University of Cyprus
Department of Biological Sciences

Quantifying the fragmentation levels of amphibian, reptile, and terrestrial mammal habitats inside and outside of Natura 2000 sites within the European Union

Sophia Economides

A Research-Based Master's Thesis
for the
Degree of Magister Scientiae in Biodiversity and Ecology.

May 25, 2023

ABSTRACT

Natural landscapes are constantly being modified and fragmented through a plethora of human activities, such as urbanisation and agriculture. Landscape fragmentation can have multiple negative effects on biodiversity. For example, it can lead various species' populations to decrease due to the reduction of habitat area, and to become isolated into genetically vulnerable sub-populations. Certain species, such as amphibians, reptiles, and some terrestrial mammals, may be at a higher risk and experience negative impacts due to fragmentation caused, for example, by roads and barriers. This is particularly true if these species have limited mobility or require a larger living space. Species' threats can be potentially mitigated through the creation of protected areas. Species and habitats of conservation importance within the EU are being protected through the establishment of a supranational network of protected areas, the Natura 2000 sites, currently covering 26% of the EU's terrestrial area. The EU's biodiversity strategy for 2030 includes plans to expand Natura 2000 areas, address landscape fragmentation and habitat loss, and protect a minimum of 30% of the EU's land area.

While previous studies have shown that, in some cases, significant proportions of the species distribution ranges lie within Natura 2000 sites, several knowledge gaps remain. First, the species' calculated distribution range may include areas which are, in fact, unsuitable for them. To produce more accurate representations of a species' suitable habitat, its area of habitat (AOH) can be derived by extracting unsuitable habitats and elevations within its geographical range. Second, although several studies have looked at what proportion of species ranges is protected (an analysis known as gap analysis), few studies have assessed and quantified the quality of the species' protected habitat, e.g., with regards to fragmentation. It's possible that the Natura 2000 sites themselves could have high levels of fragmentation.

In this research project we identify species groups, focusing on amphibians, reptiles, and terrestrial mammals, that may be under-protected by calculating their AOH, and quantifying it against landscape fragmented by transportation structures and anthropogenic barriers, within and

outside of Natura 2000 sites. The findings can help evaluate if the protection of species is sufficient and aligns with the EU's biodiversity strategies and guidelines. They can also provide a more precise understanding of which species need priority protection. In addition, we offer biogeographic and EU country assessments of fragmentation, which provide an overview of how species in those areas are affected by fragmented landscapes, both inside and outside of Natura 2000 sites. This information can help identify conservation priorities. We also analyse species groups by IUCN threat categories to examine if more threatened species tend to have more fragmented protected and unprotected habitats.

Our results show that overall species' habitats within Natura 2000 sites tend to be less fragmented than in unprotected areas. However, there are substantial variations across biogeographic regions and countries where protected areas can still be highly fragmented, like for example, in the Mediterranean. Furthermore, many species have most of their AOHs in unprotected areas with high fragmentation levels.

ACKNOWLEDGEMENTS

I am grateful to Prof. Spyros Sfenthourakis for giving me the opportunity to conduct this thesis project, and to Dr. Christos Mammides for offering extensive guidance and help in conducting this project.

I am thankful for the help from Jeff Hanson, including his immediate and precise responses concerning his AOH R package.

Words cannot express my gratitude to everyone who has supported my journey through this MSc degree; my friends and family.

COMPOSITION OF THE EXAMINATION COMMITTEE

Thesis Supervisor (Examination Committee coordinator): Prof. Spyros Sfenthourakis, Dept. of Biological Sciences, UCY

Committee Member: Assist. Prof. Anna Papadopoulou, Dept. of Biological Sciences, UCY

Committee Member: European Research Area (ERA) Fellow & Senior Researcher, Christos Mammides, Nature Conservation Unit, Frederick University

SEMINAR ANNOUNCEMENT

University of Cyprus
Department of Biological Sciences

Master Research Dissertation in Biodiversity and Ecology (BIO 831/601)

Student Presentation

Thursday, 25 May 2023 at 12:00
Building CTF01, Room 002, Panepistimioupoli Campus

This seminar is open to the public

Sophia Economides

Thesis Supervisor: Prof. Spyros Sfenthourakis

"Quantifying the fragmentation levels of amphibian, reptile, and terrestrial mammal habitats inside and outside of Natura 2000 sites within the European Union"

Natural landscapes are being constantly modified and fragmented through a plethora of human activities, such as urbanisation and agriculture. Landscape fragmentation can have multiple negative effects on biodiversity. For example, it can lead various species' populations to decrease due to the reduction of habitat area, and to become isolated into genetically vulnerable sub-populations. Some species, like amphibians, reptiles, and certain terrestrial mammals, can be more vulnerable and negatively affected by fragmentation caused by roads and barriers, for example, if they have limited movement capabilities or need a greater area to live in. The mitigation of species' threats can be approached with the creation of protected areas. Species and habitats of conservation importance within the EU are being protected through the establishment of a supranational network of protected areas, the Natura 2000 sites, currently covering 26% of the EU's terrestrial area. As part of the EU's biodiversity strategy for 2030, Natura 2000 areas will be enlarged, landscape fragmentation and habitat loss will be tackled, and at least 30% of the EU's land area will be protected.

While previous studies have shown that, in some cases, significant proportions of the species distribution ranges can lie within Natura 2000 sites, several knowledge gaps remain. First, the species' calculated distribution range may include areas which are, in fact, unsuitable for them. To produce more accurate representations of a species' suitable habitats, its area of habitat (AOH) can be derived by extracting its unsuitable habitats and elevation from its geographical range. Second, although several studies have looked at what proportion of species ranges is protected (gap analyses), very few studies have quantified the quality of the protected habitat, e.g., with regards to fragmentation, and the Natura sites themselves may be highly fragmented.

In this research project we identify species groups, focusing on amphibians, reptiles, and terrestrial mammals, that may be underprotected by calculating their AOH, and quantifying it against landscape fragmented by transportation structures and anthropogenic barriers, within and outside of Natura 2000 sites. This can contribute towards assessing whether species' protection is adequate and as originally planned through the EU's biodiversity strategies and directives, and towards offering a more accurate view for species protection prioritisation. We also provide biogeographic and EU country assessments summarising their species' fragmented landscape, within and outside of Natura 2000 sites, which could also provide a clearer picture for conservation priority and guidance. We also analyse species groups by IUCN threat categories to identify if more threatened species tend to have more fragmented protected and unprotected habitats.

Our results show that overall species' habitats within Natura 2000 sites tend to be less fragmented than unprotected areas. However, there are substantial variations across biogeographic regions and countries where protected areas can still be highly fragmented, like for example, in the Mediterranean. Furthermore, many species have most of their AOHs in unprotected areas with high fragmentation levels.

TABLE OF CONTENTS

INTRODUCTION

Protection of biodiversity is important due to the invaluable ecosystem services it provides, now more than ever, as species extinction rates are steeply rising (Singh, 2002; Rull, 2022). In the EU, a network of protected areas (Natura 2000 sites) has been established to ensure the long-term protection of various species and habitats (European Commission, 2023a). The Natura 2000 network is currently covering 26% of the EU's terrestrial area (European Commission, 2023b), and is designated under the European Union's Birds (79/409/EC) and Habitats (92/43/EC) Directives. Furthermore, as part of the EU's biodiversity strategy for 2030, Natura 2000 areas will be enlarged, landscape fragmentation and habitat loss will be tackled, and at least 30% of the EU's land area will be protected (European Commission, 2020; European Commission, 2023c). Several studies have already examined what proportion of species ranges overlaps with protected areas within the EU (gap analyses), in order to identify potential species which might not be adequately protected (Catullo et al., 2008; Abellán and Sánchez-Fernández, 2015; Maiorano et al., 2015). Such studies have shown that reptiles and amphibians are underrepresented in Natura 2000 sites, especially species with small ranges (Abellán and Sánchez-Fernández, 2015), and that protection gaps exist ranging from 14% to 33% for amphibians, reptiles, and mammals (Maiorano et al., 2015).

However, assessing species ranges solely through gap analyses could lead to incorrect assessments because species may not actually be present throughout the entirety of their range. Some species' ranges could include habitats and elevations which are not suitable for the species (IUCN, 2012b; Ramesh et al., 2017). For example, species ranges can be obtained through the IUCN which assesses the threat status of species around the world through different criteria, and documents them in the IUCN Red List for potential stakeholders to prioritise species conservation efforts (IUCN, 2023). The IUCN Red List criteria utilise species' extent of occurrence (EOO), an area which encloses together the sites of a species' occurrence, and species' area of occupancy (AOO), the subset of the EOO in which a species occurs, along with expert opinion, which could appear coarser in comparison to other methods (IUCN, 2012b;

Brooks et al., 2019). To produce more accurate representations of species potential occurrences, its area of habitat (AOH) can be derived by extracting its unsuitable habitats and elevations from its geographical range (Dória and Dobrovolski, 2021; Lumbierres et al., 2022). With the constant change of habitats and the increase of remote sensing technologies, AOH can be a solution to an improved depiction of species' presence, especially in more secluded areas.

Few studies have quantified the quality of protected habitat within the EU regarding fragmentation. Anthropogenic structures and transportation-related structures, in specific, can cause negative effects on biodiversity, like habitat loss, and increased mortality (Fahrig and Rytwinski, 2009; Rytwinski and Fahrig, 2015, Mammides et al., 2016). In addition, fragmentation can be caused by habitat destruction and habitat loss (Püttker et al., 2020). Loss of habitat can be seen in different types of landscapes and can have a harmful effect on species diversity (Haddad et al., 2015; Püttker et al., 2020). Furthermore, fragmentation can cause species to become isolated in smaller populations, which would also result in reduced dispersal capabilities. This could negatively affect species for example by reducing their genetic variability and making them susceptible to extinction (Higgins and Lynch, 2001). Amphibians can be particularly threatened by road-related effects and landscape barriers (Beebee, 2013). The same applies to reptiles which, for example, can have limited dispersal and increased mortality due to slower movement (Smith and Green, 2005; Andrews, Langen and Struijk, 2015). Mammals can also experience negative effects from fragmentation, such as lower genetic diversity and an increase in roadkill incidents (Rytwinski and Fahrig, 2015).

Our study not only examines the potential inaccuracies in species ranges, but also measures the degree of fragmentation in both protected and unprotected areas caused by transportation infrastructure and human-made barriers. This is achieved by conducting a gap analysis using the species' AOH. For instance, if there is a high level of fragmentation within a species' protected AOH, it may require focus on the species' conservation policies.

Additionally, we determine which amphibians, reptiles, and terrestrial mammals may not be receiving sufficient protection by analysing their AOH proportions and comparing it to the fragmented landscape both within and outside of Natura 2000 sites. This can contribute towards assessing whether species' protection is adequate and as originally planned through the EU's biodiversity strategies and directives (European Commission, 2023d). Additionally, through our biogeographical and EU country evaluation, we pinpoint areas that are experiencing higher levels of stress. For example, alpine areas could be under less threatening circumstances, as they can have lower fragmentation values (Lawrence and Beierkuhnlein, 2023). We analyse species based on their classification into classes, orders, and families, as well as their IUCN threat categories. This helps us identify species and groups that require prioritised conservation efforts.

MATERIALS AND METHODS

To calculate an AOH we use species range data, habitat data, and elevation data (Brooks et al., 2019). Additionally, we use protected area data for the gap analysis (Abellán and Sánchez-Fernández, 2015; Maiorano et al., 2015). We also use a fragmentation dataset (European Environment Agency, 2021) in order to measure fragmentation within AOHs. We concentrate on the 27 member states of the EU and utilise the Natura 2000 network of protected areas, which is specifically targeted through the EU biodiversity strategy 2030 (European Commission, 2023d). We establish the extent of the EU from a 1:1 million scale shapefile by Eurostat (2020), version date 03/04/2020, by only including the current 27 member states of the EU.

Data Collection

Species Ranges

Global species range data for amphibians, reptiles, and terrestrial mammals were acquired from the IUCN Red List, version December 2022 (IUCN, 2022a). The raw dataset included 22987 species, of which 7406 were amphibians, 9955 were reptiles, and 5626 were mammals. Since our study focuses on the EU, we excluded species records with ranges which did not have any part within the EU. We only included records of native species ranges by using the appropriate presence and origin values of the dataset, and only included species which had: presence values 1 (Extant) or 2 (Probably Extant), origin values of 1 (Native), 2 (Reintroduced), or 6 (Assisted Colonisation), and seasonal values of 1 (Resident), 2 (Breeding Season), 3 (Assisted Colonisation), or 4 (Passage) (IUCN, 2021). We also excluded freshwater and marine species, as firstly, the fragmentation index we would be using is a measure for landscape only, and secondly, the method we would be using to calculate AOHs is mostly designed for terrestrial species. Only 425 species were selected up to this point. In addition, we excluded species that had less than 2% of their global range within the EU (341 out of 425 species remained). This was done in order to have gap and statistical analyses that were not skewed. As seen in Figure 1, there is a disproportionately larger number of species under the 2% threshold, which mainly includes species occurring in other continents such as Africa. For example, the Egyptian fruit bat (*Rousettus aegyptiacus*) which only occurs in Cyprus within the EU, has the vast majority of its range within Africa (Korine, 2016), and could thus appear as if it is not adequately protected if analysed when this might not be the case, as its range outside the EU might be protected. The remaining 341 species consisted of 80 amphibians, 113 reptiles, and 148 mammals.

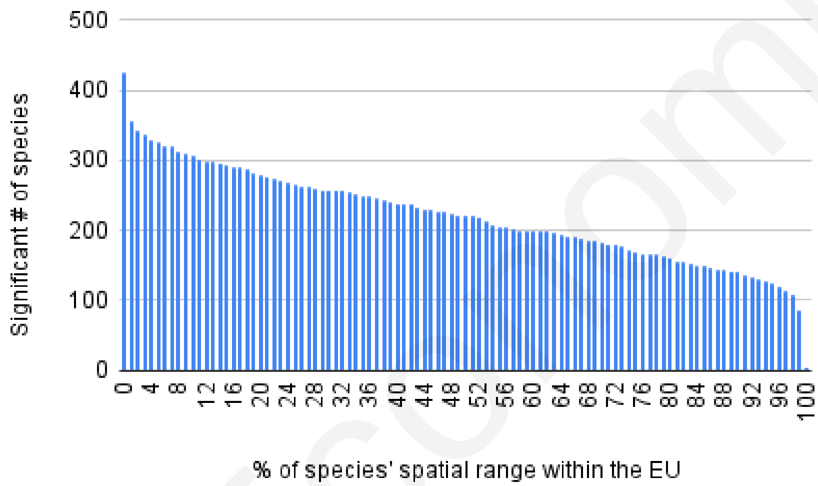

Figure 1 – The 425 species in the initial dataset, ranked in decreasing order according to the percentage of their spatial range occurring within the EU.

Elevation

Elevation data were acquired from Hanson (2021), version 1.0.0, based on data by Robinson et al. (2014), in a 100m resolution.

Habitats

The habitat data were obtained from Jung et al. (2020), who used the same habitat codes as the ones used by IUCN to describe each species' habitat(s) (IUCN, 2012a). This similarity in codes makes the results of our study more reliable since there is a complete overlap between the codes.

Natura 2000 Sites

To define the areas of a species' protected and unprotected AOH, Natura 2000 polygons from April 2022 were used (European Environment Agency, 2022b).

Fragmentation Levels

To calculate the fragmentation within each species' protected and unprotected AOH, we used the landscape fragmentation index, provided by the European Environment Agency (2021), which is measured as the effective mesh density (seff) data based on spatial data of the year 2018. The seff index measures how much barriers and obstacles interrupt a landscape. It calculates how easy or difficult it is to move between different sections of the landscape based on its fragmentation geometry. Higher landscape fragmentation geometry signifies larger seff values. In the context of species movement, seff can determine how difficult it is for some species to move between different parts of the landscape because of the way it is divided by fragmentation.

This dataset focuses on fragmentation caused by human-made elements in the landscape such as buildings, barriers, and transportation networks like roads and railways. The dataset has a high resolution of 100m (European Environment Agency, 2022a), which is currently the latest and of the best quality compared to previous datasets. The dataset's minimum value is 0, while its maximum value reaches 100,000.

Data Analysis

To calculate AOH and fragmentation levels, we used R and ArcGIS Pro software on high RAM capacity desktop computers due to the memory requirements of AOH calculations. Additionally, an internet connection and an API token were necessary to access the IUCN API during the AOH calculations.

Area of Habitat

The species' AOH was calculated using the aoh R package version 0.0.2.3 developed by Hanson (2022). The package calculated AOH via utilising elevation data (Robinson et al., 2014), and habitat data (Jung et al., 2020). By feeding the package the IUCN species range data polygons, the package removed unsuitable elevation habitats according to the species' elevation and habitat data deriving through the IUCN API version 2022-2 (IUCN, 2022b). The analysis resulted in the species' AOH rasters on which the unsuitable habitat was signified with the 0 value, and the suitable habitat was signified with the 1 value.

