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A bird's eye view over ecosystem services in Natura 2000 sites across Europe

Guy Ziv[a,*], Christopher Hassall[b], Bartosz Bartkowski[c], Anna F. Cord[d], Andrea Kaim[d], Michelle Kalamandeen[a], Patricia Landaverde-González[d,e], Joana L. B. Melo[a], Ralf Seppelt[d,f], Caitriona Shannon[b], Tomáš Václavík[d,g], Brenda Maria Zoderer[a,h], Michael Beckmann[d]

[a] School of Geography, Faculty of Environment, University of Leeds, Leeds LS2 9JT, UK

[b] School of Biology, Faculty of Biological Sciences, University of Leeds, Leeds, LS2 9JT, UK

[c] UFZ - Helmholtz Centre for Environmental Research, Department of Economics, Permoserstr. 15, 04318 Leipzig, Germany

[d] UFZ - Helmholtz Centre for Environmental Research, Department of Computational Landscape Ecology, Permoserstr. 15, 04318 Leipzig, Germany

[e] General Zoology, Institute for Biology, Martin-Luther University Halle-Wittenberg, Hoher Weg 8, 06120 Halle (Saale), Germany.

[f] Institute of Geoscience and Geography, Martin-Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany

[g] Department of Ecology & Environmental Sciences, Faculty of Science, Palacký University Olomouc, Šlechtitelů 27, 78371 Olomouc, Czech Republic

[h] Institute of Ecology, University of Innsbruck, Sternwartestr. 15, 6020 Innsbruck, Austria

* Corresponding author: Guy Ziv, g.ziv@leeds.ac.uk, +44-113-343-7994

Abstract

Recent 'New Conservation' approaches called for more ecosystem services (ES) emphasis in conservation. We analysed data from 3,757 Natura 2000 special protection areas (SPAs) and translated positive and negative impacts listed by conservation managers into indicators of the use of nine provisioning, regulating and cultural ES. Overall, the use of ES is considered by SPA managers to affect conservation goals more negatively than positively. ES associated with livestock keeping and fodder production are recorded as having the highest fraction of positive impacts on SPAs, ranging from 88% and 78% in the Boreal biogeographic region to 20% and 6% in the Mediterranean. The use of ES varied according to dominant habitat type, highlighting the dependence of specific ES on associated ecosystem functions. For instance, fibre production was the predominant ES throughout forest habitats while crop, fodder and livestock exhibit similar patterns of dominance across agricultural landscapes. In contrast, the use of wild food and recreation activities are seen as causing mainly negative effects across all habitats. Our analysis suggests that most uses of ES result in negative effects on conservation goals. These outcomes should be considered when implementing future conservation strategies.

Keywords

Species Conservation; Ecosystem Services; Synergies; Trade-offs; Natura 2000; Special Protected Areas

1. Introduction

In recent years, advocates of the ‘New Conservation’ approach (Kareiva & Marvier 2012, Holmes et al. 2017, Xu et al. 2017) have called for placing more emphasis on the provision of ecosystem services (ES) and their role in benefiting human well-being. As this concept gains momentum in science and policy agendas (but also criticism e.g. Ridder 2008, Silvertown 2015), it has redefined current biodiversity policies such as the 2020 Aichi Targets and EU Biodiversity Strategy to 2020 to conserve nature beyond its intrinsic value. A plethora of studies focused on how biodiversity loss affects the functioning of ecosystems, the supply of ES (Diaz et al. 2006, Worm et al. 2006, Balvanera et al. 2014, Harrison et al. 2014) and human well-being (Raudsepp-Hearne et al. 2010, Cardinale et al. 2012, Sandifer et al. 2015). For instance, Costanza et al (2007) estimated that a 1% change in biodiversity may result in a 0.5% change in the value of ES worldwide. The majority of these studies generally indicate that biodiversity supports the provision of ES through many strong connections (Duraiappah et al. 2005, Science for Environment Policy 2015). For example, Maes et al. (2012) demonstrated a positive correlation between current levels of biodiversity and ES supply across Europe and Harrison et al. (2014) analysed literature that links various attributes of biodiversity, including species/functional richness and abundance or community areas and structure, to different ES.

The abovementioned studies refer to community level attributes of biodiversity (e.g. taxonomic richness). Conservation practice, however, typically focuses on managing the populations of specific (e.g. listed) rare or endangered species, often within reserves or protected areas. So far, only a few studies considered the synergetic effects between the protection of endangered habitats or species and the supply of ecosystem services (but see Eigenbrod et al. 2009, Eastwood et al. 2016, Márquez et al. 2017, Xu et al. 2017). For example, Eastwood et al. (2016) investigated the effect of conservation on ES provision by comparing the provision of a broad range of ES in nine UK protected areas with nearby non-protected areas representing the same site-characteristics and habitat type, finding higher levels of ES provision (mainly cultural and regulating) in protected areas. Eigenbrod et al. (2009)found that English protected areas provide higher carbon storage and biodiversity, but not recreation potential. Conversely, in central Colombia, Márquez et al. (2017) found <60% overlap between protected areas and hotspots of ES provision, with water provision hotspots being the least protected.

Assessments demonstrating and quantifying the impacts (both positive and negative) of multiple ES use on species conservation are also rare. Macfadyen et al. (2012) suggested that management of agricultural landscapes for the provision of ecosystem services and management for biodiversity conservation can have either synergistic or conflicting outcomes. To date, there is no comprehensive analysis of these impacts at the continental scale, accounting for site-specific characteristics and spatial differences in habitat distribution, and using a range of ES.

To close this gap we here make use of data collected in sites of the European Union's Natura 2000 network, which was established to ensure the long-term survival of Europe’s most valued and threatened species and habitats. There has been many studies focusing on the biodiversity conservation within the Nature 2000 network (reviewed in Popescu et al. 2014, and, Orlikowska et al. 2016). Here, we specifically focus on “Special Protection Areas” (SPAs) which comprise a subset of the network that targets the protection of bird species listed under the “Birds Directive” (European Commission 2009, Directive 2009/147/EC). Birds have been shown to provide a good, common and well researched indicator or umbrella taxon for environmental degradation all around the globe (e.g. Gregory et al. 2005, Roberge & Angelstam 2006). The Natura 2000 data are gathered through the responsible protected area managers and are thus based on local expert knowledge. This dataset covers a large spatial scale and contains details on the conservation status of more than 1,550 protected species and 27,312 protected areas, but appears to be relatively underused in research. Only a few studies have mapped the provision of ecosystem services to existing Natura 2000 sites or? have used Natura 2000 data to analyse the potential provision of ecosystem services at the local scale (Bastian 2013).

Here, we make use of this dataset in order to assess the trade-offs and synergies between the use of ecosystem services and conservation goals. We specifically consider i) the extent to which the use of ES is leading to benefits and pressures on species conservation in SPA sites, ii) how these patterns differ across biogeographical regions and dominant habitat types, and iii) how the trends in bird species conservation are affected by the use of ES, while comparing to other sources of data regarding conservation status. To our knowledge, this is the first study that provides a detailed, continental-scale analysis of the effects ES use has on conservation goals using data from Natura 2000 sites.

