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European Bird distribution is "well" represented by Special Protected Areas: Mission accomplished?

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ABSTRACT

Based on spatial distribution maps for 495 breeding bird species inhabiting mainland Europe, we examined whether bird richness is well represented by the protected areas under the European Birds and Habitats Directives. The former regulates the designation of Special Protected Areas (SPAs) for birds, whereas the latter focuses on habitats through the Sites of Community Importance (SCI) and Special Areas of Conservation (SAC). All together, these areas conform the Natura 2000 network. To achieve our goal, we identified high-value richness areas by assessing the geographic distribution of all bird and important bird species (IBS, according to the Birds Directive) occurring in European Union (EU) countries, and investigated how well bird richness were represented in the current protected areas network. Our assessments showed little association between bird richness patterns and the cover of protected areas (PAs) across EU countries. The congruence between high-value richness areas of all bird species and IBS with PAs cover was moderate, suggesting that different conservation planning targets should be taken into account to safeguard IBS, or the composition of bird species. Our results also showed that 16 (3.9%) threatened species were present in gaps of PAs. The poor relationship between PAs cover and bird richness pattern found herein may provide evidence that the establishment of SPAs across Europe may not be fully accounting for richness patterns to enhance the performance of the current network.

1. Introduction

In the face of the alarming threats (i.e. human actions) affecting species distribution patterns, a key issue to halt species loss is to establish priority areas for conservation, regarded as areas selected to represent maximum biological diversity (Margules and Pressey, 1988). Protected areas (PAs) are considered as beachheads against biological extinction.

However, it is becoming increasingly recognised that a large proportion of PAs around the world receive ineffective enforcement (Margules et al., 2000; Wiersma and Nudds, 2009). The deficiency of well-defined goals, governmental interpretations of conservation objectives and misrepresentation of decision processes in favour of satisfying economic interests are important barriers for the implementation of PAs (Apostolopoulou and Pantis, 2009). Rather than bureaucratic issues, biodiversity conservation planning should focus more on natural processes (Maiorano et al., 2007). Conservation planning should be established in accordance with biodiversity patterns (Pressey et al., 2003). Recently, studies at different grains and spatial scales have attempted to identify PAs highlighting the importance of the spatial patterns of species distribution of different taxonomic groups (Myers et al., 2000; Rey Benayas and de la Montaña, 2003; Jelaska et al., 2010).

There have been various attempts to identify the effectiveness of PAs network (Maiorano et al., 2007; Wiersma and Nudds, 2009). This has yielded several studies recommending that further efforts are still necessary to provide adequate representativeness of biodiversity (Rodrigues et al., 2004; Wiersma and Nudds, 2009). An effective PAs network should encompass the maximum biodiversity represented by a minimum number of sites (Wiersma and Nudds, 2009). Furthermore, a particular gap analysis in current PAs networks is an important tool to assess biological representation and, therefore, help conservationists to identify priorities for the establishment of new PAs or restoration of existing ones (Wiersma and Nudds, 2009).

In Europe, the Natura 2000 network of PAs aims to conserve species and special habitat types (habitats with distinguished geographic, abiotic and biotic features) across the 27 European Union (EU) countries. Natura 2000 comprises areas under the Habitats Directive (Directive EEC/92/43) – including Sites of Community Importance (SCI) and Special Areas of Conservation (SAC) – and

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sites under the Birds Directive (Directive Directive 2009/147/EC) – including Special Protected Areas (SPAs). Specifically, SCI/SAC aim to conserve biodiversity through the persistence of most patrimonial species and habitats across Europe, whereas SPAs aim to create a comprehensive scheme for all wild birds naturally occurring in the EU countries (EC, 2009). Both directives are regarded as keystone of Europe's natural conservation.

In the present study, we tested whether PAs under the Birds and Habitats Directives network represent the patterns of breeding bird species richness across EU countries. Specifically, we aimed to: (1) identify patterns of bird species richness across Europe, (2) verify whether the spatial distribution of protected areas under the Birds and Habitats Directives follow the spatial distribution pattern of bird species richness, (3) identify the geographical location of high-value richness areas of bird species across Europe, and (4) investigate the congruence between high-value bird richness areas and PAs cover.

