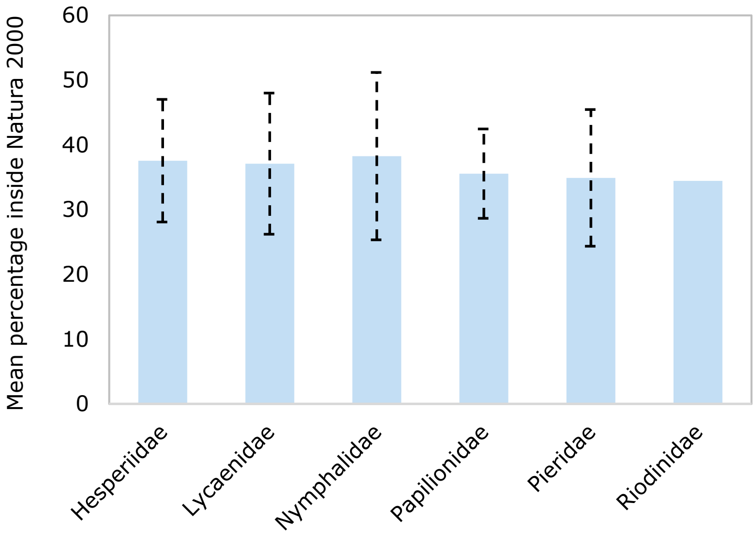


Figure 4-39 *The percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries for the six butterfly families according to the Fauna Europaea (Hesperiidae n=45; Lycaenidae n=111; Nymphalidae n=195; Papilionidae n=12; Pieridae n=47; Riodinidae n=1).*

European endemics

Species restricted to the European continent (European endemics; n=114) have a significantly higher percentage of their distribution inside Natura 2000 areas than non-endemics (Fig. 4-7; $F= 14.16$, $p<0.001$). The same counts for species restricted to the EU-27 countries (EU-27 endemics; n=55), which have a higher percentage of their distribution inside Natura 2000 areas than non-endemics (Fig. 4-40; $F= 5.716$, $p<0.05$).

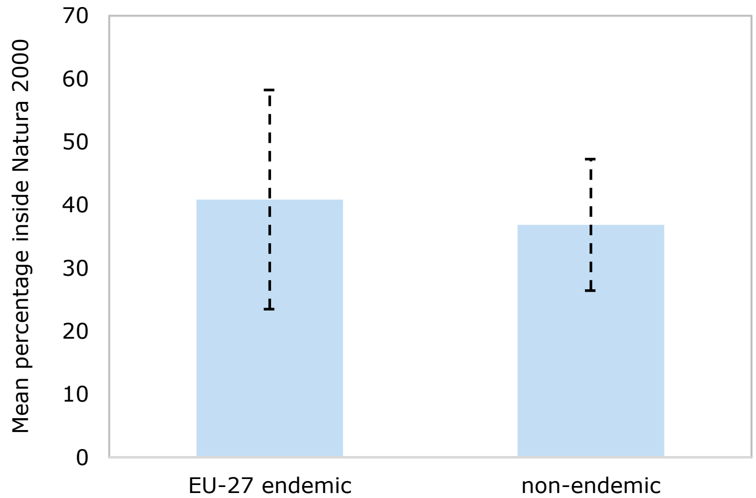


Figure 4-40 *The percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries for EU-27 endemic (n=55) and non-EU-27 endemic butterfly species (n=356).*

Threatened butterflies in habitats with a low proportion in Natura 2000
As indicated earlier, most butterflies occur in CLC3 types which are predominantly found in Natura 2000 areas. This explains why the proportion of the occurrence of butterflies inside Natura 2000 is higher than the proportion of the land cover inside Natura 2000. But are there threatened butterflies which occur in these CLC3 types? And does this require action?

Table 4-4 shows the number of threatened butterflies at European or EU-27 level according to Van Swaay *et al.* (2010) for all CLC3 types of which less than 18% are inside Natura 2000.

Table 4-4
The number of threatened butterflies at European or EU-27 level (Van Swaay et al., 2010) per CLC3 types with less than 18% inside Natura 2000. CLC3 types with no threatened species are omitted from this list.

CLC3 typology	Percentage of this CLC3 type in Natura 2000	Number of Threatened European Species	Number of Threatened EU27 Species
green urban areas	4.1		1
fruit trees and berry plantation	8.2		1
olive groves	8.5		1
land principally occupied by agriculture with significant Natural vegetation	14.2	1	2
coniferous forest	17.6	4	6

There is a lot of overlap, and the following threatened species are found in these CLC3 types: *Colias myrmidone, Erebia sudetica, Lopinga achine, Maculinea arion, Pyrgus cirsii, Nymphalis polychloros and Leptidea morsei*. In green urban areas, fruit plantations and olive groves it is actually only *Nymphalis polycloros*, a species with strong dispersal which can be seen in many habitats. All the other species have 21-39% of their occurrence in the other CLC3 types. However it should be noted that ha-squares are appointed to the CLC3 type which is most abundant, which means (especially in the case of coniferous forest) that other habitats in such a square (e.g. small grassland patches) are actually more important for the occurrence of the species than the coniferous forest (see also par. 5.2).

4.2.5 Plants

The approach for plants differed as explained in par. 3.3, due to the different resource base (EVA), consisting of a large dataset of observations. Even though the data covers a large part of Europe, it is by no means comparible with systematically collected atlas data such as is the case for the animal groups considered in this report. Moreover, not all countries are evenly represented in the database. Figure A-1 (Appendix 2) shows which countries are well represented and which are underrepresented in the database.

The following analyses are discussed in the next paragraphs:
1. Overall Red List based analysis;
2. Hot spot analysis;
3. Analysis per species.

Overall Red List based analysis
Within each species group (mentioned in the annex, Table A-8), the number of species was counted in random selected grid cells and summed up, inside and outside Natura 2000 sites. Annex II species were excluded. The number of random selected grid cells was set to 5,000 inside and 5,000 outside Natura 2000 sites, for the analyses on national level the number of random selected grid cells was set to 500 (see par. 3.3).
Figure 4-41 below clearly shows that Red List[10] species and Orchid species are more likely to be found (more than 50%) in Natura 2000 sites than outside these sites. The group of Orchid species would probably show a bigger difference between inside and outside Natura 2000 if the more common species such as *Listera ovata* and *Epipactis helleborine* would have been excluded.

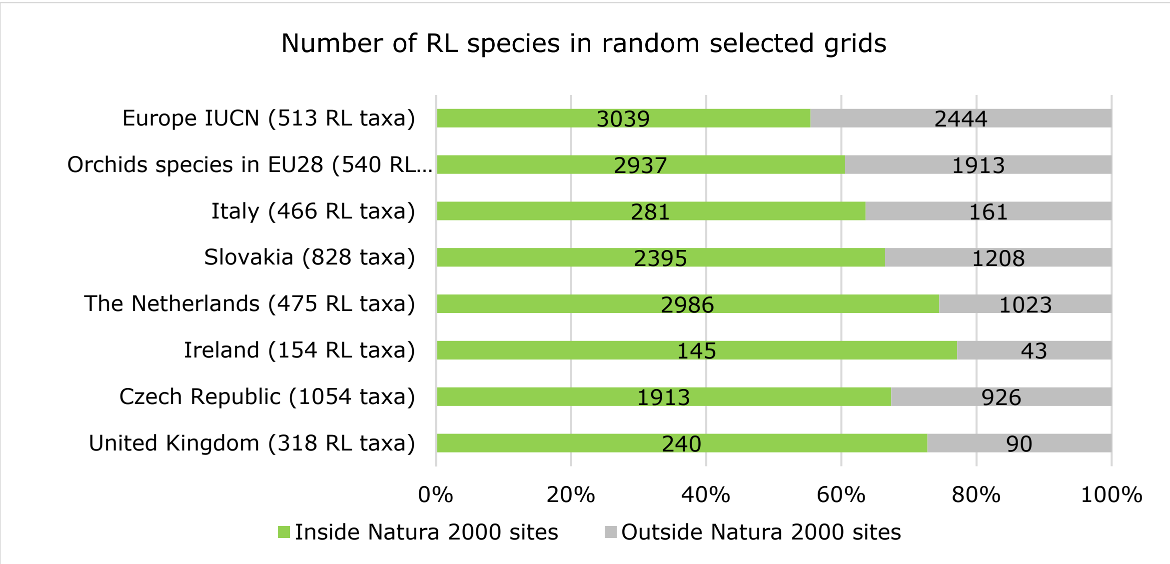


Figure 4-41 *Number of Red List plant species in random selected grid cells in and outside Natura 2000 sites. Annex II species are excluded from the analysis.*

Hot spot analysis
We calculated hotspots inside and outside Natura 2000 areas. A hotspot is defined as a 2x2 km grid cell with a minimum of 5 different Red List (or Orchid) species. The counting was performed on the

[10] It should be noted that the IUCN species cover 3 specific groups (aquatic plants, crop-wild relatives and species that are already covered by international policies) and are therefore not fully representative for overall biodiversity and may not be good indicators for this kind of analysis. However, the IUCN list does have an important status and was therefore included rather than omitted.

basis of 2,500 unique random selected grid cells at European level, and 250 random selected grid cells at national levels. This procedure was repeated 500 times to obtain a statistically reliable result.

The graphs below, representing the different species groups mentioned in Table A-8 (in the appendix), clearly show that hot spots are more likely to be found inside than outside Natura 2000 sites (Fig. 4-42). The differences between inside and outside Natura 2000 sites are less notable when the minimum number of 'hot-spot species' is set to a low value, and more obvious when increasing the minimum number of species per grid cell.

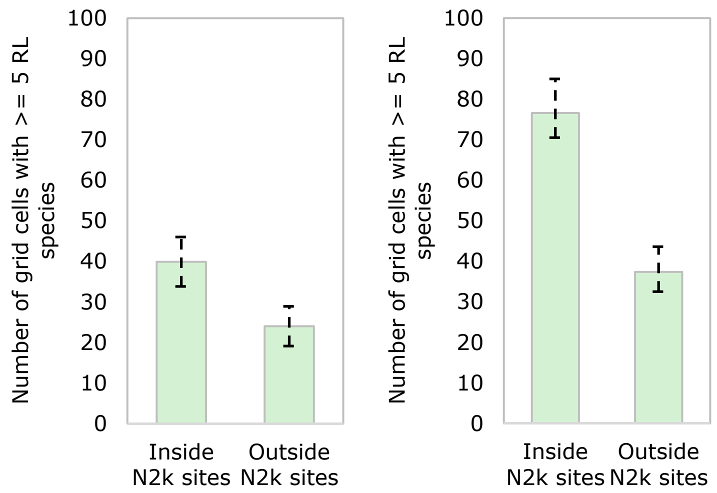


Figure 4-42 *Hotspots European Red list species IUCN (left) and Hotspots European orchid species (right). Based on 2500x2500 random sampled grids in- and outside Natura2000 sites.*

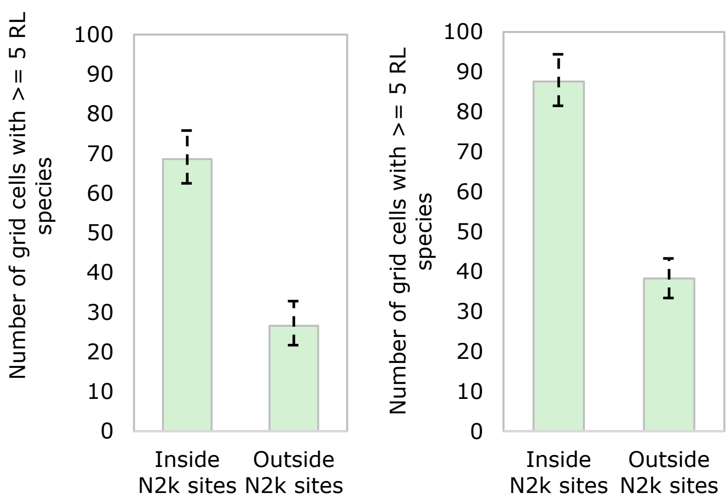


Figure 4-43 *Hotspots in the Czech Republic (left) and Hotspots Slovakia (right). Based on 250x250 random sampled grids in- and outside Natura2000 sites.*

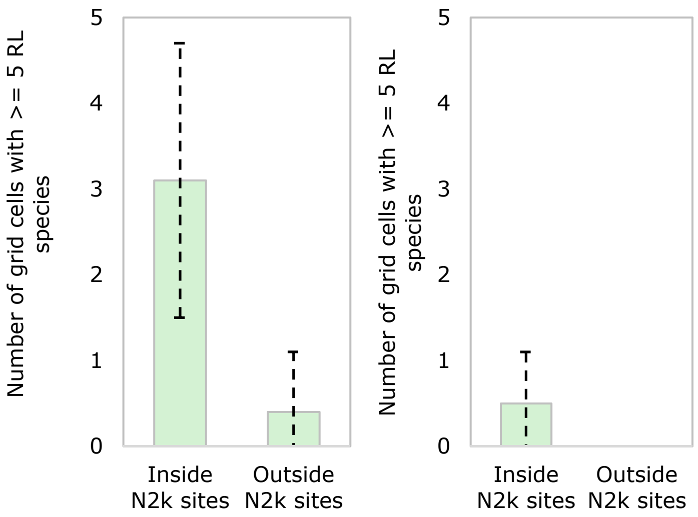


Figure 4-44 *Hotspots in the United Kingdom (left) and Hotspots Ireland (right). Based on 250x250 random sampled grids in- and outside Natura2000 sites.*

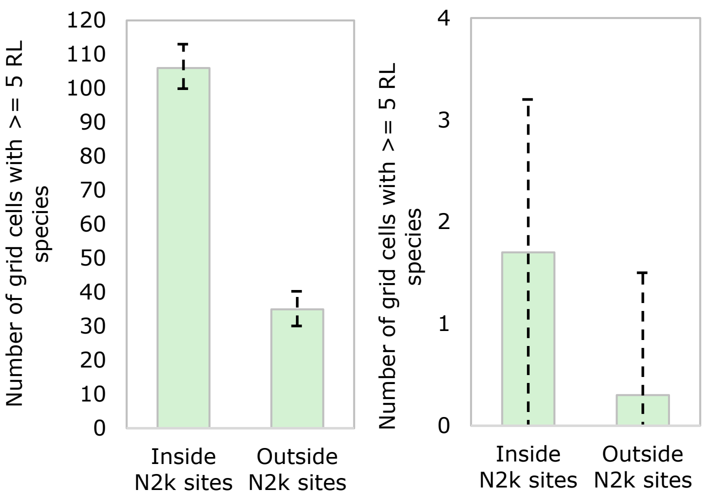


Figure 4-45 *Hotspots in The Netherlands (left) and Hotspots Italy (right). Based on 250x250 random sampled grids in- and outside Natura2000 sites.*

We also examined the distribution of the 300 most commonly occurring species in the database in relation to their occurrence inside and outside Natura 2000 sites. The minimum number of the selected common species per grid cell (2x2 km) was set to 25 to assign a cell as a hotspot. The graph below clearly shows that even though there are slightly more grids that meet the criterion outside rather than inside Natura 2000 sites, common species are more or less equally distributed inside and outside Natura 2000 sites (Fig. 4-46).

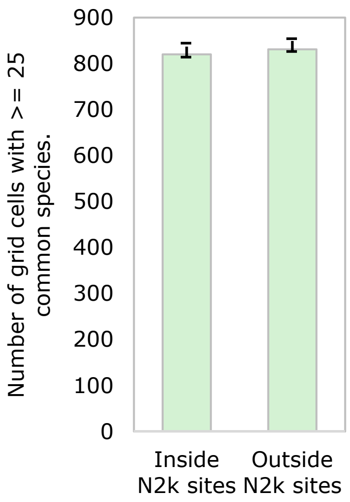


Figure 4-46 *Common plants present inside and outside Natura2000. Based on 250x250 random sampled grids.*

Analysis per species

Based on 5,000 random selected grid cells inside and 5,000 grid cells outside Natura 2000 sites, a comparison was made between the occurrence of individual species in grid cells located inside and outside Natura 2000 sites. In the graph below, a number of species are listed which are considered to be diagnostic for the selected Annex I habitat types (see Appendix 2). The total number of diagnostic species analysed was 583, Also a few very common species, typical of intensive farming landscapes, such as *Lolium perenne, Agrostis stolonifera,* and *Belles perennis* have been added to the list. The species are sorted according to increasing 'preference' for grid cells inside Natura 2000 sites (Fig. 48).

Not surprisingly, common plant species do also occur in Natura 2000 areas, which is confirmed by the second analysis (hot spot analysis). One can also see that there is a group of diagnostic species which are not so rare and as a consequence can also easily be found outside Natura 2000 sites (with a 50- 60% preference for Natura 2000 sites). Nevertheless, in total 86% of all species analysed are more likely to be found inside, rather than outside Natura 2000 sites.

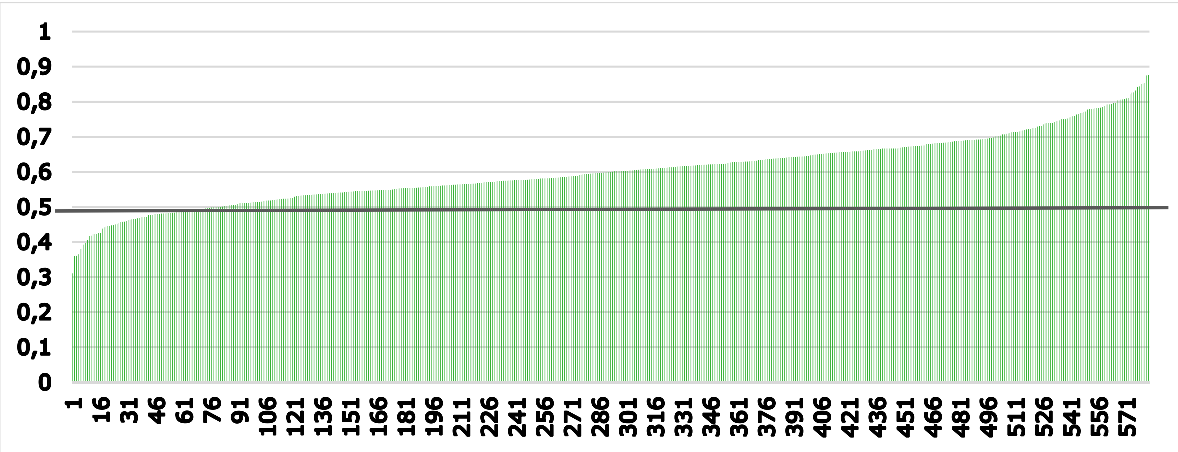


Figure 4-47 *Ranking (x-axis) of the percentages habitat inside Natura 2000 for 583 analysed plant species based on random selected 2x2 km grid cells. The blue horizontal line shows the 50% line which indicates the 'random distribution. It shows that only few, mostly very common species have a lower presence within Natura 2000.*

4.3 Integration of results

In this paragraph we combine the results for the different species groups. However, the approaches differ in particular for plants, for which it was not feasible to analyze all species. For that reason the plants are not included in the comparison presented here.

In general we observe that (based on the 18% baseline):

- All species groups benefit above what could be expected based on a random distribution – so that more than 18% of their distribution occurs in Natura 2000
- A greater number of common animal species and other 'non-Annex' animal species occur inside Natura 2000 than outside (in particular breeding birds and butterflies).
- Animal species for which Natura 2000 areas were not specifically designated (non-Annex species) do, therefore, gain benefit from the protected areas network
- The species of the Annexes benefit more (that is, generally occur more frequently within the Natura 2000 site boundaries) than the 'other' species; this is in particular the case for birds and butterflies, for reptiles and amphibians the difference is negligible

To assess the share of species which benefit from the Natura 2000 network it was determined whether the share of the range of a species within Natura 2000 exceeds the share of the range within a country (Fig. 4-49). As indicated in par. 2.2, the territory of Natura 2000 differs markedly between countries, from 8% in Denmark to almost 38% in Slovenia. Figure 4-48 shows that in particular the butterfly species have a relative high presence within the Natura 2000 network. As discussed in par. 4.2.4, this illustrates that most habitats for butterfly species are within the Natura 2000 network. Populations still occupying surrounding habitats are limited due to intensive land use and farming practices, as has been widely reported in the literature. Bird species demonstrate a pattern which, at least based on the 5x5 km modelling approaches, largely reflect the share of Natura 2000 in the countries, except for Sweden for which Natura 2000 supports a relatively high proportion of bird populations, and Slovakia with a relatively small proportion.

The presence of threatened species (Red List species) in and outside Natura 2000 (Fig. 4-5) was compared.

- The analysis shows that for all species groups a relatively large share of Red List species occurs within the Natura 2000 network
- The threatened species benefit more than the not threatened species, mostly 35-40% are found within N2000
- Not evaluated species (i.e. species classified as 'data deficient', or 'not evaluated') have significantly lower presence in Natura 2000
- Threatened birds, reptiles and butterflies in particular benefit from Natura 2000 areas

Bird endemism at species level in the EU is very low and most are found in the Macaronesian islands which were, in any case, excluded from the all the analyses carried out for this research. Birds are therefore not included in the results for endemic species (Fig. 4-7) where for other groups it was found that:

- The presence of endemic species seems consistently higher in Natura 2000
- Endemic and non-endemic reptile species are evenly distributed regarding Natura 2000
- Endemics and non-endemics of all species groups have a relatively large presence in Natura 2000 in relation to the 18% baseline

Figure 4-49 shows an index of species presence within N2000 areas. The calculation was based on the presence of species relative to the share of Natura 2000 in a country. If species presence conforms to the share of N2000, the value will be 100 (green line), the value will exceed the value of 100 for any country with higher species presence in protected areas. It also illustrates the relatively small share of species inside Natura 2000 on Cyprus and Malta and in Greece.

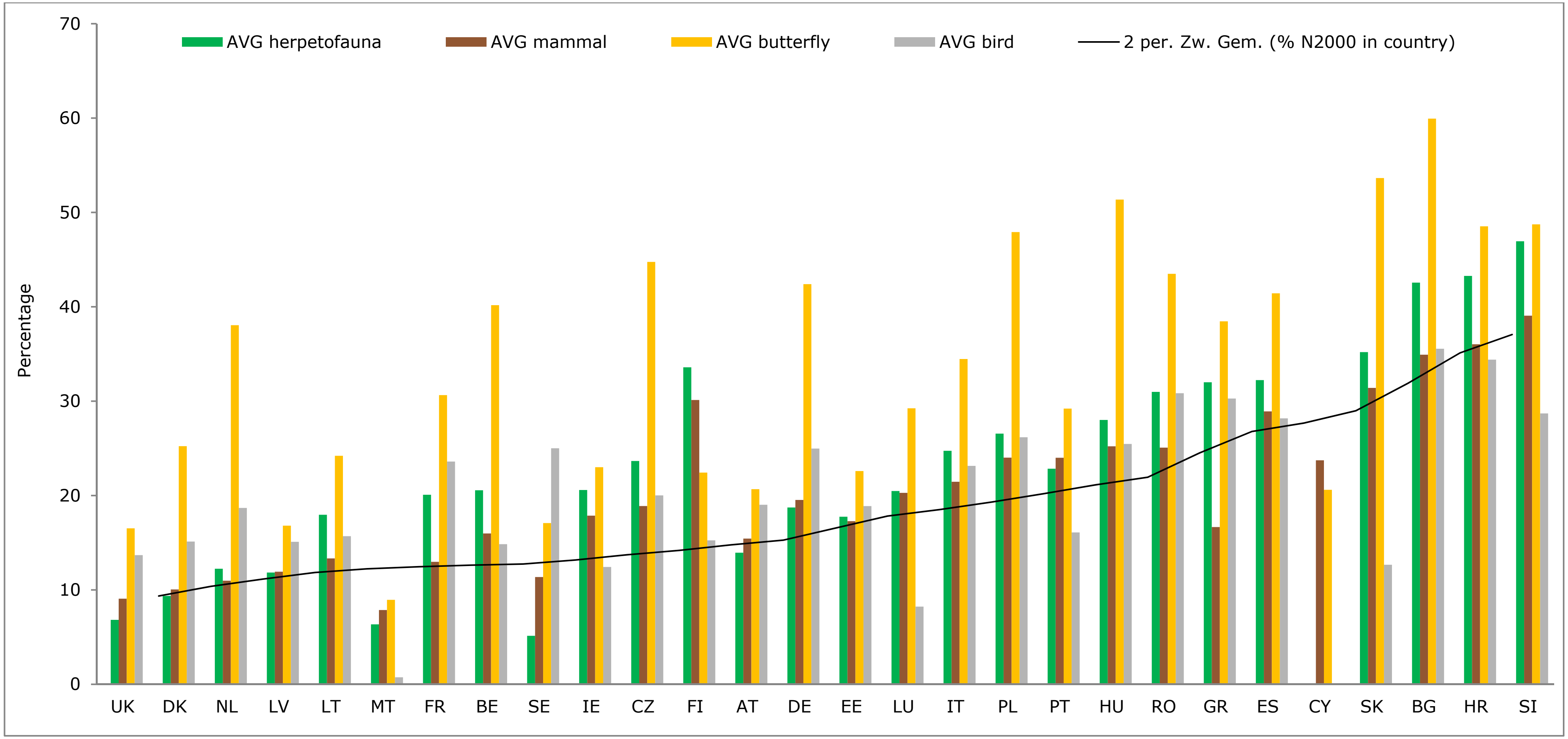


Figure 4-48 *The percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries for mammals, birds, herpetofauna and butterflies.*

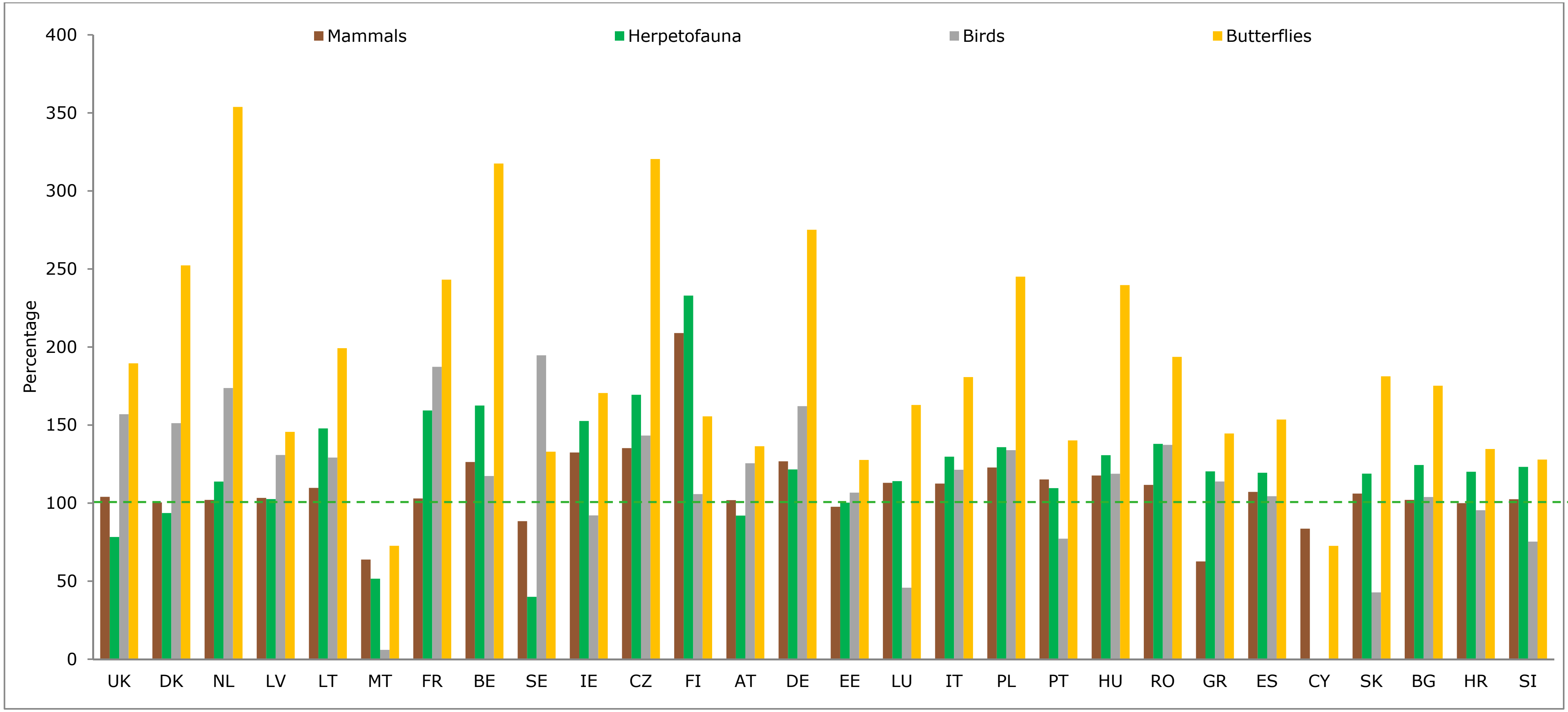


Figure 4-49 *An index of species presence within N2000 areas: calculated as species presence / share of N2000 in a country. If species presence conforms with the share of N2000, the value will be 100 (green line), therefore any country with higher species presence in protected areas will exceed the value of 100.*

4.4 Biogeographical regions and MAES

4.4.1 MAES Typologies

The protection and coverage of species provided by Natura 2000 varies considerably between region and parts of Europe. In an analysis of biogeographical regions, it was shown that the species protection level may range from 0.587 for the Black Sea region to 0.191 for the Boreal region (Trochet and Schmeller 2013). Here we first analyse the relationship between Natura 2000 coverage and the MAES typologies (MAES - Mapping and Assessment of Ecosystems and their Services) (Maes *et al.* 2014), which could help DG-Environment in applying these results in other contexts.

The distributions of European mammals in Natura 2000 areas are comprised mainly of 'woodland, forest and other wooded land' (Fig. 4-50). The other three habitat types with high coverage are 'heathland, scrub and tundra', 'grassland' and 'land dominated by forbs, mosses or lichens', and 'regularly or recently cultivated, horticultural and domestic habitats' (Fig. 4-50).