2. Data and Methods

2.1. Study area and data sources

To examine the relationship between the use of ES and conservation goals, we focused on 5,572 SPAs in Europe (Fig. 1) designated under Article 4 of the EC Birds Directive (Annex I). The data of Natura 2000 sites were available from the Data Service of the European Environmental Agency (Natura 2000 data - the European network of protected sites 2017). From the geospatial database (seventh update since 2011; database release version: “End of 2015”), we extracted geographical boundaries of all SPAs, i.e. sites classified either as SPA only or SPA fully overlapping with a ‘Site of Community Importance’ (SCI). The available site-specific data are based on standard data forms (SDF) which are used by conservation managers for communicating information that is necessary to coordinate and maintain the Natura 2000 network and to evaluate its effectiveness for conservation. We specifically used the information provided in SDF section 4.3 on ‘threats, pressures and activities’. Here, the responsible conservation managers’ report the most relevant activities occurring in each site, choosing from a list of 412 codes, ranging from agriculture and silviculture to human disturbances and biological resource use. In addition, the form includes information on (i) whether the activity has a negative or positive impact on conservation goals (i.e. the targeted species), (ii) whether the activity occurs inside or outside the SPA, and (iii) whether the importance or impact is low, medium or high, defined by the level of immediate influence and the area the activity is affecting. For the list of codes and other metadata, please see the Reference Portal for Natura 2000 (European Topic Centre on Biological Diversity 2017). From the same database, we also collected information on the biogeographical region in which each SPA occurs, the percent of coverage of habitat types and the conservation status of Annex I species.

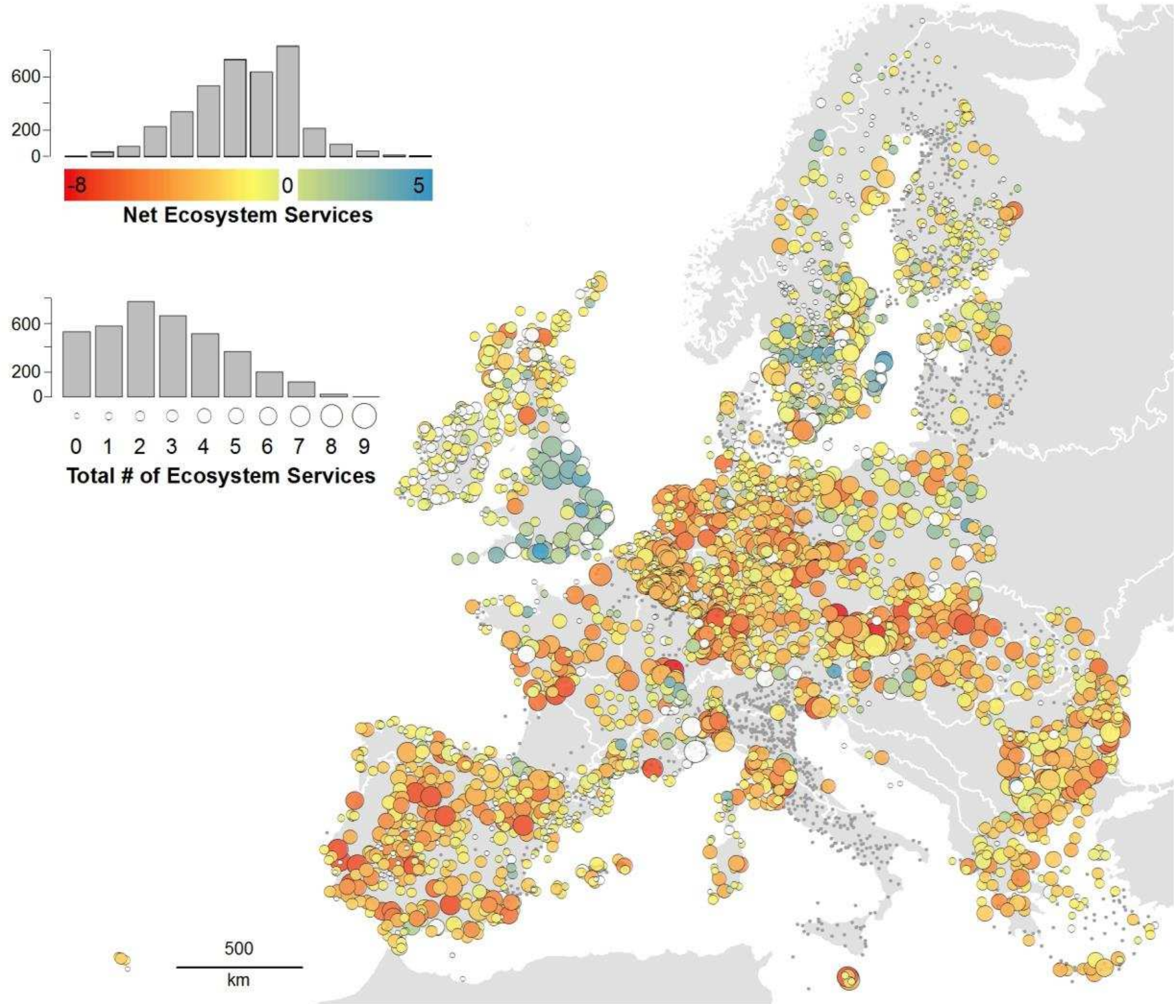

Figure 1: Distribution of Special Protection Areas (SPAs) for which data on pressures were reported and associated with the use of ecosystem services (ES). The locations represent the centroids of SPA boundaries. Grey dots represent SPAs not used for analyses. Histograms show distribution of SPAs for Net Ecosystem Services (NetES – defined as number of positive minus negative ES; upper histogram) and the total number ES detected in each site (lower histogram).

This dataset covers all member states of the European Union. However, 1,400 sites (many of which are found in Italy and the Baltic states) were excluded from further analyses because the standard data forms were unavailable or only partially completed for these sites (see Fig. A.1). We further excluded 415 sites in which, according to the SDF definition, the threats, pressures and activities had 'low' importance, i.e. they had "low direct or immediate influence, indirect influence and/or acting over small part of the area/locally". The remaining

3,757 SPAs used further in statistical analyses cover 540,479 km^2 across 9 biogeographical regions (see Fig A.1, Table A.1).

2.2. Indicators for the use of ecosystem services

To identify the positive and negative impacts of the use of ES on the conservation of bird species in SPAs, we translated the reported threats, pressures and activities with high or medium impact into indicators of ES use. Low impact codes refer to activities of low or indirect influence, and/or acting over small part of the SPA (European Commission 2011), and were excluded from this analysis. We developed a matrix where each code that represents a certain activity was linked to a specific ES class as defined by the European Common International Classification of Ecosystem Services (CICES, Haines-Young & Potschin 2013). For instance, reported agricultural or forestry activities were used as an indicator for the “provision of crops” or “provision of fibre”, respectively. We ignored codes that (i) referred to human activities and natural phenomena impacting on abiotic aspects of a site (e.g. mining, extreme events), or (ii) mentioned the absence of activity (e.g. lack of grazing or biomass removal). In cases when the code could not be meaningfully translated into the class level of CICES, we subsumed the ES class to a higher hierarchical level of the CICES classification. Some codes were also possible to consider as indicators of multiple ES, resulting in the total of 152 codes being translated (37% of all original threat codes). In total, we identified nine ES categories: seven provisioning, one cultural and one regulating which summarises all benefits derived from different regulating services in SPA sites (data available in through the project GitHub repository (Ziv et al. 2017, file ES_translation.csv).

2.3. Data Analysis

We quantified the relative proportions of ES that were recorded as having positive or negative (or both) impacts on each SPA across the whole dataset and within the five biogeographical regions that covered ca. 95% of all SPAs: Alpine, Atlantic, Boreal, Continental, and Mediterranean. We further quantified the distribution of ES across all 3,391 SPAs that were dominated by one habitat (i.e. habitat covering >50% of the area of a site). This way we identified 14 habitats that were recorded as dominant in at least 30 sites: marine (N01), intertidal (N02), shore (N05), inland water (N06), marshes (N07), heath (N08), grassland (N10), cropland (N12), improved grass (N14), other arable (M15), broadleaved wood (N16), coniferous woodland (N17), mixed woodland (N19) and other land (N23; urban and industrial sites, as well as roads and mines).

