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"Mind the gap!" – How well does Natura 2000 cover species of European interest?

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Abstract

Setting aside protected areas is widely recognized as one of the most effective measures to prevent species from extinction. Accordingly, there has been a tremendous effort by governments worldwide to establish protected areas, resulting in over 100,000 sites, which are set aside, to achieve the 10% target proposed at the Fourth World Park Congress in 1992 in Caracas. The main effort of the European Union to achieve this target is the Natura 2000 network of protected areas, comprising over 25,000 sites representing 18% of the area of the 27 Member States of the European Union. The designation of Natura 2000 sites was based on species and habitats listed in the Annexes of the Habitats and Birds Directive. The effectiveness of the selection process and the resulting Natura 2000 network has often been questioned as each country made its designations largely independently and in most cases without considering the theories of optimal reserve site selection. However, the effectiveness of the selection process and the Natura 2000 network has never been explicitly analysed at the European scale. Here we present such an analysis focusing on the representation of Annex II species of the Habitats Directive in the Natura 2000 network relative to a random allocation of species to sites. Our results show that the network is effective in covering target species and minimizing the number of gap species (i.e. species not represented in a single site of the Natura 2000 network). We demonstrate that the representation is uneven among species. Some species are over-represented and many species are only represented in a low number of sites. We show that this is mainly due to differing patterns in species ranges, as wide-spread species are inevitably represented in many sites, but narrow ranged species are often covered only by a small number of sites in a particular area. Finally, we propose a representation index that detects species that are underrepresented and could be used to direct future conservation efforts.

Keywords
Biodiversity conservation, gap species, Natura 2000 network, reserve site selection, Habitats Directive, reserve system, conservation planning

Introduction

Systematic approaches in planning reserve networks have been intensively developed to guide efficient reserve site selection (Brooks et al. 2006; Drechsler 2005; Margules and Pressey 2000; Margules and Sarkar 2007; Moilanen and Wintle 2006; Myers et al. 2000; Trakhtenbrot and Kadmon 2006). On a global scale no concerted action plan exists to nominate conservation areas, despite repeated calls for international coordination (Brooks et al. 2006; Knight et al. 2007; Mace et al. 2000) and available tools for conservation prioritization (Moilanen et al. 2009; Schmeller et al. 2008b). The main common strategy has been to designate conservation areas for species listed as threatened – so called "Red List species" (Rodrigues et al. 2004a). This encompasses designating those conservation areas where a species occurs, regardless of protection effort in other countries. Although this strategy is generally sufficient to achieve a single representation of each species (but see Rodrigues et al. 2004b), it easily leads to a biased representation of many species. For example, species with a wider distribution range are more likely to be included than species with more confined ranges. In countries of the European Union, a huge effort has been undertaken in recent years to establish and enhance the European Network of protected sites (known as Natura 2000) by designating areas to protect species and habitats listed in the corresponding Annexes of the Habitats Directive and Birds Directive (European Commission 2006).

The effectiveness of the site designation process and the resulting Natura 2000 network has often been questioned (Apostolopoulou and Pantis 2009; Pullin et al. 2009; Sánchez-Fernández et al. 2008). First, the principles of site designation were not uniform and each country selected sites largely independently of other countries (Apostolopoulou and Pantis 2009). Second, explicit criteria and methods of systematic conservation planning (Margules and Pressey 2000; Margules and Sarkar 2007) have rarely, if ever, been applied. A detailed description on the various stages of the designation process has recently been published (Evans 2012). Finally, the perception of the conservation status of species differs among countries, for example, a species of European importance may be common and perceived as less important for site designation in some countries, whereas it may be considered very important in countries where it is rarer. Such differences may have resulted in different levels of representation of the species in the network, e.g. many designated sites for the species in countries where it is rare and fewer sites in countries where it is common. Even though these and other potential problems have been addressed at a regional scale in a series of "Biogeographical Seminars", which reviewed national proposals for site designations, there has been no systematic pan-European evaluation of the effectiveness of the Natura 2000 network although there have been a number of regional studies , e.g. Greece, Crete, Spain, Poland, and Italy (Araujo et al. 2007; Dimitrakopoulos et al. 2004; Grodzinska-Jurczak and Cent 2011; Iojă et al. 2010; Maiorano et al. 2007) or certain habitat types, e.g. wetlands (Jantke et al. 2010). In these seminars, the site proposals were evaluated, species by species and habitat by habitat, and Member States asked to propose additional sites where judged necessary (Evans 2012).

Here we provide an evaluation of the effectiveness of the Natura 2000 network by studying the representation of Annex species in the non-marine part of the network. In addition, we study the effect of species ranges on representation. We used species range as reported by the Member States fulfilling their reporting requirements under Article 17 of the Habitats Directive (European Commission 2009). Reports were available for all species listed in the annexes of the directive for the period between 2001 - 2006 in Natura 2000 sites from 25 of the 27 current EU member states (Romania and Bulgaria joined after the reporting period and were not included). Species ranges were reported by Member States in a variety of formats but have been standardised to presence/absence on a 10 × 10 km grid by the European Topic Centre on Biological Diversity (ETC/BC) (European Topic Centre on Biological Diversity 2009a).

