CONL | conl12096 | Dispatch: March 24, 2014 | CE: AFL
Journal | MSP No. | No. of pages: 11 | PE: Adipta Singh

LETTER

Biodiversity funds and conservation needs in the EU under climate change

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Keywords
Birds; biodiversity conservation funding; climate change adaptation; ensemble forecasting; Europe; retention area; species distribution.

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Received
5 September 2013
Accepted
28 February 2014

Editor
Rafael Loyola

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doi: 10.1111/conl.12096

Abstract

Despite ambitious biodiversity policy goals, less than a fifth of the European Union's (EU) legally protected species and habitats show a favorable conservation status. The recent EU biodiversity strategy recognizes that climate change adds to the challenge of halting biodiversity loss, and that an optimal distribution of financial resources is needed. Here, we analyze recent EU biodiversity funding from a climate change perspective. We compare the allocation of funds to the distribution of both current conservation priorities (within and beyond Natura 2000) and future conservation needs at the level of NUTS-2 regions, using modeled bird distributions as indicators of conservation value. We find that funding is reasonably well aligned with current conservation efforts but poorly fit with future needs under climate change, indicating obstacles for implementing adaptation measures. We suggest revising EU biodiversity funding instruments for the 2014–2020 budget period to better account for potential climate change impacts on biodiversity.

Introduction

With its Habitats Directive and Birds Directive (European Commission 1992; European Parliament 2010), the European Union (EU) is considered to have one of the more advanced and effective intergovernmental biodiversity policy instruments (Trouwborst 2009). However, despite improvements in the status of target species (Donald *et al*. 2007) only 17% of species and habitats legally protected under the Directives have been estimated to have a favorable conservation status (Condé *et al*. 2010). In its biodiversity strategy (European Commission 2011a), the EU is committed to halting the loss of biodiversity by 2020 and to a long-term vision to protect and appropriately restore its natural capital. Besides nationally designated areas, the network of Natura 2000 (N2K) sites plays a crucial role in that context. Its management as well as complementary measures to reach the EU biodiversity targets in general require the availability of financial recourses and their optimal distribution and uptake (Kettunen *et al*. 2009; European Commission 2011a).

The challenge of biodiversity conservation and its adequate funding is complicated by climate change, which is expected to decrease the effectiveness of established protected areas (and in particular N2K areas) by inducing range shifts and biodiversity reshuffling (Araújo *et al.* 2011; Maiorano *et al.* 2011). Among adaptation suggestions to address this issue, expanding protected area networks with more, larger and well-connected protected areas emerges as the strategy most often supported (Heller & Zavaleta 2009). Retention areas (i.e., areas projected to be climatically suitable for species both currently and in the future) should be considered a priority for conservation (Araújo *et al.* 2004), not only to protect remaining sites for those species with contracting ranges, but also to enhance populations that could act as a source for range expansion to new sites becoming climatically suitable (Vos *et al.* 2008).

To allow uptake of such climate change adaptation strategies in EU biodiversity policy, several recommendations for policy adjustment have been made (see van Teeffelen *et al.* in review for an overview), including legal enforcement of connectivity requirements (Cliquet *et al.* 2009) and the implementation of adaptive management plans for each Special Area of Conservation (SAC) of the N2K network (Hochkirch *et al.* 2013). Guidelines for dealing with climate change in the management of N2K were developed recently (European Commission 2013b), primarily to facilitate site management and decision making at local and regional levels. However, the contribution of financial commitments to reaching EU biodiversity conservation goals remains ambiguous (Kettunen *et al.* 2009). In particular, the relationship between distribution of funds and conservation needs, whether current or expected under climate change, is unclear.

Currently, three EU level instruments provide major financial support for conserving terrestrial biodiversity: the Structural and Cohesion Funds (SCF), the LIFE programme, and the Common Agricultural Policy (CAP). Since the CAP instrument lacks a coding system that would allow identifying biodiversity-relevant funding shares, the SCF forms the largest source of tangible conservation funding in the current EU budget. The primary aim of the SCF is to achieve social, economic and territorial cohesion across the EU. At operational SCF program level, the EU and its member states agree on their use according to a list of 86 priority themes defined in Commission Regulation (EC) No 1828/2006. This list includes three themes directly relevant for biodiversity (no. 51, 55, and 65), with a total of around 5 billion Euros allocated for the 2007–2013 budget period. In addition, approximately 1.2 billion Euros have been allocated through LIFE under its strand “Nature” since 1992. The objective of LIFE is to foster the implementation of EU environmental policy by cofinancing pilot projects with European added value, in particular in relation to the Habitats and Birds Directives.

In this study, we explore the spatial allocation of these EU biodiversity funds from the climate perspective. Using European birds of conservation concern as indicators of conservation value, we identify priority areas for expanding the current N2K network, and thus facilitating biodiversity adaptation to climate change. In order to identify potential matches and mismatches of funding patterns, we compare the spatial distribution of total EU funds allocated for biodiversity conservation to (1) the existing N2K network (and other factors potentially relevant to the fund distribution), as well as to current spatial conservation priorities beyond the N2K network, and (2) future conservation priorities beyond the N2K network. These comparisons are done at the level of NUTS-2 regions.

Material and methods

EU biodiversity funding allocations

As neither CAP nor previous SCF funding periods allow disentangling the biodiversity-relevant funding shares, we focus on LIFE and the 2007–2013 period of SCF. This study was provided with the final SCF allocations, disaggregated at NUTS-2 level by the Commission Directorate-General Regional Policy (DG REGIO) through an indicative regionalization approach that applies a set of location- and fund-specific rules (e.g., location of project or intervention, splitting of multifund projects). Country-level purchasing power parity (PPP) conversion factors from EUROSTAT relative to the year 2007 (calculated for gross domestic product, GDP) were used to adjust the original DG REGIO break-downs (cf. de Groot *et al.* 2012), thus accounting for price level differences across countries.

