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The European union's 2010 target: Putting rare species in focus

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ABSTRACT

The European Union has adopted the ambitious target of halting the loss of biodiversity by 2010. Several indicators have been proposed to assess progress towards the 2010 target, two of them addressing directly the issue of species decline. In Europe, the Fauna Europaea database gives an insight into the patterns of distribution of a total dataset of 130,000 terrestrial and freshwater species without taxonomic bias, and provide a unique opportunity to assess the feasibility of the 2010 target. It shows that the vast majority of European species are rare, in the sense that they have a restricted range. Considering this, the paper discusses whether the 2010 target indicators really cover the species most at risk of extinction. The analysis of a list of 62 globally extinct European taxa shows that most contemporary extinctions have affected narrow-range taxa or taxa with strict ecological requirements. Indeed, most European species listed as threatened in the IUCN Red List are narrow-range species. Conversely, there are as many wide-range species as narrow-range endemics in the list of protected species in Europe (Bird and Habitat Directives). The subset of biodiversity captured by the 2010 target indicators should be representative of the whole

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biodiversity in terms of patterns of distribution and abundance. Indicators should not overlook a core characteristic of biodiversity, i.e. the large number of narrow-range species and their intrinsic vulnerability. With ill-selected indicator species, the extinction of narrow-range endemics would go unnoticed.

1. Introduction

The European Union has adopted the ambitious target of halting the loss of biodiversity by 2010 (European Union, 2001). It exceeds the target chosen by the nations of the world at the 2002 World Summit on Sustainable Development, which was to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth" (Convention on Biological Diversity, 2001a). In order to assess progress towards these targets, biodiversity should be monitored to know whether the rate of loss is increasing or decreasing, and eight indicators for immediate testing in seven focal areas were proposed by the CBD's seventh Conference of the Parties (COP7). In the focal area on "status and trends of the components of biological diversity" three indicators were proposed to assess progress towards the 2010 target (Convention on Biological Diversity, 2001b):

- Trends in extent of selected biomes, ecosystems and habitats.
- Trends in abundance and distribution of selected species.
- Coverage of protected areas.

In the same focal area, two other possible indicators are in development

- Change in status of threatened species.
- Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance.

Theoretically, these indicators provide a powerful way to assess progress. However, they could be difficult to implement, as data or standardized methodologies are lacking: even the assessment of the coverage of protected areas is hindered by the fact that protected areas do not have the same definitions in every country, and are sometimes difficult to attribute to IUCN Protected Area Management Categories (IUCN, 1994). Only two of these indicators are directly linked to species loss, being species-based, "Trends in abundance and distribution of selected species" and "Change in status of threatened species". Butchart et al. (2004) presented a method for producing indices based on the IUCN Red List to assess projected relative extinction risk of a species, and tested it for the world's birds and amphibians (Butchart et al., 2005). That was a major contribution to the development of the Red List indicator, which will measure changes in overall extinction risks for all species in taxa for which Red List data are available. However, at a global scale, only 0.1% of insect species, 3.1% of mollusc species and 1.3% of crustacean species have been evaluated, vs. 100% of bird species, 100% of amphibian species and 89.7% of mammal species (IUCN, 2006). Obviously, data are lacking for the assessment of whole invertebrate groups, as most invertebrate species have not been compared with the threat criteria: the Red List indicator, though powerful, is useless for species that have not been checked against the Red List criteria, i.e. most invertebrates, but also 91.9% of reptile species and 90.1% of fish species (IUCN, 2006). A number of groups are currently being assessed against the Red List (reptiles, freshwater fish, sharks, rays and chimeras and freshwater molluscs), and will be used to build a more robust aggregated Red List indicator (Butchart et al., 2005). However, this will still not cover most invertebrates, which represent the bulk of biodiversity, and one can ask whether this will even capture the main characteristics of biodiversity. Similarly, the "selected species" chosen for the indicator "Trends in abundance and distribution of selected species" should be representative of overall biodiversity, and not only of the better known species. Taking into account the neglected invertebrates in conservation policies is not only important for its own sake, but also because these species affect ecosystem functioning, although our knowledge of the linkages between biodiversity and ecosystem processes is very incomplete. Loss of biodiversity makes ecosystems vulnerable, and this may be particularly true for the neglected invertebrate taxa which, despite their minute size, play an important role in ecosystem functioning (Palmer et al., 1997; Tilman et al., 1997).

Although not directly correlated with vulnerability, rarity is a major determinant of a species' likelihood of extinction (Gaston, 1994; Yu and Dobson, 2000) and species usually become rare before going extinct (Dobson et al., 1995). There have been many attempts to recognize various forms of rarity (see Gaston (1994) for a compilation), but the most well-known is Rabinowitz (1981). In this model, three factors can be combined to assess a species' rarity: range size (distribution), population size (demography) and habitat requirements (ecology). Species demonstrating geographical rarity are narrow-range endemics; species demonstrating demographic rarity are typically represented by large predators and species in decline; ecologically rare species are specialist species, the extreme case being single host parasitic species. The combination of these factors produces eight forms of rarity, the ninth group (large range, large population size and broad habitat requirements) being common species.

In the light of these theoretical considerations on rarity, we have assessed the reliability of the CBD 2010 target indicators at the scale of the European fauna, on the basis of the Fauna Europaea dataset. The Fauna Europaea program, funded by the European Commission for a period of 4 years (1 March 2000–1 March 2004) within the Fifth Framework

Program (FP5), was designed to assemble a database of the scientific names and distribution of all living multi-cellular European land and fresh-water animals (Fauna Europaea, 2004). We address here the issue of the representativeness of the subsample of biodiversity captured by the 2010 target indicators at the European scale, with the insight given by Fauna Europaea: are the indicators currently used to assess the state of biodiversity really covering the species most at risk of extinction? In other words, the purpose of this paper is to assess whether the focus of the 2010 target indicators is on all biodiversity or on a part of it only: will these indicators give an accurate image of biodiversity loss in Europe?

2. Methods

This work was based on the Fauna Europaea list of non-marine animal species and subspecies in Europe (Fauna Europaea, 2004). This list covers all the terrestrial and freshwater fauna of Europe, i.e. ca. 130,000 species and ca. 14,000 subspecies. As subspecies have been included in Fauna Europaea for some groups only, our analyses were performed with species only. The area covered is the European mainland, plus the Macaronesian islands (excl. Cape Verde Is.), Cyprus, Franz Josef Land and Novaya Zemlya. Western Kazakhstan, Caucasus and the Asiatic part of Turkey are excluded. Three institutions have taken responsibility for the main complementary clusters of tasks: the University of Amsterdam (Zoological Museum Amsterdam) was in charge of the overall coordination and management, including the application of software and database tools to support these tasks; the University of Copenhagen (Zoological Museum) took care of the collation of the data and the creation of integrated datasets; and the Muséum national d'Histoire naturelle in Paris was responsible for the validation of the data sets. The data were gathered by 59 Group Coordinators, each of them being in charge of a taxonomic group, helped by 417 taxonomic specialists and associate specialists. All the taxonomic specialists and coordinators were selected as the key experts in their field. The Group Coordinators checked the consistency of the partial data sets, and independent validation was done in the Paris team. Moreover, for the Eastern European countries especially, a comparison was made with numerous local documents to inform the specialists about deviations. The final database of valid names, most used synonyms and distribution data should be regarded as a quality controlled product, representing currently available knowledge. For the purpose of the present analysis, a database was built to conveniently handle this huge amount of taxonomic and distribution data, the raw data being provided as Microsoft Excel sheets by the Fauna Europaea Bureau in Amsterdam.