In 2009 there were 912 species listed in Annex II of the Habitats Directive, which lists threatened species that are to be protected by protected areas (Sites of Community Importance – SCI) in the European Union. Complete range data in a digitized format were only reported for 719 species. The reports do not cover bird species (birds are the subject of the 1979 Birds Directive and not covered by the Habitats Directive), therefore we did not analyse this species group, though in principle our analysis should be possible for this group as well. Finally, our analysis was restricted to a sub-sample of 714 species, where complete distribution ranges were available (see Table S2). For each of these species we extracted the numbers of occurrences (representations) in all Natura 2000 sites that are designated under the Habitats Directive, neglecting areas that are designated due to the Birds Directive, from the June 2009 version of the Natura 2000 database (15,646 sites). Then we compared the representation of these species to the representation that would be achieved by a random allocation of species to sites, to study the effectiveness of the designation process. Once the overall performance was evaluated, we analysed the relationship of representation to a species' range to test if the representation can be primarily explained by species' ranges. Following from this, we created a representation index that is able to detect underrepresented species to guide future conservation efforts. The Natura 2000 database was provided by the European Environmental Agency for use in the "EuMon" project, a large-scale integrative research project supported by the 6th Framework Programme 6 of the European Union (http://eumon.ckff.si, Henle et al. 2010).

Methods

Gap species

If an Annex II species is not represented at all in the Natura 2000 sites, it is termed a gap species (sensu Rodrigues et al. 2004a). There are numerous ways to identify gap species in a reserve network, which depend on different sources of data. The most common approach is a GIS-based approach to overlay species range data onto a map of protected areas. In this kind of analysis a species is regarded as represented in a protected area if its range falls at least partly within it (Kremen et al. 2008; Rodrigues et al. 2004a; Rodrigues et al. 2004b). Often an arbitrary threshold, such as 10 % of the area, has to be covered before a reserve network is assumed to assure a species is efficiently protected. Given that species range maps are often highly erroneous due to incomplete and outdated data, this approach is problematic, especially for rare species (Rodrigues et al. 2004b). It is even more problematic if species ranges are given by occurrences in grid cells, as is the case here. In that case, an additional assumption has to be made: if a site of a network falls inside a grid cell where the species is present, the species is represented. Often this results in commission errors, i.e., a species is considered to be present in a protected area when it is absent (Rodrigues et al. 2004a). To avoid these potential errors we used the Natura 2000 database, which describes each Natura 2000 site and lists the Annex II species present, often based on recent ecological surveys in the protected areas. To identify gap species we queried the data base for how often a species occurred across all sites. Species without any entries were regarded as gap species.

The Natura 2000 database is constantly being updated due to additional designation of sites and changes to the description of existing sites, including the addition or deletion of Annex II species. However, poor data entry, such as misspelt species names, also introduces errors and, although the data are checked regularly, it takes time for Member States to make the corrections. Each of these effects may result in erroneous entries in the database, which in turn can lead to an under-estimation of representation and to a surplus of gap species. This may result in a higher number of so called omission errors (a species is considered to be absent from a protected area in which it is present). We believe our more conservative, precautionary approach is a more appropriate one for nature conservation, as a species that is falsely regarded underrepresented is less problematic than a species falsely regarded as overrepresented, which could potentially lead to the misguided believe that the species is adequately protected. As the database is continuously updated, we decided to use the database after the last reporting in 2009 to have a fixed reference status for future comparisons.

Selection process

To assess the efficiency of the designation process, we simulated a random designation process by assigning 714 species into 15,646 virtual Natura 2000 sites assuming that the probability of drawing a species is the ratio of its range size to the total area of the EU25 Member States. This designation process was virtually repeated 1000 times using a Monte Carlo approach, during which the distribution of representations of the 714 species was recorded for each random sample. Based on these thousand samples a confidence interval of the expected number of representation for each representation class can be created. If the distribution of observed representation is not following the distribution of representation of the random process (i.e. is above or below the 95% confidence interval), this suggests departure from a non-random and hence "organized" designation process.