In order to quantify the potential pressures of ES use on bird conservation, we calculated a net impact of ES (NetES) by summing the positive and negative impacts of all ES recorded at each site. For example, if the use of three ES (crops, livestock and recreation) was identified at a site and each had a different impact (e.g. crops were reported as having a negative impact (-1), livestock was reported as having a positive impact (+1), and recreation was reported as having a negative impact (-1)), the site was assigned a NetES score of -1. ES with both negative and positive impacts did not change the NetES score of the site. Since each of the nine ES, resulting from translating site impacts to ES, could potentially be recorded as either negative or positive, the NetES score varies between -8 and +5.

As a measure of the conservation status of each site, we calculated an SPA-specific conservation index based on the species population status reported by conservation managers in the SDF. For each species occurring in the SPAs, the managers rated the conservation value of the SPA for that specific species as “A” (“excellent conservation”), “B” (“good conservation”) or “C” (“average or reduced conservation”). We transformed the conservation value rating into numerical scores (C=0, B=1, A=2) and then averaged the scores for all species occurring at an SPA to provide a “Conservation Index” score for that SPA. For example, if an SPA has listed two species with excellent conservation value habitat (2 x “+2”), but for another species which is only at good conservation value (+1), that site will have a conservation index of +5 divided by 3 (for the total number of species present in the site) which is 1.7.

Finally, in order to compare the Natura 2000 Conservation Index to external conservation data, we extracted information on trends (increasing, decreasing or stable) and conservation classification from the IUCN (2012) database using the letsR package (Vilela & Villalobos 2015). For each SPA, a composite IUCN index was created by extracting a list of species for which that SPA was of “significant”, “good”, or “excellent” value at a global scale. The IUCN trends for each species were then converted to a numeric score (decreasing=0, stable=1, increasing=2) and scores were averaged across species for that SPA. We then evaluated the relationship between the threats posed by ES use and the conservation status by calculating Spearman’s rank correlations between NetES and both the Conservation Index and IUCN Index (R codes needed to reproduce the analysis is available on GitHub (Ziv et al. 2017)).

3. Results

3.1. Ecosystem Services Mapping

A total number of 152 reported threats, pressures and activities were mapped to 9 ecosystem services that capture provisioning, regulating and cultural services. Recreation (used in 54% of SPAs) and wild food (38%) are the most commonly used ES with either positive or negative impact on SPA sites, followed by fibre (35%) livestock (33%), crop (32%) and fodder (27%). Maintaining regulating services (19%), the provision of water (3%), and aquaculture (4%) in contrast, are mentioned to impact SPA sites least often. Our analysis shows that the Boreal biogeographical region has an overall lower number of ecosystem services reported per SPA than other regions (see Fig 1, Table A.1). While on average 2.73 ES were mentioned per SPA across Europe, the Boreal region stands out with 1.88 compared to 3.41 ES per SPA in the Alpine zone. Overall, we found that the use of ES is affecting conservation goals more negatively than positively (Fig 1, Fig 2A). In particular, the use of water (94% negative), wild food (97% negative) and recreational services (98% negative) affect conservation goals predominantly negatively. Conversely, livestock (52% positive) and fodder production (34% positive) services are the most prominently positive featured ES. When summing up all negative and positive impacts deriving from ES use on site, NetES is less negative in the UK and Southern Sweden, whereas the Iberian Peninsula and Germany contain SPAs with more negative NetES (Fig 1, Table A.2). When considering negative and positive impacts of ES separately, Austria, Hungary and Bulgaria show high numbers of both positive and negative impacts (Fig. A.2) that equal out in the calculation of NetES (Fig. 1).

3.2. Distribution of ES within biogeographical regions

Different patterns of positive and negative impacts of ES use emerge for the five most important biogeographical regions in Europe (Fig. 2B-F). The Atlantic, Alpine and Continental biogeographical regions show similar patterns, with e.g. livestock benefiting conservation goals in 48%-72% of SPA reporting this ES. At the same time, other services are less often reported to have positive impacts in these regions. The Mediterranean region reveals the overall highest proportion of negative impacts of ES use, whereas in the Boreal region positive associations are most pronounced. When recorded for an SPA in the Boreal region, livestock (88%) and fodder production (78%) are found to impact conservation goals positively.