We considered legal protection status at the European level only, with texts giving a real protection status, i.e. allowing a legal action to be taken if needed. In this framework, the only legal documents really protecting species are the Council Directive on the conservation of wild birds (Birds Directive) and the Council Directive on the conservation of natural habitats and of wild fauna and flora (Habitat Directive).

The species lists given in the Appendix of the directives were integrated into the database. Queries were generated in the Fauna Europaea database to obtain a list of all the protected species in Europe, as some species are protected at a supra-specific level (all European birds are protected by the Bird Directive for instance). This list was double-checked by hand in order to track mistakes.

Distribution data were taken from the Fauna Europaea database, i.e. presence/absence in each Fauna Europaea geographical unit. The geographical units employed in Fauna Europaea were countries, large islands or archipelagos, thus ranging from several hundreds thousands of square kilometers (France, Germany) to a few square kilometers (Selvagen Islands). Data on the distribution of Red Listed species were taken from the Red List, as Fauna Europaea does not give precise distribution data outside Europe (many European Red Listed species also range outside Europe).

The IUCN Red List is widely acknowledged as the most objective and comprehensive compilation of threatened and extinct species worldwide (Lamoreux et al., 2003), having no legal status and being compiled by thousands of scientists. As such, it is the best available basis for the indicator on "Change in status of threatened species". The list of European threatened species was thus extracted from the IUCN Red List website (IUCN, 2006), selecting the species classified as Critically Endangered, Endangered and Vulnerable for each European country. Threatened species from Russia and Turkey were checked individually to remove those occurring only in the Asian part of these countries. The list of extinct species was compiled from the 2006 IUCN Red List and from the literature, with the help of the Fauna Europaea Group Coordinators.

Each of the 804 bird species present in Fauna Europaea had to be listed as protected in our database, as the Bird Directive states that populations and habitats of all species of naturally occurring birds in the wild state in the European territory should be maintained (Articles 1, 2 and 3). However, the Fauna Europaea bird list does not comply with Fauna Europaea geographic range. In particular, it includes species from the Caucasus, Middle East and North Africa which extend beyond the Fauna Europaea zone. In order to be consistent with the other groups, these species have been excluded from our dataset. Data on species range of birds were taken from Beaman and Madge (1998).

The Fauna Europaea bird list also contains Asian or Nearctic vagrants that are seen only exceptionally in Europe. These species have been excluded from the dataset used in this study, for three reasons:

- Many of them are listed in Fauna Europaea as occurring in one European country only, because they have been recorded in Europe only once. Keeping them would produce a bias in the analysis of endemic species in Europe (97 bird species occurring in one European country only, as given by the Fauna Europaea database, definitely does not reflect the fact that only 19 bird species are European single country endemics).
- Given the high number of birdwatchers in Europe, birds are the only group with such coverage, and are much better known than any other taxon in Europe. A vagrant Diptera from America would hardly be noticed if it was blown up

by a storm to the Scilly Islands, unlike an American warbler. As it is impossible to include vagrant species in other taxa, vagrant bird species should be removed from the dataset to avoid biases.

- These vagrant birds do not breed in Europe, nor are regular migrants in Europe: strictly speaking, they do not belong to the European fauna.

Vagrant bird species were identified from Beaman and Madge (1998) and discarded.

3. Results

3.1. *Endemism in the European fauna*

The vast majority of European species have a restricted range (Fig. 1): 37% of European species are present in [part of] one Fauna Europaea geographical unit only, and half of the species are present in [part of] one or two Fauna Europaea geographical units. Moreover, species restricted to mountain ranges (e.g. Pyrenees, Alps, Carpathians, Rhodope mountains) or lakes (e.g. Lake Ohrid, Lake Constance, Lake Neusiedler or Lake Prespa) that are shared by two or three countries, which are narrow-range endemics, appear in this figure as present in two or even three Fauna Europaea geographical units. Fauna Europaea cannot provide better estimates of range size, let alone areas of occupancy: the area of its large geographical units overestimates the true areas of occupancy of species, as most endemic species do not occur in the whole of the geographical unit.

More than 99% of the species present in one Fauna Europaea geographical unit only are invertebrates, for which distributional data are sometimes inadequate: an extreme situation is the case of species only known from the holotype and the type locality (Stork, 1997). In these cases, endemism is most probably an artefact due to a lack of knowledge. In order to account for this bias, the same estimates of endemism were calculated for the best known groups: vertebrates, Mollusca, Coleoptera Carabidae, Lepidoptera, Odonata and Orthoptera (Fig. 2): the pattern is still the same as for the whole fauna: 35% of the "well-known" species are present in [part of] one Fauna Europaea geographical unit only vs. 37% in Fig. 1. Even for well-known taxa, endemism is widespread. When terrestrial vertebrates only are considered, 13% are endemic to a single Fauna Europaea geographical unit, and 19% from one or two Fauna Europaea geographical units, but 11% are present in more than 59 Fauna Europaea geographical units (Fig. 3).

Fauna Europaea lists 7070 species endemic from European islands covering less than 10,000 km^2 (Table 1). At most, the range of these species cannot exceed the area of the islands. These very rough distribution data are nevertheless enough to characterize thousands of European species as narrow-range endemics sensu Harvey (2002), i.e. naturally occurring on less than 10,000 km^2. It should be noted that there are many more islands housing single-island endemics in Europe than those listed in Table 1, e.g. Greek islands which are not treated individually in Fauna Europaea. Most of these single-island endemics are invertebrates; however, 11 European bird taxa have a range of 4000 km^2 or less, and a further eight have a range of 8000 km^2 or less, most of them in the Macaronesian islands (C. Roselaar, unpub. data).

At a fine scale, data on the range size of narrow-range invertebrates are scarce. An approximation of the maximum size of the range of endemic species can be given by the cumulative surface of the smallest territorial division known

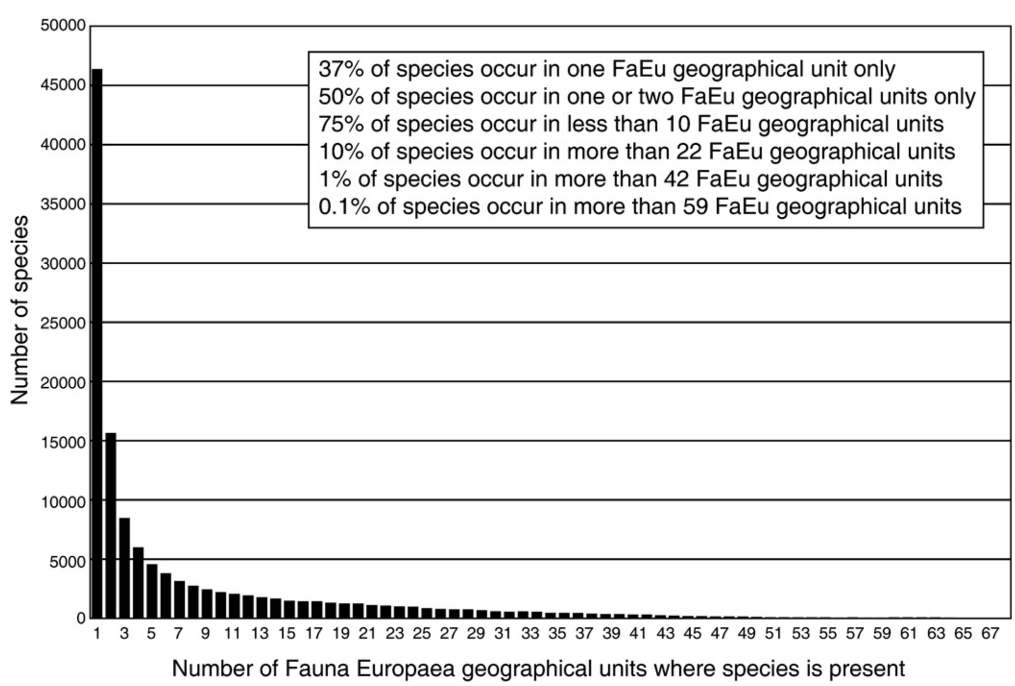

Fig. 1 – Geographical rarity: number of species present in any given number of Fauna Europaea geographical units. Based on Fauna Europaea distribution data.