Representation and range size

To analyse if the representation of a species is mainly determined by its range size we regressed these two variables against each other. Given this relationship, we wanted to quantify the status of representation of each species, i.e. whether it is overrepresented or underrepresented, taking its range size into account. Therefore we devised a representation index (REX). To calculate this index for each species, we first determined the range size of each species by summing the occurrences in grid cells of 10 x 10 km extent and multiply this by the area of one cell (100 km^2). We standardized this range size by dividing it by the total area of all EU25 countries, which results in a range size proportion between zero and one. Then we calculated the representation proportion for each species by dividing the representation of each species by the total number of Natura 2000 sites in the EU25 countries. Finally, the REX is calculated as the ratio of these two quantities:

$$\mathrm{REX} = \frac{\text{representation proportion}}{\text{range size proportion}} = \frac{\dfrac{\text{representation}}{\text{number of Natura 2000 sites in EU25}}}{\dfrac{\text{range size}}{\text{total area of EU25}}}$$

The index can be calculated for the whole of the Natura 2000 network, as well as for subunits of the network (either per country or per species group). To compare the REX among groups of species we used the median of each species per group to down weight outliers. In addition, the median REX of all species in a country can be used to compare the status of representation of all species among countries, as it can be standardized by taking the country area and number of Natura 2000 sites in a country instead of the EU25 area and number of sites as a reference.

The idea of the REX is best illustrated by an example. Assume a species whose range covers 50% of the area of the EU25 countries. If this species is represented in half of the Natura 2000 sites of the EU25 countries, it has a REX value of one, since it is represented in accordance to its range. If the species is represented in more than 50% of the sites, the REX value would be larger than one, showing an overrepresentation of a species. A REX value below one indicates an underrepresented species. A REX of two means that this species is twice as often represented as would be expected from its range size. Obviously, the higher the REX the better a species is represented and therefore its conservation is more likely to be adequate.

Results

Representation

Of the 714 species examined, 54 were apparently not recorded in any site (Fig. 1). Checking each gap species separately, most of the zero representations are due to incomplete data in the database. Most often the incompleteness of data results, either from 'confidential species', where data has deliberately been excluded from the database, or due to taxonomic changes. We had a closer look on the identity of gap species in the database. Together with experts from the ETC/BD, we created a complete list of gap species and comment on their likely status (Table S1). Among the species studied we identified three genuine gap species and these were already identified by "Biogeographical Seminars" (Papp and Toth 2006). Most of the other identified gap species are the result of incomplete reporting. Nevertheless, as a first result, the analysis of the representation of each species pointed towards potentially erroneous entries and real gap species. Notwithstanding, while not as problematic for the design of further conservation activities, such as the search for additional appropriate sites for protection, lack of information may also hamper the effectiveness of further action. In addition, the uneven distribution of representations clearly demonstrates that the selection process strongly favoured some species represented in many sites and lead to a representation of many species in a low number of sites.

Selection process

The resulting distribution of simulated random representations showed a very good fit with observed data (Kolmogorov-Smirnov-Test, $D = 0.22$, $p>0.765$), except for gap species, where the observed representation showed significant lower values, and for single plus double representations, which had significant higher values in the observed data (Fig. 1). This demonstrates that the designation process was highly effective in avoiding gap species, as it shifted them to single or few representations, but at higher representations the outcome of the designation process conforms to a random pattern.

Comparing representation and range size

Species representation is highly correlated with species range size (Fig. 2, $F_{1, 712} = 1274.3$, $P < 0.0001$, $r = 0.81$). Most species are scattered around the bisecting line,

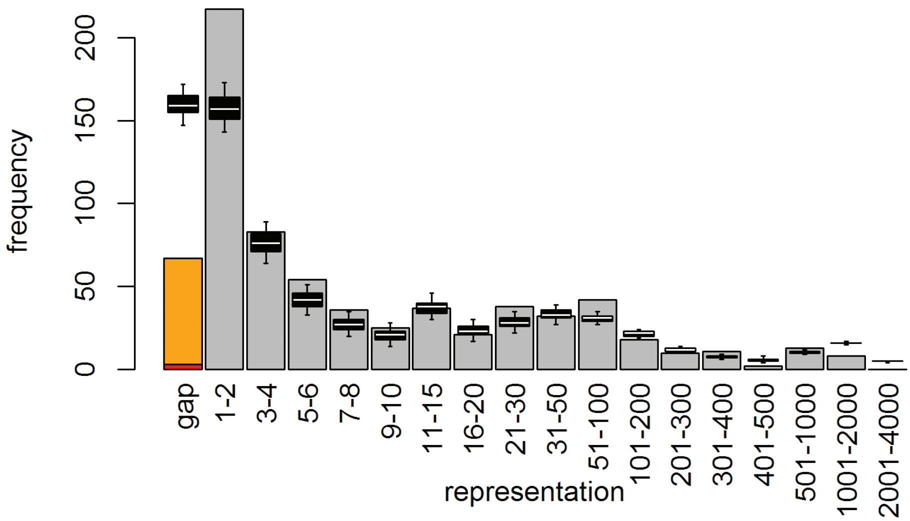

Figure 1. EU-wide representation of 714 Annex II species in the Natura 2000 network of the EU25 countries of the European Union in 2007. Species with no representation in the data base, (gap species: 54 / 714) are indicated by an orange bar. Remaining gap species based on expert knowledge are marked by the red bar (3 / 714). Whisker-boxes show the distribution under random assignment, assuming that the probability of a species to be assigned is proportional to the range size of that species. White lines indicate the median, boxes the first and third quartiles and whiskers the 5 and 95 percentile of 1000 replicates.

which can be interpreted as a null model for representation. Gap species occur from very small range sizes (likely real gap species) up to ranges of more than 30,000 km^2 (probably gap species due to incomplete entries). The representation index (REX) has a median value of 3.17 over all species for the Natura 2000 network of the EU25. This indicates that most species are represented three times more than would be expected from the species range. Of all 714 species 599 had a REX value higher than 1, so the majority of species were overrepresented in the network (Table S2).

