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Background, issues and recommendations

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IMPROVING ECOLOGICAL CONNECTIVITY IN BOREAL FORESTS OF THE BARENTS REGION: BACKGROUND, ISSUES, AND RECOMMENDATIONS

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Abstract

Enhancing ecological connectivity is an important topic in biodiversity conservation and conservation planning. Assessing the importance of ecological connectivity entails examining the efficiency of natural connecting elements in the landscape (e.g. fragments of primeval forests, habitat quality, riverine corridors, and their riparian zones) for promoting connectivity between protected and otherwise valuable remaining high-quality areas. Ecological connectivity has been considered a key theme of boreal forest conservation programmes in the Barents Region. Thus, national administrative institutes such as the Swedish Environmental Protection Agency and the Finnish Environment Institute are currently developing and applying methods for connectivity analyses, and the concept is also being implemented in Russia. In the case of boreal forests, the Barents Region is a suitable reference point, covering a vast area from the Atlantic coast of Norway to the western slopes of the Ural Mountains in Russia. When promoting ecological connectivity in this area, different geographical levels should be considered, ranging from the regional to that of landscapes, and they should include considerations about methodologies and also be based on data on valuable high-quality areas for nature conservation. Interaction between different stakeholders is important and one prerequisite if recommendations to enhance ecological connectivity are to be realised as practical solutions in the field of boreal forest conservation. Overall, in-depth assessments of ecological connectivity will improve the conceptual expertise, tools, and methods that environmental administrations could use to enhance ecological connectivity, especially in the northern parts of the boreal region. This will also be important in improving knowledge about participatory processes and social sustainability in the context of ecological connectivity and in delivering the derived know-how to stakeholders and other interested people.

Keywords: Barents Region, biodiversity, conservation, forests, landscape connectivity, protected areas network.

Swedish Abstract

Att förbättra den ekologiska konnektiviteten är ett viktigt tema när det gäller bevarandet av biodiversiteten och planeringen av skyddsåtgärder. I evalueringen av betydelsen av ekologisk konnektivitet ingår att undersöka effekten av naturligt förenande objekt i landskapet (t.ex. urskogsfragment, habitatkvalitet, vattendrag och deras strandzoner) för att främja konnektiviteten mellan skyddade och annars värdefulla kvarstående områden av hög kvalitet. Ekologisk konnektivitet har betraktats som ett nyckeltema i skyddsprogrammen för de boreala skogarna i Barentsregionen. Nationella administrativa instanser, såsom Naturvårdsverket i Sverige och Finlands miljöcentral, utvecklar och tillämpar följaktligen som bäst metoder för analyser av konnektiviteten och konceptet tillämpas även i Ryssland. Beträffande boreala skogar är Barentsregionen en lämplig referenspunkt, eftersom regionen täcker ett vidsträckt område från Atlantkusten i Norge till de västra sluttningarna av Uralbergen i Ryssland. Främjandet av ekologisk konnektivitet i det här området borde beakta olika geografiska nivåer, från regional nivå till landskapsnivå. Främjandet borde innefatta resonemang om metodiken och dessutom borde det baseras på data om värdefulla områden med hög kvalitet som är värda att skyddas. Interaktionen mellan olika intressegrupper är viktig och utgör en förutsättning för att rekommendationerna om förbättring av den ekologiska konnektiviteten ska kunna förverkligas i praktiken när det gäller skyddet av de boreala skogarna. På det hela taget kommer djupgående utvärdering av den ekologiska konnektiviteten att förbättra kunskapen inom miljöförvaltningen med avseende på koncept,

verktyg och metoder som kunde användas i förvaltningens eget arbete för att förbättra den ekologiska konnektiviteten, i synnerhet i de norra delarna av den boreala regionen. Detta kommer även att vara viktigt för att höja kunskapen om delaktighetsprocesser och social hållbarhet i anknytning till ekologisk konnektivitet och när den förvärvade kunskapen förmedlas till intressegrupper och andra intresserade.

Nyckelord: Barentsregionen, biodiversitet, naturskydd, skogar, konnektivitet i landskapet, nätverk av skyddade områden.

1. Introduction to the concepts and background ideas

All ecosystems (cf. areas, localities, habitat patches, or resource patches) are dependent on a high degree of connectivity to other ecosystems to maintain the flow of organisms and to reduce the risk of local extinctions (Leibold & Chase 2018). This is typically referred to as *ecological connectivity*. Ecological connectivity can be defined as "the degree to which the landscape facilitates or impedes movements among resource patches" (Taylor et al. 1993), or as "the degree to which regional landscapes, encompassing a variety of natural, semi-natural, and developed land cover types, are conducive to wildlife movement and to sustain ecological processes" (Ament et al. 2014). Following these definitions, resource patches may also be considered as small habitat fragments in the landscape supporting certain sets of species or, at a larger scale, as larger protected areas in the matrix of managed areas. Ecological connectivity between patches is important because it determines the number of organisms dispersed between habitat patches, which thereby affects the amount of gene flow, local adaptation, extinction risk, and colonisation probability (Baguette et al. 2013). In addition, sufficient ecological connectivity is a necessary condition for species to respond to global climate change by shifting into new climatically suitable areas (Hodgson et al. 2009; McRae et al. 2012). Not only the shifting of a single species between ecosystems, but also nutrient flows, energy flows, predator-prey relationships, pollinator-plant relationships, seed dispersal, and various other natural processes are dependent on adequate ecological connectivity (Loreau et al. 2003; Ament et al. 2014).

In general, connectivity metrics include three classes, each requiring different types of information about the systems under study (Calabrese & Fagan 2004). First, *structural connectivity metrics* are based on the features of the physical landscape. These typically include the features of patches (e.g. patch size, number of patches, average distance between patches) and landscape disturbance levels (e.g. roads, urban areas, agricultural and forested land-use areas). Second, *potential connectivity metrics* are based on the landscape structure and information involving the dispersal ability of the focal species, assumed as average dispersal distance. Third, *actual, realised, or functional connectivity metrics* (each term means basically the same thing in this context) are measured based on information about the actual movements of individuals along and across the landscape connectivity features between habitat patches. In practice, ecological connectivity can be measured via numerous approaches and metrics (see Box 1) using Geographic Information Systems (GIS).