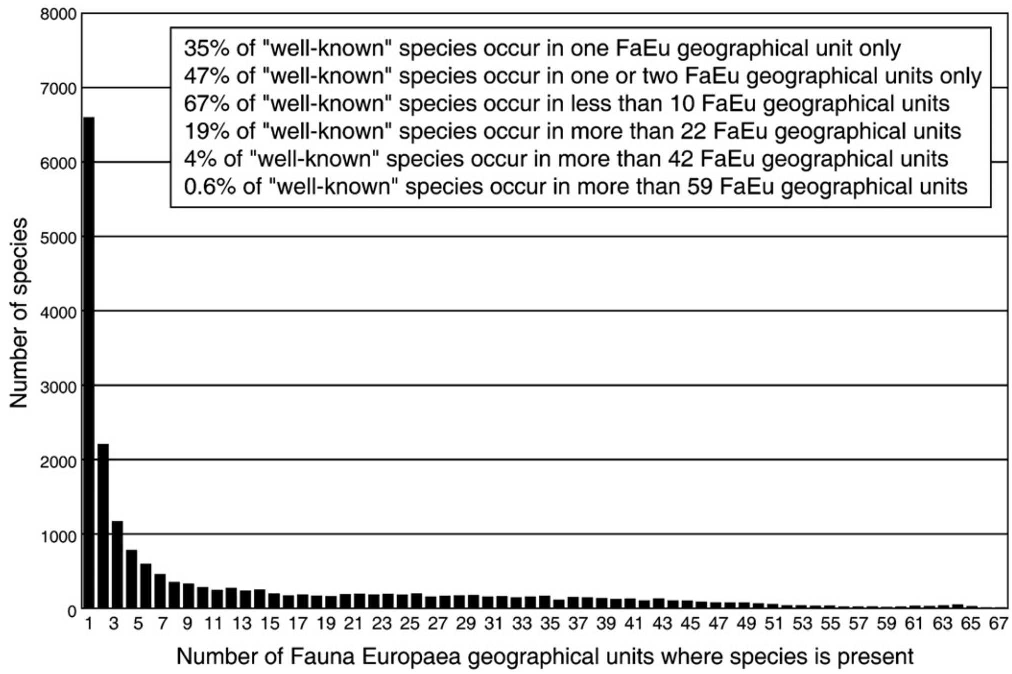

Fig. 2 – Geographical rarity: number of species present in any given number of Fauna Europaea geographical units, for the best known groups: vertebrates, Mollusca, Coleoptera Carabidae, Lepidoptera, Odonata, Orthoptera. Based on Fauna Europaea distribution data.

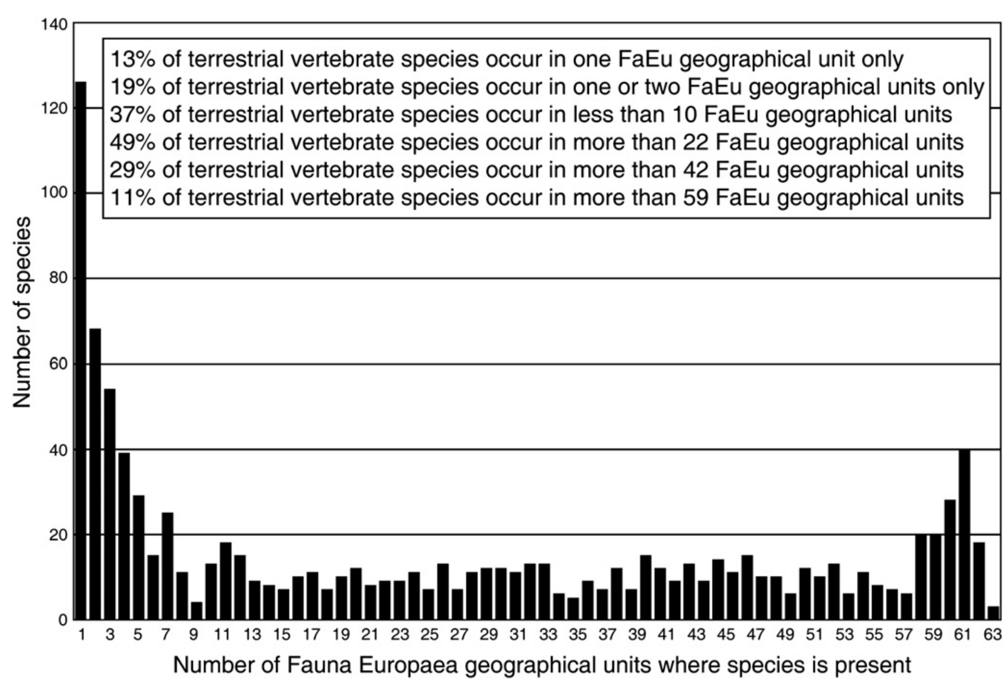

Fig. 3 – Geographical rarity: number of species present in any given number of Fauna Europaea geographical units, for vertebrates excluding fish. Based on Fauna Europaea distribution data.

to cover their total distribution range. This is a very conservative estimate, as these species occur at a few sites of occupancy, and not over all of the territorial division area: these figures must be considered as a maximum range size. For instance, 46 Collembola taxa occurring in Ariège province (Pyrénées mountains, France) are Pyrenean endemics. They are known from 1 to 19 "communes", the smallest territorial division in France, usually covering a few thousands hectares: their maximum range size is far below 10,000 km^2 (Deharveng, unpubl. data). For the 12 Collembola taxa endemic from Ariège province, this rough calculation on "commune" area gives a maximum range size varying between 5.73 km^2 and 199.90 km^2 (Fig. 4). It should be noted that the Pyrénées area is one of the best-known region in Europe for Collembola,

Table 1 – Number of endemic species in selected European islands (data extracted from Fauna Europaea database)

Island or archipelago	Number of endemic species	Area (km^2)
Madeira	956	797
Azores	278	2305
Canary Islands	3236	7272
Balearic Islands	308	5014
Corsica	552	8723
Malta	104	316
Crete	719	8313
Cyprus	917	9250

and that these taxa were specifically searched for in several localities. Even if new field searches might extend their known range, they can be considered as real local endemics, unlike other collembolan taxa which have been found in the whole region and further.

3.2. Extinct and threatened species

Table 2 shows the documented extinctions of European taxa since 1500. Among the 62 extinct taxa, 11 were wide-range taxa (including three insects, four fish, one bird and three mammals), the others being endemic to one country, or narrow-range endemics shared by two or three countries. The recorded extinctions of narrow-range taxa occurred mainly in mountain ranges (Alpine arc, Pyrenees, Balkans), and on islands (Fig. 5).