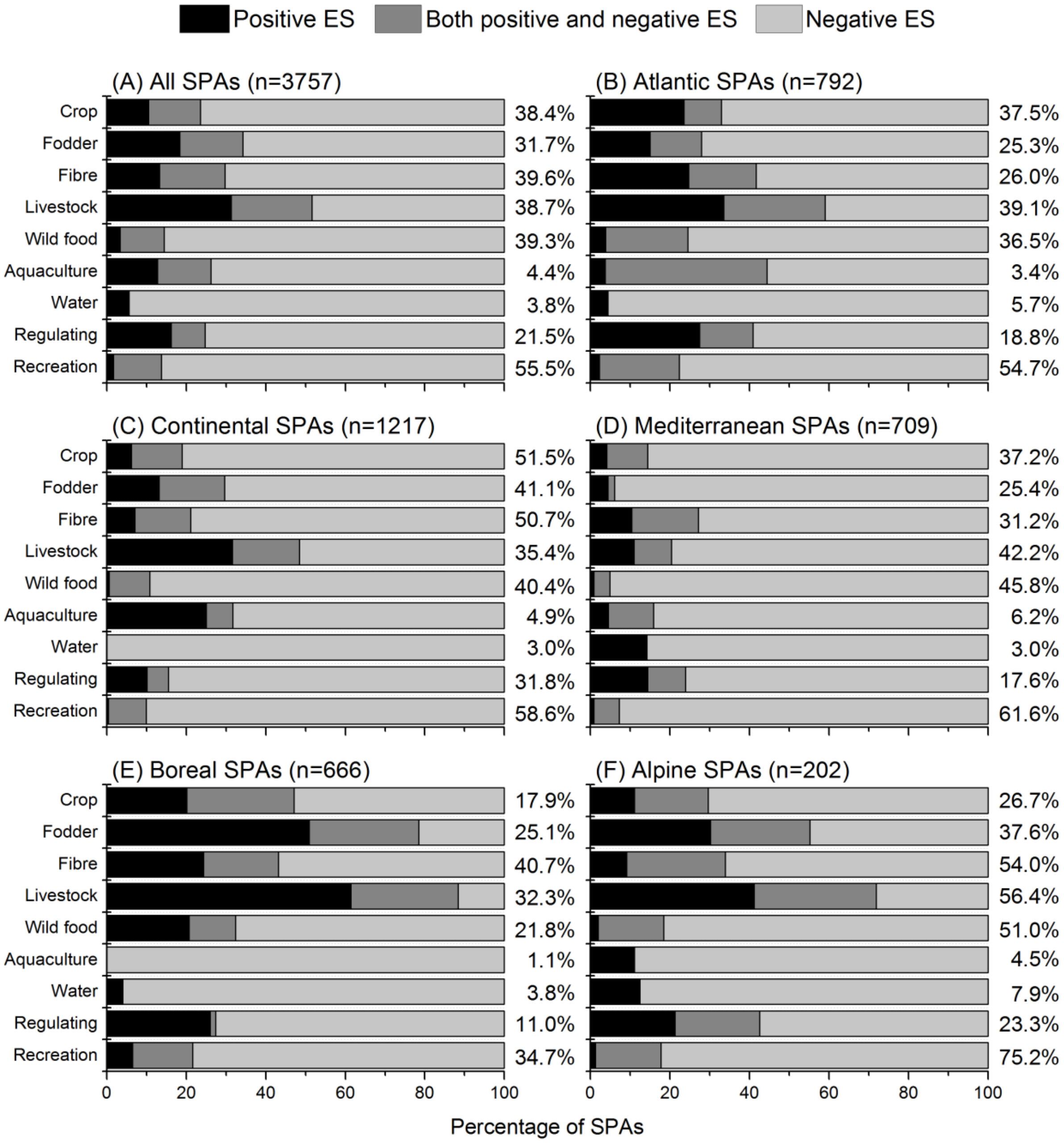

Figure 2: Sign of ecosystem services impacts in all SPAs (panel A) and within five biogeographical regions (panels B-F) comprising 95.6% of SPAs, scaled to 100% of SPAs where ES is reported (see percentage on right of bar). Services mentioned as positive (black), negative (light grey) or both (dark grey). See Fig A.1 for boundaries of each biogeographical region.

3.3. Distribution of ES within dominant habitat types

The prevalence of ES impacting SPAs either positively or negatively varies depending on dominant habitat type present in the SPAs (Fig 3). For instance, fibre production is the predominant ES throughout forest habitat classes, while crop, fodder and livestock exhibit similar patterns across agricultural landscapes (grassland, cropland, improved grassland and other arable lands). Recreation is habitat independent, except in marshes. However, overall positive or negative impacts of ES use are less often recorded for marshes, with particularly low numbers for recreation and wild food (29% and 21% of SPAs, respectively) relative to the use of those services in other habitats. Furthermore, the relative proportion of positive and negative effects changes depending on habitat type and ES under consideration. For example, while grazing from livestock, and the production of fodder and crops have predominantly positive impacts on SPAs of marine/intertidal habitats, the use of the same services causes mainly negative impacts on SPAs dominated by either agricultural or forest habitat classes. Similarly, maintaining regulating services are seen to benefit SPAs on intertidal and heathland habitats in particular, whereas for all other habitats their maintenance is seen as a threat for the realisation of conservation goals. Other services such as recreation or wild food reveal mainly negative impacts, regardless of the habitat type.

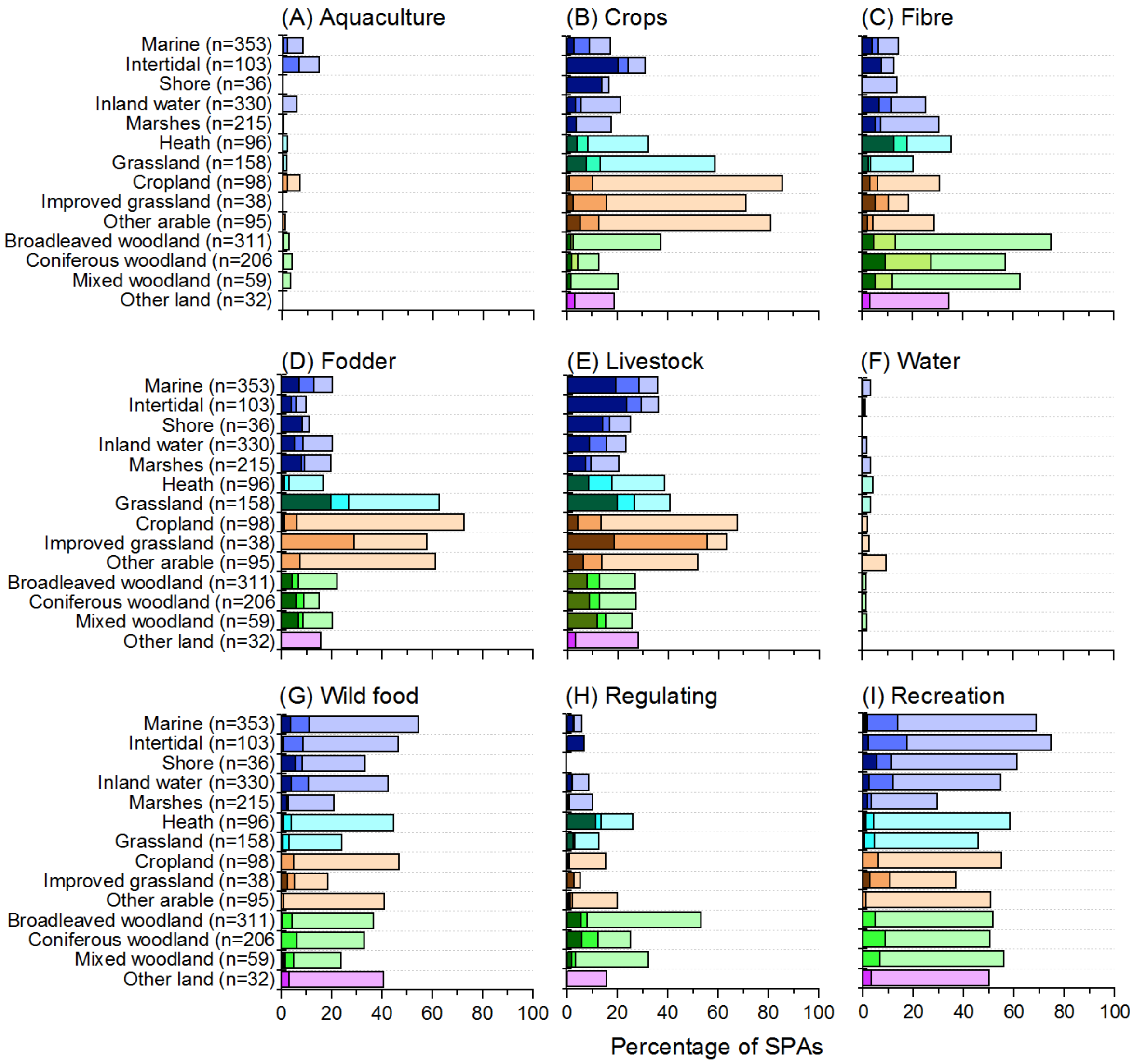

Figure 3: Prevalence of habitat types containing each ecosystem service, categorised as positive (darkest colour), both (middle colour), and negative (lightest colour). Colours indicate broad habitat classes: blue = marine/aquatic, turquoise = grass/heath, brown = agricultural, green = forest, purple = other.

3.4. Pressures of ES use on bird conservation

A significant positive correlation is found between NetES and the conservation index score reported for all SPAs across biogeographical regions (Fig. 4). However, the relationship is found to be different depending on the biogeographical region. Whereas the Atlantic region shows a significantly positive correlation (R^2=0.041, P<0.001; Fig. 4C), the Continental region reveals a significantly but weak negative association between conservation index and NetES (R^2=0.006, P=0.002; Fig. 4E). All other biogeographical regions show no clear relationship. Overall, the conservation index has higher average values in the Boreal region (Fig. 4D), thus indicating a better species population status as reported by the conservation managers of this region. In comparison with the conservation index derived from SDFs, the IUCN index did not show a significant increase or decrease with NetES in all SPAs (Fig. A.3). With a value of 0.627 the average IUCN index across all SPAs was substantially lower than the conservation index (1.083).