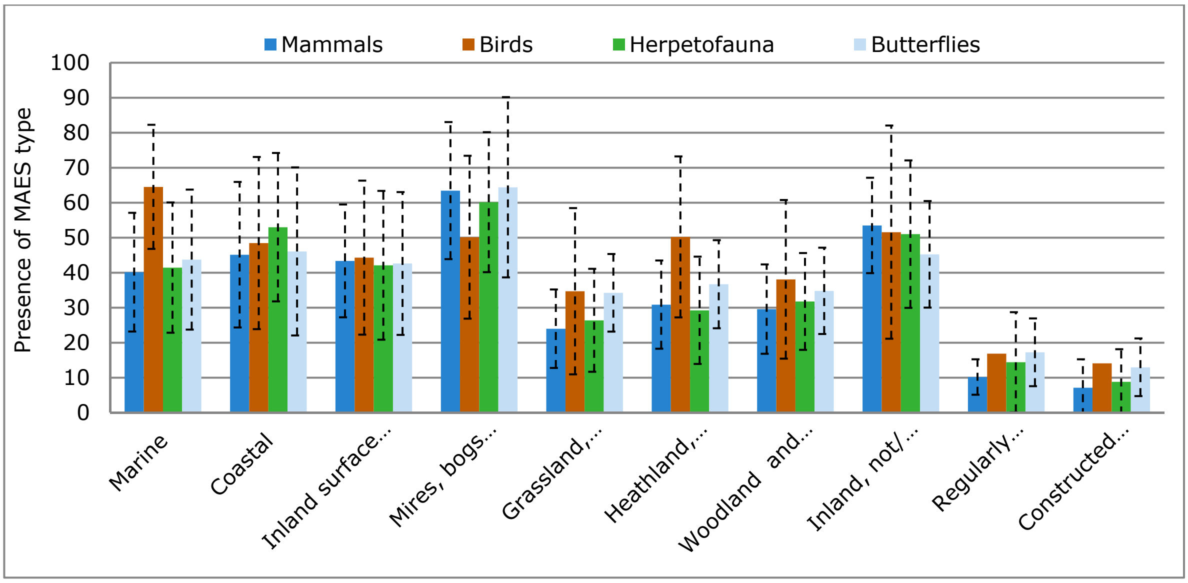


Figure 4-50 *Percentage of coverage by Natura 2000 for species in EU-28 countries, for the MAES typologies.*

The three approaches for modelling birds all show quite similar results for generalist and forest/shrub species, species in these habitat-groups having rather low coverage by Natura 2000 sites (around or slightly above 18% baseline) and also for species of open Natural habitat, a category with rather high presence in Natura 2000 sites (Fig. 4-50).

Most important habitat types for birds are the coastal/marine, marshland/wetlands and to a lesser extent not to sparsely vegetated areas. This includes the species from tundra's, fjäll and other mountainous rocky areas above the treeline, bare rock, but also (more Mediterranean) steppe-like vegetation, open habitat with low scrub (Fig. 4-50).
The analysis of MAES categories for herpetofauna shows that cultivated and built-up areas are scoring poorly in coverage by Natura 2000 for herpetofauna, and that mires bogs and fens as well as the sparsely vegetated areas (i.e. desert-like environments) score high in the protection of amphibians and reptiles (Fig. 4-50).

For butterflies an analysis was done by (manually) attributing species to CLC3 habitats (Fig. 4-51).
A large proportion of the butterfly distributions occur inside Natura 2000. Especially in mires, bogs and

fens as well as in sparsely vegetated habitats, However on articial, man-made ecotypes, such as cultivated land or industrial and other artificial habitats, the proportion inside Natura 2000 is low (as would be expected for such heavily managed or modified habitats).

The relatively high percentage for marine and coastal habitats (Fig. 4-50) should be treated with caution, as for terrestrial species of other species groups in this report. In most cases this is a consequence of small areas of terrestrial habitat in squares with much larger areas of marine or coastal habitats, a relatively large proportion of which is inside Natura 2000.

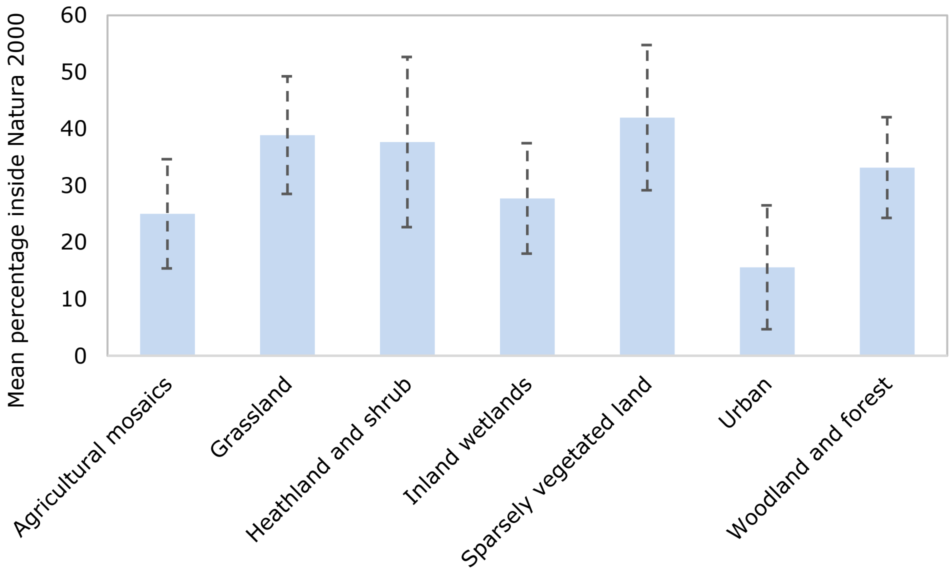


Figure 4-51 *Vegetation association for butterfly species, on the basis of species attribution to habitat types (based on Table 4-3 and Appendix 5).*

An analysis of plant biodiversity in relation to the Maes typology is not possible. Firstly, a balanced assessment requires a dataset of plants which covers the whole of the Maes-map extent, ideally a European distribution atlas of plants, which does not exist. Secondly, many of the small scale vegetation types, like grassland and heathland patches with an area of less than 25 ha, do not fall into the expected category.

A test with 6000 heathland vegetation plots shows that about 1000 plots were actually assigned to heathland and 3000 plots to Woodland. The other 3000 plots are scattered along the other 8 categories. Therefore no further analysis with the MAES typology was performed.

4.4.2 Biogeographical Regions

In a further step, an assessment of species coverage within the biogeographical regions was carried out (Fig. 4-52). The figure shows that for all faunal species groups the coverage of species in the Natura 2000 network in eight Biogeographical regions. The Black Sea and Alpine regions are where the greatest percentage of species is present within Natura 2000. Species in the Atlantic and Boreal regions have the lowest percentage presence within Natura 2000, particularly for mammals, reptiles and amphibians; and for Boreal species four of the five groups fall below the baseline of 18%. This is partly a product of the relatively small numbers of species of some taxa in these regions; for example in the Boreal region only 2 species of reptile were considered (the adder *Vipera berus*, and the common lizard *Zootoca vivipara*) which are both common and have a wide distribution. Bird and butterfly species are consistently better represented within Natura 2000 in almost all biogeographical regions. For the butterflies this reflects the fact their preferred habitats are nowadays found mainly on Natura 2000 sites.

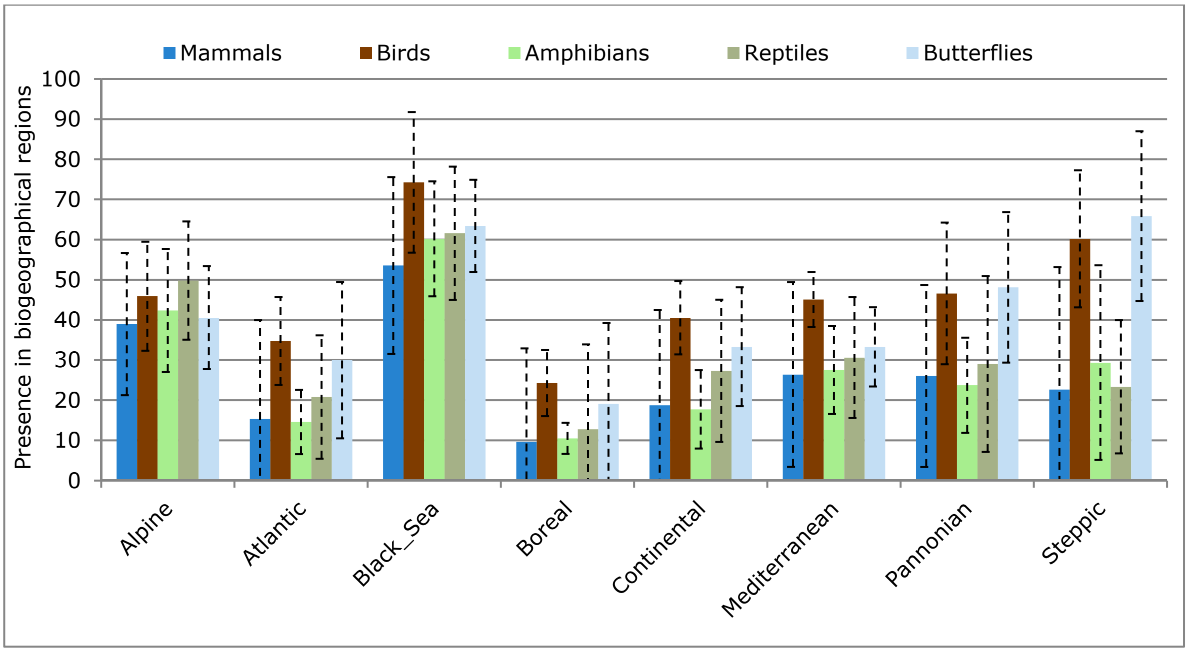


Figure 4-52 *Prevalence of occurrence in Natura 2000 in different biogeographical regions.*

An analysis was also carried out for the presence of plant species hot spots within Natura 2000 in four biogeographical regions. The results show a greater presence of Red list species (Fig. 4-53a) inside Natura 2000, which is a general trend for all regions but particularly Atlantic and Continental.

Red list plant species hotspots have their highest presence in the Natura 2000 sites within the Continental biogeographical region, whilst in the Mediterranean their presence in Natura 2000 is comparatively low, but still with more hotspots inside than outside.

For Orchids, the Alpine biogeographical region is particularly important (Fig. 4-53b). In the Mediterranean region there are more orchid species outside Natura 2000 as a proportion of those inside Natura 2000, when compared to other regions. In general Orchid species, require open areas that are not or less densely vegetated. In this region their specialised habitat requirements may occur more commonly outside Natura 2000.

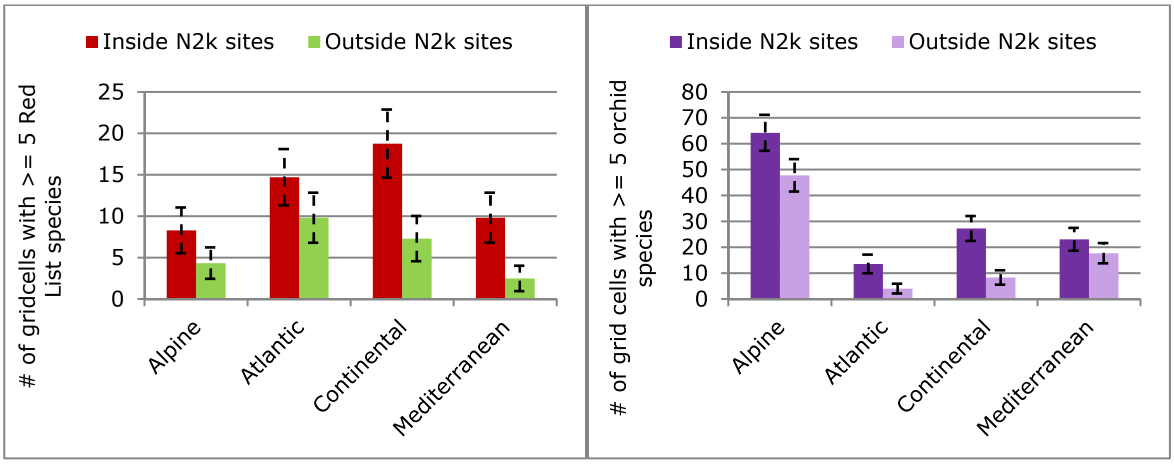


Figure 4-53 *A: Presence of plant species (Red List) hot spots and B: Orchid species hot spots in relation to the Biogeographical regions.*

4.5 Detailed country analysis

4.5.1 Mammals

The validation of the 50x50 km approach was done using the datapoints used in the BRT 5x5 km modelling. No fine resolution data were available for country-scale analyses. There were many points with accurate resolution for some species in different countries, but no country alone had sufficiently high resolution data for most of its species.

4.5.2 Birds

The 50x50 km masking analysis shows a greater proportion of species occupancy of the Natura 2000 network compared to the two alternative modelling approaches. Unlike the masking analyses, the modelling approaches generally show that the species' distribution coverages correspond well with the relative area designated as Natura 2000 site per country. There is consensus between the approaches about the countries with highest coverage: most southern and eastern countries: Bulgaria, Croatia, Slovakia, Hungary, Slovenia, Romania, Greece and Spain. Countries with low coverage in the three approaches are Latvia, Malta, Finland and Sweden.

4.5.3 Reptiles and Amphibians

For twelve countries (UK, NL, AT, DE, BE, IE, PT, IT, PL, GR, ES and BG) more detailed information on the distribution of herpetofauna species was available, and this was used to fit models at a finer scale of 1x1 km. The resulting fine scale distributions were used to calculate the percentage of Natura 2000 coverage per species, and compare these with the larger scale habitat masking and 5x5 km modelling results for validation as reported in paragraph 4.6.

Changes over time
A 50x50 km resolution map of the herpetofauna of Europa was published in 1998 (Gasc *et al.* 1998), which allows for a comparison over time. Coverage by Natura 2000 for 1998 (based on habitat masking) was compared to the habitat masking results based on the data of 2014. It must be stressed that the interpretation must be made with great care, since there can be a sampling effect due to different sampling efforts between these two periods. Also, the 1997 database covers 129 species so less species are available for comparison. Through this comparison, we identified species that differed by more than 10% from the 1:1 line, and discuss the possible differences in Table 4-5.

Table 4-5

Discussion of species that have more than 10% difference in their coverage by Natura 2000 between habitat masking in 1997 and 2014 (identified in Fig. 4-36).

Species Name	Discussion	Trend in level of protection
Alytes muletensis (Mallorcan midwife toad)  © Tuurio and Wallie	*Alytes muletensis* (IUCN status Vulnerable and on Annex II) has an wider range in the 2014 atlas compared to 1997 The species has been re-introduced to some areas north and south to its extant range, which was less well covered by the 1997 data base. Most likely, it's coverage by Natura 2000 has indeed been increasing since 1997.	Probably positive.
Proteus anguinus (Proteus)  © Arne Hodalič	For the *Proteus anguinus* (IUCN status Vulnerable and on Annex II) a decline in its occurrence range has been noted in Sillero *et al.* (2014) and this also seems to be the cause for a declining coverage by Natura 2000. It should be kept in mind that this cave dwelling species is, however, difficult to model, given its habitat.	Probably declining.
Eremias arguta (Stepperunner)  © Andrew Butko	The *Eremias arguta* (Vulnerable inside the EU, but not globally) shows a decline in coverage by Natura 2000 between 1997 and 2014. In Sillero *et al.* (2014) a decline in its range is described, and this is probably also the cause of the declining coverage by Natura 2000 based on habitat masking.	Probably declining
Montivipera xanthina (Coastal viper)  © Benny Trap	The *Montivipera xanthine* (IUCN least concern, not on Annex II) occurs mainly on the Anatolian peninsula, and it's occurrence in the EU is at the most western edge of its distribution. An increase of its range within the EU was noted by Sillero *et al.* (2014), but this seems mainly an update of its estimated range. Most likely it's distribution is stable.	Probably stable
Podarcis milensis (Milos wall lizard)  © Benny Trapp	There was no notable change in habitat occupation between1997 and 2014 for *Podarcis milensis*. However, given it's very small and restricted range, minor changes in occupancy can already cause a large change in the estimated coverage (i.e. a sampling effect).	Probably stable

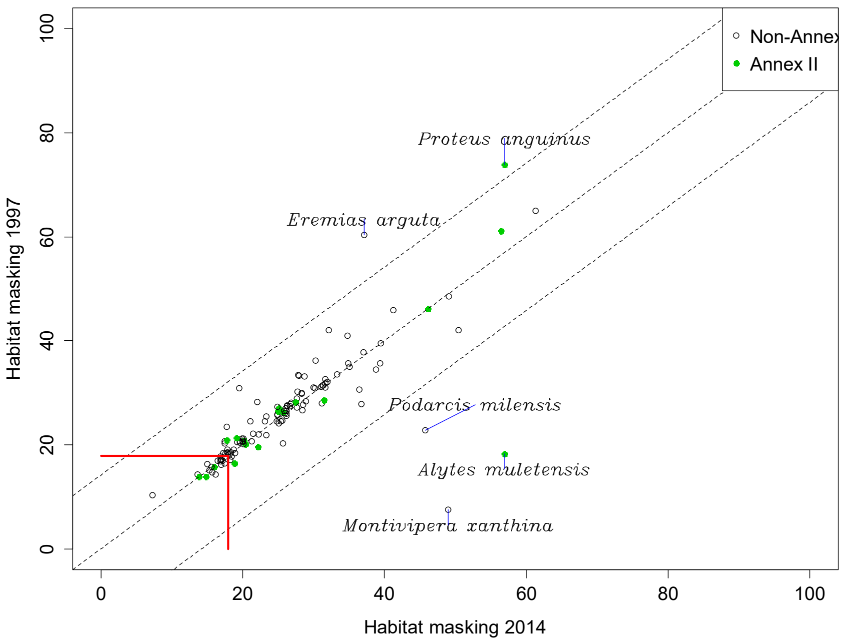


Figure 4-54 *Comparison between habitat masking in 2014 and habitat masking in 1997. Dashed lines indicate differences larger than 10%. Species with more than 10% difference between 2014 and 1997 are indicated by their name. The red lines indicate the average EU-28 land cover under Natura 2000.*

4.5.4 Butterflies

The mean percentage inside Natura 2000 per country is indicated in Figure 4-55 and ranges from 7.3% in Malta to 57.7% in Bulgaria. With the exception of Malta, Finland, Sweden, Latvia, Estonia and Cyprus, the percentage inside Natura 2000 is always higher than the percentage of land area covered by Natura 2000. In Sweden and Finland this is mainly caused by the fact that most of the large Natura 2000 areas occur in the mountains in the north. These mountains have their own special butterfly fauna, but many species occur only in the south of these countries.

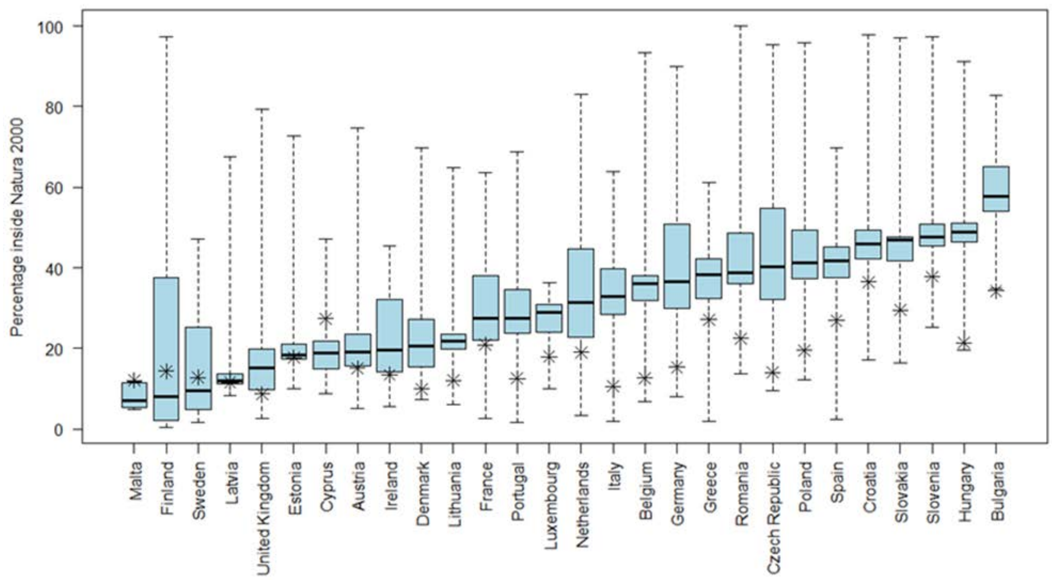


Figure 4-55 *The percentage of ha squares after habitat masking inside Natura 2000 areas for each of the EU-28 countries. The asterisk (*) indicates the percentage of Natura 2000 in that country.*

Conclusion

In almost all countries butterflies are benefitting from Natura 2000. The main reason is that butterfly habitats occur much more in Natura 2000 than in urban and agricultural areas. Threatened and endemic butterflies also occur more in Natura 2000 areas than outside. Good management of these butterfly habitats will ensure long time survival of butterflies. That way Natura 2000 is important for non-Annex II species.

Results per species

- There are no species entirely uncovered by Natura 2000 (gap species).
- The species profiting most from Natura 2000 are species with a very limited range, e.g. occurring on small islands, of which most (or even all) are inside Natura 2000, such as *Hipparchia sbordonii* (only occurring on the Italian island of Ponza), *Maniola halicarnassus* (only occurring on the Greek island of Nisiros), *Erebia polaris* (only occurring in the far north of Lapland) and *Hipparchia leighebi* (restricted to the Eolian Islands Volcano and Panarea in Italy).
- The least protected species is the Geranium Bronze (*Cacyreus marshalli*), the only invasive species in Europe occurring on Pelargonium plants in cities and villages in the Mediterranean.
- Using a baseline equal to 18% (Natura 2000 coverage in EU-28), ten species do not reach the adopted baseline. These species include:
  - an invasive species from South Africa, accidently introduced in 1988 on Mallorca, and now a resident of urban areas throughout the Mediterranean (*Cacyreus marshalli*). No action is needed for this species.

Cacyreus marshalli, an invasive exotic originating from South Africa, is mainly found in urban areas and rarely in Natura 2000.

  - a ubiquitous species occurring as good as anywhere and probably one of the few species being able to survive in intensive agriculture (though in low numbers): the Small White Pieris rapae. No action is needed for this species.
  - Originally a migrant species famous for its migration in N America, the Monarch Danaus plexippus has now settled in urban parks in SW Europe where Milkweed (Asclepias) species are grown (Milkweeds are the larval foodplants and don’t occur in Europe in the wild). The Monarch is almost exclusively found in urban areas. No action is needed for this species.
  - *Apharitis acamas* (Lebanese Silver-line) only occurs locally on Cyprus. Outside Europe this species is widespread and common over large parts of Africa and Asia. For this reason the species was not treated in the European Red List (less than 1% of the global distribution is in Europe and therefore considered Not-applicable). No action is needed for this species.
  - The Northern Chequered Skipper (*Carterocephalus silvicolus*) prefers large woodland areas in NE Europe. The species is still widespread and no action is needed.
  - The Lapland Ringlet (*Erebia embla*), the Baltic Grayling (*Oeneis jutta*) and the Moorland Clouded Yellow (*Colias palaeno*) are all species of marshes and bogs, patches of tundra and wet meadows

in open forests in Northern Europe (though *C. palaeno* also occurs on some bogs and mountains in Central Europe). These species are all non-endemics and considered not threatened at both European and EU-27 scale (Van Swaay *et al.*, 2010). No action is needed for these species, although local conservation efforts for the Moorland Clouded Yellow in Central Europe could be needed as the species might suffer from Climate change and desiccation of the bogs it inhabits.
- The Silvery Argus (*Aricia nicias*) occurs in subalpine parts of the Alps as well as in open woodlands in Sweden and Finland. No action is needed for this species.
- The Spanish Greenish Black-tip (*Euchloe bazae*) has an extremely restricted distribution on two isolated locations in Spain only. See Box 1 for more details. This species does need special attention.
- Threatened species had a mean coverage of 40.4±15.1% of which only one species had a coverage below 18% (Spanish Greenish Black-tip, *Euchloe bazae*; see Box 1).

The Spanish Greenish Black-tip (*Euchloe bazae*) is clearly the butterfly with the most obvious gap in its protection. The species is discussed in more detail in Box

Euchloe bazae is probably one of the most threatened butterflies in Europe. It only occurs in two small areas in Spain, mostly uncovered by Natura 2000.

Box 1: Spanish Greenish Black-tip

The Spanish Greenish Black-tip (*Euchloe bazae*) is endemic to Europe and the European Union, and is considered Vulnerable both in Europe and the EU-27 (Van Swaay *et al.* 2010). The species occurs almost completely outside Natura 2000 areas.

The species has been studied in great detail in 2013 and 2014 for a Species Recovery Plan (Munguira *et al.* 2015). The habitat of *Euchloe bazae* consists of sub-steppe grasslands or shrublands with continental climate. Plant communities belong to the *Rhamno lycioidi - Querceto cocciferae* series (coscojares, or kermes oak shrublands). Predominant shrubs and grasses in these communities are:
In the Hoya de Baza (subspecies bazae) esparto (Stipa tenacissima), Lygeum spartum, Retama sphaerocarpa, Ononis tridentata and Rosmarinus officinalis.
In the Monegros area (subspecies iberae) Quercus coccifera, Rosmarinus officinalis, Genista scorpius, Boleum asperum, Pistacia lentiscus, and the grass Lygeum spartum. Some areas in the area close to the town of Caspe also have pines (Pinus halepensis) and junipers (Juniperus phoenicea).

Populations of the Baza area were found at an average altitude of 872 m (range 804-958 m) and those from Monegros at an average altitude of 226 m (range 109-331 m). Therefore, the altitudes at which the two subspecies are found do not overlap. The substrate consists on marl and marl-limestone with gypsum in the Baza area and marl-limestone or marl-sandstone in the area of Monegros. In the areas where the species lives, there is frequently a high percentage of bare ground and thus the substrate is always clearly seen.

The creation of protected areas for the species is therefore urgently needed and this would favour the implementation of other relevant conservation actions. The protection of two areas in the regions where the species is present would be needed and Munguira *et al.* (2015) propose the creation of a protected area in Barranco del Espartal (Baza area) and Barranco de Valcuerna in Aragon. The steppe-like areas where the species lives are also good for steppe birds.

From Munguira *et al.* (2015).

Habitat of Euchloe bazae in the Hoya de Baza.

The cover of Natura 2000 in the countries of the EU-28 differs between 8% for Denmark and the United Kingdom to 38% for Slovenia in October 2015 (ec.europa.eu/environment/nature/Natura2000/barometer/index_en.htm). Also on a country level, most species occur more inside Natura 2000 than the land-proportion of Natura 2000 in that country. However some species occur less in Natura 2000 areas. Threatened species (Endangered EN or Vulnerable VU) at European level will be discussed in more detail.

Table 4-6
Number of species per European IUCN Red List threat status per country where the percentage of ha squares after habitat masking inside Natura 2000 areas is smaller than the proportion of Natura 2000 in that country.

Country	EN	VU	NT	LC	NA
Austria	2	2	5	37	
Belgium				3	
Croatia				10	1
Cyprus				16	1
Czech Republic				1	
Denmark				2	
Estonia				29	
Finland	1	2	4	60	
France				3	1
Germany				3	
Greece		1	1	6	3
Hungary				1	
Ireland				4	
Italy				3	1
Latvia			3	29	
Lithuania				3	
Luxembourg				6	
Malta				15	
Netherlands				2	
Poland				2	
Portugal				12	4
Romania				2	
Slovakia				2	
Slovenia			2	15	
Spain		1		12	5
Sweden	1	3	3	59	
United Kingdom				10	

Lycaena helle is considered endangered in Europe and listed on Annex II of the Habitats Directive.

Austria:

- *Lopinga achine*: Austria reports an unfavourable conservation status (U1) in the last report for Article 17 both in the Alpine and Continental region, with a range of 8600 km2 (14.1% of Alpine region, 4% of continental region) a distribution of 7300km2, an unknown populationsize on an estimated habitat area of 938 km2. The species occurs mainly north and south of the Alps in parts with a low proportion of Natura 2000. It is listed on Annex IV or the Habitats Directive.

- *Phengaris arion*: In the last Article 17 reporting of 2012 Austria mentions this species to have a range of 15800 km2 (8.4% of Alpine region, 1.1% of continental region), a distribution of 12900 km2 and 1857 km2 of suitable habitat. The population size is unknown. The conservation status is assessed as unfavourable U1 in both the Alpine and Continental region.
- In the Alps *Phengaris arion* can be widespread in low densities in the subalpine meadows along the treeline. So although much of its distribution is not in Natura 2000, this probably poses no threat to the longterm survival of this species in the Alpine parts of Austria. Phengaris arion is listed on Annex IV of the Habitats Directive.
- *Pyrgus cirsii*: there are only old records of this species from the Austrian/Swiss border area. The species is not occurring anymore in Austria.

Finland:

- *Euphydryas maturna*: Finland reports a favourable conservation status in the last report for Article 17, with a range of 66100 km2 (32.3% of Boreal region), a distribution of 22700 km2, an estimated populationsize between 5 and 10 million adult butterflies on an estimated habitat area of 180 km2. Finland is probably het only EU country where this species is not threatened and even doing very well. The species is widespread in the southeast of the country. Natura 2000 areas here are mostly situated on lakes. In Finland as a whole the large areas are all in the north. Although the species is mostly found outside Natura 2000 areas, this should not pose a problem for this species in Finland.
- *Lopinga achine*: Finland reports a favourable conservation status in the last report for Article 17, with a range of 12500 km2 (8% of boreal zone), a distribution of 4600km2, an estimated populationsize between 10000 and 50000 adult butterflies on an estimated habitat area of 25 km2. The species is local in the south of the country (Saarinen & Jantunen, 2013), where most of the Natura 2000 areas in Finland are in the north. The species is listed on Annex IV or the Habitats Directive.
- *Phengaris arion*: In the last Article 17 reporting of 2012 Finland mentions this species to have an unfavourable conservation status U2 with a range of 800 km2 (1.6% of Finnish Boreal zone), a distribution of 800 km2, a population size between 500 - 1000 adult individuals and only 0.3 km2 of suitable habitat. P. arion is divided into two separated populations in the Finnish boreal region (Saarinen & Jantunen, 2013). Phengaris arion is listed on Annex IV of the Habitats Directive.