Altogether, 560 European terrestrial or freshwater species are listed as endangered (categories Critically endangered, Endangered and Vulnerable) in the 2006 IUCN Red List (IUCN, 2006). Of these, 31.1% are molluscs, 30.9% are arthropods and 38.0% are vertebrates, and 65.0% are endemic to one country (Fig. 6). Among these endemic species, 31.6% are arthropods and 44.8% are molluscs. At the other end, among threatened species with a large range (present in 21–138 countries), 79.5% are vertebrates. Geographically, threatened species are spread all over Europe (Fig. 5), the three countries having the largest number of threatened species being among the most species-rich countries in Europe (Italy, France and Spain – see http://www.faunaeur.org/statistics.php). Countries with a lower number of threatened species either are countries with a relatively low biodiversity (northern Europe) or are probably under-studied (Balkans). Even in Europe, with 560 species listed as threatened, the Red List is far from complete, as most invertebrate species have not been assessed. Moreover, it lists only 14 extinct species in Europe, when there are at least 62 (Table 2). Despite this global under-coverage, European invertebrates are "reasonably" represented in the Red List, as they account for almost two thirds of the European species listed (at a worldwide scale, invertebrates represent only 27.2% of the animal listed in the Red List (IUCN, 2006)).

3.3. Protected species

The Bird and Habitat directives give a protection status to 1140 animal species, including 986 vertebrates and 154 invertebrates (Table 3). This represents 64.8% of the vertebrates

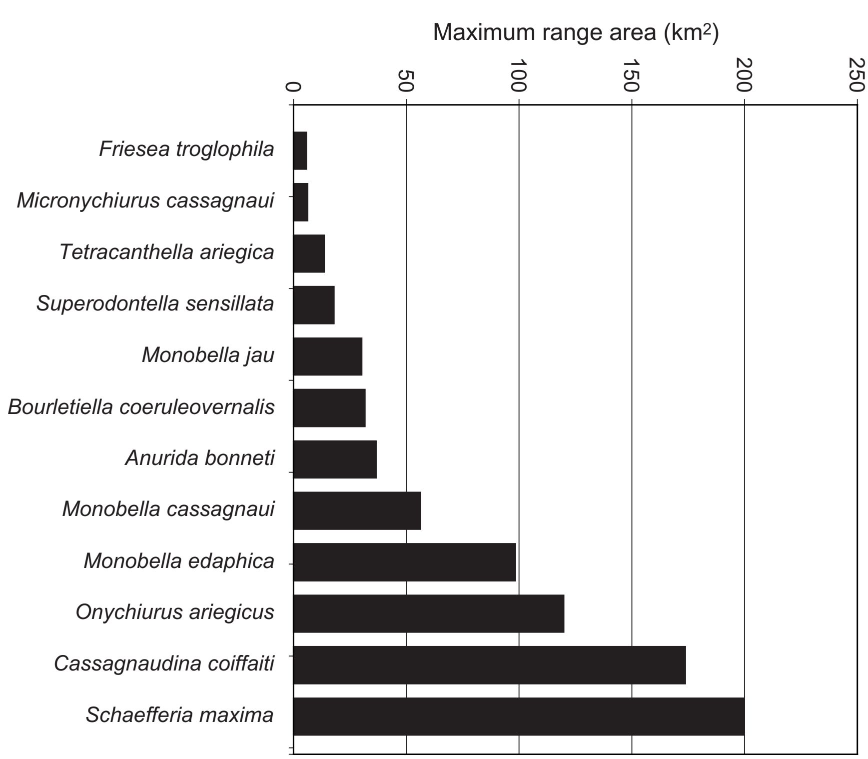

Fig. 4 – Endemic Collembola from Ariege province (France): maximum range size (km^2) given by the cumulated surface of the smallest territorial division known to cover their total distribution range (Deharveng unpubl. data).

Table 2 – European globally extinct taxa

Taxon	Group	Red List	Range	Source
Belgrandia varica (J. Paget 1854)	Gastropoda	No	France	Falkner et al. (2002)
Belgrandiella boetersi (P. Reischütz & Falkner 1998)[a]	Gastropoda	Yes	Austria	IUCN (2006)
Bythiospeum pfeifferi (Clessin 1890)[b]	Gastropoda	No	Austria	R. Bank unpub. data
Caseolus calvus galeatus (R.T. Lowe 1862)	Gastropoda	No	Madeira	R. Bank unpub. data
Discula lyelliana (R.T. Lowe 1852)	Gastropoda	No	Madeira (Deserta Grande)	R. Bank unpub. data
Discula tetrica (R.T. Lowe 1862)[c]	Gastropoda	No	Madeira (Bugio)	R. Bank unpub. data
Discus engonatus (Shuttleworth 1852)	Gastropoda	No	Canary Islands (Tenerife)	R. Bank unpub. data
Discus retextus (Shuttleworth 1852)	Gastropoda	No	Canary Islands (La Palma)	R. Bank unpub. data
Discus textilis (Shuttleworth 1852)	Gastropoda	No	Canary Islands (La Palma)	R. Bank unpub. data
Geomitra delphinuloides (R.T. Lowe 1860)[c]	Gastropoda	No	Madeira	R. Bank unpub. data
Geomitra grabhami (Wollaston 1878)	Gastropoda	No	Madeira (Deserta Grande)	R. Bank unpub. data
Graecoanatolica macedonica Radoman & Stankovic 1979	Gastropoda	Yes	Greece, Macedonia	IUCN (2006)
Gyralina hausdorfi Riedel 1990	Gastropoda	No	Greece	R. Bank unpub. data
Janulus pompylius (Shuttleworth 1852)	Gastropoda	No	Canary Islands (La Palma)	R. Bank unpub. data
Keraea garachicoensis (Wollaston 1878)	Gastropoda	No	Canary Islands (Tenerife)	R. Bank unpub. data
Leiostyla abbreviata (R.T. Lowe 1852)[c]	Gastropoda	No	Madeira	R. Bank unpub. data
Leiostyla gibba (R.T. Lowe 1852)[c]	Gastropoda	No	Madeira	R. Bank unpub. data
Leiostyla lamellosa (R.T. Lowe 1852)	Gastropoda	Yes	Madeira	IUCN (2006)
Leptaxis simia hyaena (R.T. Lowe 1852)	Gastropoda	No	Madeira (Bugio)	R. Bank unpub. data
Ohridohauffenia drimica (Radoman 1964)	Gastropoda	Yes	Lake Ohrid, Serbia and Montenegro	IUCN (2006)
Parmacella gervaisii Moquin-Tandon 1850	Gastropoda	No	France	Falkner et al. (2002)
Pseudocampylaea loweii (A. Férussac 1835)	Gastropoda	Yes	Madeira	IUCN (2006)
Zonites embolium elevatus Riedel & Mylonas 1997	Gastropoda	No	Greece (Dodecanese Islands)	R. Bank unpub. data
Zonites santoriniensis Riedel & Norris 1987	Gastropoda	No	Greece (Cyclades Islands)	R. Bank unpub. data
Zonites siphnicus Fuchs & Käufel 1936	Gastropoda	No	Greece (Cyclades Islands)	R. Bank unpub. data
Pseudoyersinia brevipennis (Yersin 1860)	Mantodea	No	France	Voisin (2003)
Anonconotus apenninigenus (Targioni-Tozzetti 1881)	Orthoptera	No	Italy	Galvagni (2004), K.G. Heller unpub. data
Oemopteryx loewii (Albarda 1889)	Plecoptera	No	Austria, Bulgaria, Czech Republic, Germany, Hungary, Netherlands, Poland, Slovakia, Ukraine	Zwick (2004)
Taeniopteryx araneoides Klapálek 1902	Plecoptera	No	Czech Republic, Germany, Hungary, Slovakia	Zwick (2004)
Hydraena sappho Janssens 1965	Coleoptera	No	Greece	Audisio et al. (1996)
Meligethes salvan Audisio et al. (2003)	Coleoptera	No	Italy	Audisio et al. (2003), P. Audisio unpub. data
Siettitia balsetensis Abeille de Perrin 1904	Coleoptera	Yes	France	IUCN (2006)
Hydropsyche tobiasi Malicky 1977	Trichoptera	Yes	Germany	IUCN (2006)
Pieris brassicae wollastoni (Butler 1886)	Lepidoptera	No	Madeira	O. Karsholt unpub. data
Thyreophora cynophila (Panzer 1798)	Diptera	No	France, Germany, Switzerland	Séguy (1950), Menier (2002)
Squalius ukliva Heckel 1843[d]	Pisces	Yes	Croatia	IUCN (2006)
Coregonus bezola Fatio 1888	Pisces	No	Lake Bourget (France)	Kottelat (1997)
Coregonus confusus Fatio 1885	Pisces	No	Lake Morat (Switzerland)	Kottelat (1997)
Coregonus fera Jurine 1825	Pisces	No	Lake Geneva (France, Switzerland)	Kottelat (1997)
Coregonus gutturosus (Gmelin 1818)	Pisces	No	Lake Konstanz (Austria, Germany, Switzerland)	Kottelat (1997)
Coregonus hiemalis Jurine 1825	Pisces	No	Lake Geneva (France, Switzerland)	Kottelat (1997)
Coregonus hoferi Berg 1932	Pisces	No	Lake Chiemsee (Germany)	M. Kottelat, unpub. data
Coregonus oxyrinchus (Linnaeus 1758)	Pisces	No	North Sea Basin	Freyhof and Schöter (2005)
Coregonus restrictus Fatio 1885	Pisces	No	Lake Morat (Switzerland)	Kottelat (1997)

