Title

Indicator framework for measuring quantity and quality of biodiversity – Exemplified in the Nordic countries

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Abstract

In 2002, world leaders made a commitment through the Convention on Biological Diversity (CBD), to achieve a significant reduction in the rate of biodiversity loss by 2010. At the Conference of the Parties of the CBD in Nagoya, Japan in 2010, the target was renewed for 2020. We have developed a Biodiversity Change Index (BCI) to help measure progress towards this target. The BCI is constructed with a two-dimensional resolution, allowing for a direct evaluation of the relative importance of changes in quantity and quality, respectively, to the overall change in biodiversity. Quantity is measured as the area of a specified habitat type and quality as the abundance of indicator species and other habitat quality parameters, such as the proportion of old trees or dead wood in forests. The BCI enables easy comparison of changes in biodiversity between different habitat types and between different regions and nations. We illustrate the use of BCI by calculating the index for the Nordic countries for two common habitat types, farmland and forest, and one habitat type of similar importance in the northern hemisphere; mires. In the period 1990–2005 declines in biodiversity of similar magnitudes are seen for farmland and mires across the Nordic countries, while for forest, trends vary considerably. Our results show that the BCI framework can be a useful tool to communicate the complex issue of biodiversity change in a simple manner. However, in accordance with other studies of biodiversity change we conclude that existing monitoring data are too scarce to consistently calculate BCI for all habitat types in all Nordic countries. In order to reasonably evaluate changes in biodiversity, further efforts towards monitoring programmes to obtain reliable and quality assured data on biodiversity at acceptable spatial and temporal resolutions are needed. Moreover, common methods to apply and harmonise data from different monitoring schemes should be developed.

Keywords: Biodiversity, Biodiversity change, Indicators, Monitoring, Nordic nature, Habitat quality

1. Introduction

The importance of protecting biodiversity is receiving growing political attention. In 2002 parties to the Convention on Biological Diversity (CBD) committed themselves "to achieve by 2010 a significant reduction of the current rate of biodiversity loss" (UNEP, 2002). The EU adopted a similar but more ambitious target that "biodiversity decline should be halted by 2010" (European

Council, 2001). The 2010 targets are important milestones for European and global efforts to protect biodiversity as any significant progress towards these targets would mean a significant shift in our attitude towards the living environment. However, the way towards halting biodiversity loss is riddled with obstacles – the first is of a very basic nature: How can we measure the state and change of biodiversity?

Overall, the evaluation of biodiversity targets depends on the use and development of accurate and robust indicators that can quantify changes in biodiversity over short time-spans and communicate this information to a policy audience (Gregory et al., 2005; Mace and Baillie, 2007; van Strien et al., 2009). Unfortunately a range of obstacles complicates the messages of biodiversity indicator assessments. Even though many biodiversity indicators aggregate information to a relatively high level, there is a widespread need to simplify their message even further. Some have suggested that economic indices such as the Dow Jones or Nikkei should been taken as models for the development of biodiversity measures (Gregory et al., 2003; Loh et al., 2005). The hope is that such indices would help getting focus on biodiversity issues in the media and in policy making. Ideally, indicators should use similar approaches and measure changes at uniform levels. Aggregating indicators according to, for example, habitat, country or bio-geographical region would then be possible (de Heer et al., 2005).

Often the available data sources are nevertheless too heterogeneous and time series too short and patchy for the required uniformity to be reached. In these cases, different visual summaries in the form of arrow, pie and traffic light symbols have been attempted (Millennium Ecosystem Assessment, 2005; Chick et al., 2007; Secretariat of the CBD, 2010). Some studies apply an approach, where human-induces changes in biodiversity are assessed by comparing the present state of biodiversity with the state in undisturbed ecosystems (ten Brink, 2000; Scholes and Biggs, 2005; Scholes et al., 2008; Alkemade et al., 2009). However, in relation to the 2010 targets, this approach has obvious limitations, because for many habitats an undisturbed state has not existed for decades or even centuries, and to assess whether loss of biodiversity is progressing or halted, requires data on recent development.

For the purpose of evaluating the 2010 target, a framework of 22 global headline indicators in 7 focal areas was established within the CBD (Secretariat of the CBD, 2006). In view of the available evidence – for several indicators temporal and geographic coverage is very sparse – it was concluded at the tenth meeting of the Conference of the Parties (COP 10) in Nagoya, Japan in 2010 that the 2010 target has not been met (Secretariat of the CBD, 2010). Assessments showed that biodiversity is being lost in all focal areas, including loss of selected ecosystems such as forests and coral reefs (Secretariat of the CBD, 2010). In parallel, European researchers have evaluated a set of 26 headline indicators, concluding that Europe's target of halting biodiversity loss by 2010 will also not be met (EEA, 2009, 2010). These assessments are highly data and labour intensive and depend on expert judgements for a number of indicators to decide if progress (or regress) has been achieved.

