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Literature Review

The ecological effectiveness of the Natura 2000 Network

McKenna Davis, Sandra Naumann,
Keighley McFarland, Andreas Graf and Doug Evans

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Authors' affiliation:

McKenna Davis, Ecologic Institute (DE)
Sandra Naumann, Ecologic Institute (DE)
Keighley McFarland, Ecologic Institute (DE)
Andreas Graf, Ecologic Institute (DE)
Doug Evans, Scottish Natural Heritage (UK), seconded to ETC/BD

EEA project manager:

Carlos Romao

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European Topic Centre on Biological Diversity
c/o Muséum national d'Histoire naturelle
57 rue Cuvier
75231 Paris cedex, France
Phone: + 33 1 40 79 38 70
E-mail: etc.biodiversity@mnhn.fr

Website: http://bd.eionet.europa.eu/

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1 Introduction

1.1 Aim and scope

The focus of the literature review[1] is on the following questions:

- What do Natura 2000 sites deliver in terms of ecological effectiveness?
- Which factors exert the most influence regarding levels of effectiveness?

By identifying, reviewing, and analyzing relevant literature, the aim is to check for available evidence underpinning these questions, draw conclusions, and highlight important messages. More specifically, data (status and trends) relevant to the analysis includes: the number and distribution of species, species diversity, conservation status of habitats, type and magnitude of existing pressures and threats, coverage of target/non-target species, and land cover changes with regards to ecosystems and habitats. Studies that allow for a comparison between Natura 2000 sites and areas outside the Natura 2000 network would also be highly relevant and could complement the analysis carried out in the technical report.

The results of this literature review will not only provide additional information for the Technical Report on Art. 12 and 17 (2007 – 2012) which will be based on the Member States' (MS) data, but will also contribute to the ongoing Fitness Check of EU nature legislation in the context of the European Commission's Regulatory Fitness and Performance Programme. The aim of this Fitness Check[2] is to assess whether the Habitats and Birds Directives are 'fit for purpose'.

1.2 Methodology

A web-based search of scientific literature (via different university libraries, SCOPUS, ScienceDirect and Google Scholar) and grey literature (via a general web search and Google Scholar) has been conducted, utilizing combinations of the following terms: "Natura 2000", "gap analysis", "effectiveness", "conservation status", "protected species", "protected areas", "habitats directive", "birds directive", and "biodiversity protection". An initial emphasis was placed on literature directly referencing Natura 2000, but the search later expanded to include relevant articles discussing 'protected areas' and their role in protecting targeted species/habitats or biodiversity. Additional references include relevant sources used in the EEA (2012a) report on protected areas and literature gathered through work at the ETC/BD and EEA. In accordance with guidance provided by the ETC/BD core team and the EEA, the literature collection focused on articles published after 2006 and which were available before end of October 2014.

Several potential limitations to this approach are acknowledged. As the search was only conducted in English, further sources in other European languages have not been included (aside from relevant articles written in German that came up during the English search). Furthermore, there was a lack of targeted searches for publications on marine protected areas that are listed under "OSPAR", "HELCOM", etc rather than "Natura 2000", perhaps resulting in an under-representation of this ecosystem/environment. Finally, the scope of search terms utilized may have excluded further articles of relevance which did not directly refer to Natura 2000 or protected areas, but which could have been relevant for this review.

[1] The starting point for the literature review is the results presented in the EEA (2012) report on protected areas. In this report, different research topics related to the Natura 2000 network are derived from literature and grouped into the following five categories: gap analysis and other assessment, surveys and monitoring, adapting to environmental change, implementation, and management (EEA 2012a: 72-73). Moreover, results from the assessment of protected areas carried out in various research projects are presented (EEA 2012a: 126-128).

[2] http://ec.europa.eu/environment/nature/legislation/fitness_check/

In order to allow for a systematic and efficient analysis of this wide sample of sources, a spreadsheet (xls-file) has been created, seeking to briefly describe the sources (content, results) and to categorize the sources. The following parameters were recorded:

- Author
- Citation (author, year of publication, title and journal)
- Year of publication
- Members State(s) involved
- Region covered (e.g. Mediterranean, southern Europe, central Europe)
- Habitat/Species addressed
- Topics addressed, including inter alia:
  - Species habitats/species assessment
  - Policy and planning (including implementation)
  - Assessment methods
  - Climate change
  - Land use change
  - Other
- Content/focus of the article
- Results presented
- Recommendations derived from the article
- Notes – Comments on the nature and results of the article to briefly summarize the content and/or relevance

A pragmatic approach was applied to filter and select the articles for an in-depth analysis and the articles were categorized based on their *level of relevance* to the key questions listed in 1.1. A ranking of level 1- 3 was assigned according to the expert judgement of the authors, correlating to:

- Level 1: direct link to the key questions e.g. studies on habitat and species assessment in Natura 2000 areas, general analysis of the effectiveness of policy implementation and planning in protected areas;
- Level 2: no direct link to the ecological effectiveness supported by Natura 2000, general evaluation of Natura 2000 implementation, studies on the application of GIS methods etc.;
- Level 3: Not relevant e.g. strong focus on testing methodologies and models or not enough information available.

Of the 142 publications identified, 62 %, 28 % and 10 % were identified as being priority levels 1, 2 and 3 respectively. For the purposes of this review, only priority level 1 and 2 studies were included in the following analysis. Figure 1 shows the distribution of the 128 priority level 1 and 2 studies across topics. Although some studies dealt with cross cutting issues, such as site and management planning recommendations based on gap analysis data, they were grouped according to the study's most dominant topic.

Of the priority level 1 and 2 studies, 27 % had a focus on particular habitats or habitat groups (e.g. forests, wetlands), and 41 % had a focus on particular species or groups of species.