The degree to which *ecological connectivity can be realised* at local, landscape, and regional scales depends on many different factors (Hodgson et al. 2009; Doerr et al. 2011; Howell et al. 2018). These include (1) distances between habitat patches, (2) habitat patch sizes, (3) habitat patch quality, and (4) anthropogenic land use in the matrix. First, based on the ideas of Island Biogeography Theory (IBT; MacArthur & Wilson 1967) more isolated, island-like habitat patches are likely to receive a smaller number of dispersing organisms than habitat patches closer to potential colonisation sources. Second, also based on IBT, large habitat patches not only support more species *per se* (MacArthur & Wilson 1967), but they also represent better targets for dispersing organisms (Leibold & Chase 2018). However, considering only relative isolation and habitat patch size may fall short of informing us about the realised ecological connectivity between sites. Hence, third, habitat quality may be of utmost importance in the conservation of species (Hodgson et al. 2009) because it strongly affects population viability (Hodgson et al. 2011). High-quality habitat patches typically support larger populations (and provide surplus individuals), from which organisms can disperse to other patches (Leibold & Chase 2018). However, in practice habitat quality may be difficult to measure for a large number of species because each species has different resource and environmental requirements (Doerr et al. 2011), although little anthropogenic impact typically can be considered to mean a more high-quality habitat patch for most species (Hodgson et al. 2009). Fourth, anthropogenic land use in the matrix's intervening high-quality habitat patches affects the degree to which the matrix can be used as a dispersal route (or as habitat) by dispersing organisms (Driscoll et al. 2013; Erős & Campbell Grant 2015). The effects of points (1) to (4) on overall ecological connectivity may also depend on spatial scale, with habitat patch size being more important at smaller landscape scales, whereas land cover and land use in the matrix increase in importance at larger regional scales. This could result from larger spatial distances between habitat patches and the effect of the matrix at larger spatial scales, both of which affect dispersal between patches. All ideas related to the interactions among patch size, patch isolation, patch quality, and land cover features in the context of ecological connectivity are important when maintaining and enhancing the existing protected areas networks.

Ecological connectivity between protected areas has been subject to a considerable amount of research recently (Kryshen et al. 2014; Santini et al. 2015; Saura et al. 2017). This is due to the realisation that conserving only isolated fragments of natural habitats in an otherwise altered or heavily managed landscapes does not provide long-term and effective protection of biodiversity because natural flows of organisms, matter, and nutrients are interrupted (Ament et al. 2014). If such natural flows are severely prevented from occurring between protected areas, biodiversity and ecological processes will decline, causing species extinctions and altered ecosystem functions. However, local species extinctions may be detected only at longer time scales, owing to a so-called "extinction debt" (Hanski 2000; Kuussaari et al. 2009). Hence, the long-term maintenance of high levels of biodiversity and functioning ecosystems requires that the ecological connectivity between protected areas is guaranteed and, where necessary, improved by land use and regional planning initiatives (Piquer-Rodríguez et al. 2012; Santini et al. 2015).

Improving ecological connectivity through land use and regional planning is also of utmost importance due to ongoing global climate change. To be effective, protected areas networks should be able to accommodate changes in climatic conditions in the future (Aapala et al. 2017). This is important because species are moving northwards into temperate, boreal, and Arctic regions (Hickling et al. 2006; Kravchenko 2007; Heino et al. 2009; Virkkala & Lehikoinen 2014). However, the current protected areas network may not always allow the movements of species to follow spatial changes in their climatically suitable areas and/or does not provide suitable high-quality habitat conditions for species escaping warming climates from south to north and from low to high altitudes. This is because there may be large expanses of unsuitable low-quality areas, often human modified, which do not allow for the dispersal of at least some species between protected areas. It also needs to be kept in mind that even high-quality areas for some species may be totally insufficient for other species to facilitate dispersal between protected areas. Therefore, improving protected areas networks in the north may prove to be highly important in the conservation of regional and global biodiversity (Aapala et al. 2017). The connectivity of suitable habitats at large regional scales is also highly important for the maintenance of species who currently prefer these habitats (Lindén et al. 2000) and will be indispensable in the future given the changing climate and changing land use practices (Piquer-Rodríguez et al. 2012). One such area where improving the ecological connectivity between protected areas is important is the Barents Region (Kuhmonen et al. 2017).

The aim of this report is to examine the importance of improving ecological connectivity in boreal forests. Rather than showing new results, our goal is to review literature on ecological connectivity in general and experiences in the Barents Region in particular, and to extract recommendations from such findings for the conservation planning of boreal forests. We will also address issues related to improving ecological connectivity in boreal forests when it comes to policy, legislation, forest management, and conservation initiatives in the Barents Region. Finally, we will consider similarities and differences between Sweden, Finland, and Russia with respect to the potential of each country to improve ecological connectivity in the boreal forests. This report builds on a recently published account of protected areas that highlights the importance of considering ecological connectivity in boreal forests in the Barents Region (Kuhmonen et al. 2017).

This report is also related to the Barents Protected Area Network (BPAN) project, which was conducted by the Barents Euro-Arctic Council's (BEAC) Working Group on the Environment and its Subgroup on Nature Protection between 2011 and 2014. The aim of the BPAN project was to promote the establishment of a representative protected areas network in the Barents Euro-Arctic Region and to contribute to conserving boreal and Arctic biodiversity (Kuhmonen et al. 2017). The process was, in practice, conducted by nature conservation authorities, scientific institutions, and non-governmental nature conservation organisations in Norway, Sweden, Finland, and north-western Russia. The present account adds to this former report by specifically focusing on how ecological connectivity in boreal forests could be enhanced to better respond to the challenges of maintaining biodiversity and ecosystem functions in the face of climate and land use changes. Importantly, this aim is also directly connected with Aichi Biodiversity Target 11: *"By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed,* ***ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape****."* The bold-faced text in particular emphasises the importance of considering ecological connectivity as a means to improve the possibilities of protected areas networks to accommodate, adapt to, and mitigate alterations in an era of rapid environmental change (Aapala et al. 2017).