Fragmentation of Area of Habitat

After the species' AOH rasters were obtained, the analysis continued with ArcGIS Pro version 3.0.2. All the layers' coordinate systems were projected to the ETRS_1989_LAEA projection (if they were not already using it), as the projection is recommended for EU geodata (European Environment Agency, 2003).

The 'Select Layer by Attribute' and 'Export Features' geoprocessing tools were used to acquire only polygons that belonged to the 27 current EU countries by selecting polygons by their country IDs. Following, the 'Multipart to Singlepart', the 'Export Features', and the 'Pairwise Dissolve' geoprocessing tools were used to exclude tropical areas of the EU (i.e., French Guiana). We also excluded tropical EU areas, as there are no tropical species within the European Union Birds (79/409/EC) and Habitats (92/43/EC) directives, which the Natura 2000 is based upon (Aguilar Mugica et al., 2009, pp. 213–228). Finally, the 'Feature Class to Geodatabase' geoprocessing tool was used to create the final single polygon representing the EU.

Secondly, the fragmentation dataset was re-calculated from having pixel values with decimal places to integer values, in order to avoid approximate statistics (Esri, 2023), i.e., by limiting the unique values of the dataset. The 'Raster Calculator' spatial analyst tool was used for this purpose, by rounding the raster's pixel values.

Thirdly, an ArcGIS Pro model was built, by using ModelBuilder, to calculate the fragmentation levels within each species' AOH. The model would use Natura 2000 polygons, and the (re-calculated) fragmentation dataset. Each species' AOH raster would then be fed through the model, which consisted of the steps seen in Figure 2, for a visual representation, and can be read in more detail in Appendix 6.

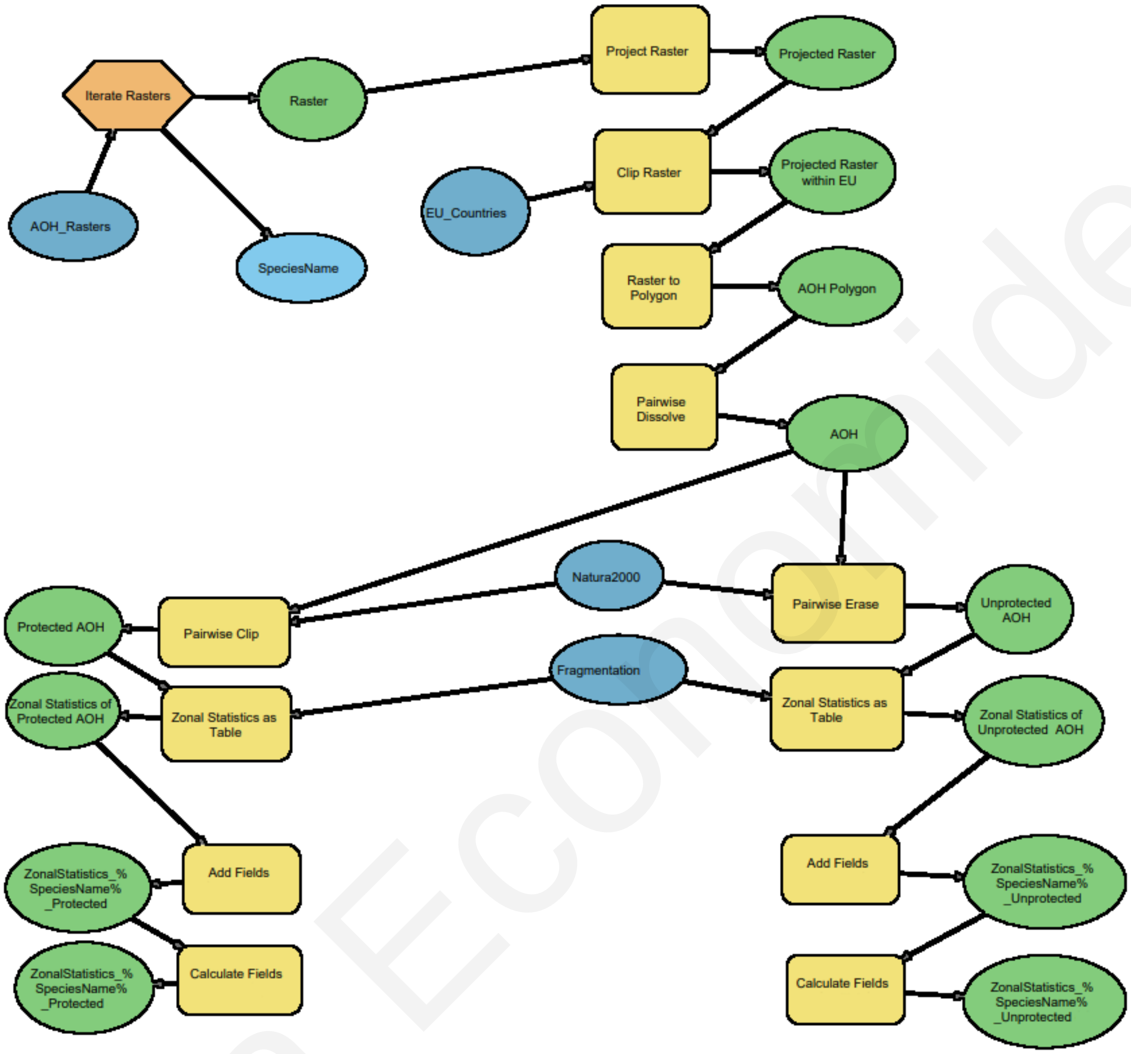

Figure 2 – Visual representation of the steps taken through ArcGIS to calculate fragmentation within species' AOHs. The yellow shapes represent geoprocessing tools, the green and blue shapes represent polygons, rasters, or tables.

After the model was ran for each species' AOH, the results included two rows summarising a species' protected AOH and its unprotected AOH with the corresponding fragmentation values within them. The fragmentation values for each region included area, minimum, maximum, mean, and standard deviation values. The rows within the tables were appended into a single table, and for each species the following data was also appended in each row, according to IUCN data: threat category (global, as European status was not available for every species), class, order, family, and genus.

Fragmentation levels were also quantified by biogeographical region and EU country, inside and outside Natura 2000 areas. The calculations were done in ArcGIS Pro, using the 'Summarize Within' geoprocessing tool to get mean fragmentation levels, which were further classified by species class. The EU countries were defined by the EU polygons mentioned above. The biogeographical regions were defined by using polygons provided by the European Environment Agency (2016).

Gap Analysis

A gap analysis was conducted by measuring the area of the species' AOH regions within the EU to find the percentage of the species' AOH that overlaps with Natura 2000 areas. We chose to define "gap species" as species having 30% or more of their AOHs unprotected, in accordance with the 30% target in the EU's biodiversity strategy for 2030 (European Commission, 2023d)

Statistical Analysis

All statistical analysis was conducted using R version 4.2.2 and RStudio version 2022.12.0. We applied a logarithmic transformation to the fragmentation values to approximate a normal distribution. To avoid logarithmic calculations with 0 ($-\infty$), we added a small step of 0.01 to all the species' mean fragmentation values. We performed paired t-tests on protected and unprotected amphibians, reptiles, and mammals, to test whether fragmentation was lower within protected areas compared to unprotected areas. We spatially represented mean fragmentation values based on biogeographical regions and EU countries. We performed ANOVAs on mean fragmentation values and IUCN threat categories, and we visualised mean fragmentation according to species orders and families. The mammals in protected areas within the CR threat category were omitted from the threat category plots as they had fewer than two data points. The species within the data deficient category (1 reptile and 4 mammals) were excluded from the IUCN threat category plots as they could be falling within other threat categories, but have not been assessed (IUCN, 2012b). We also ran ANOVAs between mean fragmentation and IUCN threat categories and excluded the data deficient species for the same reason.

RESULTS

Biogeographical Regions & EU Country Analyses

The mean fragmentation levels which were summarised by biogeographic region showed the most fragmentation within unprotected areas in the Macaronesian, Mediterranean, and Continental regions, and the most fragmentation within protected areas in the Mediterranean, and Continental regions. The results which were summarised by EU countries supported the biogeographical region results as they signified increased fragmentation levels within protected areas in the Mediterranean countries of Greece, Spain, and Italy. There is a noticeable increase in fragmentation within unprotected areas of Malta, Spain, and Italy in the Mediterranean region. The results based on species class indicate high fragmentation levels for reptiles in the Macaronesian and Mediterranean regions in unprotected areas. There are also higher fragmentation levels for reptiles in protected areas of the Mediterranean. Regarding amphibians, there were also high fragmentation levels in unprotected areas of the Continental region. A visual representation of the patterns can be seen in Figure 3.

While the definition of high or low fragmentation can differ depending on the context, for the purposes of our study we considered “very low” fragmentation to have a value of 0-1.5, “low” fragmentation to have a value of 1.5-10, “medium” fragmentation to have a value of 10-50, “high” fragmentation to have a value of 50-250, and a “very high” fragmentation value of greater than 250 (European Environment Agency, 2022a).

According to those thresholds, the Mediterranean region has a “high” fragmentation level even within protected areas, which could be a call of attention. The unprotected areas have a “very high” fragmentation level in all regions apart from the Black Sea, and the Steppic bioregions (Figure 3, Figure 4, Appendix Table 4). In protected areas, amphibians of the Continental and the Mediterranean region have “high” fragmentation, as well as the reptiles of the Mediterranean region; and all the species groups do not have “high” fragmentation in any of the other biogeographic regions (Figure 3, Figure 4, Appendix Table 5). In unprotected areas, all biogeographic regions apart from the Black Sea and Steppic regions have “high” or “very high” fragmentation values for all species groups (Figure 4, Appendix Table 5).

As for countries, in protected areas there is overall no “very high” fragmentation within any country (Figure 3, Appendix Table 2), and amphibians and mammals have “high” fragmentation in Greece, Italy, Spain, and Malta (Figure 4, Appendix Table 3). But in unprotected areas there is “high” fragmentation in Austria, Bulgaria, Cyprus, Czech Republic, Denmark, Finland, Croatia, Hungary, Poland, Portugal, Romania, and Sweden, and the fragmentation is “very high” in Greece, Spain, France, Italy, and Malta (Figure 3, Appendix Table 2). It's important to note that for smaller countries like Malta and Cyprus, the accuracy of country assessments may be affected. Our filtering process may have excluded species that only occur in these countries and not in other EU member states (but may occur in non-EU countries).

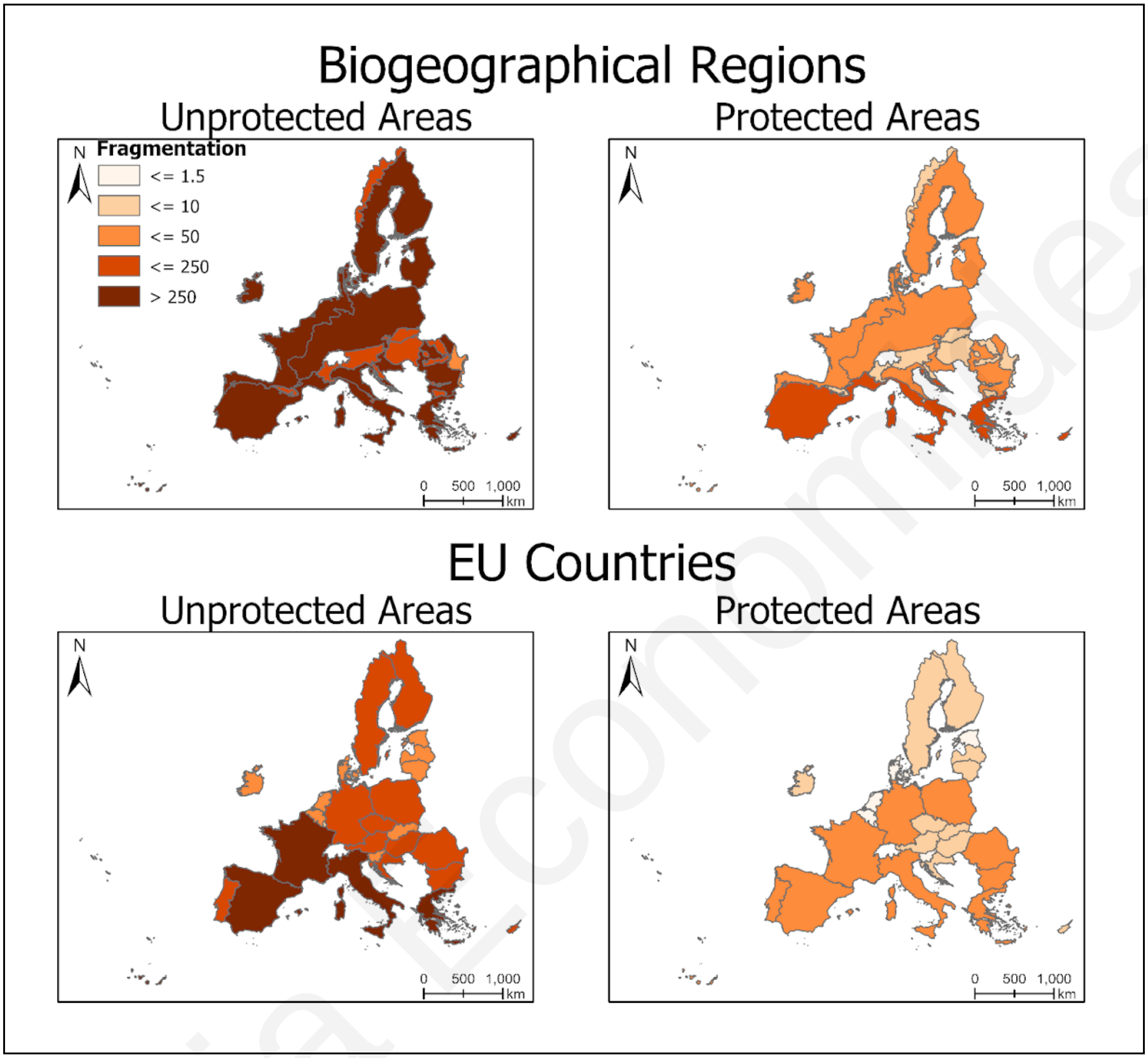

Figure 3 – Fragmentation levels by biogeographical region (top 2 maps), and by EU countries (bottom 2 maps), in unprotected (left 2 maps), and in protected (right 2 maps) areas. The colours reflect the four fragmentation levels: very low, low, medium, high, and very high fragmentation.

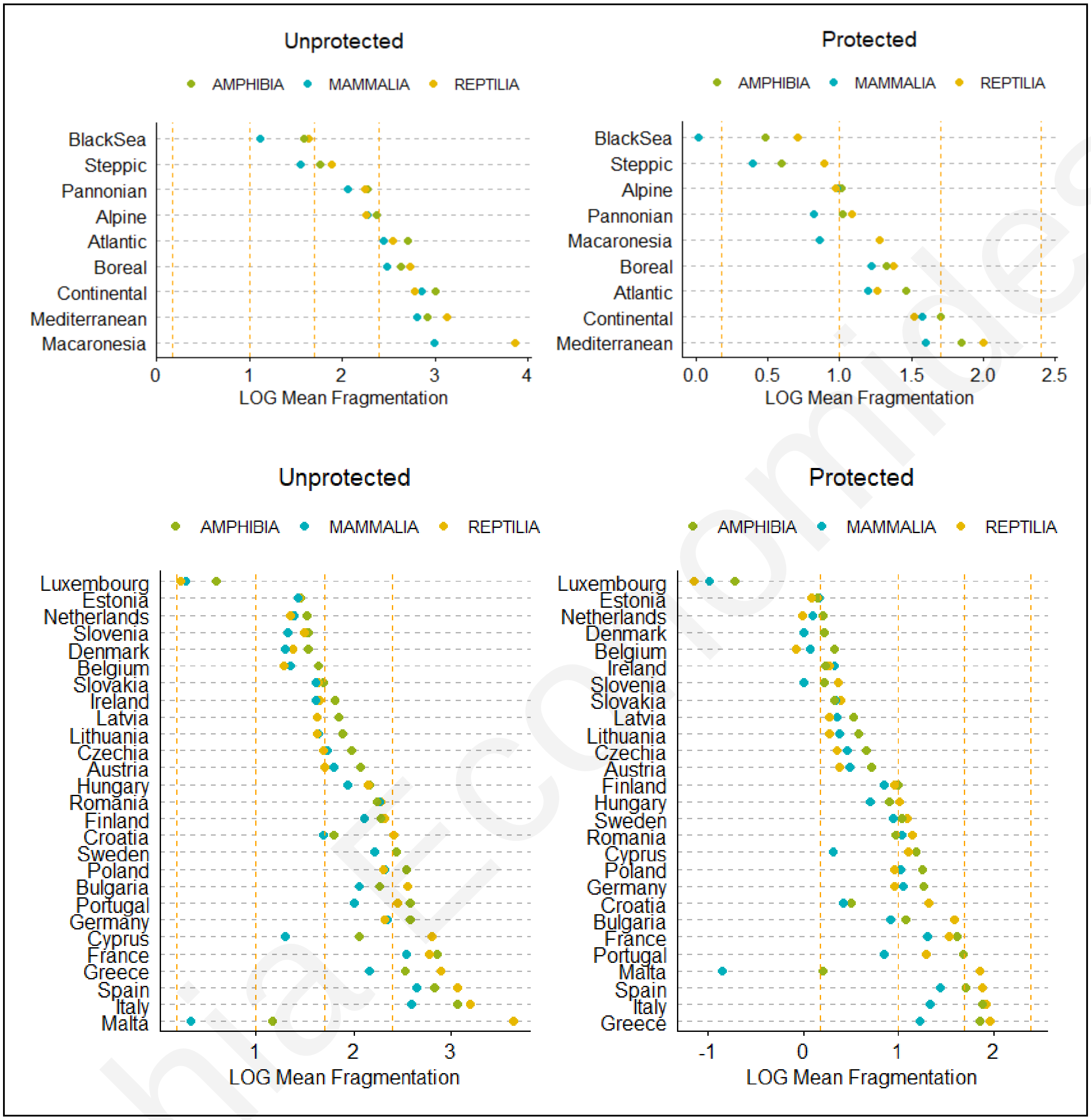

Figure 4 – Average mean fragmentation by biogeographical region (top), and EU countries (bottom), in unprotected (left), and in protected (right) areas, sorted by log mean fragmentation value in ascending order.