Greece:

- *Pseudochazara amymone*: Until recently this butterfly was known from less than ten observations in the mountains in NW Greece. Recently the species has been found in Albania, where relatively large populations occur. It is unclear if this species still occurs in Greece (in spite of many attempts to find it) and if yes, where they are (probably close to the Albanian border). It is highly likely that almost the whole world population occurs in Albania.

Spain:

- *Euchloe bazae*: see the box in the previous paragraph for all background details on this species which is endemic to Spain.

Sweden:

- *Coenonympha hero*: Sweden reports a unfavourable conservation status U2 both in the Boreal zone in the last report for Article 17, with a range of 23500 km2 (14.3% of Boreal region), a distribution of 9200 km2, an estimated populationsize between 20000 and 40000 adult butterflies on an estimated habitat area of 5 km2. *Coenonympha hero* is listed on Annex IV of the Habitats Directive. Most of the large Natura 2000 areas in Sweden are in the mountains in the north, whereas this species occurs further south in the lowland, where the proportion of Natura 2000 areas is low.
- *Euphydryas maturna*: In the last Article 17 reporting of 2012 Sweden mentions this species to have a range of 600 km2 (0.3% of Boreal region), a distribution of 600 km2, a population size of 800-2000 adults and 1 km2 of suitable habitat. The conservation status is assessed as unfavourable U2. The species is listed on Annex II of the Habitats Directive.
- *Lopinga achine*: In the last Article 17 reporting of 2012 Sweden mentions this species to have an unfavourable conservation status U2 with a range of 2100 km2 (1.3% of Swedish Boreal zone), a

distribution of 1500 km2, a population size between 12000 - 18000 adult individuals and only 8 km2 of suitable habitat. L. achine is divided into two separated populations in the Swedish boreal region, one on the mainland, and one on the island Gotland. The mainland population is threatened while the population on Gotland is judged to have a favourable conservation status in the Swedish Red List. The species is listed on Annex IV or the Habitats Directive.

- *Phengaris arion*: Sweden reports a unfavourable conservation status U2 both in the Boreal and Continental zone in the last report for Article 17, with a range of 14200 km2 (21.2% of Boreal region, 1.3% of continental region), a distribution of 8300 km2, an estimated population size between 7000 and 11000 adult butterflies on an estimated habitat area of 12 km2. *Phengaris arion* is listed on Annex IV of the Habitats Directive.

Almost all butterflies benefit from Natura 2000, also at a national level. Where this is not the case, the species are not threatened, with a few exceptions. Threatened species underrepresented in Natura 2000 areas are listed below:

Three species of Annex IV of the Habitats Directive. It is striking that from the species which are threatened in Europe and whose occurrence in some countries is less than the percentage of landcover of Natura 2000, three of them (*Phengaris arion, Coenonympha hero* and *Lopinga achine*) are already listed on Annex IV of the Habitats Directive, but not on Annex II. This means that no Natura 2000 areas have to be designated for these species, but these threatened butterflies would certainly profit from extra protection provided by the Natura 2000 areas.
We advise that these three species are listed on Annex II of the Habitats Directive.

Two of the species are already on the Annex II of the Habitats Directive (*Euphydryas maturna* and *Lycaena helle*). For *Euphydryas maturna* this is not a big issue in Finland, where the species is widespread in the southeast of the country. However it would be good to study the situation in Sweden in more detail. For *Lycaena helle* in Austria recent research in 2013 and 2014 to this species has revealed a more detailed distribution and Austria is now in the process of designating Natura 2000 areas for this species.
We advise checking with the member states if all designations of Natura 2000 for Annex II species have been done.

One threatened butterfly, *Euchloe bazae*, is also underrepresented in Natura 2000 areas at a European level (see Box …).
We advise including Echloe bazae on the annexes II and IV of the Habitats Directive.

One species, *Pseudochazara amymone,* for which the present situation in the EU is unclear, and which probably has its main distribution in Albania (so outside the EU). No action is needed.

4.5.5 Plants

Hot spot analysis with buffering

To gain more insight in the biodiversity in the area immediately adjacent to the Natura 2000 sites, a buffer of 500 meters around all Natura 2000 sites was incorporated into the analyses. For technical reasons it was not possible to do this procedure for all European countries. Therefore it was only done for the Czech Republic, Slovakia and The Netherlands. In the analysis the 2x2 km grid cells were assigned to three classes: the area inside the Natura 2000 sites, the 500 meter buffer zone, and the area outside the buffer zone. As in the previous analyses, the number of Red List species were counted in 250 random selected grid cells. Grid cells with a minimum of 5 different Red List species were considered to be a hotspot. This procedure was repeated 250 times to obtain a statistically reliable result. The results are shown in the graphs below.

The figures for the three countries (Fig. 4-56) demonstrate that the number of hotspots in the buffer zones was intermediate, ie lies between the numbers inside and outside Natura 2000 sites. This means that – at least for the countries concerned – the biodiversity just outside Natura 2000 sites may not be as important as the biodiversity inside the sites, but is still higher compared with areas further away from the sites. There can be various reasons for this: better site conditions, less environmental pressure, presence of seed sources nearby, etc. One of the implications is that more biodiversity could be preserved by extending the Natura 2000 sites (e.g. by establishing buffer zones with some level of protection).

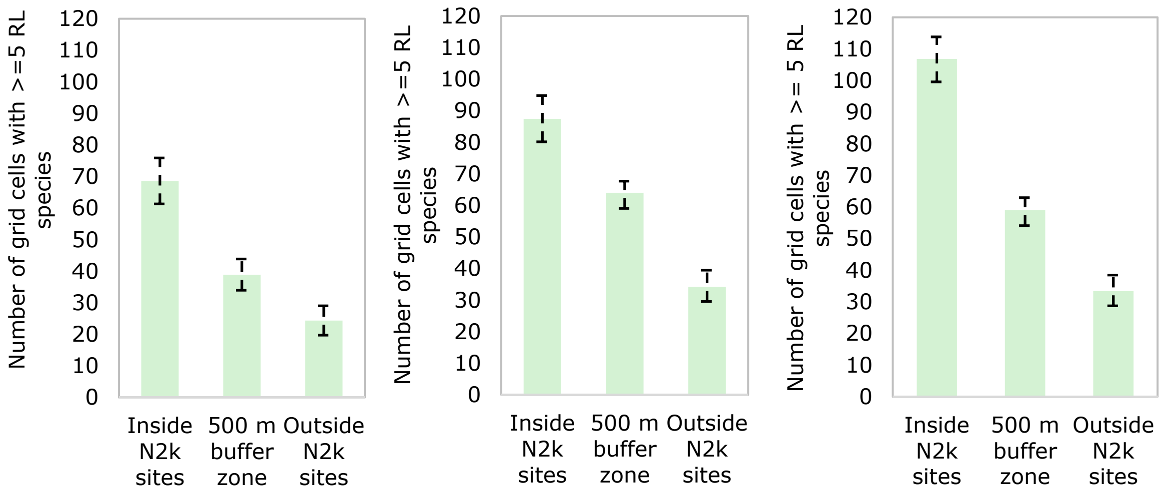


Figure 4-56 *Hotspots in the Czech Republic (left) and Hotspots Slovakia (middle) and The Netherlands (right). Based on 250x250 random sampled grids in Natura2000 sites, in a 500 m buffer zone, and outside Natura2000 sites.*

4.6 Agreement between estimation techniques

In this section we provide the outcomes of a number of tests to compare the results of different modelling approaches, to assess their robustness and whether they provide adequate answers to key questions addressed by this work. An important caveat about comparing methods of unknown accuracy, is that they be tested to see if they result in the same answer – but this does not tell us about how close that answer is to reality. This is not a true validation of the outputs because there may be good reasons why the two methods agree but still give incorrect answers. Nevertheless, if there is overall agreement between results across taxa and country comparisons, it suggests that the chosen methods are robust.

For true validation, extensive empirical field measurements would be required in different regions of Europe for all the different taxa. These data are not all available and hence this is not feasible. However, we can undertake validate the approaches used for a subset of taxa and regions for which independent empirical (observed) data are available (although there there remain potential scale issues).

Birds: comparison of EU-wide approaches using national fine-grained distribution maps
The comparison of the three EU-wide approaches described in the previous sections revealed differences in the results between the 50×50 km masking analysis and the two modelling 5×5 km approaches (although the latter two yielded similar results). In the following section we validate the performance of these three approaches using fine-grained empirical distribution maps of birds for a set of EU-countries from different biogeographic regions.

Observed proportions of species' ranges covered by protected areas are shown in Figure 4-57. The results are broadly in agreement with EU-scale analyses, with most species having less than 20% of range protected, and Spain and Bulgaria having above-average protection corresponding to their higher than average protection of land.

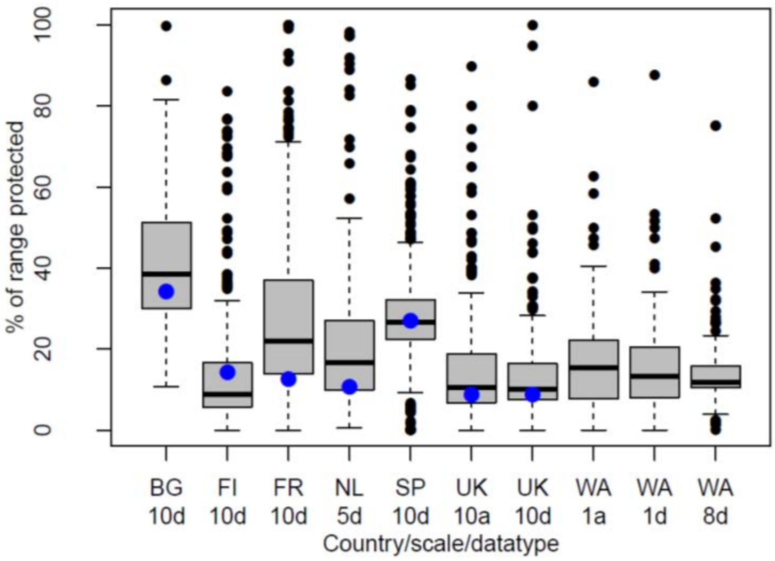


Figure 4-57 *Box-whisker plots indicating the proportions of species' ranges protected by the Natura 2000 network in seven countries. X-axis labels indicate the country (BG = Bulgaria, FI = Finland, FR = France, SP = Spain, UK = United Kingdom and WA = Wallonia) followed by the grid resolution of the data (1-km, 5-km, 5×8 km or 10-km) and whether data indicated distribution (d) or relative abundance (a). For comparison purposes, blue dots show the percentage of the nation's land designated.*

Comparison of approaches

When we compare estimated protection statistics for species with equivalent figures from observed bird data we generally find a positive correlation (See Table 4-7 and five panels of Fig. 4-58 below, and in Annex 1). However, all methods generated noticeable errors, with significant numbers of species known to be present in each country, which were not predicted to be present by the models. This can arise in two ways, either because no robust Europe-wide model was produced or because a model was produced but it did not predict occupancy within a particular country. The opposite type of errors also occurred, where a species was known to be absent from a country but models predicted it to be present (see Errors columns in Table 4-7). For this application, the ultimate test of each modelling method is how accurately it predicts the number of species deemed to be adequately protected. Observed and estimated figures for the percentage of the range protected were dichotomised into protected/not-protected using a baseline set by the relevant country's percentage of land protected. On this basis, on average, the masking method achieved 67% accuracy. That is, averaged across countries, 67% of species were correctly classified as protected or not-protected by the masking method. Similar figures (67% and 68%) were achieved for EBCC modelling and recent data modelling where predictions were dichotomised. However, accuracy was considerably lower (c40%) when using model probabilities. The methods were not uniformly effective across countries. Although masking achieved 86% accuracy in Bulgaria, in the Netherlands it achieved only 56% accuracy. Average sensitivity across all methods and countries was only 55% - i.e. of those species truly protected, only 55% of them were correctly assessed to be protected by models. Similarly, only 48% of species truly unprotected were correctly assessed as unprotected.

Conclusions from the comparison model quality

- there is no clear difference in performance between the three presence/absence models (masking EBCC (50×50 km), modelling EBCC (5×5 km) and modelling recent data (5×5 km).
- performances of the three presence-absence methods differ between countries.
- average accuracy of the models when compared to fine-grained national analysis is moderate (55%).

What may have affected the performance of different models/approaches?

- Quality of spatial coverage of habitats in Corine Land Cover map. As discussed earlier the coverage of some scarcer and small-scale habitat elements in the Corine Land Cover map is rather poor. These are particularly situated outside protected (Natura 2000) areas, which may result in underestimation of the contribution of outside Natura 2000 to a species distribution in 50x50 km masking analysis.
- The Corine land cover classification is not ideal for describing bird habitats, leading to assignments of birds to Corine land cover types that only partly represent their real habitat or conversely, land cover types that cover more habitats than the habitat occupied by the species (50×50 km masking analysis.
- Allocating grid cell based presences to (non) Natura 2000 sites. Presence in a grid cell does not necessarily mean that the species occurs across all habitats in that particular cell. This may be likely for a widespread species but less so for restricted-range species. This applies to both masking 50×50 km and modelling approaches. In the modelling options 5x5 km were assigned to outside and inside Natura 2000 sites proportionally to the surface covered by both. In the case of species characteristic of Natural habitats this may lead to an overestimation of the importance of outside Natura 2000, as the Natural habitat is generally situated inside Natura 2000. The reverse applies to species of anthropogenic habitats.

Conclusions

All approaches have their shortcomings. It is plausible that 50×50 km masking analyses overestimate the value of Natura 2000 sites for species of Natural habitats and that modelling at 5×5 km overestimates the value of the areas outside Natura 2000 for species of Natural habitats, as explained above.

Table 4-7

Results of comparison analyses comparing proportions of species ranges protected according to downscaling and modelling methods compared to fine-resolution observed distribution and abundance data. Country codes are BG = Bulgaria, FI = Finland, FR = France, SP = Spain and UK = United Kingdom. Data types are D = distribution and A = abundance.

Modelling method	Observed data		Number of species		Correlation		Errors		Validation statistics		
	Country	Data type	In country	In country and predictions	r	P	Present, no model	Model, not present	Acc.	Sens.	Spec.
Masking EBCC	BG	D	264	247	0.06	0.347	17	8	86%	0.90	0.21
	FI	D	290	232	0.66	<0.001	58	3	71%	0.66	0.73
	FR	D	318	263	0.53	<0.001	55	7	68%	0.70	0.65
	NL	D	149	137	0.41	<0.001	12	55	56%	0.76	0.48
	SP	D	312	246	0.22	0.001	66	8	77%	0.78	0.68
	UK	D	292	209	0.28	<0.001	83	4	62%	0.55	0.63
	UK	A	243	200	0.12	0.092	43	13	51%	0.43	0.53
Modelling EBCC (presence/ absences)	BG	D	264	184	0.55	<0.001	80	19	60%	0.66	0.04
	FI	D	290	151	0.88	<0.001	139	18	82%	0.39	0.95
	FR	D	318	188	0.64	<0.001	130	34	63%	0.43	0.83
	NL	D	149	92	0.25	0.015	57	50	58%	0.10	0.80
	SP	D	312	183	0.49	<0.001	129	47	50%	0.52	0.43
	UK	D	292	135	0.47	<0.001	157	34	80%	0.21	0.93
	UK	A	243	126	0.21	0.016	117	43	79%	0.13	0.90
Modelling EBCC (probabilities)	BG	D	264	189	0.64	<0.001	75	48	59%	0.71	0.02
	FI	D	290	172	0.78	<0.001	118	62	43%	0.56	0.40
	FR	D	318	193	0.67	<0.001	125	57	43%	0.60	0.28
	NL	D	149	92	0.18	0.078	57	140	26%	0.65	0.15
	SP	D	312	187	0.55	<0.001	125	74	54%	0.65	0.25
	UK	D	292	148	0.42	<0.001	144	86	42%	0.60	0.39
	UK	A	243	131	0.04	0.621	112	103	37%	0.68	0.33
Modelling recent (presence/ absences)	BG	D	264	185	0.64	<0.001	79	41	59%	0.68	0.09
	FI	D	290	152	0.91	<0.001	138	20	83%	0.47	0.93
	FR	D	318	196	0.52	<0.001	122	47	64%	0.53	0.74
	NL	D	149	88	0.46	<0.001	61	50	61%	0.21	0.79
	SP	D	312	179	0.52	<0.001	133	49	55%	0.57	0.48
	UK	D	292	123	0.58	<0.001	169	24	78%	0.22	0.91
	UK	A	243	117	0.2	0.031	126	30	76%	0.15	0.87
Modelling recent (probabilities)	BG	D	264	191	0.72	<0.001	73	79	55%	0.72	0.01
	FI	D	290	179	0.79	<0.001	111	94	34%	0.59	0.29
	FR	D	318	202	0.61	<0.001	116	69	43%	0.64	0.25
	NL	D	149	94	0.57	<0.001	55	178	22%	0.65	0.12
	SP	D	312	190	0.72	<0.001	122	83	53%	0.66	0.23
	UK	D	292	153	0.32	<0.001	139	117	37%	0.62	0.33
	UK	A	243	134	0.11	0.189	109	136	33%	0.70	0.29

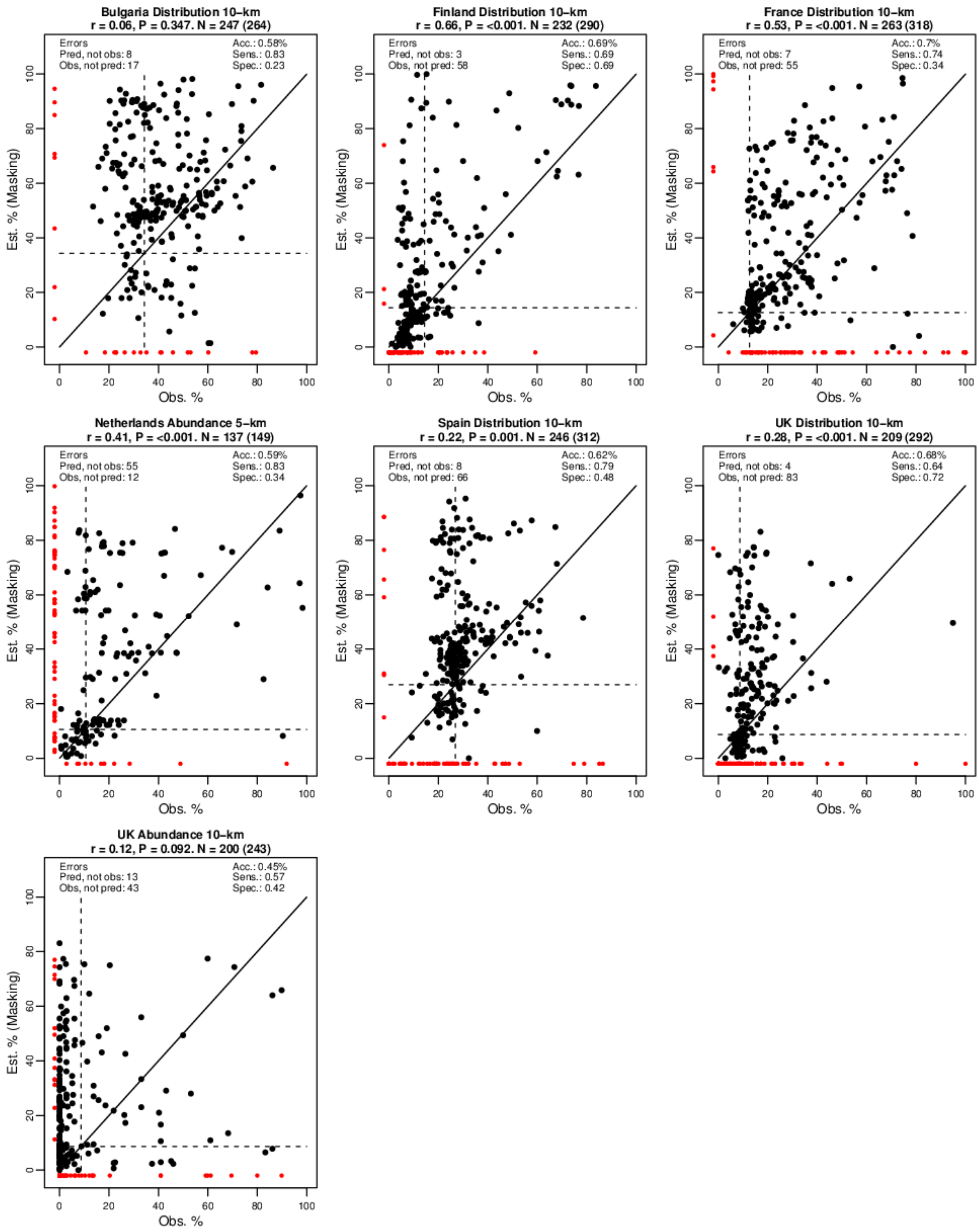


Figure 4-58 *Validation plots showing the relationship between observed % of each bird species' range protected and that estimated by the masking of 50×50 km EBCC data. Red dots show species that were present but for which models failed to predict occurrence (dots along x-axis) or species absent but predicted to be present (dots along y-axis). The solid line shows the line of equality indicating perfect agreement. Dashed lines are at the national % of land designated; species to the right of the vertical line are truly protected accordingly to observed data, and those above the horizontal line are those predicted to be protected by the particular modelling method. The Accuracy, Sensitivity and Specificity statistics are derived from the number of species falling in the four quadrants defined by these dashed lines.*

Herpetofauna

We also undertook tests to evaluate results for Herpetofauna using data for individual countries. Figure 4-59 shows the average level of protection and the spread per country according to the habitat masking method, the 5x5 km modelling, and the 1 km by 1 km (for the selected countries only). It shows that in general the 5x5 km modelling and habitat masking provide similar results. There seem to be more differences between the habitat masking and the 1 km by 1 km modelling, whereas the 1 km by 1 km modelling in most instances suggests higher levels of protection for species compared to the other methods. With modelling at higher resolution, there is less over-estimation of suitable extent for species, and therefore the percentage of its suitable range covered by Natura 2000 will be higher. In most cases the 1 km by 1 km estimates will be more accurate; however, these data are not available for all countries. Also, we have seen from the highlighted cases (Table 4-1 and 4-2) that in some instances the habitat masking provides more realistic estimates than the 1km by 1km modelling (e.g. the case of the *Macrovipera schweizeri*, see above).

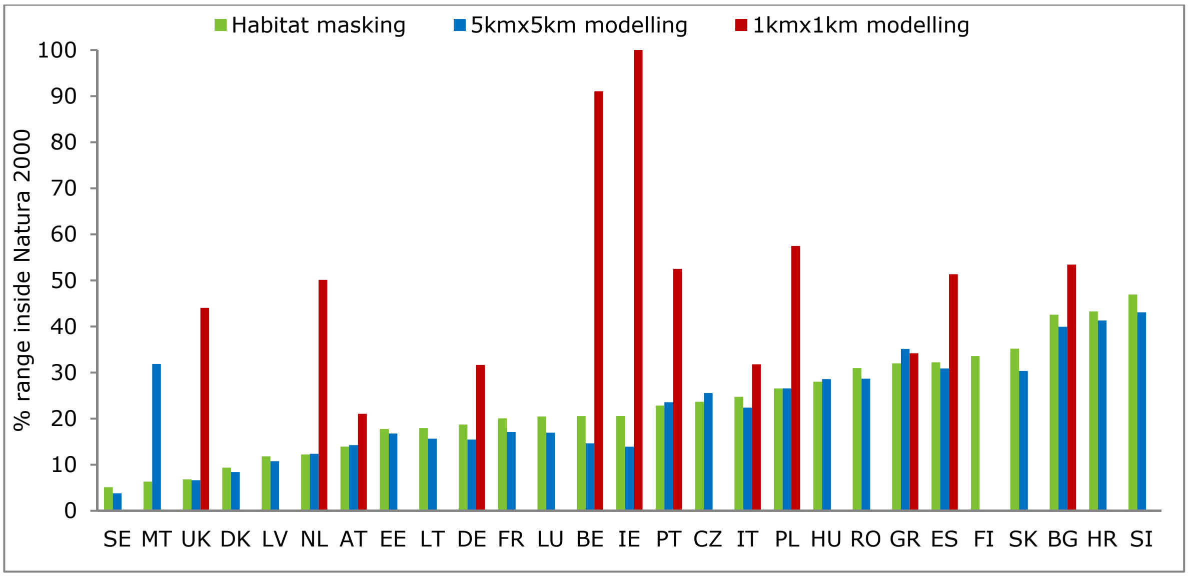


Figure 4-59 *The percentage Natura 2000 coverage per country according to the habitat masking method (green) the 5x5 km modelling (blue) and the 1km by 1km modelling (red). Countries are sorted according to the mean percentage of protection across all herpetofauna species that occur in the respective countries.*

The share of Natura 2000 areas is not equal for all countries. The baseline of 18% is therefore high if only 6 or 7% of the territory has been designated as Natura 2000 area. In Figure 4-60 we show the percentage range of herpetofauna species within Natura 2000 in relation to the share of Natura 2000 in a country. This allows us to assess whether the herpetofauna has more than what would be expected if there were to be a random distribution in the country. In countries which have designated a relatively small proportion of the territory (Sweden, Malta, UK, Denmark, Netherlands) have a relatively low diversity within their protected areas (Fig. 4-60), which could well be the result of fragmentation or edge effects of smaller protected areas. A country which has a relatively large herpetofauna coverage by Natura 2000 is Finland despite its smaller protected area (14.45. This could be the result of extensive Natural areas surrounding the protected areas.

Next we calculated the fraction of species present in Natura 2000, i.e. the percentage of the species range divided by the percentage of Natura 2000 area. The results show that, if the share is more than 100, the taxa benefit more than would be expected from the Natura 2000 area. We calculated this for the herpetofauna (Fig. 4-61) finding that most countries (22) have a fraction above one, so more than expected share of the herpetofauna (if randomly distributed) is presented within the Natura 2000 network. Also here we see that countries which have designated a relatively small proportion of the territory have a lower fraction of diversity within its protected area, and Finland has a very high fraction.

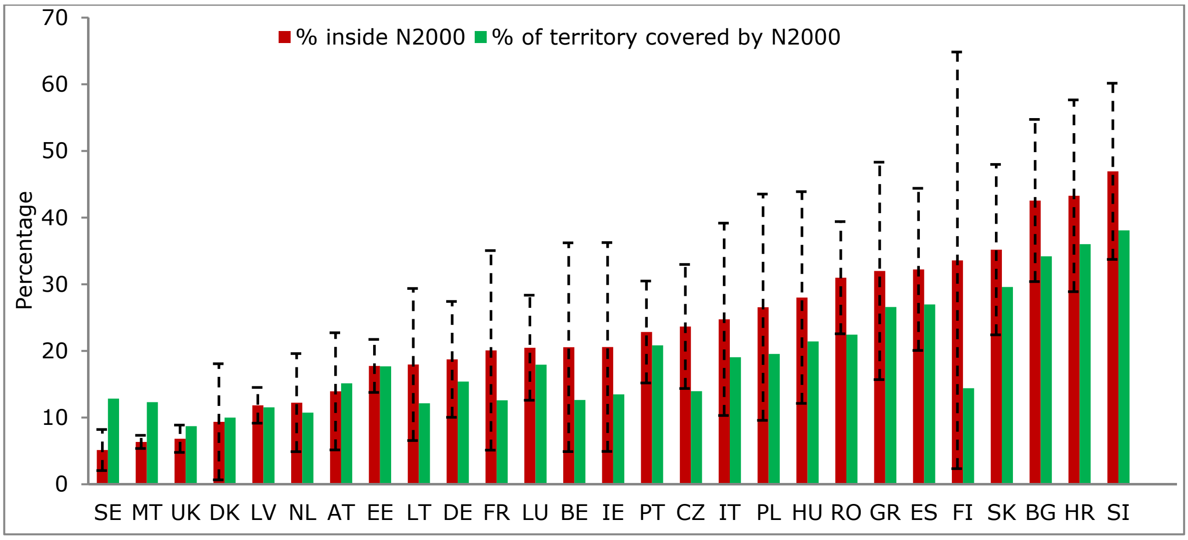


Figure 4-60 *The graph shows the % of herpetofauna species within N2000 areas in a country (red), and the share of the national territory of the country which is included in N2000 (green). Where the red bar exceeds the green bar for a country, there is 'above average' presence of species within N2000.*

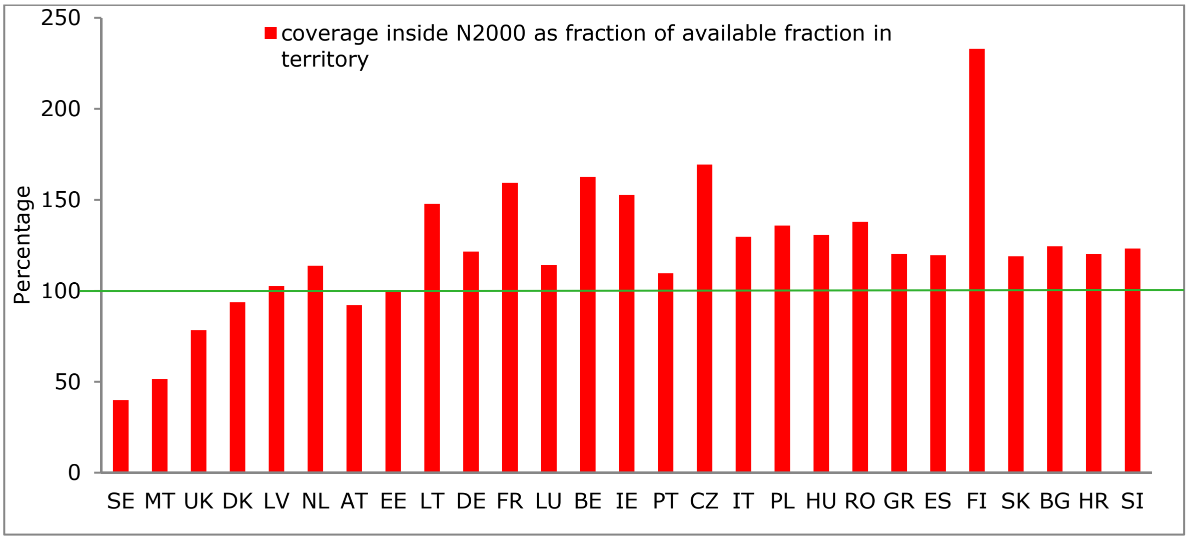


Figure 4-61 *An index of herpetofauna species presence within N2000 areas: calculated as species presence / share of N2000 in a country. If species presence is conform the share of N2000, the value will be 100 (green line), therefore any country with higher species presence in protected areas will exceed the value of 100.*

Scatterplots that compare the methods per country are displayed in Figures 4-62 and 4-63. There is a large spread between countries in the degree to which methods show similar results. For most countries with many species (Italy, France, Spain, Greece, Slovenia) correlations are high (r > 0.5), but not for all (Portugal, Romania; r<0.3). Countries with low numbers of amphibian and reptile species show more variability in correlations, from really high (Lithuania,; r=0.82) to really low (Luxembourg, -0.68). For these countries, given the small number of species, and in some instances the small area considered (e.g. Luxembourg) spurious results for one species can have a large effect on the overall correlation for that country.