For demonstration purpose we will elaborate on the REX using four exemplary species. These species show the four principally combination of distribution and representation, namely broad/narrow ranged species, which are over/under represented (Table 1).

Myotis bechsteinii (wide range/ low representation)

The Bechstein's bat (*Myotis bechsteinii*) is a representative of the case where a species is widely distributed across Europe, but because it is specialised on a nowadays rare habitat - mature deciduous forests - it is only recorded in 27 sites across its range. The EU assessment of the species (European Topic Center 2009b, Report on *Myotis bechsteinii*) shows that in many countries and biogeographic regions the conservation status of *Myotis bechsteinii* is unknown, due to its highly cryptic nature. It has a very low REX value (0.04) which is in line with the current known representation of the species. An obvious recommendation would be to increase the knowledge on the actual distribu-

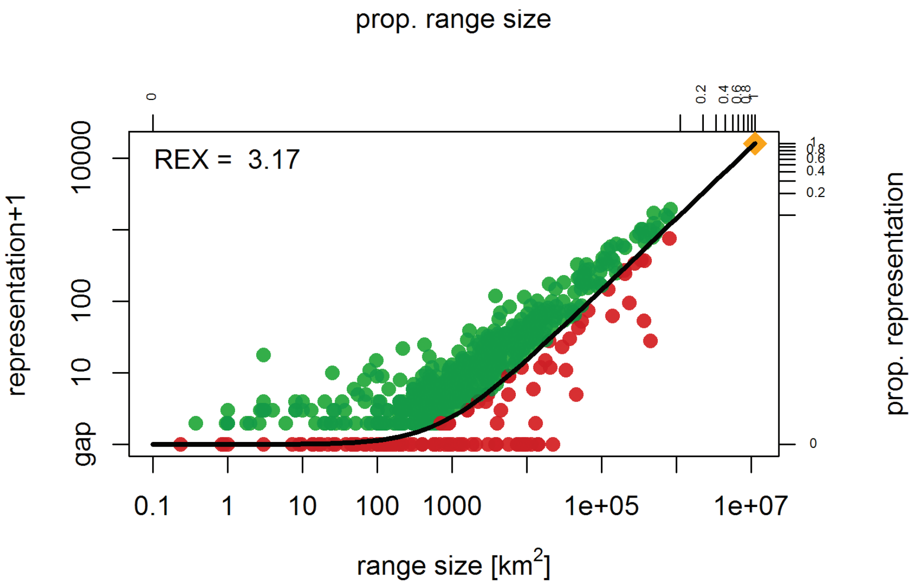

Figure 2. The relationship between species representation and range size for 714 Annex II species in the EU25 countries. Red dots indicate underrepresented species (REX < 1) and green dots overrepresented species (REX > 1). The bisecting line marks values of REX equal to one. Note that the bisecting line turns into a curve on a log-log scale. The orange diamond marks the maximum possible representations for a hypothetical species distributed over the total area of the EU25 countries. The median representative index for all species is given in the upper left corner.

Table 1. Example of representation, distribution and REX of four species.

Species	Representation [number of N2K sites]	Distribution [km^2]	REX
Myotis bechsteinii	27	452395	0.04
Paracaloptenus caloptenoides	4	4588	0.06
Mustela lutreola	119	3802	21.83
Lutra lutra	3185	1382075	1.61

tion of the species, which hopefully leads to the identification of additional Natura 2000 sites that already protect a population of the species, followed by potential new designated sites to increase the overall representation.

Paracaloptenus caloptenoides (narrow range / low representation)

The cricket *Paracaloptenus caloptenoides* is an endemic, narrow-ranged species that occurs mainly in Hungary, with some population reported from Slovakia and Greece. In its limited range it is only represented in four Natura 2000 sites, which results in a very low REX value (0.06). Based on the assessment of the EU (European Topic Centre 2009b, Report on *Paracaloptenus caloptenoides*) it is regarded to be overall in an unfavourable status as there is a lack of knowledge on the distribution of the species (Slovakia and Greece) and the status in Hungary is critical. Therefore we conclude that the low REX value is in line with the current knowledge on the species and its representation in Natura 2000 sites.