A simple and accessible approach to aggregate biodiversity data has been to combine measurements of the quantity and quality of nature habitats into a single composite index called the Natural Capital Index (NCI) (ten Brink, 2000; ten Brink et al., 2002). In developing NCI it was recognised that biodiversity loss consists of two components: (i) loss of habitats or 'ecosystem quantity', resulting from the decline in habitat area and (ii) loss of 'ecosystem quality' (in the remaining area) due to factors such as climate change, pollution, habitat fragmentation and over-exploitation.

Here we suggest a framework for clarifying the use of biodiversity indicators that monitors progress towards the 2010, and subsequently 2020, targets. Based on the NCI concept (ten Brink, 2000; ten Brink et al., 2002), biodiversity change is conveyed two-dimensionally by constructing aggregated indicators for the quantity and quality components of biodiversity, respectively. The indicator framework is applied at a national level in the Nordic countries: Finland, Sweden, Norway, Denmark and Iceland, but it may be used at any geographical level. The Nordic region represents a wide range of habitat types, including mountainous landscapes, boreal and nemoral forests, inland waters and mires as well as a long coastline spanning over a large variation of bio-geographical zones. For many of these habitats human influences are low compared to other European countries. Furthermore, all Nordic countries have adopted EU's 2010 target (Nordic Council of Ministers, 2004).

<Table 1>

2. An indicator framework for measuring changes in biodiversity

Indicators are used to quantify and communicate complex phenomena – such as biodiversity change – in a simple manner (Bibby, 1999). However, there is no conceivable indicator, which could accurately reflect changes in biodiversity in different ecosystems at different spatial and temporal scales, because of the inherent complexity of habitats within the ecosystems. Subsets of indicators are therefore needed to obtain balanced assessments of the trends in biodiversity. Table 1 lists relevant criteria for obtaining good biodiversity indicators. It is not often the case that all criteria are met, but the list comprises a useful tool when choosing and developing biodiversity indicators.

Focusing on the state and impact components of the DPSIR framework (Smeets and Weterings, 1999; Lin et al., 2009) and using the model of quantity and quality from the definition of the Natural Capital Index (NCI) (ten Brink, 2000), we have developed a simple indicator framework to describe changes in biodiversity in two dimensions (Fig. 1). Changes in biodiversity quantity are measured as trends in the extent of pre-defined habitat types. Changes in biodiversity quality are measured as trends in the abundance of selected species within these habitat types and – dissimilar to the NCI – by other key indicators for habitat quality, such as trends in the proportion of old trees or dead wood in forests. Estimating species abundance trends is a broadly accepted approach to generating indicative measures of biodiversity (Mace and Baillie, 2007; Collen et al., 2009; EEA, 2010).

<Figure 1>

Based on this concept, we define a two-dimensional Biodiversity Change Index (BCI), where quantity of biodiversity (BN_t) is appointed to the x-axis and quality of biodiversity (BL_t) to the y-axis (Fig. 2). In a baseline situation – for example in a predefined base year or in pre-industrial time – both parameters are set to 100. BN_t and BL_t are then computed as indexed values of time series following these equations:

Biodiversity quantity (BN_t) of a predefined habitat:

$$BN_t = 100 \frac{\sum_{i=1}^{n} a_{it}}{\sum_{i=1}^{n} a_{ib}} \qquad (1)$$

where n is the number of sub-habitats; a_{it} is the area of sub-habitat i in the year t; a_{ib} is the area of sub-habitat i in the base year (or baseline situation) b.

Biodiversity quality (BL_t) of a predefined habitat:

$$BL_t = 100\left(\prod_{i=1}^{n}\left(\frac{N_{it}}{N_{ib}}\right)^{w_i}\right)^{1/\sum_{i=1}^{n} w_i} \qquad (2)$$

where n is the number of species abundance (or habitat quality) measures;
w_i is the weighted proportion of species abundance (or habitat quality) measure i; N_{it} is species abundance (or habitat quality) measure i in the year t; N_{ib} is species abundance (or habitat quality) measure i in the base year (or baseline situation) b.