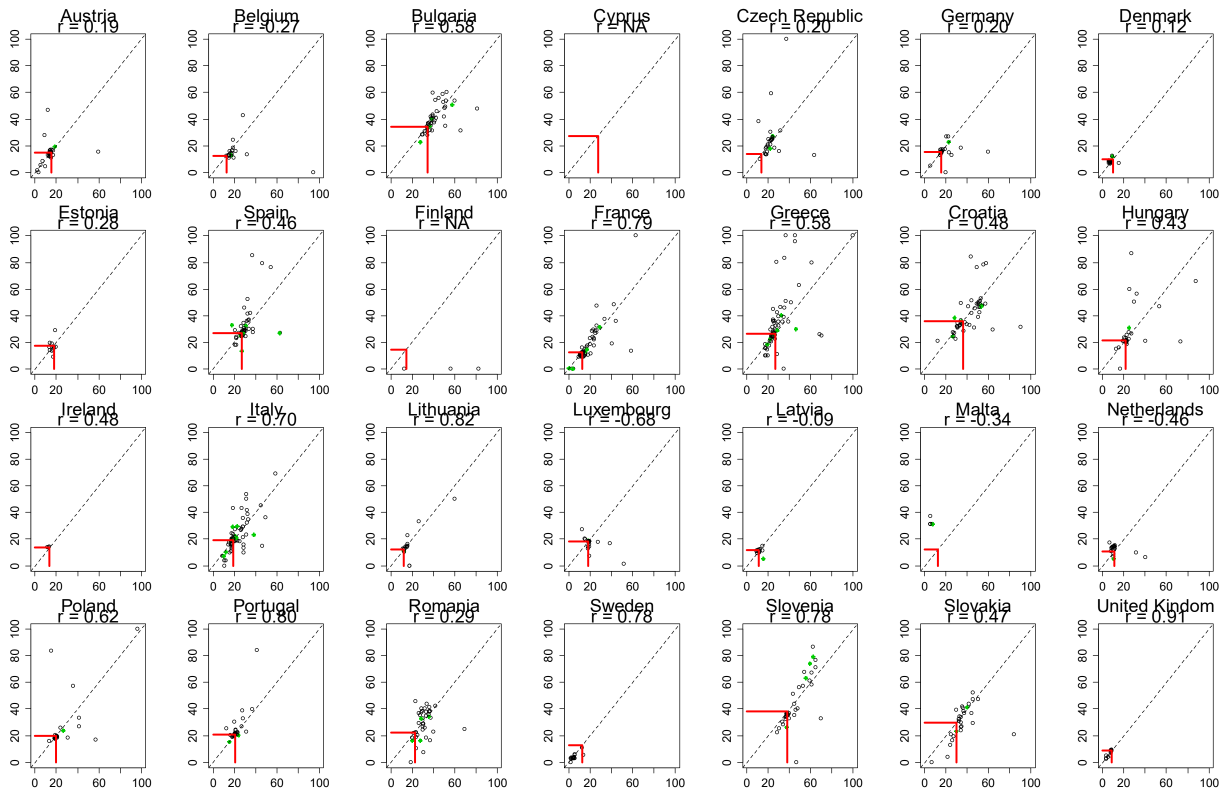


Figure 4-62 *Comparison of the estimated coverage for herpetofauna by Natura 2000 between habitat masking (x-axis) and 5x5 km modelling (y-axis). Dashed line indicates the 1:1 line, the red lines indicate the percentage of Natura 2000 coverage for the indicated country.*

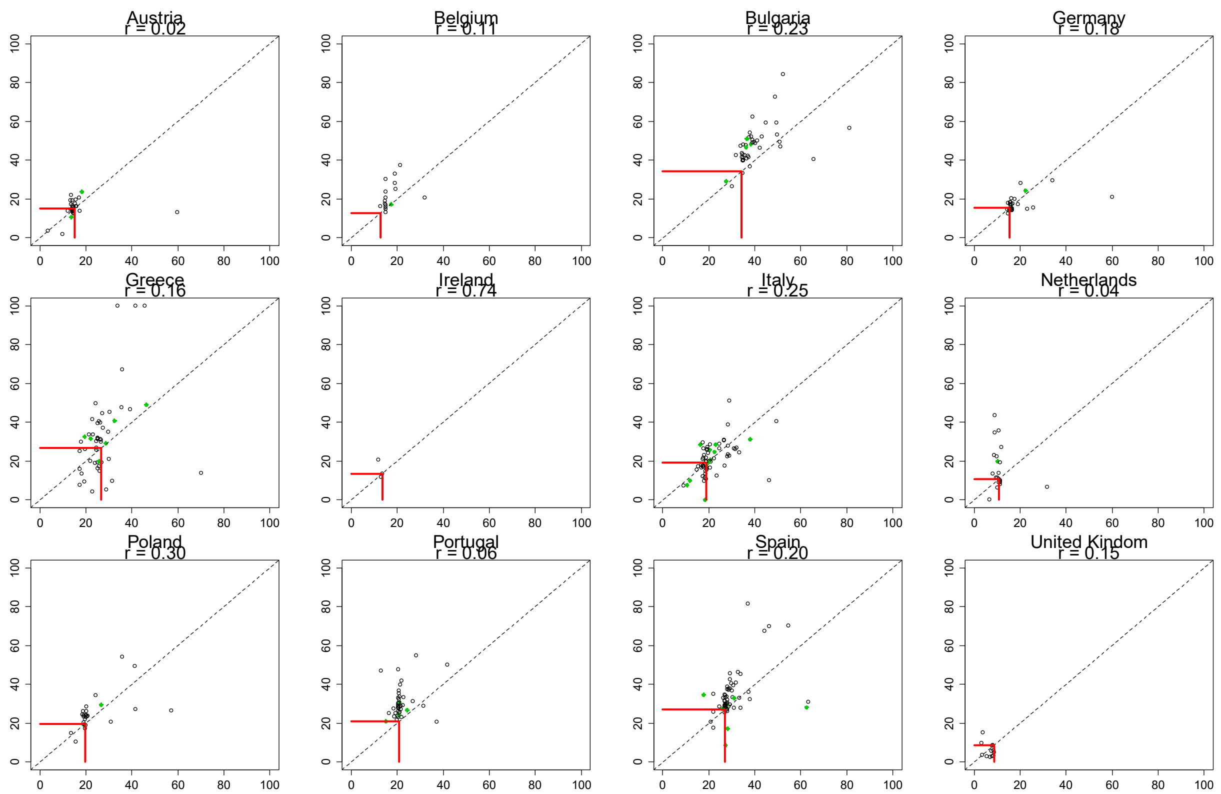


Figure 4-63 *Comparison of the estimated coverage for herpetofauna by Natura 2000 between habitat masking (x-axis) and 1km by 1km modelling (y-axis). Dashed line indicates the 1:1 line, the red lines indicate the percentage of Natura 2000 coverage for the indicated country.*

Validation of habitat masking by 5x5 km models for butterflies

EU-27 level
The 50x50 km distribution maps were used to produce models incorporating more than 70 variables related to climate, soil, pressures, etc. (Table A-4 in Appendix 2). The models were used to generate distribution maps at a more detailed level, in this case 5x5 km. This process is illustrated in Appendix 2.

These 5x5 km maps were overlaid with the Natura 2000 coverage maps to calculate the proportion of the distribution in and outside Natura 2000. Figure 4-64 plots the values of the 50x50 km maps with habitat masking against the 5x5 km maps which result from the models. There is a significant relationship (t=17.646; $p<0.001$; $R^2= 0.4563$).

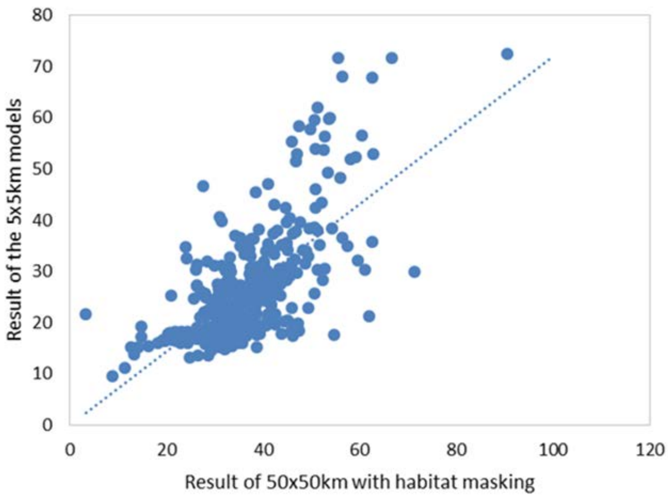


Figure 4-64 *The proportion (as percentage) of the butterfly distribution inside Natura 2000 as a result of the 5x5 km models (y-axis) compared to the percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries at EU=28 level for all species (n=371 as some species did not generate a 5x5 km model, mostly because they are too rare).*

The results of the habitat masking on 50x50 km distribution data are compared with modelled distribution on 5x5 km scale, also using more than 70 underlying input variables (Table A-7). This is done for the EU-28 level as well as on a country level.

For the Netherlands the results of the habitat masking are evaluated by comparing them with 250m distribution maps. These maps have been generated by Van Swaay (2013) to test for Dutch Nature Conservation quality and are based on:
- Real observations, as long as their precision is better than 250m.
- The allocation by probability maps (Van Swaay *et al.* 2006) where there are no real observations of high precision and if the occupancy of the 1 km square is higher than 0.5

For butterflies in The Netherlands, detailed maps on a 250m scale are available (based on Van Swaay, 2013). A comparison of the results of the habitat masking of the 50x50 km squares for the Netherlands gives a positive relationship with the percentage of 250m squares inside Natura 2000 (t-value 4.266; $p<0.001$; Fig. 4-65). However the graph also shows that some species deviate markedly from the trendline. An example is *Pyronia tithonus* (in Fig. 4-65 with 58% on the x-axis and 9% on the y-axis). This is a species of grasslands which can be very common and widespread. However in the Netherlands this species reaches the NW border of its distribution, and the species is missing in large parts of the country. Estimation by habitat masking is therefore much too high for this species.

Although habitat masking with CLC-3 on 50x50 km maps has its limitations, especially near the edge of the distribution of a species, it still produces reliable estimates of the percentage inside Natura 2000.

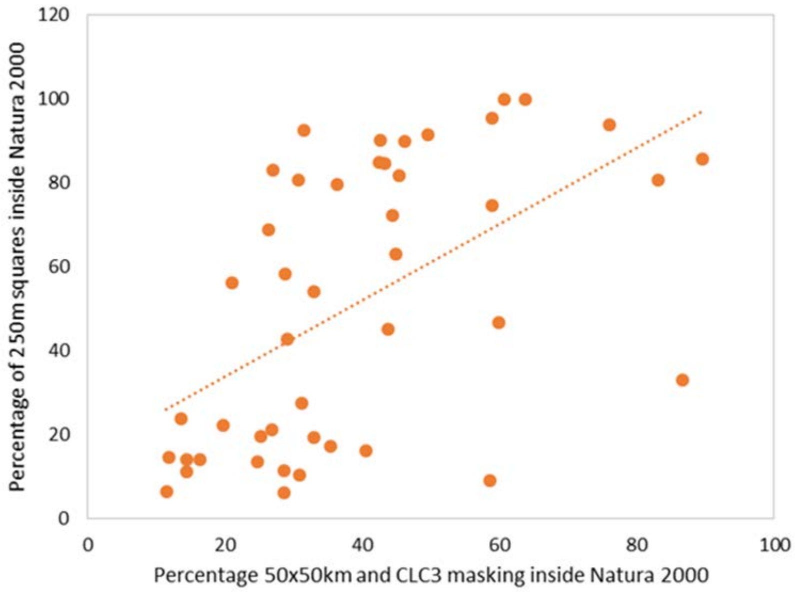


Figure 4-65 *The proportion (as percentage) of the distribution inside Natura 2000 as a result of the 250m maps for butterflies in the Netherlands (y-axis) compared to the percentage of ha squares after habitat masking inside Natura 2000 areas in the Netherlands (n=58).*

5 Discussion, conclusions and recommendations

5.1 Discussion of results

5.1.1 Mammals

Overall we considered 169 species of mammals excluding invasive and domestic species. Of these, 36 are listed under Annex II of Habitat directive and 18 are considered threatened (VU=12; EN=4; CR=2) and 6 Data Deficient according to the IUCN Red List.

Mammal species have a mean coverage of 23.1±11.1% (mean±SD). The only species that is entirely uncovered by Natura 2000 (a true gap species) is the Bavarian pine vole (*Microtus bavaricus*), a critically endangered species occurring in Austria. According to a baseline equal to 18% (Natura 2000 coverage in EU28), 55 species (32.5%) were partial gap (PG) species (species included in the Natura 2000 network but whose coverage do not reach the adopted baseline) while the remaining 113 species (66.9%) were adequately protected. Annex II species had a mean coverage of 26.5±12.2, and six species did not meet the target (for PG species=16.7%). In contrast, species not listed under Annex II had a mean coverage 22.1±10.7, of which 53 species were PG (39.8%). Threatened species had a mean coverage of 32.9±15.8 with only two PG species (8.3%), whereas non-threatened species had a mean coverage 21.4±9.3 whose 51 species were PG (38.3%). By adopting different baselines for each country corresponding on their Natura 2000 coverage, the worst performing countries were Malta (PG=100%), Austria (PG=79.5%), Finland (PG=78.6%), Sweden (PG=76.2%), Denmark (PG=74.5%), Estonia (PG=71.9%) and Cyprus (PG=68.2%).

5.1.2 Birds

A comparison was made of species which seem to benefit more or less than expected from Natura 2000. Table 5-1 lists species that consistently show more than twice the percentage of the range in Natura 2000 than expected (>36%). The table clearly shows that species of Natural habitats, in particular mountainous areas, are covered well by Natura 2000.

On the other hand, some species have a relatively limited percentage of their range on Natura 2000 areas. If we use the 18% baseline, we see in Table 5-2 that Annex 1 forest species' distributions (mainly boreal species) are underrepresented. Evidently, vast stretches of boreal forest habitat are not protected by Natura 2000.

Some general conclusions are:

- Annex 1 species' distributions are covered better by Natura 2000 sites than non-Annex 1 species. However Annex 1 forest species are underrepresented in Natura 2000 network
- For EU Red List species, there is no consistent pattern of better coverage/ overrepresentation in the Natura 2000 network
- Small range species: better coverage in Natura 2000 network compared to large range species.
- Habitat: Species from Natural habitats (in particular mountainous area) in addition to forest/scrub (in particular boreal forests) have better coverage/overrepresentation in Natura 2000 network. There is no evidence that generalist species and farmland species have better coverage/overrepresentation in the Natura 2000 network.
- Countries having the highest coverage of species' distribution in Natura 2000 comprise a set of southern and eastern European countries: Bulgaria, Croatia, Slovakia, Hungary, Slovenia, Romania, Greece and Spain.
- Some of the countries having the lowest coverage of species' distribution in Natura 2000 include Latvia, Malta, Finland and Sweden.

Table 5-1
Bird species which benefit in particular from Natura 2000.

Species	Annex 1	EU-Red List	Habitat
Clangula hyemalis		VU	coastal/marine
Gypaetus barbatus	x	VU	open natural habitat
Falco rusticolus	x	VU	open natural habitat
Lagopus mutus		VU	open natural habitat
Charadrius morinellus	x	LC	open natural habitat
Calidris maritima		NT	open natural habitat
Limosa lapponica	x	LC	marshlands/wetlands
Stercorarius longicaudus		LC	open natural habitat
Larus genei	x	LC	marshlands/wetlands
Eremophila alpestris		NT	open natural habitat
Anthus cervinus		NE	marshlands/wetlands
Prunella collaris		LC	open natural habitat
Monticola saxatilis		LC	open natural habitat
Pyrrhocorax graculus		LC	open natural habitat
Calcarius lapponicus		NT	marshlands/wetlands
Plectrophenax nivalis		LC	open natural habitat

Table 5-2
Bird species which are underrepresented in Natura 2000.

species name	Annex1	EU-Red List	habitat
Circus cyaneus	x	LC	semi-Natural open+farmland
Tetrastes bonasia	x	LC	forest/shrub
Tetrao urogallus	x	LC	forest/shrub
Coturnix coturnix		LC	semi-Natural open+farmland
Crex crex	x	LC	semi-Natural open+farmland
Haematopus ostralegus		VU	semi-Natural open+farmland
Vanellus vanellus		VU	semi-Natural open+farmland
Glaucidium passerinum	x	LC	forest/shrub
Strix uralensis	x	LC	forest/shrub
Strix nebulosa	x	LC	forest/shrub
Aegolius funereus	x	LC	forest/shrub
Alauda arvensis		LC	semi-Natural open+farmland
Anthus pratensis		VU	semi-Natural open+farmland
Locustella fluviatilis		VU	marshlands/wetlands
Sylvia communis		LC	semi-Natural open+farmland
Phylloscopus trochilus		LC	forest/shrub
Regulus regulus		NT	forest/shrub
Nucifraga caryocatactes		LC	forest/shrub
Sturnus vulgaris		LC	generalist

5.1.3 Reptiles and amphibians

The estimation of coverage by Natura 2000 with different methods (distribution modelling at various scales and habitat masking) seems remarkably robust when applied at the extent of the EU-28 (Fig. 4-35) and also at the scale of the larger countries (Fig. 4-62). Nevertheless not all species show similar results when applying the different methods. Species with restricted ranges (e.g. isolated on islands or mountain peaks) are more complicated and require additional attention. However, when looking at individual species and their estimated ranges, an expert judgement can usually help in deciding which estimated coverage is most accurate (Table 4-1 and 4-2). Besides species that are difficult to model, the use of Corine Land Cover was found to be restrictive when masking the habitat of fresh water restricted species. This was a problem especially for Marsh turtles.

5.1.4 Butterflies

The scale of the available information has a strong influence on the results. As we lack data with greater detail for most of Europe, we use habitat masking in this report as a proxy for more detailed information. For butterflies, species with small home ranges tend to benefit from small landscape elements such as hedgerows, or well-developed forest edges. The effect of scale is very important, more important perhaps than for other taxa. Because this is a general aspect, the scale effect is worked out in more detail in paragraph 5.2.

The more widespread a species, the more likely that the proportion of its distribution inside Natura 2000 will approach the proportion of Natura 2000 of the land (Fig. 5-1). As a result of the preference of butterflies for CLC-3 types found mainly inside Natura 2000, the percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries for species with a large distribution is around 25%.

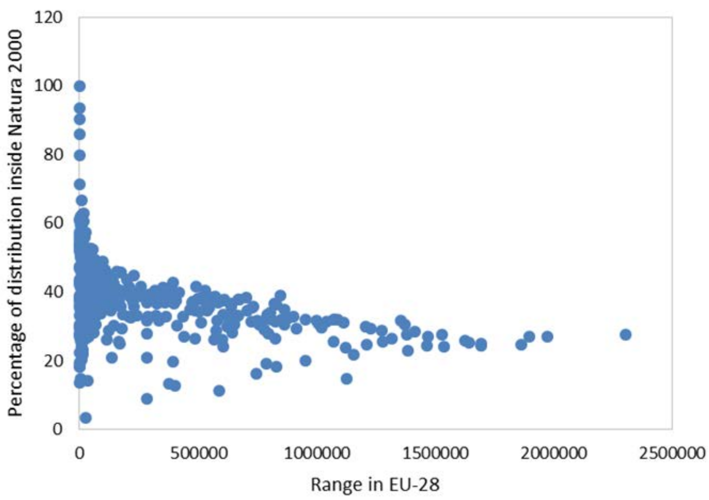


Figure 5-1 *The percentage of ha squares after habitat masking inside Natura 2000 areas in the EU-28 countries (y-axis) as a function of its range (km2) inside the EU-28 (x-axis).*

5.1.5 Plants

Based on the analyses of plant species distribution we conclude that:

1. Red list species and some other rare species occur significantly more often inside than outside Natura 2000 sites. Protected areas are generally selected on habitat based criteria; qualifying habitats are generally species-rich, often including rare species. In this way, it is demonstrated that Natura 2000 is protecting the majority of the most diverse and species-rich habitats and that outside protected areas, there are fewer species of nature conservation interest present.
2. None of the plant species considered have a strong preference for areas outside Natura 2000 sites. Nevertheless, most Red list species and some other rare species do – to some extent – occur outside Natura 2000 sites. From this, it might be concluded that biodiversity is not an exclusive phenomenon for Natura 2000 sites.
3. Extending Natura 2000 sites with a 500 meter buffer zone shows (at least for the countries covered by the analysis) that biodiversity, measured in terms of number of hotspots, is intermediate between the Natura 2000 sites and the area outside the buffer zone. Extending Natura 2000 sites (by setting a buffer) may therefore better secure biodiversity in protected areas.

5.2 Methods: Consequences of scale

The scale of the available information has a strong influence on the results. As we lack data with great detail for most of Europe, we use habitat masking in this report as a proxy for more detailed information. Here we discuss the effect of scale, using data from the Netherlands, a country with exceptionally good data available on the distribution of butterflies. *Phengaris teleius*, a rare and very local species of conservation interest has been studied in great detail.

Figure 5-2L shows the detailed distribution of *Phengaris teleius*. Almost all observations are done on Junco-Molinion grasslands (Habitat type 6410 of Annex I of the Habitats Directive) on the southern edge of the nature reserve Moerputten, near the city of 's-Hertogenbosch (NE of the nature reserve). Furthermore some vagrant butterflies are found in other parts of the nature reserve, as well as along a few roads and a canal to the south. The agricultural land outside the Natura 2000 area Vlijmens Ven, Moerputten & Bossche Broek consists of intensively used Lolium perenne grasslands or Maize fields.
P. teleius is a species mentioned on Annex II and IV of the Habitats Directive. As a consequence, Natura 2000 area has been designated for this species. Figure 5-2R shows the Natura 2000 area as an overlay over the distribution. Almost all observations are inside the Natura 2000 borders, with the exception of a few vagrant butterflies. When assigned to the Dutch 1km grid (Fig. 5-3) it becomes clear that most of the population is occupying only three 1 km squares, but that in total eight squares are occupied (although some of them only with one observation).
When we calculate the proportion of these eight squares in and outside Natura 2000 (Fig. 5-3), 57% of these 8 km^2 appears to be inside Natura 2000.

Moving to a more coarse level of 5x5 km leaves only 25% of these three grid squares inside Natura 2000 (Fig. 5-4L), including a dry area further south which has no habitat for the species. Figure 5-3R shows the distribution of Phengaris teleius on the CLC3 map. All observations fall either in CLC3 type 23 (dark green, broad-leaved forest) or 18 (light green, pastures). This is an artefact of the fact that all 100m squares are assigned to the dominant CLC3 type, and also that the CLC3 types are so coarse, that they cannot distinguish between intensive agricultural grassland (completely unsuitable for this butterfly) and the semi-Natural grasslands with Sanguisorba officinalis as well as the Junco-Molinion grassland (Habitattype 6410 of Annex I of the Habitats Directive) where the butterflies have their main distribution.

In summary, this example illustrates how the use of coarse European data can influence the results for a critical species, with very specific habitat requirements and a narrow distribution.

Figure 5-2 *Detailed observations (precision of less than 25m) of Phengaris teleius in the Netherlands (left) and Detailed observations of Phengaris teleius in the Netherlands. Natura 2000 is indicated in purple (right).*

Figure 5-3 *Detailed observations of Phengaris teleius in the Netherlands. Natura 2000 is indicated in purple, the Dutch 1km grid system in blue.*

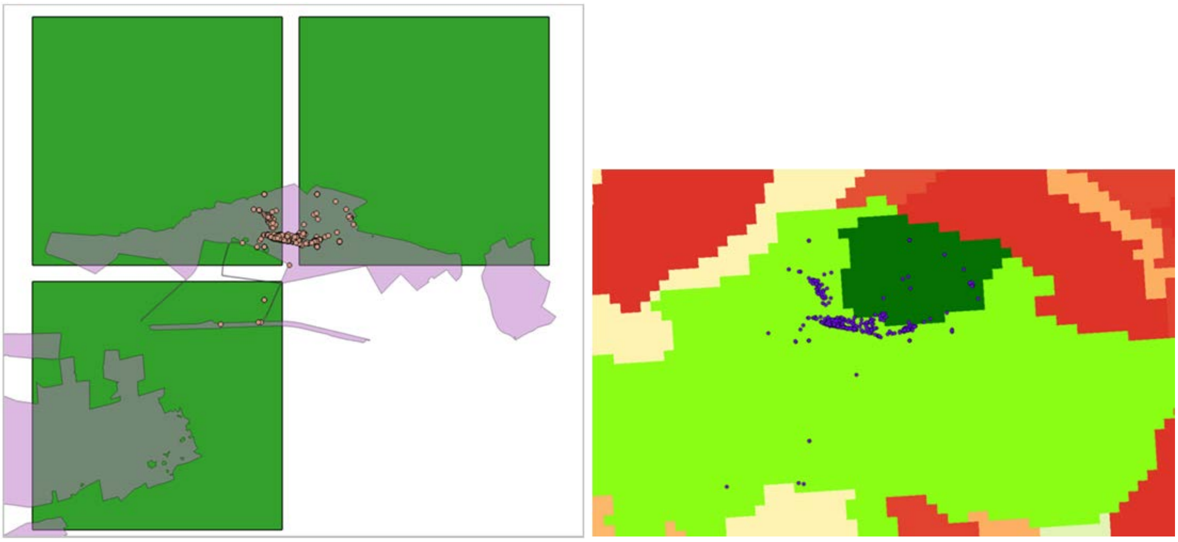


Figure 5-4 *Detailed observations of Phengaris teleius in the Netherlands. Natura 2000 is indicated in purple, the Dutch 5km grid system in green (left). Detailed observations of Phengaris teleius in the Netherlands. CLC3 types are coloured, the ones relevant for the distribution of P. teleius in either light green (CLC3 18, pastures) and dark green (CLC3 23, broad-leaved forests). In the 100m squares these CLC3 types are the most abundant ones (right).*

5.3 Methods: Modelling approach

From the analyses of **bird species**, for which we have most supporting data, we conclude that no particular approach for downscaling EU-wide coarse resolution occurrence data performs significantly better than the others and that the quality of the models is moderate. This means that we have to be cautious when interpreting the results with regard to the importance of Natura 2000 for breeding birds and base conclusions on the consensus in the results of several approaches rather than the outcome of one model.

Overall (see Section 4.6) the results of different approaches were not consistent in absolute proportions, but some general conclusions could be made. In general, the 50×50 km EBCC-habitat masking analyses resulted in estimates of higher species coverage by the Natura 2000 network than the results based on the two modelling approaches. Despite these differences, similar patterns of species coverage in relation to conservation threat status and other classifications were found. Below, we provide a summary of the main consistencies and inconsistencies between the approaches based on a comparison of the results in section 4.2.

Comparison of the three models
Annex 1 species generally have relatively high coverage by the Natura 2000 network compared to non-Annex 1 species. The exact importance of Natura 2000 sites for EU Red List species species' distributions varies by approach. EU Red List species generally have relatively high coverage in the Natura 2000 network, compared to non-EU Red List species. Species with small ranges also have a relatively high proportion of the distribution in the Natura 2000 network whereas generalist species have a relatively small proportion of their range in Natura 2000. Species of open nature habitat have rather high coverage in Natura 2000 areas.

Countries having the highest proportion of their range inside Natura 2000 sites are southern and eastern European countries: Bulgaria, Croatia, Slovakia, Hungary, Slovenia, Romania, Greece and Spain. Some of the countries having the lowest coverage of their species' distribution in Natura 2000 sites: Latvia, Malta, Finland and Sweden.

Species performing consistently in three models
Another way to get more insight into patterns in the results is by selecting the species that performed consistently in the three approaches. 231 species were shared by the three approaches. Considering that 18 percent is the baseline for below or above average coverage of a species distribution by Natura 2000 site, we selected species that scored consistently higher in the approaches and those that scored consistently lower (n=69). These results are summarised in Figure 5-5, 5-6 and 5-7 and show that considerably more species are overrepresented (n =49) in Natura 2000 network than underrepresented (n =21. Note: 161 species having inconsistent outcomes).