2. Methods

2.1. Data

Distribution data for bird species were obtained from the European Bird Census Council Atlas of European Breeding Birds (EBCC) (Hagemeijer and Blair, 1997). These data integrates 25 years of continuous field surveys by ornithologists in more than 40 countries, and comprises 495 European Bird species (Hagemeijer and Blair, 1997). After excluding all those species not occurring in all EU countries, a total of 416 bird species were used in the analysis. We recognise that more recent data (i.e. Birds of Western Palearctic Interactive (BWPi), 2006) could be also used in this analysis. However, BWPi provides bird species range maps and this approach imposes some limitations. First, range maps produces less reliable information than survey data and contain less information, especially at finer scales (Hurlbert and Jetz, 2007). Second, range maps tend to overestimate the presence of species (generating false positives), inflating the error of commission (Hurlbert and Jetz, 2007). This overestimation may affect conclusions in the identification of high-value richness areas, making results unreliable. Consequently, the atlas of the EBCC seems to be the most suitable tool for broad scale analyses.

The Birds Directive (Directive 2009/147/EC) provides a list of 193 bird species that shall be subject of species conservation measures to safeguard their survival and reproduction. For analyses, we grouped birds into: (1) all bird species and (2) important bird species (IBS), comprising those species listed in the Birds Directive Annex I (139 species). Additionally, bird species were classified according to the categories defined by the International Union for Nature Conservation (IUCN 2010) into unthreatened (i.e. species considered of least concern (LC), 358 species) and threatened species, including those considered as endangered (En, 2 species), vulnerable (Vu, 12 species), and near threatened (NT, 17 species). 27 species were not found in the IUCN (2010) database.

Next, we overlapped all bird species distributions onto a UTM grid cell of 50 × 50 km each (1695 cells) to generate cell richness values for all species and IBS in UTM grid cells. Also, we used Natura 2000 data network (EEA 2012) to generate maps of PAs under the Birds Directive (SPAs) and a map of combined PAs – including SPA, SAC and SCI. Finally, we superimposed the 50 × 50 km grid to the Natura 2000 data network map to calculate the percentage and number of SPAs and combined PAs for each cell.

2.2. Data analyses

Relationship between bird species richness (all and IBS species) and protected areas cover, including SPA, SAC and SCI areas, were investigated by means of Poisson regression models. We also calculated the likelihood ratio index proposed by McFadden (1974). This index is a pseudo R-squared measure and is often used to measure the explained variation or coefficient of determination when data are not normally distributed (Cameron and Windmeijer, 1996). McFadden index was expressed as:

$$R_{\mathrm{MF}} = 1 - \frac{\ln(L_{\mathrm{M}})}{\ln(L_0)} \tag{1}$$

where L_{M} represents likelihood for the model containing all variables and L_0 represents the likelihood with intercept only.

To identify local spatial clusters of cells of high-richness value of bird species we used G^* spatial statistics (Getis and Ord 1992). This technique allows the identification of spatial clusters of similar values that are high or low relative to the mean (Getis and Ord 1992, Nelson and Boots, 2009). Also, *G* statistics produces a *Z* value, used as diagnostic tool. High *Z* values represented spatial aggregation of high bird richness values whereas low *Z* values represented spatial aggregation of low bird richness values. Values greater than two were used to indicate spatial clusters of values that were extreme and high relative to the mean (Nelson and Boots, 2008). Additionally, we used Bonferroni tests to assess whether these values were statistically significant. Those significant cells were considered as hotspots of richness for bird species, hereafter high-value richness areas (hvra).

Finally, we superimposed the maps of hvra on the maps of SPAs and the combined PAs. Those cells without SPAs but with SAC/SCI cover were classified as partial gaps of bird species richness. Cells without any PA cover were considered total gaps. Complementary, we investigated the distribution of threatened bird species occurring in areas without SPA cover, by describing the spatial distribution of such species. All statistical analyses were performed in R (R Development Core Team, 2009), including its packages 'spdep' (Bivand et al., 2012) and 'pscl' (Jackman, 2012), and Geographic Resources Analysis Support System (GRASS GIS 6.4, Neteler et al. 2012).