Finally, BCI is calculated as:

$$\text{BCI} = \frac{BN_t BL_t}{100} \qquad (3)$$

In Eq. (2) we use geometric mean rather than arithmetic mean because we consider – in agreement with a number of species monitoring schemes (Gregory et al., 2005; EBCC, 2007) – that species population data have exponential characteristics. Compared to the Dutch NCI (ten Brink, 2000), the BCI is less restrictive in defining the quality parameter, as the NCI is solely based on species data. Moreover, the NCI makes use of a pre-defined baseline situation (natural state), while the BCI allows for trend analysis between a base year (e.g. 1990) and a target year (e.g. 2010). In some cases a causal relationship between the two biodiversity parameters of the BCI may be present as species abundance can depend on the size of the habitat if changes are extreme. However, our concept aims at illustrating changes over shorter well-defined time spans without extreme changes in habitat area. Therefore a potential causal relationship between the parameters is negligible.

<Figure 2>

If consistent data of good quality and adequate temporal resolution exist, the BCI can be aggregated to any habitat level, country level or even pan-Nordic level (Fig. 3). In terms of communication to policy makers, it would be of interest to calculate just one overall BCI that can describe changes in biodiversity in all habitat types for a whole country or even all Nordic countries together. However, aggregating BCI to such high aggregation level would obscure trends of change at lower levels. Therefore, there is also a need to show BCI at lower levels, i.e. at the level of habitat types within the different countries, in a hierarchical setting (Fig. 3). In this work we illustrate the calculations of BCI for selected habitats where adequate data in the Nordic countries are available.

<Figure 3>

3. Measuring quantity of biodiversity

To measure changes in the quantity of biodiversity (BN_t) in the Nordic countries requires an applicable classification of habitat types. The classification scheme should be detailed enough to distinguish between habitat types, which are of importance in a Nordic context. At the same time it has to be relatively broad with a limited number of well-defined habitat types to guarantee transparency and applicability with respect to data collection. A review of existing habitat classification schemes (European Commission, 1991; Påhlsson, 1998; EEA, 2002; Davies et al., 2004; Bunce et al., 2005) revealed that a scheme, which could be used for our purpose, does not exist. We decided to elaborate a distinctive two-level classification scheme based on the European

Nature Information System (EUNIS) (Davies et al., 2004). In some cases conditions in the Nordic countries differ considerably from the pan-European scale and therefore the EUNIS system was adjusted to conditions relevant in a Nordic context. The elaborated Nordic habitat type classification defines 10 main habitat types at the 1st level and 25 sub-habitats at the 2nd level (Fig. 4). To make our system as compatible as possible to other studies, we related habitat types from our classification to habitat types from existing classification schemes (see Appendix A for definitions of Nordic habitat types and conversions to EUNIS). The classification at the 1st level is based on well-defined criteria including the type and degree of vegetation cover, the type of underlying substrate and human influences, such as agricultural management. The division into sub-types at the 2nd level is based on a less stringent evaluation of various relevant criteria. The choice to include sub-types was based on the relevance of these habitat types in the Nordic countries. For example, as vast areas of northern Scandinavia are influenced by permanent or seasonal frost, aapa and palsa mires that depend on frost and ice conditions were included. In comparison, constructed and highly artificial habitat types were not divided into sub-habitats.

<Figure 4>

The availability of area data differs substantially between countries and habitat types (Table 2). For habitat types of high economic interest, primarily agriculture (N2 and partly N8) and forestry (N9), complete time series, going back more than a century, exist in most countries. On the contrary, very few data exist for most nature types within the coastal habitats (N4), sparsely vegetated habitats (N6), mires (N7) and grasslands (N8). In these cases lack of data restrain the construction of useful biodiversity indicators and hence trend analyses.

<Table 2>

The most recent statistics for land cover in the Nordic countries illustrate the considerable differences in the quantity of the predefined main habitats in the Nordic countries (Table 3). Finland, Sweden and Norway are dominated by forest, Denmark by cultivated land and Iceland by sparsely vegetated land such as inland rocks, glaciers and volcanic areas. Mires take up large areas in Finland and Sweden, whereas grasslands and shrub heathlands, mostly in the alpine region, are predominant in Norway and Iceland.

<Table 3>

4. Measuring quality of biodiversity

Measurements of changes in biodiversity quality (BL_t) build on the selection of relevant species abundance and other habitat quality indicators that conform to a majority of the indicator quality criteria set out in Table 1. Our selection of indicators follows a *top-down approach*, implying that for each habitat, species and quality parameters that – based on scientific literature and expert judgements – are known to be indicative for biodiversity quality are selected. This is similar to the European bird indices, which are calculated from trend data for bird species that expert ornithologists agree to be representative of for example farmland or forest (Gregory et al., 2005). In comparison, the Living Planet Index follows a bottom-up approach for which all available species abundance trends are aggregated into a global index (Collen et al., 2009).