The ratio between Annex 1 and non-Annex 1 species is higher in the "overrepresented" category than in the "underrepresented". This is not the case for species on the EU Red List; the ratio between Red List and non-Red List is even higher in the "underrepresented" category.
When considering habitat groups we see that species from Natural habitats with exception of forest/shrub are barely present in the "underrepresented" category.

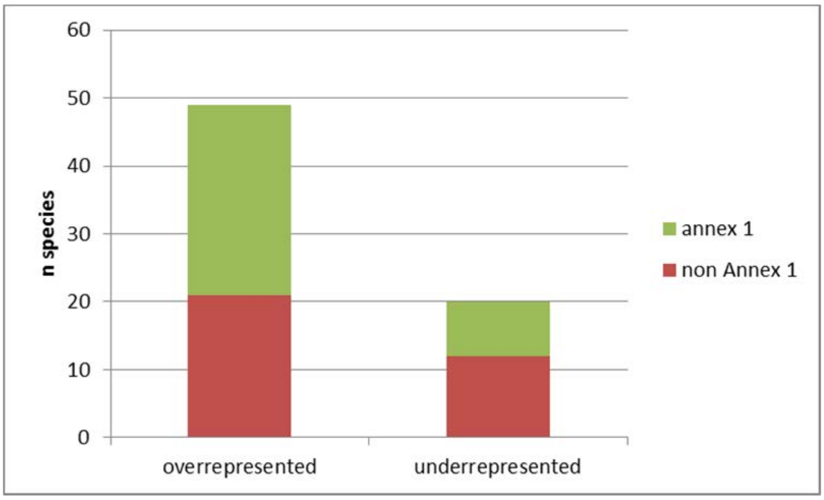


Figure 5-5 *Comparison of number of (non)-Annex 1 species overrepresented (>18% distribution inside Natura 2000) in Natura 2000 network and species underrepresented (<18%).*

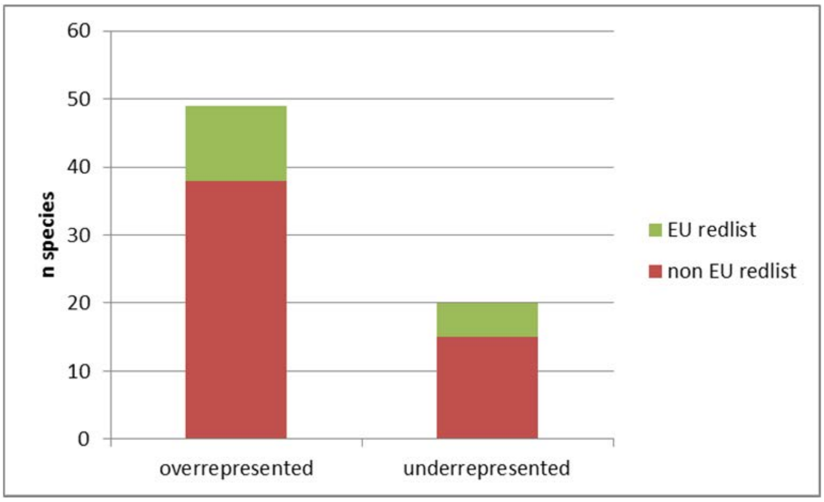


Figure 5-6 *Comparison of number of (non)-EU Red List species overrepresented (>18% distribution inside Natura 2000) in Natura 2000 network and species underrepresented (<18%).*

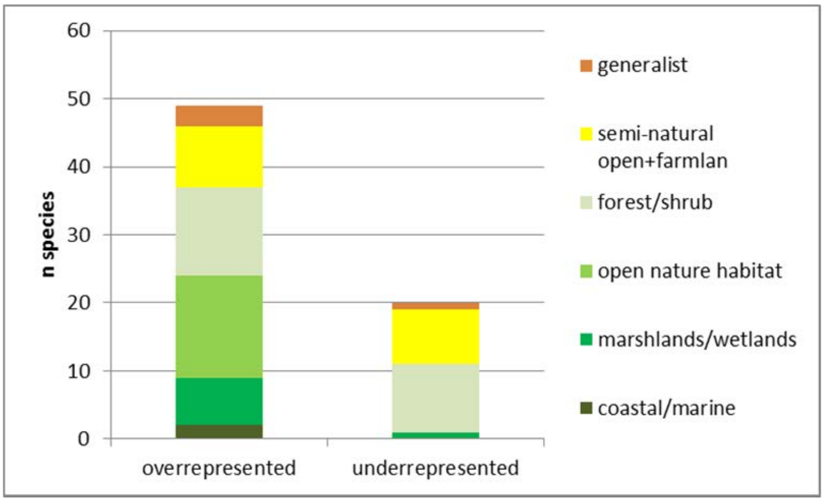


Figure 5-7 *Comparison of number of species per habitat category overrepresented ((>18% distribution inside Natura 2000) in Natura 2000 network and species underrepresented (<18%).*

In summary, this approach supports the general results that overall, Annex 1 species have higher coverage on Natura 2000 sites than non-Annex 1 species. It does not support the general results that EU Red List species overall have higher coverage by Natura 2000 sites than non EU Red List species. In addition to the general results it shows that in addition to species from open Natural habitats, species from marine and coastal areas and species from marsh- and wetlands also perform relatively well in Natura 2000 sites.

5.4 Conclusions

5.4.1 General Conclusions

In summary for the animal groups:

- A greater number of common animal species and other 'non-Annex' animal species occur inside Natura 2000 than outside (in particular breeding birds and butterflies).
- Animal species for which Natura 2000 areas were not specifically designated (non-annex species) do, therefore, gain benefit from the protected areas network.
- The species of the annexes benefit more (that is, generally occur more frequently within the Natura 2000 site boundaries) than the non-annex species; this is in particular the case for birds and butterflies, for amphibians and reptiles the difference is negligible.

Overall, results show that all faunal species groups benefit more than might be expected based on the terrestrial coverage of Natura 2000. 18% of the land area of the Member States is covered by Natura 2000 sites and, if species were randomly distributed, then 18% of their distribution would be expected to fall within the Natura 2000 site boundaries. However, for every animal group, a greater proportion of the species that do not provide the reason for the designation of the sites (i.e. the common and other 'non-Annex' species) occur inside Natura 2000 than outside. Species for which Natura 2000 areas were not specifically designated do, therefore, gain benefit from the protected areas network. In addition, Annex-listed species for which the Natura 2000 sites are designated also occur more frequently within the site boundaries[11] in particular for birds and butterflies.

Natura 2000 sites do not only therefore serve their purpose in protecting the Annex 1 (Birds Directive) and Annex 2 (Habitats Directive) species but also provide significant added value to non-Annex species. The reasons for this are evident in the results for the individual animal groups, in particular the birds and butterflies, as elaborated below.

5.4.2 Birds

Thus Table 5-1 lists the bird species that benefit most from Natura 2000; those showing more than twice the expected relative percentage distribution within Natura 2000. They are associated with habitats for which the best examples (the most characteristic, complete and, often, the largest, etc.) are mostly now found in Natura 2000 sites (in particular mountainous areas and wetlands).

[11] A small number of Annex II species provide notable exceptions to this rule, listed and explored in more detail in the text below.

However, the converse is true for a number of other bird species that have a relatively limited percentage distribution within Natura 2000 areas. Using the 18% baseline, it can be seen in Table 5-2 that a number of Annex 1 forest species are underrepresented. In many cases these are boreal species. This reflects the fact that large areas of boreal forest of sufficient quality to support these species occur outside Natura 2000 and further indicates that, with the exception of forest habitat, much of the 'better' habitat for birds is within Natura 2000 (for Annex and non-Annex species). Species such as the Corncrake (*Crex crex*), Eurasian Skylark (*Alauda arvensis*), Northern Lapwing (*Vanellus vanellus*) and Common Quail (*Coturnix coturnix*) are characteristic of open country but also show a strong association with cultivated land, particularly crops, for breeding and foraging. Populations of these species are under-represented because this relatively intensively managed habitat is widespread over large parts of Europe but poorly covered by the Natura 2000 network. These species are still widespread but suffering significant declines from agricultural intensification (which reflects the fact that they are Vulnerable – whereas the forest species are mainly Least Concern).

Further conclusions for birds are that:

- Species with smaller ranges and restricted distributions have better coverage in the Natura 2000 network compared to species with large ranges and wider distributions.
- Species associated with natural habitats (as opposed to semi-natural habitats), in particular mountainous areas, have better coverage/ over-representation in the Natura 2000 network.
- The countries having highest coverage of species' distribution in Natura 2000 are the 'set' of South and East European countries: Bulgaria, Croatia, Slovakia, Hungary, Slovenia, Romania, Greece and Spain.
- In general, species for which Natura 2000 sites have been designated (Annex I species) have a larger proportion of their distribution in the network than non-Annex I species.

Bird species of open natural habitats and coastal and marine habitats are best represented within the Natura 2000 sites. Forest-species are generally represented according the proportion of Natura 2000 sites. Bird species of farmland are relatively well represented in the Mediterranean area, but underrepresented in the Atlantic and continental part of Europe; this may be due to the fact that in western Europe large areas of farmland are designated for the protection of wintering birds and not so much for breeding birds. Unsurprisingly. generalist bird species are underrepresented in the Natura 2000-network since large parts of their ranges lie within intensively used areas such as cities.

5.4.3 Butterflies

The beneficial effects of the Natura 2000 network are also seen with butterflies. The more widespread a species is the greater likelihood that the proportion of its distribution inside Natura 2000 will reflect the proportion of the land-cover of Natura 2000. Non-Annex butterflies (more than any other animal group) occur more frequently inside Natura 2000 than outside. This is mainly because butterflies show a strong preference for Corine Land Cover-3 habitat types and these are mainly found inside Natura 2000 because outside they have been lost as a result of a range of modern pressures and threats and competing land uses (such as agricultural intensification and urban sprawl).

The butterfly species which profit most from Natura 2000 are those species with a very limited distribution such as those on small islands, of which most (or even all) are inside Natura 2000. Remarkably all of the species that were considered occur in Natura 2000 (even if at a low percentage). Butterflies on Annex II of the Habitats Directive, for which Natura 2000 areas have to be designated, occur significantly more in Natura 2000 than other species. Threatened butterflies, both on the European and the EU-27 list, clearly benefit from Natura 2000 areas. Endemic species, that only occur in Europe or the EU-27 and for which we have a high responsibility, also occur more in Natura 2000 areas, this pattern more evident for butterflies than other species.

The scarce fritillary (Euphydryas maturna) is a species of woodlands. In most of Europe it is found in Natura 2000 areas. (Photographer Chris van Swaay)

For butterflies it can be further concluded that:
- In almost all countries butterflies are benefitting from Natura 2000.
- Threatened butterflies, either on the pan-European or on the EU-27 list, are benefitting from Natura 2000 areas.
- Endemic butterflies benefit from Natura 2000 areas

The main reason for this is that key butterfly habitats occur more frequently in Natura 2000 sites than in surrounding urban and agricultural areas. Furthermore, in Eastern and Southern Europe where grasslands have been abandoned and turn into shrub and later secondary forest, all specialist butterfly species are lost. Active management of the butterfly habitats in Natura 2000 would be required to ensure long term survival of butterflies and these areas therefore provide an important tool for preserving Europe's butterfly diversity.

5.4.4 Mammals

The mammals showed a similar but less strong pattern to the birds and butterflies with differences emerging for large mammals. The main conclusions are that:
- A majority of European mammal species benefit from Natura 2000.
- Large mammals are less likely to show an association with, or to derive an identifiable benefit from Natura 2000.

Large mammals often live at low densities and their territories can cover very large areas, that may include Natura 2000 but which will extend far into the wider countryside. They are therefore less likely to be closely associated with Natura 2000 using the approached adopted in this study. Furthermore:
- Although Natura 2000 sites are not evenly distributed in EU-28, and some countries have very low percentages of coverage, some countries protect mammal species less than expected by the total number and area of sites.

This is illustrated best by the results for Malta, Sweden and Cyprus. This outcome may however be indicative of mammal species distribution and behaviour and is not necessarily policy-related.

5.4.5 Amphibians and Reptiles

For the amphibians and reptiles it can be concluded that:
- A majority of European species benefit from Natura 2000.
- There is little difference in the level of protection by Natura 2000 for Annex II species and non-Annex II species.

The European green toad (Bufo viridis) is a species of toad found in many areas in mainland Europe, including steppes, mountainous areas, semi-deserts, and urban areas. (Photographer Fabrice Ottburg)

Four Annex II species had relatively restricted distributions and their Natura 2000 coverage was below the threshold of 18%. For three of the four Annex II species higher resolution data were available at the country level, revealing that these species are in fact probably well protected. Only one species, Italian Agile Frog (*Rana latastei*), had markedly lower coverage by Natura 2000 than the baseline of 18%. Furthermore:
- There was a clear north south gradient in the level of coverage by Natura 2000.

Reptiles and amphibians are not evenly distributed across European countries. Northern countries have fewer species, mainly common species that occur proportionately less in Natura 2000 because of their wide distribution. Southern countries have more species restricted in their distribution and which have higher coverage by Natura 2000 because their preferred key habitats tend to occur more frequently in Natura 2000. Finally:
- The assessment was less accurate for marsh turtles and cave salamanders

The marsh turtles and cave salamanders are typically difficult to assess. The major land cover types associated with marsh turtles (small wetlands and marshes) are underrepresented in the CLC map, leading to an underestimation of the distribution of their habitat. This causes higher estimations of their protection by Natura 2000. For cave salamanders of the genus *Speleomantes* detailed maps of the caves are not available at the level of Europe or even country (Italy, and a small part of France) where these species occur. However, in all cases these species were considered to be better covered by Natura 2000 than expected by chance.

5.4.6 Plants

Based on the analyses of plant species distribution conclusions are that:
- Red list species and some other rare species occur significantly more often inside than outside Natura 2000 sites.
- None of the plant species considered in this study showed a strong preference for areas outside Natura 2000 sites

Bee orchid (Ophrys apifera). (Photographer Fabrice Ottburg)

Natura 2000 sites are generally selected on habitat based criteria; hence qualifying habitats are generally rich in plant species, including rare species. In this way, confirming the results for the animal groups, it demonstrates that Natura 2000 is protecting the majority of the most diverse and species-rich habitats and that outside Natura 2000 there are fewer species of nature conservation interest. Nevertheless, most Red list species and some other rare species do – to some extent – also occur outside Natura 2000 sites. From this, it might be concluded that improved biodiversity cannot be attributed solely to the influence of the Natura 2000 sites. Furthermore:

- Natura 2000 sites exert a strong 'buffer zone' effect.

By extending the plant analysis beyond the boundaries of Natura 2000 sites to a 500 meter 'buffer zone' it was shown that, at least for the countries covered by this analysis, biodiversity in buffer zones (measured in terms of number of hotspots) is intermediate between the Natura 2000 sites and the area outside the buffer zone. The presence of Natura 2000 sites therefore seems to result in improvements in biodiversity around Natura 2000 as well as within – with implications for both policy and practice.

5.5 Recommendations

Mammals
In general, a majority of European mammal species benefit from Natura 2000. However, Natura 2000 network could be improved for some species and in some countries.

- Natura 2000 protection reflects species listed under Annex II, which are indeed more protected than other species. However, this list should be at least updated to include the Azores Noctule (*Nyctalus azoreum*) and the Bavarian pine vole (*Microtus bavaricus*). These species are endemic to Europe and characterized by very narrow distributions, they are both highly threatened (EN, CR according to EU Red List) and scarcely (Azores Noctule) and not protected (Bavarian pine vole) by Natura 2000 network.
- Natura 2000 sites are not evenly distributed in EU-28, and some countries have very low percentages of coverage. Irrespective of national coverage by the network, some countries protect mammals less than expected by the total number of sites. Illustrative examples are Malta, Sweden and Cyprus. This may either indicate conservation that is not targeted to mammals, or, more worryingly, that sites have been placed in areas of low conservation interest.

- The percentage of protection in Natura 2000 (representation) may be misleading when focusing on large mammals (Santini *et al.*, 2014, 2015). These species live at very low densities and require much larger areas to be protected than smaller or ectothermic (cold-blooded) species. The density of Natura 2000 sites in EU-28 is already very high, for conserving more effectively these species an increase of the size Natura 2000 sites within their range would be required. In many cases, these sites are too small to support even a few individuals of large mammals (Santini *et al.* 2015; Santini *et al.* 2014).
- The comparison of range maps and habitat models revealed good performance in general. However, the cross-validation with statistical models showed that although the two models correlated, there are some consistent differences. These are likely due to the quality of the information used to build the two models. More information on species habitat selection and presence points in under-sampled areas are required to improve the accuracy of these models.

Birds
- Better spatial habitat map describing bird habitats in the EU-28 more properly, including small habitat elements.
- As raw data become available for other taxa, similar comparitative analyses should be considered to test how well downscaling methods perform for other taxa.

Reptiles and Amphibians
Two amphibians were identified that definitely require more protection given the baseline used to identify species not well protected. The top three countries where Natura 2000 areas show the highest overlap with home ranges of amphibians and reptiles are Bulgaria, Croatia and Slovenia (Fig. 4-8).

Butterflies
Which are the butterflies that significantly benefit from the Natura 2000-related site conservation requirements under the EU Birds and Habitats Directive?
- The species profiting most from Natura 2000 are those with a very limited range, e.g. occurring on small islands, of which most (or even all) is inside Natura 2000, such as *Hipparchia sbordonii* (only occurring on the Italian island of Ponza), *Maniola halicarnassus* (only occurring on the Greek island of Nisiros), *Erebia polaris* (only occurring in the far north of Lapland) and *Hipparchia leighebi* (restricted to the Eolian Islands Volcano and Panarea in Italy).
- There are no species entirely uncovered by Natura 2000, i.e. no truegap species.
- Butterflies on Annex II of the Habitats Directive, for which Natura 2000 areas have to be designated, occur significantly more in Natura 2000 areas than other species.
- Threatened butterflies, both on the European as well as the EU-27 list, benefit from Natura 2000 areas.
- Endemic species, that only occur in Europe or the EU-27 and for which we have a high responsibility, occur more in Natura 2000 areas than other species.
- Threatened butterflies which occur in CLC3 types which are relatively rare in Natura 2000 areas, have their main occurrence in other CLC3 types.
- In almost all countries butterflies are benefitting from Natura 2000. The main cause is that butterfly habitats occur much more frequently in Natura 2000 than in urban and agricultural areas. Good management of these butterfly habitats will ensure long time survival of butterflies, and hence Natura 2000 is important for non-Annex II species.
- Natura 2000 areas form an important tool to preserve Europe’s butterfly diversity as part of our biodiversity.

However:
- The least protected species – by no surprise - is the Geranium Bronze (*Cacyreus marshalli*), the only invasive butterfly species in Europe occurring on Pelargonium plants in cities and villages in the Mediterranean.
- Nine other species had a coverage below 18%. Almost all of them are non-threatened. The only threatened species is the Spanish Greenish Black-tip, *Euchloe bazae*. We suggest including *Echloe bazae* on the annexes II and IV of the Habitats Directive.
- It is striking that from the species which are threatened in Europe and whose occurrence in some countries is less than the percentage of landcover of Natura 2000, three of them (*Phengaris arion*,

Coenonympha hero* and *Lopinga achine*) are already listed on Annex IV of the Habitats Directive, but not on Annex II. This means that no Natura 2000 areas have to be designated for these species, but these threatened butterflies would certainly profit from extra protection provided by the Natura 2000 areas.
- We suggest that these three species are also listed on Annex II of the Habitats Directive.
- Two of the species which are threatened in Europe and whose occurrence in some countries is less than the percentage of landcover of Natura 2000, are already on the Annex II of the Habitats Directive (*Euphydryas maturna* and *Lycaena helle*). For *Euphydryas maturna* this is not a big issue in Finland, where the species is widespread in the southeast of the country. However it would be good to study the situation in Sweden in more detail. For *Lycaena helle* in Austria, research in 2013 and 2014 to this species has revealed a more detailed distribution and Austria is now in the process of designating Natura 2000 areas for this species.
- We advise checking with the member states if all designations of Natura 2000 for Annex II species have been done.

Limitations of this study
- Although the habitat masking technique performed well (see chapter 5), it is hampered by the fact that the CLC3 map only shows the most widespread habitat type in that 100m square. Hence, important (but not dominant) patches of suitable habitat for butterflies are missed. The suitability of these data would greatly increase if it proportions of each CLC3 type per square, were available.
- Allocating CLC3 habitat types to species means that the habitat preference from a species is generalized over its entire range. However species exhibit broader habitat use (i.e. use more habitats and are less specialized) in the centre of their distribution than on the edge. This can lead to serious over- or underestimates, certainly at the country level. However on a continental scale it is probably less relevant.

5.6 Recommendations for future research

The availability of online maps (e.g. Ebird, Observado, Artportalen, Ornitho, etc.) will make more detailed study possible in the near future, mainly through the availability of more up-to-date and detailed maps. Most of these systems, however, do not upload their data to GBIF. The EU-28 could make studies like this more efficient by encouraging the use of GBIF as online repository of wildlife observations, as probably none of the online portals will ever contain a complete overview as such.

Note that most of these web portals only record casual (presence only) observations are recorded. A drawback of maps based on this type of data (compared to systematically collected data) is that they may not show the real distribution. They do have a value as additional data source for atlas-projects.
The present study focuses on the value of the Natura 2000 network in covering the distribution of butterflies. The next big step should be to investigate whether trends of threatened and endemic species occupying Natura 2000 areas differ significantly from those outside, such as has recently been done for birds (Sanderson *et al.* 2015).

The presence of a strong buffer zone effect around sites for plants suggests that, whilst future work could look at the implications of this and test with other taxonomic groups, there are other issues related to the impact of the wider countryside connected to but beyond Natura 2000. Green infrastructure has Natura 2000 and other protected areas at its heart and the approach and analysis that have been used here could be applied to questions about policy and practice in relation to connectivity through buffer zones, stepping stones and ecological corridors. This could be facilitated by the investigation and use of additional information on habitats and networks derived from Copernicus as well as other remote sensing data.

Furthermore the approaches used in this study could be applied to other drivers of biodiversity patterns such as climate change, for example modelling the impacts of temperature increase. Another policy issue of relevance, linked to the importance of high quality habitats for a range of species, and which could be modelled is that of land abandonment. This process has already had a detrimental effect on butterflies, less so for large mammals and it could be valuable to assess its impact for other groups.

Finally, the role of taxa such as butterflies as indicators of the health of habitats and ecosystems within the Natura 2000 network might also be explored further as their sensitivity to both biotic and abiotic change could tell us much about species, in particular the huge array of other invertebrates, some with similar associations to habitats.

5.7 Concluding Remarks

The results confirm that Natura 2000 sites provide important additional value for a range of biodiversity, and among the taxonomic groups tested the butterflies and birds appear to benefit the most. The study also confirms that Natura 2000 sites are fulfilling their primary purpose of protecting the species in Annex I of the Birds Directive and Annex II of the Habitats Directive.

It is also clear that the majority of species rich habitats in Europe are already in Natura 2000 sites. This emphasises the importance of policy and financial instruments and the associated management measures which are used to continue to maintain and restore habitats in Natura 2000 sites to a condition that is favourable for all of their associated species. The exceptions to this include habitats in the Boreal region and some areas of traditionally managed agricultural land in Eastern and Southern Europe. Whilst this conclusion should be further investigated, the results of this study suggest that more forest and traditional agricultural land should be included within Natura 2000 or, at least, should be considered for sympathetic management.

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Appendix 1 Glossary of terms

BD	Birds Directive
BTO	British Trust for Ornithology
CBD	Convention on Biological Diversity
CLC	Corine Land Cover
CLC3	Corine Land Cover Level 3
CORINE	Coordinate Information on the Environment
distribution	the range of a species with confirmed presence
DG-Envi	Directorate General Environment of the European Union
EEA	European Environmental Agency
ESA	European Space Agency
EU	European Union
EU-28	The EU-countries as of 2015, which includes Croatia etc.
gap-analysis	an assessment of the extent to which a protected area system meets protection goals set by a nation or region to represent its biological diversity (CBD)
gap species	species that are threatened but poorly protected under Natura 2000
Geographical range	(Natural) distribution range of a species, where it may occur
GIS	Geographical Information System
GLC	Global Land Cover
HD	Habitats Directive
IEA	Institute for Applied Ecology
ITC	Internationaal Training Centrum, nowadays Faculty of Geo-Information Science and Earth Observation of University Twente
range	see Geographical range
SAC	Special Area of Conservation
SCI	Site of Community Importance
Sovon	Samenwerkende Organisaties Vogelonderzoek Nederland
SPA	Special Protection Area

Appendix 2 Detailed method description

Mammals

Overall we considered 169 species of mammals following the European Red List of Mammals and excluding invasive and domestic species. Of these, 36 were listed under Annex II of Habitat directive and 18 were considered threatened (VU=12; EN=4; CR=2) and 6 Data Deficient according to the IUCN Red List. Mammal species have a mean coverage of 23.1±11.1% (mean±SD).

For mammals we collected 981,844 occurrence points for 131 European mammal species with a precision higher than 5km and not older than 1990, and stored them as a comprehensive dataset. The data points were collected from Observado (Observation.org; http://observation.org) and GBIF databases (www.gbif.org/), and CKmap project (http://www.faunaitalia.it/ckmap/). Additional data were available from the GMA personal database (http://globalmammal.org). These data were used as the basis for the validation of the expert-based distribution models and for developing statistical models of species distribution.

Data collection
For conducting the coarse 50x50 km analysis we collected range maps and habitat suitability models for European mammal species occurring in EU-28, excluding those recently introduced, for a total of 177 species. For mammals we used range maps, as the only European atlas available for mammals is outdated (Mitchell-Jones *et al.* 1999). Additionally, atlases are known to be very inaccurate proxy of the distribution of cryptic animals such as mammals, for which absence can be largely over-estimated, especially when atlases are realized on opportunistic data collection (Rondinini *et al.* 2006). Range maps were downloaded from (IUCN 2013) whereas habitat suitability models were obtained from Rondinini *et al.* (2011). Habitat suitability models were developed at 300-m resolution based on species preferences for land cover, elevation, dependence on water and tolerance to human presence. These models classify all habitat within a species range in three suitability levels: high (i.e. primary habitat of a species), medium (i.e. secondary habitat where a species can be found, but not persist in the absence of primary habitat) or low suitability (i.e. where species are expected to be only occasionally found). The estimated suitable habitat from these models covers on average ca. 50% of the geographical range. Since these models might suffer from commission error (false presences), for the analyses on spatial overlap we considered high suitability as presence, and medium and low suitability as absences.

Then we collected 981,844 occurrence points for 131 European mammal species with a precision higher than 5km and not older than 1990, and stored them as a comprehensive dataset. The data points were collected from Observado (Observation.org; http://observation.org) and GBIF databases (www.gbif.org/), and CKmap project (http://www.faunaitalia.it/ckmap/). Additional data were available from the GMA personal database (http://globalmammal.org). These data were used as the basis for the comparison of the expert-based distribution models and for developing statistical models of species distribution.

Coarse analysis (50x50 km analysis)
We performed a coarse analysis on a 50x50 km grid basis, using range maps filtered by habitat suitability models. For each species we assessed the amount of suitable habitat covered by Natura 2000. We calculated the proportion of coverage both within the whole EU-28 territory, and within each individual EU-28 country. This analysis, although coarse, allowed to assess Natura 2000 for all European wild mammal species (177 species).

We validated the distribution models based on range maps and habitat suitability models using the point of presence data. We performed the validation by sampling for 100 times 1000 random points in the study area, and obtaining at each iteration a proportion of correctly predicted presences. Then we performed a significance test, whether the percentage of correct classification with real data fell in the upper 2.5% of the distribution. The distribution models of 98 species out of 113 (~87%; all species for which occurrence data were available) performed significantly better than random. Only 4 species performed worse than random.

Species distribution models (5x5 km analysis)
For mammals the 5x5 km species modelling is done. The 50x50 km maps were simply masked using CLC or habitat models and used for the gap analysis.

Four species were excluded because having < 30 data points, which was considered insufficient to build reliable large scale distribution models (Boitani *et al.* 2011). As predictors of species presence we used climatic variables from BioClim (Temperature seasonality, Minimum Temperatures of the coldest month, Mean Temperature of the driest quarter, Annual precipitation, Precipitation seasonality, Potential evapotraspiration), Distance to water, hyper-temporal NDVI classification, and the proportion of available habitat calculated as the proportion of high suitable habitat in the expert-based models (Rondinini *et al.* 2011) in each 5km cell. Climatic variables important for mammals were chosen on the basis of previous publications on species distribution models for mammals in Europe (Levinsky *et al.* 2007; Maiorano *et al.* 2011).

We performed presence-only data modelling using Generalized Boosted Trees and by sampling 10.000 background points for a total of 10 replicates, using biomod2 package in R (Thuiller *et al.* 2009). Because species presence data are collected on an opportunistic basis and spatial bias might affect the prediction, we applied a spatial bias correction technique that consists of weighing presence points proportionally to their density in each 100km grid cell (in other words, we over-weighted points in under-sampled areas and under-weighted points and highly sampled areas). This allowed for a reduction of the error by predicting a high probability of presence where many presence data are available, and predicting low probability of presence where presence data are unavailable (but the species could be present). Predicted maps of probability of occurrence were binarized in presence-absence maps by setting a probability baseline that equally weighted specificity and sensitivity values (rate of correctly predicted presences and rate of correctly predicted absences, respectively). In other words, we obtained a presence/absence map where presences had the same error rate than absences.

We used these binary prediction maps for assessing the spatial overlap of species distribution with Natura 2000 network (as previously done for the coarse analysis) both in the EU-28 territory and within each individual country, and for development of species' conservation curves. Species conservation curves summarize how many species do benefit from Natura 2000 at increasing target thresholds.