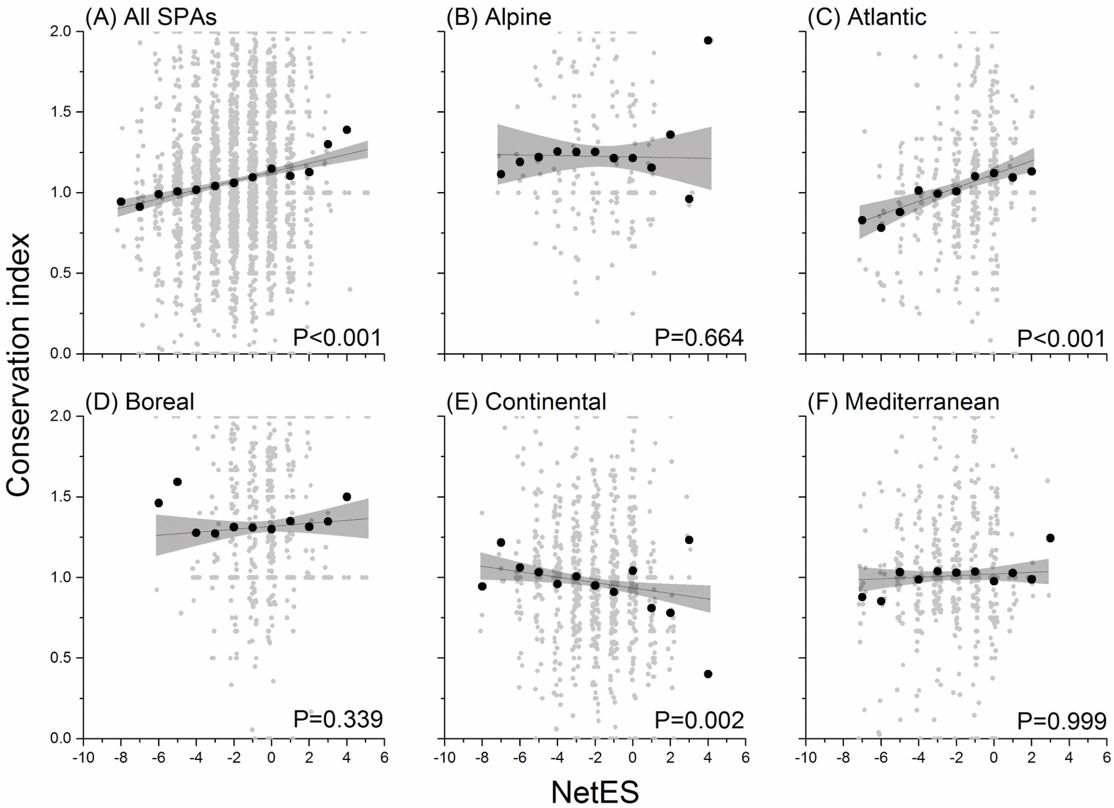

Figure 4: Relationships between the NetES *and the conservation status ("excellent", "good", "average/reduced" scored as 2, 1, 0 respectively) of each site plotted as sites grouped by net ESS* category for (A) all SPAs (R^2=0.017), (B) Alpine SPAs (R^2=-0.005), (C) Atlantic SPAs (R^2=0.041), (D) Boreal SPAs (R^2<0.001), (E) Continental SPAs (R^2=0.006), and (F) Mediterranean SPAs (R^2=-0.001). Shaded areas show 95% confidence intervals associated with linear regression of raw data (grey points, shown with jitter to enhance clarity), R^2 values are adjusted R^2 for the linear regression of the raw data, and p-values are from Spearman rank correlations on raw data. Black points show mean Conservation Index values for each value of NetES.

4. Discussion

This study shows that species conservation and the use of ecosystem services in Natura 2000 SPAs does not exhibit a single dominant relationship pattern: synergies, trade-offs and combinations of the two can all be observed. Thus, our analysis cannot provide evidence that managing for ES has generally positive implications for biodiversity conservation nor that such management has clear negative impacts. Instead, the variations we observe across biogeographical regions and habitats suggest that the relationship between conservation and the use of ecosystem services depends on factors such as timing, intensity of use, and the type of impacted species.

4.1. Specific impacts of ES use on bird conservation

The relationship between biodiversity and ES is often discussed as a multi-layered relationship (Mace et al. 2012). A widely accepted typology of ES-biodiversity relationships suggests that provisioning services have win-lose relations with biodiversity, whereas regulating services are win-win and cultural services are win-neutral (Reyers et al. 2012). However, the results presented here suggest a more nuanced picture. We found that the use and/or maintenance of provisioning, regulating or cultural services can have positive, negative or both impacts on conservation goals even within the same SPA. However, when qualitatively assessing the management plan documents of a random sample of SPAs across Europe, we found many different examples for synergies and trade-offs documented in the Natura 2000 database (Table 1). The trade-offs we encounter are largely as expected - e.g. damage and degradation of habitat or the depletion of food resources reduce the conservation importance of a site for local bird species. Direct negative impacts on individuals are another main cause of trade-offs, for example through physical harm to young and mature birds, damage by chemical runoff or poisonous compounds as well as noise pollution or disturbance caused by recreational activities (Table 1). However, we also find a surprising number of positive impacts, which indicate a synergistic relationship between conservation and ES use, such as increasing the availability and/or quality of food resources and habitats, maintaining some habitats that are historically human-dominated (mainly grasslands in parts of Europe), which supports earlier conceptual considerations (Seppelt et al. 2016) and similar empirical findings (Maes et al. 2012). The examples we extracted from the management plans (Table 1) suggest that more traditional land-use types such as pond aquaculture and extensive livestock may help creating and maintaining synergies between ES use and conservation goals.

Table 1: Examples of synergies and trade-offs between Ecosystem Services and threats, pressures or activities reported by managers of the Natura 2000 Special Protection Areas (SPA). Examples were obtained from randomly selected management plan documents of European sites classified as SPA. Each site is recognised by a unique site code comprising two letters for country code usually followed by an alphanumeric code (unique codes of reference sites shown in parentheses). Management plans available online or made available by the responsible entities as of February 2017 – see http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=SITECODE for contact information and URLs.

Examples of synergies	Examples of trade-offs
Aquaculture	
Fish-ponds provide habitats for waterfowl. Fish-ponds with littoral vegetation and stable water level are important nesting sites (DE5412401).	**Intensive aquaculture damages nesting habitat.** Frequent manipulations with water level and industrial sediment removal destroy or disturb nesting sites (CZ0621031, CZ0211010).

Draining creates feeding grounds. Decreasing water level of ponds for fishing provides feeding grounds for birds (AT1201000).	**Stocked fish populations reduce food resources.** Heavy stocking can have adverse effects on wintering wildfowl through lowering aquatic plant and invertebrate availability (UK9012171).
Crops and Fodder	
Agricultural crops especially from organic farming provide food sources. Birds feed on crops. Limited use of pesticides leads to higher abundance of arthropod food resources (DE4543451)**.** **Coastal fields provide wintering habitat.** When overwintering, Lapwing makes use of a variety of habitats including coastal fields (UK9013011).	**Rodenticides and soil sterility reduce food sources.** Application of rodenticides and use of crops that lead to soil sterility after harvest (corn, sunflower, energy crops) reduce availability of food (CZ0531013). **Bioenergy crops reduce food sources.** Shifting to bioenergy crops (corn and wheat) increases pesticide application and reduces the availability of arthropods as a food source for rearing birds (DE3639401). **Chemicals harm birds and their development.** Fertilizers and insecticides threaten bird species through the consumption of contaminated prey and food. Bioaccumulation in tissues and their transmission to eggs affect embryonic development (ES0000119, ES0000142, CZ0421005) **Spill-over of fertilizer leads to eutrophication.** Spill-over of fertilizers used in agriculture alters nutrient conditions in protected areas (DE3437401). **Changes in management practices lead to habitat loss.** Loss of rough grassland to other crop types are responsible for reductions in Chough numbers (UK9003171).
Fibre	
Reforestation extends habitat area. Reforestation with native species or promotion of natural regrowth increases natural habitat of endangered species (PTZPE0033, ES0000364). **Clearance and removal of undergrowth improve habitats.** Forestry operations aimed at promoting regeneration of fruit-producing species improve habitats of the Cantabrian grouse and partridge (ES0000364).	**Alien trees affect native habitat.** Native forest habitats are threatened by spread of invasive species or by reforestation with exotic trees (AT1125129, PTZPE0033). **Disturbance of habitat by removal of understory and dead trees.** Fire prevention activities lead to the loss of nesting habitat for many species (ES0000119, ES0000142). **Changes in tree species composition lead to habitat loss.** Typical forests providing habitats for bird species are repressed by the afforestation with spruce (AT1201000). Previous monocultures of the non-native blue spruce became a secondary habitat for the Black grouse. Replacing forest stands by native spruce species and replanting of forest openings are threats for bird populations (CZ0421005). **Forest clearings lead to habitat loss.** Harvesters in intensively used forests alter soil conditions. Black stork and black woodpecker habitat trees are removed (DE4232401).

