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Identification of top priority areas and management landscapes from a national Natura 2000 network

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ABSTRACT

The Natura 2000 (N2k) network of protected areas is a backbone of biodiversity conservation in Europe, with likely further relevance for the development of green infrastructure. EU member states have legal responsibilities for evaluating the condition of and maintaining their national networks. While it is desirable to maintain the condition of the N2k network or even improve it by habitat restoration, it is a fact that national environmental bodies operate under budgetary constraints – money available for conservation is limited. Consequently, there may be a need to prioritize targeting of conservation effort in and around the N2k network. In this study we develop a high-resolution spatial conservation prioritization for the Finnish national N2k network, using data about the distribution and quality of 68 N2k habitats occurring in Finland. The aim of the work is to identify management landscapes, landscapes that have exceptionally high conservation value and which could be managed as one management unit. We identify top-priority areas of the N2k network. We also identify highest-priority N2k areas that do not have the status of a protected area in the Finnish legislation. The present work was commissioned by the Natural Heritage Services of Metsähallitus, a national administrator that is responsible for the maintenance of the Finnish protected area network. The primary purpose of this work is to assist targeting of habitat maintenance, management and restoration in and around the Finnish N2k network. The analysis done here could be replicated elsewhere using publicly available spatial prioritization software.

1. Introduction

The Habitats Directive 92/43/EEC is the pivotal European law for building a continental network of sites for nature conservation. The principal objective of including sites into Natura 2000 (N2k) is to achieve or maintain a favourable conservation status of habitats and species named in the EU Birds and Habitats directives (Pedersen et al., 2009). For example, in Italy it was discovered that the N2k network covered potential natural vegetation much better than the national protected area network, which had displayed significant shortcomings and biases (Rosati et al., 2008). The implementation of the Habitats Directive has required the allocation of significant resources to fulfil requirements, but the optimal allocation of those resources is difficult (Strange et al., 2007). Information-based quantitative spatial prioritizations are one input that can facilitate well-informed targeting of conservation effort in and around the N2k network (Strange et al., 2007). Monitoring of N2k sites is required under the Habitats Directive, and Member States are required to report to the European Commission (Cantarello and Newton, 2008; Chiarucci et al., 2008).

The present work was developed to answer the needs of the Natural Heritage Services of Metsähallitus (NHS), a Finnish

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administrator that, among other things, is responsible for the maintenance of the Finnish protected area network. Earlier unrelated work developed by the NHS identified landscapes relevant for management of nature tourism (Björkvist et al., 2009), and it was recognized that a similar analysis implemented for biodiversity could be helpful for guiding ground operations. As a response to this need, we show an operational way forward for the national-level prioritization of a N2k network. As the present work produces a N2k-based prioritization inside the Finnish protected area network, it can be beneficial in many different ways: (i) it increases awareness about where the most valuable and unique landscapes of the Finnish N2k network are when having nature conservation in mind, (ii) it identifies top-priority management landscapes around which habitat maintenance and restoration could be highly valuable ecologically, and (iii) identifies those N2k areas that are high-priority but which are presently under a lesser degree of legal protection. In addition to these, the present analysis may (iv) help in the guidance of nature-based tourism, (v) facilitate impact-avoidance in the neighbourhood of highest-priority areas, and (vi) be informative for any land-use decisions in and around N2k habitats in Finland.

We do the present analysis using the Zonation framework and software for spatial conservation prioritization (Moilanen et al., 2005, 2009, 2011a,b). This software is capable of doing national-scale high-resolution analysis on top of maps describing the distributions of many biodiversity features, including species or environment types. Zonation analyses can account for a wide range of factors relevant for spatial conservation planning, including many features and their local quality across the landscape, feature-specific connectivity considerations, feature priorities (weights), uncertainty in distribution information, land cost, and opportunity costs. Additional to the typical target-based planning of systematic conservation planning (Margules and Pressey, 2000), Zonation also implements multiple conceptually different ways of how local habitat quality and the distributions of many features are aggregated into conservation value (Moilanen, 2007). Priority rank maps produced by Zonation show a full gradation of conservation priority through the landscape, identifying most important and least important areas by one analysis.

Various analyses of biodiversity distribution have been applied to N2k networks before. Velazquez et al. (2010) combine information about vital functions, floristic richness, forest structure, area occupied by the habitat, recovery capacity and vulnerability of habitats to generate management areas and prioritize management actions. Marcer et al. (2010) develop a database and information system that is intended for the storage and processing of information about individual N2k sites, changes in them, and their administration. Graziano et al. (2009) apply multi-criteria evaluation based on indicators to suggest urgent conservation strategies and future monitoring activities. A further approach to the management of the network of N2k sites is development of site-specific management protocols, with the aim of soliciting the support and participation of local actors (Dimitrakopoulos et al., 2004; Alphandery and Fortier, 2010). These approaches effectively combine various local information to produce scores, which is different from the present analysis which produces a balanced complementarity-based high-resolution spatial conservation prioritization (Moilanen et al., 2011a).