(*continued on next page*)

Table 2 – *continued*

Taxon	Group	Red List	Range	Source
Eudontomyzon (?)sp.	Pisces	No	Ukraine, Russian Federation	Kottelat et al. (2005)
Gasterosteus crenobiontus Bacescu & Mayer 1956	Pisces	No	Romania	Kottelat (1997)
Knipowitschia cameliae Nalbant & Otel 1995	Pisces	No	Romania	Nalbant and Otel (1995)
Romanogobio antipai (Banarescu, 1953)	Pisces	No	Romania, mouth of River Danube	Banarescu (1994)
Salmo schiefermuelleri Bloch 1784	Pisces	No	Baltic Sea, Austria, Hungary	Kottelat (1997)
Salvelinus neocomensis Freyhof & Kottelat 2005	Pisces	No	Lake Neuchatel (Switzerland)	Freyhof and Kottelat (2005)
Salvelinus profundus (Schillinger 1901)	Pisces	No	Lake Konstanz (Austria, Germany, Switzerland)	Kottelat (1997)
Stenodus leucichthys (Güldenstädt 1772)[e]	Pisces	No	Caspian Sea Basin	M. Kottelat, unpub. data
Gallotia auaritae Mateo, García Márquez, López Jurado & Barahona, 2001[f]	Reptilia	Yes	Canary Islands	IUCN (2006)
Haematopus meadewaldoi Bannerman 1913	Aves	Yes	Canary Islands	IUCN (2006)
Pinguinus impennis (Linnaeus 1758)	Aves	Yes	Iceland, Ireland, United Kingdom, Denmark	IUCN (2006)
Saxicola dacotiae murielae Bannerman, 1913	Aves	No	Canary Islands	Fuller (1987)
Capra pyrenaica lusitanica Schlegel 1872	Mammalia	No	Portugal, Spain	Fauna Europaea
Capra pyrenaica pyrenaica Schinz 1838	Mammalia	Yes	Spain	IUCN (2006)
Bison bonasus hungarorum Kretzoi 1946	Mammalia	No	Hungary, Romania, Slovakia, Ukraine	Pucek et al. (2004)
Bos primigenius Bojanus 1827	Mammalia	No	Most of Europe	Fauna Europaea
Equus ferus Boddaert 1785[g]	Mammalia	Yes	Poland, Germany, Lithuania, Belarus, Russian Federation, Ukraine	IUCN (2006)
Prolagus sardus (Wagner 1832)	Mammalia	Yes	Corsica, Sardinia	IUCN (2006)

The column "Red List" indicates whether the taxon is listed as extinct in the IUCN Red List.

Note: The 2006 IUCN Red List lists *Bythinella intermedia* Mahler 1950 (Gastropoda) as extinct. However, this is a synonym of *Bythinella austriaca* (Frauenfeld 1857), which is not extinct (http://www.faunaeur.org/full_results.php?id=269218). It also lists *Telestes turskyi* (Heckel 1843) as extinct, but M. Kottelat (pers. comm.) considers it as still extant, though critically endangered, and did not list it as extinct in his 1997 checklist (Kottelat, 1997); this species is considered as an insufficiently documented to be classified as extinct by Harrison and Stiassny (1999). *Chondrostoma scodrense* Elvira 1987, said to be extinct (Crivelli and Rosecci 1994 in Kottelat, 1997), is probably still extant (M. Kottelat pers. comm.). These taxa were not included in the present table.

a Listed as *Belgrandiella intermedia* in the Red list. We follow here Fauna Europaea.
b Listed as Endangered in the Red List.
c Listed as Critically Endangered in the Red List.
d Listed as *Telestes ukliva* in the Red list. We follow here Fauna Europaea.
e Apparently extinct in the wild, the only breeding populations are captive.
f This taxon is not included in Fauna Europaea, as it was originally described as a subspecies of *Gallotia simonyi*, but was elevated at species level in 2003 (Afonso and Mateo, 2003).
g Extinct in the wild but still survives in captivity.