2. Features of forest use and ecological connectivity in the Barents Region

Prior to the era of increasing human impact within the last few hundreds of years, the boreal part of the Barents Region was covered by large expanses of boreal forests and associated ecosystems, providing good ecological connectivity for forest-associated biota. Since that time, increasing human impacts have decreased ecological connectivity, causing difficulties for organisms to move freely across the landscapes in the Barents Region. Kuhmonen et al. (2017) noted that it would be important to further examine how ecological corridors in the Barents Region, such as the Fennoscandian Green Belt (see Box 2), could help maintain the survival of species when environmental changes are rapid. They suggested that enlarging protected areas, increasing their heterogeneity (within and among areas), and reducing current anthropogenic pressures should be at the heart of developing present representations of protected areas (Kuhmonen et al. 2017). In addition, increasing connectivity between these protected and otherwise valuable forest areas would most likely increase the probability of the survival of species that have to shift towards north or to higher altitudes in the Barents Region in the face of climate change (Aapala et al. 2017). This would entail considering the networks of remaining high-quality forest patches as steppingstones, facilitating the dispersal of organisms and environmental flows between protected areas. These steppingstones might be further connected by natural features, such as river networks, lake riparian zones, and coastal areas (Kravchenko & Kuznetsov 2003; Kravchenko 2014). Here, we compare the forest use history and ecological connectivity among protected areas in each country (Sweden, Finland, and Russia) in the Barents Region and provide examples of and ideas about how connectivity could be improved within and among these countries.

There are certainly differences between Sweden, Finland, in Russia in terms of their current states, perspectives and aims to promote connectivity in boreal forests. Generally, in contrast to Finland and Sweden, north-western Russia still harbours vast areas of minimally disturbed forests and wetlands, and there are thus good possibilities for the establishment of new protected areas for creating a real network connected by ecological corridors. In contrast, in vast areas in Finland and Sweden protected areas and other valuable forests are merely islands in a sea of relatively strongly modified and managed landscapes.

2.1. Forest use history and ecological connectivity in Finland

In Finland, there has been a profound change in the forest landscapes and forest cover since the 1850s (Hetemäki et al. 2011). This change has been mostly due to increased forestry practices and more effective means of harvesting forests. In the 1950s, clear-cuts became the main way to practice forestry, and in the 1960s intensive forestry practices with a dense forest road network appeared (i.e., big forestry vehicles, peatland draining, and fertilisation).

The history of forest use and forestry is relatively long in Finland. Beginning in the 1850s, forestry started to develop rapidly. Between the First and Second World Wars, forestry came to account for the largest use of wood. The purpose of forests was then to produce raw material for the forest industry, and forest use thus became dependent on the development of forestry (Hetemäki et al. 2011). Until the 1950s, the main method of forest cutting was to select large-sized and good-quality trees for the purposes of sawmills, whereas smaller and poor-quality trees were left standing in the forests. When this kind of cutting was prohibited, forestry became based on different forestry practices, including logging rotation. In the 1960s, there was a move toward efficient forestry practices, which included cutting and collecting wood by vehicles, the renewal of low-productive forests, strong modification of the ground as well as regeneration of clear-cuts by planting, and the thinning and managing of young stands. Managed forests are thinned twice or three times before they are clear-cut at the age of 60 to 120 years. The purpose of thinning is to produce high-quality timber and to increase tree volume and tree growth. However, thinning prevents the formation of decaying trees in managed forests; in natural forests, trees die out as a consequence of competition between different tree individuals, whereas fallen trees are usually removed from managed forests (Virkkala & Toivonen 1999). Consequently, the volume of dead wood is very low in managed forests (<5 m^3/ha) compared to natural old-growth forests (60 - 120 m^3/ha; Siitonen 2001). In addition, draining, ditching, and fertilising were previously common practices, reaching their highest level of use in the late 1960s and early 1970s. During the same period, almost 60% of Finnish mires and peatlands were ditched. Between the 1970s and 2000s, the amount of growth and tree volume have increased tremendously in the peatlands because of the draining of mires. In addition, the forest road network has increased rapidly in extent.

Nowadays, over 90% of forests are under management in Finland (Hanski 2003; Myllyntaus & Mattila 2002; Kouki et al. 2001; Löfman & Kouki 2011; Rouvinen et al. 2002).

Slash-and-burn cultivation decreased the proportion of old-growth forests (>200 years old) to one-third in southern Finland already by the early 1800s. The density of human population and forestry in southern Finland and along the coast of the Baltic Sea resulted in the intensive use of forests in these areas. Nowadays, natural-like or near-pristine forests comprise only 0.2% of forests in southern Finland. Even in the protected areas, the proportion of old-growth forests is small, being 5.5% in hemiboreal and southern boreal zones in Finland (Virkkala et al. 2000). In contrast, in northern Finland the intensity of forestry was minor until the early 1900s, and changes in forest structure have been smaller. The proportion of old-growth forests in northern and north-eastern Finland is approximately 10% at present (Hanski 2003; Myllyntaus & Mattila 2002; Kouki et al. 2001; Löfman & Kouki 20011; Rouvinen et al. 2002).

This overall development in forestry practices has also led to the increased isolation of remaining protected areas and otherwise valuable forests. Given the fact that most of these areas are becoming even more isolated, the means to restore connectivity or to purchase remaining valuable, yet still unprotected, areas may prove to be suitable approaches to attain the best level of ecological connectivity for boreal forests in Finland.

2.2. Forest land use and ecological connectivity in Sweden

The northern part of Sweden was one of the last parts of Europe where large-scale forestry activities occurred. The forest landscapes have relatively few tree species, with Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) being the dominant species. Scots pine dominates the dry parts of the landscape, and Norway spruce dominates the moist parts. In the forests close to the Scandinavian mountains, the mountain birch is the dominant tree species and covers the lower part of the mountains with pure forests. When the forest inventories started in Sweden in 1925, Norway spruce was the most common tree species in pure forests. The forestry activities have, in the 1900s, increased Scots pine forests because forest companies believed this species is more productive. Norway spruce forests have decreased from approximately 23% to 20% and Scots pine forests have increased to 50% due to these forestry activities.

Human impact on the Swedish forests has a long history. The first humans arrived in the north of Sweden when the ice first melted after the last Ice Age. Even during those early times, the small human populations had a reduced impact on the forests, but some archaeologists speculate about larger human impacts due to forest fires (Hörnberg et al. 2006). The first proper human forest activities began in the 1600s; however, this occurred at a small scale (Zackrisson 1978; Niklasson & Granström 2000). More comprehensive industrial forestry practices began in the 1700s in association with the ironworks close to the coastal areas (Norberg 1958) and the arrival of the first small sawmills. Forestry activities were restricted by transportation problems in the beginning. Later, transport in the form of floatways facilitated the transport of logs and led to the expansion of forest activity from the coast to western parts of Sweden. The first cutting activities focused on extracting the largest and more valuable trees (Wik 1950). In the 1900s, the forests, especially along the coast, had already been cut down and only lower quality trees were left in the forests. Also, at this time the papermills became common and used the remaining lower quality trees.