There are significant concerns over the extent to which existing protected area systems can maintain their biodiversity values, particularly given the small size of many of these areas and likely impacts of climate change (Gaston et al., 2008). Especially, species living in successional or traditional agricultural N2k environments may require their habitats to be maintained and managed (Ostermann, 1998; Anadon et al., 2006; Buse et al., 2007), although targeting of management is complicated by the fact that management action may have conflicting consequences for different species (Muller, 2002). Knowledge about biodiversity priority areas facilitates the well-informed allocation of management effort. While the present analysis is concerned about the identification of the highest-priority bits of the Finnish national N2k network, it may be equally valuable to investigate the low-priority end of a ranking: targeting economically harmful activity to ecologically low priority areas facilitates impact avoidance (Moilanen et al., 2011a). The analyses described here have been delivered to the NHS for operational use. Given interest and the availability of national N2k data, a similar analysis could be done in some other EU member state or even across the EU. A similar analysis could also be done outside Europe in any location where there are spatial data about the distributions and condition of relevant habitat types.

2. Methods

2.1. *Spatial prioritization and identification of management landscapes*

The spatial priority ranking utilized here was developed using the Zonation framework and software (Moilanen et al., 2005, 2009, 2011a,b). This approach computes a complementarity-based priority ranking based on principles that can be summarized as maximal retention of weighted range-size corrected feature richness (Moilanen et al., 2011a). Expanding this somewhat involved characterization, Zonation starts from the assumption that the best possible situation is to protect, or by analogy manage, all of the landscape, which here consists of the N2k habitat areas. Then, spatial units (grid cells) are iteratively removed from the landscape, at each stage minimizing loss of conservation value. In this process least valuable grid cells are removed first and most valuable last, thereby producing the ranking. During the ranking process, Zonation accounts for the fraction remaining and fraction lost for the distribution of each feature influencing the ranking: the value of the remaining occurrences go up when the distribution shrinks. This range-size normalization maintains a balance between all features all through the ranking. Relevant ecological factors such as connectivity and uncertainty in inputs can be accounted for in the ranking. Further details of Zonation analyses and applications in different environments are summarized in recent publications and references in them (Carroll et al., 2010; Moilanen and Arponen, 2011; Moilanen et al., 2011a,b). Fig. 1 summarizes the main components and the flow of the present analysis.