Species persistence in Natura 2000
Because the mere presence within Natura 2000 network does not necessarily translate into higher probability of species persistence, we also assessed population persistence within Natura 2000. In fact, a species range may be largely covered by protected areas, but the proportion of distribution covered may still be insufficient for species persistence because fragmented small patches are still insufficient to sustain viable populations (Bolck *et al.* 2004; Van der Sluis *et al.* 2004). This is especially relevant for large endothermic species that have a low population density, such as large mammals (Groot Bruinderink *et al.* 2003; Santini *et al.* 2014). In order to assess which mammal species benefit from Natura 2000 in terms of increase of population persistence, we followed the analytical framework presented in (Santini *et al.* 2014). First, for all European mammal species we estimated the median dispersal distance and the average population density using the allometric relationships as described in Santini *et al.* (2013) and Silva *et al.* (1997) respectively. Then we modified the habitat suitability models from Rondinini *et al.* (2011) to develop new distribution maps that represent clusters of habitat patches potentially able to support viable populations within the protected area network. In these models, patches of suitable habitat were removed when smaller than the minimum patch size (MPS) of the species. We defined the MPS here as the minimum area required to sustain 10 individuals according to the species average population density, which accounts for the probability of a reproductive event at least. Patches of suitable habitat larger than the MPS were assumed to be able to allow reproduction and thus species dispersal. All patches of protected suitable

habitat larger than the MPS and within dispersal distance were assumed to be part of the same cluster of patches of the network. Finally, all clusters that were estimated to (potentially) support populations smaller than a minimum viable population (based on species average population density), were removed. As there is no consensus on the minimum population size necessary to ensure, we then quantified the number of species that could be considered protected by Natura 2000 for at least one viable population at increasing viability targets, from 100 to 2000 individuals.

Validation
We validated the distribution models based on range maps and habitat suitability models using the point of presence data. We performed the validation by sampling for 100 times 1000 random points in the study area, and obtaining at each iteration a proportion of correctly predicted presences. Then we tested if the percentage of correct classification with real data fell in the upper 2.5% of the distribution (significance test). The distribution models of 98 species out of 113 (~87%; all species for which occurrence data were available) performed significantly better than random. Only 4 species resulted to perform worse than random.

Birds

The question 'What proportion of the species' distribution is inside Natura 2000 areas' for the bird species in the EU-28 ideally should be answered based on real data –based fine grained EU-wide maps of species occurrence in- and outside Natura 2000. However this data is not available. So we had to search for alternative, feasible approaches to assess the importance of Natura 2000 areas for breeding bird species, given the available breeding bird distribution data.

For birds the basic distribution data of 402 EU-breeding bird species from the European Breeding Bird Atlas (Hagemeijer and Blair 1997) were used. The Atlas covers the Pan-European distribution of all breeding bird species at 50×50 km scale. However, Cyprus and the Canary Islands, both EU-territory were not included in the Atlas. The distribution maps are based on field observations carried out during 1970–1993.

Although the Atlas-distributions were not based on one standardized method and there were differences in the quality of field ornithology and the relative number of observers between countries, the quality of the data in particular when expressed as presences and absences at a coarse 50×50 km scale is considered high. The distribution covers the period 1970–1993, before Natura 2000 sites were designated. However, presence/absence data at 50×50 km scale are not considered sensitive to large changes in distribution, apart from a small number of species that underwent considerable ranges changes recently.

We decided to work out: an approach using real but coarse pan-EU distribution data of breeding birds, approaches using two types of modelled, but more detailed distribution maps of EU-breeding birds and an approach using real data-based fine-grained distributions from a set of countries. These approaches (their basic data, modelling and data-quality) are described in more detail in the following three sections.

50×50 km Atlas breeding bird distribution and habitat masking
The basic distribution data of 402 EU-breeding bird species from the European Breeding Bird Atlas (Hagemeijer and Blair 1997) were used. The Atlas covers the Pan-European distribution of all breeding bird species at 50×50 km scale. However, Cyprus and the Canary Islands, both EU-territory were not included in the Atlas. The distribution maps are based on field observations carried out during 1970–1993.

As Annex 1 of the Bird Directive includes some sub-species, not distinguished in the Atlas (n=9) the distribution of these subspecies were selected ad hoc, based on knowledge of their geographical distribution (Sargatal *et al.* 1992) and added to the data set, resulting in distribution maps of 411 taxa.

Although the Atlas-distributions were not based on one standardized method and there were differences in the quality of field ornithology and the relative number of observers between countries, the quality of the data in particular when expressed as presences and absences at a coarse 50×50 km scale is considered high. The distribution covers the period 1970–1993, before Natura 2000 sites were designated. However, presence/absence data at 50×50 km scale are not considered sensitive to large changes in distribution. Five species that are known to have undergone considerable distribution changes were excluded from the analysis.

Habitat masking
Habitat masking was carried out to estimate the fine-scale spatial distribution of available breeding bird habitat within each 50×50 km cell occupied by a species. Species-specific habitat masks were made by assigning breeding birds to Corine Land Cover habitats. A spatial Corine Land Cover map (@ version) is available for most EU-territory with the exception of The Azores and Madeira.

Assigning breeding birds to Corine land cover types was carried out as follows. An existing database containing EUNIS-habitats of European breeding birds (Van Kleunen 2003) was linked to the CORINE land cover types, using the CORINE-EUNIS habitats crosswalk (European Environmental Agency 2013) and some ad hoc linking (pm insert habitat allocations per species as annex). Next an overlay was made between the species' 50×50 km distribution maps and the Corine Land Cover types, resulting in maps showing apparently suitable Corine Land Cover types within the species known range for the EU. These masked distribution maps were validated by experts.

This validation revealed some limitations of the Corine Land Cover map. In general the land cover types distinguished in Corine do not adequately differentiate among habitat types occupied and unoccupied by breeding birds. Furthermore the Corine map seems incomplete/too coarse: in particular small land cover features are absent/underrepresented in the land cover data sets, for instance: streams, small rivers, small lakes, fens and open areas in forests.

Habitat masked maps that were obviously incomplete/incorrect were excluded from further analysis; for the breeding birds 44 species (which are searchable in the data tables associated with the project technical report) were therefore excluded due to the unsuitability of the CLC information and 7 additional island endemic species were simply not covered by CLC.

Calculating area occupied area in- and outside Natura 2000
Finally an overlay was made between the patches of Corine Land Cover types thought to be occupied by a species and the boundaries of Natura 2000 areas (shapefile Natura2000_end2013_rev1, downloaded 16-2-2015 from EEA website), so that the area of habitat in- and outside Natura 2000 in 50 × 50 km where the species was present could be calculated. This was done for 355 taxa, including 145 Annex I taxa.

Modelled 5×5 km breeding bird distribution

Breeding bird distribution maps
For the Bioscore project (Sierdsema 2014) more detailed, 5×5 km distribution maps covering the Pan European distribution of a selection of breeding birds species were compiled. Two models were made based on partly different sources:

1. Based on the 50×50 km distribution data from the European Breeding bird atlas. These were downscaled to 5×5 km cells using spatial regression modelling techniques. Co-variates in the models were: soil and climate data, forest management, nitrogen and sulphur deposition and the Corine Land cover types (2010). This resulted in distribution maps of 274 species (pm list in annex). 36 species were excluded from further analysis because their habitat is poorly covered in the Corine landcover map or the Atlas distribution is outdated (see section 2.4.1).
2. Based on bird observations submitted to the web portals: e-bird (www.ebird.org), GBIF (http://www.gbif.org), Observado & Waarneming.nl (www.observado.org). and Bulgarian bird counts (pc.trektellen.nl) and EU Bird Directive reporting 2008–2012 10×10 km distribution maps (www.eea.eu). Spatial regression models were built to compile distribution maps based on these data and co-variates in the models were soil and climate data, forest management, nitrogen deposition and the Corine Land cover types.

Spatial modelling

For the regression modelling we considered both Maxent and Boosted Regression Trees (BRT), a version of Generalized Boosting Models (GBMs). Both MaxEnt and BRT are machine-learning techniques, able to handle nonlinear relationships and to take into account synergistic effects between the different factors affecting a species' distribution (Couce *et al.* 2013). MaxEnt (Elith *et al.* 2011; Phillips *et al.* 2006) is widely used in ecological studies, including the prediction of climate change impacts on a species or ecosystem's potential distribution. To date, BRT is used less widely, despite having comparable predictive capabilities (Anderson *et al.* 2006; Elith *et al.* 2008). Although Maxent has some possibilities to include absence data, BRTs are better equipped to deal with presence-absence data sets. We tested this also for the dataset of a plant species, where the predictions resulting from the BRT showed a wider range in predictions, and performed better in areas where the species was expected to be absent. For the modelling we used a suite of R-scripts, called TRIMmaps. TRIMmaps is also available as an R-package (Hallmann *et al.* 2014). TRIMmaps can be used for the spatial modelling of presence-only, presence-absence and count data and features a wide range of regression techniques amongst which GLM, GAM, MARS, BRT and Random Forest. Within TRIMmaps, Maxent can be used to generate pseudo-absences on locations with a low habitat suitability.

In order to be used within the EU-BD-project predicted probabilities of occurrence had to be transformed to predicted presences and absences. There is wide range of methods available to transform probabilities into presence-absence maps. See http://www.cawcr.gov.au/projects/verification/#Methods_for_dichotomous_forecasts for an overview. Here we used Hanssen and Kuipers discriminant (true skill statistic, Peirce's skill score):

$$HK = \frac{hits}{hits + misses} - \frac{\text{false alarms}}{false\ alarms + correct\ negatives}$$

A cut off was chosen, so that the proportion of correctly predicted occurrences (sensitivity) is comparable to the proportion of correctly predicted absences (specificity). We adapted the R-code that is used in BIOMOD (Thuiller *et al.* 2009) to calculate the cut off-value.

The proportion of type 1-errors and type-2 errors governs the sensitivity and specificity of the predictions. A proportion higher than 1 focusses more on correctly predicted occurrences, while a proportion smaller than 1 focusses more on correctly predicted absences.

Calculating area occupied area in- and outside Natura 2000

The 5×5 km cells where a species is present according to the model-predictions were assigned to in-/outside Natura 2000 proportional to the ratio cell area in-/outside Natura 2000.

Fine scaled national breeding bird distribution

Several European countries have undertaken recent detailed distribution atlas projects which provide observed distribution data at relatively fine scale (e.g. 5×5 km or 10×10 km). Data from these atlases offer an opportunity to ground-truth estimates of species coverage by the Natura 2000 network. We contacted a number of countries throughout Europe with a view to ensuring biogeographic coverage. Ultimately we were able to source data for seven countries. These are biased towards northwest Europe, plus one Mediterranean country, one Fenno-scandinavian country, and one eastern European country. This coverage should be considered when interpreting results. The type and resolution of data provided by counties varied, and is summarised below:

Table A-1
Selected countries for detailed analysis of bird distribution, with indication of data type and resolution of data.

Country	Coverage	Type	Grid resolution	Number of species
Bulgaria	Nationwide	Distribution	10×10 km	264
Belgium	Wallonia	Distribution	5×8 km	176
		Distribution	1×1 km	161
		Abundance	1×1 km	161
France	Nationwide	Distribution	10×10 km	318
Finland	Nationwide	Distribution	10×10 km	290
Netherlands	Nationwide	Abundance	1×1 km	149
Spain	Nationwide	Distribution	10×10 km	312
United Kingdom	Nationwide	Distribution	10×10 km	292
		Abundance	10×10 km	243

For each country, the grid on which the data were collected was intersected with the Natura 2000 network to determine the proportion of each grid cell protected. Next, for each dataset and taking each species in turn, we calculated an area weighted sum of the data across protected and unprotected parts of grid squares. For example, if 18% of the area of an occupied grid cell was protected, a value of 0.18 contributed towards the protected total, and a value of 0.82 towards the unprotected total. Such values, when summed across squares, can be used to give an estimate of the proportion of the range overlapping the protected area network. This is a conservative approach in that it assumes species are distributed uniformly within squares with respect to protected area boundaries.
Having derived estimates of protection status for each species in each country, we summarise these as a series of box plots to indicate the range of protection statuses. These are useful for direct comparison with equivalent plots produced using other methods. For a formal comparison of methods we plot the percentage of each species' range protected according to observed data against estimates of protection status derived from: a) habitat masking of 50×50 km EBCC atlas data, b) downscaled predictions of models of 50×50 km EBCC atlas data (model probabilities and dichotomised presence/absence predictions) and c) predictions of models of recent casual records (model probabilities and dichotomised presence/absence predictions). For each comparison we calculate a number of statistics:

1. The correlation coefficient between observed and estimated protection status values for species known to be present for which model predictions were available.
2. The number of species present in the country for which no model predictions were available (for example because the model failed to predict occupancy in the country)
3. The number of species absent from a country but where models predicted occupancy
4. Using each country's baseline percentage of land designated to assign species as protected or not protected according to observed and estimated values, we produced a confusion matrix from which we calculated:
   a. Accuracy = how often is the method correct (sum of true positives and true negatives as proportion of total number of species)
   b. Sensitivity (True Positive Rate) = the proportion of species truly protected that models indicated were protected
   c. Specificity = the proportion of species truly not protected that models indicated were not protected

Reptiles and Amphibians

The basic data used for the Amphibians and Reptiles was the data published by Sillero *et al.* (2014). For the modelling a standardized set of layers for Europe at a resolution of 1 km by 1 km was used (Table A-2).

Table A-2
variables used in the distribution modelling.

Variable description	Spatial resolution	Units	Source
Topographic variables			
Altitude	1 km by 1 km	Meters above sea level	
Northness	1 km by 1 km	(-)	Derived from Altitude
Eastness	1 km by 1 km	(-)	Derived from Altitude
Slope	1 km by 1 km	Degrees (°)	Derived from Altitude
Aspect	1 km by 1 km	Degrees (°)	Derived from Altitude
Incoming solar radiation			
Climatic variables			
Temperature sum			
Annual Precipitation (BIO12)	1 km by 1 km		Worldclim.org
Precipitation of Warmest Quarter (BIO18)	1 km by 1 km		Worldclim.org
Isothermality (BIO3)	1 km by 1 km		Worldclim.org
Temperature Seasonality (BIO4)	1 km by 1 km		Worldclim.org
Max Temperature of Warmest Month (BIO5)	1 km by 1 km		Worldclim.org
Min Temperature of Coldest Month (BIO6)	1 km by 1 km		Worldclim.org
Mean Temperature of Wettest Quarter (BIO8)	1 km by 1 km		Worldclim.org
Mean Temperature of Driest Quarter (BIO9)	1 km by 1 km		Worldclim.org
Precipitation of Wettest Month (BIO13)	1 km by 1 km		Worldclim.org
Precipitation of Driest Month (BIO14)	1 km by 1 km		Worldclim.org
Precipitation Seasonality (Coefficient of Variation: BIO15)	1 km by 1 km		Worldclim.org
Precipitation of Coldest Quarter (BIO19)	1 km by 1 km		Worldclim.org
Annual mean moisture index (BIO28)	10' by 10'		Kriticos *et al.* 2012
Evapotranspiration			MODIS Global Evapotranspiration Project
Potential evapotranspiration			MODIS Global Evapotranspiration Project
Actual over potential evaporation (APET)			Derived from Evapotranspiration and potential evapotranspiration
Landcover			
Corine Land cover	100 m by 100 m		
Percentage suitable habitat			Derived from Corine
Percentage prime habitat			Derived from Corine
Distance to water			
NDVI temporary profiles	1 km by 1 km	(-)	Spot vegetation
Edaphic			
Soil clay content			
Soil organic matter content			
Soil silt content			
Soil sand content			
Soil ph			
Soil salt			

The extent that was used for the modelling is displayed in Figure A-1, which covers the mainland territories of the EU-28 and bordering and enclosed countries.

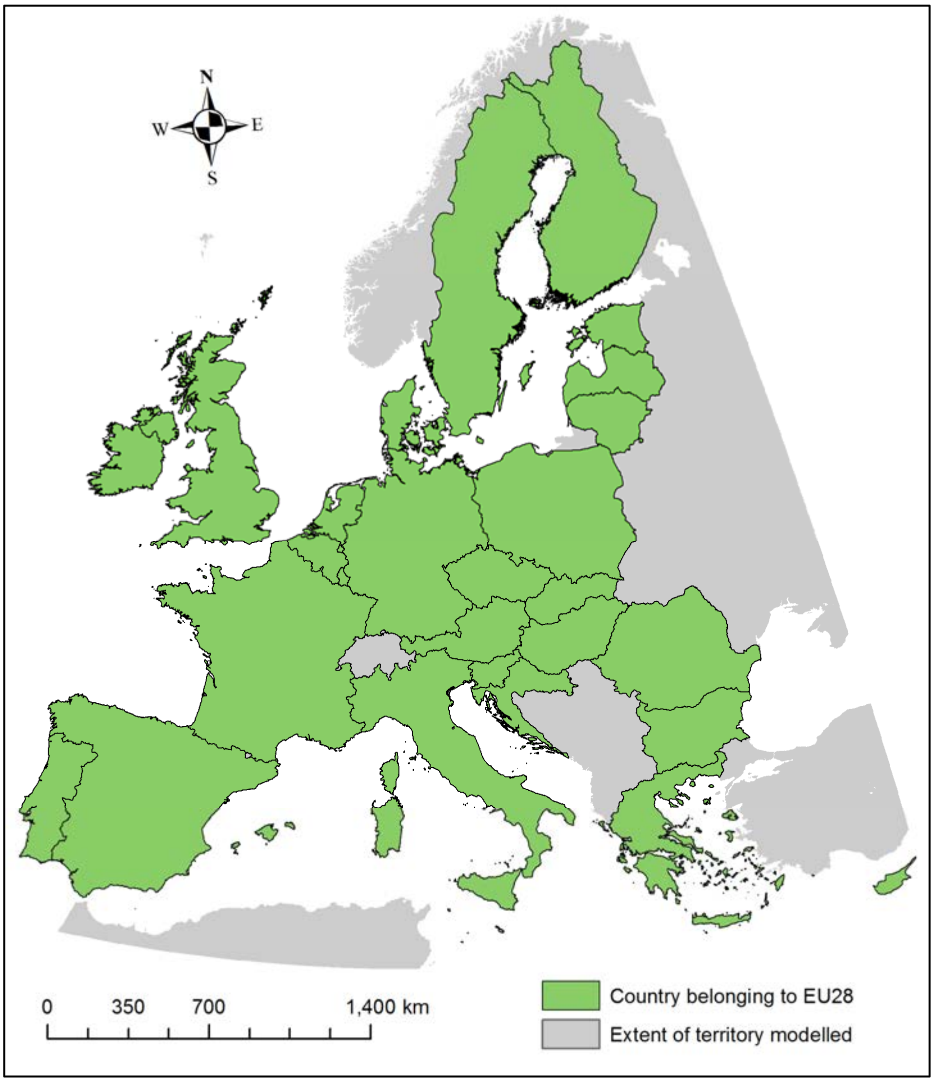

Figure A-1 *Overview of extent that was used for modelling at 5km by 5 km resolution, based on the 50x50 km presence absence data of the SHE.*

Distribution models at a 5km by 5 km resolution were produced for 153 species out of the 165 species that occur within the EU-28. For 36 endemic and rare species there were not enough records in the SHE database to produce reliable models at the Extent of Europe. All these species occurred in southern European countries (Fig. A-3). For 19 of these species, they still could be modelled at a resolution of 5km by 5 km at the extent of Europe by using country specific data.

On top of that for the following countries the distribution of species was modelled at a 1km by 1 km resolution: Austria, Belgium, Bulgaria, Germany, Great Britain, Greece, Ireland, Italy, the Netherlands, Poland, Portugal and Spain (Fig. A-2; Table A-3).

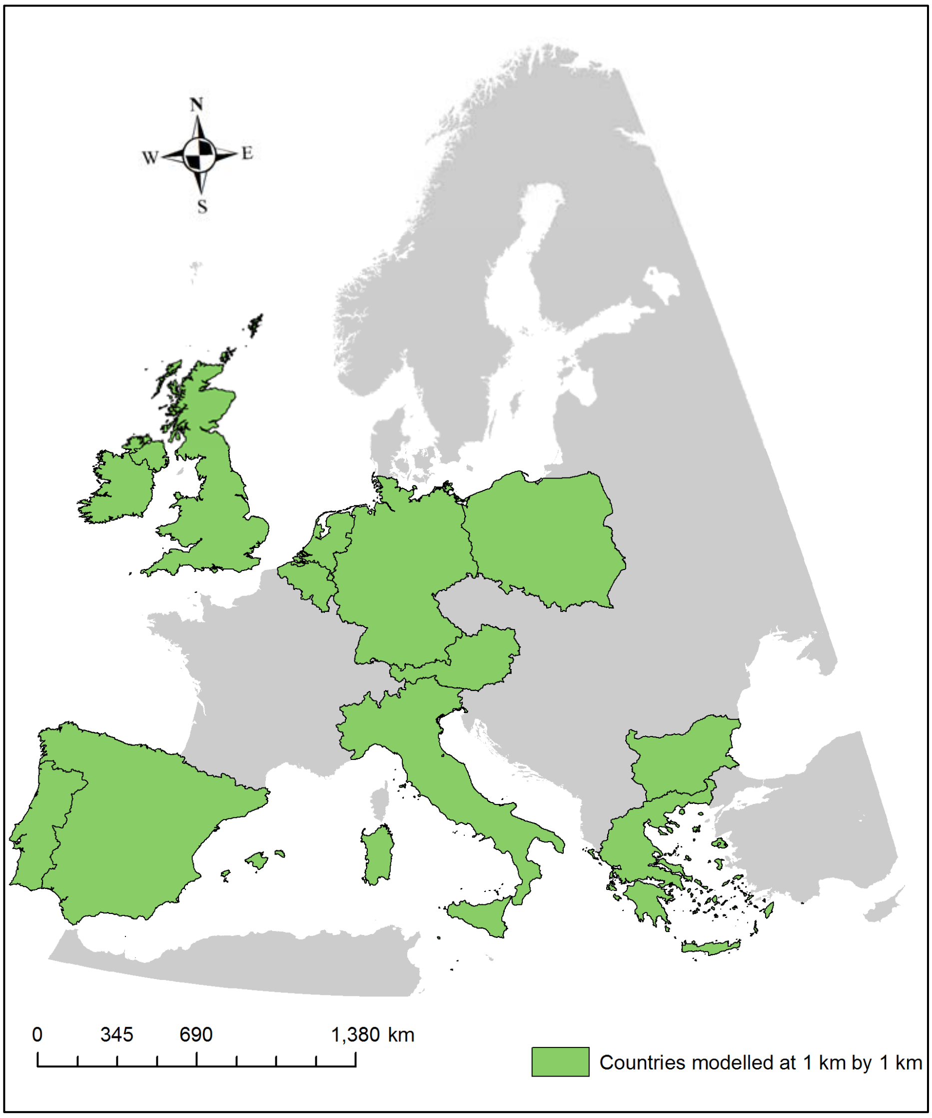

Figure A-2 *Countries that were modelled at 1km by 1km resolution based on country specific presence and absence data (see Table A-3).*

Table A-3

Data source herpetofauna and specifications for the countries that were modelled at 1km by 1km resolution.

	Format - Resolution	Nr. Of points available for analysis	Source
Austria	Vector Grid - aprox. 5x5 km (large grid in 15x15 min.ggr: subdivided in 5x3min.ggr)		Cabela *et al.* (2001)
Belgium	Vector Grid – 4x4 Km		Observatoire de la Faune (2004)
Bulgaria	Vector Grid (International standard (1/3-2/3)) - 10x10 Km		Naumov and Stanchev (2006)
Germany	Vector Grid - 11.5x11.5 km		Günther (1996)
Greece			National History Museum Crete (NHMC) (
Italy	Vector Grid (International standard (1/3-2/3)) - 10x10 Km		Sindaco *et al.* (2006)
Ireland			National Biodiversity Network Trust (
Netherlands			RAVON (
Poland	Vector Grid - aprox. 10x10 Km		Głowaciński and Rafiński (2003)
Portugal			Malkmus (2004)
Spain	Vector Grid (International standard (1/3-2/3)) - 10x10 Km		Pleguezuelos *et al.* (2004)
United Kingdom			National Biodiversity Network Trust (

Distribution modelling

Distribution models were fitted using Boosted regression trees, using the GBM and Biomod2 packages in R (Thuiller *et al.* 2009). For each species 10 models were fitted on different random subsets of data to get more robust models. Each subset was a random division op presence and absence locations to a training subset (80%) and a validation subset (20%). Reported distributions and accuracies are averages of these 10 randomized realisations of model fits. Accuracies of fitted models were assessed by looking at the True Skill Statistic (TSS, which is the same as HK; (Allouche *et al.* 2006)). TSS can only be calculated when a distribution map, giving probabilities of presence between 0 and 1, is converted into a binomial presence absence map, by setting a baseline. We used that baseline at which the HK was maximized.

Distribution models at a 5km by 5 km resolution were produced for 153 species out of the 165 species that occur within the EU-28. For 36 endemic and rare species there were not enough records in the SHE data base to produce reliable models at the Extent of Europe. All these species occurred in southern European countries (Fig. A-3). For 19 of these species, they still could be modelled at a resolution of 5km by 5 km at the extent of Europe by using country specific data.

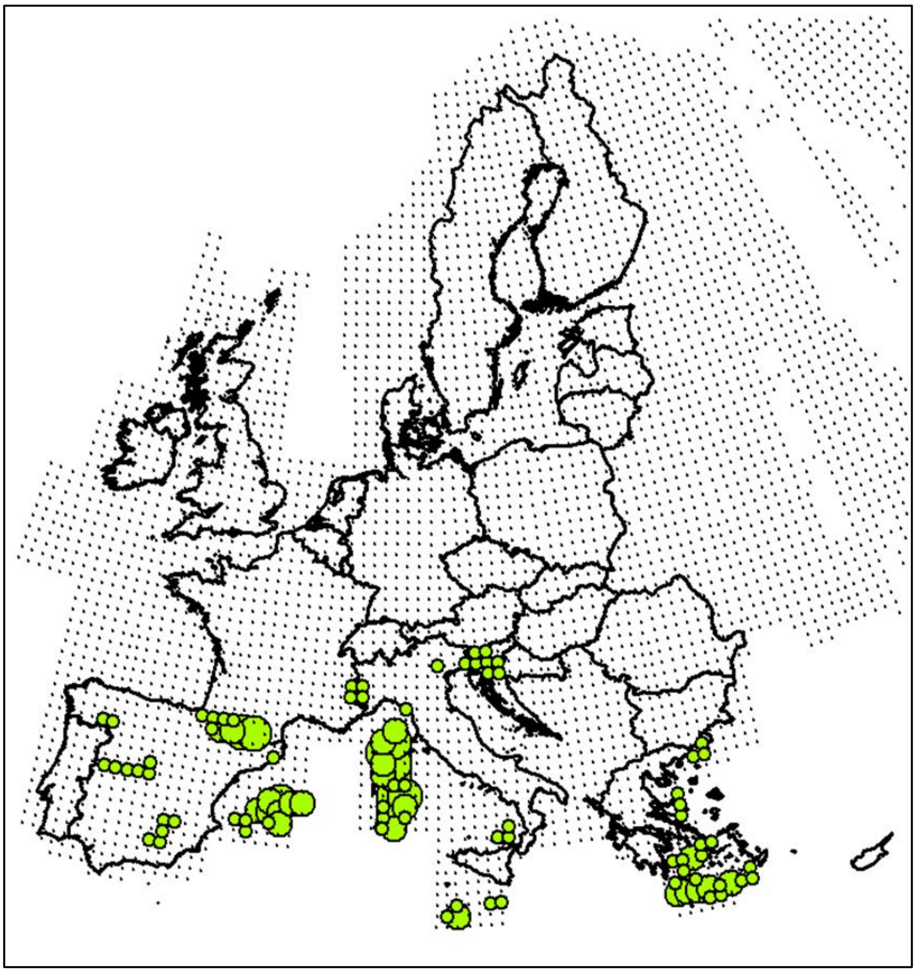

Figure A-3 *Bubble map showing locations of species that had too restricted ranges to be modelled at 5x5 km when only using the SHE map. This consisted of 39 species. For 19 of these species, 5x5 km modelling was still possible using country specific data. Bubble sizes indicate the number of species.*

Validation

The habitat masking approach was applied as basis for reporting, as explained in the methods section. This method was validated against two other, alternative, methods: modelling at the extent of Europe on a 5x5 km grid resolution, and for a selected number of countries modelling at the extent of 1km by 1km. Species that appeared to be notable outliers from these comparisons where identified and closer examined to check which analysis provided the most reliable results. We looked at two issues, firstly we identified gap species (i.e. with a NATURA 2000 coverage that were below the average coverage in Europe of 18%) with an Annex II status. We investigated if these lower values were correct. Secondly, we compared estimated coverage from the habitat masking with the estimated coverage from the 5x5 km mapping. Estimates that deviate more than 10% from the 1:2 line were subjected to further investigation to define which of the two methods was more accurate.

Butterflies

Butterfly distribution data is available from many European countries, however the gridsize, cover, time-period and data-collection period differ enormously (see e.g. Bos *et al.* 2006; Fox *et al.* 2011; García-Barros *et al.* 2004; Maes *et al.* 2013; Saarinen and Jantunen 2013; Verovnik *et al.* 2012). Furthermore some of the larger countries don’t have a complete overview of the distribution of species in their country (e.g. France and Italy), where others only have regional or state maps (e.g. Germany).

Europe-wide distribution maps are available from two European Distribution Atlases (Kudrna 2002; Kudrna *et al.* 2011), both on a scale of 1o by 0.5o. In the autumn of 2015 a new and updated version was published (Kudrna *et al.* 2015) as well as an online atlas LepiDiv (http://www.ufz.de/european-butterflies/index.php?en=22481) partly based on (Kudrna *et al.* 2011) but with more recent data added. These atlases cover the EU-28 countries well, though there are still gaps in some of the larger countries and they comprise a long period (from 1980 until now).

For this study the maps have been enriched by the more recent maps used for the European Red List of Butterflies (Van Swaay *et al.* 2010). These maps have been further improved based on national and regional atlases as far as available. The maps have been transformed into an ETRS grid of 50x50 km.

The database as used in this project contains 209253 records of the distribution of 464 species in the EU-28 on a scale of 50x50 km ETRS generally covering the period 1980-2010. As a result the completeness is high, with few areas missing (in the EU, outside the EU there are much large gaps, especially in Russia and other Eastern European countries).