Figure 1: Distribution of priority level 1 and 2 studies across topics

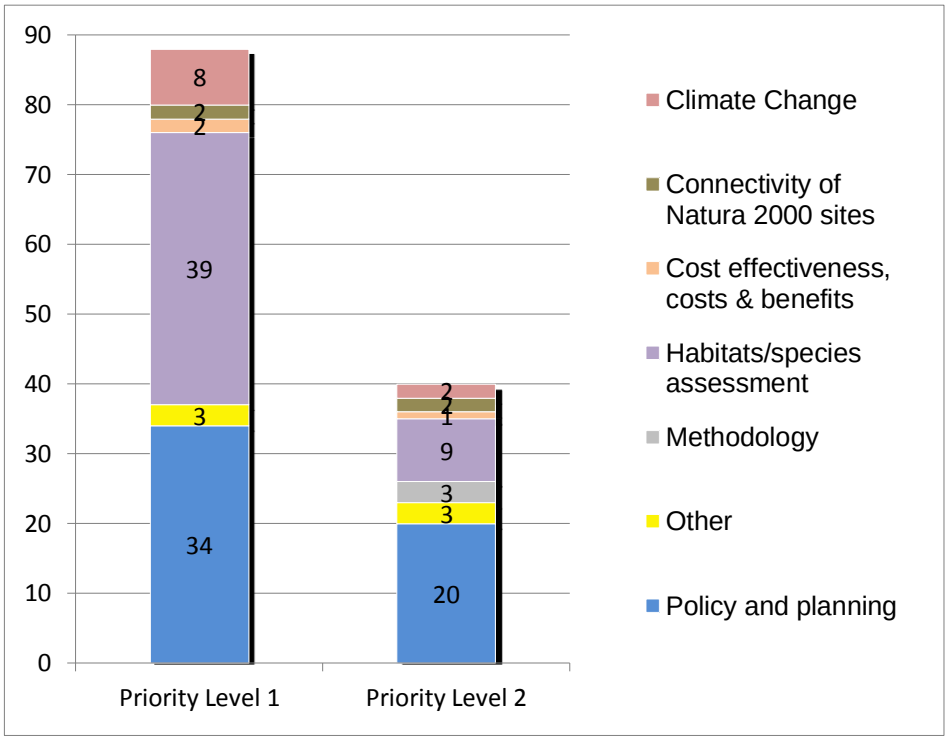
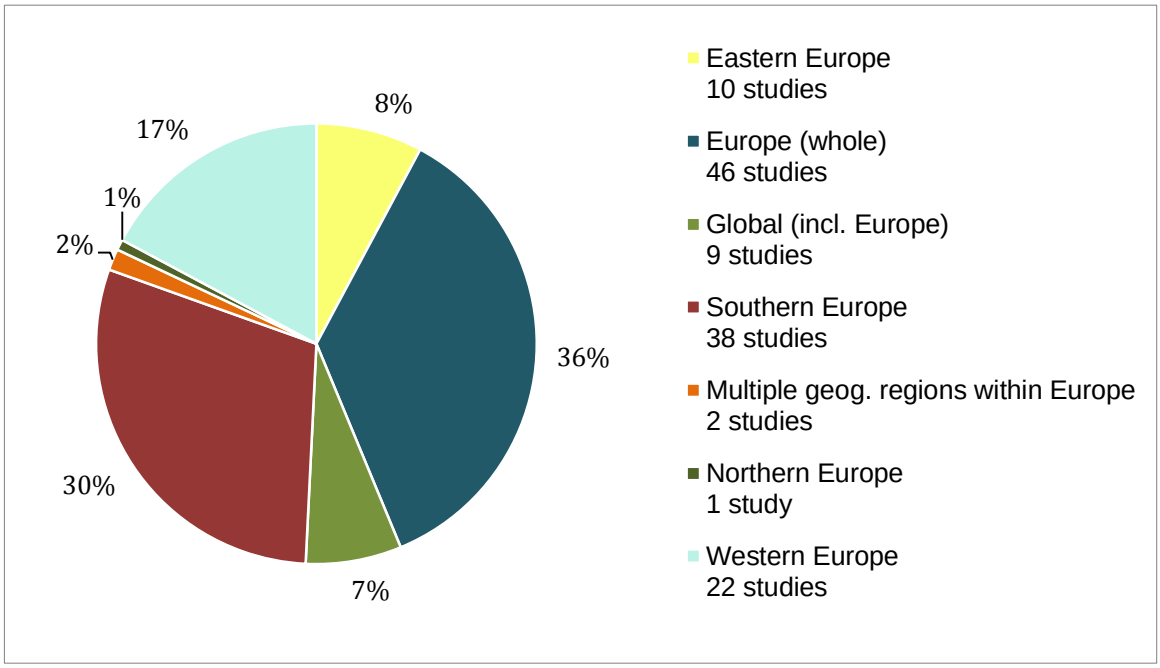


Figure 2 shows the geographical distribution of priority level 1 and 2 studies, including the number of studies in each area. Just over a third of the studies looked at Europe as a whole. 57 % of the studies concentrated on a specific area or Member State within Europe, the largest portion of which focused on the Southern European area. Spain was the MS that appeared in the most studies (15), followed by Italy (10). Only one study was concerned with Northern Europe, which focused on Denmark.

Figure 2: Geographical distribution of priority level 1 and 2 studies



The following Member States were specifically covered in the literature[3]:

- Western Europe: Austria, Belgium, France, Germany, the Netherlands
- Eastern Europe: Czech Republic, Poland, Romania
- Northern Europe: Denmark, United Kingdom
- Southern Europe: Greece, Italy, Slovenia, Spain, Portugal
- Multiple geographic regions within Europe: This includes two studies that concerned separate geographical regions but not the whole of Europe (Wätzold et al. 2010 covering Finland, Germany, Poland, and the Netherlands; Opermanis et al. 2013 covering Austria, Germany, Spain, and Portugal)

Other Member States not investigated specifically in the studies were taken into consideration in larger geographical scale studies in the groups Europe (whole) and Global (including Europe). Though not accounted for in the geographical categorization, most of the studies in France concentrated on Southern France and the French Mediterranean coast.

1.3 Definition and approach to assessing 'ecological effectiveness'

In discussing the ecological effectiveness of the Natura 2000 network/site and protected areas/ protected area systems (PA), the literature distinguishes two main approaches: '*gap analysis*' and '*conservation status*'. The clear division between these terms within the reviewed studies represents an initial finding in itself, and also provides a useful framework for presenting article results. Accordingly, both approaches are first defined in detail below (see Table 1 for an overview) and used to frame the subsequent analysis (see Chapter 2).

[3] These countries have been grouped according to the United Nations "Classification of countries by major area and region of the world" (see http://esa.un.org/unpd/wup/CD-ROM_2009/WPP2009_DEFINITION_OF_MAJOR_AREAS_AND_REGIONS.pdf).

Table 1 Typology of assessments of ecologic effectiveness

Type of assessment		Criteria to define ecological effectiveness
Measuring the delivery of ecological requirements	Representation gap analysis	Meets geospatial requirements: Does the geospatial coverage of protected areas/protected area systems (PA) sufficiently represent a given species/habitat to ensure its long-term survival?
	Ecological gap analysis	Meets ecological requirements: Does the geospatial coverage of PA include adequate ecological conditions and/or account for species movements necessary for long-term species/habitat survival?
Measuring ecological condition	Conservation status analysis	Favourable conservation status, as defined by the Habitats Directive, is ensured: In what condition are species (individuals or populations) or habitats and what have PA contributed to this state?

1.3.1 Gap analysis approach

The large majority of analysed studies adopted a '**gap analysis**' approach when discussing the ecological effectiveness of Natura 2000 sites for given species and/or habitats. As defined by the Convention on Biological Diversity, a gap analysis within the conservation context is "*an assessment of the extent to which a protected area system meets protection goals set by a nation or region to represent its biological diversity*". In short, gap analyses determine ecological effectiveness based on whether the site or network of sites provide the necessary requirements or coverage of a species/habitat for achieving favourable conservation status in the long-term.

Within this approach, the literature further distinguishes between representation and ecological gap analyses. Representation gap analysis examines whether species/habitat distributions and ranges are included in the geospatial coverage of the Natura 2000 network and/or additional protected areas. Reviewed studies employing this kind of analysis focused on e.g. representation under current or future conditions (taking into account processes such as global warming) or species richness and species composition. Ecological gap analysis, on the other hand, examines whether protected areas are able to meet the ecological conditions and/or account for species movement necessary for the functioning and survival of a habitat or species.

1.3.2 Conservation status analysis

The second approach utilized in the literature was a **conservation status analysis,** in which the ecological condition of habitats or species was examined. In this approach, the literature assessed ecological effectiveness based on whether Natura 2000 sites or other protected areas/protected area systems successfully ensured favourable conservation status for given species/habitats. Within such analyses, population trends were only occasionally considered.

Interestingly, while a significant number of publications refer to the definition of conservation status from the Habitats Directive (see Box 1) to address management and other issues that fall outside the scope of this study, relatively little of the scientific literature uses this definition and the data arising out of Article 12 and 17 to frame analyses of ecological effectiveness (even when assessing Natura 2000 sites and explicitly referencing associated European and Member State laws). On limited occasions, the IUCN's Red List criteria are used instead. It is unclear why there is not more widespread uptake and application of the Habitats Directive definition as it could represent a consistent set of criteria for analysis, but perhaps insufficient access to reliable and current data are underlying causes or the application of specific assessment methodologies.

Box 1. What is 'conservation status'?

The Habitats Directive (Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora) defines conservation status and the designation 'favourable' for species and habitats as follows:

Article 1.i.

"*conservation status of a species* means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the territory referred to in Article 2;

The *conservation status* will be taken as 'favourable' when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis;"

Article 1.e.

"*conservation status of a natural habitat* means the sum of the influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species within the territory referred to in Article 2.