3. Results

The spatial distribution of SPA and combined PAs showed similar patterns (Appendix A.1 and A.2). A high PAs cover was observed especially in the North (Finland) and Mediterranean area (Spain and France). About 10% of cells (166) remained without SPA cover (SPA gaps) and 0.8% (14) cells without combined PAs cover (combined PAs gaps). Most of them were located in Sweden, France and Finland.

The overall geographic distribution of bird species richness showed similar trends, with richness increasing eastwards. Considering all bird species, the richest cells were mostly located in Bulgaria (201 species), Poland (190 species), Lithuania (184 species) and the Czech Republic (181 species) (Fig. 1A). The highest richness cells of IBS were mostly located in Greece and Bulgaria, representing 66 and 60 bird species; whereas the lowest was found in United Kingdom, with 1 species (Fig. 1B).

Poisson regression models indicated that the relationship between bird spatial richness patterns and Natura 2000 protected areas (SPA and combined PA cover) were in general weak (Table 1). Similarly, the relationship between richness and the number of PAs was low (Table 1). In general, models explained very low variance of bird richness patterns. The regression coefficient of these models showed that the PA cover and the number of PAs were both positively correlated with bird richness.

A total of 248 (14.6%) hvra cells for bird species were observed (Fig. 2A). From these, 143 cells were hvra of all bird species richness and 189 cells were hvra of IBS richness. The congruence between hvra cells for all bird and IBS was moderate. From the 248

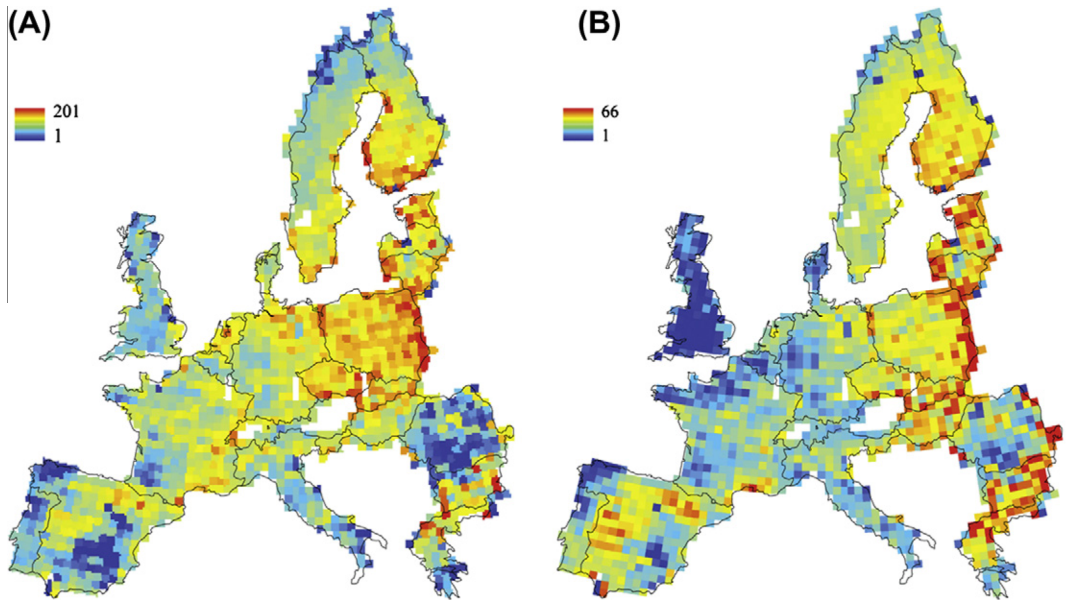

Fig. 1. Geographic patterns of bird species richness across Europe. Data represent all bird richness (A) and IBS richness (B).

Table 1
Poisson regression models used to investigate the relationship between bird species richness with Natura 2000 areas cover and between bird species richness and the number of protected areas cover. Natura 2000 areas represent areas for special protection for birds (SPAs) and the combined areas, including SPA areas and Sites of Community Importance (SCI) and Special Areas of Conservation (SAC). The pseudo R^2 is also given. Bird richness is represented by all species and Important Bird Species (IBS).