For the butterfly data an important source of bias is in the transformation to the ETRS grid. Without the underlying much more precise data, such a transformation always has the risk of misplacing the occupied squares. This will be of relatively low relevance to common and widespread species, but for rare species with restricted distributions this can lead to more serious errors. For this reason an overlay has been made with the shapes of the distribution maps which have been produced for the European Red List of Butterflies and where necessary the maps have been corrected, with special attention to rare species.

To establish the importance of the designation of Natura 2000 areas for butterflies, we have calculated the percentage of the species' distribution inside Natura 2000 areas (both Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the Habitats Directive and Birds Directive) using two methods: (1) habitat masking and (2) by distribution modelling.

Habitat masking
In habitat masking a 'mask' is created of 100m squares which contain suitable habitat for a species. This mask is put on top of the distribution of each species, and the area with the right habitat in the 50 km ETRS squares of the distribution of a species can be calculated inside and outside Natura 2000 areas.

For the habitat mask the Corine Land Cover (CLC) map of 2012 is used (with the exception of Greece, for which the 2006 map is used). The CLC map is an inventory of land cover in 44 CLC3-classes available on http://www.eea.europa.eu/data-and-maps/data. An overview of the CLC3-classes is given in table…

Every butterfly species has been assigned to CLC classes. This was done on a transformation from the biotope preferences, one of the results of the Red Data Book of European Butterflies (Van Swaay and Warren 1999). For this Red Data Book information of the biotope preference (using Corine Biotopes: Moss and Wyatt 1991)) for each species was collected. This information was transferred to habitat profiles for all species by (Van Swaay *et al.* 2006). These habitat profiles have been converted to CLC types following Table A-4. Annex 1 gives the final allocation of all butterflies occurring in the EU-28 and the CLC3 classes. For the whole distribution in the EU-28 for each butterfly species occurs, the percentage inside Natura 2000 is calculated as:

100 * suitable habitat protected under Natura 2000 / overall suitable habitat

These calculation are made on different scales:
- At EU-28 level
- Per country
- Per biogeographical region/MAES

The value of Natura 2000 for a species is large if the species occurs in a relatively high percentage inside Natura 2000 areas and is relatively rare. In the final result table (data product, annex) this is indicated with the total area of suitable habitat of the species in the EU-28 countries.

Table A-4
Corine Land Cover classes. In this report CLC3 types are used for habitat-masking.

CLC1	CLC2	CLC3_name	CLC3
Artificial surfaces	urban fabric	continuous urban fabric	1
Artificial surfaces	urban fabric	discontinuous urban fabric	2
Artificial surfaces	industrial	industrial and commercial units	3
Artificial surfaces	industrial	road and rail networks and associated land	4
Artificial surfaces	industrial	port areas	5
Artificial surfaces	industrial	airports	6
Artificial surfaces	mines and dumps	mineral extraction sites	7
Artificial surfaces	mines and dumps	dump sites	8
Artificial surfaces	mines and dumps	construction sites	9
Artificial surfaces	green non-agricultural	green urban areas	10
Artificial surfaces	green non-agricultural	port and leisure facilities	11
Agricultural areas	arable land	non-irrigated arable land	12
Agricultural areas	arable land	permanently irrigated land	13
Agricultural areas	arable land	rice fields	14
Agricultural areas	permanent crops	vineyards	15
Agricultural areas	permanent crops	fruit trees and berry plantation	16
Agricultural areas	permanent crops	olive groves	17
Agricultural areas	pastures	pastures	18
Agricultural areas	heterogeneous agriculture	annual cops associated with permanent crops	19
Agricultural areas	heterogeneous agriculture	complex cultivation patterns	20
Agricultural areas	heterogeneous agriculture	land principally occupied by agriculture with significant Natural vegetation	21
Agricultural areas	heterogeneous agriculture	agro-forestry areas	22
Forests and semi-Natural	forest	broad-leaved forest	23
Forests and semi-Natural	forest	coniferous forest	24
Forests and semi-Natural	forest	mixed forest	25
Forests and semi-Natural	shrub	Natural grasslands	26
Forests and semi-Natural	shrub	moors and heath lands	27
Forests and semi-Natural	shrub	sclerophyllous vegetation	28
Forests and semi-Natural	shrub	transitional woodland-scrub	29
Forests and semi-Natural	open bare spaces	beaches, sand, dunes	30
Forests and semi-Natural	open bare spaces	bare rocks	31
Forests and semi-Natural	open bare spaces	sparsely vegetated areas	32
Forests and semi-Natural	open bare spaces	burnt areas	33
Forests and semi-Natural	open bare spaces	glaciers and perpetual snow	34
Wetlands	inland wetlands	inland marshes	35
Wetlands	inland wetlands	peat bogs	36
Wetlands	coastal wetlands	salt marshes	37
Wetlands	coastal wetlands	salines	38
Wetlands	coastal wetlands	intertidal flats	39
Water bodies	inland waters	water courses	40
Water bodies	inland waters	water bodies	41
Water bodies	marine waters	coastal lagoons	42
Water bodies	marine waters	estuaries	43
Water bodies	marine waters	sea and ocean	44

Table A-5

Butterflies listed on the Annexes II and IV of the Habitats Directive (http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:01992L0043-20070101&from=EN). Only species of Annex II qualify for the designation of Special Areas of Conservation (SACs) in the Natura 2000 network. Species of Annex IV are in need of strict protection.

Family	Species name	Annex 2	Annex 4
Papilionidae	Zerynthia polyxena		X
Papilionidae	Parnassius mnemosyne		X
Papilionidae	Parnassius apollo		X
Papilionidae	Papilio hospiton	X	X
Papilionidae	Papilio alexanor		X
Pieridae	Leptidea morsei	X	X
Pieridae	Colias myrmidone	X	X
Lycaenidae	Lycaena helle	X	X
Lycaenidae	Lycaena dispar	X	X
Lycaenidae	Pseudophilotes bavius	X	X
Lycaenidae	Phengaris arion		X
Lycaenidae	Phengaris teleius	X	X
Lycaenidae	Phengaris nausithous	X	X
Lycaenidae	Plebejus aquilo	X	
Lycaenidae	Polyommatus golgus	X	X
Nymphalidae	Argynnis elisa		X
Nymphalidae	Boloria improba	X	
Nymphalidae	Nymphalis vaualbum	X	X
Nymphalidae	Euphydryas maturna	X	X
Nymphalidae	Euphydryas aurinia	X	
Nymphalidae	Apatura metis		X
Nymphalidae	Lopinga achine		X
Nymphalidae	Coenonympha oedippus	X	X
Nymphalidae	Coenonympha hero		X
Nymphalidae	Erebia christi	X	X
Nymphalidae	Erebia sudetica		X
Nymphalidae	Erebia polaris	X	
Nymphalidae	Erebia calcaria	X	X
Nymphalidae	Melanargia arge	X	X

Table A-6

Conversion table from Corine biotopes (Moss and Wyatt 1991) as used in the Red Data Book of European Butterflies and Van Swaay et al. (2006a) to the Corine Land Cover (CLC3) types. Corine biotopes as well as CLC3 types without butterflies (e.g. aquatic) have been removed from the table.

	CLC																									
Corine Biotope (Moss and Wyatt 1991)	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
scrub and grassland													●					●	●	●	●					
inland rocks, screes and sands																						●	●	●		
agricultural land and artificial landscapes								●	●	●	●	●	●	●												
coastal sand-dunes and sand beaches																						●				
cliffs and rocky shores																							●			
islets and rock stacks																							●			
heath and scrub																			●							
sclerophyllous scrub																				●						
Phrygana																				●						
dry calcareous grasslands and steppes																		●						●		
dry siliceous grasslands																		●						●		
alpine and subalpine grasslands																		●						●		
humid grasslands and tall herb communities																		●							●	
mesophile grasslands																		●								
broad-leaved deciduous forests															●											
coniferous woodland																●										
mixed woodland																	●									
alluvial and very wet forests and brush															●						●					
broad-leaved evergreen woodland															●											
raised bogs																										●
blanket bogs																										●
water-fringe vegetation																									●	
fens, transition mires and springs																									●	
screes																							●	●		
inland cliffs and exposed rocks																							●			
inland sand-dunes																						●				
volcanic features																							●			
improved grasslands											●															
orchards, groves and tree plantations									●	●																
tree lines, hedges, small woods, bocage, parkland dehesa						●			●					●												
urban parks and large gardens						●	●																			
towns, villages, industrial sites	●	●	●	●	●																					
fallow land, waste places					●								●													

Models for validation

To test the quality of the results of habitat masking, models were generated using the 50x50 km data as input with the parameters listed in Table A-7.

For the modelling we used a suite of R-scripts, called TRIMmaps and also available as R-package (Hallmann *et al.* 2014). TRIMmaps can be used for both the spatial modelling of both presence-only, presence-absence and count data and features a wide range of regression techniques amongst which GLM, GAM, MARS, BRT and Random Forest. Within TRIMmaps, Maxent can be used to generate pseudo-absences on locations with low habitat suitability (Hallmann *et al.*, 2014).
Models were built using TRIMmaps 1.10.2 (Hallmann *et al.* 2014) under R version 3.0.3.

In order to be used the predicted probabilities of occurrence had to be transformed to predicted presences and absences. A cutoff was chosen, so that the proportion of correctly predicted occurrences (sensitivity) is comparable to the proportion of correctly predicted absences (specificity). The factor in this script was set to 1.0, which means that sensitivity and specificity get the same weight.

Table A-7
Parameters used as input for the production of 5x5 km models of the distribution of all European butterflies.

Variable description	Spatial resolution	Units	Source
Topographic variables			
Altitude	1 km by 1 km	Meters above sea level	
Northness	1 km by 1 km	(-)	Derived from Altitude
Eastness	1 km by 1 km	(-)	Derived from Altitude
Slope	1 km by 1 km	Degrees (°)	Derived from Altitude
Aspect	1 km by 1 km	Degrees (°)	Derived from Altitude
Incoming solar radiation			
Climatic variables			
Temperature sum			
Annual Precipitation (BIO12)	1 km by 1 km		Worldclim.org
Precipitation of Warmest Quarter (BIO18)	1 km by 1 km		Worldclim.org
Isothermality (BIO3)	1 km by 1 km		Worldclim.org
Temperature Seasonality (BIO4)	1 km by 1 km		Worldclim.org
Max Temperature of Warmest Month (BIO5)	1 km by 1 km		Worldclim.org
Min Temperature of Coldest Month (BIO6)	1 km by 1 km		Worldclim.org
Mean Temperature of Wettest Quarter (BIO8)	1 km by 1 km		Worldclim.org
Mean Temperature of Driest Quarter (BIO9)	1 km by 1 km		Worldclim.org
Precipitation of Wettest Month (BIO13)	1 km by 1 km		Worldclim.org
Precipitation of Driest Month (BIO14)	1 km by 1 km		Worldclim.org
Precipitation Seasonality (Coefficient of Variation: BIO15)	1 km by 1 km		Worldclim.org
Precipitation of Coldest Quarter (BIO19)	1 km by 1 km		Worldclim.org
Annual mean moisture index (BIO28)	10’ by 10’		Kriticos *et al.* 2012
Evapotranspiration			MODIS Global Evapotranspiration Project
Potential evapotranspiration			MODIS Global Evapotranspiration Project
Actual over potential evaporation (APET)			Derived from Evapotranspiration and potential evapotranspiration
Landcover			
Corine Land cover	100 m by 100 m		
Percentage suitable habitat			Derived from Corine
Percentage prime habitat			Derived from Corine
Distance to water			
NDVI temporary profiles	1 km by 1 km	(-)	Spot vegetation
Edaphic			
Soil clay content			
Soil organic matter content			
Soil silt content			
Soil sand content			
Soil ph			
Soil salt			

Plants

European Vegetation Archive

For assessing the (vascular) plant species (Annex II and and species of European and some national Red Lists) in relation to Natura 2000-sites, the optimal source would have been a comprehensive plant species distribution database for the whole of Europe, at a detailed level (e.g. 1x1 km). Such a database, however, is not available. In contrast to the other species groups (birds, mammals, reptiles) the distribution atlasses for plants, based on 50x50 km grid cells (http://www.luomus.fi/en/database-atlas-florae-europaeae), only covers about 20% of the European species. Moreover, of the 2,632 plant species currently covered by *Flora Europaeae*, limited information is available on the correlation with habitats (e.g. Corine Land Cover classes, Natura 2000 habitats, EUNIS habitat types).

Fortunately, the recent and rapid development of vegetation inventories throughout Europe, resulting in the European Vegetation Archive EVA (Chytrý *et al.* 2014), is recording such spatial information that could be of direct importance. EVA, an initiative of the European Vegetation Survey, is a centralised database of vegetation plots, storing copies of national and regional databases on a single software platform, using a unified taxonomic reference database. By September 2015, about 80 databases from all European regions, were brought together (www.euroveg.org/eva-database).

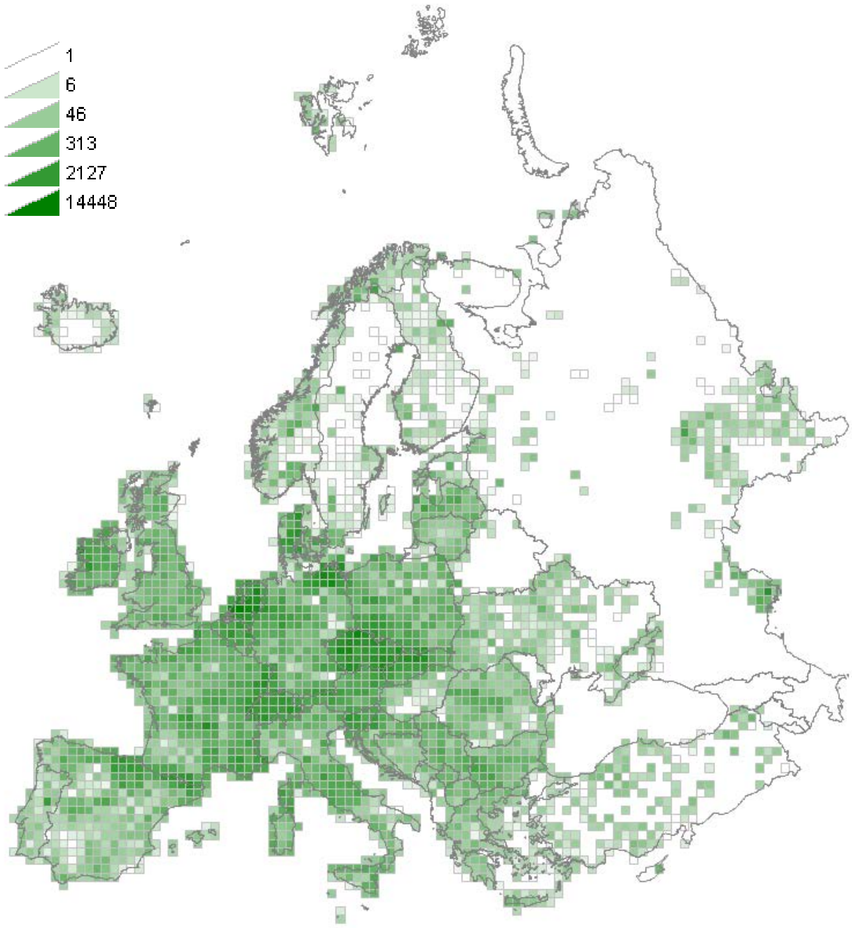

Figure A-4 *Spatial distribution of the vegetation plots available in the European Vegetation Archive (EVA). Colours indicate number of plots per 50x50 km grid cell.*

Through a couple of relatively simply analyses we have tried to find out what the importance is of the Natura 2000 network for biodiversity in Europe, using the vegetation data stored in EVA. The European Vegetation Archive currently contains 1,122,134 vegetation plots, comprising 25,069,904 species recordings. In total, more than 50,000 taxa are represented in the databases. Even though cryptogams are present in the database, we have restricted the assessment to vascular plants which are better represented in the database than cryptogams.

Alltogether 779,635 plots are georeferenced and located in EU-28 countries, representing 395,499 unique locations (Fig. A-4). These unique locations in EU-28 countries have been assigned to 107,730 unique 2x2 km grid[12] cells, of which 52,695 grid cells are located within Natura 2000 sites and 55,035 grid cells outside Natura 2000 sites. In Table 3-8 the number of unique grid cells is listed for Europe and the countries on which the analysis focused and for countries for which Red Lists for vascular plants are available. Within this procedure, a grid cell has been assigned to the Natura 2000 network whenever it intersects (at least partly overlaps) with a site.

Red Lists of vascular plants and diagnostic species

It may be clear that not all (approximately 25,000) European vascular plants can be assessed for the present study. We have therefore restricted the analyses to those plant species that are listed in European Red List of vascular plants of the IUCN, and a number of national Red Lists. Criteria for selecting national Red List species were the availability of national Red Lists of vascular plants in digital form, as well as the availability of sufficient well located plot data in the vegetation database at national levels.

Species indicated as 'Least Concern' (LC) were excluded from the analysis, as well as species from the Annex II list. The latter group has been excluded because these are species that have contributed to the designation of Natura 2000 sites.

In general the Red Lists contain few Annex II species, with the exception of the IUCN European Red List of vascular plants (Bilz *et al.* 2011). A complete overview of all the plant species included in the analysis can be found in the file HUB2000_plants.xlsx.

We further compiled a list of European orchid species on the basis of the European Vegetation Archive, and a list of species diagnostic for a number of Annex I habitat types. The latter is based on the project BioScore 2 (Hennekens *et al.* in prep.). The 40 Annex I habitat types that have been selected, are listed in Appendix 4 and represent habitats which are in most cases widely distributed in Europe. Orchid species are selected because they capture the interest of many people, but also because these species often occur in vulnerable habitats.

Finally we analysed the presence of species in a 500 m buffer zone surrounding the protected areas network. To this end, each grid cell was assigned as Natura 2000, buffer zone, or other cells. A grid cell assigned to the buffer zone always intersects (overlaps) with the buffer zone, and at the same time does NOT intersect with the Natura 2000 area. Therefore the 'buffer grids' are always located outside Natura 2000 sites. As such the actual buffer size is actually not 500 m, but has a max span of 2000 + 500 = 2500 m. Nevertheless, the plots assigned to the buffer area are all located in the vicinity of Natura 2000 sites and should represent the vegetation (species) in the buffer zone.

[12] The grid size of 2x2km has been chosen because of the uncertainty of the location precision of the plots. With a grid size of 1x1 km too many plots would have been excluded.

Appendix 3 Selection of Annex I habitat types

1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
2120	Shifting dunes along the shoreline with Ammophila arenaria ("white dunes")
2130	Fixed coastal dunes with herbaceous vegetation ("grey dunes")
2160	Dunes with Hippophaë rhamnoides
2210	Crucianellion maritimae fixed beach dunes
3110	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)
3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
4010	Northern Atlantic wet heaths with Erica tetralix
4030	European dry heaths
4060	Alpine and Boreal heaths
4070	Bushes with Pinus mugo and Rhododendron hirsutum (Mugo-Rhododendretum hirsuti)
5130	Juniperus communis formations on heaths or calcareous grasslands
5210	Arborescent matorral with Juniperus spp.
5420	Sarcopoterium spinosum phryganas
6110	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi
6120	Xeric sand calcareous grasslands
6150	Siliceous alpine and boreal grasslands
6170	Alpine and subalpine calcareous grasslands
6210	Semi-Natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
6220	Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea
6230	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)
6240	Sub-Pannonic steppic grasslands
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)
6520	Mountain hay meadows
7110	Active raised bogs
7130	Blanket bogs (* if active bog)
7150	Depressions on peat substrates of the Rhynchosporion
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae
7230	Alkaline fens
8210	Calcareous rocky slopes with chasmophytic vegetation
8220	Siliceous rocky slopes with chasmophytic vegetation
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli
9190	Old acidophilous oak woods with Quercus robur on sandy plains
91D0	Bog woodland
9410	Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)

Appendix 4 Supplementary figures for birds, a validation of downscaling methods

Validation plots showing the relationship between observed % of each species' range protected and that estimated by each downscaling or modelling method (Fig. 4-58 shows dichotomised presence-absence values). In each plot, red dots show species that were present but for which models failed to predict occurrence (dots along x-axis) or species absent but predicted to be present (dots along y-axis). The solid line shows the line of equality indicating perfect agreement. Dashed lines are at the national % of land designated; species to the right of the vertical line are truly protected accordingly to observed data, and those above the horizontal line are those predicted to be protected by the particular modelling method. The Accuracy, Sensitivity and Specificity statistics are derived from the number of species falling in the four quadrants defined by these dashed lines.

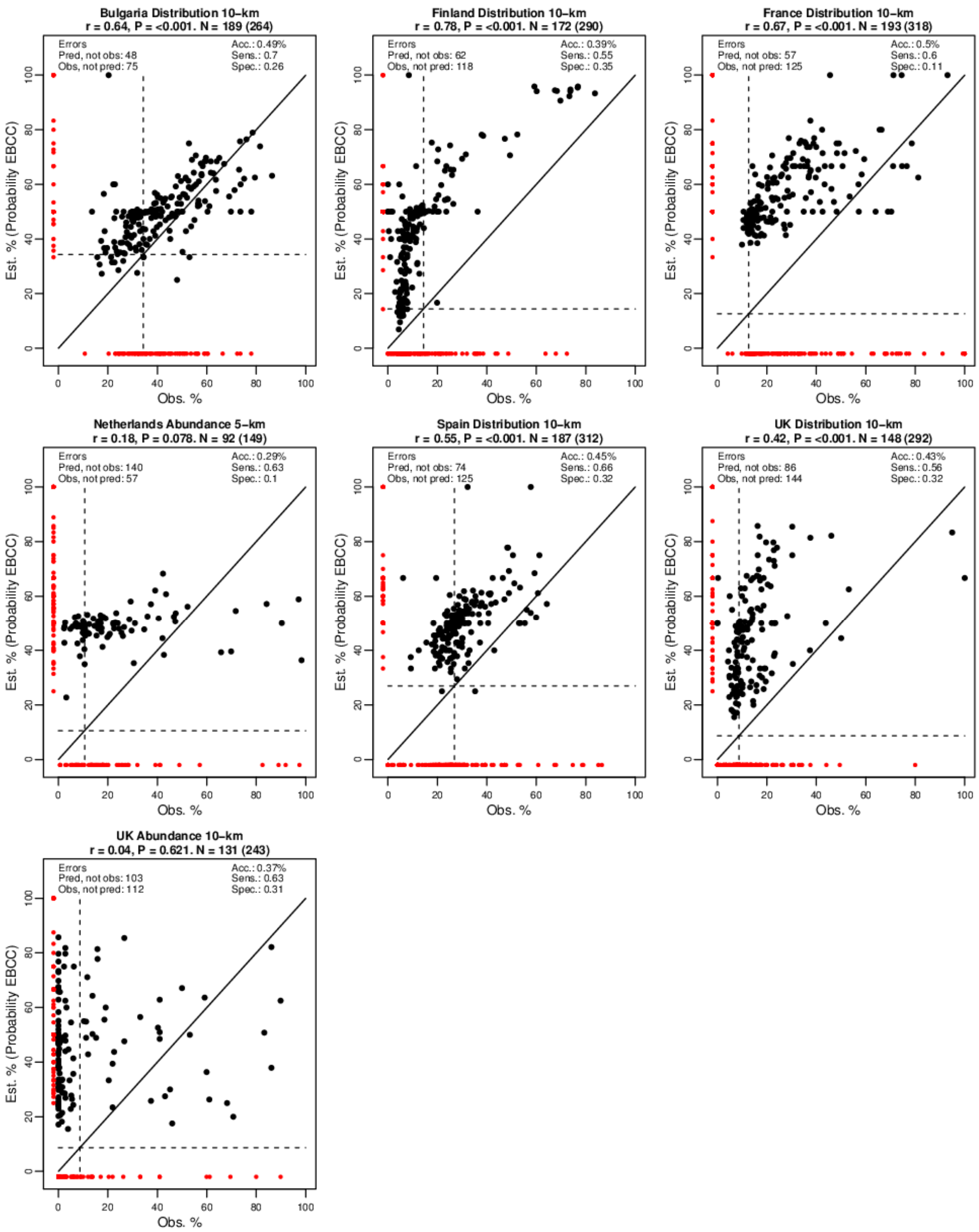

Figure A-5 *Validation results for EBCC data models (raw probabilities).*

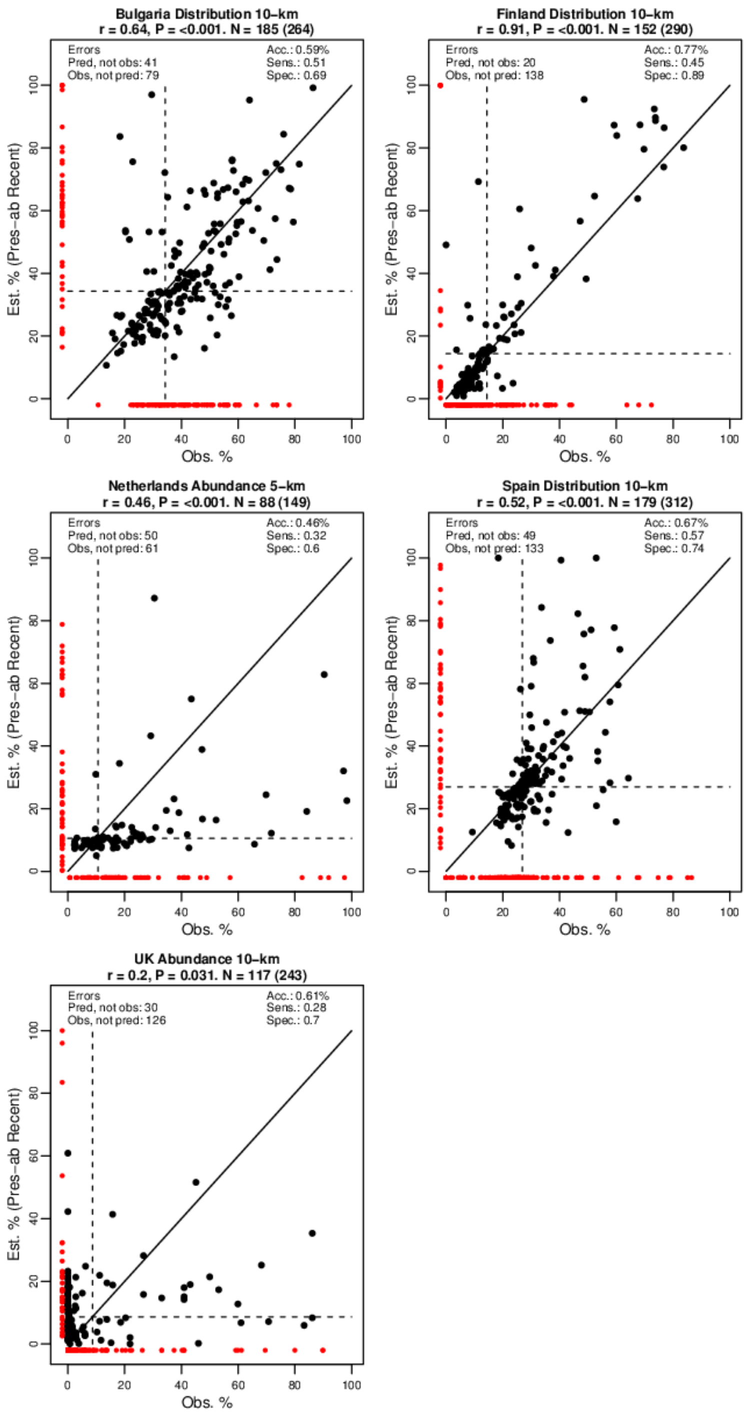

Figure A-6 *Validation results for Recent data models (dichotomised presence-absence values).*

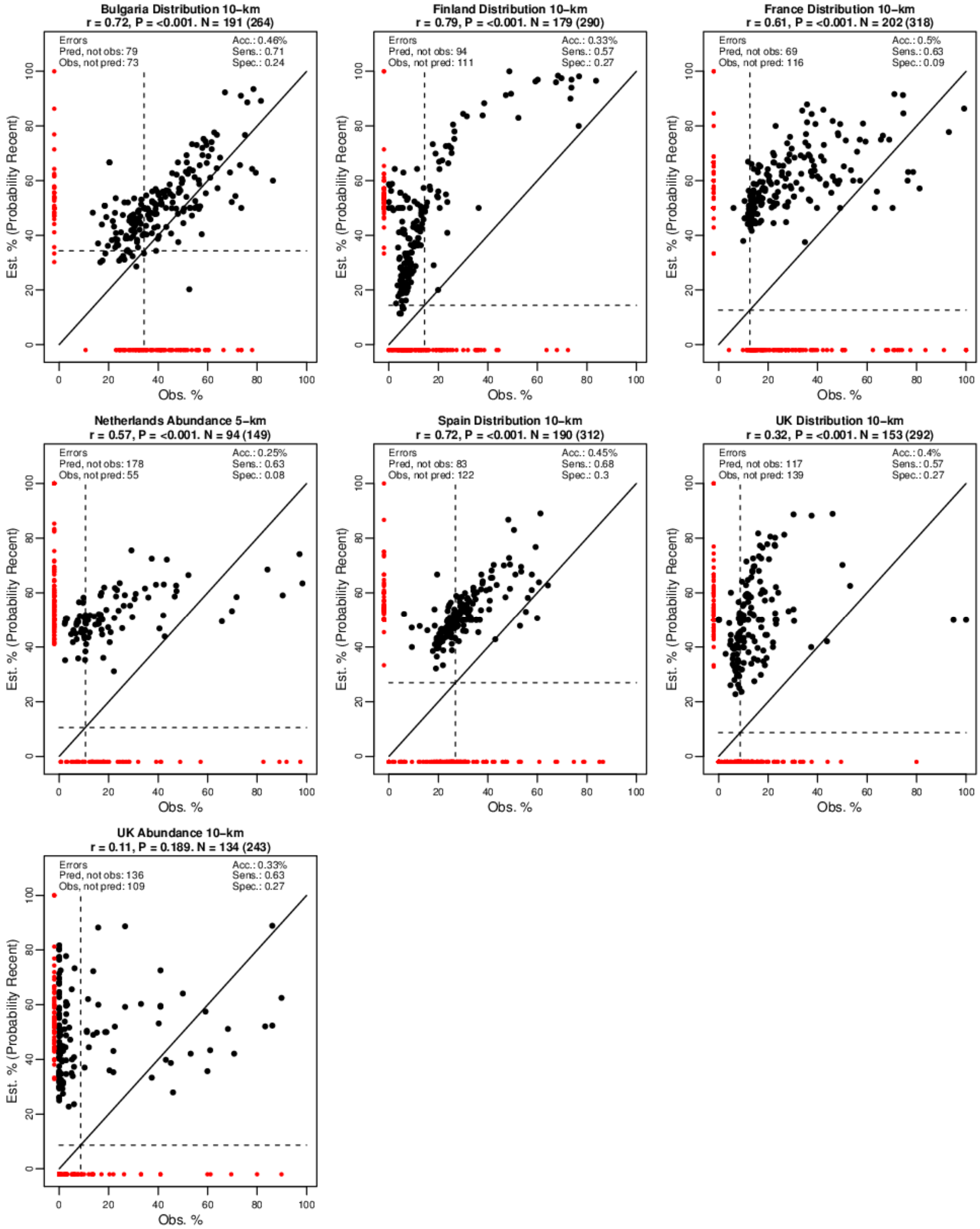

Figure A-7 *Validation results for Recent data models (raw probabilities).*

Appendix 5 Allocation of butterflies occurring in the EU-28 to CLC3-classes

This table gives the final allocation of all butterflies occurring in the EU-28 and the CLC3 classes.