In Table 4 we propose indicators that are relevant to assessing biodiversity quality of the main habitat types. Indicators for sub-habitats are also included in cases where data and methodology are established. In the Nordic countries the most comprehensive data series are found for birds, mammals and a few insect orders. For these groups historical data are available and often updated annually. Also, indirect species abundance indicators based on hunting and fishing statistics are widely available but as they may be biased towards economic or cultural interests they should be used with precaution. In contrast, the data availability for most other species groups, including the majority of insects, mosses, lichens, fungi and microorganisms are very scarce. Some rare plant species including native orchid species are monitored in some locations but in general, trends in the extent of plant species are not known. Among the habitat quality indicators that we have selected, area-based indicators such as the proportion of pristine nature types are the richest in data. In the case of surface waters, biochemical quality indicators are also available and for forest some relevant structural indicators can be obtained from national forest inventories.

<Table 4>

5. Application of indicator framework

By exploiting a wide array of national data sources within the Nordic countries, we have obtained data sets for the calculation of indicators for BN_t and BL_t. The availability of consistent historical data for especially BL_t varies between the different countries, between different habitat types and between the different species groups. Lack of applicable data implied that we were not able to consistently calculate the BCI for all habitat types within all countries. However, for a number of habitat types, we found that data were acceptable to illustrate the application of the BCI concept. Here we present BCIs for farmlands, mires and forests. In the examples, indicators for BL_t are solely represented by groups of bird species as these represent the most robust quality indicators that we were able to establish. In general, birds can be considered good indicators of the state of biodiversity in different habitats (Gottschalk et al., 2010) although some traits, as the tendency to migrate and the often relatively great capacity to adapt to changing environment, may complicate interpretation (Billeter et al., 2008). The abundance was calculated as the geometric mean of a selected number of common bird species according to Eq. (2) and the European species classification system (EBCC, 2007). Each species was weighted equally in the equation. Furthermore, in order to reduce the effect of annual fluctuations, we applied a three-years flowing average. 1990 is set as base year, as from this point in time an appropriate time span is covered in relation to the 2010 target.

<Figure 5>

By using area data for farmland and species abundance data for common farmland birds (Fig. 5), we have calculated BCI for farmland in the Nordic countries (Fig. 6). It shows that in all cases, BCI for farmland has decreased since 1990, mainly caused by decreases in farmland bird populations (BL_t) while BN_t only changed marginally (Fig. 6). At European level indicators for farmland birds show similar declines over the past two to three decades (Gregory et al., 2005; EEA, 2009).

<Figure 6>

The area of mires has remained almost unchanged in the Nordic countries since 1990, while the abundance of mire birds, in spite of some fluctuations, follows a downward trend (data not shown). Due to incomplete data, BCI for mires could only be calculated for Finland and Sweden (Fig. 7). The substantial decreases in BCI for both countries are mainly a consequence of declines in BL_t, while BN_t only changed marginally.

<Figure 7>

In contrast to the BCI for farmland and mires, there is no clear common trend in the development of BCI for forest (Fig. 8). In Finland BCI decreases from 1990 to 1995 and afterwards increases. In Norway and Denmark, BCI increases while in Sweden BCI decreases. Noticeably, the development of respectively BN_t and BL_t varies considerably between countries. In Sweden, BCI decreases due to a substantial decrease in BL_t, while BN_t in fact increases. The increase in BCI in Denmark and Norway is due to increases in BN_t, while BL_t decreases in Denmark and is largely unchanged in Norway. The increase in BCI for Finland is due to an increase in BL_t, while BN_t is largely unchanged.

<Figure 8>

Fig. 9 allows a direct comparison of the development in BCI between the different Nordic countries. It clearly demonstrates that for farmland and mires, development in BCI follows similar decreasing trends in all countries as a result of substantial decreases in the abundance of bird populations (BL_t), while habitat area (BN_t) only changes marginally. In contrast, developments in BCI for forest vary considerably between the different countries.