The vertical orange dashed lines signify the thresholds of very low (< log(1.5)), low (log(1.5) to log(10)), medium (log(10) to log(50)), high (log(50) to log(250)), and very high (>log(250)) fragmentation.

Area of Habitat

Amphibians, reptiles, and mammals were all relatively equally represented by their AOHs in comparison to their EU spatial ranges. On average, around 75% of all species' EU ranges corresponded to their AOH. The mean value was between 71% and 76% with the standard deviation ranging between 26% and 29%, the maximum value was at 99%, and the minimum value had the greatest difference between groups, as it was between 0% and 13% (Figure 5).

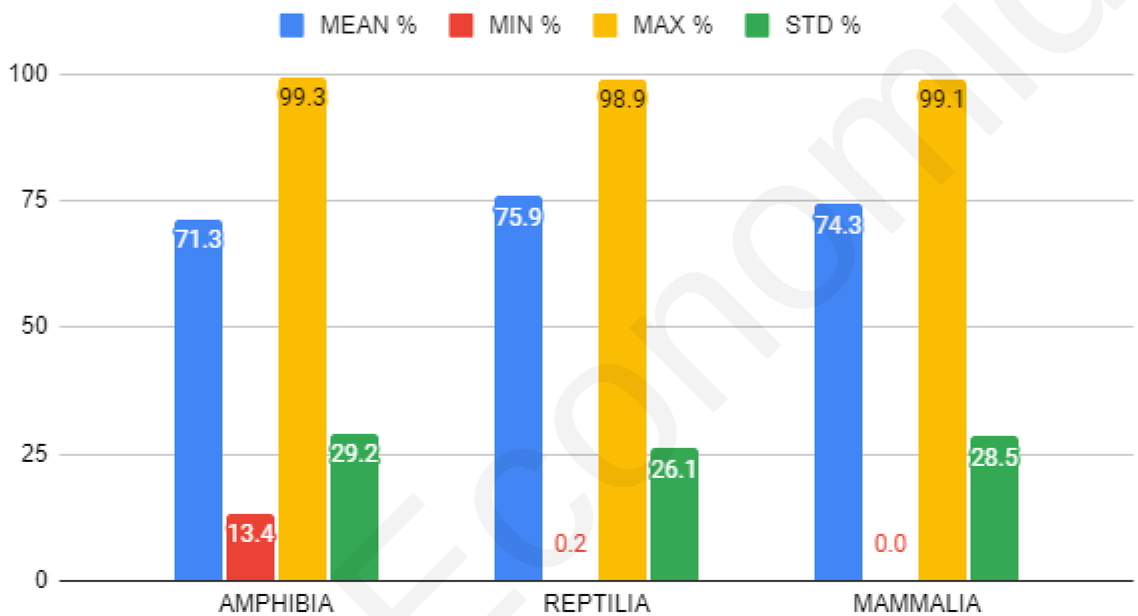

Figure 5 – Proportion of species' EU ranges represented by their AOH, grouped by species class.

Some species resulted in having 0 AOH (within the EU). This was sometimes a result of a species' spatial range having no suitable habitat nor suitable elevation. We infer this result coming from potential inaccuracies related to the elevation and/or habitat data. An example of this is Galan's rock lizard (*Iberolacerta galani*), a species only occurring in Spain, with an EOO of less than 5,000km^2 (Arribas, 2008).

Gap Analysis

Out of 341 species, we found that only 93 of them (27% of all species) have 30% of their AOHs protected under the Natura 2000 network (seen in Appendix Table 1). By species class, that corresponds to 19 amphibians, 46 reptiles, and 28 mammals, as seen in Figure 6. Amphibians have the lowest gap percentage values, except for minimum AOH gap values (Figure 7). The Bavarian Pine Vole (*Microtus bavaricus*) was the only "total gap species"; none of its AOH was protected, which causes the 0% minimum mammal gap value in Figure 7.

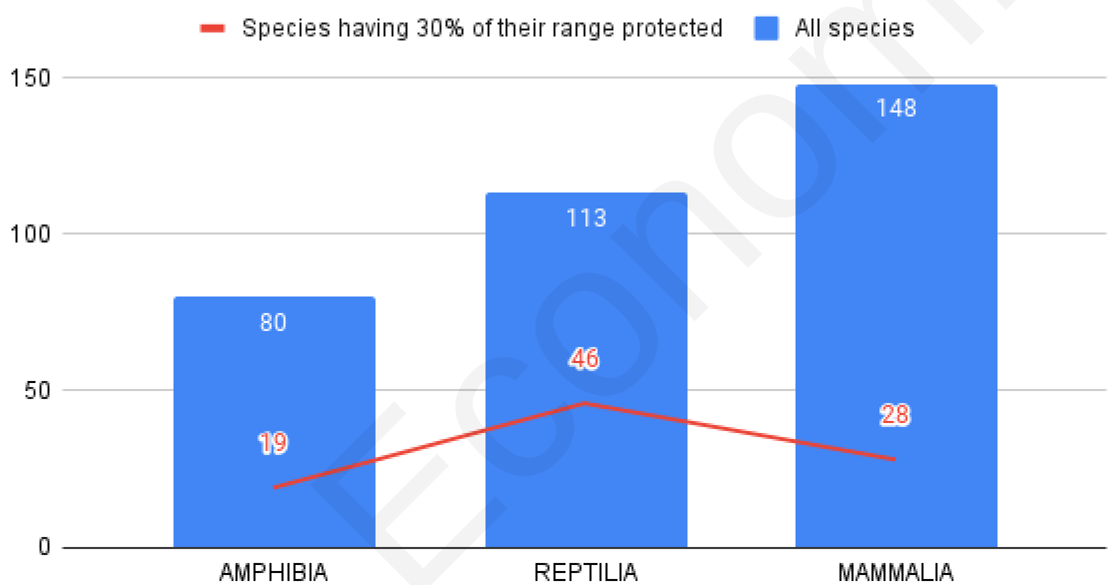

Figure 6 – All 341 species grouped by class. 24% of amphibians, 41% of reptiles, and 19% of terrestrial mammals have at least 30% of their EU ranges protected.

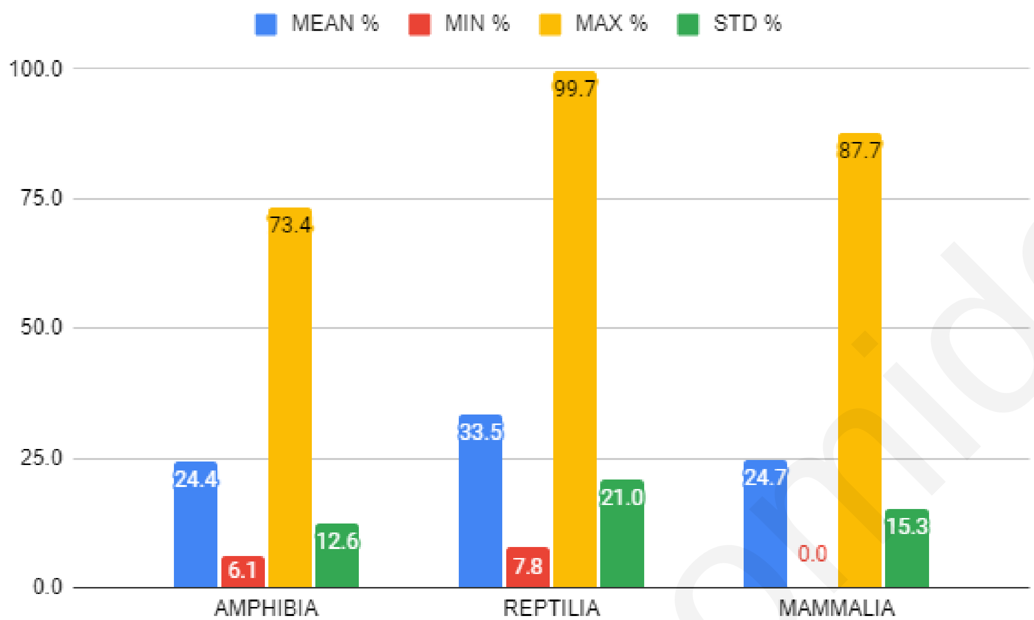

Figure 7 – Species' AOHs in Natura 2000 areas mean, min, max, and STD gap percentages by species class.

Statistical Analysis

The paired t-tests on protected and unprotected amphibians, reptiles, and mammals, were statistically significant and reported lower levels of fragmentation in protected areas (Amphibians: MD = -1.03, Reptiles: MD = -1.20, Mammals: MD = -1.13) rather than in unprotected areas (Amphibians: $t(79) = -15.59$, $p < 2.2e^{-16}$; Reptiles: $t(112) = -21.04$, $p < 2.2e^{-16}$; Mammals: $t(147) = -36.19$, $p < 2.2e^{-16}$), as also seen in Figure 8. Our produced dot charts show variable fragmentation within different biogeographic regions and within different EU countries (Figure 4), which follow the results of the biogeographical regions and EU country analyses. The produced box plots and violin plots demonstrate varying fragmentation levels per IUCN threat categories (Figure 9), species orders (Figure 10) and species families (Figure 11). ANOVAs revealed statistically significant differences in mean fragmentation between at least two threat categories for amphibians and reptiles, but not for mammals. Protected amphibians ($F(4, 75) = 7.50$, $p = 3.86e^{-05}$), unprotected amphibians ($F(4, 75) = 7.76$, $p = 2.74e^{-05}$), protected reptiles ($F(4, 107) = 10.59$, $p = 2.88e^{-07}$), and unprotected reptiles ($F(4, 107) = 15.96$, $p = 2.83e^{-10}$) had a statistically significant difference in mean fragmentation between at least two threat categories.

Protected mammals (F(4, 138) = 1.26, p = 0.29), and unprotected mammals (F(4, 139) = 1.62, p = 0.17) had no statistically significant difference in mean fragmentation between the threat categories.

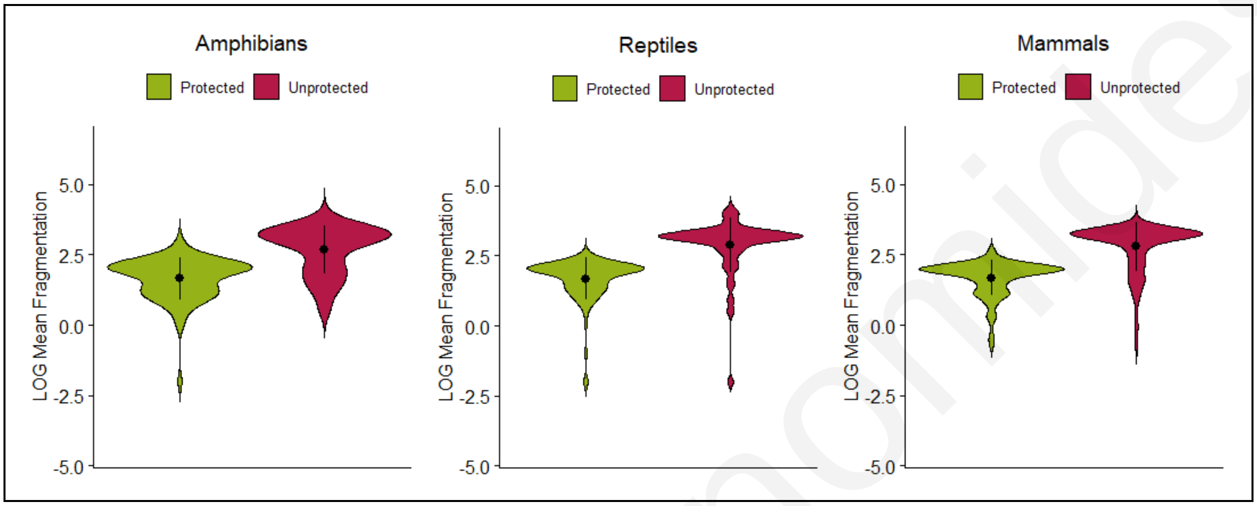

Figure 8 – Fragmentation of species classes in protected (green) and unprotected (red) areas for amphibians (left), reptiles (middle), and mammals (right). The dots and lines within the violins represent the mean and the standard deviation values respectively.

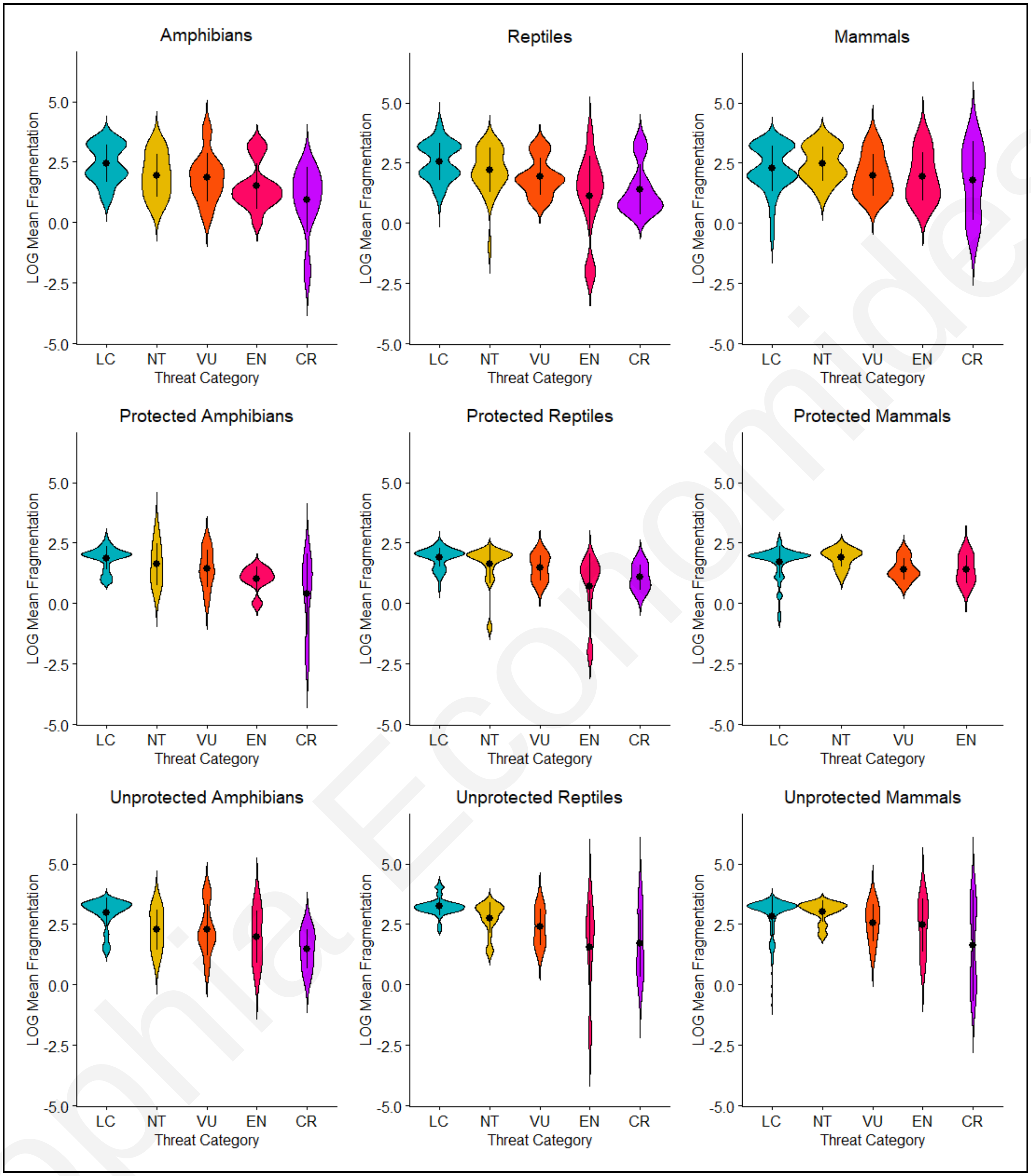

Figure 9 – Amphibians (left), reptiles (middle), and mammals (right) fragmentation by threat category in both protected and unprotected areas (top), protected areas only (middle), and unprotected areas only (bottom). The dots and lines within the violins represent the mean and the standard deviation values respectively.