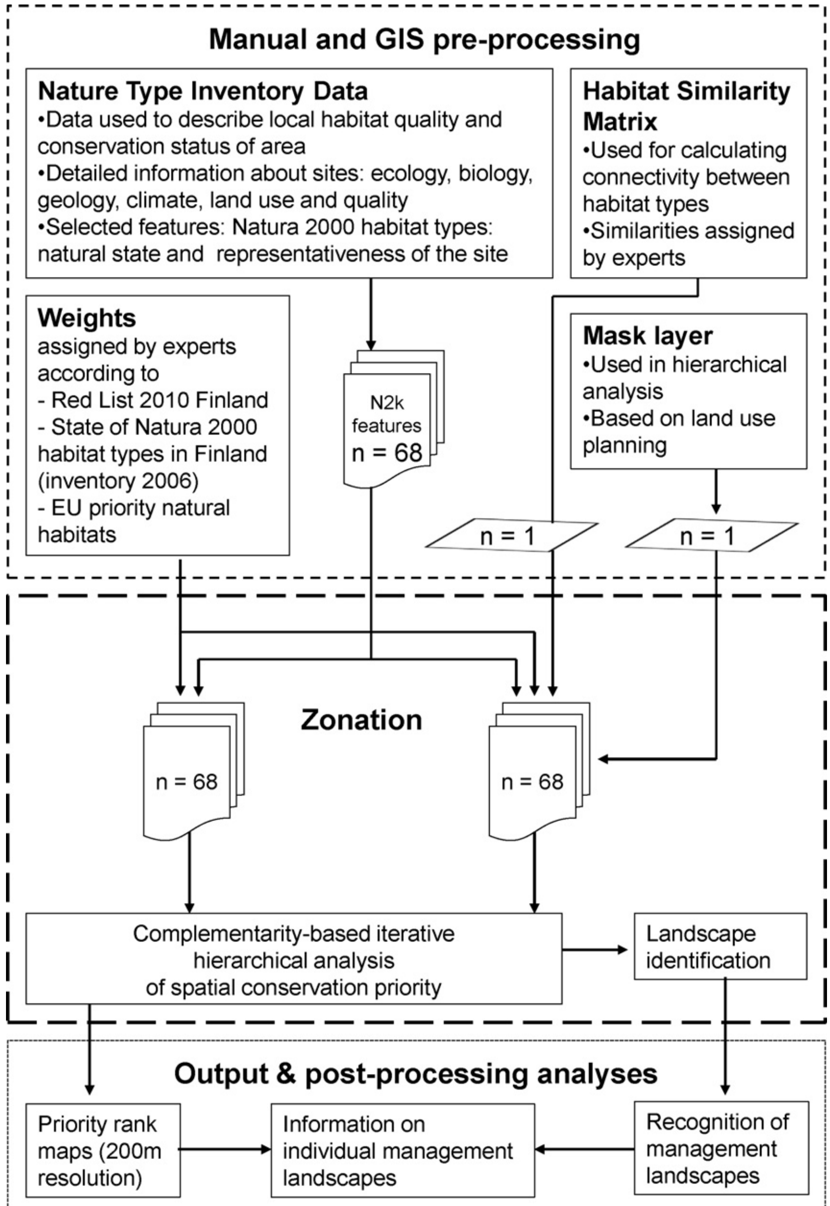

Fig. 1 – A schematic summary of the analysis.

It is relevant for the present purpose that Zonation rankings support various functions of reserve network design and analysis. The top fraction of the priority ranking includes best areas for the full set of biodiversity features entered into analysis. Also utilized here is a hierarchical ranking, in which two or more hierarchy levels are enforced into the solution. Here, the hierarchy was used so that highest ranks were forced to strictly protected areas (36% of study area), second highest ranks to wilderness or similarly managed areas (52% of study area), third highest ranks to recreational outdoor areas (4% of study area), and lowest ranks to the rest of the landscape (8% of study area). This kind of ranking can help in the evaluation of conservation areas and in the design of conservation area expansions (Leathwick et al., 2008; Lehtomäki et al., 2009). Here, hierarchical analysis was used to identify highest-priority N2k areas that were not strictly protected. Effectively, a gap analysis is done: features that are poorly represented in existing protected areas receive increased priority in the expansion of the network.

Connectivity is a relevant factor for any high-resolution spatial analysis, fundamentally because small spatial units are not ecologically independent from their neighbours. As the present analysis was done in terms of habitat types, it was desirable to use a form of connectivity that is relevant for the connectivity between several partially similar habitat types (Lehtomäki et al., 2009; Arponen et al., 2012). In terms of the present analysis, individual N2k habitat types belonging to the same Nk2 major habitat category should all help each other's connectivity – e.g. nominally different forest types are not completely dissimilar ecologically. While different forest types would have relatively high similarity, a peatland and a coastal dune would be completely dissimilar. The finer the division to habitat types the greater the similarities between the types. This way of modelling connectivity requires specification of both relevant spatial scales and pair wise similarity coefficients between habitat types (Lehtomäki et al., 2009).

Following spatial prioritization, management landscapes were identified using the method of Moilanen et al. (2005), which looks for ecologically similar sets of patches that are spatially close to each other. The interpretation of ecologically similar and spatially close can be tuned by algorithm parameters. Here, landscape identification was applied to the top 30% fraction of the landscape, as determined by the prioritization rank map. We used four different sets of algorithm parameters to identify management landscapes from the south (1), north (1) and archipelago (2). This was because the Finnish conservation area network is very fragmented in the South whereas in the North most of the land is conservation areas or wilderness areas managed by the NHS. Therefore, the operationally relevant definition of proximity differs between South-Finland and North-Finland. Following the parameterization of Moilanen et al. (2005), we specify parameters as quadruples (top fraction%, minimum inclusion %, maximum distance, and minimum similarity). The interpretation of these parameters are the priority rank top fraction of interest (e.g. 10%), additional requirement for how highly ranked cells must be present in each area for it to be accepted as a management landscape (e.g. top 1%), maximum nearest neighbour distance (measured in grid cells) between spatially distinct patches and log-10 transformed mean difference in occurrence levels between features. Given in these terms, we used parameter sets (25%, 10%, 1 km, 2) for North-Finland, (30%, 30%, 4 km, 2) for South-Finland and (30%, 30%, 6 km, 2) and (30%, 30%, 8 km, 2) for archipelagos. Heuristically, these parameters identified the top 30% fraction of the landscape, with relaxed requirements for inter-patch distances in the south, and only a small effect of ecological similarity of sites. Identification of management landscapes is not an exact science; it is best seen as a convenient tool for separating ecologically or spatially distinct units from the landscape. The representation levels of features which we report for management landscapes were computed by Zonation from the original input data layers.

The analyses done here were developed in stages, starting from a non-spatial analysis with all features equally weighted. Feature weights were added next, and in the most realistic analyses both community similarity and connectivity were considered as well. Analysis outcome was at each stage checked for logical consistency, a practice that helps detect setup and data errors that may be accidentally introduced into complicated analyses. Here, we only show results only for the final analysis, not those for the development stages.