With respect to LIFE, we used all EU financial contributions within the strand “Nature” covering the period 1992 to 2013 from the LIFE database of Commission Directorate-General Environment (DG ENV). Allocations from the first three programme phases (i.e., 1992 to 2006) were inflation-corrected to match the SCF financial data, using 2007 (i.e., the year of the allocation of the SCF) as reference year, and assuming a standard annual inflation of 3%. We also applied the PPP-correction as described for the SCF above. Finally, for each NUTS-2 region the total of PPP-corrected SCF and LIFE funding was calculated that is hereafter referred to as EU biodiversity funding (Figure 1a).

Bird and climate data

We used distribution maps from the Birds of the Western Palearctic database (BWPi 2006) for 156 bird species (see Table S1 for a complete list), digitized on a 50 km × 50 km

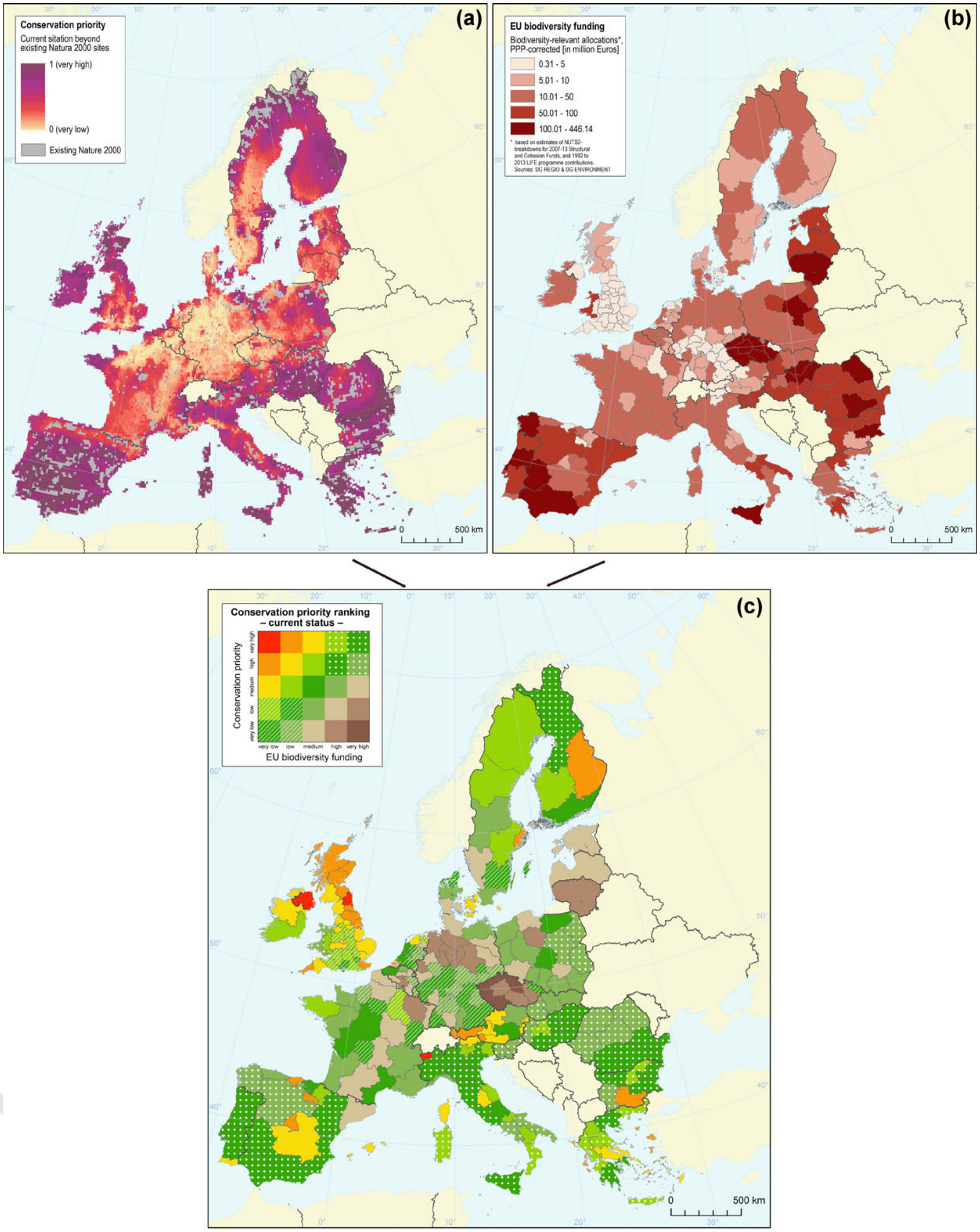

Figure 1 (a) Map of current biodiversity conservation priorities beyond the existing Natura 2000 network as derived from ensembles bird distribution modeling; (b) Map of the distribution of EU biodiversity funding at NUTS-2 level, under the 2007–2013 Structural and Cohesion Funds as well the LIFE programme 1992–2013; and (c) Map combing (a) and (b), that is, showing the alignment of EU biodiversity funding with current mean NUTS-2 conservation priority areas beyond the existing Natura 2000 network. Scores on the map are classified into five classes (very low, low, medium, high, and very high) according to percentile thresholds.

grid (Barbet-Massin *et al.* 2012). The species included in our analysis are all listed in the Birds Directive Annex I (European Parliament 2010), implying that at a minimum, their conservation status should be favorable. We selected five uncorrelated variables from the Worldclim database (Hijmans *et al.* 2005): temperature seasonality, maximum temperature of the warmest month, minimum temperature of the coldest month, precipitation of the wettest month, and precipitation of the driest month. Projections of the five climate variables for two emission scenarios—B1 and A2 of the SRES scenario family (Nakićenović & Swart 2000)—were generated with the Rossby Center Regional Climate Model (RCA3, Samuelsson *et al.* 2011) driven by the global ECHAM5 (Roeckner *et al.* 2003) circulation model.