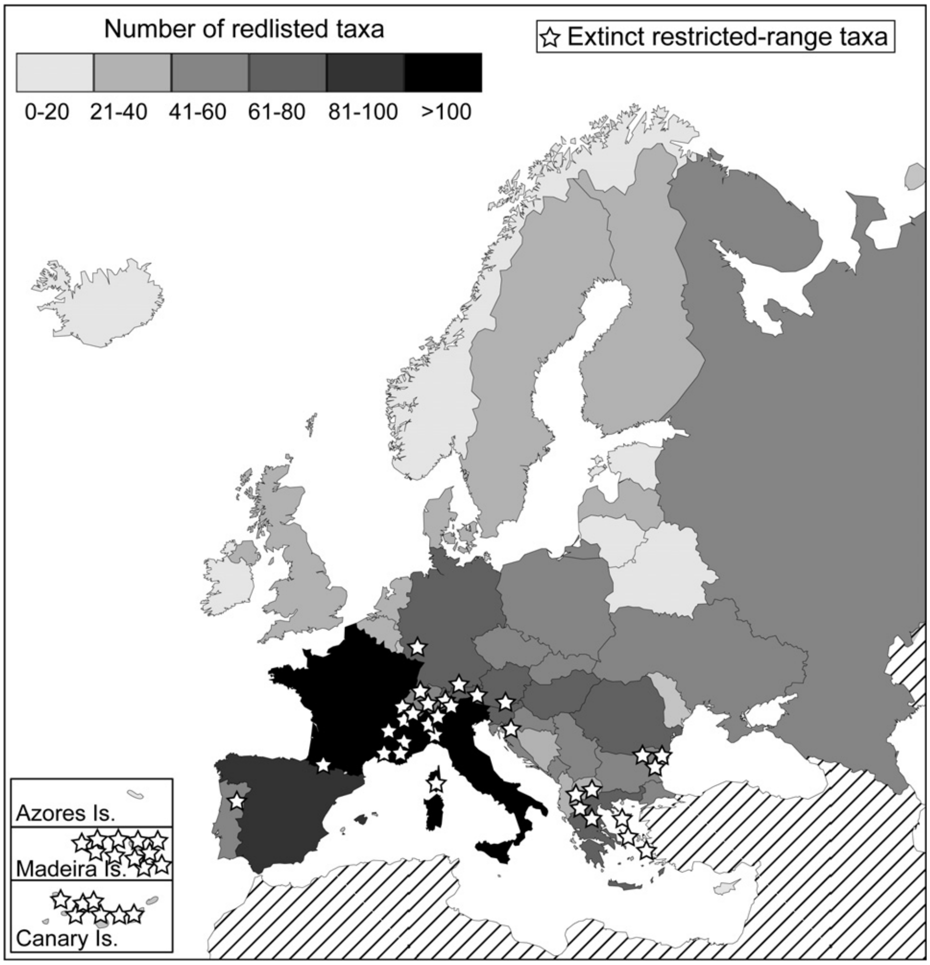

Fig. 5 – Distribution of extinct and threatened (critically endangered, endangered and vulnerable) species in Europe (data extracted from the 2006 IUCN Red List). Species present in more than one country are counted for each of these countries. Stars indicate the approximate location of narrow-range globally extinct taxa.

and 0.1% of the invertebrates present in Europe. Among protected invertebrates, 24% are Mollusca, 30% are Lepidoptera, and 23% are Coleoptera.

Out of the 560 European Red Listed non-marine species, 397 are not included in the directives (306 invertebrates and 91 vertebrates). On the other hand, 977 taxa are protected by the directives but are not Red Listed (864 vertebrates and 113 invertebrates) and 163 taxa are Red Listed and protected, i.e. 122 vertebrates and 41 invertebrates (Fig. 7). Three extinct invertebrates (the gastropods *Leiostyla lamellosa*, *L. gibba* and *L. abbreviata*) are listed in Appendix II of the Habitat Directive.

Two subspecies of Lepidoptera (*Gortyna borelii lunata* and *Hesperia comma catena*) and one mammal subspecies (*Cervus elaphus corsicanus*) are listed in the directives but not in Fauna Europaea. Even if their taxonomic validity is debatable, they represent small populations, and the governmental advisors have considered that they have a conservation value (Bouchet, 2006).

Fig. 8 presents the extent of occurrence of taxa listed in the directives. It does not follow the same abundance-rank pattern as in Figs. 1 and 2: a large proportion (11%) of protected taxa are endemic to one Fauna Europaea geographical unit, but a similar proportion (12%) of the protected taxa has a large range, i.e. occurring in more than 58 Fauna Europaea geographical units. All these wide-range taxa are birds. Among protected taxa endemic to one Fauna Europaea geographical unit, 25% are invertebrates.

4. Discussion

The Fauna Europaea dataset shows that a high proportion of the European species are single country endemics. Narrow-range species are especially vulnerable and a significant proportion of documented extinctions in Europe were of taxa with a restricted range. Rarity, and particularly geographical rarity, should then be considered when choosing indicator species for the 2010 target.

4.1. *Geographical rarity*

Geographical rarity (extent of occurrence) cannot be defined the same way for all species. In its assessment of the threat status of the birds of the world (Birdlife International, 2000), as well as in the prioritization of conservation areas (Stattersfield et al., 1998), Birdlife defines an endemic bird as a species whose range is below 50,000 km^2, i.e. an area larger than

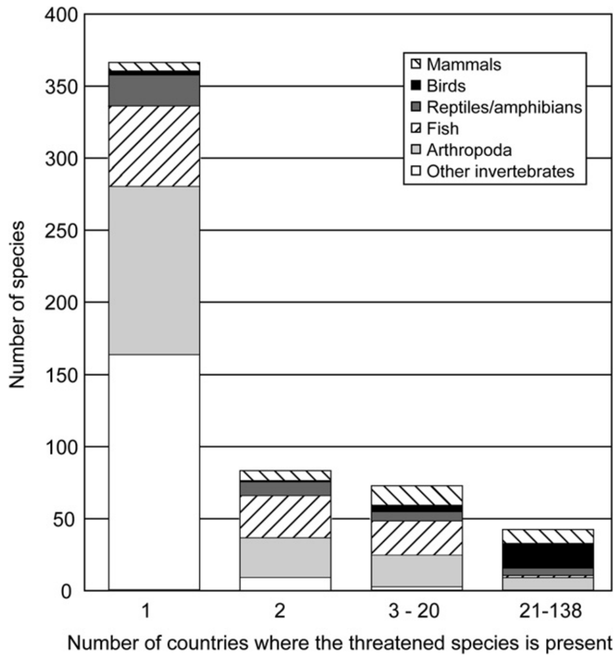

Fig. 6 – European species listed as threatened (critically endangered, endangered and vulnerable) in the 2005 IUCN Red List and the number of countries where they occur (distribution data as given in the IUCN Red List).

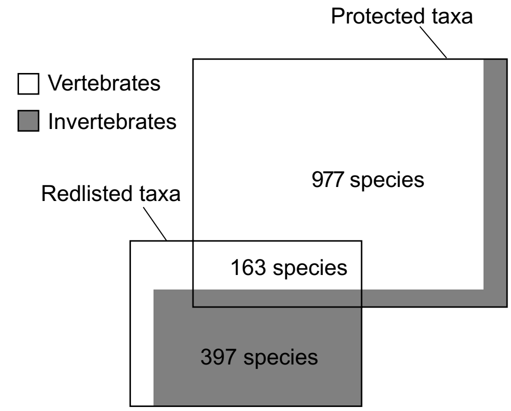

Fig. 7 – Protected species (Bird and Habitat Directives) and Red Listed species in Europe.

Table 3 – Species listed in the Bird Directive and Habitat Directive

Group	No. of species listed in directives	% of the European fauna
Mammals	95	37.4
Birds	533	100
Reptiles	82	53.2
Amphibians	51	66.2
Fish	225	44.8
Lepidoptera	46	0.5
Coleoptera	36	0.1
Other insecta	28	0.05
Mollusca	37	1.2
Other invertebrates	7	0.02
All vertebrates	986	64.8
All invertebrates	154	0.1

Slovakia. This threshold has proven useful for large species such as birds and practical for conservation policies, but it is at least one order of magnitude too large to mark endemism in invertebrates, as shown by the data on Collembola. Patterns of distribution with very small ranges are probably common among invertebrates: at a worldwide scale, Solem (1984) predicted a median range of less than 100 km^2 for all land snail species, and probably less than 50 km^2. With a threshold of 10,000 km^2, Harvey (2002) found that narrow-range endemism was widespread among several groups of Australian invertebrates, and was restricted to taxa with low vagility, highly seasonal life cycles, and restricted habitat usage.