2.2. Data

Our primary input data was the official distribution information about 68 N2k habitat types that occur in areas which are managed by NHS (Table 1). These N2k habitat types cover in total 35,787 km^2, which is approximately 10% of the area of Finland. The condition of each N2k habitat type across the landscape was accounted for by converting spatially explicit qualitative information about habitat representativeness and naturalness. If the habitat was recorded to be in ''excellent'' condition locally, the occurrence level of the feature in the grid cell was set to 1.0; sites in ''good'' condition were given a local occurrence level of 0.7, and sites that were degraded but retained some representative habitat values were given a local value of 0.4. Degraded N2k habitats that no longer were significantly representative were allocated a low local occurrence value of 0.2 – these areas nevertheless are recorded as N2k habitat so a complete lack of local quality would have been inappropriate. While these numbers are by necessity subjective, they capture the fact that N2k habitats exist in states ranging from heavily impacted to practically pristine. The original N2k data was stored in a polygon-type database, which was initially sampled at a 25 m spatial resolution to produce high-resolution raster maps about the distributions of N2k habitat types. To facilitate analysis, this data was aggregated up by summation to a 200 m × 200 m grid resolution, resulting in a data set with approximately 1 million grid

Table 1 – Characterization of major N2k habitat categories in Finland. Parentheses are used in cases when numbers vary for the individual habitat types inside the main category. First column: number of habitat types belonging to major category. Second, area (km^2) and the respective coverage (%) of N2k areas. Third, percentage of area with highest conservation status in each category according to classification in hierarchical mask analysis. Columns 4–6 are the key elements of priority weight calculations, with higher values indicating higher priority. (CS): mean conservation status of habitat types (scale 1–3), (EU): mean EU priority (1 = normal status, 2 = EU priority in Finland) and (BD): biodiversity status of the major habitat class (scales 1–3). We used the same BD for every N2k habitat type belonging to the same major category. The last column gives the final priority weight received by the habitat type. Full information for all 68 N2k habitat types is given in Supplementary Table1.

Major habitat categories	Habitat types	Area, km^2	Con %	Key elements of habitat weights			Weight
				CS	BD	EU	
Coastal and halophytic habitats and dunes	20	104 (0.3%)	26	2.10 (1–3)	1	1.20 (1–2)	0.158 (0.125–0.333)
Freshwater habitats	7	4516 (12.6%)	44	2.00 (1–3)	1	1.00 (1)	0.429 (0.286–0.571)
Heaths, scrubs and grasslands	11	10 (0.03%)	47	3.00 (3)	2	1.36 (1–2)	0.448 (0.267–0.667)
Alpine	7	11,967 (33.4%)	14	1.29 (1–2)	1	1.00 (1)	0.327 (0.286–0.429)
Raised bogs, mires and fens	9	10,327 (28.9%)	49	2.22 (2–3)	1	1.56 (1–2)	0.357 (0.214–0.571)
Rocky habitats	3	602 (1.7%)	22	1.33 (1–2)	1	1.00 (1)	0.777 (0.667–1.000)
Forests	11	11,962 (33.4%)	45	2.09 (1–3)	3	1.55 (1–2)	0.455 (0.294–0.588)
	68	39,488 (110%)					

cells of information. Note that this summation retains all information present in the original 25 m cells, except for the spatial location of each small cell inside the bigger 200 m cell. Thus, aggregating up to 200 m resolution did not cause any significant loss of information.

Feature weights which are an integral component of Zonation analyses were here defined as a combination of three factors, the biodiversity of the habitat type, the conservation status of the habitat in Finland and the EU-level priority of the habitat (Table 1). These three factors were translated into a numerical form and converted into a relative weight for each 68 habitat type (Table 1). The biodiversity weight (BD) was based on the Finnish ''Red book'', scaled by the portion of threatened species that use that particular habitat as their primary habitat (Rassi et al., 2010). Biodiversity weights were given to each major N2k habitat class so that priority increased with the number of threatened species. Major classes with more than 30% of all species threatened got weight 3, major classes with between 20 and 30% of threatened species got weight 2, and major classes with less than 20% of threatened species were assigned value 1.

The conservation status (CS) of habitat types was taken from the Finnish national report to the EU commission about the implementation of Habitats Directive in Finland (Finnish Ministry of Environment, 2007). According to EEC directive 92/43/EEC, this report that is about the evaluation of the conservation status of N2k habitat types has to be delivered to the EU commission every 6 years. If the conservation status of certain habitat was *bad* or *not known*, the habitat was given weight 3; if the conservation status was *insufficient*, weight 2 was used; if the conservation status was *favourable*, the weight was set to 1. The final component, EU-level priorities (EU) of habitats, were set so that a relative weight of 2 was given to those N2k habitats that are classified as *priority natural habitat types*; these habitats are endangered and the EU has special responsibility for them (92/43/EEC; Airaksinen and Karttunen, 2001). All other habitats had EU priority 1.