Projections of bird distributions and conservation priorities

We used ensemble modeling to account for model-based uncertainty (Buisson *et al.* 2010) when assessing climatic suitability for the bird species. Despite intrinsic uncertainties (Heikkinen *et al.* 2006), species distribution models have proven to be a useful tool for conservation prioritization under climate change (Williams *et al.* 2013). We generated an ensemble of projected species distributions for each of the 156 species at a resolution of 10′ (approximately 18 km × 18 km), using five modeling techniques implemented within the BIOMOD framework in R (Thuiller *et al.* 2009): Generalised Additive Models (GAM), Boosting Regression Trees (BRT), Classification Tree Analysis (CTA), Multiple Adaptive Regression Splines (MARS), and Random Forest (RF). We calibrated the models for the baseline period using a 65% random sample and evaluating against the remaining 35% data (with 5-fold internal cross-validation). The final ensemble included 30 predicted probabilities of occurrence for each species. Models were evaluated with the True Skill Statistics (TSS) (Allouche *et al.* 2006).

In addition, we identified areas of retention for each species and for each of the future scenarios (i.e., B1 and A2) by transforming the probabilities into binary presences and absences using the threshold that maximized the TSS. We defined a cell as a retention cell, if a species was predicted to be present in that cell both currently and in the future.

We used the spatial prioritization software "Zonation" (Moilanen *et al.* 2012) to conduct a conservation priority ranking separately for present distributions and for areas of retention. "Zonation" identifies networks of areas which represent as much of the biodiversity features as possible while minimizing cost or area required. We used the core area zonation (CAZ) algorithm to determine the biodiversity value in each cell (for details see Moilanen *et al.* 2012), without applying species-specific weighting or cost data, that is, values were treated equally for all species and cells. We obtained the conservation priority networks by calculating the mean rank for each cell from 100 samples across the ensembles (referred to as postselection consensus technique; see Meller *et al.* ~~in press~~ and Supplementary Information). When focusing on priorities beyond the existing N2K sites, we masked out the N2K sites while still accounting for their contents. This allowed us to identify areas that would best complement them. The final priority rankings beyond the existing N2K network (Figure 1~~b~~) were used to calculate four NUTS2 level indicators of priority ranking: mean rank, median rank, maximum rank, and NUTS-2 area-weighted (i.e., multiplied by NUTS-2 area size) mean rank.

Comparison of funding allocations with conservation priorities

For the current conditions, we explored the funding data in relation to several factors that might explain their distribution at NUTS-2 level: (a) financial capital (using GDP as proxy), (b) generic adaptive capacity (measures the capability of a NUTS-2 region to cope with the adverse impacts of climate change, see Lung *et al.* 2013), (c) size of existing N2K (both absolute size and percentage of NUTS-2 area), (d) NUTS-2 area size, and (e) current conservation priorities beyond the existing N2K network (using the four indicators of priority ranking, see previous section). Spearman's rank correlations and linear regression models were used to test for correlations. As GDP and generic adaptive capacity are highly correlated (see Table 1), only one of them should be retained in a regression model. Likewise, from the variables related to area (i.e., N2K, $N2K_p$, Area, and $P_{curMW,}$ see Table 1) only one should be used in a single model due to collinearity. Based on these restrictions, we defined several models a priori, and conducted tests of goodness of fit using the Akaike Information Criterion (AIC) (Akaike 1974) for model selection to evaluate which (combination of) factors explain the NUTS-2 level distribution of the funds best.

In addition, in order to visualize the fit between EU biodiversity funding and current conservation priority needs on a map, we classified the funding data as well as the "mean rank" indicator for current conservation priority into five categories ("very low," "low," "medium," "high," "very high") according to percentile thresholds (i.e., 0%–20%, 20%–40%, etc.). The categories represent relative differences between European regions.

The alignment of EU biodiversity funding with future conservation priorities (expressed as retention priorities)

Table 1 Correlation matrix (rank correlation coefficients) of variables tested in relation to EU biodiversity funding, at regional NUTS-2 level

	F_{PPP}	GDP_{PPS}	AC	N2K	$N2K_p$	Area	P_{curM}	P_{curMW}	P_{curMD}	P_{curMX}
F_{PPP}	1.00									
GDP_{PPS}	−0.57	1.00								
AC	−0.47	0.80	1.00							
N2K	0.68	−0.46	−0.45	1.00						
$N2K_p$	0.45	−0.36	−0.39	0.71	1.00					
Area	0.62	−0.37	−0.33	0.84	0.25	1.00				
P_{curM}	0.29	−0.31	−0.46	0.43	0.39	0.29	1.00			
P_{curMW}	0.57	−0.40	−0.45	0.81	0.36	0.85	0.73	1.00		
P_{curMD}	0.28	−0.29	−0.45	0.40	0.38	0.28	0.99	0.72	1.00	
P_{curMX}	0.33	−0.28	−0.39	0.50	0.39	0.45	0.90	0.80	0.88	1.00

F_{PPP}, EU biodiversity funding; GDP_{PPS}, gross domestic product of 2007 in purchasing power standards; AC = indicator of adaptive capacity (Lung *et al*. 2013); N2K, Natura 2000 area in square kilometers; $N2K_p$, percentage of NUTS area covered by Natura 2000 sites; Area, NUTS-2 area in square kilometers; $P_{curM}/P_{curMW}/P_{curMD}/P_{curMX}$, mean/NUTS-2 area-weighted mean/median/maximum of current priority ranking outside the existing Natura 2000 network.

were analyzed for both scenarios (A2 and B1), again using the four indicators (i.e., mean, area-weighted mean, median, and maximum) and employing Spearman's rank correlations and a spatial visualization according to the five categories.