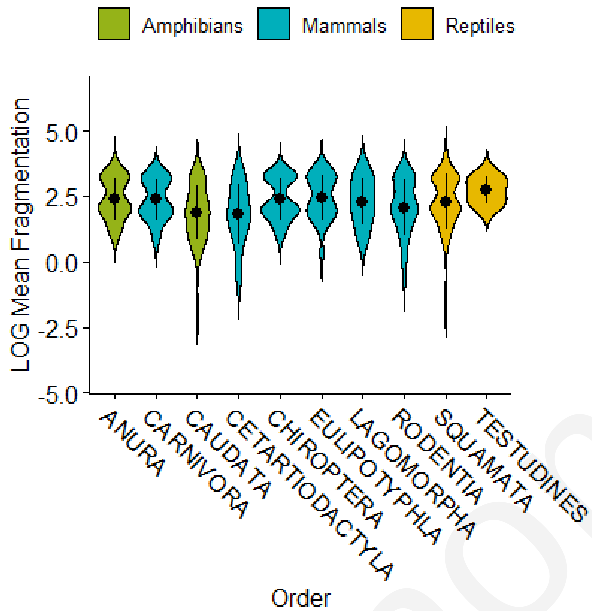

Figure 10 – Fragmentation levels per species orders. The dots and lines within the violins represent the mean and the standard deviation values respectively.

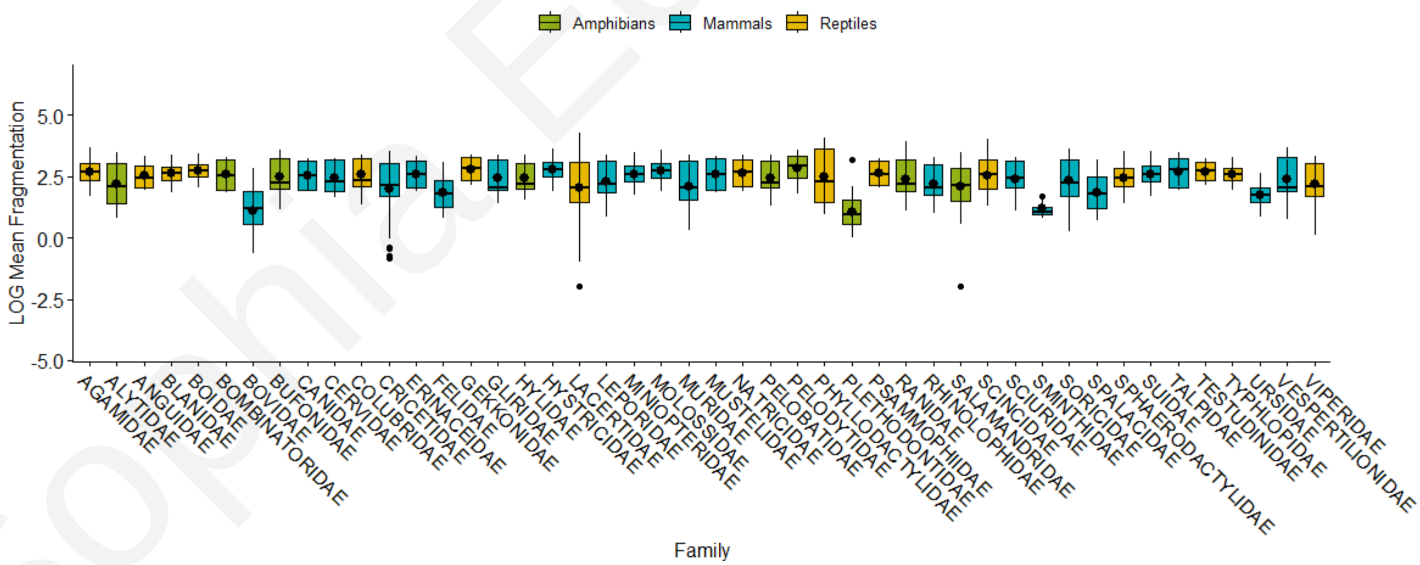

Figure 11 – Fragmentation levels per species families. The dots and lines within the bars represent the mean and the standard deviation values respectively. The dots outside the bars represent outliers.

DISCUSSION

Our results showed that the Natura 2000 sites are less fragmented than unprotected areas (Figure 8), but there are biogeographic regions and countries where protected areas can still be highly fragmented (Figure 3, Figure 4). Furthermore, many species' AOHs have large, unprotected portions with "high" fragmentation values (Appendix Table 1).

Biogeographical Regions & EU Country Analyses

The biogeographic region and country analyses revealed geographic areas of possible conservation priority. The fact that species AOHs are highly fragmented in the Mediterranean region is cause for concern because the Mediterranean basin is the second largest biodiversity hotspot in the world (CEPF, 2017).

In addition, the EU's biodiversity strategy for 2030 aims to enlarge the Natura 2000 network. Expanding protected areas into less fragmented landscapes is a sound ecological strategy, as suggested by Lawrence and Beierkuhnlein in 2023. To achieve this, we recommend expanding sites located in regions with less fragmented species habitats, such as the Black Sea, Steppic, Alpine, and Pannonian biogeographic regions shown in Figure 4 and Appendix Table 4.

The EU country analysis results are in partial contrast to holistic landscape fragmentation of EU countries by the European Environment Agency (2022a). Malta, the Netherlands, Belgium, Germany, and Luxembourg have "high" and "very high" fragmentation (in more than 65% of their whole relative area). But the Netherlands and Belgium actually have "medium" fragmentation in their species' unprotected areas, and "low" to "very low" fragmentation in their species' protected areas (Figure 4). Luxembourg has "low" fragmentation in its species' unprotected areas, and "very low" fragmentation in its species' protected areas (Figure 4).

Threatened Species

In light of the recently proposed nature restoration law in the EU (European Commission, 2022), we would like to bring species and species groups under heavy fragmentation (Figure 4) to the attention of EU member states' decision-makers, to restore their fragmented and degraded habitats.

It's important to note that a species range with high fragmentation values does not always mean it automatically has a higher conservation priority. The degree to which fragmentation negatively affects a species can vary, with some non-specialist species (Devictor et al., 2008), and species with poorer dispersal (Bélisle et al., 2001) being more impacted than others. For example, even though bats can have a high fragmentation within their ranges (as seen in Figure 10 for order Chiroptera), they can be found in higher abundances within partly fragmented landscape (Gorresen and Willig, 2004). Furthermore, we can see in Figure 11 that the amphibian family Plethodontidae has lower fragmentation than other amphibian families. Conservation efforts focused on fragmentation may not be able to prioritise all amphibians equally. Instead, it may be more effective to prioritise smaller groups of species, such as specific families or even individual species. Further research on species interactions could help identify higher priority species since the decline or extinction of species lower on the food chain could have a domino effect on many other species (Koh et al., 2004)

As seen in Figure 9, the fragmentation values of unprotected areas are more widely distributed than protected areas, especially for species in the vulnerable, endangered, and critically endangered threat categories. In the three categories, there are species with "high" fragmentation values.

1. The Italian Cave Salamander (*Speleomantes italicus*), an Italian endemic species, is currently endangered, only has 22% of its range protected, and its unprotected area's fragmentation is "very high" (seff = 1518).
2. The European Souslik (*Spermophilus citellus*) has 81% of its range in the EU, is currently endangered, only has 14% of its AOH protected, and its unprotected area's mean

fragmentation is "very high" (seff = 1734), and its protected area's mean fragmentation is "high".

3. Schreiber's fringe-fingered lizard (*Acanthodactylus schreiberi*), a species possibly only extant in Cyprus, has a very high unprotected area mean fragmentation (seff = 3406), with only 9% of its range being protected.
4. Ambrosi's Cave Salamander (*Speleomantes ambrosii*), an Italian endemic, only has 26% of its range protected, is currently critically endangered, and has a "high" mean fragmentation both within its protected and unprotected range.
5. Other currently vulnerable species without 30% of their ranges being protected and having "high" fragmentation include the Corsican Hare (*Lepus corsicanus*), the Skyros Wall Lizard (*Podarcis gaigeae*), Lataste's Viper (*Vipera latastei*), Schreiber's Bent-winged Bat (*Miniopterus schreibersii*), the Cretan Frog (*Pelophylax cretensis*), and the Italian agile frog (*Rana latastei*).

Furthermore, there are 178 species which are in the least concern threat category that have "high" fragmentation values within their AOHs. Of these species, 13 have "very high" fragmentation values both within their protected and unprotected areas: Erhard's Wall Lizard (*Podarcis erhardii*), the Maltese Wall Lizard (*Podarcis filfolensis*), the Limbless Skink (*Ophiomorus punctatissimus*), the Marginated Tortoise (*Testudo marginata*), the Sicilian Shrew (*Crocidura sicula*), the Calabria Pine Vole (*Microtus brachycercus*), the Macedonian Mouse (*Mus macedonicus*), the Balkan Mole (*Talpa stankovici*), the Balearic Green Toad (*Bufotes balearicus*), the Painted Frog (*Discoglossus pictus*), the Portuguese Smooth Newt (*Lissotriton maltzani*), the Lusitanian Parsley Frog (*Pelodytes atlanticus*), and the Balkan Water Frog (*Pelophylax kurtmuelleri*).

It is worth noting that the above species all have the majority of their EU ranges within their AOH, apart from the Limbless Skink, whose AOH only corresponds to 35% of its EU range. Furthermore, as seen in Appendix Table 1, there are 74 species whose AOH only corresponds to less than 50% of their EU ranges, out of which 64 of them have the majority of their global ranges within the EU. Only 23 of those species have 30% of their AOHs protected.

As seen in the statistical analysis results, fragmentation levels are related to the threat categories of amphibians and reptiles, but they are not related to the threat categories of mammals. Furthermore, as seen in Figure 9, fragmentation does not predict the extinction risk of any species class, contrary to other literature finding that fragmentation predicts extinction risk in mammals (Crooks et al., 2017). This might be a result of our use of better resolution elevation and habitat layers, and an AOH algorithm that utilises habitat maps with an exact match to IUCN habitat classification instead of using Habitat-Suitability Models (Rondinini et al., 2011) or similar methods.

Bringing some attention to the category of data deficient species of this study, as many of them could be threatened (Borgelt et al., 2022), out of all species studied, 5 were in this category: the Italian Aesculapian Snake (*Zamenis lineatus*), the Crete Spiny Mouse (*Acomys minous*), the Alcathoe Whiskered Bat (*Myotis alcathoe*), the Maghreb Mouse-eared Bat (*Myotis punicus*), and the Lesser Mole Rat (*Nannospalax leucodon*). The Crete Spiny Mouse is the only one of them which has at least 30% of its EU range protected, and the Italian Aesculapian Snake and the Lesser Mole Rat have “high” fragmentation values both within and outside their protected areas. This suggests possible threat and shows a possible demand for the same amount of attention as threatened species.

Based on Figure 5, the AOHs of species are about 75% smaller than their original geographical ranges. This percentage is higher than what other studies have found, which is around 40% for forest-dependent species outside the EU in areas experiencing rapid deforestation (Li et al., 2016). It seems that focusing on different habitats can impact this percentage (Li et al., 2016; Ocampo-Peñuela et al., 2016; Tracewski et al., 2016). However, it is clear that AOHs are significantly smaller than the geographic ranges of species.

We still have a long way to go in protecting at least 30% of all amphibian, reptile, and terrestrial mammal habitats of importance. Appendix Table 1 and Figure 6 show that only 41% of reptile species, 24% of amphibian species, and 19% of mammal species have 30% or more of their habitats within the Natura 2000 networks.

The lower fragmentation values of species' AOHs within Natura 2000 sites should not lower our guards. Natura 2000 areas can still be highly fragmented, especially in specific biogeographic regions and countries. Species' AOHs are considerably smaller than their geographic ranges, and a majority of them fall within unprotected areas, which are heavily affected by fragmentation.

Limitations

Fragmentation

The fragmentation dataset we used in this study is calculated based on anthropogenic barriers and transportation infrastructure. This is of course not the only way a landscape can become fragmented. For example, fragmentation can be evident via deforestation and wildfires (Harper et al., 2007; Bosso et al., 2018) - which we did not consider in this study and could thus yield different results according to the dataset used.

Protected Areas

"Gap species" obtained through the gap analysis (i.e., species not reaching representation targets) can be set with varying criteria. Our gap analysis set the species representation targets at 30%, in line with the EU's biodiversity strategy for 2030 as an approximate standard. However, we could have instead used proportional representation targets, based on the species' range size (Catullo et al., 2008), or based on alternative habitats available for a species to use through ecological niche shift in the scenario that their current habitat is destroyed, e.g. through fragmentation.

Habitats and AOHs

The habitat dataset we used has a global range. Utilising a dataset that focuses on European habitats could yield more accurate habitat results (Jung et al., 2020). Moreover, there is no standard for the validation of AOHs. Validation could be approached by cross-checking the AOHs with species occurrence points, if they exist and if they are not biased (Dahal et al., 2022).

Future Work

Habitats

The AOH data deriving from the analyses of this study could be used in further work to provide insights into the prioritisation of the creation or expansion of conservation areas for locally valuable species of particular EU member states (Figure 4).

While AOH is not identical to EOO nor AOO, it can be used to estimate EOO's maximum boundary (Brooks et al., 2019). So, by using our resulting species AOH rasters and their mean fragmentation values, species' threat categories could be assessed through IUCN criterion B1a (IUCN, 2012b). If our AOH rasters are scaled to a 2x2km grid, they can also be used to estimate the maximum boundary of AOO, and could be used to assess species' threat categories through IUCN criterion B2a (IUCN, 2012b; Brooks et al., 2019).

Moreover, since species are associated with specific habitats, more work could be done to identify habitats which are more likely to be fragmented, and thus perhaps uncover which habitats are of greatest conservation priority.

Protected Areas

Even though the establishment of Natura 2000 sites often targets the protection of particular species or habitats (Directorate-General for Environment (European Commission) et al., 2008), they can also be beneficial to other species within their area, simply by co-existing, or for example through habitat connectivity (De La Fuente et al., 2018).

Future studies could take into account protected areas of different networks outside the EU (Bosso et al., 2018), and not just the Natura 2000 network, for example using the World Database on Protected Areas compiled by the UNEP (2023). They could seemingly provide a more well-rounded gap analysis for each species in terms of protected AOH, especially within the Mediterranean which also consists of African and Middle Eastern countries.

In addition, further work incorporating the results of this study could be done for other species groups. For example plants as they are on the first trophic levels, or birds as they can be affected by anthropogenic fragmentation (Mammides et al., 2016). Assuming data is available in a format which incorporates species and landscape habitats, similar work could be done on other terrestrial species groups such as arthropods as they tend to be lower on the trophic web.

The species filtering that we applied could be removed for more in-depth country-level studies which could also take place to inform local governing bodies and conservation actions. For example, our filter excluded species like the Egyptian fruit bat which can provide Cyprus great pollination and seed dispersal services (del Vaglio et al., 2011). Such studies would also require less computing power and thus this could be a subject accessible to even more researchers.

ABBREVIATIONS

ABBREVIATION	MEANING
ANOVA	Analysis of Variance
API	Application Programming Interface
CEPF	Critical Ecosystem Partnership Fund
ETRS_1989_LAEA	European Terrestrial Reference System 1989 Lambert Azimuthal Equal-Area
EU	European Union
GB	Giga Byte
IUCN	International Union for Conservation of Nature
RAM	Random Access Memory
UNEP	United Nations Environment Programme

BIBLIOGRAPHY

ABELLÁN, P. and SÁNCHEZ-FERNÁNDEZ, D. (2015) A gap analysis comparing the effectiveness of Natura 2000 and national protected area networks in representing European amphibians and reptiles. *Biodiversity and Conservation*, 24(6), pp. 1377–1390.

AGUILAR MUGICA, S. et al. (2009) *Important bird areas Americas: priority sites for biodiversity conservation*. Quito, Ecuador: Birdlife International.

ANDREWS, K.M., LANGEN, T.A. and STRUIJK, R.P.J.H. (2015) Reptiles: Overlooked but Often at Risk from Roads. In: VAN DER REE, R., SMITH, D.J. and GRILO, C. (eds.) *Handbook of Road Ecology*. Chichester, UK: John Wiley & Sons, Ltd, pp. 271–280.

ARRIBAS, O. (2008) IUCN Red List of Threatened Species: Iberolacerta galani. *IUCN Red List of Threatened Species*, [Online] Available from: https://www.iucnredlist.org/en [Accessed 26/04/2023].