Specifically, feature weights were computed as follows: first, each N2k major habitat category (including several individual habitats) was assigned an aggregate weight of BD + CS, where BD and CS are the species richness and threat components (Table 1) – the threat component was in fact treated as specific to individual habitat (Supplementary Table 1). Next, the aggregate weight was distributed to the individual habitat types inside the major category: weights were distributed equally except that EU priority habitats were given double weights. Table 1 summarizes weights for the 7 major N2k habitat categories in Finland. Full information for all 68 individual habitat types is given by Supplementary Table 1; from this table it is apparent that weights vary both between and inside major habitat categories.

It is relevant to account for the similarities between habitat types in spatial prioritization (Arponen et al., 2008; Leathwick et al., 2010; Moilanen et al., 2011b). For example, two nominally different peatland types could share a large number of peatland species. Here, similarities between habitats were accounted for in connectivity computations according to the method of Lehtomäki et al. (2009) using a mean spatial scale of 2 km. The pair wise similarity matrix between habitat types was developed in collaboration with experts from the Finnish environmental administration (Supplementary Table 2). These similarities provided in this table provide a first-order correction to the fact that nominally different habitat types are not necessarily ecologically fully dissimilar and independent.

One further input layer was needed to facilitate the hierarchical analysis across areas of different conservation status. This so-called mask layer had 4 levels that correspond to the level of legal protection these areas enjoy in Finnish legislation. Strictly protected areas including national parks were given the highest mask level, 4. Lower levels of protection (mask levels 3, 2, and 1) were given to wilderness areas, recreation areas or national hiking areas. Spatial prioritization can be made to conform to this hierarchy.

3. Results

Fig. 2 shows the spatial priority ranking for the N2k network of Finland. This analysis was done in two major variants: either ignoring or accounting for the present conservation status of habitats. Fig. 2A shows the analysis when conservation status is not accounted for. The highest-ranked areas of this prioritization are the areas of Finland that contain a balanced set of rarest N2k habitat types in the most pristine state. These areas and their neighbourhoods are areas of high conservation relevance in terms of habitat maintenance and possibly habitat restoration. The lowest-priority parts of this ranking include areas that hold relatively widespread Nk2 habitats in variably degraded condition.

Fig. 2B shows the hierarchical priority ranking of the N2k network, accounting for conservation status. In this analysis the ranking is produced in stages, with lowest ranks going to least protected areas within N2k habitats, next highest ranks go to areas that have a higher degree of legal protection, and highest ranks go to N2k areas that already are under strictest protection. This analysis is informative about at least two items of interest: first, where are the highest-priority areas of the present protected area network, and second, where are the highest priorities in less protected areas?

On their own Fig. 2A and B provides information about priorities, but this information lacks quantification about how different low-priority and high-priority areas are. The difference between best and least significant parts of the landscape could be small or it could be huge – this information is not conveyed by the priority map itself. Consequently, these maps should be interpreted in conjunction with further quantitative information. The performance curves of Fig. 2C and D provide such information. From these curves it is possible to read the mean fractions of main habitat categories included in any top or bottom fraction of the landscape. For example, the top 25% of the landscape includes on average approximately 90% of the quality-corrected distributions of all Finnish N2k habitat areas. This result implies that many Finnish N2k habitats have narrow distributions that can be almost fully protected within a relatively small amount of land. In comparison, the curves for the hierarchical analysis look rather different. These curves reveal, for example, that there are some N2k habitats that completely occur outside strictly protected areas. It is also shown that some N2k main habitat categories have a less than 20% protection level inside strictly protected areas.