In the 1950s, modern forestry practices began with the clearcutting of forests. The result was even-aged forests, which made the silvicultural management of such forests easier. Low productive forests or areas difficult to cut were left untouched. The forest landscape became more even-aged, with a higher proportion of young forests. The numbers of old big trees diminished. Deadwood in the forest is approximately 7 m^3/ha over 10 cm in diameter that can be related to over 27 m^3/ha, but it was not unusual to have 60 m^3/ha of deadwood in the older forests (Linder et al. 1997). The clearcutting silvicultural management practices resulted in a mosaic forest landscape in which younger forests are more common that older forests. That has resulted in a fragmented habitat for species that are dependent on old forests and on continuous forest cover.

The largest threats against green infrastructure and, in addition, the connectivity of the forests in the north of Sweden are as follows: fragmentation of the forests, cutting of the continuous forests, a lack of deadwood, reduced forest-fire continuity, and fewer deciduous forest. However, the north-western parts of Sweden still include areas spared from modern forest activities; these areas belong to the green belt of Scandinavia. Though the green belt includes large protected areas, they are located close to the mountains and are at relatively high elevations in the landscape. This landscape should facilitate ecological connectivity from south to north in Sweden. Otherwise, the rest of the landscape will be quite perturbed, though some remaining forest landscapes show possibilities for acting as a means of improved ecological connectivity. On the other hand, there are landscapes in which ecological connectivity is poor precisely because the landscapes have lost a high amount of forest habitat. However, there are still some landscapes with continuous forests that provide possibilities to facilitate ecological connectivity in otherwise perturbed landscapes. These landscapes have some connectivity in the west-east direction, but most likely Sweden will need to protect the remaining high value forests and do some restoration efforts in the future to ensure the best possible levels of ecological connectivity.

2.3. Protected areas and ecological connectivity in Russia

In Russia, there are still large areas of pristine or near-pristine boreal forest left in the Barents Region, which presents a brighter situation for forest biodiversity and its conservation compared to Finland and Sweden. However, the establishment of new protected areas is not easy, even in Russia, because they can be established only in accordance with programmes approved by the Russian state authorities. Therefore, the planning of new protected areas is feasible only in cases where such plans are already included in the programmes of the Russian government (federal PAs: strict nature reserves and national parks) or the regional governments (regional PAs: nature parks, nature reserves, and natural monuments). In practice, the most realistic way is to recommend creating relatively small-sized regional protected areas, like nature reserves and especially natural monuments in the hotspots important for increasing ecological connectivity between the existing protected areas. There are also other possibilities for promoting ecological connectivity between protected and as yet unprotected areas with high conservational value in the Barents Region. For example, this could mean "protective forests", a special category of forests in Russia which serves to protect natural watersheds, including lentic and lotic ecosystems.

Scientists from research centres in the republics of Karelia and Komi, the Arkhangelsk and Murmansk regions, and St Petersburg (Bogolitsyn et al. 2011) have all suggested creating four green belts as key elements of the protected areas system in north-western Russia and northern Europe. All of them include the last remaining large massifs of primeval forests and stretch in the meridional direction. It is quite probable that in the coming decades, outside the current and planned protected areas, more and more forests will be cut down or become more fragmented. In connection with this development, researchers have suggested giving these forests priority when organising protected areas networks. Historically, all the green belts are located near the administrative boundaries of the Russian Federation.

The Green Belt of Fennoscandia (GBF) is the only one located along a state (between Russia, Finland, and Norway) border. It is a line (an average width of 50 km on the Russian side) with several large (up to 200 000 hectares) fragments of well-preserved forests in national parks and primeval forests in strict nature reserves (Box 2). This belt stretches along the Murmansk, Karelian and Leningrad parts of the Russian-Norway and Russian-Finnish border, with the background of fragmented territories being deeply transformed by economic activity. The key areas (the largest and the most important for connectivity) among already existing protected areas of the GBF in the Russian territory are as follows: a) in the Murmansk Region, the state strict nature reserve "Pasvik" (14 700 hectares) and the state landscape (integrated) reserve (LR) "Kutsa" (48 600 hectares); b) in the Republic of Karelia, national parks (NP) "Paanajärvi" (104 500 hectares), "Kalevala" (74 500 hectares) and "Ladoga Skerries" (c. 122 000 hectares), the state strict nature reserve "Kostomuksha" (47 500 hectares), LR "Voynitsa" (8 300 hectares), "Tolvajärvi" (42 000 hectares), "ISO-Iijärvi" (6 000 hectares) and the "Western archipelago" (19 500 hectares); and c) in the Leningrad Region, the state strict nature reserve "East of the Gulf of Finland", LZ "Ptich'i ostrova" (55 300 hectares), "Vyborg" (11 300 hectares), "Gladyshevsky" (8 400 hectares), "Ridge Vyaryamyanselka" (7 300 hectares), "Rakovye ozera" (9 700 hectares), and so forth. The total area of the GBF's protected areas is close to 1 million hectares in Russia.

The White Sea-Onega Green Belt (WSOGB) is much more important from a biogeographical standpoint because it ranges along the border of Fennoscandia and the Russian plain, and moreover, it protects biogeographical corridors connecting Fennoscandia with other European territories (Lindèn et al. 2000; Курхинен и др. 2009). The WSOGB is connected to the GBF via the Lapland Strict Nature Reserve in the north and by protected forests in the Onega-Ladoga system, including the Nizhne-Svirskii Strict Nature Reserve. The key reserves (the largest and most important with respect to connectivity) among the already existing protected areas of the WSOGB are as follows: a) SR "Laplandskii" along the coast of the White sea – LZ "Colvitsky" (43 600 hectares), "Kenozersky" (65 700 hectares), "Poliarnyi krug" (28 300 hectares), "Gridino" (43 800 hectares), "Syrovatka" (31 400 hectares), "Kuzova" (3 600 hectares), "Soroksky (73 900 hectares), and the SSR "Kandalaksha" (70 500 hectares); b) along the border between the Republic of Karelia and the Vologda and Arkhangelsk regions – NP "Vodlozersky" (468 300 hectares), "Kenozersky" (121 000 hectares), LZ "Kozhozersky" (201 600 hectares), "Onezhskii" (25 300 hectares); and c) along the border of the Vologda and Leningrad regions – Nature Park "Vepskii les" (190 000 hectares), and in the Vologda region – NP "Russkii Sever" (166 000 hectares). The total area of the WSOGB protected areas is more than 1.5 million hectares.