Results

EU biodiversity funding vs. current conservation needs

EU biodiversity funding has strongest correlations with the size of N2K area per NUTS-2 region followed by the size of the NUTS-2 regions, and regional gross domestic product, which is negatively correlated to funding (i.e., the lower the GDP the higher the funding, Table 1 and Figure 2). Regarding the four indicators of current conservation priorities beyond the existing N2K network, the NUTS-2 area-weighted mean shows the highest rank correlation coefficient (0.57), whereas low correlation coefficients are revealed for the simple mean (0.29), median (0.28), and maximum (0.33) of current priority ranking. From the tested linear regression models, the best fit model (AIC 285.3) uses only GDP and N2K area per NUTS-2 region as covariates, leading to a coefficient of determination (R^2) of 0.54. A model using the area-weighted mean as area-related variable in addition to GDP performed worst (AIC 383.6) of all tested models, while the nonarea-weighted mean, median, and maximum were all not significant in any of the tested models, thus confirming a generally weak match of current priority ranking beyond the existing N2K network with EU biodiversity funding.

The spatial distribution of alignment of EU biodiversity funding with current conservation needs beyond the existing N2K network shows a distinctive pattern across Europe. Some regions, (e.g., within Spain, Alps, and British Isles) stand out with high or very high current conservation needs but with low or very low funding, relative to other NUTS-2 regions (red- and orange-colored regions in Figure 1c). The contrary pattern, low or very low conservation needs but high or very high funding is found for a cluster of regions in northern Germany, in the Czech Republic, and in the Baltic states (brownish colors in Figure 1c). For the remaining regions funding appears to be reasonably aligned with conservation needs (green colors combined with white hatching or dots in Figure 1c).

EU biodiversity funding versus future conservation needs

The correlations of EU biodiversity funding with the four indicators of future retention priorities beyond the existing N2K network reveal a pattern similar to that of the current situation, for both B1 and A2 scenarios. While highest correlation coefficients (0.47 and 0.41) are seen for the area-weighted indicators due to influence of the NUTS-area weighting, the other three indicators (mean, median, and maximum) show low correlations, with only marginal differences between the two scenarios (Table 2).

The spatial alignment of EU biodiversity funding reveals similarities but also distinct differences between current conservation priorities and future retention priorities, whereas there are hardly any differences in future priority areas between the climate scenarios B1 and A2 (Figure 3). For both the current situation and retention priorities, the Alps as well as most regions of the British Isles show the largest discrepancies between funding and conservation needs (i.e., relatively low funding but high needs), with slightly stronger mismatches for