<Figure 9>

6. Discussion and future recommendations

In this paper we present the BCI framework as a useful tool for communicating the complex issues related to biodiversity change. It allows us to show changes in biodiversity and to make comparisons between different types of habitats and between different nations or regions in a simple and communicative way. By its nature, applying indicators and indices always involves a simplification and therefore contains a risk of obscuring the phenomena itself as well as the underlying reasons and causes related to it (Heink and Kowarink, 2010). In this perspective, the strength of the BCI concept is the two-dimensional mode of presentation, which elucidates the relative contribution of change in quantity and quality of biodiversity to the overall change in biodiversity. Moreover, the fact that the BCI can be aggregated and disaggregated at different levels increases its transparency.

With due consideration of the limited data availability, our results indicate that biodiversity decline continues in the Nordic countries. The quality aspect of biodiversity has declined in most habitat types. Only the quality of forest habitats as measured by the abundance of common forest birds has increased in some countries. However, this development would likely appear differently if the quality of forest habitats could be calculated from structural indicators (e.g. dead wood and tree age) or the abundance of beetles or lichens, for example.

Recognising that the target of reducing the rate of biodiversity loss by 2010 has not been met, world leaders adopted a 2020 Strategic Plan and 20 new headline targets at the COP 10 meeting of the CBD in Nagoya, Japan to “take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services” (Secretariat of the CBD, 2011). Similarly, the European Council (2010) and the Nordic Council of Ministers (2010) have agreed on new 2020 targets. These new policy targets call for strengthening of efforts towards preserving biodiversity but also need to be accompanied by robust and representative methods in order to measuring changes in biodiversity. Much has already been achieved, however, as a number of assessments including our study show; the most important limitation in determining biodiversity trends is the general lack of monitoring data (Collen et al., 2009; Butchart et al., 2010; EEA, 2010; Secretariat of the CBD, 2010). If we want to make a balanced and comprehensive assessment of the development of biodiversity – and hence evaluate the 2020 targets – further efforts towards monitoring programmes to obtain reliable, high quality data on biodiversity at acceptable spatial and temporal resolutions are required.

Presently, monitoring programmes are under development in all Nordic countries. These include the Swedish National Inventory of Landscapes in Sweden (NILS), which was launched in 2003 and complements the Swedish National Forest Inventory (NFI) in a common effort to describe terrestrial habitats and ecosystems in a detailed and consistent way, in all terrestrial habitats (Ståhl et al., 2011). In Norway, a Nature Index (NI) to monitor trends in nature has been developed (Certain and Skarpaas, 2010; Nybø et al. 2011). Equivalent to the BCI, the NI combines quantity and quality measures but the latter is based on data from both monitoring and expert judgments. The Danish National Monitoring and Assessment Program for the Aquatic and Terrestrial Environment (NOVANA), launched in 2004, includes a wide array of measures for state of and pressures on nature and biodiversity. However, monitoring in Denmark is almost exclusively carried out in Natura 2000 sites, representing approx. 8% of the land area. Monitoring outside Natura 2000 sites is infrequent, which prevents nation-wide assessment of biodiversity change. In Finland a new monitoring programme was set up in 1995 to study the impacts of the EU agri-environmental scheme. This programme, now at its third period for 2008–2013, has advanced the understanding of farmland biodiversity and generated some long-term monitoring studies on its components (Kuussaari et al., 2008; Heliölä et al., 2010). The Finnish NFI has also been changed recently to include more biodiversity related variables (Winter et al., 2008). Based on these and other monitoring schemes, a set of more than 100 biodiversity indicators has been composed to evaluate the state and development of biodiversity nationally (Auvinen et al., 2010). In Iceland a recent survey of lowland land use ('nytjaland') and a nationwide survey of land use using CORINE classification make a good basis for monitoring changes and ensure classifications, comparable to other European countries.

A central aim of applying indicators and indices for biodiversity is to enable comparison of biodiversity trends across geographical regions, e.g. across different countries. Availability of monitoring data, at least within some of the Nordic countries will be improved within the near future. However, in order to apply these new data into robust and consistent indicators for biodiversity, such as the BCI, further efforts to apply and harmonise data from different monitoring schemes are also needed.

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Appendix A. Description of the Nordic habitat classification system and its conversion to the European Nature Information System (EUNIS).