Mustela lutreola (narrow range / high representation)

The European Mink (*Mustela lutreola*) is an example of a species that has a very limited current range, probably due to destruction of habitat and replacement by the invasion of the American Mink (*Neovision vision*) in Europe. The remaining current distribution is therefore very fragmented and scattered across Europe (European Topic Centre 2009b, Report on *Mustela lutreola*). Being critically endangered, this species has received considerable attention and is currently represented in 119 sites. This leads to a very high REX value (21.8). Therefore we conclude that the species is well represented by the Natura2000 network, but as the population is still in decline, management should concentrate on restoring the habitat and controlling the American mink at sites where both species occur.

Lutra lutra (wide range / high representation)

The Eurasian otter (*Lutra lutra*) is a widespread species that is represented in more than 3000 sites and has therefore an overall REX value of 1.6. This demonstrates that the species is well covered by the Natura2000 network and the REX is in line with its status based on the EU assessment (European Topic Centre 2009b, Report on *Lutra lutra*). While its conservation status may be insufficient in some biogeographic regions, it is "*favourable in a number of countries with stable or increasing trends and good future prospects*" (European Topic Center 2009b, Report on *Lutra lutra*).

To summarize the examples, it can be shown that the REX quantifies the overall representation of a species with respect to its range, but should be complemented by species population trends for a final detailed assessment of the status of a species.

If we compare the REX values against species range it clearly demonstrates the inverse relationship of the two components – the wider the species range, the lower tend to be the REX value, though the variation at smaller range sizes tends to be higher (Fig. 3). This indicates the potential of REX, as it can differentiate between narrow-ranged species that are still well represented (high REX value) and species with a narrow range size, which are nevertheless underrepresented. Species of most concern are easily identified, namely species having a small range size and a small REX value.

Comparing the REX for different species groups demonstrates significant differences between groups (Fig. 4, $F_{5, 707} = 3.37$, $P < 0.01$). Plants achieve the highest REX (3.51), followed by reptiles (2.41), invertebrates (2.37), fishes (1.59), amphibians (1.46) and finally mammals (1.44). This sequence is a consequence of the highly uneven number of studied species per group on the Annex II list, with plants being

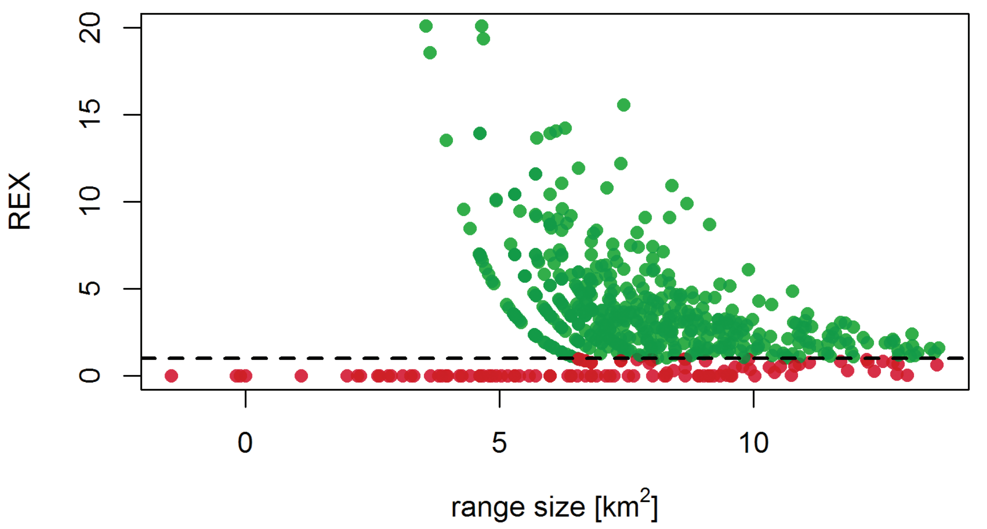

Figure 3. The relationship between species range sizes for 714 Annex II species and their associated REX value. Red dots indicate underrepresented species (REX < 1) and green dots overrepresented species (REX > 1). Note the log scale of the x-axis.