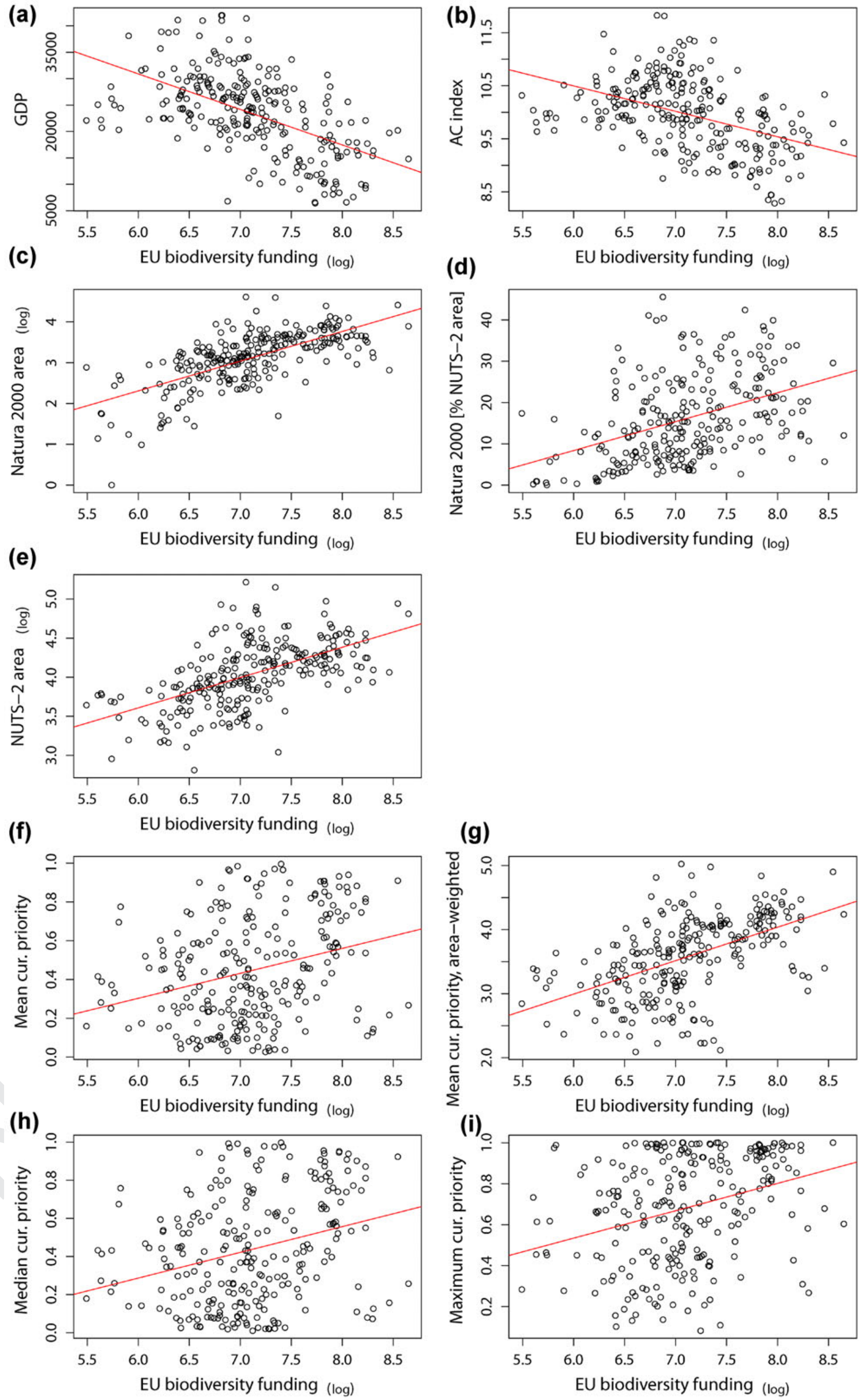

Figure 2 Scatter plots of EU biodiversity funding versus (a) gross domestic product of 2007 (in purchasing power standards, PPS), (b) adaptive capacity (Lung *et al*. 2013), (c) Natura 2000 area, (d) percentage of NUTS area covered by Natura 2000 sites, (e) NUTS-2 area, (f) mean of current priority ranking, (g) mean of current priority ranking weighted by NUTS-2 area, (h) median of current priority ranking, and (i) maximum of current priority ranking; at NUTS-2 spatial level. Note that some of the variables were log-transformed due to be presence of outliers.

Table 2 Rank correlation coefficients of EU biodiversity funding vs. different measures of future priority ranking (retention) beyond the existing Natura 2000 network, aggregated at regional NUTS-2 level

Indicator	F_{PPP}
Mean retention priority, A2 scenario	0.03
Mean (NUTS-2 area weighted) retention priority, A2 scenario	0.47
Median retention priority, A2 scenario	0.02
Maximum retention priority, A2 scenario	0.15
Mean retention priority, B1 scenario	−0.06
Mean (NUTS-2 area weighted) retention priority, B1 scenario	0.41
Median retention priority, B1 scenario	−0.08
Maximum retention priority, B1 scenario	0.08

F_{PPP}, EU biodiversity funding.

future retention (compare Figures 1c and 3). On the contrary, in particular in southern (Italy) and Eastern Europe (Hungary, Romania, Bulgaria) many regions are seen with relatively high funding but low-retention priority (Figure 3).

Discussion

We found that the distribution of EU biodiversity funding across NUTS-2 regions is reasonably well aligned with current spatial conservation effort, that is, the existing N2K network, as well as with financial resources (using GDP as proxy). As many of the projects funded under SCF and LIFE relate to the management of the N2K areas, this allocation is well justified. However, due to the additional threats posed by climate change and the fact that a large number of birds of conservation concern are not favorably protected at present (European Community 2009), there is a pressing need to expand biodiversity management beyond the currently protected sites (e.g., Hannah *et al*. 2007). Our results highlight that the current distribution of biodiversity funds is not well aligned with future needs under climate change.

Our results support the conclusion from previous studies that EU biodiversity policy is poorly geared to facilitating ecological dynamics in changing conditions (e.g., Cliquet *et al*. 2009) through funding distribution. But we note that this is a relative comparison of financial allocations versus conservation priority needs, not an assessment of the overall sufficiency of the resources available for biodiversity projects with respect to EU biodiversity targets. The European Commission recently estimated that only around 20% of the financing needs for the existing N2K network are covered by current EU instruments (European Commission 2011b), l*et al*one conservation needs beyond this network. This highlights the general need to better mainstream climate change concerns into the policy area of biodiversity conservation and to support the implementation of adaptation actions with more substantial financial resources distributed according to the needs under climate change.

The overall amount of EU funding that directly or indirectly relates to biodiversity purposes is difficult to assess and quantify (Kettunen *et al*. 2009). In this study, neither biodiversity-relevant support within the CAP framework nor pre 2007 SCF biodiversity funds could be disentangled, due to the absence of a sufficient coding system. If science is to assist in improving EU funding distributions, previous allocations should be fully traceable. Thus, we encourage a coding system more distinct in relation to biodiversity, and a more transparent monitoring of the use of EU funding instruments over the newly commenced budget period 2014–2020.

In the light of our findings, both positive and concerning developments are currently underway at EU level at this early stage of the 2014–2020 budget period. The European Commission has recently proceeded several initiatives, such as a proposal to reform the LIFE programme to explicitly take into account synergies and conflicts of biodiversity/nature protection versus climate change (European Commission 2011c), or guidelines for integrating climate change and biodiversity into strategic environmental assessments (which is of particular importance for the cohesion funds) (European Commission 2013a). Yet, both the allocation of funds and the evaluation of the effectiveness and progress achieved through the projects are missing a clear connection to the EU Biodiversity Strategy. How candidate projects contribute to reaching the Biodiversity Strategy goals, and how this is weighed in the allocation of funds, is of particular importance but remains unclear. Overall, the measures already integrated into existing policy documents and guidelines cover a large share of recommendations for climate change adaptation for biodiversity ~~call~~, but they need to be applied using "climate lenses" instead of "past or current situation lenses" (Trouwborst 2011).