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Table 1. Quality criteria to obtain relevant biodiversity indicators

Quality	Explanation
1. Representative and good coverage	Includes a large enough or representative group of species and has a good spatial coverage
2. Temporal and up-to-date	Shows temporal trends and can be updated routinely, e.g. annually
3. Simplifying information	Summarises a complicated phenomenon into a simple and intelligible form
4. Clear presentation	Possible to display clear messages with eye-catching graphics
5. Indicative	Indicates changes in a broader scale
6. Sensitive	Measured qualities are more sensitive to change than their environment (i.e. early warning)
7. Quantitative and statistically sound	Based on real quantitative observations and statistically sound data collection methods
8. Relatively independent of sample size	Usable data may be obtained even with relatively small sample sizes
9. Realistic	Based on existing monitoring programmes. Implementation is economically feasible
10. User-driven and acceptable	Responds to the needs of stakeholders and is broadly accepted amongst them
11. Normative and policy relevant	Linked to politically set goals and baselines. Enables assessing progress towards targets
12. Not sensitive to background changes	Buffered from natural fluctuations. Measures changes caused by humans
13. Explainable	The impact and significance of the change measured by the indicator must be known
14. Predictable	May be forecast and linked to socio-economic models
15. Comparable	Enables comparison (e.g. benchmarking of countries)
16. Aggregatable and disaggregatable	Data may be aggregated and disaggregated into different levels (e.g. country vs. community)

Constructed on the basis of Noss (1990), Delbaere (2003), Gregory et al. (2005) and EEA (2009)

Table 2. Availability of area data for Nordic habitat types

Habitat	Finland	Sweden	Norway	Denmark	Iceland
N1 Constructed habitats	1980-	1990-	2000-	1881-	1970-
N2 Regularly or recently cultivated land	1975-	1865-	1900-	1861-	1900-
N4 Coastal habitats	2005	ND	ND	2000-	2000-
N4.1 Coastal sand and dune	ND	ND	ND	1881-	ND
N4.2 Coastal shingle	ND	ND	ND	ND	ND
N4.3 Rock cliffs, ledges and shores	ND	ND	ND	ND	ND
N4.4 Coastal and seashore meadows and marshes	ND	ND	ND	1946-	2000-
N5 Inland surface waters	2000-	2000-	2007-	2000-	2000-
N5.1 Surface standing waters	2000-	2000-	2007-	2000-	2000-
N5.2 Surface running waters	2000-	2000-	2007-	2000-	2000-
N6 Sparsely vegetated and unvegetated habitats	2000-	2003-	2007-	ND	2000-
N6.1 Inland cliffs, rocky outcrops and screes	2000-	ND	ND	ND	2000-
N6.2 Snow or ice dominated habitats	2000-	ND	ND	NE	2000-
N6.3 Recent volcanic features	NE	NE	NE	NE	2000-
N6.4 Miscellaneous with very sparse or no vegetation	ND	ND	ND	ND	2000-
N7 Mires, bogs and fens	1952-	1929-	2007	1951-	1940-
N7.1 Raised and blanket bogs	ND	2003-	ND	ND	NE
N7.2 Transition mires and poor fens	ND	2003-	ND	ND	ND
N7.3 Aapa mires	ND	2000-	ND	NE	ND
N7.4 Palsa mires	1998-	2007-	ND	NE	ND
N7.5 Wooded mires	1980-	2000-	2007-	ND	ND
N8 Grasslands and shrub heathlands	1998-	1927-	2007-	1861-	2000-
N8.1 Dry calcareous and alvar grasslands	ND	2002-	ND	Incl. in N8.2	NE
N8.2 Dry / mesic open grasslands	1998-	2002-	1907-	1861-	ND
N8.3 Dry / mesic wooded grasslands	1998-	2007-	ND	ND	ND
N8.4 Wet or seasonally wet grasslands	1998-	2007-	ND	1861-	ND
N8.5 Scrubs and shrub heathlands	1998-	2007-	2007-	1881-	2000-
N9 Forest	(1921)[a] 1952-	(1923)[a] 1983-	(1919)[a] 1990-	1866-	1940-
N9.1 Deciduous forest	2000-	(1923)[a] 1983-	(1919)[a] 1990-	1881-	ND
N9.2 Coniferous forest	2000-	(1923)[a] 1983-	(1919)[a] 1990-	1881-	ND
N9.3 Mixed forest	2000-	(1923)[a] 1983-	(1919)[a] 1990-	ND	1940-
N9.4 Mountain birch forest	2000-	2003-	2007-	NE	2000-
N9.5 Other forest	2000-	(1923)[a] 1983-	ND	1881-	ND

ND = No data available;
NE = Habitat does not exist in the particular country;
[a] Data have been collected starting from the year shown in parenthesis but area data only readily available in databases since the later date.