Livestock	
Grazing maintains open habitats. Open habitats, essential for many bird species, remain open through grazing which prevents succession (AT1201000, AT1209000, AT1125129). **Traditional land use maintains habitat structure.** Austrian alms or Mediterranean humid meadows are extensively grazed to maintain their structural diversity and functions (AT1203000).	**Overgrazing degrades habitats.** Overgrazing, intensification (high cattle numbers) and clearing of prostrate shrubs negatively affect populations of the black grouse (AT1203000) and other endemic bird species (ES4210008, ES0000388). **Conversion of Laural forests to pastures causes habitat loss.** Intensive grazing and the conversion of Laurel forests to pastures threaten protected bird species (PTZPE0033, PTMAD0001, PTZPE0041). **Intensive grazing destroys clutches.** Nests of ground nesting bird species are destroyed by grazers, if intensity is high, especially, if grazing of river banks is allowed (DE3639401).
Water	
Protection of area for water extraction has positive effect on conservation goals. Measures taken to protect quality of drinking water have generally positive outcomes for conservation (CZ0811020, DE4232401).	**Hydroelectric power generation conflicts with fluvial ecosystems.** Hydroelectric power stations cause conflict for the maintenance of the fluvial ecosystem (CZ0811020). **Noise pollution is a disturbance.** Noise caused by water pumps and maintenance of wells disturbs bird species (DE3635401).
Regulating	
Forest replanting increases carbon sequestration. Plantations on ancient woodland sites are being managed with the aim of restoring native pinewood (UK9001791). **Restoring flood-plain forest improves water retention.** Inundation of the alluvial plain helps maintain forest habitats (CZ0711018).	**Channelization and damming of rivers alters habitats.** Removal of meandering river channels and building dams for flood regulation destroys bird habitats (DE6533471, AT1201000).
Recreation and Wild Food	
Hunting prevents damage to forest. High density population of game animals are reduced by hunting, thereby retaining forest habitats (ES6140004). **Anglers help protect food sources.** Recreational anglers release fish species into protected area and increase food resources for waterfowl (DE4232401).	**Recreational activities disturb birds and habitats.** Windsurfing, kayaking, hiking, climbing, cycling and other activities in protected areas represent a disturbance to natural breeding or feeding sites (AT1201000, CZ0421005, PTCON0061, UK9006161). **Visitors disturb breeding birds.** Excessive use of tracks disturb birds during breeding, especially highly sensitive species such as vultures (ES0000007). **Ammunition poisons birds of prey.** Lead poisoning in scavenging species is found in areas with high hunting activity (ES0000119, ES0000142). **Recreational fishing has negative impacts on bird**

	conservation. Recreational fishing leads to disturbance of riverbanks, introduction of non-native fish species, or to accidental captures of birds (ES0000319, UK9002031).

4.2 Relationship with biogeographical regions

The main biogeographical regions within Europe showed marked variation in the number of ES and their overall impact (as estimated by NetES, Fig. 1 and Fig. A.1). In the Boreal region, for example, we identified fewer and more positive impacts of ES use and a generally better conservation status when compared to other regions such as the Mediterranean (Fig. 1). There are several possible explanations for this observed spatial pattern. First, the use of ES depends on human population density; hence, for areas of lower population density and increased distance of SPAs from population centres, as in the case of the Boreal region, to find overall lower levels of ES use are expected. Secondly, as we found positive synergies linked to habitat and food availability, the creation or maintenance of certain habitats (e.g. by grazing) and availability of grain or fish food sources in otherwise low-productivity landscapes may explain why NetES is more positive in high latitude areas. On the other hand, it is also possible that the lower ecological resilience in water-limited Mediterranean ecosystems make human activity (specifically livestock pressure) more detrimental to bird species, creating an overall higher negative impact of ES use. In Continental regions, we find a generally larger fraction of the sites receiving benefits from livestock-related services, which confirms the expectations and previous findings, for example for Germany (Dittrich et al. 2017).

4.3 Effects of habitat type and reporting issues

The distribution of services across dominant habitats also follows our expectations and supports our approach of translating site impacts into indicators for ES use. In particular, we find that some services are dependent on specific habitat types (in particular crop, fibre and livestock), whereas cultural services are present throughout all habitats. This finding is in agreement with a report by the Institute for European Environmental Policy (Gantioler et al. 2010), based on 111 responses to a survey, showing cultural services (including ecotourism & recreation, cultural values & inspirational services and landscape & amenity services) are perceived to have high relevance across different parts of the EU. The only notable exception to the commonness of recreational services are those areas that are difficult to access (e.g. marshes).

Ultimately, we suggest that NetES may be regarded as a relevant indicator for habitat quality within SPAs for birds, although it only explains <5% of the variance. At a continental scale, however, our analysis indicates that ES use does not seem to affect the trend in conservation of bird species (IUCN status) and therefore does not reflect global species status trends. Therefore, the conservation status of SPAs seems to be affected more by other threats not accounted for in our analysis. These threats could possibly be ES used but not reported in SDFs (e.g. Lisón et al. 2017 found SDFs underestimate bats distribution across Spain), additional human activities not related to biotic ES use (e.g. abiotic outputs such as mining, wind-energy production), potential inconsistencies in reporting the impacts, or the presence of other individual conscious or unconscious biases influencing the reporting in SDFs. Furthermore, migratory bird species in particular may be affected by impacts occurring outside of SPAs or even outside of Europe (Sanderson et al. 2006). Some ES may also have indirect positive effects, for example recreation may help with funding of conservation activities in the site, raise awareness and decrease pressures. Finally, while the format of the SDFs is unbiased (section 4.3 in the SDF has two side-by-side tables titled 'Negative impacts' and 'Positive impacts', see European Commission 2011), the codes originate from two decades of reporting to Article 17 (Habitat Directive), Article 12 (Birds Directive), Water and Marine Strategy Framework Directives and Ramsar Convention reporting – and may limit the reporting of positive ES use, or bias towards more well-characterized trade-offs between provisioning services and conservation. Despite these potential shortcomings, in our compilation of management plans (Table 1) we observed that the data SPA managers enter into the Natura 2000 database through the SDF is less negative than the management plans. The more negative tone of the management plans may be due to the open, discursive format of the plans, which also encourages more room for subjective statements and evaluations, with the potential for deliberate/political bias towards negative contexts. This is often strengthened by national guidelines or templates for management plans which highlight negative threats and consequences and do not give room for authors to elaborate on positive synergies with human activities. While not fully complete (e.g. no information in Italy in this database release), the Natura 2000 database is a useful source as compared to doing a large content analysis across the Natura 2000 network management plans - most of which are hard to find online.