Beside Collembola, many examples of narrow-range endemism are known from the European fauna. Narrow-range endemic species occur in many lakes (Kottelat, 1997; WCMC, 1998) as well as within terrestrial species (e.g. Lumaret et al., 1996). In particular, cave species are well-known to have a very high level of endemism, often being restricted to few caves in the same area (Mauries, 1986; Deharveng and Thibaud, 1989; Heurtault, 1994).

European globally extinct taxa give an insight into the vulnerability of narrow-range taxa. For instance, the gastropod *Belgrandia varica* was endemic to the floodplains of the Var estuary in southern France. This area has drastically changed during the 20th century, due to urbanisation, and the species has never been found since 1910, despite targeted searches, and is considered extinct (Falkner et al., 2002). Based on a specimen collected in 1912, the beetle *Meligethes salvan* was described from a small basin in the Italian Alps. The area was almost entirely destroyed by works associated with a hydroelectric power plant in the 1970s, and despite several attempts, no new specimen of this species has ever been found (Audisio et al., 2003). Another example is *Romanichthys valsanicola*, a fish that was restricted to the upper reaches of Arges, Vilsan and Doamnei rivers in Romania. In 1992, it was only found on 1 km of the Vilsan river, due to habitat degradation and water pollution; it might be extinct today (Perrin et al., 1993).

There are far too few experts on many invertebrate groups to obtain a comprehensive picture of extinctions. Most invertebrate extinctions are likely to be overlooked (Centinelan extinctions *sensu* Wilson (1992)) even in well-studied areas such as Europe, mainly because of a lack of knowledge and monitoring of these taxa (Dunn, 2005). The beetle *Meligethes salvan* was believed to be extinct ca. 40 years after its possible extinction (Audisio et al., 2003), and the beetle *Hydraena sappho* was declared extinct some 25–30 years after its actual extinction (Audisio et al., 1996). Moreover, the Mediterranean region is a centre of endemism (Myers et al., 2000), but has experienced serious degradations due to urbanisation, altered fire regimes and agriculture: in Europe, it is probably an area where Centinelan extinctions have occurred. For these reasons, the 62 extinct taxa for Europe presented in Table 2 are probably an underestimate. Even when the extinction is confirmed by the experts, the information is still often ignored to the wider community: 48 extinct European taxa, including 28

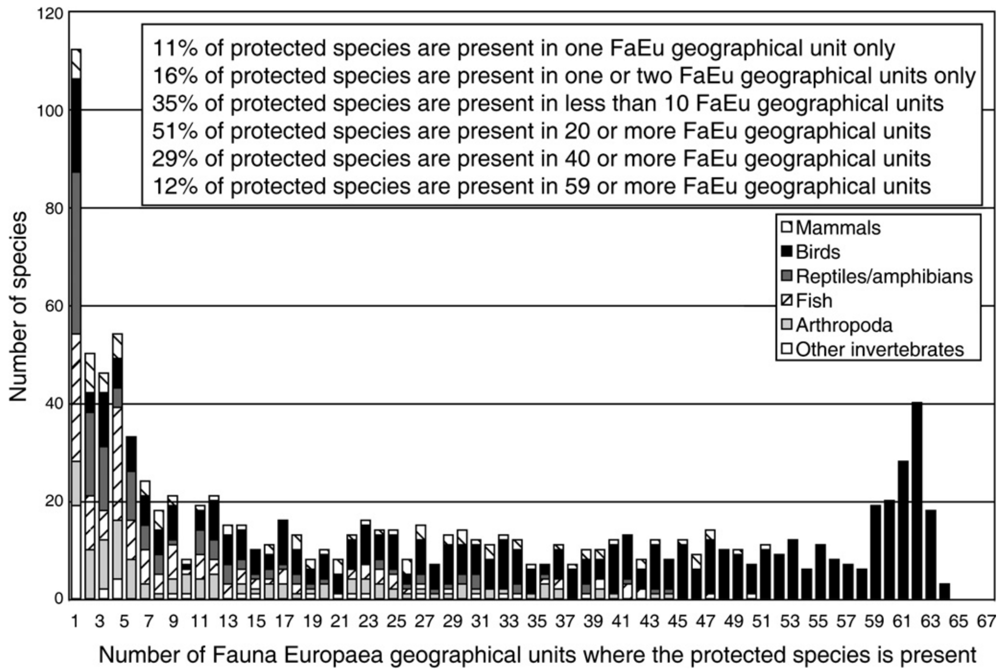

Fig. 8 – Number of protected species (Bird and Habitat Directives) present in any given number of Fauna Europaea geographical units.

invertebrates, are not included in the Red List (Table 2). Despite this incomplete image of extinctions, the list of European extinct taxa shows that geographically rare taxa are by far the most at risk of extinction (51 extinct taxa out of 62 had a restricted range). There could be a bias there, as it is easier to assess extinction of a narrow-range species than of a demographically rare species with a large range. However, it does not undermine the fact that geographically rare species must be prioritized for the assessment of the 2010 target.

In order to be representative of the European fauna, the subset of European species captured by the 2010 target indicators should include a statistically significant proportion of narrow-range species. Popular groups such as butterflies, dragonflies, bumblebees, hoverflies and ants should be investigated for use as potential indicators (Thomas, 2005). Cave species should also be represented in the indicators, as most of them are local endemics. We emphasize that as many taxonomic groups as possible should be represented, taking into account geographical rarity.

4.2. *Ecological rarity*

Among the extinct taxa in Europe (Table 2), three insects ranged over large areas, covering several countries, but had strict ecological requirements. Two species of Plecoptera were associated with large lowland rivers where suitable habitats have been fragmented and eventually destroyed by human activities (Zwick, 1992). The third species, the Diptera *Thyreophora cynophila*, was found exclusively on large mammal carcasses until the mid 1800s (Séguy, 1950). It is suspected that the extinction of this species could be due to changes in livestock management and improved carrion disposal following the Industrial Revolution in Europe. On a longer time scale, however, its extinction is likely to have been caused by the impoverishment of the megafauna – in Europe, there are now too few large predators that leave large carcasses. Another well-known example of a species threatened because of its ecological requirements is the leather beetle *Osmoderma eremita*, which resides in hollow deciduous trees and is classified as Vulnerable by the IUCN Red List. With modern forestry practices, hollow trees are seldom left standing, and the leather beetle is becoming rarer over most of its range (Ranius et al., 2005).

The information collected by Fauna Europaea does not include species' ecological requirements, so we cannot assess the extent of ecological rarity in Europe. There are tight relationships between species and their habitats, and some species can be highly restricted in their requirements, a characteristic that increases their vulnerability because a single change in the habitat can have devastating effects on such species. The extreme case of habitat specialization is shown by host-specific species, and in particular parasitic species. No documented case of parasite extinction exists in Europe, but some parasitic species are known to be threatened because of their host being itself threatened (Stork and Lyal, 1993), and there are examples outside Europe of host-specific parasite species which became extinct after the extinction of their host (Mey, 2005). In Europe, extinct mammals and birds most probably had host-specific lice (Phthiraptera), which went extinct with their host. In particular, the great auk *Pinguinus impennis* must have had lice of the genus *Austromenopon*, *Mjoberginirmus* and *Saemundssonia*, as Alcidae regularly host these genera, with host-specific species (Price et al., 2003).