The next area to the east is the Timan-Pechora Green Belt (TPGB). Here, one can find the largest areas covered by primeval forests in all Europe. Vast tracks of pristine taiga with a variety of clearings and secondary forests of different ages are located between the Northern Dvina and Pechora River. The most valuable part of the territory with primeval forests belongs to the Timan Ridge on both sides of the border between the Arkhangelsk region and the Komi Republic. The TPGB is not yet organised in environmental terms. The Arkhangelsk region, near the border with the Republic of Komi, includes the following reserves: LZ "Verkolsky" (46 500 hectares), "Puchkomsky" (12 000 hectares), Uftiugo-Ileshskii` (78 700 hectares), and the biological reserve "Surskii" (13 500 hectares). The middle of this planned belt includes the state strict reserve "Pinezhsky", with unique ecosystems in the karst landscapes. In the Republic of Komi, in an effort to save the intact forests of high conservation value inside the TPGB, the following protected areas have been established: LZ

"Udorskiy" (242 000 hectares), "Puchkomski" (24 000 hectares), "Pyscskii" (60 000 hectares), "Sodzimskiy" (33 000 hectares), and "Ezhugskii" (46 hectares). Most of these reserves are located along the river basins and have an elongated form.

The Ural Green Belt (UGB) stretches in the meridional direction along the eastern border of the Komi Republic through the foothills and western slope of the Ural Mountains. Europe’s largest massifs of primeval taiga can be found in the UGB. A considerable part of the UGB is located within the largest national park in Russia, "Yugyd VA "(1 892 000 hectares), as is also "Pechora-Ilych " Strict Nature Reserve (723 000 hectares) and its buffer zone (497 500 hectares).

The green belts that have been developed and that are being developed in northern Europe represent a ready basis for the creation and development of a common inter-regional ecological system. The disadvantage is that they extend mainly in the meridional direction and are too isolated from each other to form a complete system, which would require directly connecting these belts. There is also an obvious need to justify and create new protected areas that make up a chain stretching in the latitudinal direction. A structure is already in place in the Arkhangelsk Region comprising a number of seaside PA (LZ "Primorskii" and "Mudyugskii" and the biological reserves "Dvinskoi", "Belomorskii", "Unski", and LZ "Soyanskiy").

Among the most urgent and still unresolved problems regarding the protection of natural complexes in the south-eastern part of Fennoscandia is the development of effective conservation measures in Europe's largest water system, comprising Lake Onega, the Svir' River, Lake Ladoga, the Neva River, and the Gulf of Finland. It also includes Lake Ilmen together with the Volkhov River, Lakes Chudskoe and Pskovskoe, the Saimaa lake system in Finland, and the Vuoksa river system in the Karelian Isthmus. This array of water systems, with its established natural complexes and processes, connects the GBF and WSOGB, and it flows between the ecosystems of six administrative regions of the Russian Federation and Finland. In this case, it is necessary to mention the importance of water protected areas and forests on the Russian side of the border. Water protection zones are very effective in terms of connecting green belts in the western part of northern Europe, where the hydrographic network is strongly developed. The forest environment has often been preserved around water protected areas for many years. These zones may well be considered ecological corridors connecting individually protected areas. They ensure the migration and movement of animal and plant species and the sustainable existence of their populations (Kryshen et al. 2014).

3. Practical issues related to improving ecological connectivity in the Barents Region

There are a number of major issues that affect the improvement of ecological connectivity in the Barents Region, and these issues are not mutually exclusive but rather act in concert. In the following section, we will consider legislation, forest management, and conservation initiatives when it comes to improving ecological connectivity and enhancing the representativeness of the protected areas network in the Barents Region. Here, we summarise these issues by country.

3.1. Issues in Finland

At present, the protected forest area in the whole of Finland is estimated to be 2.7 million ha, or 12% of the forest area (https://www.luke.fi/uutiset/metsapinta-alasta-suojeltu-12-prosenttia/). The protected forests comprise forests protected by law and biodiversity hotspots in managed forests. Legally-protected forest areas comprise 2.4 million ha, and biodiversity hotspots in managed forest comprise 0.3 million ha. However, these overall estimates are misleading, and corrected estimates for protected forests are approximately 5.7% of productive forest area (http://www.luontoliitto.fi/ajankohtaista/tiedotteet/luonnonvarakeskuksen-tuoreet-tilastot-liioittelevat-suojeltujen-metsien-maaraa). Other estimates have shown that almost half of the protected forests, i.e. 1.07 million ha, are poor-quality scrubland in terms of tree growth (annual increment between 0.1 and 1.0 m^3/ha), such as sparse pine mires and mountain birch woods near the tree line, and approximately 43% of the scrubland is protected. Of the productive forest land in Finland (annual increment >1.0 m^3/ha), only 6.6% (1.33 million hectares) is legally protected, but restricted cuttings are allowed in some of the areas so that only 5.7% of productive forest land is strictly protected (see above). In Finland, most protected forest areas are in the northern part of the country, i.e. in Kainuu, northern Ostrobothnia and Lapland (7.5% of forest land), whereas forests in the southern part of the country are less well protected (only 2.3% of forest land).

In addition to the small areal extent of protected forests, the current state of ecological connectivity between the protected areas is poor. Old boreal forest species live more or less in the last sanctuaries or old focal areas, and there can be ten times more red-listed species living in areas that are well-connected than in the highly fragmented surroundings (Nordin et al. 2013). Exceptions can be found close to the eastern border of Finland, where rare boreal forest species still can be found (Kouki et al. 2012). However, it is not clear whether these findings are signs of sink areas for forest species or if these species were there originally, comprising everything that is left of rare forest species in Finland.

Because of strong industrial pressure due to the bioeconomy boom in Finland, logging rates have increased to a level where they are close to the maximum sustainable level, even when based only on forestry practices. Large parts of the cut forests comprise old-growing trees, which leads to a decline in many wood-inhabiting species (Berglund et al. 2011; Luontotyyppien Uhanalaisuus 2018, http://urn.fi/URN:ISBN:978-952-11-4816-3). The amount of old-growth forest is getting smaller and there will be practically nothing left of these forests (older than 120 years) by the end of this century, other than those in conservation areas, if forestry practices continue as before (Fayt 2018). In northern Finland, the proportion of forests older than 120 years declined from 55% to 17% between 1924 and 2013 due to logging (Fayt 2018).