BEEBEE, T.J.C. (2013) Effects of Road Mortality and Mitigation Measures on Amphibian Populations: Amphibians and Roads. *Conservation Biology*, 27(4), pp. 657–668.

BÉLISLE, M., DESROCHERS, A. and FORTIN, M.-J. (2001) INFLUENCE OF FOREST COVER ON THE MOVEMENTS OF FOREST BIRDS: A HOMING EXPERIMENT. *Ecology*, 82(7), pp. 1893–1904.

BORGELT, J. et al. (2022) More than half of data deficient species predicted to be threatened by extinction. *Communications Biology*, 5(1), p. 679.

BOSSO, L., ANCILLOTTO, L., et al. (2018) Loss of potential bat habitat following a severe wildfire: a model-based rapid assessment. *International Journal of Wildland Fire*, 27(11), p. 756.

BOSSO, L., SMERALDO, S., et al. (2018) Nature protection areas of Europe are insufficient to preserve the threatened beetle *Rosalia alpina* (Coleoptera: Cerambycidae): evidence from species distribution models and conservation gap analysis: Conservation gap analysis for R. alpina in Europe. *Ecological Entomology*, 43(2), pp. 192–203.

Brooks, T.M. et al. (2019) Measuring Terrestrial Area of Habitat (AOH) and Its Utility for the IUCN Red List. *Trends in Ecology & Evolution*, 34(11), pp. 977–986.

Catullo, G. et al. (2008) A gap analysis of Southeast Asian mammals based on habitat suitability models. *Biological Conservation*, 141(11), pp. 2730–2744.

CEPF (2017) *Ecosystem Profile: Mediterranean Basin Biodiversity Hotspot* .

Crooks, K.R. et al. (2017) Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals. *Proceedings of the National Academy of Sciences*, 114(29), pp. 7635–7640.

Dahal, P.R. et al. (2022) A validation standard for area of habitat maps for terrestrial birds and mammals. *Geoscientific Model Development*, 15(13), pp. 5093–5105.

De La Fuente, B. et al. (2018) Natura 2000 sites, public forests and riparian corridors: The connectivity backbone of forest green infrastructure. *Land Use Policy*, 75, pp. 429–441.

Devictor, V., Julliard, R. and Jiguet, F. (2008) Distribution of specialist and generalist species along spatial gradients of habitat disturbance and fragmentation. *Oikos*, 117(4), pp. 507–514.

Directorate-General for Environment (European Commission) et al. (2008) *Natura 2000 :protecting Europe's biodiversity*. LU: Publications Office of the European Union.

Dória, T.A.F. and Dobrovolski, R. (2021) Improving post-2020 conservation of terrestrial vertebrates in Caatinga. *Biological Conservation*, 253, p. 108894.

Esri (2023) *Some statistics are approximate — ArcGIS Pro | Documentation*. Available from :
https://pro.arcgis.com/en/pro-app/3.0/tool-reference/tool-errors-and-warnings/010001-020000/tool-errors-and-warnings-10626-10650-010644.htm [Accessed 28/03/23].

European Commission (2020) *Biodiversity Strategy for 2030 Bringing nature back into our lives*.

European Commission (2022) *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on nature restoration*.

European Commission (2023a) *Natura 2000 - Environment*. Available from : https://ec.europa.eu/environment/nature/natura2000/index_en.htm [Accessed 28/03/23].

European Commission (2023b) *EU Biodiversity Strategy Dashboard*. Available from : https://dopa.jrc.ec.europa.eu/kcbd/dashboard/ [Accessed 07/04/23].

European Commission (2023c) *Biodiversity strategy for 2030*. Available from : https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en [Accessed 09/03/23].

European Commission (2023d) *Nature Restoration Law*. Available from : https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en [Accessed 07/05/23].

European Environment Agency (2003) JRC ESDI Action 2142.

European Environment Agency (2016) *EEA geospatial data catalogue*. Available from : https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/c6d27566-e699-4d58-a132-bbe3fe01491b [Accessed 05/04/23].

European Environment Agency (2021) *EEA geospatial data catalogue*. Available from : https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/67110f21-39cb-48be-878e-d08b64a72256 [Accessed 09/03/23].

European Environment Agency (2022a) *Landscape fragmentation pressure in Europe*. Available from : https://www.eea.europa.eu/ims/landscape-fragmentation-pressure-in-europe [Accessed 28/03/23].

European Environment Agency (2022b) *Natura 2000 data - the European network of protected sites — European Environment Agency*. Available from : https://www.eea.europa.eu/data-and-maps/data/natura-13 [Accessed 28/03/23].

Eurostat (2020) *Countries - GISCO* . Available from : https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries [Accessed 28/03/23].

Fahrig, L. and Rytwinski, T. (2009) Effects of Roads on Animal Abundance: an Empirical Review and Synthesis. *Ecology and Society*, 14(1), [Online] Available from: doi.org/10.5751/ES-02815-140121 [Accessed 05/04/2023].

Gorresen, P.M. and Willig, M.R. (2004) LANDSCAPE RESPONSES OF BATS TO HABITAT FRAGMENTATION IN ATLANTIC FOREST OF PARAGUAY. *Journal of Mammalogy*, 85(4), pp. 688–697.

Haddad, N.M. et al. (2015) Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, 1(2), p. e1500052.

Hanson, J. (2021) Digital elevation model (100m) Version 1.0.0.

Hanson, J. (2022) aoh: Create Area of Habitat Data.[R].

Harper, G.J. et al. (2007) Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation*, 34(04), [Online] Available from: doi.org/10.1017/S0376892907004262 [Accessed 13/04/2023].

Higgins, K. and Lynch, M. (2001) Metapopulation extinction caused by mutation accumulation. *Proceedings of the National Academy of Sciences*, 98(5), pp. 2928–2933.

IUCN (2012a) *IUCN Habitats Classification Scheme Version 3.1*. Available from : https://www.iucnredlist.org/en [Accessed 09/05/23].

IUCN (2012b) *IUCN Red List categories and criteria, version 3.1*. second. IUCN.

IUCN (2021) *Mapping Standards and Data Quality for IUCN Red List Spatial Data*. Available from : https://www.iucnredlist.org/resources/mappingstandards [Accessed 28/03/23].

IUCN (2022a) *IUCN Red List of Threatened Species*. Available from : https://apiv3.iucnredlist.org/ [Accessed 28/03/23].

IUCN (2022b) *Spatial Data Download*. Available from : https://www.iucnredlist.org/resources/spatial-data-download [Accessed 28/03/23].

IUCN (2023) *IUCN Red List of Threatened Species*. Available from : https://www.iucnredlist.org/en [Accessed 22/03/23].

JUNG, M. et al. (2020) A global map of terrestrial habitat types. *Scientific Data*, 7(1), p. 256.

KOH, L.P. et al. (2004) Species Coextinctions and the Biodiversity Crisis. *Science*, 305(5690), pp. 1632–1634.

KORINE, C. (2016) IUCN Red List of Threatened Species: Rousettus aegyptiacus. *IUCN Red List of Threatened Species*, [Online] Available from: https://www.iucnredlist.org/en [Accessed 28/03/2023].

LAWRENCE, A. and BEIERKUHNLEIN, C. (2023) Detecting low fragmented sites surrounding European protected areas – Implications for expansion of the Natura 2000 network. *Journal for Nature Conservation*, 73, p. 126398.

LI, B.V. et al. (2016) Remotely Sensed Data Informs Red List Evaluations and Conservation Priorities in Southeast Asia. *PLOS ONE*, 11(8), p. e0160566.

LUMBIERRES, M. et al. (2022) Area of Habitat maps for the world's terrestrial birds and mammals. *Scientific Data*, 9(1), p. 749.

MAIORANO, L. et al. (2015) On how much biodiversity is covered in Europe by national protected areas and by the Natura 2000 network: insights from terrestrial vertebrates. *Conservation Biology*, 29(4), pp. 986–995.

MAMMIDES, C. et al. (2016) Do unpaved, low-traffic roads affect bird communities? *Acta Oecologica*, 71, pp. 14–21.

MEINIG, H. (2019) IUCN Red List of Threatened Species: Microtus bavaricus. *IUCN Red List of Threatened Species*, [Online] Available from: https://www.iucnredlist.org/en [Accessed 05/04/2023].

NIKOLAOU, C. (2017) *Ta agria thēlastika tēs Kyprou*. Leukōsia: Philodasikos Syndesmos Kyprou.

OCAMPO-PEÑUELA, N. et al. (2016) Incorporating explicit geospatial data shows more species at risk of extinction than the current Red List. *Science Advances*, 2(11), p. e1601367.

PÜTTKER, T. et al. (2020) Indirect effects of habitat loss via habitat fragmentation: A cross-taxa analysis of forest-dependent species. *Biological Conservation*, 241, p. 108368.

Ramesh, V. et al. (2017) IUCN greatly underestimates threat levels of endemic birds in the Western Ghats. *Biological Conservation*, 210, pp. 205–221.

Robinson, N., Regetz, J. and Guralnick, R.P. (2014) EarthEnv-DEM90: A nearly-global, void-free, multi-scale smoothed, 90m digital elevation model from fused ASTER and SRTM data. *ISPRS Journal of Photogrammetry and Remote Sensing*, 87, pp. 57–67.

Rondinini, C. et al. (2011) Global habitat suitability models of terrestrial mammals. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1578), pp. 2633–2641.

Rull, V. (2022) Biodiversity crisis or sixth mass extinction?: Does the current anthropogenic biodiversity crisis really qualify as a mass extinction? *EMBO reports*, 23(1), [Online] Available from: doi.org/10.15252/embr.202154193 [Accessed 13/04/2023].

Rytwinski, T. and Fahrig, L. (2015) The Impacts of Roads and Traffic on Terrestrial Animal Populations. In: Van Der Ree, R., Smith, D.J. and Grilo, C. (eds.) *Handbook of Road Ecology*. Chichester, UK: John Wiley & Sons, Ltd, pp. 237–246.

Singh, J.S. (2002) The biodiversity crisis: A multifaceted review. *Current Science*, 82(6), pp. 638–647.

Smith, A.M. and Green, D.M. (2005) Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? *Ecography*, 28(1), pp. 110–128.

Tracewski, Ł. et al. (2016) Toward quantification of the impact of 21st-century deforestation on the extinction risk of terrestrial vertebrates: Effects of Deforestation on Vertebrates. *Conservation Biology*, 30(5), pp. 1070–1079.

UNEP (2023) *Protected Planet*. [Online] Protected Planet. Available from : https://www.protectedplanet.net/en/about [Accessed 05/04/23].

del Vaglio, M.A. et al. (2011) A first assessment of feeding habits in the fruit bat Rousettus aegyptiacus on Cyprus island. *Hystrix, the Italian Journal of Mammalogy*, 22(2), [Online] Available from: doi.org/10.4404/hystrix-22.2-4587 [Accessed 20/04/2023].

APPENDIX

Appendix Table 1

Species data including: proportion of a species' EU range represented by its AOH, proportion of AOH being protected, mean fragmentation value in unprotected areas, and mean fragmentation value in protected areas (before adding a 0.01 step to all values). Area values are represented in km^2, fragmentation values are represented in seff.

Species Name	Global Range Area (ArcGIS)	EU Range Area (ArcGIS)	% Of Global Range In EU	AOH Area In EU	% Of AOH From EU Range	Protected Fragmentation Mean	Unprotected Fragmentation Mean	Protected Area	% Of AOH In EU	Species Class	IUCN Category
Ablepharus budaki	121191	9133	7.5	8728	95.6	26.3	2890.7	1622.03	18.6	REPTILIA	LC
Algyroides marchi	3537	3537	100.0	916	25.9	6.3	9.4	740.37	80.9	REPTILIA	EN
Anatololacerta oertzeni	41440	1700	4.1	1404	82.6	26.3	940.4	482.21	34.3	REPTILIA	LC
Chalcides chalcides	240739	203814	84.7	195022	95.7	148.8	2319.0	32936.45	16.9	REPTILIA	LC
Chalcides sexlineatus	1538	1522	99.0	1020	67.0	20.2	10892.8	433.14	42.5	REPTILIA	LC
Chalcides simonyi	534	529	99.1	365	69.0	44.2	447.6	169.61	46.4	REPTILIA	EN
Chalcides striatus	508659	508142	99.9	499581	98.3	117.9	1593.4	121298.81	24.3	REPTILIA	LC
Chalcides viridanus	1958	1819	92.9	1259	69.2	24.1	5611.4	586.19	46.6	REPTILIA	LC
Dalmatolacerta oxycephala	26943	10430	38.7	7861	75.4	102.6	1204.0	3663.23	46.6	REPTILIA	LC
Dolichophis caspius	1532101	260777	17.0	254688	97.7	107.5	1106.1	74184.74	29.1	REPTILIA	LC
Elaphe sauromates	2275072	102688	4.5	76498	74.5	142.9	1080.6	16759.69	21.9	REPTILIA	LC
Euleptes europaea	33816	33326	98.6	21016	63.1	50.6	1620.8	3127.64	14.9	REPTILIA	NT
Gallotia caesaris	660	605	91.5	388	64.1	20.1	305.2	235.46	60.8	REPTILIA	LC
Gallotia intermedia	100	94	94.1	24	25.0	7.5	988.0	19.72	83.8	REPTILIA	CR
Gallotia simonyi	7	6	94.0	1	15.2	6.3	5.0	0.92	95.8	REPTILIA	CR
Gallotia stehlini	1538	1522	99.0	898	59.0	19.5	11313.6	407.27	45.4	REPTILIA	LC
Hemidactylus turcicus	875892	91625	10.5	76260	83.2	140.2	1969.5	14969.1	19.6	REPTILIA	LC
Hemorrhois hippocrepis	802749	349335	43.5	297295	85.1	135.0	1873.5	71409.46	24.0	REPTILIA	LC
Hierophis cypriensis	1373	1373	100.0	710	51.7	23.2	116.1	398.49	56.1	REPTILIA	EN
Iberolacerta monticola	20285	20199	99.6	10917	54.0	9.2	83.7	4654.34	42.6	REPTILIA	VU
Lacerta bilineata	815403	805813	98.8	782166	97.1	139.8	2394.9	124806.17	16.0	REPTILIA	LC
Lacerta viridis	1130059	609725	54.0	598535	98.2	86.5	1274.3	144291.45	24.1	REPTILIA	LC
Macrovipera schweizeri	304	258	85.0	215	83.1	14.1	473.0	93.26	43.4	REPTILIA	EN
Malpolon insignitus	2068696	151014	7.3	148438	98.3	135.1	1217.6	45049.46	30.3	REPTILIA	LC
Malpolon monspessulanus	1195684	573755	48.0	498200	86.8	126.7	1783.0	116598.93	23.4	REPTILIA	LC
Montivipera xanthina	231334	6210	2.7	4863	78.3	42.2	913.7	1738.25	35.7	REPTILIA	LC
Platyceps najadum	1477463	161286	10.9	158250	98.1	121.4	1195.0	49769.92	31.5	REPTILIA	LC
Podarcis carbonelli	4684	4641	99.1	694	15.0	42.4	234.9	350.84	50.6	REPTILIA	EN
Podarcis erhardii	144732	98105	67.8	67435	68.7	258.7	1621.9	16685.77	24.7	REPTILIA	LC
Podarcis filfolensis	317	291	91.7	281	96.6	290.3	18026.4	21.91	7.8	REPTILIA	LC
Podarcis melisellensis	31591	19640	62.2	19107	97.3	144.3	2019.0	9107.56	47.7	REPTILIA	LC
Podarcis milensis	243	199	82.1	175	87.7	17.5	574.8	90.64	51.8	REPTILIA	VU
Podarcis pityusensis	660	642	97.2	448	69.8	126.8	2312.2	62.79	14.0	REPTILIA	NT
Podarcis siculus	275646	273206	99.1	269613	98.7	141.5	3090.7	49774.77	18.5	REPTILIA	LC
Podarcis tauricus	404061	272198	67.4	200724	73.7	175.9	1331.8	43770.43	21.8	REPTILIA	LC
Podarcis vaucheri	305799	44656	14.6	43863	98.2	53.9	1903.8	10172.07	23.2	REPTILIA	LC
Psammodromus hispanicus	488886	488488	99.9	434214	88.9	125.9	1738.5	101545.13	23.4	REPTILIA	LC
Psammodromus jeanneae	245806	245112	99.7	91933	37.5	14.9	183.3	35697.72	38.8	REPTILIA	LC
Pseudopus apodus	1186914	159422	13.4	157011	98.5	143.9	1100.6	47836.26	30.5	REPTILIA	LC
Tarentola boettgeri	1756	1710	97.4	787	46.0	17.8	11788.5	316.97	40.3	REPTILIA	LC
Tarentola delalandii	2745	2624	95.6	2104	80.2	13.4	5645.5	1159.2	55.1	REPTILIA	LC
Tarentola gomerensis	366	340	92.9	143	42.2	9.0	284.8	76.25	53.2	REPTILIA	LC
Telescopus fallax	1262262	163575	13.0	158930	97.2	128.3	1284.8	48187.16	30.3	REPTILIA	LC
Timon lepidus	619377	618610	99.9	611470	98.8	104.3	1610.8	150829.93	24.7	REPTILIA	NT
Vipera ammodytes	540875	341249	63.1	330975	97.0	94.3	1085.2	101019.91	30.5	REPTILIA	LC
Vipera berus	9011563	2227994	24.7	2137538	95.9	68.3	1455.2	311693.99	14.6	REPTILIA	LC
Vipera graeca	17204	10686	62.1	23	0.2	1.2	3.0	22.47	99.7	REPTILIA	EN
Vipera seoanei	82889	82607	99.7	81705	98.9	34.8	970.9	19073.06	23.3	REPTILIA	LC
Vipera ursinii	66692	38120	57.2	18935	49.7	85.4	1729.5	6984.8	36.9	REPTILIA	VU
Zamenis scalaris	549249	548754	99.9	520566	94.9	110.5	1721.3	133088.09	25.6	REPTILIA	LC