4.4 Implications

The arguments of the 'New Conservation', calling for more emphasis on benefits to human well-being (Kareiva & Marvier 2012) or even a new category of ES-based protected areas (Xu et al. 2017), build on the premise that a certain level of biodiversity is needed for the delivery of ES. However, a comprehensive analysis has been missing to date that would examine the extent to which the use of ES in protected areas leads to benefits and pressures on biodiversity conservation. Our study is a first step towards an in-depth assessment of these impacts in the SPA sites of the European Natura 2000 network, accounting for site-specific characteristics and using a range of ES. Further analysis of the same database is needed to test if abiotic pressures impact bird conservation status, and extend the analysis to include SCIs and the variety of taxonomic groups protected by the Habitat Directive. In contrast with the abovementioned arguments, we find little evidence that the relationship between conservation goals and ES use is always beneficial. Rather, the use of ES in the majority of SPA sites and across most biomes and habitat types shows negative effects on the conservation status of species under protection (Reyers et al. 2012). However, there is clear potential within some geographical regions to create opportunities for conservation in line with Reyers et al (2012), but caution should be taken not to replace policies for biodiversity conservation operating across diverse local and regional contexts. In particular, identifying the particular mechanisms of action of ES on conservation outcomes on particular sites could provide a substantial body of novel management approaches that could be applied across the network.

5. Conclusions

Human activities are causing direct and indirect impacts on ecosystems, affecting bird populations as well as those of other fauna and flora. The drivers of these activities may be proximate, or linked via supply chains to consumption of goods and services in faraway countries (Moran & Kanemoto 2017). Better management of our natural environment to meet targets (e.g. CBD Aichi Targets, EU Biodiversity Strategy 2020 goals) for networks of protected areas such as Natura 2000, requires a better understanding of where and how those actions will have negative or positive effects on biodiversity. Here, we present a novel use of standardized data collected from across all 28 EU member states, and demonstrate quantitatively that this question is more spatially and thematically detailed and context-specific than simple win-win, win-lose and win-neutral relationships with provisioning, regulating and cultural services (Reyers et al. 2012). Our findings imply that if we want to strengthen the legitimacy of nature conservation and maintain the argument that managing protected areas for ES is consistent with conservation goals, we need to enhance our knowledge not only on how biodiversity underpins ES but also on how the use of ES in protected areas affect the conservation of valuable species and habitats.

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Appendix A

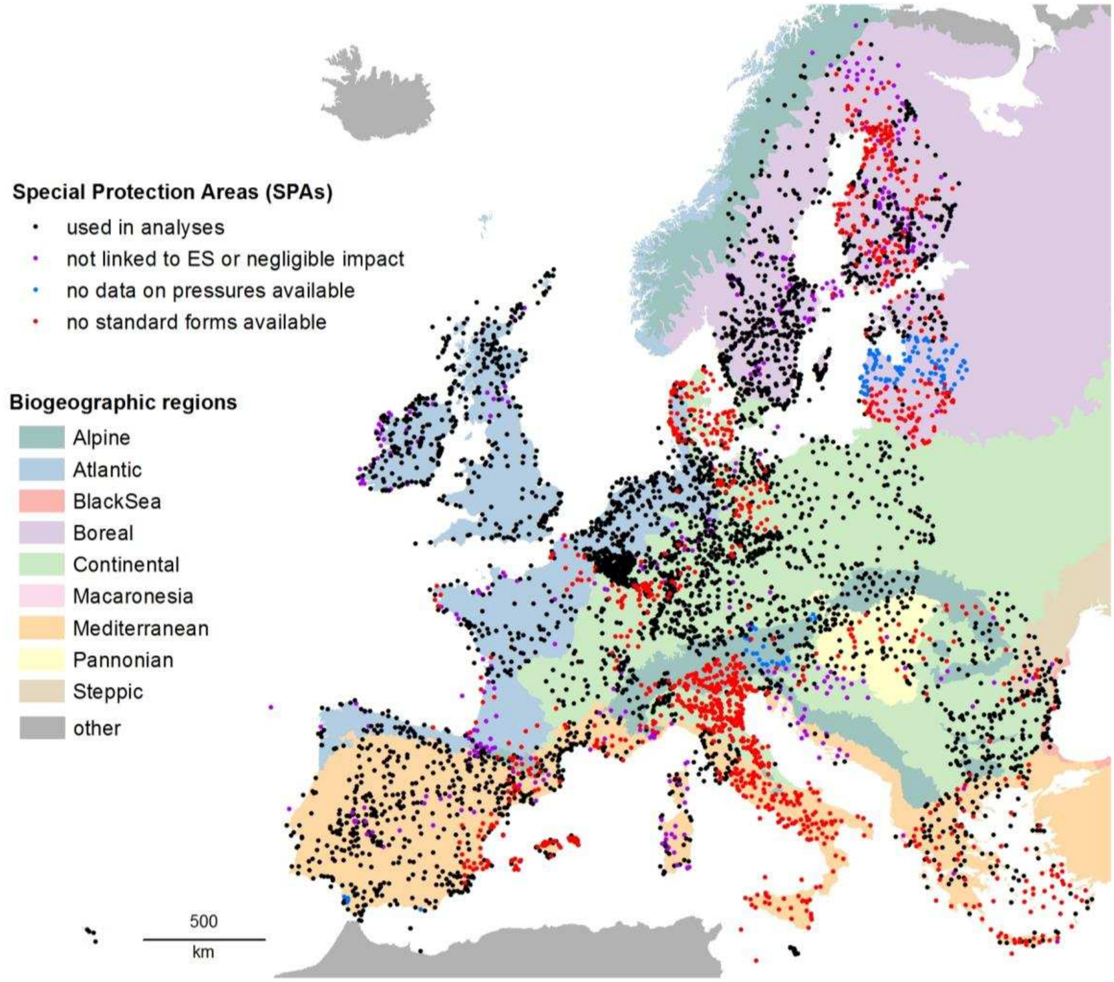

Fig A.1: Distribution of SPAs within different biogeographical regions in Europe. The points represent the centroids of SPA boundaries. Their colour shows whether the sites were used in the analyses (n=3757, black), or whether they were excluded because (i) their reported pressures were not linked to the use of ES or their impact was reported as negligible (n=415, purple), (ii) the standard data forms were incomplete (n=137, blue) or (iii) the standard data forms were unavailable/not submitted (n=1263, red).