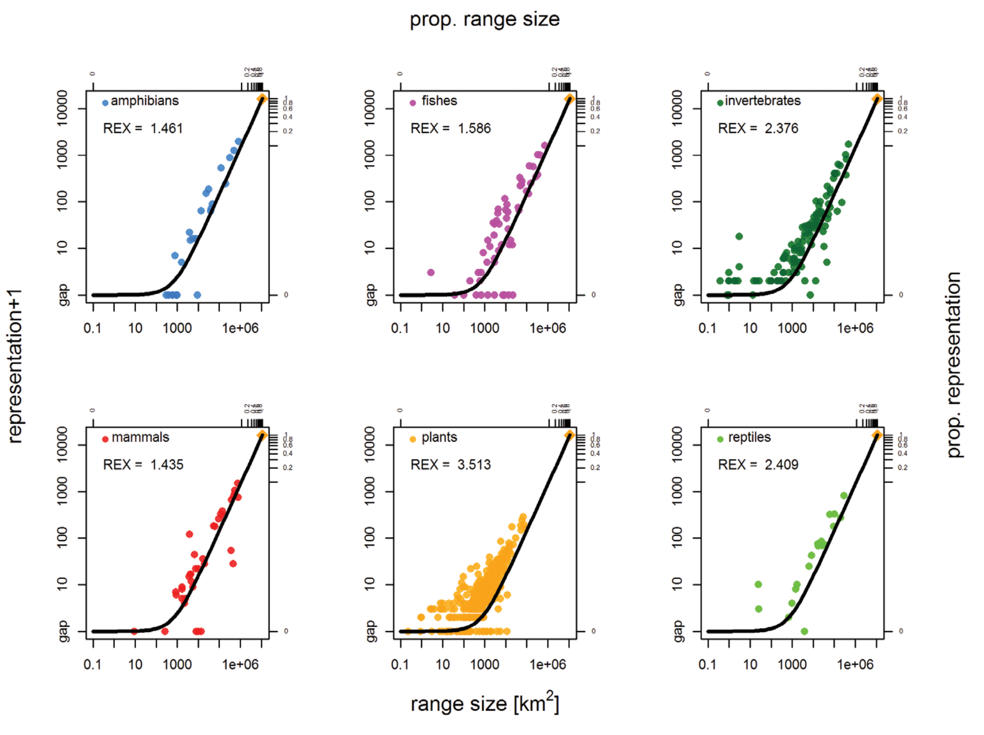

Figure 4. The relationship between species representation and range size for major taxonomic groups. The orange diamond indicates the maximum possible representation for a species distributed over the total area of the EU25 countries. REX is the median representation index for each species group.

the most prominent group, represented by 464 species, followed by invertebrates (114 species) and the other groups represented by a comparatively low number of species (19 reptiles, 24 amphibians, 34 mammals and 55 fishes). Therefore the comparison between species groups is most likely biased by the uneven distribution and the does not necessarily reflect species groups attributes.

The REX can also be used to compare the species representation status among countries (Fig. 5). Please note that here the basis to calculate the REX value for each species in a country is calculated using the area and the number of Natura 2000 sites of a specific country as reference. The REX values of the EU25 countries varies widely from about 0.3 (Lithuania) to over 25 (Cyprus). On average, all countries designated around 10-15% of their area to Natura 2000 sites (exception are Slovenia 31.4% and Spain 24.7%). This implies that countries with a lower number of Natura 2000 sites have on average designated sites with larger areas. Neglecting very small countries such as Malta and Cyprus, it can be seen that countries with a small number of larger sites (e.g. Portugal, Greece and Spain) achieve higher REX values than countries with many small sites (e.g. Czech Republic, Germany; Fig. 6).