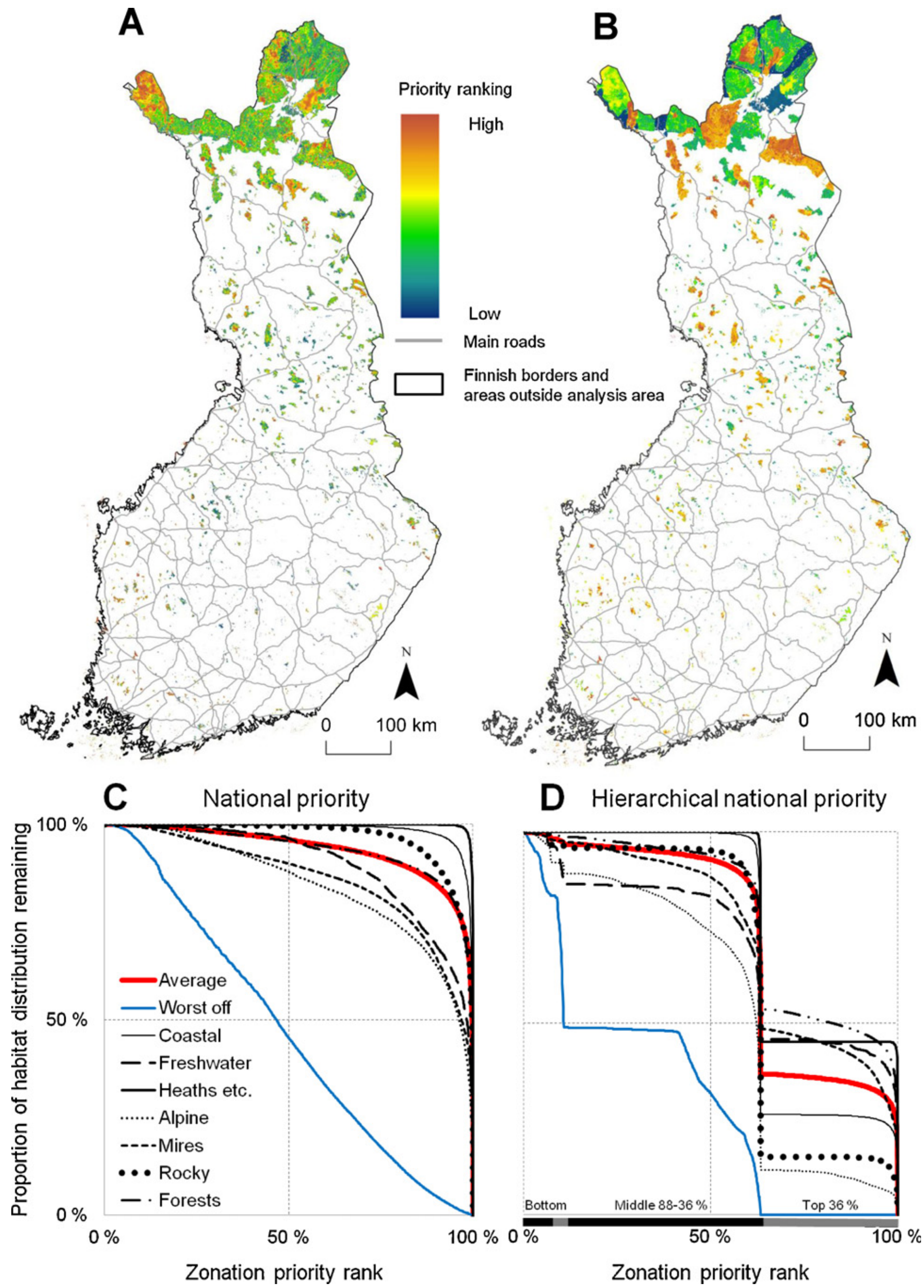

Fig. 2 – Zonation main outputs. (A) National priority map, (B) hierarchical national priority map with highest priorities forced to present protected areas, and (C and D) the respective performance curves showing the mean fractions of N2k main habitat categories (*y*-axis) included in different top fractions of the analysis areas (*x*-axis). In (C) and (D) the solid lines in red and blue indicate the mean and minimum performances across all 68 habitat types and their connectivity. The scale bar at the bottom of D indicates parts of the ranking corresponding to strictly protected areas (top 36%), wilderness etc. areas (middle 36–88%), recreation areas (bottom 8–12%) and other areas (bottom 8%).

Only a few percent of N2k land outside the strictly protected areas already include significant natural values, as evidenced by the steep rise of protection levels when the prioritization moves outside strictly protected areas. Table 2 gives accurate numeric information for the mean protection levels afforded for main habitat categories under different landscape top fractions. The same information for all 68 N2k habitat types is given in Supplementary Table 3.

The analysis of Fig. 2 is indicative of priority areas, but it does not fully answer the need of the environmental administration to know about priority management landscapes. A management landscape could include several