Table A.1: Total number of SPAs vs Number of SPAs included in the analysis

Biogeographical Regions	Total number of SPAs	Number of SPAs included in the analysis	Percent of SPAs included in the analysis	Mean number of ES per SPA*
EU-28	**5572**	**3757**	**67.4%**	**2.73**
Alpine	358	175	48.9%	3.41
Atlantic	937	792	84.5%	2.46
Black Sea	27	26	96.3%	3.69

Boreal	1171	669	57.1%	1.88
Continental	1705	1232	72.3%	3.18
Macaronesia	74	31	41.9%	2.16
Mediterranean	1155	721	62.4%	2.70
Pannonian	101	77	76.2%	4.17
Steppic	44	34	77.3%	3.03

* Calculated in those SPAs included in the analysis

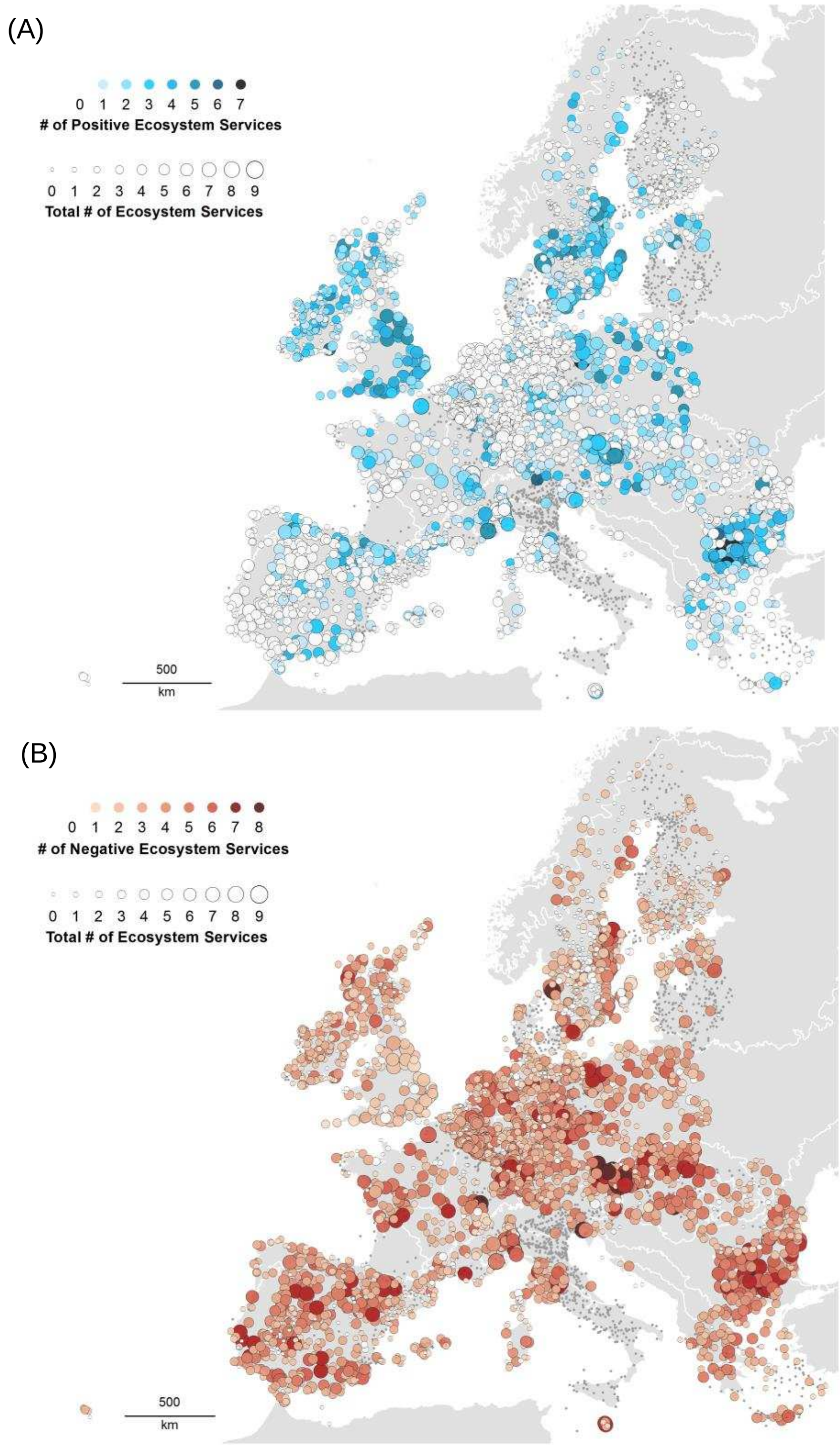

Fig A.2: Distribution of Special Protection Areas (SPAs) for which data on pressures were reported and associated with the use of ecosystem services (ES). The locations represent the centroids of SPA boundaries. The size of the symbols represents the total number of ES and the colour refers to the number of positive ES (A) or negative ES (B) reported in each SPA. Grey dots represent SPAs not used for analyses.

Table A.2: Mean NetES in SPAs per EU member state

EU Member State	Mean NetES per member state
EU-28	**-1.71**
Austria	-2.52
Belgium	-2.80
Bulgaria	-2.95
Croatia	-1.00
Cyprus	-2.86
Czech Republic	-2.44
Denmark	-0.21
Estonia	-1.05
Finland	-0.78
France	-1.63
Germany	-2.30
Greece	-2.59
Hungary	-2.80
Ireland	-0.48
Italy	-2.82
Latvia	0.00
Lithuania	-2.00
Luxembourg	-2.06
Malta	-2.18
Netherlands	-2.26
Poland	-1.46
Portugal	-3.36
Romania	-2.18
Slovakia	-3.98

Slovenia	-1.50
Spain	-2.10
Sweden	-0.31
United Kingdom	-0.41

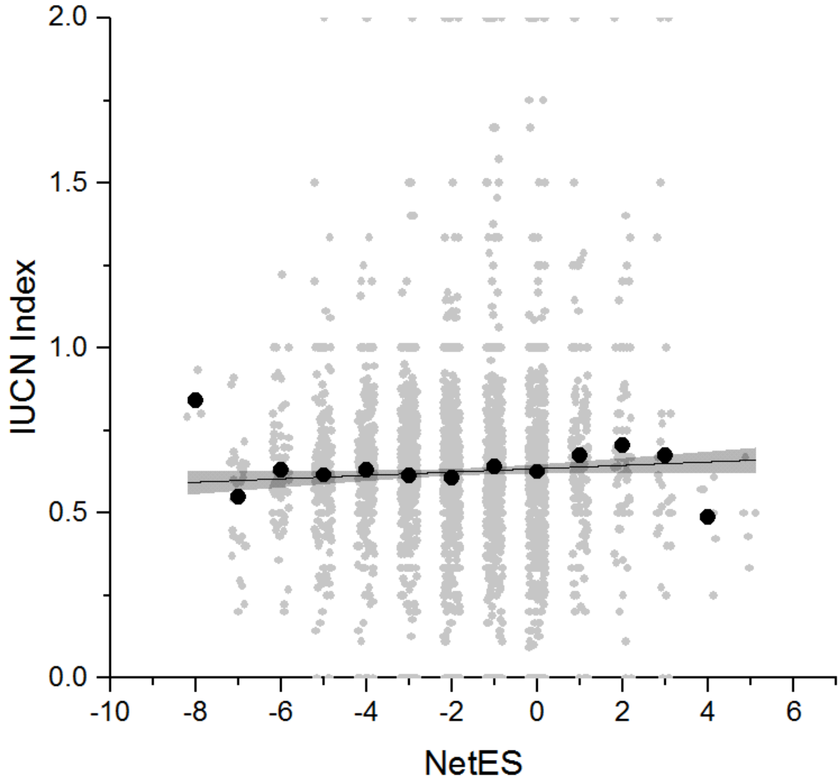

Fig A.3: Relationships between the NetES *and the IUCN trends index (“increase”, “stable”, “decrease”* scored as 2, 1, 0) plotted as sites grouped by NetES category. Shaded areas show 95% confidence intervals associated with regression of raw data. *Spearman’s ρ=0.113, p<0.001. R*^{2} from a linear regression is 0.016.

Appendix B

ES_translation.csv - Mapping of negative threats and positive impacts to ES

Appendix C

ES_breakdown.xls – Detailed breakdown of positive, negative or both impacts across biogeographic regions and dominant habitats

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