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Aglais ichnusa	x	x	x	x	x	x	x		x				x	x	x		x	x			x				x	
Aglais urticae	x	x	x	x	x	x	x		x				x	x	x		x	x			x				x	
Anthocharis cardamines						x	x		x					x	x		x	x								
Anthocharis damone																		x	x	x				x		
Anthocharis euphenoides															x			x		x		x		x		
Anthocharis gruneri																		x		x			x	x		
Apatura ilia															x		x				x					
Apatura iris						x	x							x	x		x				x					
Apatura metis															x		x				x					
Aphantopus hyperantus						x			x					x	x		x	x			x			x	x	
Apharitis acamas																		x						x		
Aporia crataegi						x			x					x	x		x	x	x	x				x		
Araschnia levana						x	x		x					x	2		x	x			x				x	
Archon apollinus																			x	x						
Arethusana arethusa															x			x					x	x		
Argynnis adippe															x		x	x						x	x	
Argynnis aglaja															x		x	x				x		x	x	
Argynnis elisa															x			x						x		
Argynnis laodice						x			x					x	x		x	x			x				x	
Argynnis niobe															x		x	x	x			x		x	x	
Argynnis pandora														x	x		x	x		x	x			x		
Argynnis paphia						x								x	x	x	x	x			x					
Aricia agestis													x		x			x						x		
Aricia anteros																		x					x	x		
Aricia artaxerxes															x		x	x	x					x		
Aricia cramera													x	x	x			x	x	x				x		
Aricia eumedon															x			x						x	x	
Aricia montensis															x		x	x	x					x		
Aricia morronensis																		x					x	x		
Aricia nicias															x	x	x	x						x		
Aricia teberdinus																		x						x		
Azanus ubaldus																								x		
Boloria alaskensis																		x							x	
Boloria angarensis																		x							x	
Boloria aquilonaris																										x
Boloria chariclea																		x	x					x		
Boloria dia															x		x	3			x			2		
Boloria eunomia																		x							x	x
Boloria euphrosyne															x	x	x	x						x		x
Boloria freija																		3	x							x
Boloria frigga																									x	x
Boloria graeca																x	x	x						x		
Boloria improba																		x	x					x	x	
Boloria napaea																		x	x					x		x
Boloria pales																		x						x		x
Boloria polaris																		x	x					x		
Boloria selene															x	x	x	x						x	x	
Boloria selenis															x		x	x						x	x	
Boloria thore															x		x	3	x					x	x	

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Boloria titania															x	x	x	x							x	
Borbo borbonica																				x						
Brenthis daphne						x								x	x		x	x	x		x			x	x	
Brenthis hecate															x		x	x						x		
Brenthis ino															x		x	2			x				3	x
Brintesia circe															x	x	x	x		x			x	x		
Cacyreus marshalli	x					x																				
Callophrys avis															x				x	x						
Callophrys butleri																							x	x		
Callophrys rubi						x								x	x	x	x	x	x	x	x			x		x
Carcharodus alceae						x				x			x	x	x			2						x		
Carcharodus baeticus																						x	x	x		
Carcharodus floccifera															x		x	x						x	x	
Carcharodus lavatherae															x			x		x				x		
Carcharodus orientalis																		x		x				x		
Carcharodus stauderi																				x			x			
Carcharodus tripolinus						x				x			x	x	x			x						x		
Carterocephalus palaemon															x		x	x			x				x	
Carterocephalus silvicola															x	x	x				x					
Celastrina argiolus	x					x	x							x	x		x		x		x					
Charaxes jasius																				x	x	x		x		
Chazara briseis															x		x	x		x			x	x		
Chazara persephone																	x							2		
Chazara prieuri																				x				x		
Chilades galba																				x				x		
Chilades trochylus																				x						
Coenonympha amaryllis																								x		
Coenonympha arcania														x	x	x	x	x	x		x			x		
Coenonympha corinna																				x				x		
Coenonympha darwiniana																		x						x		
Coenonympha dorus																				x				x		
Coenonympha gardetta															x			x						x		
Coenonympha glycerion															x		x	x						x	x	
Coenonympha hero															x		x	2			x				x	
Coenonympha leander															x		x	x			x			x		
Coenonympha oedippus															x		x				x				x	x
Coenonympha orientalis															x			x						x		
Coenonympha pamphilus		x		x	x	x							x	x	x			x	x					x		
Coenonympha rhodopensis																		x						x		
Coenonympha thyrsis																				x				x		
Coenonympha tullia																									x	x
Colias alfacariensis													x					x			x			x		
Colias aurorina																x		x		x				x		
Colias caucasica																x		x	x					x		
Colias chrysotheme																		x		x				x		
Colias croceus						x		x	x	x	x	x	2	2				3		x	x			2		
Colias erate											x		x					x		x				x		
Colias hecla																		x	x			x		x		
Colias hyale											x		x					x						x		
Colias myrmidone																x	x	x	x					x		
Colias nastes																		x	x					2	x	
Colias palaeno																x	x	x							x	x
Colias phicomone																		x						x		
Colotis evagore													x										x	x		
Cupido alcetas															2		x	x	x	x	x			x	x	
Cupido argiades															x			x			x			x		
Cupido decolorata															x			x		x	x			x		
Cupido lorquinii																				x				x		
Cupido minimus													x		x			x						x		
Cupido osiris													x			x	x	x			x			x		
Danaus chrysippus																				2						

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Danaus plexippus						x		x		x		x	x	x						x						
Erebia aethiopella															2			x			x			x		
Erebia aethiops																x	x	x			x			x		
Erebia alberganus															x			2			x			x		
Erebia calcaria																		x					x	x		
Erebia cassioides																		x					x	x		
Erebia christi																		x						x		
Erebia claudina																		x						x		
Erebia cyclopius																	x	x								
Erebia disa																	x	2							x	x
Erebia discoidalis																		2						x	x	
Erebia embla																x	x	x							x	x
Erebia epiphron																		x	x					x		
Erebia epistygne																		x						x		
Erebia eriphyle																		x						x		
Erebia euryale															x	x	x	x	x		x			x		
Erebia fasciata																	x	x						x		
Erebia flavofasciata																		x						x		
Erebia gorge																		x					x	x		
Erebia gorgone																		x					x	x		
Erebia graucasica																		x						x		
Erebia hispania																		x					x	x		
Erebia iranica																		x								
Erebia lefebvrei																		x					x	x		
Erebia ligea															x	x	x	x			x			x		
Erebia manto															x	x		x	x		x			x		
Erebia medusa															x	x	x	x			x			x		
Erebia melampus																		x						x		
Erebia melancholica																		x						x		
Erebia melas																x		x					x	x		
Erebia meolans															x	x		2	x		x			x		
Erebia mnestra																		x						x		
Erebia montana																		x					x	x		
Erebia neoridas																x		x					x	x		
Erebia nivalis																		x					x	x		
Erebia oeme																		3	x					x		
Erebia orientalis																	x	x			x			x		
Erebia ottomana																x		4					x	x		
Erebia palarica																		x						x		
Erebia pandrose																		x	x					x		
Erebia pharte																		x					x	x		
Erebia pluto																		x					x	x		
Erebia polaris																		x						x		
Erebia pronoe																		x	x				x	x		
Erebia rhodopensis																x		x						x		
Erebia rondoui																		x					x	x		
Erebia rossii																		x						x		
Erebia scipio																							x	x		
Erebia sthennyo																		x					x	x		
Erebia stirius																		x					x	x		
Erebia styx																		x					x	x		
Erebia sudetica																x	x	2					x	x		
Erebia triaria															x	x		x			x			x		
Erebia tyndarus															x			x					x	x		
Erebia zapateri																x										
Erynnis marloyi																		x		x			x	x		
Erynnis tages													x		x			x	x					x		
Esperarge climene															x		x	x	x	x	x			x		
Euchloe ausonia						x							x		x		x	x		x	x			x		
Euchloe bazae																		x						x		
Euchloe belemia													x					x						x		

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Euchloe charlonia																		x						x		
Euchloe crameri						x							x	x				2		2		x		2		
Euchloe eversi													x					x						x		
Euchloe grancanariensis													x					x						x		
Euchloe hesperidum													x					x						x		
Euchloe insularis																		x		x				x		
Euchloe penia																		x		x			x	x		
Euchloe simplonia																		x		x		x		x		
Euchloe tagis					x								x		x			2		2	x	x		x		
Euphydryas aurinia															x			x	x					x	x	
Euphydryas cynthia															x	x	x	x			x		2	2	x	x
Euphydryas desfontainii															x			x		x	x			x		
Euphydryas iduna																		2	x					x	x	x
Euphydryas intermedia															x	x	x	2	x		x		x	x	x	x
Euphydryas maturna															x		x	x			x					
Gegenes nostrodamus																		x		x				x		
Gegenes pumilio																		x		x			x	x		
Glaucopsyche alexis															x			x		x	x			x		
Glaucopsyche melanops															x				x	x	x					
Glaucopsyche paphos															x					x	x			x		
Gonepteryx cleobule													x		x						x					
Gonepteryx cleopatra										x			x		x				x	x	x					
Gonepteryx farinosa															x					x	x		x	x		
Gonepteryx maderensis															x			x			x					
Gonepteryx rhamni						x	x						x	x	x		x		x		x					
Hamearis lucina															x		x	x			x			x		
Hesperia comma																		x	x			x		3		
Heteropterus morpheus															2		x	x	x		x				2	
Hipparchia alcyone															x	x	x	x	x	x		x		x		
Hipparchia aristaeus																	x	x		x	x		x	x		
Hipparchia autonoe																		x						x		
Hipparchia azorina												x	x	x				x	x							
Hipparchia bacchus															x			x						x		
Hipparchia christenseni																				x						
Hipparchia cretica																				x						
Hipparchia cypriensis																x	x	x		x	x		x	x		
Hipparchia fagi															x	x	x	x	x				x	x		
Hipparchia fatua																x	x	x		x	x		x	x		
Hipparchia fidia															x			x		x	x			x		
Hipparchia gomera															x			x						x		
Hipparchia leighebi															x			x						x		
Hipparchia maderensis															x	x	x	x			x		x			
Hipparchia mersina																x										
Hipparchia miguelensis												x	x	x				x	x	x						
Hipparchia neapolitana															x			x						x		
Hipparchia neomiris																		x	x	x				x		
Hipparchia occidentalis												x	x	x				x	x	x						
Hipparchia pellucida																x	x	x		x	x		x	x		
Hipparchia sbordonii															x			x						x		
Hipparchia semele															x	x	x	x	x			x	x	x		
Hipparchia senthes															x		x	x		x	x		x	x		
Hipparchia statilinus															x	x		x	x	x		x	x	x		
Hipparchia syriaca															2	x	x	x			x			x		
Hipparchia tamadabae															x			x						x		
Hipparchia tilosi															x			x						x		
Hipparchia volgensis															x		x	x		x	x		x	x		
Hipparchia wyssii															x			x						x		
Hyponephele lupinus															x		x	x		x	x			x		
Hyponephele lycaon															x	x		x	x		x			x		
Inachis io	x	x	x	x	2	x	x		x	x			x	x	x		x	x			x				x	
Iolana iolas																		x		x				x		

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Iphiclides podalirius						2	x			x			x	x	x		x	x	x	x				x		
Issoria eugenia																x		x						x		
Issoria lathonia			x		x								x	x	x			x	x			x		x		
Kirinia roxelana															x					x						
Laeosopis roboris						x			x					x	x						x					
Lampides boeticus					x	x			x	x			x	x	x			x	x	x	x			x		
Lasiommata deidamia																	x						x			
Lasiommata maera															x	x	x	x	x					x		
Lasiommata megera		x			x	x			x				x	x	x			x	x		x		x	2		
Lasiommata paramegaera																		x		x				x		
Lasiommata petropolitana															x	x	x	x	x							
Leptidea duponcheli																	x	x	x	x			x	x		
Leptidea morsei															x	x	x	x			x			x		
Leptidea sinapis complex						x								x	x		x	x			x			x		
Leptotes pirithous					x	x	x	x		x			x	x				x		x				x		
Libythea celtis						x	x								x		x	x			x			x		
Limenitis camilla															x		x				x					
Limenitis populi															x		x	x						x		
Limenitis reducta															x	x	x	x		x	x			x		
Lopinga achine															x	x	x				x					
Lopinga deidamia															x	x	x				x					
Lycaena alciphron															x			x						x		
Lycaena bleusei																		x	x					x		
Lycaena candens																		x						x		
Lycaena dispar															x			x							x	
Lycaena helle																		x							x	x
Lycaena hippothoe																		x							x	
Lycaena ottomanus																	x	x		x				x		
Lycaena phlaeas	x	x	x	x		x				x			x		x			2	x					x		
Lycaena thersamon						x							x		x			x			x			x		
Lycaena thetis															x			x		x				x		
Lycaena tityrus															x			x	x					x	x	
Lycaena virgaureae															x	x	x	x			x			x		
Maculinea alcon																		x	x						x	
Maculinea arion																x		x	x					x		
Maculinea nausithous																		x							x	
Maculinea rebeli																		x						x		
Maculinea teleius																		x							x	
Maniola chia																				x						
Maniola cypricola																		x		x				x		
Maniola halicarnassus																		x		x				x		
Maniola jurtina		x				x					x		x	x	x		x	x			x			x	x	
Maniola megala																									x	
Maniola nurag																		x		x				x		
Maniola telmessia																		x		x				x		
Melanargia arge																		x		x				x		
Melanargia galathea		x											x		x		x	x			x			x		
Melanargia ines																		x		x				x		
Melanargia lachesis													x		x			x	x	x	x		x	2		
Melanargia larissa																		x		x			x	x		
Melanargia occitanica																		x		x				x		
Melanargia pherusa																		x		x				x		
Melanargia russiae																x	x	x		x				2		
Melitaea aetherie															x											
Melitaea arduinna															x		x	x			x			3		
Melitaea asteria																		x						x		
Melitaea athalia															x	x	x	2	x		x			x		
Melitaea aurelia																		x						3	x	
Melitaea britomartis															x		x	x			x			x		
Melitaea cinxia													x		x			x						x		
Melitaea deione																		x						x		

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Melitaea diamina															x			x			x			x	x	
Melitaea didyma													x		x			x						x		
Melitaea parthenoides															x			x			x			x		
Melitaea phoebe															x			x			x			x		
Melitaea telona																		x			x			x		
Melitaea trivia															x			x			x			x	x	
Melitaea varia																		x						x		
Minois dryas															x			x			x					
Muschampia cribrellum																		x		x				x		
Muschampia proto																		x		x				x		
Muschampia tessellum						x	x											x		x			x	x		
Neolycaena rhymnus																		x					x	x		
Neozephyrus quercus						x								x	x		x									
Neptis rivularis															x		x				x					
Neptis sappho															x		x				x					
Nymphalis antiopa															x	x	x				x					
Nymphalis polychloros						x			x	x				x	x	x	x				x					
Nymphalis vaualbum	x					x									x		x				2					
Nymphalis xanthomelas						x									x		x				x					
Ochlodes venata														x	x		x	x			x			x	x	
Oeneis bore																		x	x				x	x		
Oeneis glacialis																		x					x	x		
Oeneis jutta																x		x						x	x	x
Oeneis magna																		x						x	x	
Oeneis melissa																		x						x		
Oeneis norna																		x	x					x	x	x
Oeneis patrushevae																		x							x	
Oeneis polixenes																		x						x	x	
Oeneis tarpeia																		2						2		
Papilio alexanor																		x	x	x				x		
Papilio hospiton																		x	x	x				x		
Papilio machaon	x			x		x	x	x		x			x		x			x						x	x	
Pararge aegeria						x	x		x				x	x	x	x	x				x					
Pararge xiphia															x											
Pararge xiphioides						x									x											
Parnassius apollo															x	x		x					x	x		
Parnassius mnemosyne															x		x	x			x		x	x	x	
Parnassius phoebus																		x					x	x	x	
Pelopidas thrax																				x				x		
Pieris balcana															x	x	x									
Pieris brassicae	x	x	x	x	x	x	x		x	x			x	x				x			x				x	
Pieris bryoniae															x	x	x	x	x					x		
Pieris cheiranthi															x											
Pieris ergane															x		x	x		x			x	x		
Pieris krueperi																		x					x	x		
Pieris mannii															x		x	x		x			x	x		
Pieris napi	x			x		x							x	x	x		x	x			x				x	
Pieris rapae	x	x	x	x	x	x	x		x	x		x	x	x				x								
Pieris wollastoni															x											
Plebeius aquilo																		x	x				x	x		
Plebeius argus																x	x	x	x					x		
Plebeius argyrognomon															x			x						x		
Plebeius eurypilus																				x						
Plebeius glandon																		x	x				x	x		
Plebeius hesperica					x								x					x						x		
Plebeius idas															x		x	2	x					x		x
Plebeius loewii																				2						
Plebeius optilete																x	x	x	x						x	2
Plebeius orbitulus																		x					x	x		
Plebeius psylorita																				x						
Plebeius pylaon																		x		x			x	x		

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Plebeius pyrenaica																		x					x	x		
Plebejus bellieri																		x		x			x	x		
Plebejus dardanus																		x					x	x		
Plebejus hespericus																		x		x			x	x		
Plebejus sephirus																		x		x			x	x		
Plebejus trappi																		x		x			x	x		
Plebejus zullichi																				x			x	x		
Polygonia c-album	x					x	x							x	x		x				x					
Polygonia egea																		x		x				x		
Polyommatus admetus															x			x			x			x		
Polyommatus albicans																		x		x				x		
Polyommatus amandus															x			x						x		
Polyommatus andronicus																		x						x		
Polyommatus aroaniensis																		x		x			x	x		
Polyommatus bellargus															x			x						x		
Polyommatus caelestissimus															x			x						x		
Polyommatus coelestina																		x						x		
Polyommatus coridon															x			x	x					x		
Polyommatus cyane																		x						x		
Polyommatus damocles																		x					x	x		
Polyommatus damon															x			x						x		
Polyommatus damone																		x						x		
Polyommatus daphnis															x		x	x			x			x		
Polyommatus dolus																		x		x				x		
Polyommatus dorylas															x			x						x		
Polyommatus eleniae																		x					x	x		
Polyommatus eroides																x	x	x				x		x		
Polyommatus eros																		x					x	x		
Polyommatus escheri																		2		2			x	x		
Polyommatus fabressei																		x		x				x		
Polyommatus fulgens																		x						x		
Polyommatus galloi																		x		x				x		
Polyommatus golgus																		x					x	x		
Polyommatus hispana																		x	x	x				x		
Polyommatus humedasae															x			x						x		
Polyommatus icarus		x	x	x	x	x	x	x		x			x					x						x	x	
Polyommatus iphigenia																		x		x				x		
Polyommatus menelaos																		x						x		
Polyommatus nephohiptamenos																		x					x	x		
Polyommatus nivescens																		x		x			x	x		
Polyommatus orphicus																		x					x	x		
Polyommatus philippi																		x						x		
Polyommatus pljushtchi																		x					x	x		
Polyommatus poseidon																		x					x	x		
Polyommatus ripartii																	x	3		x				x		
Polyommatus semiargus															x		x	x						x	x	
Polyommatus thersites															x			x	x	x				x		
Polyommatus violetae																		x		x				x		
Pontia callidice																	x	x					x	x	x	
Pontia chloridice																		x					x	x		
Pontia daplidice complex		x	x		x	x		x		x			x	x	x			x		x	x			x		
Praephilotes anthracias																		x						x		
Proterebia afra																	x	x		x				x		
Pseudochazara amymone																				x						
Pseudochazara anthelea																		x		x			x	x		
Pseudochazara cingovskii																		x						x		
Pseudochazara euxina																		x					x	x		
Pseudochazara geyeri																		x						x		
Pseudochazara graeca																		x					x	x		
Pseudochazara hippolyte																		x	x				x	2		
Pseudochazara mniszechii																x				x						

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Pseudochazara orestes																				x			x	x		
Pseudochazara pelopea																		x						x		
Pseudochazara schakuhensis																		x						x		
Pseudophilotes abencerragus													x					x						x		
Pseudophilotes barbagiae																		x		x				x		
Pseudophilotes baton																		x	x	2				x		
Pseudophilotes bavius																		x		x			x	x		
Pseudophilotes panope																		x						x		
Pseudophilotes panoptes																		x	x	2				x		
Pseudophilotes vicrama																x		x	x	x				x		
Pyrgus alveus																		x	x					x		
Pyrgus andromedae																		x	x				x	x	x	
Pyrgus armoricanus																		x	x					2		
Pyrgus bellieri																		x						x		
Pyrgus cacaliae																		x						x	x	
Pyrgus carlinae																		x				x		x		
Pyrgus carthami															x			x					x	x		
Pyrgus centaureae																										x
Pyrgus cinarae																		x	x				x	x		
Pyrgus cirsii													x					x				x		x		
Pyrgus malvae															x		x	x	x					x	x	
Pyrgus malvoides																		x	x	x	x			x	x	
Pyrgus onopordi																		x		x				x		
Pyrgus serratulae																		x						x		
Pyrgus sidae																x		x		x			x	x		
Pyrgus warrenensis																		x						x		
Pyronia bathseba																			x	x	x			x		
Pyronia cecilia															x			x		2	x			x		
Pyronia tithonus						x								x	x			x	x		x			x	x	
Satyrium acaciae															x		x	x	x		x			x		
Satyrium esculi						x				x			x	x	x					x	x					
Satyrium ilicis															x		x				x					
Satyrium ledereri																				x						
Satyrium pruni										x					x		x		x	x	x					
Satyrium spini															x		x	x			x			2		
Satyrium w-album						x	x								x		x									
Satyrus actaea																		x	x					x		
Satyrus ferula															x					x	x		x	x		
Satyrus virbius																		x						x		
Scolitantides orion															x			x		x			x	x		
Spialia orbifer															x			x		x	x		x	x		
Spialia phlomidis																		x		x			x	x		
Spialia sertorius																		x	x					x		
Spialia therapne																		x		x				x		
Tarucus balkanica																				x						
Tarucus theophrastus																			x	x						
Thecla betulae		x				x	x		x					x	x		x				x					
Thymelicus acteon															x			x		x				x		
Thymelicus christi																		x		x				x		
Thymelicus hyrax																				2						
Thymelicus lineola		x		x		x			x				x		x			x						x	x	
Thymelicus sylvestris													x		x		x	x						x	x	
Tomares ballus													x					x		x				x		
Tomares callimachus															x		x	x					x	x		
Tomares nogelii															x			x		x				x		
Tongeia fischeri															x			x						x		
Triphysa phryne																	x	x						x		
Turanana endymion																				x						
Turanana taygetica																		x						x		
Vanessa atalanta		x				x	x					x	x	x	x		x	x			x				x	
Vanessa cardui		x				x	x	x		x			x	x				x		x	x			x	x	

Species	2	4	5	6	8	10	11	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36
Vanessa indica														x							x					
Vanessa virginiensis														x							x					
Vanessa vulcania						x						x	x	x	x		x				x					
Ypthima asterope																				x						
Zegris eupheme		x			x								x					x						x		
Zegris pyrothoe																		x						x		
Zerynthia caucasica																	x	x	x	x	x			x		
Zerynthia cerisy								x									x	x	x	x	x			x		
Zerynthia cretica																			x	x						
Zerynthia polyxena															x		x	x	x	x	x			x	x	
Zerynthia rumina						x									x			x	x	x		x		x		
Zizeeria karsandra		x			x	x	x	x		x			x					x						x		
Zizeeria knysna		x			x	x	x	x		x			x					x						x		

Appendix 6 Plant databases used

Database name	Custodian	GIVD code (www.givd.info)
Austrian Vegetation Database	Wolfgang Willner	EU-AT-001
Balkan database	Andraž Čarni	
Balkan Dry Grasslands Database	Kiril Vassilev	EU-00-013
Balkan Vegetation Database	Kiril Vassilev	EU-00-019
Beech Forest Vegetation Database of SE Balkan	Aleksander Marinšek	EU-00-012
Bulgarian Vegetation Database	Iva Apostolova	EU-BG-001
CoenoDat Hungarian Phytosociological Database	János Csiky	EU-HU-003
Croatian Vegetation Database	Željko Škvorc	EU-HR-002
Czech National Phytosociological Database	Milan Chytrý	EU-CZ-001
Database of Forest Vegetation in Republic of Serbia + Vegetation Database of Northern Part of Serbia (AP Vojvodina)	Mirjana Krstivojević Ćuk	EU-RS-003 + EU-RS-004
Dutch National Vegetation Database	Joop H.J. Schaminée	EU-NL-001
EcoPlant: A forest site database linking floristic data with soil and climate variables	Jean-Claude Gegout	
European Coastal Vegetation Database	John Janssen	EU-00-017
European Mire Vegetation Database	Tomáš Peterka	EU-00-022
Georeferenced Vegetation Database - Sapienza University of Roma	Emiliano Agrillo	EU-IT-011
German Vegetation Reference Database (GVRD)	Ute Jandt	EU-DE-014
Halophytic and coastal vegetation database of Ukraine	Tetiana Dziuba	EU-UA-005
Hellenic Natura 2000 Vegetation Database (HelNatVeg)	Panayotis Dimopoulos	EU-GR-005
Hellenic Woodland Database + Hellenic Beech Forests Database (Hell-Beech-DB)	Ioannis Tsiripidis	EU-GR-006 + EU-GR-007
Iberian and Macaronesian Vegetation Information System (SIVIM)	Xavier Font	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Scrubs)	Rosario G Gavilán	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Sclerophyllous)	Federico Fernández-González	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Floodplains)	Rosario G Gavilán	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Wetlands)	Aaron Pérez-Haase	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Forests)	Juan Antonio Campos	EU-00-004
Iberian and Macaronesian Vegetation Information System (SIVIM) (Grasslands)	Maria Pilar Rodríguez-Rojo	EU-00-004
INBOVEG	Els De Bie	EU-BE-002
Irish Vegetation Database	Úna FitzPatrick	EU-IE-001
Italian National Vegetation Database (BVN/ISPRA)	Laura Casella	EU-IT-010
KRITI	Erwin Bergmeier	EU-GR-001
Lithuanian vegetation Database	Valerius Rašomavičius	EU-LT-001
Lower Volga Valley Phytosociological Database	Valentin Golub	EU-RU-002
Mediterranean Ammophiletea database	Corrado Marcenò	EU-00-016
National Vegetation Database of Denmark	Jesper Erenskjold Moeslund	EU-DK-002
Nordic-Baltic Grassland Vegetation Database (NBGVD)	Jürgen Dengler	EU-00-002
Phytosociological Database of Non-Forest Vegetation in Croatia	Zvjezdana Stančić	EU-HR-001
Polish Vegetation Database	Zygmunt Kącki	EU-PL-001
Romanian Forest Database	Adrian Indreica	EU-RO-007
Romanian Grassland Database	Eszter Ruprecht	EU-RO-008
SE Europe forest database	Andraž Čarni	EU-00-021
Semi-natural Grassland Vegetation Database of Latvia	Solvita Rūsiņa	EU-LV-001
Slovak Vegetation Database	Milan Valachovič	EU-SK-001

Database name	Custodian	GIVD code (www.givd.info)
Swiss Forest Vegetation Database	Thomas Wohlgemuth	EU-CH-005
The Nordic Vegetation Database	Jonathan Lenoir	EU-00-018
UK National Vegetation Classification Database	John S. Rodwell	EU-GB-001
Ukrainian Grasslands Database	Anna Kuzemko	EU-UA-001
Vegetation Database Grassland Vegetation of Serbia	Svetlana Aćić	EU-RS-002
Vegetation Database of Albania	Michele De Sanctis	EU-AL-001
Vegetation Database of Slovenia	Urban Šilc	EU-SI-001
Vegetation Database of the Republic of Macedonia	Renata Ćušterevska	EU-MK-001
Vegetation Database of the Volga and the Ural Rivers Basins	Tatiana Lysenko	EU-RU-003
Vegetation-Plot Database of the University of the Basque Country (BIOVEG)	Idoia Biurrun	EU-00-011
VegetWeb Germany	Jörg Ewald	EU-DE-013
VegItaly	Roberto Venanzoni	EU-IT-001
VegMV	Florian Jansen	EU-DE-001
VIOLA	Angela Stanisci	EU-IT-019

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The mission of Wageningen UR (University & Research centre) is ‘To explore the potential of nature to improve the quality of life’. Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 9,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.

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