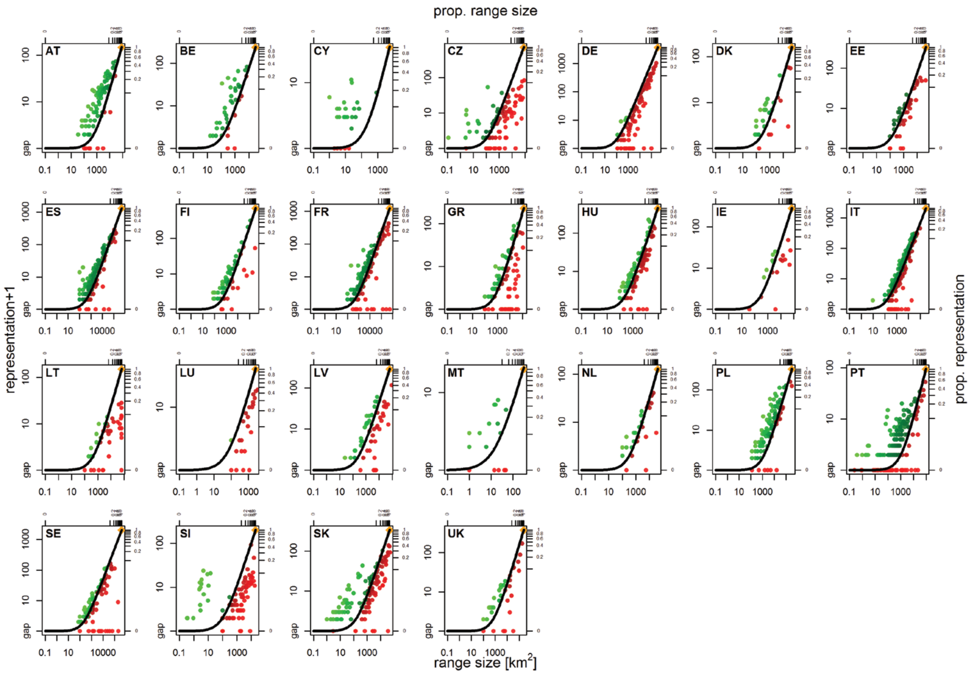

Figure 5. Representation as a function of species range sizes of Annex II species per EU25 country. The orange diamond marks the maximum possible representation of a species in a EU25 country occurring in the whole country. REX is the median represention index for each country. The coding of country names is as following: AT Austria, BE Belgium, BG Bulgaria, CY Cyprus, CZ Czech Republic, DE Germany, DK Denmark, EE Estonia, ES Spain, FI Finland, FR France, GR Greece, HU Hungary, IE Ireland, IT Italy, LT Lithuania, LU Luxemburg, LV Latvia, MT Malta, NL Netherlands, PL Poland, PT Portugal, RO Romania, SE Sweden, SI Slovenia, SK Slovakia, UK Great Britain.

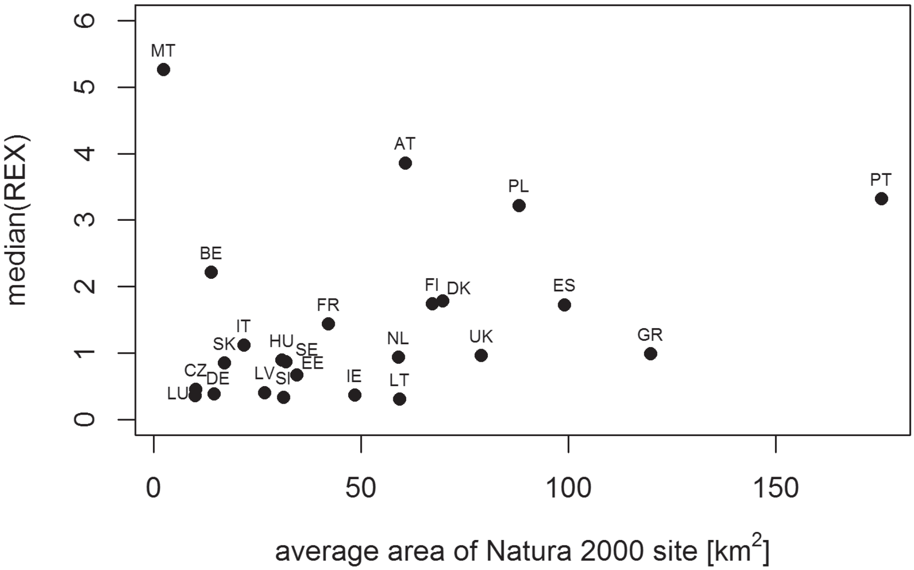

Figure 6. The relationship between average Natura 2000 and median REX value for each EU25 country.

Discussion

Our evaluation of the Natura 2000 reserve network found that the network adequately minimizes gap species by providing representation for many species of restricted ranges. It also demonstrates that the representation of Annex II species in the network is uneven, and it identifies species that currently have a low EU-wide representation. We argue that the representation of Annex II species and the derived representation index REX can be used to identify gaps in the Natura 2000 network and to guide future conservation effort.

Establishing a reserve network such as the Natura 2000 network will necessarily remain suboptimal to some degree. That is always the case in an opportunistic designation process limited by economical, cultural, political and scientific constraints, and one which builds on already existing national networks of protected areas (Knight and Cowling 2007). In many countries Natura 2000 has been largely based on existing protected areas (European Topic Centre on Biological Diversity 2005). Our results showed that this designation process leading to most species being represented as expected if sites were selected at random and an overrepresentation of wide ranging species (e.g. the Eurasian otter *Lutra lutra*, is listed in 3,185 sites). This indicates that there was relatively little coordination among countries in site selection. Notwithstanding, a certain level of coordination was achieved by “Biogeographical Seminars” (European Topic Centre on Biological Diversity 2005), which resulted in fewer gap species than expected if sites were selected at random. In these seminars, the designation of sites for each species was coordinated among countries sharing a biogeographic region (typically 2–6). We stress that we do not think that overrepresentation is a disadvantage for the species involved. However, we are convinced that it would be more effective to designate future Natura

2000 sites dependent on existing representations of species, considering the 2020 target of halting the loss of biodiversity and the limited resources available.

One might argue that the Natura 2000 network was established not only for species but also for habitats listed in Annex I of the Habitats Directive and therefore our analysis is not measuring the full benefit of the network. Nevertheless, as the REX index was below one for 115 of the 714 species (see Table S2 for species names), i.e. below the value expected by their range, this demonstrates that for these species the selection process for covering species was insufficient. So we would argue, even if the network is successful in covering habitats (which has not been demonstrated), it fails short in achieving a protection of all Annex II species (Moilanen and Arponen 2011).