The *conservation status* of a natural habitat will be taken as 'favourable' when:

- its natural range and areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable as defined in (i)"

2 Evidence of ecological effectiveness of the Natura 2000 network

2.1 Ecological effectiveness for habitats

2.1.1 Gap analysis of (Annex I) habitats

Of the identified studies adopting a gap analysis approach in evaluating the ecological effectiveness of the Natura 2000 network for habitats, it is noteworthy that almost all were concentrated on the Mediterranean region/basin. The identified studies observed that some habitat types targeted by the Natura 2000 network are not sufficiently designated and are therefore underrepresented, namely:

- Marine protected areas (almost all are coastal, with very few covering pelagic, deep sea habitats) (Abdulla et al. 2008; Evans, MacSharry, and Opermanis 2011; Olsen et al. 2013; EEA 2014);
- Temporary freshwater habitats in the Mediterranean (due to difficulty identifying habitats and being a low policy priority, despite their classification as a priority habitat in the Habitats Directive) (Bagella, Caria, and Filigheddu 2013); and
- Lowland areas (Metzger et al. 2010 and, focusing on Italy specifically, Maiorano et al. 2007).

In Italy specifically, more than 50 % of areas designated as 'highly irreplaceable' were not included within the network; of those areas included, highland areas were found to be overrepresented, in contrast to the underrepresentation of lowland areas (Maiorano et al. 2007).

2.1.2 Conservation status of habitats

Maintaining and where necessary restoring habitats and species of European interest to favourable conservation status is a key objective of the Habitats Directive and, to this end, the Natura 2000 network makes an important contribution. Habitats in favourable status were found to provide "more biodiversity and had a higher potential to supply, in particular, regulating and cultural ecosystem services" than habitats with unfavourable status (Maes et al. 2012: 1). Yet the level of effectiveness of the Natura 2000 network for achieving or preserving favourable status is highly variable (see Box 2) and difficult to generalize based on limited existing evidence and the lack of coverage of numerous habitat types in the literature; additional considerations such as the date of accession to the EU also impact effectiveness, as this reflects the length of time Natura 2000 has been implemented in a given Member State.

While some studies report evidence of improvements, others highlight unfavourable or worsening conservation statuses, implying that the protection afforded by the Natura 2000 network to habitats is inconsistent. While this is perhaps to be expected given the relatively young age of the network and the variable amounts of time required to effectively restore habitats (ranging from years to decades), available findings are nevertheless worth noting and are outlined below.

Box 2. Mixed impacts on habitats from the Natura 2000 network

Improvements in conservation status of English habitats: Reviews of Sites of Special Scientific Interest (SSSI) in England (which includes all of England's Natura 2000 sites) in Lawton (2010) found that 93 % of habitats within sites were in either 'favourable' or 'unfavourable-recovering' condition, in line with England's goal of reaching 'favourable' or 'unfavourable-recovering' status in 95 % of sites. Improvement has continued since then (EEA 2012). Although of the sites, a much larger proportion (63 %) had 'unfavourable-recovering' status then 'favourable' status (30 %), this represents a regular increase from 2005/2006, when indicators were introduced. The English Natura 2000 network demonstrates a generally positive trend in habitat conservation status.

Worsening status in Romania's Natura 2000 sites: A study examining the efficacy of Romania's protected areas network (including all protected sites) indicates that the degree of effectiveness decreased following the creation of the Natura 2000 sites (Iojă et al. 2010). The sudden increase in protected lands combined with financial issues and a lack of knowledge of species and habitat areal distributions resulted in a failure to significantly improve the conservation status of species and habitats of European concern. These issues were compounded by an overall lack of enforcement and implementation of conservation goals in the newly designated Natura 2000 sites. It should be noted, however, that these findings are preliminary given the recent accession of Romania to the EU in 2007 and the often delayed impacts of conservation measures.

The literature identified suggests that habitats, which are part of landscapes used for agricultural are at particular risk of being in unfavourable condition. High nature value farmland is at particular risk of being in unfavourable condition due in part to the lack of adequate support by the Common Agricultural Policy (CAP) and its rural development policy (European Commission 2008).[4] The decreasing area of agricultural land in most Member States compounds the worsening conservation statuses. Causes of declining area include: settlement expansion, agricultural intensification (i.e. increase of monoculture and mono-cropping, more widespread use of chemical inputs, field and farm consolidation), or the abandonment of agricultural practices (Touloumis and Pantis 2014). The last factor particularly affects habitats which depend on agricultural practices for their survival and has resulted in a marked decline in these areas (Halada et al. 2011). For example, coastal dunes are not managed explicitly for agricultural purposes, but a selection depend on traditional livestock grazing for vegetation control (Halada et al. 2011; Pye, Blott, and Howe 2014).

Abandonment and intensification of agricultural and forestry activities was cited by many studies as a driver of habitat loss and degradation within the Natura 2000 network across Europe, leading many authors to question the strength of protection afforded by Natura 2000 designation as a result of improper implementation and lacking control by authorities (see e.g. Santos et al. 2008; Ioja et al. 2010; Halada et al. 2011; Miklín and Čížek 2014). In Eastern Europe in particular (likely as a result of the significant political changes occurring in 1989), protected forest habitats were found to be in declining condition as a result of pressures created by the aforementioned intensive forestry activities (Ioja et al. 2010; Miklín and Čížek 2014).

While not representative for all of Europe, additional studies highlight regionally or nationally threatened habitats. A study by Pye, Blott, and Howe (2014), for example, found coastal dune habitats to be in unfavourable condition across most of the Welsh Natura 2000 network, due largely to inappropriate management strategies. To return the status of this habitat type to a favourable condition within this geographic context, additional large-scale intervention measures were cited as being necessary (such as removing vegetation, improving sand profiling, and reducing damage from rabbits). In the Czech Republic, the condition of open woodland habitats covered by the Natura 2000 network have been found to be worsening as a result of an intensification of forestry activities (leading to too little growth of new solitary trees and excessive infilling of open canopy areas for logging) (Miklín and Čížek 2014).

[4] Low-intensity farming systems, which are developed from the growing recognition that the conservation of biodiversity in Europe. According to the European Commission (2008): A significant presence of semi-natural vegetation is also essential. In situations where the proportion of land under semi-natural vegetation is reduced, a high diversity of land cover (mosaic) under low-intensity farming may enable significant levels of biodiversity to survive, especially if there is a high density of features providing ecological niches. A high diversity of land cover alone does not indicate HNV farming.

2.2 Ecological effectiveness for birds

2.2.1 Gap analysis for birds

Only five priority level 1 studies were identified in the review that utilised a gap analysis to assess the ecological effectiveness of the Natura 2000 network for birds, looking at a mix of target and non-target species. Only a single article looking at a specific bird species – the Bonelli eagle, *Aquila fasciata* (see López-López et al. 2007).

Adopting a broad Europe-wide focus, Albuquerque et al. (2013) used spatial distribution maps for 495 breeding bird species inhabiting mainland Europe to determine whether bird richness is sufficiently represented by the protected areas under the European Birds and Habitats Directives. Their assessments revealed that there is a low association between bird richness patterns and the cover of protected areas across EU countries[5]. This finding is supported by the Mediterranean study of the Bonelli eagle, which suggests that the current network of Special Protection Areas is insufficient to protect the Bonelli eagle due to inadequate inclusion of its habitat (López-López et al. 2007). Assessing a total of 26 forest specialist bird species (all listed in Annex I) in Romania regarding the suitability of selected Natura 2000 sites for their needs, Sandor and Domsa (2012) found that between 6.2 % and 31.4 % of the national populations of these species of community importance were breeding inside the current SPA network. The study further concludes that the current network of SPA protects less than 10 % of breeding population for a number of forest dependent bird species. Finally, Albuquerque et al. (2013) conclude that a total of 16 (3.9 %) threatened species were present in the gaps of the Natura 2000 protected areas network, highlighting the need to better account for richness patterns in the future when designating special protected areas for birds to enhance effectiveness.