Species Name	Global Range Area (ArcGIS)	EU Range Area (ArcGIS)	% Of Global Range In EU	AOH Area In EU	% Of AOH From EU Range	Protected Fragmentation Mean	Unprotected Fragmentation Mean	Protected Area	% Of AOH In EU	Species Class	IUCN Category
Zamenis situla	388748	165615	42.6	119233	72.0	232.5	1924.3	29988.69	25.2	REPTILIA	LC
Zootoca vivipara	14041981	2678016	19.1	2576822	96.2	72.7	1723.6	404750.33	15.7	REPTILIA	LC
Ablepharus kitaibelii	683687	290771	42.5	283199	97.4	103.4	1195.2	78894.17	27.9	REPTILIA	LC
Acanthodactylus erythrurus	699083	336359	48.1	311981	92.8	92.1	1597.5	86807.32	27.8	REPTILIA	LC
Acanthodactylus schreiberi	8606	8219	95.5	6592	80.2	35.7	3406.5	603.96	9.2	REPTILIA	EN
Algyroides fitzingeri	32884	32479	98.8	31911	98.3	30.3	996.1	5363.1	16.8	REPTILIA	LC
Algyroides moreoticus	22701	22476	99.0	20777	92.4	94.8	498.8	3158.19	15.2	REPTILIA	NT
Algyroides nigropunctatus	65236	37617	57.7	36595	97.3	103.0	1134.1	14838.24	40.5	REPTILIA	LC
Anguis cephallonica	22883	22655	99.0	20982	92.6	96.3	484.8	3194.06	15.2	REPTILIA	NT
Anguis fragilis	2673612	2106227	78.8	2047160	97.2	105.9	2270.5	331368.35	16.2	REPTILIA	LC
Archaeolacerta bedriagae	4449	4389	98.6	1798	41.0	8.5	26.0	636.45	35.4	REPTILIA	NT
Blanus cinereus	387748	387416	99.9	381216	98.4	115.1	1507.9	98078.39	25.7	REPTILIA	LC
Chalcides bedriagai	356695	356366	99.9	350337	98.3	99.4	1445.3	96969.31	27.7	REPTILIA	NT
Coronella austriaca	6216925	2656456	42.7	2602066	98.0	91.8	2036.7	492567.83	18.9	REPTILIA	LC
Coronella girondica	1200003	796814	66.4	787437	98.8	94.7	1618.5	184662.34	23.5	REPTILIA	LC
Darevskia praticola	271841	87889	32.3	61941	70.5	27.9	542.3	19911.79	32.1	REPTILIA	NT
Dinarolacerta mosorensis	16692	2766	16.6	806	29.2	6.8	39.2	309.9	38.4	REPTILIA	VU
Elaphe quatuorlineata	303925	242631	79.8	237578	97.9	147.4	1700.8	62082.78	26.1	REPTILIA	NT
Eryx jaculus	2307641	85315	3.7	62740	73.5	183.5	1734.9	14442.19	23.0	REPTILIA	LC
Gallotia atlantica	2521	2421	96.0	434	17.9	111.1	10401.3	179.21	41.3	REPTILIA	LC
Gallotia bravoana	3	3	100.0	2	65.2	3.0	3.0	0.17	9.1	REPTILIA	CR
Gallotia galloti	2745	2624	95.6	2158	82.2	13.0	5643.8	1212.83	56.2	REPTILIA	LC
Hellenolacerta graeca	21406	21239	99.2	20840	98.1	77.6	483.1	3768.78	18.1	REPTILIA	NT
Hierophis gemonensis	110763	81959	74.0	55554	67.8	214.2	1720.8	13996.59	25.2	REPTILIA	LC
Hierophis viridiflavus	654954	647478	98.9	617229	95.3	132.8	2173.9	94350.88	15.3	REPTILIA	LC
Iberolacerta aranica	60	60	100.0	27	44.5	0.0	0.0	20.95	78.6	REPTILIA	EN
Iberolacerta aurelioi	122	111	90.8	85	76.2	0.0	0.0	60.58	71.6	REPTILIA	EN
Iberolacerta bonnali	1583	1583	100.0	1057	66.7	0.1	25.8	899.75	85.2	REPTILIA	NT
Iberolacerta cyreni	6609	6609	100.0	3152	47.7	15.5	135.0	2082.14	66.1	REPTILIA	EN
Iberolacerta horvathi	13382	13382	100.0	8397	62.7	11.3	122.8	4084.12	48.6	REPTILIA	NT
Iberolacerta martinezricai	248	248	100.0	73	29.5	42.7	8.5	70.38	96.2	REPTILIA	CR
Lacerta agilis	9395101	1760001	18.7	1724728	98.0	93.4	2321.6	302806.84	17.6	REPTILIA	LC
Lacerta schreiberi	139406	139125	99.8	136345	98.0	92.8	1272.9	37096.04	27.2	REPTILIA	NT
Lacerta trilineata	537609	225571	42.0	158623	70.3	180.0	1337.5	41271.36	26.0	REPTILIA	LC
Macroprotodon brevis	434880	229685	52.8	225961	98.4	108.3	1574.7	63969.09	28.3	REPTILIA	NT
Mediodactylus kotschyi	655286	165113	25.2	124367	75.3	240.7	1816.5	28543.06	23.0	REPTILIA	LC
Natrix maura	1753661	955671	54.5	919626	96.2	112.0	1587.6	190621.05	20.7	REPTILIA	LC
Natrix natrix	12633377	2006658	15.9	1947128	97.0	76.2	1479.0	349667.22	18.0	REPTILIA	LC
Natrix tessellata	7647439	999070	13.1	635153	63.6	158.4	2406.3	109456.83	17.2	REPTILIA	LC
Ophiomorus punctatissimus	24905	16838	67.6	5899	35.0	373.6	663.3	578.4	9.8	REPTILIA	LC
Phoenicolacerta troodica	9273	9133	98.5	7640	83.6	33.0	3095.0	1008.1	13.2	REPTILIA	LC
Podarcis bocagei	58389	58209	99.7	57158	98.2	47.5	1318.8	12048.36	21.1	REPTILIA	LC
Podarcis cretensis	2946	2864	97.2	289	10.1	17.3	124.0	149.79	51.9	REPTILIA	EN
Podarcis gaigeae	227	211	93.0	22	10.3	72.1	49.5	3.33	15.3	REPTILIA	VU
Podarcis hispanicus	561362	560372	99.8	530115	94.6	99.4	1437.6	137646.74	26.0	REPTILIA	LC
Podarcis lilfordi	119	12	9.7	6	49.8	73.3	6255.7	5.6	97.2	REPTILIA	EN
Podarcis muralis	1831048	1444035	78.9	1418012	98.2	101.0	2010.8	293203.04	20.7	REPTILIA	LC
Podarcis peloponnesiacus	21407	21240	99.2	15144	71.3	106.3	646.8	2614	17.3	REPTILIA	LC
Podarcis raffonei	8	4	49.3	3	65.7	41.6	2454.4	2.27	84.4	REPTILIA	CR
Podarcis tiliguerta	32898	32486	98.7	31916	98.2	30.4	996.1	5367.6	16.8	REPTILIA	LC
Podarcis waglerianus	23914	23695	99.1	23293	98.3	166.0	2375.6	3775.6	16.2	REPTILIA	LC
Psammodromus manuelae	327766	327526	99.9	93244	28.5	24.2	183.6	31936.85	34.3	REPTILIA	LC
Stellagama stellio	864870	23820	2.8	19025	79.9	95.3	2402.2	4661.62	24.5	REPTILIA	LC
Tarentola angustimentalis	2521	2421	96.0	434	17.9	111.1	10401.3	179.21	41.3	REPTILIA	LC
Tarentola mauritanica	1624661	709695	43.7	564957	79.6	142.4	2064.9	122018.51	21.6	REPTILIA	LC
Teira dugesii	817	774	94.7	750	96.9	3.9	2465.7	226.55	30.2	REPTILIA	LC
Testudo hermanni	459489	325322	70.8	319054	98.1	140.2	1739.5	81014.48	25.4	REPTILIA	NT
Testudo marginata	83273	82107	98.6	74699	91.0	268.6	1093.5	14062.03	18.8	REPTILIA	LC
Vipera aspis	732293	709987	97.0	680165	95.8	145.6	2178.3	105873.87	15.6	REPTILIA	LC
Vipera latastei	592601	495156	83.6	468667	94.7	103.0	1488.2	119725.65	25.5	REPTILIA	VU
Xerotyphlops vermicularis	1725790	143358	8.3	138915	96.9	132.3	1177.1	38307.74	27.6	REPTILIA	LC
Zamenis lineatus	79557	79040	99.4	77663	98.3	209.0	2311.4	16246.38	20.9	REPTILIA	DD
Zamenis longissimus	1775364	1308660	73.7	1148995	87.8	80.6	1400.9	247219.68	21.5	REPTILIA	LC
Acomys minous	8345	8196	98.2	601	7.3	11.6	102.1	298.27	49.7	MAMMALIA	DD
Alces alces	23097504	1189091	5.1	934314	78.6	43.5	450.6	102782.35	11.0	MAMMALIA	LC
Alexandromys oeconomus	18612435	681837	3.7	657859	96.5	51.6	1058.2	131842.36	20.0	MAMMALIA	LC
Apodemus agrarius	11531281	1369124	11.9	1236314	90.3	60.3	1409.4	233446.68	18.9	MAMMALIA	LC
Apodemus alpicola	110808	89243	80.5	31033	34.8	5.3	32.5	6023.53	19.4	MAMMALIA	LC
Apodemus epimelas	174084	111502	64.1	0	0.0	2.0	2.9	0.01	5.6	MAMMALIA	LC
Apodemus flavicollis	6066213	2778570	45.8	879132	31.6	32.1	247.0	215913.1	24.6	MAMMALIA	LC
Apodemus sylvaticus	5002014	3297751	65.9	3229625	97.9	101.5	2029.1	599958.38	18.6	MAMMALIA	LC
Apodemus uralensis	7231854	575570	8.0	528318	91.8	47.7	1071.7	103193.93	19.5	MAMMALIA	LC
Arvicola scherman	831164	764365	92.0	31136	4.1	0.9	16.3	15011.56	48.2	MAMMALIA	LC
Barbastella barbastellus	3742891	2675087	71.5	816393	30.5	33.9	295.3	227218.81	27.8	MAMMALIA	NT
Bison bonasus	24304	4917	20.2	4837	98.4	13.7	118.5	2946.78	60.9	MAMMALIA	NT
Canis aureus	10745822	418502	3.9	406135	97.0	97.3	1145.3	110442.48	27.2	MAMMALIA	LC
Canis lupus	55647050	3051206	5.5	2952991	96.8	75.3	1422.9	534815.05	18.1	MAMMALIA	LC
Capra ibex	19201	13398	69.8	10340	77.2	0.2	0.4	5516.05	53.3	MAMMALIA	LC
Capra pyrenaica	92675	92646	100.0	41876	45.2	11.9	135.8	22017.76	52.6	MAMMALIA	LC