Especially if national red lists are used in several countries independently there is a high chance that wide-spread species are well covered by the network and narrow to mid-ranged species are under-represented. A possible solution is provided by the idea of assigning different conservation responsibilities to countries, which reflects the contribution of a country or area to the survival of a species (Schmeller et al. 2008a; Schmeller et al. 2008b). We demonstrate the effect of using Annex list species as the main designation criteria, by comparing the achieved representation to the representation if species were randomly allocated to sites.

Assuming that countries selected their sites primarily for the rarer habitats and species to ensure they are covered by the network, the more common species will often occur in these sites and so inevitably emerge as highly represented. We conclude that to ensure the effectiveness of future designations, sites should not be designated primarily for wide-ranging Annex species that are already well represented elsewhere; rather the focus should be on underrepresented species.

In principle the same kind of analysis could be done for habitats, which are listed in the Habitats Directive and also reported by Article 17 of the Directive. We excluded these from our analysis as in our opinion the representation concept is less applicable to habitats. Habitat interpretations vary between countries, and sometimes between regions in the same country (e.g. Belgium and Spain; Evans 2010); in contrast populations of animal species, such as the Eurasian otter in Germany and the Czech Republic, still may belong to the same metapopulation. Therefore, we based our evaluation of the Natura 2000 solely on the Annex II species, neglecting the positive effects of the network on birds (Donald et al. 2007) and habitats. Our analysis is still an important evaluation of one of the central goals of the Habitats Directive, namely the protection of its Annex II species.

As the proposed REX index is calculated by a fraction of two values, there are in principle to ways to achieve a high REX value. Either having a high value in the numerator by protecting a species in a large number of sites or by having a small value in the denominator, which is easier achieved, if species have a small range size. Illustrated by an average REX value of 3.51, plants are highly overrepresented in the Natura 2000 network. A likely reason why plants are well covered is that many Annex II species have a fairly restricted range size, which allows for high REX values in this species group where Annex II includes many localised endemics, particularly in Macaronesia and the

Mediterranean. In contrast to this, it is much harder to achieve a high REX value for wide ranging species, such as many mammal species, which likely is the reason why the average REX value for mammals is the lowest among species groups. In addition, the REX is more sensitive (changes more quickly) if sites of narrow ranged species compared to wide ranged species are lost, which is a good characteristic for a representation index – hence it weights sites in accordance to their importance for a species.

On the scale of countries, the REX favours countries with fewer, but larger sites that protect more species at once. Countries with fewer and larger sites, such as Spain, have simply a smaller value in the denominator of the REX formula. Both ways to increase the REX value (having a large numerator or a low denominator) are desirable properties of the REX in terms of conservation, as it favours larger sites and obviously a representation in a large number of sites. Both size and number of sites are important factors contributing to the survival of species (Hanski and Gilpin 1997; Henle et al. 2004). The general notion that it is preferable to have fewer and larger sites (smaller denominator), if representation is achieved on a similar level, is in our view a too narrow proposal. A country with many smaller sites (larger numerator) may also achieve high representation despite societal constraints posed on the designation of sites (e.g. human population density, subsidiary governance structures).

Conclusions

Our evaluation of the Natura 2000 reserve network demonstrates that the site selection process succeeded in avoiding gap species but was inefficient as many species are underrepresented relative to expectation based on their range size. Despite this inefficiency the selection process led to species with smaller ranges being relatively better represented than wide-ranging species, as demonstrated by their higher REX index. Most importantly, our evaluation identified species that currently have a low EU-wide representation and should be targeted in further site designations. Here, in contrast to complex reserve site selection algorithms, our approach has the advantage to be rapid and simple. It thus can serve as a rapid assessment tool for elucidating effectiveness and deficiencies of the Natura 2000 network across the EU and within Member States and it is easily transferable to other developing reserve networks (Hartley et al. 2007).

Supporting information

Table S1, S2 are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Appendix 1

List of gap species in the Natura 2000 network (Natura 2000 database, June 2009, European Environmental Agency). (doi: 10.3897/natureconservation.3.3732.app1). File format: MS Exel Document (xls).

Explanation note: Table S1: The table shows the 54 gap species ordered by species group. Please note: The comment column is based on expert opinion of the European Topic Centre, which has the latest version of the Natura2000 data base and also knowledge on confidential sites, which are deleted from the public version of the data base to protect rare species.

Citation: Gruber B, Evans D, Henle K, Bauch B, Schmeller DS, Dziock F, Henry P-Y, Szabolcs L, Margules C, Dormann CF (2012) "Mind the gap!" – How well does Natura 2000 cover species of European interest?. Nature Conservation 3: 45–63. doi: 10.3897/natureconservation.3.3732.app1

Appendix 2

Table S2: List of 714 Annex II species (ordered by REX). (doi: 10.3897/natureconservation.3.3732.app2). File format: MS Exel Document (xls).

Explanation note: This table shows Eunis-Code, species name, species group and REX value of all Annex II species for all 714 that were included in the study, because complete distribution data from all EU25 member states were available.

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