The configuration and size of ecological networks were also raised as being of central importance to ecological effectiveness in order to combat the threats of habitat fragmentation and minimize edge effects on Annex 1 bird populations (Abellán et al. 2011) and non-target bird species (Pellissier et al. 2013); see 2.3.1 for further information. A study exploring the effectiveness of protected areas on 10 raptor species in Spain found that the surface area played a crucial role, with the smallest areas being the least effective at including both territories and optimal habitats within its borders (Abellán et al. 2011). Given this conclusion and the fact that Natura 2000 sites in France were found on average to be larger than other existing protected areas, it could be hypothesized that this partially accounts for their higher effectiveness regarding bird conservation. Despite this, Donald et al. (2007) was positive (see 2.2.2).

2.2.2 Conservation status of birds

As with habitats, the literature is inconclusive about the impact of Natura 2000 and protected areas/protected area systems on bird species. A study by Donald et al. (2007) is one of the most frequently cited in the literature about Natura 2000 effectiveness, finding that the Birds Directive – supported by the Natura 2000 network – has had a measurable positive effect on bird conservation in the EU. While there have been concerns raised about the study's methodology by Rodriguez-Munoz et al (2008) which suggest that the conclusion did not take into account factors such as the dynamics of population trends and contained unjustified assumptions, the robustness of the results and further justifications giving weight to the findings were outlined in a detailed response by Donald et al (2008).

Since this study was published, there has been significant further investigation of the effectiveness of Natura 2000 for bird conservation in France and on a European level, yielding mixed results. A 2007 study of common birds in France found that many common birds had higher population densities

[5] However, due to data limitations, the study notes that the impact of small protected areas in the Natura 2000 network might be underestimated.

outside PA (including Natura 2000 sites and other French protected areas). This can be accredited to the species' high dependency on human activities and cultural or urban landscapes (Devictor et al. 2007), which are not largely covered within the Natura 2000 network. Nevertheless, French Natura 2000 sites have been found to have largely positive effects on common breeding bird populations, with Pellissier et al. (2013) showing an increased abundance of 54 out of 100 monitored bird species with increased Natura 2000 coverage[6]. Additionally, the conservation status of common bird species with negative population trends tended to worsen more slowly within protected areas than outside (Devictor et al. 2007; Brodier et al. 2014). A further French study concentrated on marine protected areas (MPA), finding that they have a positive impact on yelkouan shearwater (*Puffinus yelkouan*) populations (Péron et al. 2013). This suggests that although most MPA (Natura 2000 and other networks) are usually not specifically designed for pelagic seabirds, they can still be beneficial for their conservation.

A study led by Pellissier (2014) expanded on the French common bird study to investigate 166 common bird species populations across Europe (as well as 103 butterfly species populations - see section 2.3.2). The predominantly positive effects of the network on breeding bird populations are outlined in Box 3 below.

Box 3. Largely positive effect of Natura 2000 coverage on common breeding bird populations

Pellissier (2014) assessed the impact of the Natura 2000 network on 166 common breeding bird species using data gathered through volunteer-based schemes in 13 EU countries and the EU Natura 2000 database. The study found that of the investigated species, around 50% showed higher abundances with increased Natura 2000 coverage. A further 27% of the species have lower abundances with higher coverage and the remainder did not show a particular response. These findings indicate that the Natura 2000 areas designated upon the presence of targeted bird species listed in Annex I of the Birds Directive also harbour a substantial number and population of common bird species (only 16 of the species responding positively to Natura 2000 are Annex 1 species).

The most abundant bird species benefiting from the network are woodland specialists, such as the Great and Lesser spotted woodpeckers (*Dendrocops medius* and *Dendrocops minor*) and the Eurasian nuthatch (*Sitta europea*). Furthermore, results indicate the potential of the Natura 2000 network to be an efficient tool to help mitigate the decline of habitat specialist bird species with a narrower ecological niche. The network also supports species with longer trophic chains that are less biologically homogeneous than the communities outside. Finally, it appears that the declining trend of farmland birds observed throughout Europe seems to be less acute within the Natura 2000 network.

Source: Pellissier (2014)

2.3 Ecological effectiveness for other (target and non-target) species

2.3.1 Gap analysis for other (target and non-target) species

Consistent with the finding for birds, the literature highlights the need to include adequately sized spatial areas to meet the (ecological) needs of the targeted populations and reasonable distances between Natura 2000 sites (e.g. de la Montaña et al. 2011). The first aspect of maintaining suitable ecological conditions is particularly important to ensure long-term population viability, as illustrated with three examples below (see Box 4).

[6] Of these species, 11 were farmland specialists, 9 were woodland specialists and 5 were habitat generalists (representing 55 %, 43 % and 35 % of these species types, respectively). Three Annex I species within this sample (*A. campestris, L. arborea* and *S. undata*) exhibited significantly greater abundance within than outside of the network. Six species decreased in abundance with greater Natura 2000 coverage, including two farmland, one woodland and one generalist species (10 %, 5 % and 7 % of these species types, respectively). For the remaining 40 species, no significant effects were observed as a result of increase Natura 2000 site coverage.

Box 4. Potential long-term effects of site size and ecological condition on species populations

Regarding the **English Natura 2000 network**, Lawton et al. (2010) concludes that biodiversity is currently adequately covered, with the exception of a limited number of individual species. However, the report points out that the sites are nevertheless not sufficient to avert future species losses as a consequence of the small site sizes and considering extinction debt (i.e. species may be present in current samplings that are already below viable population numbers due to habitat loss, thus being destined to long-term extinction).

The conservation of six Annex II **cave-dwelling bat species in the Mediterranean** faces similar challenges. Here, gap analyses indicate that ca. 60 % of roosts are protected by Special Areas of Conservation (SAC), but that less than 40 % protection is offered to suitable and optimal habitats (Lisón, Palazón, and Calvo 2013).

On the other hand, small sites can be integral for some species. In the case of **butterfly populations in Slovenia**, for example, the Natura 2000 network was found to offer good coverage of threatened (according to the European and national Red Lists) butterfly ranges, with small protected areas being of particular importance (Verovnik, Govedič, and Šalamun 2011). **Plant micro-reserves** (small areas of 5-20 ha) are also a relatively new tool for conservation that have been shown over the last two decades to be effective for conserving populations of rare and threatened plant species; evidence on the positive effects exists to date for Spain (Valencia and Minorca), Slovenia (Karst Edge) and Greece (Crete), with further pilot sites in Cyprus (Kadis et al, 2010).

Furthermore, the importance of neighbouring sites and buffer zones outside of protected areas were emphasized (e.g. Henle et al. 2014 and Johnson et al. 2008). In considering natural and semi-natural habitats outside of protected areas when designating sites, these 'external' habitats can be strategically used as buffers and facilitate both connectivity and the overall viability of metapopulations and species in fragmented landscapes (Henle et al. 2014). Similarly, Papaioannou and Kati (2007) highlight the need to establish hunting-prohibited protected corridors between existing Natura 2000 sites to support the undisturbed movements of the Balkan chamois (*Rupicapra rupicapra balcanica* - Annex II) in Greece.

The reviewed studies indicate several species (groups) that were found to be inadequately covered in certain regions by the Natura 2000 network; gaps for Annex II species were identified as part of the Natura 2000 seminars (see Evans 2012; Gruber et al. 2012) but many still have to be addressed. As these findings cannot be generalized for all European Natura 2000 sites, the geographical context or scope is provided where relevant.