	All species			IBS		
Natura 2000 areas	Poisson coefficient	Probability	Pseudo R^2	Poisson coefficient	Probability	Pseudo R^2
Cover						
SPAs	0.0013	<0.001	0.0034	0.0055	<0.001	0.0168
Combined	0.0002	0.0577	0.0001	0.0041	<0.001	0.0124
Number						
SPAs	0.0089	<0.001	0.0139	0.0085	<0.001	0.0032
Combined	0.0034	<0.001	0.0041	0.0016	<0.001	0.0096

Table 2
List of bird species present in partial and total gaps. The IUCN red list status is also given. Important Bird Species (IBS) is highlighted.

Genus	Species	IUCN category	IBS	Partial gaps	Total gaps
Aythya	*nyroca*	NT	1	1	1
Coracias	*garrulus*	NT	0	1	1
Falco	*vespertinus*	NT	1	1	1
Gallinago	*media*	NT	1	1	1
Limosa	*limosa*	NT	0	1	1
Milvus	*milvus*	NT	1	1	1
Numenius	*arquata*	NT	0	1	1
Sylvia	*undata*	NT	1	1	0
Tetrax	*tetrax*	NT	1	1	0
Aquila	*heliaca*	VU	0	1	1
Acrocephalus	*paludicola*	VU	1	1	1
Anser	*erythropus*	VU	1	1	1
Aquila	*adalberti*	VU	1	1	0
Otis	*tarda*	VU	1	1	0
Syrmaticus	*reevesii*	VU	0	1	0
Neophron	*percnopterus*	EN	1	1	0

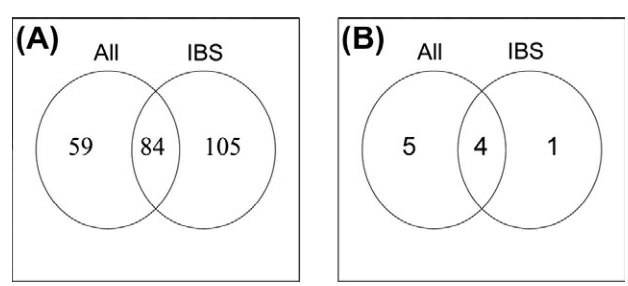

Fig. 2. Venn diagram showing the extent of overlap between hvra for all bird species and Important Bird Species (IBS) (A) and between partial gaps of hvra for all bird species and IBS (B).

cells considered as hvra, 84 (33.9%) of them overlapped (Fig. 2A). Similar results were observed for the overlap between partial gaps of hvra (Fig. 2B).

The spatial pattern of hvra cells showed similar results (Fig. 3A and B). For both species groups, the highest number of hvra cells were found in eastern Europe. Considering all bird species, most of the hvra cells were localised in Poland and Finland; whereas the lowest number of hvra cells was found in Romania and Sweden (Fig. 3A). Most of partial and total gaps of hvra for all bird species were observed in Poland and the Czech Republic (Fig. 3A). For IBS, the highest number of hvra cells was also found in Poland, followed by Finland (Fig. 3B). Partial gaps for IBS were specially located in Poland, Finland, Lithuania and Greece (Fig. 3B).

Partial gaps included 355 bird species comprising 318 unthreatened species, 16 threatened species and 21 species not found in the IUCN database. Of all threatened species, nine were considered near threatened, six were considered vulnerable and one was