Table 3. Area (km²) of main habitat types in the Nordic countries

Habitat	Finland		Sweden		Norway		Denmark		Iceland		Total	
	km²	Percentage	km²	Percentage	km²	Percentage	km²	Percentage	km²	Percentage	km²	Percentage
N1 Constructed habitats	6025	1.8%	5765	1.3%	2294	0.7%	4207	9.8%	1353	1.3%	19,165	1.5%
N2 Regularly or recently cultivated land	22,588	6.7%	27,469	6.1%	8499	2.6%	24,783	57.5%	1365	1.3%	84,266	6.7%
N4 Coastal habitats	1500	0.4%	ND [e]	ND [e]	ND [e]	ND [e]	568	1.3%	750	0.7%	2818	0.2%
N5 Inland surface waters	33,600	9.9%	39,960	8.9%	19,532	6.0%	743	1.7%	2353	2.2%	97,266	7.7%
N6 Sparsely vegetated/unvegetated	20,900	6.2%	4486	1.0%	72,500 [a]	22.4%	ND [e]	ND [e]	64,081	60.6%	157,481	12.5%
N7 Mires, bogs and fens	89,830	26.6%	51,652	11.5%	18,770	5.8%	1017	2.4%	8704 [b]	8.2%	163,131	12.9%
N8 Grasslands and shrub heathlands	186 [c]	0.1%	41,946	9.4%	72,500 [a]	22.4%	2649	6.1%	25,644	24.2%	126,449	10.0%
N9 Forest	152,000 [d]	45.0%	283,789	63.0%	129,600	40.0%	5345	12.4%	1516	1.4%	529,831	42.0%
N10 Undefined	11,511	3.4%	0	0.0%	0	0.0%	3786	8.8%	0	0.0%	80,256	6.4%
Total land area	338,140	100.0%	448,360	100.0%	323,695	100.0%	43,098	100.0%	105,766	100.0%	1,260,663	100.0%

Data are based on a range of national data sources from 2000 to 2010.

[a] Expert estimates,
[b] Drained mires not included.
[c] Finnish grassland data represent the most valuable traditional rural biotopes and are hence underestimated compared to the other countries.
[d] Unproductive forests not included.
[e] No Data.

Table 4. Proposed biodiversity indicators and data availability for each indicator

Habitat	Indicator type	Finland	Sweden	Norway	Denmark	Iceland
N1 Constructed habitats						
City and garden birds	SpA	1979-	1975-	1995-	1976-	1970-
Tree and plant species in city areas	SpA	SP	SP	SP	SP	SP
Small rodents/mammals	SpA	SP	ND	ND	ND	ND
Butterflies/insects	SpA	ND	ND	ND	ND	ND
Proportion of green areas in cities	HaQ	2000-	SP	SP	SP	SP
N2 Regularly or recently cultivated land						
Farmland birds (breeding)	SpA	1979-	1975-	1995-	1976-	ND
Farmland butterflies/insects	SpA	1999-	2004-	ND	SP	ND
Wild plants/weeds	SpA	1960s-	ND	SP	ND	ND
Mammals	SpA	1989-	2003-	SP	SP	ND
Hunting statistics (mammals and birds)	SpA	1996-	1939-	1900-	1941-	1995-
Density of hedgerows and other uncultivated biotopes	HaQ	SP	SP	SP	SP	ND
Mean field size	HaQ	1990-	2003-	SP	1998-	1998-
N4 Coastal habitats						
Birds nesting on rock cliffs (N4.3)	SpA	1930s-	1975-	1995-	ND	SP
Shorebirds nesting on coastal meadows (N4.4)	SpA	SP	1975-	1995-	1976-	SP
White-tailed eagle (and other birds of prey)	SpA	1970-	1924-	2000	1950-	1870-
Seals	SpA	2000-	1976-	SP	1976-	1975-
Proportion of undisturbed coastline	HaQ	1999	1992-	1985-	SP	ND
Proportion of pristine meadows (N4.4)	HaQ	ND	ND	ND	ND	ND
N5.1 Surface standing waters						
Underwater plants (macrophytes)	SpA	SP	1986-	SP	ND	ND
Crustaceans/crayfish	SpA	2006-	SP	SP	ND	ND
Insects	SpA	ND	SP	SP	ND	ND
Waterfowl	SpA	1986-	1976-	1995-	1976-	1974-
Fish	SpA	SP	1989-	SP	ND	ND
Amphibians	SpA	ND	ND	SP	SP	NE
Fishing statistics	SpA	1988-	1979-	SP	ND	1970-
Visibility depth	HaQ	1980-	1986-	1988-	1989-	SP
Chlorophyll concentration	HaQ	1980-	1978-	1988-	1989-	SP
Nutrient concentration (N/P)	HaQ	1980-	1978-	1988-	1989-	SP
Underwater vegetation cover	HaQ	NDSP	1986-	SP	1993-	SP
N5.2 Surface running waters						
Underwater plants (macrophytes)	SpA	ND	1986-	SP	1996-	ND
Crustaceans/crayfish	SpA	2006-	SP	SP	ND	ND
Insects	SpA	ND	SP	SP	1984-	SP
Waterfowl	SpA	SP	SP	SP	ND	ND
Fish	SpA	SP	1989-	1876-	SP	SP
Mammals	SpA	SP	SP	SP	1985-	NE
Fishing statistics	SpA	1988-	1979-	SP	ND	1970-
Visibility depth	HaQ	1960-	1962-	SP	ND	ND
Chlorophyll concentration	HaQ	1982-	1962-	SP	ND	ND
Nutrient concentration (N/P)	HaQ	1976-	1962-	1990-	1989-	ND
Underwater vegetation cover	HaQ	SP	ND	SP	ND	ND
N6 Sparsely vegetated/unvegetated						
Mosses and lichens	SpA	ND	ND	ND	ND	ND
Vascular plants	SpA	ND	ND	ND	ND	ND
N7 Mires, bogs and fens						
Mire birds (breeding)	SpA	1979-	1975-	1995-	1980-	ND
Mire butterflies/insects	SpA	1991-	ND	ND	ND	ND
Amphibians	SpA	NE	ND	SP	SP	NE
Vascular plants	SpA	1952, 1986, 1995	2003-	SP	ND	ND
Proportion of pristine mires	HaQ	1950-	2003-	SP	ND	1950-