- **Non-target water beetles and macroinvertebrates in Spain** - Water beetles are largely lacking legal protection and are were therefore found to be highly underrepresented in the Natura 2000 network in Segura river basin in Spain; given that these species are good indicators for other aquatic biodiversity, the study concludes that the Natura 2000 network does not provide adequate protection for freshwater macroinvertebrates more generally (Sánchez-Fernández et al. 2006; Hernández-Manrique et al. 2012);
- **IUCN red list fish** (predominantly non-target species) – the Natura 2000 network was found to have a good coverage of distribution ranges for many IUCN red listed mammal, bird, and reptile species (i.e. also species not included in the birds and habitats directives), but poor coverage for fish and amphibians (some of them listed on the European annexes); the analysis suggests that a high level of urbanization and presence of industrial heritage negatively influenced the establishment of Natura 2000 sites which would have more effectively covered species ranges (Trochet 2013);
- ***Rosalia alpina*, Rosalia longicorn beetle in Italy** – A gap analysis revealed that more than 52 % of potential *Rosalia alpina* (Annex II priority species) habitat is unprotected in Italy, with the Natura 2000 network protecting only 42 % of potential habitat. Large amounts of habitat fragmentation due to farmland necessitate the creation or restoration of forest corridors to bridge these otherwise impermeable gaps and increased Natura 2000 protection being granted to the still largely unprotected area of the Italian territory (Bosso et al. 2013);

- ***Graellsia isabelae,* Spanish Moon Moth** (Annex II listed and 'Data Deficient' IUCN Red List species) – The study found that SCI which are under protection are not sufficient to maintain current moth populations; it is recommended to therefore expand protection areas to include suitable neighbouring habitats (Chefaoui and Lobo 2007);
- Selected **plants and invertebrates species in Romania** – While over 80 % of the species of European conservation concern (listed in Annexes II and IV of the Habitats Directive) were found to be included in at least one protected area within Romania, plants and invertebrates were found to be underrepresented (Iojă et al. 2010);
- **Terrestrial vertebrates in Italy** were found to be covered by the network only in a "patchy and inconsistent" manner; the examined vertebrates comprised a mix of target and non-target species (Maiorano, Falcucci, and Boitani 2006);
- **Mediterranean lichen species –** The effectiveness of the Natura 2000 network for protecting 18 lichen species, a group not listed in Annex II, was found to be quite low in Spain; the results indicate that the network does not guarantee the protection of Mediterranean lichen or other 'non-charismatic' species (Rubio-Salcedo et al. 2013);
- **Mobile and wide-ranging pelagic taxa** – Marine protected areas have most often been designated to protect benthic habitats and their biota, but there is an increasing need to account for highly mobile pelagic taxa, such as marine birds, mammals and turtles, and their oceanic habitats (particularly regarding the foraging grounds and movement corridors of breeding seabirds, which can often extend to hundreds of kilometres from breeding colonies) (Louzao et al. 2006).

More generally, a study by Gruber et al (2012) found that while the Natura 2000 network is largely effective in covering target species and minimizing the number of gap species[7], there is an uneven degree of representation between species. Several species were identified as being overrepresented, while others were only represented in an inadequate number of sites. The study attributes such variations in large part to differing patterns in species ranges, given that widespread species are inevitably represented in more sites than narrow ranged species. This is supported by Jantke et al. (2011), who looked at the degree of coverage of 70 endangered wetland vertebrate species listed in the Birds and Habitats annexes by the Natura 2000 network (including 16 amphibians, 4 reptiles, 41 breeding birds, and 9 mammals). This study found that most wetland species were covered adequately by the existing system, with potential for improvement for five area-demanding species. For example, the European otter (*Lutra lutra*) has several remaining insufficiencies, the Corsican painted frog (*Discoglossus montalentii*) – while having most of their distribution covered by 14 sites and being reported as having a 'Favourable' conservation status – could benefit from larger sites, and the Mallorcan midwife toad (*Alytes muletensis*) – while noted as 'sufficient' – could profit from improved coverage of its reported distribution.

2.3.2 Conservation status of other (target and non-target) species

Only two of the reviewed publications used a conservation status approach to analyse the ecological effectiveness of the Natura 2000 network for species other than birds, as presented below. Several studies did, however, justify their methodological approach by citing the insufficiency of available data for determining conservation status.

Deinet et al. (2013) present an overview of population trends of 18 mammals (and 19 bird species) across Europe, many of which are listed in Annex II of the Habitats Directive (e.g. European Bison, southern Chamois, Eurasian and Iberian lynx, Wolverine, and grey seal). While the impact of Natura 2000 is not the only variable analysed regarding changes in conservation status, the linkages are

[7] i.e. species not represented in a single site of the Natura 2000 network

nevertheless clearly outlined where possible. The Eurasian lynx (*Lynx lynx*), for example, remains under threat in Europe; however, overall increases in abundance can be tied to strict legal protection under the Habitats Directive in all MS (except Estonia) and associated conservation actions, as well as to reintroductions, translocations and natural recolonisation (Deinet et al. 2013).

In addition to exploring the effects of Natura 2000 sites on common breeding bird species, Pellissier (2014) also looked at 103 butterfly species populations. While the study made use of data provided through volunteer-based schemes in six countries/regions, the authors emphasize that the following results should be considered as preliminary. According to the results, a greater number of butterfly species are more abundant in areas with a high Natura 2000 coverage. Of the examined species, 32 have higher abundances with a larger Natura 2000 coverage, 16 have lower abundances and the remaining 55 did not exhibit a particular response to the network.

2.4 Limitations to the analysis of ecological effectiveness

Several factors were outlined in the literature as being barriers to determining the ecological effectiveness of the Natura 2000 network. Amongst these factors, the **lack of available and reliable data** was most frequently cited/quoted in the reviewed sources. In the context of marine protected areas, the lack of before-after-control-impact assessment was cited as a limitation for assessing effectiveness (Olsen et al. 2013). For studies that gathered data first-hand, it was found to be patchy and inconsistent in terms of the methodologies used, making a uniform comparison of data and analyses across studies difficult. Also, many articles cited the **resolution of data** as limiting the extent of detail possible in analyses. Data was often only available at coarse scales, which in some cases may have obscured recognition of the impacts of small Natura 2000 sites. Despite these shortcomings, Henle et al. (2014) highlights that the majority of Member States do not officially recognize the need to collect more data and that the institutions which are currently involved in biodiversity monitoring activities are largely lacking knowledge, financial resources and human capacities to respond to emerging European priorities.

A number of studies cited the **long-term nature of ecological timescales** as a limiting factor for determining conservation status and correctly identifying trends, also taking into account the difficulties in separating Natura 2000 status from other designations as a cause for a given effect (EEA 2012a). As pointed out in Pellissier et al. (2013), **the Natura 2000 network is still relatively young** in ecological terms; in their analysis of its effects on French bird populations, it was concluded that the network was too young to attribute any effect on population trends. Similarly, given the short time series which are usually available, Gaston et al. (2008) highlighted the difficulties in determining to which factors population trends can be attributed and if the responsible pressures stem from within or outside of the protected areas being evaluated. Finally, long ecological timescales result in potential inadequacies of species inventories. Estimated population trends based on current protected area data may be inflated by extinction debt (see 2.3.1) (Gaston et al. 2008).

3 Factors influencing the ecological effectiveness of the Natura 2000 network

3.1 Policy planning and implementation process

Multiple factors were cited in the literature which can impede the ability of policy makers and planners to make appropriate policy decisions in response to current and potential future threats, therewith jeopardizing effective conservation management (see e.g. Apostolopoulou and Pantis 2009; Bagella, Caria, and Filigheddu 2013; Albuquerque et al. 2013). In addition to a range of contextual barriers which come into play (including, e.g. economic, financial, institutional and political barriers), this incapacity also results from a **lack of reliable data** (Abdulla et al. 2008; Henle et al. 2014) and from **insufficient communication of scientific data to policymakers and planners** (i.e. inadequate 'knowledge transfer'), particularly within the context of performing gap analyses (Müller and Opgenoorth 2014; Milberg 2014). Regarding marine protected areas, for example, Johnson et al. (2008) found that current knowledge of species' role in maintaining the structure and function of marine habitat types presented a barrier to efficient selection of these sites; using only a key species as an indicator for site performance or habitat health could be counterproductive, since too little is understood about marine species and marine ecology. In the face of coming challenges such as climate change, more emphasis needs to be placed on sharing objective, scientific information in the policy planning and implementation processes in order to increase the effectiveness of the Natura 2000 network (Maiorano et al. 2007).