There are several aims to promote ecological connectivity in boreal forests. Foremost among these are the METSO programme, the Nature Act and the Forest Act (10§). However, these can help only somewhat to achieve the 17% target for conserving habitats (The Aichi Biodiversity Target 11). The METSO programme is based on voluntarily contributions, and landowners are paid for the loss of profits. This system is insufficient because of the small budget and small targets: the entire programme only targets 100 000 ha for permanent conservation and 100 000 ha for the maintenance of natural characteristics. These figures should be compared with additional bioeconomy-boosted forestry cuttings yearly, which are at least 50 000 ha (assuming 300 m^3/ha cut).

The Finnish Forest Act (https://www.finlex.fi/en/laki/kaannokset/1996/en19961093.pdf) lays out a number of important points directed at the conservation and preservation of forests. These include, in general, the preservation of forest biodiversity and habitats of specific concern. More specifically, the act says that forests should be managed such that the requirements for the existence of biological diversity are guaranteed through the preservation of important habitats of up to one hectare. In this context, such habitats exist in a natural state or close to it, and they can be easily distinguished in the forest landscapes. Their typical features include the following:

(1) surrounding springs, brooks, and rivulets, as well as ponds less than 0.5 ha in area. These surroundings typically include specific environmental features in terms of microclimate and water economy;

(2) certain types of mire habitats demonstrating a natural or natural-like water economy;

(3) patches of herb-rich forests, the features of which include brown soil, characteristic vegetation, and natural or near-natural tree canopy and shrub vegetation;

(4) patches of mineral-soil forests located on non-ditched peatlands;

(5) deep ravines or gullies in the bedrock or soil, the vegetation of which differs from the surrounding vegetation;

(6) the forests beneath more than 10-metre high cliffs, the forest vegetation of which is distinct; and

(7) sandy and rocky areas, which are less productive than *Cladonia*-type forests.

While the Finnish Forest Act (as well as the Finnish Nature Act) focuses on the preservation of small core areas where these specific forest habitat types occur, it remains silent about the ecological connectivity of these habitats. Given that each forest habitat type harbours at least partly different sets of species, it should be a major aim to guarantee that ecological connectivity for each habitat type is included in future forest legislation in Finland.

It must be remembered that the occurrence of valuable forest types (*cf.* also habitat quality) is a local-scale phenomenon, whereas connectivity entails movements between patches of different quality and is basically a regional-scale phenomenon (see also Leibold & Chase 2018). However, in practice these habitat quality and regional dispersal phenomena cannot be separated, as they affect each other, with high-quality patches providing more dispersing organism and thus affecting the dispersal between patches. Therefore, in Finland legislation and practical conservation and forest management approaches should recognise the need to consider both phenomena when planning the location of new protected areas. Even though the focus of the Finnish Forest Act is on small-scale habitat features, the same issues regarding the importance of ecological connectivity are also relevant for larger protected areas.

In the METSO programme, the main focus is on high-quality forest areas (i.e. METSO I class). However, if the focal forest area is of lower quality but has high connectivity (usually identified from forest biodiversity value maps made with spatial conservation prioritisation Zonation software (Moilanen et al. 2014)), serious consideration should be given as to whether to include it in the programme. Previously, before the present minimum conservation budget, considering connectivity was a rule of thumb, but nowadays criteria for purchasing the areas for permanent conservation have more stringent (Syrjänen et al. 2017).

3.2. Issues in Sweden

In Sweden, environmental work is based on international agreements. The most important for the work with ecological connectivity is the Nagoya Agreement, with the respective 20 Aichi goals. The European Commission resolved in its 2011 strategy to meet the Aichi goals through six strategies. The strategy also includes the goal of prioritising green infrastructure (directly linked to connectivity). Such work will take place at the local, national, and international levels. By the year 2020, the green infrastructure should contribute to the preservation of ecosystems and ecosystem services. The Swedish parliament established a strategy for ensuring biodiversity and ecosystem services (Regeringens proposition 2013/14:141. Svensk strategi för biologisk mångfald och ekosystemtjänster). The strategy mentions that the work should be based on green infrastructure and landscape perspectives. In addition to the green infrastructure approach, Sweden works with environmental goals, 28 of which have been devised to address the priority of ensuring biological connectivity. The strategy also highlights the importance of ensuring biological resilience, the value of preserving biodiversity, endangered species, and biotopes, and need to increase knowledge about genetic diversity. Further, four phase goals were decided upon in 2014, with the aim of speeding up the process of achieving the environmental goals. They include areas linked to ensuring biological connectivity, such as adopting a holistic view of land use, protecting land areas, addressing environmental concerns related to forestry practices, preserving varied silvicultural management, and promoting a dialogue process as part of the national forest programme.

Regarding the situation with forests, Sweden has the environmental goal of maintaining "living forests". One of the principal aspects of this goal is to identify landscapes with high biological values at a landscape level, called "tracts". These tracts should be areas with high concentrations of biological value. They should, if possible, maintain metapopulations and meet requirements regarding areas with high-value forests and ecological connectivity inside the tracts. To ensure such connectivity, the tracts should comprise the beginnings of a green infrastructure, but the tracts should even have some connectivity between them as well.

To help establish the tracts, the Swedish Environmental Protection Agency has done some connectivity analysis based on graph theory. The results help the various counties have a more national point of view regarding ecological connectivity (Metria 2017). This even avoids the problem of edge effect, namely the lack of relevant data from the surrounding counties. The analysis has been done at a large landscape level, but some of the counties have done regional analyses for a more detailed view of the connectivity within a region. The county of Västerbotten works using graph theory to do connectivity analysis focused on a stepping-stone approach to analyse the whole county (County Administrative Board of Västerbotten 2016). It even started analysing the situation in detail and focused their efforts on analysing connectivity inside the tracts while taking “barrier effects” into better account.

The national strategy for forest protection 2017 (Swedish Environmental Protection Agency 2018) notes in particular the need for cooperation between the different actors in the Swedish forestry industry in protecting Swedish forests. This cooperation should result in formal protected areas, voluntary protected areas, environmental considerations for silvicultural management, and regeneration methods that improve the green infrastructure. The voluntary protected areas are a key factor in the strategy, and efforts to maintain them are fundamental to a working forest protection strategy in Sweden. The forestry companies have even protected landscapes that are fundamental for the establishment of the tracts mentioned above.