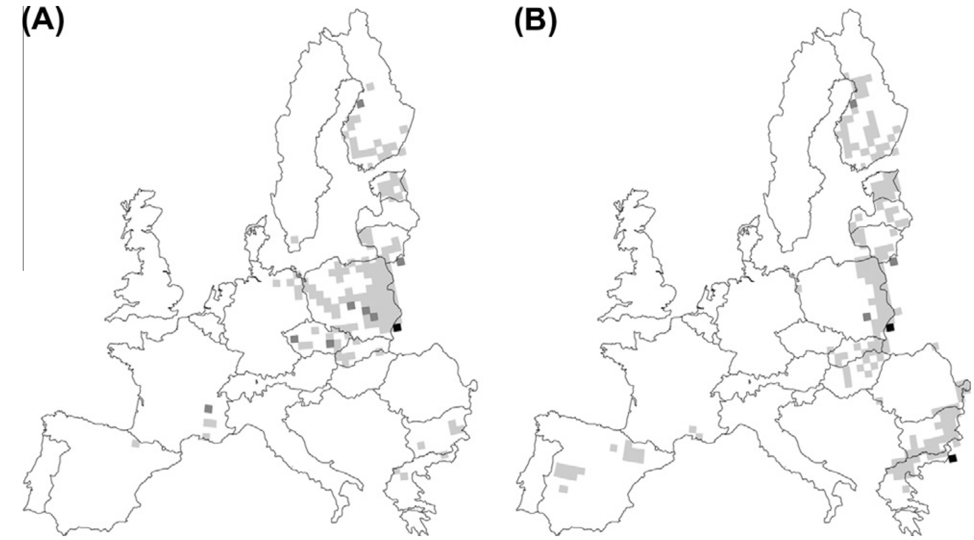

Fig. 3. Geographic patterns of high-value richness area (hvra) of bird species across Europe. Data represent hvra of all bird richness (A) and hvra of IBS bird richness (B). Light grey cells represent hvra, mid grey represent partial Spa gaps and black cells represent total gaps.

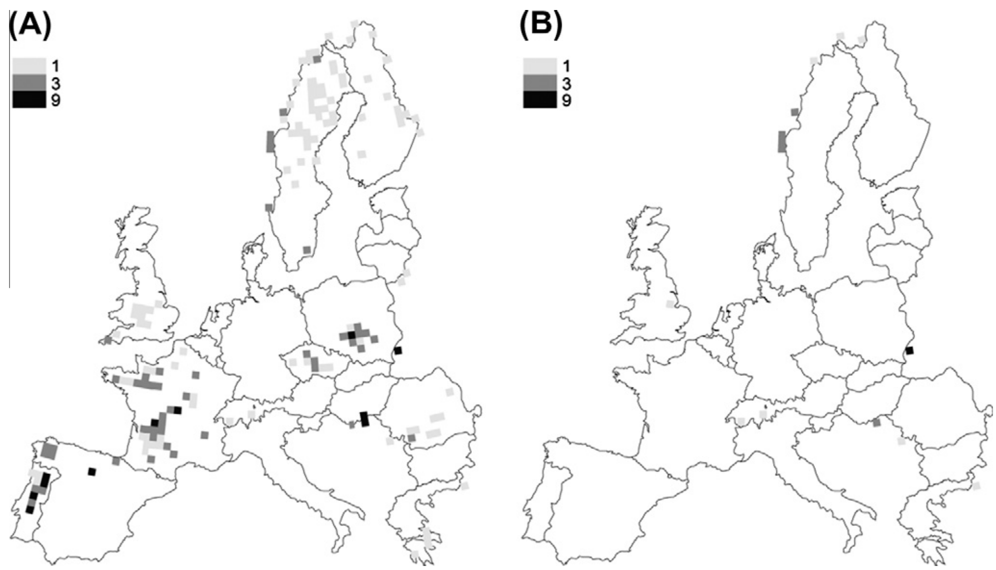

Fig. 4. Geographic patterns of threatened bird species richness across total and partial SPA gaps in Europe. Data represent threatened bird richness in partial SPA gaps (A) and threatened bird richness in total SPA gaps (B).

considered endangered (Table 2). Combined gaps included 10 threatened species: seven near threatened and three vulnerable species (Table 2). Most of the species classified as IBS were mainly found in Poland, Hungary and Portugal (Fig. 4A and B).

4. Discussion

This study investigates whether bird diversity species is well represented by the European protected areas network and identifies high-value areas by assessing the geographic distribution of bird species richness derived from distribution maps. In this study, we did not aim to criticise the importance of Natura 2000 in halting biodiversity loss in Europe, but rather to suggest suitable areas for the expansion of SPAs, considering richness of all bird species and IBS as well as the distribution of threatened species in gaps of SPA and combined PAs. In general, the tenet that many PAs do not fulfil completely the role for which they were created and fail to attain their objective as sites for the preservation of biological diversity receives partial support. On the one hand, although our results indicated that bird diversity is well represented, about 4% of hvra is not represented by SPAs cover. On the other hand, results showed that 16 threatened species were present in gaps of SPAs. Our results also provide the spatial distribution of gaps of SPA cover, indicating the spatial richness patterns of threatened species across these gaps.