Accurate data on the proportion of host-specific species in insect communities are scarce. It varies among taxonomic groups and ecosystems, between 5% of the phytophagous beetle species being monophagous in a tropical rainforest (Basset et al., 1996), and 90% of aphid species being highly host-specific (Dixon et al., 1987). Even with these somewhat imprecise figures on proportions of host specific species, their number in Europe reaches the thousands: taking the lowest figure given in the above references as a conservative estimate of host-specific species, i.e. 5%, there would be at least 4600 host-specific species among the ca. 93,000 European insects, and certainly much more when parasitoid species are considered. Host-specific species representing the extreme case of ecological specialization, many more species can be considered as having strict ecological requirements. The 2010 target indicators should then include ecologically rare species. Special attention should be given to freshwater species which are known to be, on average, at higher risk of extinction than terrestrial ones (Revenga et al., 2005), and to cave species, which usually receive little attention in conservation strategies.

4.3. *Demographic rarity*

Species demonstrating demographic rarity are typically represented by large vertebrate predators, which occur naturally at low density (e.g. Slough and Mowat, 1996; Penteriani et al., 2002). Because of their low densities, these species can easily be eradicated from an area when they are hunted (Breitenmoser, 1998). This is the main form of rarity already represented in the indicators and in legal texts, with large vertebrates. However, invertebrates can experience demographic rarity as well, as is shown in the Red List where two thirds of the European species listed on demographic criteria are invertebrates (237 species). These invertebrate species Red Listed on demographic criteria could be a starting point for the selection of demographically rare species for the 2010 target indicators.

5. Conclusion

Our aim while writing this paper was to highlight that current indicators do not cover the species most at risk of extinction: currently, most categories of rare species are not in focus for the assessment of progress toward the 2010 target. Existing indicators deliver important informations on biodiversity trends (Julliard et al., 2004; Butchart et al., 2005; De Heer et al., 2005), but there is a need to develop alternative indicators dealing with rare species, which would complement informations already existing with a focus on the most threatened species. Funding is scarce and we are running out of time if the assessment of the progress towards the 2010 target is to be made before 2010, but assessing the success (or the failure) of the 2010 biodiversity target requires that the indicators cover a representative subsample of biodiversity (Balmford et al., 2005), with common and rare species. However, the main practical reason for choosing a species as indicator is the availability and quality of data attached to this species: birds are overrepresented in the various indices because they constitute the best known taxonomic group, with updated data gathered by thousands of people all over the world. Except for birds and a few other groups (large mammals, butterflies) or a scattering of individual species that are not necessarily representative of the whole European fauna, data on abundance, distribution and conservation status are difficult to find for most species. Indeed, the main argument against using rare species in indicators is their practical usefulness, i.e. data availability.

We did not address the issue of the composition of the alternative indicator, which would need at least another paper, but we give below some elements in this respect. The choice of indicator species needs a rigorous evaluation based on several parameters, including rarity. Ideally, a subsample of the European biodiversity to be used as indicators would be a set of species randomly picked from the European fauna. It should be stratified according to realms, biomes, ecosystems and taxonomic groups (Butchart et al., 2005). In any case, the indicator should avoid taxonomic bias, i.e. not over-represent vertebrates. Composite indices (e.g. Butchart et al., 2004; De Heer et al., 2005; Loh et al., 2005; Maes and Van Dyck, 2005) should be used, and the stratification should take into account the different forms of rarity, which appear to be a major characteristic of biodiversity.

When data are missing, targeted species should be chosen for monitoring, and the data that do not exist yet have to be gathered for this purpose. Choosing these target species must be done by specialists, i.e. taxonomists, who have the best available knowledge on ranges, vulnerability and ecological preferences of rare species. Data on the extent of distribution should be used when available; if not, a surrogate is given by Fauna Europaea distribution data. A threshold on the extent of range could be used to define geographically rare species to be used as indicators. Although there is no comprehensive database on species ecological needs, information about ecology, e.g. host plant preference of phytophagous insects, are documented for a large number of species, and these should be used when selecting ecologically rare species. Ecologically rare species could also be randomly picked in groups known to include species with strict ecological requirements (e.g. aquatic arthropods, old-growth forest dwellers, large carnivore parasites, cave species).

This data gathering will have a financial cost, since rare species, usually narrow-range invertebrates, need to be surveyed by specialists who know how to find and identify them. Current indicators (mainly birds, mammals, butterflies) have the advantage that they do not need highly specialized people to be monitored. However, as they tend to be wide-range species, they need to be surveyed by a large number of people for the data to be reliable (a large number of days/person is necessary). On the contrary, endemics, which need qualified people, can be surveyed with a much smaller number of days/person, as they have short ranges. They are then comparatively cheaper to survey than wide-range ones.

The most well-known species, terrestrial vertebrates and butterflies (1523 species in Europe) constitute the bulk of current indicator species (e.g. Butchart et al., 2004; De Heer et al., 2005; Loh et al., 2005). The overlap between these and the 560 Red Listed European taxa is small, 98 species only being both Red Listed and indicator: this represents 6.4% of the indicator species being considered as threatened by the IUCN. Similar results about the low overlapping between Red Listed and indicator species have been found for cryptogams (Paltto et al., 2006). On the other hand, ca. half of these 1523 indicator species are protected by the European directives: indicator species (i.e. terrestrial vertebrates and butterflies) are more representative of protected species than of threatened species. With the indicators currently chosen, we could loose a significant number of species by 2010 and all these extinctions could go unnoticed. It is therefore essential to add new indicators or change the target.

6. Author contributions

B. Fontaine and P. Bouchet contributed to the ideas and methodology developed in this paper. B. Fontaine analyzed the data and wrote the paper. O. Gargominy designed the database used to handle the data. W. Bogdanowicz, P. Bouchet, H. Enghoff, D. Goujet, and W. Los, as members of the management team, lead the Fauna Europaea project. G. Boxshall, A. Minelli, and M. Ramos were members of the Fauna Europaea taxonomic advisory group. Y. de Jong, V. Michelsen, N. Bailly, P. Chylarecki, from the Fauna Europaea Project Bureau, collated the taxonomic and geographical information from the Group Coordinators. K. van Achterberg, M.A. Alonso-Zarazaga, R. Araujo, U. Aspöck, P. Audisio, B. Aukema, N. Bailly, M. Balsamo, R.A. Bank, P. Barnard, C. Belfiore, W. Bogdanowicz, T. Bongers, G. Boxshall, D. Burckhardt, J.-L. Camicas, P. Crucitti, L. Deharveng, A. Dubois, H. Enghoff, A. Faubel, R. Fochetti, D. Gibson, R. Gibson, M.S. Gómez López, M.S. Harvey, K.-G. Heller, P. van Helsdingen, H. Hoch, H. de Jong, O. Karsholt, L. Lundqvist, W. Magowski, R. Manconi, J. Martens, J.A. Massard, G. Massard-Geimer, S.J. McInnes, V. Michelsen, L.F. Mendes, E. Mey, A. Minelli, C. Nielsen, J.M. Nieto Nafría, E.J. van Nieukerken, J. Noyes, T. Pape, H. Pohl, W. De Prins, C. Ricci, C. Roselaar, E. Rota, A. Schmidt-Rhaesa, H. Segers, R. zur Strassen, A. Szeptycki, J.-M. Thibaud, A. Thomas, T. Timm, J. van Tol, W. Vervoort, R. Willmann, as Group Coordinators, collated the data on their respective groups (see details on http://www.faunaeur.org/experts.php). M. Asche collated the data on Hemiptera Fulgoromorpha and Cicadomorpha.

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