Species Name	Global Range Area (ArcGIS)	EU Range Area (ArcGIS)	% Of Global Range In EU	AOH Area In EU	% Of AOH From EU Range	Protected Fragmentation Mean	Unprotected Fragmentation Mean	Protected Area	% Of AOH In EU	Species Class	IUCN Category
Capreolus capreolus	6439886	3533374	54.9	3420686	96.8	85.3	1693.6	569718.2	16.7	MAMMALIA	LC
Cervus elaphus	4274533	2745899	64.2	2684946	97.8	79.4	1665.6	507106.55	18.9	MAMMALIA	LC
Chionomys syriacus	890860	422262	47.4	3587	0.8	0.2	0.1	2060.79	57.4	MAMMALIA	LC
Clethrionomys glareolus	8679141	2985927	34.4	1113286	37.3	32.2	213.2	218915.67	19.7	MAMMALIA	LC
Craseomys rufocanus	13113552	411804	3.1	361297	87.7	0.4	12.6	74393.78	20.6	MAMMALIA	LC
Cricetus cricetus	4839646	247254	5.1	213986	86.5	120.1	1789.3	24232.67	11.3	MAMMALIA	CR
Crocidura canariensis	2480	2391	96.4	1465	61.3	37.3	4126.9	745.86	50.9	MAMMALIA	EN
Crocidura leucodon	3926703	1669503	42.5	1245002	74.6	168.3	2772.3	180985.32	14.5	MAMMALIA	LC
Crocidura pachyura	64331	24419	38.0	20425	83.6	45.8	1440.5	3121.23	15.3	MAMMALIA	LC
Crocidura russula	1924753	1419761	73.8	1161930	81.8	169.9	3054.6	175534.15	15.1	MAMMALIA	LC
Crocidura sicula	25786	25510	98.9	22713	89.0	449.4	2529.7	2802.2	12.3	MAMMALIA	LC
Crocidura suaveolens	12623402	1914845	15.2	1404314	73.3	165.3	2344.6	209711.18	14.9	MAMMALIA	LC
Dama dama	188661	166355	88.2	164754	99.0	67.8	1545.2	44200.96	26.8	MAMMALIA	LC
Dryomys nitedula	5229024	947405	18.1	911384	96.2	76.7	1135.9	209463.97	23.0	MAMMALIA	LC
Eliomys quercinus	2361939	1914290	81.0	1553738	81.2	126.0	2340.0	257986.03	16.6	MAMMALIA	NT
Eptesicus isabellinus	852638	177538	20.8	173656	97.8	69.6	1577.4	48300.47	27.8	MAMMALIA	LC
Eptesicus nilssonii	10472431	1901862	18.2	1554976	81.8	69.3	1318.8	207430.53	13.3	MAMMALIA	LC
Eptesicus serotinus	10167259	2617959	25.7	2582319	98.6	109.9	2275.7	491234.03	19.0	MAMMALIA	LC
Erinaceus europaeus	3807091	2771399	72.8	2323518	83.8	129.3	2229.3	324293.1	14.0	MAMMALIA	LC
Erinaceus roumanicus	6029388	1327200	22.0	1256044	94.6	79.3	1090.9	254657.21	20.3	MAMMALIA	LC
Felis silvestris	1423737	905904	63.6	894664	98.8	68.2	1287.8	243406.14	27.2	MAMMALIA	LC
Glis glis	3715658	2244335	60.4	2160360	96.3	102.6	1998.9	412687.84	19.1	MAMMALIA	LC
Hypsugo savii	4281068	1201653	28.1	1186820	98.8	90.8	1880.5	283280.91	23.9	MAMMALIA	LC
Hystrix cristata	5369200	187826	3.5	160897	85.7	146.9	2374.4	32264.21	20.1	MAMMALIA	LC
Lepus castroviejoi	4980	4980	100.0	4067	81.7	7.0	29.9	3399.37	83.6	MAMMALIA	VU
Lepus corsicanus	105793	105240	99.5	104274	99.1	178.0	2399.3	23242.52	22.3	MAMMALIA	VU
Lepus europaeus	10415654	2870280	27.6	2100766	73.2	146.6	2548.6	289269.73	13.8	MAMMALIA	LC
Lepus granatensis	529412	528885	99.9	521967	98.7	98.5	1306.2	130145.66	24.9	MAMMALIA	LC
Lepus timidus	20133041	1168388	5.8	1084031	92.8	11.2	512.3	146623.69	13.5	MAMMALIA	LC
Lynx lynx	20530860	1057083	5.1	640081	60.6	6.4	55.2	131145.53	20.5	MAMMALIA	LC
Lynx pardinus	1192	1192	100.0	453	38.0	11.6	331.7	397.13	87.7	MAMMALIA	EN
Marmota marmota	186614	146632	78.6	59059	40.3	11.9	611.2	18838.46	31.9	MAMMALIA	LC
Martes foina	12453146	3085617	24.8	2973313	96.4	103.8	2093.0	561045.94	18.9	MAMMALIA	LC
Martes martes	9925492	3556433	35.8	3318856	93.3	93.0	1725.1	510394.1	15.4	MAMMALIA	LC
Meles meles	9801230	3897895	39.8	3774519	96.8	93.1	1689.5	642169.94	17.0	MAMMALIA	LC
Mesocricetus newtoni	38264	38187	99.8	32580	85.3	180.4	996.8	6043.28	18.5	MAMMALIA	NT
Micromys minutus	18265465	2699989	14.8	2588120	95.9	97.0	2024.9	409010.67	15.8	MAMMALIA	LC
Microtus agrestis	10818826	2956412	27.3	2837194	96.0	81.9	1652.8	436542.77	15.4	MAMMALIA	LC
Microtus arvalis	6888072	2359763	34.3	2316318	98.2	94.8	2107.4	406152.05	17.5	MAMMALIA	LC
Microtus bavaricus	16	16	100.0	11	69.8	0.0	1.0	0	0.0	MAMMALIA	CR
Microtus brachycercus	70227	69864	99.5	53398	76.4	299.6	2944.5	8546.8	16.0	MAMMALIA	LC
Microtus cabrerae	115857	115814	100.0	88737	76.6	185.7	1137.5	22320.01	25.2	MAMMALIA	NT
Microtus duodecimcostatus	531628	531080	99.9	426491	80.3	126.3	1882.1	98337.33	23.1	MAMMALIA	LC
Microtus felteni	35700	3843	10.8	3046	79.2	47.2	136.4	1195.2	39.2	MAMMALIA	LC
Microtus gerbii	219432	206040	93.9	163326	79.3	112.8	1695.1	22350.24	13.7	MAMMALIA	LC
Microtus guentheri	642349	47520	7.4	19403	40.8	110.0	845.9	5007.75	25.8	MAMMALIA	LC
Microtus liechtensteini	115712	77391	66.9	65830	85.1	57.4	1855.9	20243.47	30.8	MAMMALIA	LC
Microtus lusitanicus	253377	253048	99.9	203227	80.3	134.6	1369.8	42163.33	20.7	MAMMALIA	LC
Microtus multiplex	135253	121729	90.0	105234	86.4	57.5	3573.8	17937.01	17.0	MAMMALIA	LC
Microtus mystacinus	3719296	436008	11.7	374820	86.0	86.0	559.0	61066.83	16.3	MAMMALIA	LC
Microtus savii	218238	216458	99.2	211313	97.6	156.6	3585.5	35305.49	16.7	MAMMALIA	LC
Microtus subterraneus	2884189	1637157	56.8	1586827	96.9	104.2	2285.5	280869.27	17.7	MAMMALIA	LC
Microtus tatricus	18331	13149	71.7	6916	52.6	2.0	7.2	4086.26	59.1	MAMMALIA	LC
Microtus thomasi	106710	70976	66.5	33447	47.1	248.2	588.6	6757.72	20.2	MAMMALIA	LC
Miniopterus schreibersii	1979127	1060239	53.6	1044301	98.5	97.7	1736.1	254312.68	24.4	MAMMALIA	VU
Mus cypriacus	9273	9133	98.5	1212	13.3	13.6	37.4	609.5	50.3	MAMMALIA	LC
Mus macedonicus	1386761	129589	9.3	59334	45.8	333.8	2156.0	13603.63	22.9	MAMMALIA	LC
Mus spicilegus	828033	318832	38.5	165589	51.9	133.3	1406.3	22941	13.9	MAMMALIA	LC
Mus spretus	963963	520738	54.0	514597	98.8	109.9	1735.7	134164.05	26.1	MAMMALIA	LC
Muscardinus avellanarius	3612986	2269214	62.8	487468	21.5	26.0	82.5	149489.52	30.7	MAMMALIA	LC
Mustela erminea	41219409	3109278	7.5	3006169	96.7	76.8	1670.0	465607.9	15.5	MAMMALIA	LC
Mustela eversmanii	13301370	273570	2.1	211892	77.5	71.1	1447.5	35134.33	16.6	MAMMALIA	LC
Mustela nivalis	43168725	3910690	9.1	3799901	97.2	87.6	1686.9	683250.62	18.0	MAMMALIA	LC
Mustela putorius	6011620	3372768	56.1	3283571	97.4	95.9	1900.3	580074.8	17.7	MAMMALIA	LC
Myomimus roachi	19563	6265	32.0	4788	76.4	106.4	1795.4	2400.65	50.1	MAMMALIA	VU
Myopus schisticolor	10209784	506127	5.0	9588	1.9	0.3	0.9	3221.84	33.6	MAMMALIA	LC
Myotis alcathoe	513093	426956	83.2	79417	18.6	44.2	100.2	19378.63	24.4	MAMMALIA	DD
Myotis aurascens	2607415	261021	10.0	87871	33.7	10.2	36.7	35684.87	40.6	MAMMALIA	LC
Myotis bechsteinii	2651641	2329214	87.8	2206840	94.7	121.7	2190.2	387891.48	17.6	MAMMALIA	NT
Myotis blythii	6188236	1744998	28.2	1300063	74.5	134.2	2001.8	250540.6	19.3	MAMMALIA	LC
Myotis brandtii	5453703	1782613	32.7	1722184	96.6	74.9	1667.9	268189.64	15.6	MAMMALIA	LC
Myotis capaccinii	1228990	699254	56.9	76118	10.9	44.2	333.5	19457.46	25.6	MAMMALIA	VU
Myotis dasycneme	5448300	999932	18.4	909541	91.0	79.7	2191.0	142554.46	15.7	MAMMALIA	NT
Myotis daubentonii	7013025	2977466	42.5	2803599	94.2	101.1	1902.1	425426.75	15.2	MAMMALIA	LC
Myotis emarginatus	4646845	2383087	51.3	1804913	75.7	162.3	2426.5	295146.12	16.4	MAMMALIA	LC
Myotis escalerai	438410	437825	99.9	170275	38.9	17.9	160.2	66383.76	39.0	MAMMALIA	LC
Myotis myotis	3874502	2832723	73.1	2728072	96.3	109.1	2153.2	519286.17	19.0	MAMMALIA	LC
Myotis mystacinus	4946497	2670125	54.0	2560650	95.9	102.1	1914.0	424814.9	16.6	MAMMALIA	LC
Myotis nattereri	3817843	1990892	52.1	1937994	97.3	109.7	2139.5	294794.98	15.2	MAMMALIA	LC

Species Name	Global Range Area (ArcGIS)	EU Range Area (ArcGIS)	% Of Global Range In EU	AOH Area In EU	% Of AOH From EU Range	Protected Fragmentation Mean	Unprotected Fragmentation Mean	Protected Area	% Of AOH In EU	Species Class	IUCN Category
Myotis punicus	654272	32592	5.0	32214	98.8	29.5	1156.2	5379.45	16.7	MAMMALIA	DD
Nannospalax leucodon	533110	276303	51.8	180892	65.5	167.2	1500.3	38607.11	21.3	MAMMALIA	DD
Nyctalus azoreum	2237	2127	95.1	980	46.1	17.5	784.9	76.2	7.8	MAMMALIA	VU
Nyctalus lasiopterus	2917436	976605	33.5	336312	34.4	23.0	164.2	104181.09	31.0	MAMMALIA	VU
Nyctalus leisleri	5171189	2748733	53.2	2652764	96.5	108.1	2031.6	484500.36	18.3	MAMMALIA	LC
Nyctalus noctula	7209840	2704241	37.5	2357233	87.2	109.2	2230.7	378153.97	16.0	MAMMALIA	LC
Oryctolagus cuniculus	633360	632199	99.8	626312	99.1	90.5	1427.6	157838.04	25.2	MAMMALIA	EN
Pipistrellus hanaki	48450	8195	16.9	7772	94.8	38.9	941.4	2225.28	28.6	MAMMALIA	VU
Pipistrellus kuhlii	10879235	1967908	18.1	1906740	96.9	104.6	1649.5	403875.7	21.2	MAMMALIA	LC
Pipistrellus maderensis	4204	3989	94.9	2183	54.7	17.0	5029.6	951.77	43.6	MAMMALIA	VU
Pipistrellus nathusii	5890284	2797547	47.5	2457392	87.8	108.2	2241.5	411838.99	16.8	MAMMALIA	LC
Pipistrellus pipistrellus	7533396	2968864	39.4	2878677	97.0	107.3	2133.7	530678.87	18.4	MAMMALIA	LC
Pipistrellus pygmaeus	1936638	1445335	74.6	1230557	85.1	100.7	1731.2	226051.94	18.4	MAMMALIA	LC
Plecotus auritus	5717005	2528897	44.2	2425516	95.9	88.9	1875.9	391781.15	16.2	MAMMALIA	LC
Plecotus austriacus	2318975	1675342	72.2	1655232	98.8	109.2	2167.5	335950.47	20.3	MAMMALIA	NT
Plecotus kolombatovici	978140	82633	8.4	61608	74.6	170.5	1904.0	15205.87	24.7	MAMMALIA	LC
Plecotus macrobullaris	1010912	237776	23.5	229638	96.6	76.4	1822.9	59758.33	26.0	MAMMALIA	LC
Plecotus sardus	23981	23775	99.1	3014	12.7	5.4	13.8	793.32	26.3	MAMMALIA	VU
Plecotus teneriffae	3040	2889	95.0	284	9.8	12.1	73.3	232.94	82.0	MAMMALIA	VU
Rattus norvegicus	18826048	4057072	21.6	2369996	58.4	169.4	2511.1	306851.22	12.9	MAMMALIA	LC
Rhinolophus blasii	3410524	244591	7.2	103842	42.5	10.5	47.2	40711.1	39.2	MAMMALIA	LC
Rhinolophus euryale	2891643	1522373	52.6	1410172	92.6	119.5	1765.1	294828.08	20.9	MAMMALIA	NT
Rhinolophus ferrumequinum	9746916	2142893	22.0	2110640	98.5	101.5	1866.7	451915.93	21.4	MAMMALIA	LC
Rhinolophus hipposideros	6258793	2474395	39.5	2408818	97.3	100.4	1802.6	484401.33	20.1	MAMMALIA	LC
Rhinolophus mehelyi	1974512	465260	23.6	73051	15.7	18.6	142.0	23393.14	32.0	MAMMALIA	VU
Rupicapra pyrenaica	15276	14810	97.0	12029	81.2	2.4	17.6	8082.94	67.2	MAMMALIA	LC
Rupicapra rupicapra	206150	142898	69.3	139049	97.3	19.6	730.0	44148.09	31.8	MAMMALIA	LC
Sciurus vulgaris	19812115	3762387	19.0	3115597	82.8	99.5	1865.5	490036.21	15.7	MAMMALIA	LC
Sicista betulina	6815729	651624	9.6	232768	35.7	13.0	50.8	37527.05	16.1	MAMMALIA	LC
Sicista trizona	238	238	100.0	228	96.0	9.8	8.4	199.59	87.5	MAMMALIA	EN
Sorex alpinus	422054	309466	73.3	264337	85.4	32.2	1274.8	79144.33	29.9	MAMMALIA	NT
Sorex antinorii	189655	169798	89.5	154	0.1	73.4	1267.5	72.27	46.9	MAMMALIA	LC
Sorex araneus	13235907	2528345	19.1	2340411	92.6	71.8	1584.7	357686.43	15.3	MAMMALIA	LC
Sorex caecutiens	17656010	495628	2.8	313588	63.3	2.3	41.0	41738.21	13.3	MAMMALIA	LC
Sorex coronatus	884149	858930	97.1	245343	28.6	80.1	469.9	46753.38	19.1	MAMMALIA	LC
Sorex granarius	69969	69811	99.8	68555	98.2	170.3	1778.1	15660.93	22.8	MAMMALIA	LC
Sorex minutissimus	17484068	380993	2.2	220062	57.8	1.8	33.7	21099.57	9.6	MAMMALIA	LC
Sorex minutus	14289750	3641795	25.5	3515016	96.5	87.2	1691.5	590013.32	16.8	MAMMALIA	LC
Sorex samniticus	157739	157116	99.6	41594	26.5	19.2	48.4	11455.29	27.5	MAMMALIA	LC
Spalax antiquus	294	294	100.0	246	83.7	5.2	21.5	44.01	17.9	MAMMALIA	EN
Spalax graecus	17564	13132	74.8	10397	79.2	14.8	354.9	457.05	4.4	MAMMALIA	VU
Spermophilus citellus	432583	350022	80.9	263542	75.3	133.2	1733.9	37783.54	14.3	MAMMALIA	EN
Suncus etruscus	3314257	954747	28.8	942861	98.8	102.9	1884.3	222611.47	23.6	MAMMALIA	LC
Sus scrofa	28013292	2863808	10.2	2816603	98.4	88.7	1842.9	553682.19	19.7	MAMMALIA	LC
Tadarida teniotis	3844213	1189640	30.9	939651	79.0	133.8	2250.6	205043.59	21.8	MAMMALIA	LC
Talpa caeca	243390	184578	75.8	165354	89.6	98.1	3113.8	30225.02	18.3	MAMMALIA	LC
Talpa europaea	6455978	2773453	43.0	2684916	96.8	91.5	1991.4	433743.49	16.2	MAMMALIA	LC
Talpa occidentalis	476305	475775	99.9	470650	98.9	103.3	1320.5	118018.59	25.1	MAMMALIA	LC
Talpa romana	98019	97669	99.6	86600	88.7	162.7	2745.2	19108.33	22.1	MAMMALIA	LC
Talpa stankovici	51886	27792	53.6	14356	51.7	451.7	769.2	3590.71	25.0	MAMMALIA	LC
Ursus arctos	24954868	923789	3.7	475345	51.5	13.0	242.5	82085.24	17.3	MAMMALIA	LC
Vespertilio murinus	15712047	1924313	12.2	1868142	97.1	72.3	1864.5	324680.1	17.4	MAMMALIA	LC
Vulpes vulpes	48528871	4037575	8.3	3924794	97.2	87.5	1667.2	700998.35	17.9	MAMMALIA	LC
Alytes almogavarii	38572	38082	98.7	31281	82.1	23.6	3221.8	10273.09	32.8	AMPHIBIA	LC
Alytes cisternasii	168716	168667	100.0	146267	86.7	122.1	878.2	44087.92	30.1	AMPHIBIA	LC
Alytes dickhilleni	31457	31457	100.0	15505	49.3	25.6	562.6	5985.32	38.6	AMPHIBIA	EN
Alytes muletensis	229	229	100.0	94	41.2	7.4	1838.1	34.08	36.2	AMPHIBIA	EN
Alytes obstetricans	955305	937648	98.2	914614	97.5	120.8	2074.5	148020.32	16.2	AMPHIBIA	LC
Bombina bombina	2923523	916109	31.3	839081	91.6	86.8	1383.7	152243.65	18.1	AMPHIBIA	LC
Bombina variegata	1204864	966742	80.2	892786	92.4	85.3	1858.5	194072.93	21.7	AMPHIBIA	LC
Bufo bufo	10546413	3826247	36.3	3722647	97.3	95.2	1735.1	640173.95	17.2	AMPHIBIA	LC
Bufotes balearicus	224056	223053	99.6	156641	70.2	257.8	3860.1	17918.85	11.4	AMPHIBIA	LC
Bufotes cypriensis	9273	9133	98.5	1221	13.4	13.6	117.9	508.18	41.6	AMPHIBIA	NT
Bufotes viridis	3697858	1358150	36.7	1337683	98.5	91.3	1686.5	266437.39	19.9	AMPHIBIA	LC
Calotriton asper	27428	26963	98.3	12934	48.0	7.5	21.2	5910.48	45.7	AMPHIBIA	LC
Chioglossa lusitanica	54111	53885	99.6	14696	27.3	29.6	105.9	1869.23	12.7	AMPHIBIA	NT
Discoglossus galganoi	488944	488510	99.9	467510	95.7	100.6	1201.7	118304.32	25.3	AMPHIBIA	LC
Discoglossus montalentii	4155	4154	100.0	2005	48.3	6.1	28.9	306.01	15.3	AMPHIBIA	NT
Discoglossus pictus	344705	25689	7.5	25325	98.6	288.7	2600.0	4292.2	16.9	AMPHIBIA	LC
Discoglossus sardus	32996	32572	98.7	6661	20.5	8.4	29.3	1249.83	18.8	AMPHIBIA	LC
Epidalea calamita	2234801	2048797	91.7	2025779	98.9	117.5	2287.2	347878.81	17.2	AMPHIBIA	LC
Euproctus montanus	7956	7797	98.0	4318	55.4	8.3	41.6	543.67	12.6	AMPHIBIA	LC
Euproctus platycephalus	5723	5723	100.0	2247	39.3	3.7	22.5	548.82	24.4	AMPHIBIA	VU
Hyla arborea	1771403	1539343	86.9	1518789	98.7	132.2	2541.9	255609.54	16.8	AMPHIBIA	LC
Hyla intermedia	153867	153151	99.5	138185	90.2	167.1	2460.9	26928.29	19.5	AMPHIBIA	LC
Hyla molleri	360696	360220	99.9	357086	99.1	108.9	1174.0	89036.13	24.9	AMPHIBIA	LC
Hyla orientalis	1852620	423655	22.9	416074	98.2	62.4	903.0	85912.37	20.6	AMPHIBIA	LC
Hyla perrini	77116	76115	98.7	17435	22.9	41.7	141.3	3032.35	17.4	AMPHIBIA	LC
Hyla sarda	31504	31062	98.6	30672	98.7	33.8	1035.8	4994.68	16.3	AMPHIBIA	LC