According to the IUCN Red List (IUCN, 2010), most of the threatened bird species found in Europe are decreasing in population, mostly as a result of human actions (BirdLife International, 2012a,b,c,d,e). In Europe, the Birds Directive policy brings measurable conservation benefits to bird populations (Donald et al., 2007) and also establishes a general system of protection, which avoid deliberate killing or capture, destruction of eggs, nest disturbance and keeping of hunting birds. In the view of our results, it seems that the current network of bird PAs could be reinforced if areas with partial or total gaps holding a high number of threatened species would be designated as SPAs.

Even so the most important objectives of the Natura 2000 network is to ensure the long-term survival of the most valuable and threatened species and habitats (EU, 2010), there are some common species that are susceptible to environmental change, resulting in their significant decline or even extinction (Lindenmayer et al., 2011). Common species can play key roles for ecosystem structure and function (i.e. seed dispersal, pollinators) (Elliot et al., 2010). Therefore, the development of conservation plans across EU countries should require different conservation goals for unthreatened and threatened species.

Although one should expect bird species richness to increase along SPA cover, our results showed little association between bird richness patterns and the geographic distribution of SPAs across EU countries (see Table 1). After including SCI/SCA this pattern remains. Although low, the significant relationship between IBS spatial richness and PA cover suggests that the design of Natura 2000 network accomplish their objectives by representing the majority of the IBS used in this study. We acknowledge that the low association between IBS richness and Natura 2000 cover found herein could be masked by the geographical extent of this study, since PAs not always are designed at the same scale as gradients of species richness. Likewise, the spatial scale of each PA may not be in accordance with the scale at which species richness is measured. This may reflect a limitation in settling efficient PAs networks. For instance, there are not any PA covering the entire surface of a 50×50 km grid cell, nor there might be many 50×50 cells near completely covered by small PAs. Therefore, PAs could reach part of their objectives (protection of the birds in "special" areas) even if they do not match large-scale richness patterns. Moreover, most of the birds occurring in the EU are migratory species, which requires trans-frontier programmes for an effective protection (Directive 2009/147/EC). Thus, conservation policies must address common responsibilities of the EU countries using a large-scale approach.

Previous studies highlight the need to take into account biodiversity patterns and spatial components to make PAs more efficient (Pressey et al., 2003 and references therein). Furthermore, the low relationship between SPA cover and bird richness pattern found in our study may also reflect the lack of clear targets of the Natura 2000 network, administrative interpretations of conservation objectives and misrepresentation of decision processes in favour of economic and development interests, regarded as major causes opposed to conservation goals (Margules et al., 2000; Apostolopoulou and Pantis, 2009). Moreover, in most countries of the world, there are a high number of protected areas established without effective management and at the same time face a plenty of threats (Brandon et al., 1998). In this sense, management could be more effective by identifying major threats and by assessing the adequacy of resources to respond to those threats and other needs (Hockings et al., 2006).

Even if the richness patterns found herein were similar, our analyses identified a moderate congruence between high-value richness areas for bird species. Such congruence suggests that different conservation planning targets should be taken into account to represent hvra areas adequately to safeguard all bird species.

In summary, the poor relationship between PAs cover and bird richness pattern found herein may provide evidence that the establishment of SPA areas across Europe may not be fully accounting for richness patterns to enhance the performance of the current network. The previous debates on biodiversity conservation across EU countries (Pressey et al., 2003; Maiorano et al., 2007; Apostolopoulou and Pantis, 2009) are consistent with this interpretation, and suggest a future venue of investigations on the efficiency of the Natura 2000 network in Europe. They also agree that additional areas are still required to fulfil species representation. Although we acknowledge that there are several targets to accomplish these objectives (Pressey et al., 2003), our study provides suitable areas, based on biodiversity pattern criteria, to extend SPAs across the 27 EU countries.