Insufficient participation of the public and of land owners and **lacking support of local authorities** was also found to negatively impact the effectiveness of Natura 2000 implementation. While local authorities play an important part in identifying important areas for conservation (especially in connecting sites), targeted efforts to increase their support for the Nature Directives (Beunen, Van Assche, and Duineveld 2013; Grodzinska-Jurczak and Cent 2011) should be complemented with increased (voluntary) participative (Beunen and de Vries 2011; Lawton et al. 2010; Henle et al. 2014; Apostolopoulou, Touloumis, and Pantis 2014) and bottom-up processes (Grodziska-Jurczak et al. 2012; Mathevet et al. 2014).

The **conflict between economic interests and conservation goals** was identified as a further risk to conservation planning and implementation (see e.g. Albuquerque et al. 2013; Papageorgiou and Vogiatzakis 2006; Péron et al. 2013; Miklín and Čížek 2014). In France, for example, concern has been expressed about successfully implementing marine protected areas with weak regulations that do little for helping conservation status, or whose efficiency is threatened by high and/or increased fishing activity at marine protected area borders (Péron et al. 2013). A lack of support by local authorities was also found in Poland due to concerns about potential restrictions on various types of economic and infrastructure development which might result as a consequence of new Natura 2000 site designations (Grodzinska-Jurczak and Cent 2011). A lack of clear goals and divergences between stated and actual goals in Greece has also been cited as having "led to bureaucratic interpretations of conservation objectives and distortion of decision processes in favour of satisfying economic and development interests" (Apostolopoulou and Pantis 2009: 221). This factor is exacerbated by the lack of access to and use of scientific data, meaning that other concerns assume a more dominant role in planning and implementation than objective scientific information.

Inadequate personnel, administrative and financial resources resulting in ineffective management are cited in the literature as a further factor hindering the effective implementation of Natura 2000 goals(see e.g. Abdulla et al. 2008; Albuquerque et al. 2013; Iojă et al. 2010). In Romania, for example, newly designated Natura 2000 sites have been deemed as being largely ineffective due to the lack of capacities to monitor and enforce necessary restrictions (see Box 2 for more details). Albuquerque et al. (2013) recommends to prevent these gaps from appearing by making sure to

identify major threats and assess the adequacy of resources to respond to those threats and other needs before beginning to implement protected sites.

Weaknesses in policy design and **low policy coherence across sectors** area also cited limitations. As mentioned in previous sections, habitats and species which depend on human activity and especially agriculture and forestry practices tend to have worse conservation status. Halada et al. (2011) found that the distribution of agricultural and agri-environmental support payments did not effectively target high nature value farmland. This has lead to the disappearance of low-intensity land use practices that support biodiversity both inside and outside of Natura 2000 (Halada et al. 2011). Furthermore, apart from the Natura 2000 legislative framework, numerous additional policies such as the CAP, transport, planning, development, fisheries or energy policies strongly influence economic activity and land use changes which have profound impacts on the effectiveness of the network (Touloumis and Pantis 2014). In a marine context, for example, additional management measures regarding e.g. fisheries and marine traffic can serve to complement the aims of network, particularly in terms of protecting species whose ranges extend beyond the periphery of designated marine protected areas.

3.2 Selection of Natura 2000 sites at Member State level

Many studies found low correlation between the occurrence of species and habitats concerned and the sites selected for the Natura 2000 network (see e.g. Araújo, Lobo, and Moreno 2007; Bagella, Caria, and Filigheddu 2013; Albuquerque et al. 2013). Factors such as **unclear conservation goals of the Natura 2000 network, politically motivated site selection, and a low prioritization of conservation objectives and socio-economic considerations** as compared to economic objectives were cited as contributing to the inefficiency of site selection (Gaston et al. 2008; Apostolopoulou and Pantis 2009; Ioja et al. 2010; Tsianou et al. 2013). Of particular note has been the delayed focus on marine protected areas to date in many Member States (Evans 2012), such as in the UK (JNCC 2014).

A **bias towards areas more removed from human activity** was also identified, which affects not only the Natura 2000 network, but protected area site selection and European ecosystem research more generally as well (Metzger et al. 2010). In Italy, for example, sites in historically more intensively used lowland areas were under-represented as compared to highland areas that historically played less of a role for human activities, despite the existence of many valuable and irreplaceable habitats and species in lowland areas (Maiorano et al 2007).

Furthermore, several studies noted **incoherent planning and site selection approaches** between existing protected areas and new Natura 2000 sites. Studies in Greece, Romania, the Czech Republic, and Italy found that the Natura 2000 network was not planned to complement existing protected areas, but instead often simply superimposed on existing networks or planned without considering existing protected areas (Papageorgiou and Vogiatzakis 2006; Maiorano et al. 2007; Ioja et al. 2010; Miklín and Čížek 2014). To address the resultant weaknesses, the literature recommends to integrate objective scientific information into site selection process, through for example the use of algorithms or site selection programs to increase coverage efficiency (see e.g. Papageorgiou and Vogiatzakis 2006; Trochet 2013). Sectoral legal frameworks to promote environmental goals alongside economic ones were suggested for the case of Greece (Papageorgiou and Vogiatzakis 2006).

In some cases, **insufficient functional connectivity**[8] **and spatial connectedness** between neighbouring countries and habitats occurred as a result of dissimilar Natura 2000 site selection processes. According to Opermanis et al. (2012), the connectivity measure was below 50 % in 11 of the 34 investigated EU borders. In these cases, increased coordination in site selection between bordering countries could enable improved species movement, migration and dispersal; for example,

[8] Connectivity was measured by the dispersal success of 192 reptile, amphibian, invertebrate and plant species from Annex II of the European Union Habitats Directive selected as they were considered sensitive to connectivity, based on the presence of same species on both sides of the borders.

Alpine ibex *Capra ibex* have a summer range in Vanoise National Park in France but winter in the adjacent Gran Paradiso National Park in Italy (Opermanis et al. 2012).

Coherence gaps also exist within Member States and point to the need to "enhance connections between, or join up, sites, either through physical corridors, or through 'stepping stones'" (Catchpole n.d., 14) and increase protection of "key sites" located in habitats outside of the Natura 2000 network (Papanikolaou et al. 2014) . This finding is supported by several studies (e.g. see papers in Henle et al. 2014) and highlights the need to increase connections between protected areas and the level of protection beyond PA to ensure effectiveness. In the marine context, for example, Hiddink et al. (2006) provide evidence that displacing existing fishing activities from PA can generate negative impacts on biodiversity in adjacent marine areas if no additional management measures are implemented. Furthermore, Henle et al. (2014) found that larger protected areas require more connecting corridors than their smaller counterparts, and that smaller protected areas should be connected to a large one rather than interconnecting multiple smaller protected areas. Adopting a long-term perspective, the importance of creating functional connections that enable species to migrate over long distances in pursuit of habitats that have shifted as a consequence of climate change will increase in importance (see 3.4.1).

3.3 Management of Natura 2000 sites

Effective management is key to the success of Natura 2000, but is challenged by the inclusion of a variety of land categories with different ownership status, types of land use and levels of human activity (Grodzinska-Jurczak et al. 2014) as well as varying amounts of data availability.

Most habitats in the Natura 2000 network have historically been created and/or significantly affected by human activity (Maiorano, Falcucci, and Boitani 2006), leading many studies urge the consideration of human activities as an integral part of habitat and species management. The literature review found that the central role of conservation and low-intensity agriculture and forestry activities in preserving valuable habitats is **not reflected in Member State policy priorities and site management** (see e.g. Maiorano, Falcucci, and Boitani 2006; Halada et al. 2011; Miklín and Čížek 2014). In Romania for example, participation of land owners and users also posed a challenge to effective management (Ioja et al. 2010; Stancioiu, Abrudan, and Dutca 2010).

The **lack of adequate conservation data** is also a hindrance to effective management (Abdulla et al. 2008; Henle et al. 2014). Data on smaller, less "charismatic" species as well as data from less-researched ecosystems such as marine habitats is often lacking (Henle et al. 2014), and their role in ecosystems is too poorly understood to adequately inform management decisions based on just a few easily-monitored species (Johnson et al. 2008; Trochet 2013).