In the strategy, landscape is considered at a management level. The action plan for green infrastructure takes regional aspects into account with the help of national guidelines to harmonise the work. Biodiversity is an important part of green infrastructure work, and likewise functional ecological networks of habitats should permit the use and management of the forests in a way that promotes biodiversity in the whole landscape. The action plans establish activities for work in the forest sector that take into account considerations about green infrastructure and ecological connectivity. Another aspect of the strategy is ecological landscape planning, according to which forestry companies concentrate on achieving biodiversity goals and practicing good biodiversity management. These ecological landscapes can be between 5 000 and 25 000 hectares, in which a part of the forest is excluded from the forestry activities. In addition, silvicultural management practices seek to improve, for instance, the connectivity between ecological landscapes.

Private forest owners who do not have large forest areas normally use a green silvicultural plan. The forest and the most valuable parts of it are described in the green silvicultural plan. These high-value forests are considered normally in terms of voluntary forest protection. This green silvicultural plan can even be used as the basis for certifying particular actions in the forests.

3.3. Issues in Russia

At present, the different categories of "protective forests" in Russia total approximately 2.8 million km^2, i.e. approximately one-fourth of the total forest-covered area or 16.5% of the entire territory of the Russian Federation (Kobyakov & Titova 2017). Given their large spatial coverage and widespread occurrence in all Russian regions, protective forests could play an important role in connecting protected areas, e.g. they could provide contact zones or ecological corridors between individual parts of many protected areas and other natural sites.

The main hindrance here is a lack of land use restrictions in some categories of protective forests.

It is valuable to compare the categories of protective forests in the Russian Federation with the six types of High Conservation Value (HCV) forest categories proposed by Jennings et al. (2003) (https://www.hcvnetwork.org/). As can be seen from the table in this paper, the current system of protective forests for the most part fails to take into account categories associated with the conservation of biodiversity, rare species, ecosystems, and key habitats (Kobyakov et al. 2013). Likewise, categories aimed at the preservation of large forest landscapes are largely absent, although sufficiently large compact forest areas are distinguished as part of the tundra and mountain protective forests. Row categories are allocated to take the interests of local residents into account (HCV forest types 5 and 6). However, such categories are limited, and there is a need to expand the list and to introduce a new category of protective forests — “social forests” (Shwarts et al. 2012). Thus, in general the existing system of protective forests is fairly good, taking the environmental protection functions of forests into account, but it is not enough. This is because all other ecosystem and social functions are necessary for the inclusion of new categories in Russia.

According to the current Russian Forest Code, all forests located inside existing protected areas are classified as protective. Previously, prior to the revised Forest Code, only some of the forests in protected areas belonged to protective forests (so-called “forests of group 1”, or forests inside nature reserves, national and natural parks, and natural monuments). However, the way in which the areas of protective forests are accounted for in the Russian Federation is not yet correct, because there is a problem of overlapping forests inside existing protected areas and other categories of protective forests. If we do not take forests inside protected areas into account, the proportion of protective forests in the overall forest-covered area of the Russian Federation makes up about 20% (Kobyakov et al. 2013).

Thus, the system of Russian protective forests together with protected areas could be considered one of the best examples of the creation of an ecological network of territorial protection for forests, preserving the environmental protection functions.

The most important threat factor to protective forests in Russia is the uncertain regime regarding their use. Historically, there is still a situation in which the use of forest resources in protective forests is not always carried out according to the special rules, but often according to the same rules as applied to forests used for timber production, just with some minor restrictions. Of these restrictions, the most common are the prohibition against clearcuttings and the prohibition against transferring protective forest areas into other land-use categories.

At present, according the Federal Law of 22 July 2008 (No. 143-FZ), a protection system for protective forests in Russia has clearer rules than before. For most categories of protective forests, clearcuttings are prohibited. On the other hand, some weakening of the regime occurred for water protection zones and forest zones, and also with respect to the spawning grounds of valuable commercial fish, for which selective cuttings are allowed. In addition, the new Forest Code introduced a significant fundamental change in the status of protective forests — a concept regarding the purpose of forests (Article 10). Previously, forests were simply divided into categories. The new Forest Code clearly specifies the goal of creating protective forests: preserving the environment-forming, water-protective, sanitary and hygienic, recreational and other useful functions of forests (Article 12). The use of protective forests for purposes that do not meet their intended goal is prohibited (Article 102). However, there are still possibilities for several kinds of selective cutting in protective forests. After the appearance of new restrictions in the ongoing Forest Code and its subsequent upgraded versions, an intensive process of "managing" protective forests has been started. In fact, the "classical" sanitary felling and the development of new types of thinning, the so-called cutting "renovation" and "reorganisation" process, do not differ from selective forest cutting in their organisational and technical characteristics. The vast majority of these forest cuttings also focus on protective forests. This has led to a critical depletion of protective forests. Clarifying the need for a maximum strict regime of protective forests is necessary.

Another threat to the protective forests in Russia also exists. According to the current legislation, all restrictions on the use of protective forests concern chiefly forest logging, whereas activities such as mining, construction of roads or buildings could be avoided. Can water-protected forest belts along rivers and lakes serve as ecological corridors connecting protected areas? The answer is that water-protective forest belts on their own are definitely not enough to ensure such corridors because they are too narrow. For instance, the width of protective belts along rivers vary from 50 to 200 m depending of the size of a river. They could be used as links between protected areas only in combination with other elements of transitional areas. Transitional areas are usually transformed to some extent, but they do not include insurmountable barriers.

Mamontov (2017) has presented several interesting ideas on ecological connectivity. He notes: "Unfortunately, there is no category of protected areas in the Russian legislation corresponding to the ecological corridor linking protected areas into a united ecological network. It is impossible to prohibit economic activity in large areas, and the basis for ecological corridors should therefore be a network of protective forests and specially protected forest areas (SPFA). To link protected areas together, it is expedient to make the maximum possible use of natural migration pathways, such as river valleys and adjacent forests. It should be noted that it is not enough to preserve forests along watercourses to ensure the connectivity of forest habitats. River valleys often have dense human populations, and riparian forests are heavily transformed and do not fulfill the habitat requirements of boreal species. To act as an ecological corridor the strips should be much wider, to ensure the highest possible diversity of preserved habitats. All possible types of SPFA should be identified through a detailed survey of the territory identified as an ecological corridor. For a more compact arrangement of the preserved fragments of habitats, it is necessary to single out protective zones around all lekking grounds of Capercaillie in the given territory, not only around three lekking grounds per 100 square km." These ideas clearly underscore the need to think "big" and consider the ecological corridors at a large spatial scale, aiming to set up new protected areas such that they can improve ecological connectivity between existing protected areas.