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Appendix A

See Fig. A1.

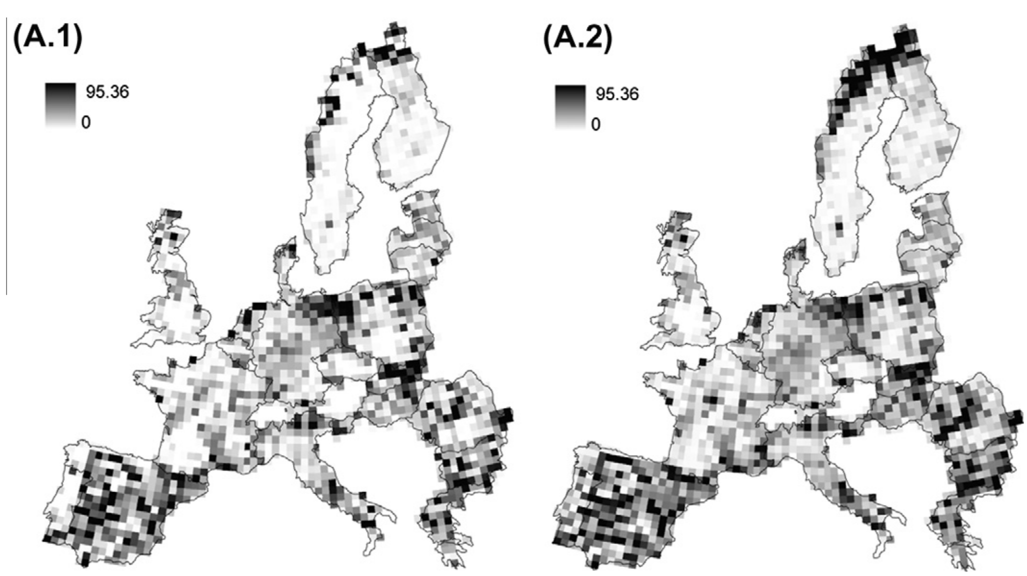

Fig. A1. Geographic patterns of Natura 2000 cover across Europe. Data represent SPA cover (A.1) and Combined Pas cover (A.2)

References

Apostolopoulou, E., Pantis, J.D., 2009. Conceptual gaps in the national strategy for the implementation of the European Natura 2000 conservation policy in Greece. Biol. Conserv. 142, 221–237.

Brandon, K., Sanderson, S., Redford, K., 1998. Parks in Peril: People, Politics, and Protected Areas. Island Press, Nature conservancy, 532 pp.

Birds of Western Palearctic Interactive, 2006. Birdguides, Oxford University Press, UK (DVD-ROM).

BirdLife International, 2012a. *Otis tarda*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org> (downloaded 13.07.12).

BirdLife International, 2012b. *Anser erythropus*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org> (downloaded 10.06.12).

BirdLife International, 2012c. *Aquila adalberti*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org> (downloaded 12.07.12).

BirdLife International, 2012d. *Aquila heliaca*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org> (downloaded 10.07.12).

BirdLife International, 2012e. *Acrocephalus paludicola*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org>. (downloaded 11.07.12).

Bivand, R., Altman, M., AnselinM, L., Assunção, R., Olaf, B., Bernat, A., Blanchet, G., Blankmeyer, E., Carvalho, M., Christensen, B., Chun, Y., Dormann, C., Dray, S., Halbersma, R., Krainski, E., Legendre, P., Lewin-Koh, N., Li, H., Ma, J., Millo, G., Mueller, W., Ono, H., Peres-Neto, P., Piras, G., Reder, M., Tiefelsdorf, M., Yu, D., 2012. Spatial Dependence: Weighting Schemes, Statistics and Models, version 0.5-46. <http://CRAN.R-project.org/package=spde>.

Cameron, A.C., Windmeijer, F.A.G., 1996. R2 measures for count data regression models with applications to health-care utilization. J. Bus. Econom. Statist. 14, 209–220.

Directive 2009/147/EC DIRECTIVE 2009/147/EC of the European Parliament and of the Council of 30 November, 2009. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:EN:PDF>.