Studies also found an **insufficient implementation of management plans** across Member States (MS), species, and habitats, which negatively impacted progress towards conservation goals (Abdulla et al. 2008; Agardy, di Sciara, and Christie 2011; Henle et al. 2014). The establishment of management authorities has been uncoordinated and inefficient in many Member States, especially when multiple protection designations cover the same area, as is the case especially in Greece and parts of Eastern Europe (Apostolopoulou and Pantis 2009; Henle et al. 2014; Miklín and Čížek 2014). Management authorities are still lacking for many parts of the Natura 2000 network, and, as raised in section 3.1, there is also a significant **need to increase stakeholder participation and community engagement** in management processes (Apostolopoulou, Drakou, and Pediaditi 2012; Grodzinska-Jurczak et al. 2014); Grodzinska-Jurczak et al 2014).

Finally, **incoherent management approaches between marine and terrestrial Natura 2000 sites** was raised as a barrier to effectiveness in some cases. In the UK, for example, a compartmentalised approach regarding the management of terrestrial and marine environments fails to address the fact that terrestrial catchments exert direct influence on the coastal and marine environment (e.g. via riverine discharge) (JNCC 2014). This separated approach also jeopardizes the effectiveness of the

Natura 2000 network sites for migratory species of conservation importance that have marine and freshwater life stages.

3.4 Global and local challenges

3.4.1 Climate change

The effect of climate change on the Natura 2000 network has been the subject of much research, focusing more frequently on species than habitats. Most studies found that climate change presents a serious challenge to the Natura 2000 network in terms of both habitat and species protection. Although climate change's impact on the network's connectivity is predicted to be rather small (Mazaris et al. 2013), the literature demonstrates that **climatic shifts will affect habitats and species**. More specifically, species and habitat range shifts and population declines due to climate impacts will negatively impact the effectiveness of the Natura 2000 network across the EU (Gardiner et al. 2007; Normand, Svenning, and Skov 2007; D'Amen et al. 2011; Araújo et al. 2011; EEA 2012b; Ellwanger, Ssymank, and Paulsch 2012). Of particular concern is the possibility that many protected sites under the Natura 2000 network that are currently hosting target species will become unsuitable for those species (Brambilla et al. 2014).

Regarding specific habitats groups, coastal and freshwater habitats, bogs, mires and fens, and alpine habitats are forecast to the most vulnerable within the Natura 2000 network; highly affected species groups include amphibians and fish, but potentially also many invertebrates[9] (European Commission 2013). For both habitats and species, climate change is expected to affect not only those that currently have an unfavourable conservation status, but also those that are considered as favourable until now. Anecdotal evidence on the envisioned effects of climate change on select species and habitat types within the network is provided in Box 5 below.

Box 5. Potential effects of climate change on select species and habitat types within the Natura 2000 network

In England, Gardiner et al. (2007) found that sea level rise driven by climate change threatens several **coastal habitat types** from the Habitats Directive. Local compensation for the loss of these habitats is possible through the protection of similar habitats (e.g. lost coastal grazing marshes are compensated with fluvial grazing marshes), though habitat functionality may change (Gardiner et al. 2007). This will have an effect on the species dependent on these habitats.

Papanikolaou et al. (2014) evaluated the projected performance of the Natura 2000 network against future changes, focusing on **grassland ecosystems** and a group of species sharing similar traits. The findings indicate that the efficiency of the network regarding grassland avian fauna will be severely affected by climate and land use changes. Model projections further show a substantial reduction of grasslands within PA, suggesting that the current Natura 2000 network configuration may be insufficient to protect grassland birds in upcoming years. Therefore, it is suggested to establish additional PA that could sufficiently protect grasslands and reduce the danger of range contractions and local extinctions to their species.

The potential effect of temperature increases on the distribution of **pygmy and boreal owls** was explored in the Italian Alps, as well as the relative effectiveness of the Natura 2000 network at the regional level (Brambilla et al. 2014). The study concluded that the potential regional distribution of both species will be greatly reduced (boreal owl by 52–54 % and pygmy owl by 23–34 %), given the particular vulnerability of mountainous habitats. While the network currently covers over 30 % of suitable sites for these species, a significant 64 % of the suitable sites in the future scenarios are not included in any Site of Community Importance or Special Protection Areas. As has been previously mentioned, increasing network coverage and ensuring sufficient forest management outside the Natura 2000 sites will be necessary to conserve these species in the future.

[9] For many invertebrates (with the exception of e.g. butterflies, dragonflies and moths), not much is known about their response to climate change due to limited knowledge about their ecology or their present distribution (European Commission 2013).

Several recommendations for adapting the Natura 2000 network to climate change are included in Box 5. The European Commission (2013) also published a targeted guidance document specifically on climate change and Natura 2000 to optimally address the impacts of climate change in managing the network's protected sites. The necessity of including surrounding landscapes in vulnerability assessments and management decisions (i.e. ensuring connectivity) emphasized in order to maximize the ability of species and habitats to adapt to climate change. Additional sources from the literature complement these recommendations and suggest the following: creation of additional policy or changes to existing policy (Araújo et al. 2011), designation of new sites (D'Amen et al. 2011), flexibility of site designation and targeted management based on habitat and species range change (i.e. adaptive management) (Mazaris et al. 2013; Gies and Albrecht 2013), and the creation of site restoration plans (Verschuuren 2010). Adapting the Natura 2000 network to climate change based on current policy requires voluntary action by the MS, which may not be timely or ambitious enough (Verschuuren 2010).

3.4.2 Land use change and infrastructure development

Land use change and infrastructure development pose different challenges to the Natura 2000 network across Europe. Rapid economic and infrastructural change in some of the less-industrialized MS has led to changes in patterns of land use (Pullin et al. 2009), which has meant the de-intensification of some large scale agricultural operations from before 1989. While these changes have benefited biodiversity in some regards, it has also lead to the deterioration and reduction of agricultural landscapes, an intensification and expansion of forestry (Touloumis and Pantis 2014) and therewith also had negative consequences for biodiversity within the Natura 2000 network.

As stated in previous chapters, **changes in agriculture and forestry activities and structure and expansion of built land (artificial areas) are serious threats** to biodiversity across all of Europe and within the Natura 2000 network (Touloumis and Pantis 2014). For example, urban expansion and increasing tourism infrastructure and recreation in Italy are major causes of declines in Annex I habitats (Viciani et al. 2014) and amphibians (D'Amen and Bombi 2009). Mazaris et al. (2013) found that for a selection of raptors across Europe, land use change in Natura 2000 sites posed a larger threat to the species survival in Europe than climate change. Intensified forestry has also been found to be a problem in protected areas and Natura 2000 sites across Eastern Europe (Ioja et al. 2010; Miklín and Čížek 2014).

On the other hand, select beneficial effects on species have also been realized as a result of land use change. In the case of red deer (*Cervus elaphus*), for example, a reduction in sheep grazing and subsequent reforestation aided the expansion of the species in Scotland; furthermore, land abandonment was also beneficial to this species in Switzerland, northern Italy and Slovenia (Deinet et al. 2013). This study did not, however, take into account the potentially negative effects of land abandonment on other (protected) species or habitats.

Land use changes occur with different characteristics and at varying speeds across MS and regions. Touloumis and Pantis (2014) suggest that more effort should be put into developing regional and local policies to stem land use change, as change processes and socio-economic, historical and political factors differ greatly between regions. The size of protected areas should also be taken into account. Smaller PA were found to exhibit higher rates of land use change than larger PA - especially from natural to artificial land uses - than larger sites (Maiorano, Falcucci, and Boitani 2008), although these rates remain lower than in non-protected areas.