Cohesion Policy for 2014–2020 has 11 thematic objectives, one of which is "protecting the environment and promoting resource efficiency." The objective provides opportunities for area management within and beyond the N2K network to protect and restore biodiversity and ecosystem services (IEEP & Milieu 2013). Cohesion Policy in general is geared toward integrated projects that benefit regional livelihoods, recreation and education while improving the state of species and habitats. Setting project targets and evaluating success may then become the defining element for project effectiveness from the biodiversity perspective: is the emphasis on social, economic, or environmental aspects? Which indicators are used to monitor progress? Over the 2007–2013 period, the European Commission has used seven core indicators to

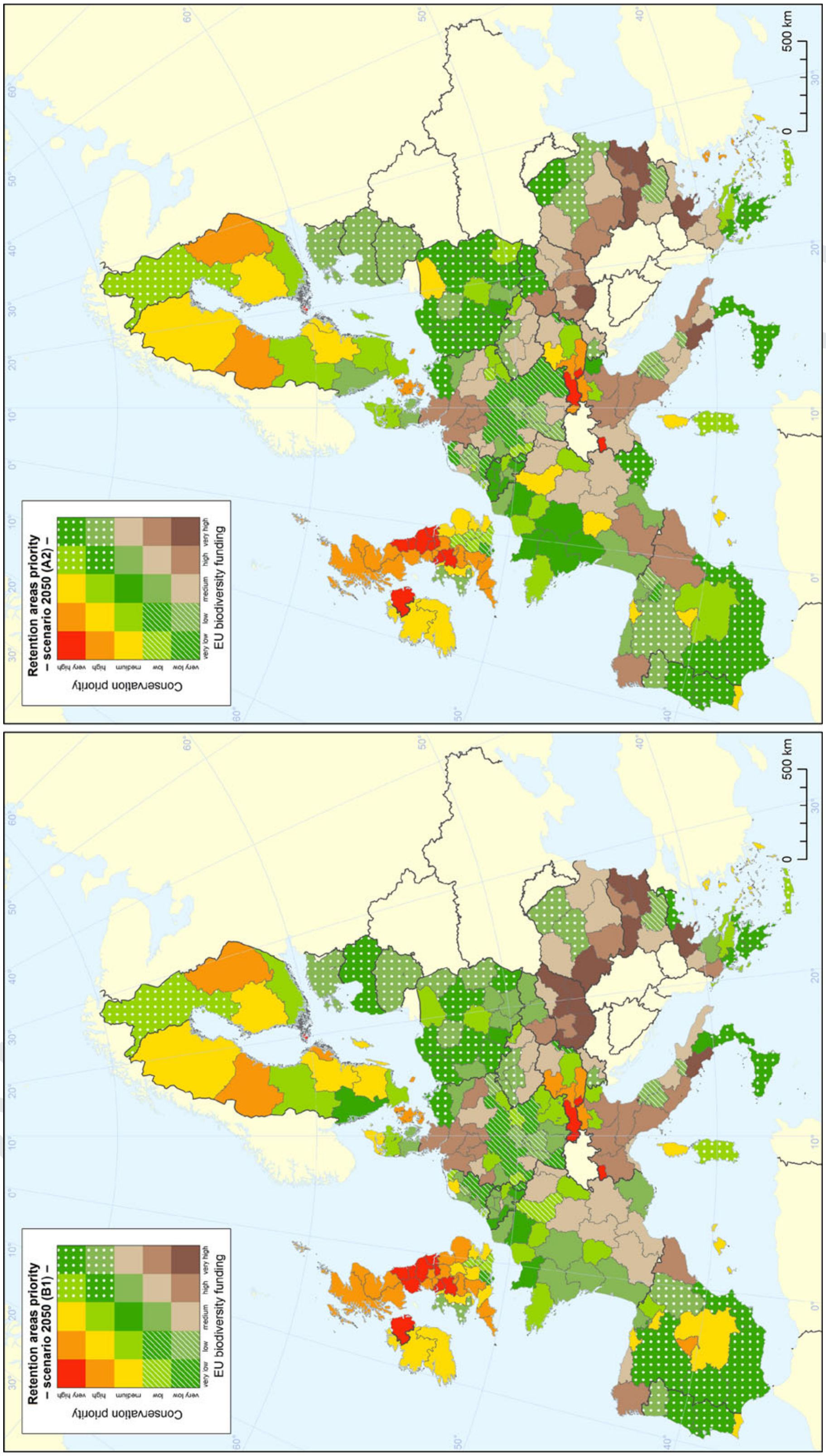

Figure 3 Maps showing the alignment of EU biodiversity funding with future mean NUTS-2 conservation priority (expressed as retention priority) beyond the existing Natura 2000 network, for B1 and A2 scenarios. Scores on the map are classified into five classes (very low, low, medium, high, and very high) according to percentile thresholds.

evaluate project outcomes in the environment theme: additional population served by water projects, number of waste projects, number of projects on improvement of air quality, area rehabilitated (km^2), number of risk prevention projects, number of people benefiting from flood prevention measures and number of people benefiting from forest fire protection and other protection measures (European Commission 2013c). The set of core indicators would need to be complemented with one that allows proper evaluation of the outcome in terms of biodiversity conservation. Regarding LIFE for 2014–2020, a share of the funds will be distributed through a separate subprogramme for Climate Action. Carefully planned and implemented projects could support climate change mainstreaming to various policy sectors. However, such a division of LIFE budgets runs a risk of disconnecting climate change considerations from projects under the conventional Environment subprogramme.