4. Main remaining issues related to improving ecological connectivity of boreal forests in the Barents Region

Many issues hinder the improvement of ecological connectivity and forest conservation in the Barents Region. First, one of the main issues is that there are different definitions of forest conservation in Finland, Sweden, and Russia. If there are no common legislative measures, definitions, or vocabulary, it may be difficult to provide overall practices and recommendations for improving ecological connectivity in the boreal forests of the Barents Region. Second, how ecological connectivity is understood differs somewhat between different countries and researchers, implying that using the same concepts and methods when talking about ecological connectivity and measuring it in practice is of utmost importance. This is important because using different terms and methods will lead to misconceptions and most likely hinder large-scale considerations of forest conservation in the Barents Region. This can be improved by standardising the terms related to ecological connectivity. Third, the interplay between different research institutes, NGOs, forest companies, and policy makers should be improved when it comes to delivering information about the importance of ecological connectivity for maintaining and securing biodiversity and ecosystem services. This interplay should also cross borders in the Barents Region, which also has a direct link to the first and second points given above.

5. Recommendations for practical improvements to ecological connectivity in boreal forests

1. Ecological connectivity should be improved by taking into consideration the four main aspects comprising connectivity: isolation, area, habitat quality, and matrix features. Isolation is quite important because it affects the degree to which organisms can disperse between protected areas, while area is related to extinction risk (the smaller the habitat area, the higher the extinction risk), habitat quality affects population viability and population size, and matrix quality interacts with isolation, area, and habitat quality in affecting ecological connectivity.

2. Conserving steppingstones (e.g. smaller remnants of high-quality forests) and other connecting elements in the landscape (e.g. riverine and lakeshore corridors) should be a prerequisite in improving ecological connectivity between protected forests.

3. Forestry companies and individual forest owners should be made aware of the importance of retaining steppingstones and other connecting elements in the landscape. Even though current legislation in the countries of the Barents Region "somewhat" recognises the importance of these elements, such legislation should be included more directly into broad-scale conservation planning and forest management.

4. Environmental managers and policy makers should receive better information about the urgency of guaranteeing enough ecological connectivity between protected areas, so as to maintain biodiversity, endangered species associated with forests, and the ecosystem functions and services that rely on biodiversity.

5. All recommendations (1 to 4) should be considered across the entire Barents Region, which would entail sharing ecological, forestry, conservation, legislative, and policy information among these countries.

6. Conclusions

Improving ecological connectivity is an important topic in biodiversity conservation and land use planning, and it has been considered a key topic in the boreal forest conservation programmes in the Barents Region. The Barents Region is a suitable reference point for these kinds of studies and considerations of practical issues because there are still some remnants of natural forests left, especially in the eastern part of the region. Promoting ecological connectivity in the Barents Region should consider different geographical levels, from landscapes to regions, and be based on data on valuable high-quality forest areas. It should take into account isolation, area, habitat quality, and matrix features in order to lead to ecologically desirable outcomes. To attain these goals, interaction between different stakeholders is important and a key prerequisite if recommendations to enhance ecological connectivity are considered as practical solutions to boreal forest conservation. Overall, in-depth assessments of ecological connectivity will improve the conceptual expertise, tools, and methods that environmental administrations could use to enhance and improve connectivity. This review has focused on these issues and concluded by proposing recommendations to improve ecological connectivity ranging from ecological through societal to legislative and political views.

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Box 1. Some approaches and metrics useful in quantifying ecological connectivity

GIS-derived metrics used to measure ecological connectivity range from simple, direct overland distances between patches to more sophisticated ones involving physical information about (more or less realised) dispersal routes between habitat patches. In the context of corridor-like landscape features, river network distances between habitat patches may also be useful because many terrestrial and aquatic species use river-riparian corridors as dispersal routes (Tonkin et al. 2018). Ecological connectivity between habitat patches can thus focus on taking advantage of various approaches, methods, and metrics (Heino et al. 2017). In one widely used approach, the focal system is considered a graph (a set of nodes and links) in which nodes represent the habitat patches and links show the connectivity relationships between these habitat patches in an area (Calabrese & Fagan 2004; Urban et al. 2009). In such analyses, spatially explicit data derived from geographic information systems (GIS) can be combined with information on the dispersal routes and behaviours of organisms (Calabrese & Fagan 2004; Erős & Campbell Grant 2015). Different distance classes among the nodes can also be used to set different weights for the links as a proxy for indicating habitat suitability (e.g. features of ground-layer vegetation for small mammals) or barriers (e.g. non-permeable matrix for small mammals) for dispersing organisms. Graphs can also be used to indicate the importance of upstream *versus* downstream or watercourse *versus* overland dispersal in riverine systems (Galpern et al. 2011; Erős et al. 2012), and similar weighting systems may also be useful when the dispersal of terrestrial organisms shows some directionality between habitat patches (Ament et al. 2014). The use of such graphs hence also necessitates the determining of connections and their weights (Heino et al. 2017). These include Euclidean (the shortest overland distance between sites), network (the shortest distance along ecological corridors), flow (the impeding effects of stream flow or wind conditions are taken into account in the calculations of the distance between sites), and topographical (the optimal routes along which organisms can avoid steep upward slopes) distances. In addition, more sophisticated cost distances can be utilised to measure the distance between sites (while representing potential landscape resistance to an organism's movements) by using variables related to land cover, human land use, and topography (Zeller et al. 2012). Cost distances have typically been used to model the features of movements of large terrestrial mammals (e.g. Larkin et al. 2004), although they may also be potentially relevant for the organisms inhabiting various other environments (e.g. Kärnä et al. 2015).

Box 2. The Green Belt of Fennoscandia enhances connectivity conservation

The Green Belt of Fennoscandia is a network of existing and planned protected areas adjacent to the borders of Finland, Russia, and Norway (http://www.ym.fi/en-US/International_cooperation/Green_Belt_of_Fennoscandia). This network is based on cooperation agreements between these three countries, and it is also related to the aims of the International Convention on Biological Diversity. One goal of this cooperation is to develop the Green Belt of Fennoscandia into a widely acknowledged transboundary model area. A second goal is to increase awareness of this particular area and its natural values both in the participating countries and internationally. The Green Belt of Fennoscandia belongs to European Green Belt, being the northernmost part of this network. Given the fact that the Green Belt of Fennoscandia stretches from south to north, it has good potential to act as a zone that allows for tracking the northward shift of species as a result of changes in climatic conditions.