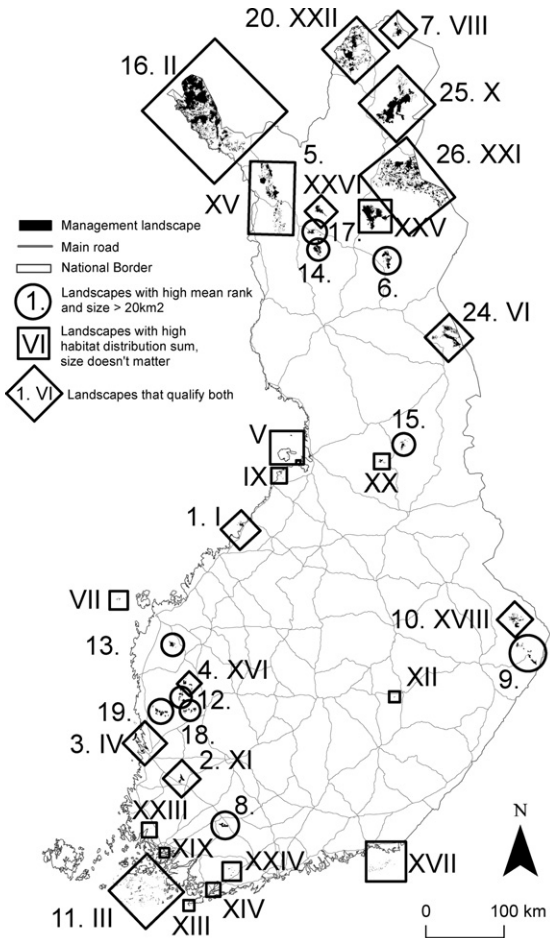

Fig. 3 – Management landscapes identified from the top 30% of analysis area. Management landscapes indicated by squares and roman numbers each hold at least the equivalent of the full distribution of one N2k habitat type, summed across the 68 habitats. Areas indicated by circles are large areas, over 20 km^2 in size, and were highly ranked in the analysis with mean rank over 0.87. Areas indicated by diamonds belong to both these categories. The numbering next to areas indicates their rank order, with highest ranked areas having smallest numbers. Further details about ten top areas are given in Table 3.

spatially aggregated patches that jointly include nationally significant values; a single small high-priority patch does not make a national-scale priority management landscape. Fig. 3 shows the result from a post-processing analysis to identify management landscapes. Two kinds of management landscapes are indicated on the map, those that are large and on average highly ranked and those that may be of any size but which include a significant fraction of the distributions of N2k habitat types. Table 3 gives information about the top ten landscapes, including selection criteria and more detailed information about what N2k habitats occur in each area and to which extent.

4. Discussion

The present analysis can be used by the Finnish environmental administration as one source of information that helps targeting of conservation effort, including habitat protection, management, maintenance or restoration. Top priority areas and habitats included in them can be identified for both the entire N2k network and for the N2k areas that already are strictly protected. These areas and their neighbourhoods are top-priority for conservation in Finland. If top-priority areas are endangered by external degrading threats, they can be targeted for habitat maintenance and/or measures can be taken to control the external threats. Areas spatially close to top-priority N2k areas are candidates for habitat restoration – the high-quality N2k core areas can likely serve as recolonization sources of endangered fauna or flora following habitat restoration. Neighbourhoods of top-priority areas could also be designated as buffer areas, where, for example, reduced intensity forestry could be practiced. The present analysis can also help administrative bodies satisfy EU regulations about satisfactory management of the N2k network. Data delivered to the NHS also included further information not shown here, including a full list of top 30 management landscapes and detailed information about what is in them (expanded from Table 3). Separate analyses and maps were provided for each N2k major habitat category. Management landscapes were additionally identified for the hierarchical analysis (not shown), thus concentrating on priority areas of the Finnish protected area network.

Table 2 – Mean representation levels (%) for the 7 main habitat categories (Table 1) corresponding to different top fractions of the N2k areas for the unconstrained (Fig. 2A) and the hierarchical analysis (Fig. 2B). For the hierarchical analysis, both the top 10% and 25% fractions are included inside the highest hierarchy level, that is, nationally strictly protected areas. Full information for all 68 N2k habitat types is given in Supplementary Table 3.

Major habitat categories	Unconstrained analysis				Hierarchical analysis			
	Top 5%	Top 10%	Top 25%	Top 50%	Top 5%	Top 10%	Top 25%	Top 50%
Coastal and halophytic habitats and dunes	95	97	99	100	25	26	26	100
Freshwater habitats	61	69	85	96	41	43	46	83
Heaths, scrubs and grasslands	100	100	100	100	45	45	45	100
Alpine	54	64	77	88	7	9	11	74
Raised bogs, mires and fens	55	66	81	90	34	40	46	88
Rocky habitats	81	90	98	100	14	15	15	95
Forests	80	86	92	96	45	48	52	94

Table 3 – The top ten management landscapes and reasons for their high rank. The numbering corresponds to that of Fig. 3. The column MR/DS indicates the mean rank and distribution sum for the area; DS sums to 136 in total, which is the number of layers in analysis. Column 50/10/1% indicates the count of features that have more than 50%, 10% and 1% of their distributions within the management landscape. Jointly, these 10 top areas (2431 km^2 in total, 6.8% of the N2k network area) include 35.3% of quality-corrected distributions of N2k habitats in Finland. In the table some habitat names were abbreviated, complete names can be found in Supplementary Table1.