4 Conclusions and recommendations

The information identified in this review was limited and largely inconsistent and anecdotal in nature due to the diverse methodologies utilized and an often narrow focus on individual habitats/species populations within a limited, context-specific area. It is therefore difficult to generalize conclusions about the effects of the Natura 2000 network on ecological conservation status. Furthermore, given the recent accession of several Member States to the European Union and thus the rather young nature of the Natura 2000 network in ecological terms, indiscriminate and generalized statements about effectiveness should be used with caution. However, the reviewed publications serve as a solid foundation regarding potential means to address shortcomings and improve on existing positive aspects of the network. These insights have been clustered and formulated into recommendations below.

Overall, the evidence identified was largely focused on representation gap analysis, measured using geospatial criteria. The minority of studies concentrated on ecological gap analysis or conservation status. Concerns such as population dynamics, habitat structure, or ecological condition were integrated in only a few studies, although they inherently play a role in determining conservation status. Rarely did indicators such as individual and population health, population trends, reproduction success rates, ecosystem service provision, etc. appear in analyses in the literature. Geographic coverage of the studies predominantly focused on the Mediterranean biogeographical region more generally or specific countries, regions, habitats and/or species therein. The Nordic region was notably absent from the literature. Finally, less charismatic species and habitats (such as insect and plant species), which are less understood (such as marine pelagic species and habitats) were found to be underrepresented in the literature and the network itself.

On the basis of the reviewed publications, the following recommendations have been developed.

1. Address knowledge and communication gaps in science, policy, and practice

There are two major gaps presenting barriers to the effectiveness of Natura 2000, namely the lack of reliable ecological information and communication gaps.

Regarding the knowledge gap, the reviewed literature was characterized by a lack of consistency in analytical methods and approaches, frameworks, scale, data collection, and even terminology. This limits opportunities for making generalized conclusions about the effectiveness of the network. Interestingly, almost none of the scientific literature examining Natura 2000 made mention or use of the definitions of conservation status provided in the Directives or of the Natura 2000 reporting data submitted by the MS. More emphasis should be given to effective dissemination of the Member States reporting data to encourage its broader uptake and application as it represents an important source of data that is readily available and comparable across MS. Research can *inter alia* fill in data gaps in the Member States reporting and provide very valuable insights and detailed case studies on selected species and habitats. The need for targeted research could be supported by relevant funding mechanisms at national and EU level.

The second gap exists in the communication between science, policy, and practice. Sound scientific knowledge should play a greater role in decisions about planning, site selection, management, and policy, and insights from implementation should be more fundamentally integrated into science. It is necessary to implement an ecological focus in implementation and monitoring, as well as to put more effort into harmonizing monitoring across MS. The literature also suggests dedicating more resources to the communication of science to administrations and implementation to improve effectiveness. At the same time, communication should be encouraged from practice to scientists and policy.

2. Increase the adaptive capacity of and functional connectivity between protected sites

Climate change and land use change represent challenges to the Natura 2000 network and will affect regions, species and habitats in different ways and with varying severity. The literature suggests increasing the level of attention being paid to changes both in and near Natura 2000 sites, as developments outside of Natura 2000 sites will also impact the network's effectiveness. Flexible mechanisms for adaptation should also be integrated into the network to deal with the global challenge of climate change, following so-called 'adaptive management' principles. This may be possible through the use of buffer zones, changing the spatial distribution of sites, and emphasizing adequate functional connectivity. Effective and consistent monitoring and adaptive planning and management measures will also enhance the ability of the network to adapt successfully to future change. Literature also suggests to expand the network and increase its coverage as well as to include more suitable sites, which would help species and habitats to better adapt to climate change. The use of current and reliable science in adaptive planning is also key.

Moreover, the coordination with other protected area networks is lacking in some Member States but also between bordering Member States, leading to high bureaucratic burdens and lower effectiveness of sites. Improved coordination could minimize bureaucratic barriers and support functional connectivity into the future across borders.

3. Increase policy coherence between biodiversity policy and other policy areas

Policies beyond the Nature Directives, such as in the fields of agriculture and economic and rural development, have the potential to jeopardize the goals and effectiveness of the Natura 2000 network. Competition between economic and conservation interests is cited in the literature as one cause of certain habitats (e.g. marine, lowland, and freshwater) and species (e.g. those living in agricultural and urban area) to be underrepresented by the network. EU policies still need to improve their pursuit of a more holistic and integrated approach to recognize and address potential conflicts between economic and conservation interests and foster synergies. Concrete suggestions include strengthening environmental impact assessment requirements for EU policies and increasing the focus of responsible authorities on potential synergies, such as green infrastructure, ecosystem-based disaster protection, and climate mitigation and adaptation to reach other policy goals in parallel with PA support. Evidence suggests that there is also a great potential for increasing the ecological and cost effectiveness of Natura 2000 via improved policy coherence.

4. Improve the effectiveness of management practices, in part via increased public participation

Management practices are a key determinant of the effectiveness of the Natura 2000 network and are frequently raised in the identified literature, but are viewed as not receiving adequate attention in policy or implementation. The literature found that management plans, which can increase the ecological and cost effectiveness of conservation measures, are absent or poorly implemented in many cases. While several examples already exist[10], additional standards and guidance documents for management could be developed at the European or MS level to encourage their more consistent use and practices.

The role of the public, according to the reviewed publications, is often unacknowledged by decision makers and implementing authorities. However, the crucial role of landowners and users, local populations and volunteers are highlighted as being key for reaching high ecological effectiveness in Natura 2000 sites. Further guidelines and models for public participation should thus be developed and implemented across Europe. Volunteer-driven citizen science also has the potential to play an

[10] See e.g. http://ec.europa.eu/environment/nature/info/pubs/pubs_en.htm

increasingly important role in biodiversity conservation and monitoring in the future as the vast data volume that can be collected by a large number of volunteers far exceeds professional capacity for monitoring (as has already been recognized by the EEA and Eionet[11], amongst others). Furthermore, such approaches are beneficial to raising public awareness and the level of understanding of issues related to biodiversity. Monitoring systems that incorporate volunteer data and encourage the sharing of knowledge should continue to be developed.

5. Increase the consideration of non-conservation activities within the network and activities outside of protected areas

The ecological effectiveness of Natura 2000 sites depends not just on conservation measures within the sites, but also on non-conservation-focused activities within site boundaries and on land use decisions outside of sites and in buffer zones. According to the literature, the Natura 2000 network may have an advantage over other types of protected areas/protected area systems in some MS due to their larger size (e.g. in Spain), which minimizes edge effects. Natura 2000's focus on creating networks of protected areas is already a positive step towards an integrated, ecological approach to conservation. However, the role of non-conservation focused human activities were highlighted as not being sufficiently considered in the Natura 2000 network, though they have a major impact on habitats and species. Habitats and species that depend on traditional land use patterns for their survival are at particular risk within the Natura 2000 network. Policy is thus recommended to focus more on establishing effective buffer zones and semi-natural habitats outside protected areas as well as ensuring adequate levels of protection inside sites. As previously outlined, increasing policy coherence between biodiversity policy and other policy areas could also greatly improve Natura 2000's ecological and cost effectiveness in this regard.

Final remarks

The literature review reveals that valuable data and information on the effectiveness of the Natura 2000 network and its influencing factors is available, but it also does not allow for general conclusions at an EU level. Several gaps and potential actions on how to address these shortcomings have been identified, which can serve to support and increase the effectiveness of the Natura 2000 network. These actions target a range of spatial scales, including the site-level (e.g. implementation of management practices, monitoring), regional level (designation of sites, selection of management practices and participation processes), national level (selection of sites, setting policy objectives) and even the transnational level (e.g. coordination of site selection and designation in coordination with bordering countries). Given these considerations, a multilevel and multi-stakeholder approach is deemed necessary to increase the effectiveness of the Natura 2000 network in achieving its conservation aims.

[11] The EEA and Eionet have already begun to integrate citizen science approaches into biodiversity monitoring, focusing on producing data regarding common bird and grassland butterfly population trends (see http://www.eea.europa.eu/themes/biodiversity/biodiversity-monitoring-through-citizen-science/).

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