Species Name	Global Range Area (ArcGIS)	EU Range Area (ArcGIS)	% Of Global Range In EU	AOH Area In EU	% Of AOH From EU Range	Protected Fragmentation Mean	Unprotected Fragmentation Mean	Protected Area	% Of AOH In EU	Species Class	IUCN Category
Ichthyosaura alpestris	1364866	1184787	86.8	1168014	98.6	107.7	2698.0	202391.16	17.3	AMPHIBIA	LC
Lissotriton boscai	201777	201511	99.9	192359	95.5	101.7	952.6	49549.34	25.8	AMPHIBIA	LC
Lissotriton graecus	107005	65045	60.8	63448	97.5	212.4	525.4	15931.66	25.1	AMPHIBIA	LC
Lissotriton helveticus	1083035	856055	79.0	841882	98.3	162.7	3006.3	114860.22	13.6	AMPHIBIA	LC
Lissotriton italicus	75200	74858	99.5	73692	98.4	169.3	2439.1	15621.39	21.2	AMPHIBIA	LC
Lissotriton maltzani	25147	25035	99.6	24776	99.0	323.6	2444.2	5382.17	21.7	AMPHIBIA	LC
Lissotriton montandoni	123020	92358	75.1	81090	87.8	12.2	694.4	27457.11	33.9	AMPHIBIA	LC
Lissotriton vulgaris	898567	436854	48.6	380463	87.1	10.6	577.3	23027.43	6.1	AMPHIBIA	LC
Lyciasalamandra helverseni	399	362	90.6	56	15.6	21.6	79.2	26.51	46.9	AMPHIBIA	VU
Pelobates balcanicus	135219	100235	74.1	89485	89.3	169.3	1193.2	22519.32	25.2	AMPHIBIA	LC
Pelobates cultripes	493069	492611	99.9	148547	30.2	19.8	173.5	55228.34	37.2	AMPHIBIA	VU
Pelobates fuscus	2385980	1237379	51.9	1196980	96.7	96.9	2313.6	180507	15.1	AMPHIBIA	LC
Pelobates syriacus	372113	12714	3.4	12460	98.0	116.6	1706.2	4884.38	39.2	AMPHIBIA	LC
Pelodytes atlanticus	44521	44396	99.7	31645	71.3	610.4	3763.2	4437.4	14.0	AMPHIBIA	LC
Pelodytes ibericus	102533	102509	100.0	98878	96.5	63.9	1220.4	26094.34	26.4	AMPHIBIA	LC
Pelodytes punctatus	707169	706133	99.9	457801	64.8	210.7	2736.5	57504.2	12.6	AMPHIBIA	LC
Pelophylax bergeri	176443	175481	99.5	156895	89.4	193.4	2271.6	23616.1	15.1	AMPHIBIA	LC
Pelophylax cerigensis	4	4	100.0	1	20.5	17.3	14.7	0.15	18.1	AMPHIBIA	CR
Pelophylax cretensis	2536	2384	94.0	946	39.7	238.0	4795.9	140.6	14.9	AMPHIBIA	VU
Pelophylax cypriensis	2248	2235	99.4	854	38.2	23.0	89.3	515.21	60.3	AMPHIBIA	VU
Pelophylax epeiroticus	12316	11050	89.7	5949	53.8	1024.1	830.5	710.97	12.0	AMPHIBIA	NT
Pelophylax kurtmuelleri	132618	104232	78.6	64029	61.4	378.0	1613.3	11175.31	17.5	AMPHIBIA	LC
Pelophylax lessonae	3251760	1585351	48.8	1559226	98.4	121.7	2576.4	235430.74	15.1	AMPHIBIA	LC
Pelophylax perezi	640571	639736	99.9	611662	95.6	106.1	1577.6	142791.47	23.3	AMPHIBIA	LC
Pelophylax ridibundus	7192051	1654907	23.0	1630678	98.5	106.0	2229.9	280862.27	17.2	AMPHIBIA	LC
Pleurodeles waltl	377577	322798	85.5	279445	86.6	153.4	1596.3	66033.25	23.6	AMPHIBIA	NT
Rana arvalis	9841743	1735729	17.6	1659569	95.6	87.7	1531.6	197386.56	11.9	AMPHIBIA	LC
Rana dalmatina	1806721	1483577	82.1	364258	24.6	24.4	80.0	122234.16	33.6	AMPHIBIA	LC
Rana graeca	236206	126194	53.4	77235	61.2	74.5	338.3	25812.67	33.4	AMPHIBIA	LC
Rana iberica	106638	106366	99.7	26304	24.7	19.6	100.6	7010.35	26.7	AMPHIBIA	VU
Rana latastei	33696	33348	99.0	30387	91.1	227.5	8269.7	2298.7	7.6	AMPHIBIA	VU
Rana parvipalmata	36626	36403	99.4	19718	54.2	12.5	131.5	5169.53	26.2	AMPHIBIA	LC
Rana temporaria	7786712	2888779	37.1	2784590	96.4	73.7	1630.9	435751.41	15.6	AMPHIBIA	LC
Salamandra atra	111210	89063	80.1	76361	85.7	16.4	665.4	19093.62	25.0	AMPHIBIA	LC
Salamandra corsica	4418	4418	100.0	2510	56.8	7.0	32.9	349.49	13.9	AMPHIBIA	LC
Salamandra lanzai	780	780	100.0	560	71.8	0.0	150.3	143.86	25.7	AMPHIBIA	CR
Salamandra salamandra	2161491	1908927	88.3	1602262	83.9	115.7	2460.5	312652.56	19.5	AMPHIBIA	LC
Salamandrina perspicillata	74001	73973	100.0	31256	42.3	16.4	42.2	8783.92	28.1	AMPHIBIA	EN
Salamandrina terdigitata	28138	27993	99.5	9851	35.2	13.8	41.4	3722.19	37.8	AMPHIBIA	LC
Speleomantes ambrosii	271	268	98.9	146	54.5	64.4	125.9	37.27	25.6	AMPHIBIA	CR
Speleomantes flavus	631	631	100.0	90	14.3	9.5	8.4	18.68	20.7	AMPHIBIA	EN
Speleomantes genei	1145	1145	100.0	285	24.9	1.3	4.1	139.07	48.8	AMPHIBIA	VU
Speleomantes imperialis	2658	2658	100.0	526	19.8	4.0	13.2	63.41	12.0	AMPHIBIA	NT
Speleomantes italicus	21056	21015	99.8	18959	90.2	34.1	1518.5	4132.02	21.8	AMPHIBIA	EN
Speleomantes sarrabusensis	103	103	100.0	58	56.5	3.0	3.0	42.75	73.4	AMPHIBIA	CR
Speleomantes strinatii	10275	10273	100.0	7149	69.6	13.0	37.0	1730.68	24.2	AMPHIBIA	EN
Speleomantes supramontis	574	574	100.0	108	18.9	1.0	3.6	74.1	68.4	AMPHIBIA	EN
Triturus carnifex	500699	385349	77.0	369034	95.8	143.1	2571.3	73572.69	19.9	AMPHIBIA	LC
Triturus cristatus	4374961	1698806	38.8	1502317	88.4	114.8	2402.5	206905.82	13.8	AMPHIBIA	LC
Triturus dobrogicus	271909	224888	82.7	206697	91.9	84.1	1400.2	38753.14	18.7	AMPHIBIA	LC
Triturus karelinii	448092	100786	22.5	98937	98.2	68.6	1094.6	35908.28	36.3	AMPHIBIA	LC
Triturus macedonicus	186110	40557	21.8	39500	97.4	173.7	586.7	12183.5	30.8	AMPHIBIA	VU
Triturus marmoratus	474836	473789	99.8	470582	99.3	131.6	1603.8	73851.19	15.7	AMPHIBIA	LC
Triturus pygmaeus	174285	174102	99.9	163365	93.8	138.9	1474.6	45283.86	27.7	AMPHIBIA	NT

Appendix Table 2

Fragmentation results by country. The colours reflect the fragmentation dataset's thresholds of very low to very high fragmentation.

Country Name	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation	Country Name	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation
Austria	68.74	3.38	Ireland	43.41	2.08
Belgium	25.77	1.35	Italy	609.00	35.06
Bulgaria	156.30	12.92	Lithuania	48.79	2.60
Cyprus	221.35	5.97	Luxembourg	2.25	0.12

Czechia	61.51	3.20	Latvia	45.88	2.42
Germany	249.61	12.65	Malta	1998.65	32.48
Denmark	22.65	1.13	Netherlands	25.57	1.30
Estonia	26.96	1.45	Poland	233.03	11.90
Greece	337.41	44.10	Portugal	186.60	17.26
Spain	622.08	41.05	Romania	185.04	11.02
Finland	141.75	7.60	Sweden	188.16	9.35
France	432.43	24.86	Slovenia	24.14	1.23
Croatia	78.21	5.13	Slovakia	41.92	2.22
Hungary	96.91	5.70			

Appendix Table 3

Fragmentation results by country and by species class. The colours reflect the fragmentation dataset's thresholds of very low to very high fragmentation.

Country Name	Species Class	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation	Country Name	Species Class	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation
Austria	AMPHIBIA	118.10	5.29	Ireland	AMPHIBIA	64.74	1.71
Austria	MAMMALIA	61.26	3.11	Ireland	MAMMALIA	40.91	2.14
Austria	REPTILIA	50.03	2.40	Ireland	REPTILIA	44.58	1.88
Belgium	AMPHIBIA	42.73	2.12	Italy	AMPHIBIA	1156.37	75.86
Belgium	MAMMALIA	22.05	1.20	Italy	MAMMALIA	389.31	21.64
Belgium	REPTILIA	18.99	0.84	Italy	REPTILIA	1549.62	84.09
Bulgaria	AMPHIBIA	186.76	11.86	Lithuania	AMPHIBIA	75.69	3.82
Bulgaria	MAMMALIA	113.74	8.23	Lithuania	MAMMALIA	43.29	2.39
Bulgaria	REPTILIA	354.99	38.31	Lithuania	REPTILIA	41.96	1.87
Cyprus	AMPHIBIA	112.26	15.42	Luxembourg	AMPHIBIA	3.85	0.19
Cyprus	MAMMALIA	19.55	2.04	Luxembourg	MAMMALIA	1.86	0.10
Cyprus	REPTILIA	641.87	12.75	Luxembourg	REPTILIA	1.67	0.07
Czechia	AMPHIBIA	94.27	4.65	Latvia	AMPHIBIA	69.79	3.39
Czechia	MAMMALIA	53.44	2.87	Latvia	MAMMALIA	41.60	2.28
Czechia	REPTILIA	49.56	2.28	Latvia	REPTILIA	41.58	1.85
Germany	AMPHIBIA	381.19	18.43	Malta	AMPHIBIA	14.65	1.62
Germany	MAMMALIA	218.92	11.43	Malta	MAMMALIA	2.09	0.14
Germany	REPTILIA	208.40	9.17	Malta	REPTILIA	4419.77	71.39

Denmark	AMPHIBIA	34.44	1.68	Netherlands	AMPHIBIA	32.85	1.63
Denmark	MAMMALIA	19.47	1.00	Netherlands	MAMMALIA	24.17	1.26
Denmark	REPTILIA	23.48	1.02	Netherlands	REPTILIA	21.97	0.98
Estonia	AMPHIBIA	28.12	1.42	Poland	AMPHIBIA	351.69	18.05
Estonia	MAMMALIA	26.73	1.48	Poland	MAMMALIA	208.31	10.72
Estonia	REPTILIA	27.83	1.23	Poland	REPTILIA	201.87	8.99
Greece	AMPHIBIA	340.14	72.05	Portugal	AMPHIBIA	380.05	48.61
Greece	MAMMALIA	143.54	17.13	Portugal	MAMMALIA	100.88	7.18
Greece	REPTILIA	783.98	92.03	Portugal	REPTILIA	281.06	19.85
Spain	AMPHIBIA	678.38	51.56	Romania	AMPHIBIA	172.39	9.36
Spain	MAMMALIA	441.47	27.40	Romania	MAMMALIA	186.29	10.97
Spain	REPTILIA	1177.61	77.92	Romania	REPTILIA	192.44	14.14
Finland	AMPHIBIA	188.86	9.91	Sweden	AMPHIBIA	272.69	10.80
Finland	MAMMALIA	127.98	7.14	Sweden	MAMMALIA	163.26	8.72
Finland	REPTILIA	207.48	9.19	Sweden	REPTILIA	276.21	12.24
France	AMPHIBIA	712.80	41.26	Slovenia	AMPHIBIA	33.96	1.68
France	MAMMALIA	351.37	20.17	Slovenia	MAMMALIA	21.24	1.00
France	REPTILIA	603.08	34.21	Slovenia	REPTILIA	31.28	2.30
Croatia	AMPHIBIA	62.07	3.21	Slovakia	AMPHIBIA	48.17	2.12
Croatia	MAMMALIA	48.82	2.60	Slovakia	MAMMALIA	40.84	2.22
Croatia	REPTILIA	254.65	20.83	Slovakia	REPTILIA	43.42	2.51
Hungary	AMPHIBIA	145.77	8.13				
Hungary	MAMMALIA	86.15	5.04				
Hungary	REPTILIA	141.86	10.28				

Appendix Table 4

Fragmentation results by biogeographical region. The colours reflect the fragmentation dataset's thresholds of very low to very high fragmentation.

Biogeographical Region Code	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation
Alpine	193.50	9.64
Atlantic	329.51	18.52
Black Sea	20.40	1.85
Boreal	342.68	17.93
Continental	752.39	39.64
Macaronesia	3473.71	11.90
Mediterranean	799.24	56.04

Pannonian	127.36	7.46
Steppic	41.89	3.10

Appendix Table 5

Fragmentation results by biogeographical region by species class. The colours reflect the fragmentation dataset's thresholds of very low to very high fragmentation.

Biogeographical Region Code	Species Class	Mean Unprotected Area Fragmentation	Mean Protected Area Fragmentation
Alpine	AMPHIBIA	236.36	10.25
Alpine	MAMMALIA	189.05	9.58
Alpine	REPTILIA	182.08	9.44
Atlantic	AMPHIBIA	504.29	28.94
Atlantic	MAMMALIA	282.09	15.87
Atlantic	REPTILIA	354.56	18.39
Black Sea	AMPHIBIA	38.36	3.05
Black Sea	MAMMALIA	13.28	1.05
Black Sea	REPTILIA	44.05	5.08
Boreal	AMPHIBIA	423.88	21.01
Boreal	MAMMALIA	306.87	16.75
Boreal	REPTILIA	531.41	23.62
Continental	AMPHIBIA	1014.49	50.72
Continental	MAMMALIA	708.39	37.78
Continental	REPTILIA	595.37	33.05
Macaronesia	MAMMALIA	974.52	7.21
Macaronesia	REPTILIA	7171.86	18.85
Mediterranean	AMPHIBIA	819.29	70.17
Mediterranean	MAMMALIA	631.16	39.69
Mediterranean	REPTILIA	1351.41	100.74
Pannonian	AMPHIBIA	189.24	10.55
Pannonian	MAMMALIA	113.77	6.65
Pannonian	REPTILIA	174.45	12.20
Steppic	AMPHIBIA	57.85	3.91
Steppic	MAMMALIA	35.60	2.46
Steppic	REPTILIA	76.07	7.78

Appendix 6

Below are the ArcGIS model steps through which each species' AOH raster was fed:

- Projecting the coordinate system of the AOH raster to ETRS_1989_LAEA.
- Removing the unsuitable AOH (value 0), and AOH outside EU areas via the 'Clip Raster' geoprocessing tool according to EU polygons, and signifying a NoData value of 0.
- Using the 'Raster to Polygon' geoprocessing tool (without simplifying polygons).
- Using the 'Pairwise Dissolve' geoprocessing tool, to create an aggregated polygon.

To calculate data for AOH within Protected Areas included the steps of:

- Using the 'Pairwise Clip' geoprocessing tool according to the Natura 2000 polygons.
- Using the 'Zonal Statistics as Table' geoprocessing tool according to the fragmentation raster.
- Adding and calculating 2 new fields within the above resulting table for 1) the species name, and 2) for signifying the protected status, via the 'Add Fields' and the 'Calculate Fields' tools.

To calculate data for AOH within Unprotected Areas the steps included:

- Using the 'Pairwise Erase' geoprocessing tool, according to the Natura 2000 polygons.
- Using the 'Zonal Statistics as Table' geoprocessing tool, according to the fragmentation raster.
- Adding and calculating 2 new fields within the above resulting table for 1) the species name, and 2) for signifying the unprotected status, via the 'Add Fields' and the 'Calculate Fields' tools.