Management landscape rank, name and area	MR/DS	50/10/1%	Brief characterization of the area
1. I; Vattajanniemi; 26.6 km^2	0.982 11.6	5/10/14	Finland's nationally most representative coastal and dune habitat area, with 50%+ of the distributions of five N2k types
2. XI; Puurujärvi – Isosuo National Park; 28.7 km^2	0.954 2.03	1/1/5	Includes 85% of naturally eutrophic lakes in Finnish N2k areas
16. II; Kilpisjärvi; 1870 km^2	0.877 11.07	5/11/17	Includes almost all of siliceous alpine and boreal grasslands in Finland, and 50%+ of the national distributions of four other N2k habitat types
3. IV; Coastal areas of Pori; 54.9 km^2	0.949 6.13	3/7/12	More than 75% of large and shallow bays and river deltas. Significant occurrences of coastal grasslands
11. III; Saaristomeri marine area; 77.4 km^2	0.888 6.3	1/9/18	High occurrences of esker islands, islet and small islands, various meadows, grasslands, rocky and sandy coastal habitats etc.
4. XVI; Koihna peatland; 24.2 km^2	0.926 1.7	1/1/2	Officially includes 82% of N2k type "restorable peatland". In reality, this N2k category makes little sense as there are large areas of high-quality peatlands both in and out of N2k areas
5. XXVI; Loukinen marshland area; 57.7 km^2	0.926 1.0	0/1/7	Varied high-quality mire areas, including 22% of nutrient rich spring mires
V; Hailuoto and Santapankki; 11.3 km^2	0.954 3.89	2/3/12	98% of dry sand heaths with Calluna and Genista, >50% of underwater sand dunes; different types of vegetation-covered dunes and coastal habitats
6. Luiro marshland area; 90.4 km^2	0.924 0.97	0/3/6	52% national representation for six different valuable peatland or swamp wood environments
24. VI; Oulanka National Park; 190 km^2	0.851 3.25	1/2/11	99.5% of calcareous lakes and ponds; significant high-quality representations for varied peatland, forest and meadow areas

Information about biodiversity-level priorities can also be used for planning that is not directly about biodiversity. The present analysis provides information relevant for environmental impact assessment around the national N2k network-it has been found that such assessments are in Finland somewhat compromised by a lack of data and quantitative analysis to support them (Söderman, 2009). The present analysis helps identify areas where impact assessments and avoidance of impacts can by particularly important. Tourism could be guided to or guided away from top-priority N2k areas. There may be conflicting goals when needs of biodiversity and tourism are balanced (Parolo et al., 2009).

While the present analysis is operationally relevant in Finland, it can also serve as a model for similar analysis elsewhere, in some other EU state, across the EU, or in some other region where spatial information about ecosystem types and their condition is available. With the proliferation of accessible remote-sensing data, large-scale high-resolution prioritization analyses are becoming increasingly more feasible. Analyses developing from the one done here can be implemented elsewhere using the publicly available Zonation v3 software for spatial conservation prioritization (Moilanen et al., 2005, 2009, 2011a,b). Recent analyses done using this software have been applied on raster-based landscape descriptions up to 30 million effective grid cells in size (Arponen et al., 2012), implying ability to run relatively high resolution analyses across the entire EU area, of course conditional on availability of data.

Given the complexity of the ecological world, it is obvious that any quantitative analysis of conservation priority is only a partial truth about reality, and consequently these analyses should best be viewed as one input into well informed planning (Knight et al., 2006; Pressey et al., 2007; Ferrier and Drielsma, 2010). There also are obvious ways to improve the utility of the present work beyond what is immediately relevant for the N2k habitat network. Species-based quantitative prioritization has been elsewhere applied to a N2k site network, and it could be used for complementing habitat-based approaches (Borges et al., 2005; Araujo et al., 2007). Another factor ignored here is cost-effectiveness of management, a factor known to be important for resource allocation around the N2k network (Watzold et al., 2010). If known, information about management cost can be accounted for in Zonation analyses (Moilanen et al., 2011b), and regional priorities could be accounted for as well (Moilanen and Arponen, 2011). It would also be relevant to have reliable information about the distributions of N2k habitats outside the N2k network – not all occurrences of N2k habitats have necessarily been observed and habitat outside the network may be more important for isolated sites than the network itself (Johnson et al., 2008; Mucher et al., 2009).

A degree of subjectivity in the selection of analysis features and priority weights given to them cannot be avoided. While such subjectivity cannot be completely removed, it can be alleviated by inclusion of stakeholders and experts into the planning process. In this particular case, subjectivity was significantly limited by the fact that the N2k habitat types are described in EU legislation, thereby providing a natural and limited choice of policy-relevant analysis features. Overall, we propose that the present analysis can serve as one model of how national-scale high-resolution habitat-based spatial conservation prioritization can be implemented using presently available tools for ecologically based conservation decision analysis.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2012.10.022.

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