Directive EEC/92/43 Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora of 21 May, 1992. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF>.

Donald, P.F., Sanderson, F.J., Burfield, I.J., Bierman, S.M., Gregory, R.D., Walicky, A., 2007. International conservation policy delivers benefits for birds in Europe. Science 317, 810–813.

EC (European Commission), 2009. Natura 2000 – Europe's Nature for You (General Presentation of Natura 2000). <http://ec.europa.eu/environment/nature/info/pubs/paper_en.htm> (accessed December 2010).

EEA, 2012. European Environment Agency – Natura 2000 Data – The European network of Protected Sites. <http://www.eea.europa.eu/data-and-maps/data/natura-2> (assessed May 2012).

EU, 2010. The European Union's Biodiversity Action Plan "Halting the Loss of Biodiversity by 2010 – and Beyond". <http://ec.europa.eu/environment/nature/info/pubs/paper_en.htm> (accessed March 2011).

Elliot, G.P., Wilson, P.R., Taylor, R.H., Beggs, J.R., 2010. Declines in common, widespread native birds in a mature temperate forest. Biol. Conserv. 143, 2119–2126.

Getis, A., Ord, J.K., 1992. The analysis of spatial association by use of distance statistics. Geogr. Anal. 24, 189–206.

Hagemeijer, E.J.M., Blair, M.J. (Eds.), 1997. The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. T & AD Poyser, Londres.

Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J. 2006. Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas. second ed. IUCN, Gland, Switzerland and Cambridge, UK. xiv+. 105 pp.

Hurlbert, A.H., Jetz, W., 2007. Species richness, hotspots, and the scale dependence of range maps in ecology and conservation. Proc. Natl. Acad. Sci. USA 104, 13384–13389.

IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <http://www.iucnredlist.org> (downloaded 01.03.11).

Jackman, S. 2012. pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory, Stanford University. Department of Political Science, Stanford University. Stanford, California. R Package Version 1.04.4. <http://pscl.stanford.edu/>.

Jelaska, S.D., Nikoli, T., Seri Jelaska, L., Kusan, V., Peternel, H., Guzvica, G., Major, Z., 2010. Terrestrial biodiversity analyses in Dalmatia (Croatia): a complementary approach using diversity and rarity. Environ. Manage. 45, 616–625.

Lindenmayer, D.B., Wood, J.T., McByrney, L., MacGregor, C., Yougentob, K., Banks, S.C., 2011. How to make a common species rare: a case against conservation complacency. Biol. Conserv. 144, 1663–1672.

Maiorano, L., Falcucci, A., Garton, E.O., Boitani, L., 2007. Contribution of the Natura 2000 network to biodiversity conservation in Italy. Conserv. Biol. 21, 1433–1444.

Margules, C.R., Pressey, R.L., 1988. Selecting networks of reserves to maximize biological diversity. Biol. Conserv. 43, 63–76.

Margules, C.R., Nicholls, A.O., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243–253.

McFadden, D., 1974. Conditional legit analysis of qualitative choice behaviour. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, New York, NY, pp. 105–142.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kents, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.

Nelson, T.A., Boots, B., 2009. Detecting spatially explicit hot spots in landscape-scale ecology. Ecography 31, 556–566.

Neteler, M., Hamish Bowman, M., Landa, M., Metz, M., 2012. GRASS GIS: A multi-purpose open source GIS. Environ. Model. Software 31, 124–130.

Pressey, R.L., Cowling, R.M., Rouget, M., 2003. Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. Biol. Conserv. 112, 99–127.

R Development Core Team. 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. <http://www.R-project.org>.

Rey Benayas, J.M., De la Montaña, E., 2003. Identifying areas of high-value vertebrate diversity for strengthening conservation. Biol. Conserv. 114, 357–370.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J., Yan, X., 2004. Effectiveness of the global protected area network in representing species diversity. Nature 428, 640–643.

Wiersma, Y.F., Nudds, T.D., 2009. Efficiency and effectiveness in representative reserve design in Canada: the contribution of existing protected areas. Biol. Conserv. 142, 1639–1646.