This study neither takes into account nationally designated areas, nor national investments in conservation; as such data are not consistently available. This—as well as the fact that the SCF distribution is strongly driven by economic criteria (see results, high correlation with GDP)—might affect the revealed spatial patterns. For instance, our results point to a high relative mismatch between biodiversity funding and conservation needs in Scotland (Figures 1c and 3). Nevertheless, it would be tenuous to conclude that Scottish biodiversity conservation under climate change is generally lacking financial resources, in particular in light of the existing comprehensive climate adaptation strategy that also includes biodiversity-related issues (Scottish Government 2009). This calls for a clarification of the interplay between EU and national investments, which could be facilitated by more transparent national investment data and combined monitoring to evaluate progress toward EU targets.

In conclusion, our study highlights a mismatch between current EU biodiversity funding patterns and needs under climate change. Moreover, there is a pressing need for more transparent targets and monitoring of funding. In that context, we discuss some possible improvements with respect to LIFE and Cohesion Policy 2014–2020, thus providing further guidance for the transformation of EU funding instruments into tools that effectively facilitate biodiversity adaptation to inevitable climate change. In addition, we hope to stimulate a debate along some of the unresolved and often overlooked matters in relation to adaptation for biodiversity under climate change, such as "Should the N2K network be amended before its complete implementation?" or "Should future EU funds focus on retention areas?" We strongly suggest their serious consideration already now at the start of the new EU funding period.

Acknowledgments

This work was funded by the Research Directorate-General of the European Commission through its Seventh Framework Programme project RESPONSES (Grant Agreement number 244092). LM acknowledges LUOVA graduate school for funding. WT received funding from the European Research Council under the European Community's Seven Framework Programme FP7/2007–2013 Grant Agreement no. 281422 (TEEMBIO). MC received funding from the Academy of Finland (grant 257686). Moreover, we would like to thank two anonymous reviewers for their constructive feedback on an earlier version of this manuscript.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Supporting Information S1: Identifying Conservation Priorities Beyond Existing Natura 2000 Areas Q2

Figure S1 Conservation priority rankings for the current time and for the future in two climatic scenarios were based on ensembles of projected climatic suitability for 156 bird species within the EU. Priority rankings were determined for 100 datasets, where species distribution layers for each species were sampled from the ensembles of projections. The final priority rankings of the grid cells were determined as the mean ranking of each cell across the 100 rankings.

Table S1 Changes in climatically suitable range sizes of species included in the analysis: current climatically suitable range size, projected future range size, extent of climatic retention, and change in climatically suitable range size by 2050 in two future scenarios. Note: species losing suitable climatic space are typed in bold; species names as in Birds of the Western Palearctic Interactive (2006).

References Q3

Akaike, H. (1974). A new look at the statistical model identification. *IEEE T. Automat. Contr.*, **19**, 716-723.

Allouche, O., Tsoar, A. & Kadmon, R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *J. Appl. Ecol.*, **43**, 1223-1232.

Araújo, M.B., Alagador, D., Cabeza, M., Nogués-Bravo, D. & Thuiller, W. (2011). Climate change threatens European conservation areas. *Ecol. Lett.*, **14**, 484-492.

Araujo, M.B., Cabeza, M., Thuiller, W., Hannah, L. & Williams, P.H. (2004). Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. *Glob. Change Biol.*, **10**, 1618-1626.

Balmford, A., Gaston, K.J., Blyth, S., James, A. & Kapos, V. (2003). Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. *Proc. Natl. Acad. Sci. USA*, **100**, 1046-1050.

Barbet-Massin, M., Thuiller, W. & Jiguet, F. (2012). The fate of European breeding birds under climate, land-use and dispersal scenarios. *Glob. Change Biol.*, **18**, 881-890.

Buisson, L., Thuiller, W., Casajus, N., Lek, S. & Grenouillet, G. (2010). Uncertainty in ensemble forecasting of species distribution. *Glob. Change Biol.*, **16**, 1145-1157.

BWPi (2006). *Birds of the western palearctic interactive*. BirdGuides, Oxford, UK.

Cliquet, A., Backes, C., Harris, J., & Howsam, P. (2009). Adaptation to climate change: legal challenges for protected areas. *Utrecht Law Rev.*, **5**, 158-175.

Condé, S., Jones-Walters, L., Torre-Marin, A. & Romão, C. (2010). *EU 2010 biodiversity baseline*. EEA Technical report 12/2010, Copenhagen, Denmark.

de Groot, R., Brander, L., van der Ploeg, S., *et al.* (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services*, **1**, 50-61.

Donald, P.F., Sanderson, F.J., Burfield, I.J., Bierman, S.M., Gregory, R.D. & Waliczky, Z. (2007). International conservation policy delivers benefits for birds in Europe. *Science*, **317**, 810-813.

European Commission (1992). Council directive 92/43/EEC of 1992 on the conservation of natural habitats of wild fauna and flora. Available from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF. Accessed 13 May 2013.

European Commission (2011a). Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. COM(2011)244. Available from http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1˙EN˙ACT˙part1˙v7[1].pdf. Accessed 13 May 2013.

European Commission (2011b). Investing in Natura 2000: delivering benefits for nature and people. Commission stuff working paper, SEC(2011) 1573 final.

European Commission (2011c). Proposal for a regulation of the European parliament and of the council on the establishment of a programme for the Environment and Climate action (LIFE). COM(2011) 874 final.

European Commission (2013a). Guidance on integrating climate change and biodiversity into strategic environmental assessment. Available from http://ec.europa.eu/environment/eia/pdf/SEA%20Guidance.pdf. Accessed 13 May 2013.

European Commission (2013b). Guidelines on climate change and Natura 2000. Dealing with the impact of climate change on the management of the Natura 2000 Network of areas of high biodiversity value. Technical Report, 2013–068. Brussels. Available from: http://ec.europa.eu/environment/nature/climatechange/pdf/Guidance%20document.pdf. Accessed 13 August 2013.

European Commission (2013c). Cohesion policy. Strategic report 2013. Factsheet: Environment.

European Community (2009). Fourth national report of the European Community to the Convention on Biological Diversity. Available from http://www.cbd.int/doc/world/eur/eur-nr-04-en.pdf. Accessed 26 August 2013.

European Parliament (2010). Directive 2009/147/EC of the European Parliament and of the Council of November 2009 on the conservation of wild birds. Available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:en:PDF. Accessed 13 May 2013.

Hannah, L., Midgley, G., Andelman, S., *et al.* (2007). Protected area needs in a changing climate. *Front. Ecol. Environ.*, **5**, 131-138.

Heikkinen, R.K., Luoto, M., Araújo, M.B., Virkkala, R., Thuiller, W. & Sykes, M.T. (2006). Methods and uncertainties in bioclimatic envelope modeling under climate change. *Prog. Phys. Geog.*, **30**, 751-777.

Heller, N.E. & Zavaleta, E.S. (2009). Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biol. Conserv.*, **142**, 14-32.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.*, **25**, 1965-1978.

Hochkirch, A., Schmitt, T., Beninde, J., *et al.* (2013). Europe needs a new vision for a Natura 2000 network. *Cons. Lett.*, ~~doi: 10.1111/conl.12006~~ Q4

IEEP & Milieu (2013). The guide to multi-benefit cohesion policy investments in nature and green infrastructure. A report for the European Commission, Brussels, by Peter Hjerp, Patrick ten Brink, Keti Medarova-Bergstrom, Leonardo Mazza, and Marianne Kettunen of IEEP, together with Jennifer McGuinn, Paola Banfi and Guillermo Hernández of Milieu.

Kettunen, M., Baldock, D., Adelle, C., *et al.* (2009). Biodiversity & The EU Budget: making the case for conserving biodiversity. A report commissioned by the World Wide Fund for Nature (WWF) to the Institute for European Environmental Policy (IEEP), Brussels. Available from http://awsassets.panda.org/downloads/wwf_biodiversity_and_eu_budget.pdf. Accessed 13 May 2013.

Lung, T., Lavalle, C., Hiederer, R., Dosio, A. & Bouwer, L.M. (2013). A multi-hazard regional level impact assessment for Europe combining indicators of climatic and non-climatic change. *Global Environ. Change*, **23**, 522-536.

Maiorano, L., Falcucci, A., Zimmermann, N.E., *et al.* (2011). The future of terrestrial mammals in the Mediterranean basin under climate change. *Philos. T. Roy. Soc. B*, **366**, 2681-2692.

Meller, L., Cabeza, M., Pironon, S., *et al.* (~~in press~~). Ensemble distribution models in conservation prioritization: from consensus predictions to consensus reserve networks. *Divers. Distrib.*, doi:10.1111/ddi.12162

Q5 Moilanen, A., Meller, L., Leppänen, J., Montesino Pouzols, F., Arponen, A. & Kujala, H. (2012). *Spatial conservation planning framework and software Zonation*. Version 3.1 User manual. Helsinki. pp. 285.

Nakićenović, N. & Swart, R. (eds.) (2000). *Emissions scenarios 2000. Special report of the intergovernmental panel on climate change (IPCC)*. Cambridge University Press, Cambridge.

Rodrigues, A.S.L. & Brooks, T.M. (2007). Shortcuts for biodiversity planning: the effectiveness of surrogates. *Annu. Rev. Ecol. Evol. S.*, **38**, 713-737.

Roeckner, E., Bäuml, G., Bonaventura, L., *et al*. (2003). The atmospheric general circulation model ECHAM5. Part I. Model description. Max Planck Institute for Meteorology, Report No. 349, Hamburg.

Samuelsson, P., Jones, C.G., Willén, U., *et al*. (2011). The Rossby Centre regional climate model RCA3: model description and performance. *Tellus*, **63**, 4-23.

Scottish Government (2009). Scotland's climate Change Adaptation framework. The Scottish Government, ISBN 978-0-7559-8179-3. Available from http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/adaptation/AdaptationFramework. Accessed 13 May 2013.

Thuiller, W., Lafourcade, B., Engler, R. & Araújo, M. B. (2009). BIOMOD—a platform for ensemble forecasting of species distributions. *Ecography*, **32**, 369-373.

Trouwborst, A. (2009). International nature conservation law and the adaptation of biodiversity to climate change: a mismatch? *J. Environ. Law*, **21**, 419-442.

Trouwborst, A. (2011). Conserving European biodiversity in a changing climate: the Bern Convention, the European Union Birds and Habitats Directives and the adaptation of nature to climate change. *Rev. Eur. Comm. Int. Environ. Law*, **20**, 62-77.

Van Teeffelen, A.J.A., Meller, L., Van Minnen, J., Vermaat, J. & Cabeza, M. (in review) How climate proof is the European Union's biodiversity policy? *Reg. Env. Change* Q6

Vos, C.C., Berry, P., Opdam, P., *et al*. (2008). Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. *J. Appl. Ecol.*, **45**, 1722-1731.

Williams, J.W., Kharouba, H.M., Veloz, S., *et al*. (2013). The ice age ecologist: testing methods for reserve prioritization during the last global warming. *Glob. Ecol. Biogeogr.*, **22**, 289-301.

Queries

Q1: Author: Please check Tables 1 and 2 along with their footnotes as typeset.

Q2: Author: Please check "Supplementary Information" section as typeset.

Q3: Author: References Rodrigues & Brooks (2007) and Balmford *et al.* (2003) have not been cited in the text, please cite them at relevant places or delete from the Reference List.

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