Nutrient deposition (nitrogen)	HaQ	1980-	ND	ND	1990-	ND
Dead wood in wooded mires (N7.5)	HaQ	1998-	2003-	1996-	ND	ND
N8 Grasslands and shrub heathlands						
Birds (breeding and migrant)	SpA	1979-	1975-	1995-	1976-	ND
Butterflies/insects	SpA	1991-	2006-	SP	SP	1995-
Reptiles	SpA	ND	ND	ND	SP	ND
Orchids	SpA	ND	SP	SP	1980s-	ND
Vascular plants	SpA	ND	2003-	SP	SP	ND
Old solitary trees in wooded grasslands (N8.3)	HaQ	ND	2006-	SP	ND	NR
Grazing and mowing	HaQ	1995-	2006-	SP	ND	1900-
Nutrient deposition (nitrogen)	HaQ	1980-	ND	1980-	1990-	ND
N9 Forest						
Woodland insects	SpA	ND	ND	ND	ND	ND
Woodland birds (breeding)	SpA	1979-	1975-	1995-	1976-	2002-
Epiphytic mosses and lichens	SpA	ND	SP	SP	ND	ND
Woodland fungi	SpA	ND	SP	SP	ND	ND
Rodents	SpA	SP	1972-	SP	2000	ND
Large mammals	SpA	1989-	1995-	SP	2000	NE
Vascular plants (selected interior forest species)	SpA	1952, 1986, 1995	1983-	1993-	SP	ND
Brambling bird (indicator for N9.4)	SpA	1983-	1975-	1995-	NR	ND
Hunting statistics (deer, moose, etc,)	SpA	1996-	1939-	1900-	1950-	NE
Tree species composition (e.g. Shannon-Weaner index)	HaQ	1952-	1983-	1993-	ND	ND
Volume of dead wood	HaQ	1998-	1996-	1996	SP	ND
Old-growth forest (e.g. >140 years)	HaQ	1975-	1983-	1990-	1951-	ND
Proportion of large trees	HaQ	ND	1985-	1925-	ND	ND
Proportion of burnt area/clear cutting	HaQ	1975-	1983-	1950-	ND	ND
Proportion of natural/unproductive forest	HaQ	1952-	1983-	1990-	2006	ND

SpA, Species abundance indicator;
HaQ, Habitat quality indicator;
ND, No data available;
SP, Sporadic, not temporal or spatially covering data;
NE, Species are not existing in the particular country.

Figure captions

Fig. 1: Two-dimensional concept for measuring biodiversity change for a given habitat type.

Fig. 2: Model of a two-dimensional Biodiversity Change Index (BCI). Loss of biodiversity over time is shown as an example but an increase may also be the case.

Fig. 3: Chart showing the possible modes of aggregation of the Biodiversity Change Index (BCI) in the Nordic countries. The lowest level of aggregation is BCIs for different habitat types in different countries (A). These BCIs can be further aggregated to BCIs for all (or more than one) habitat types at national level (B) or BCIs for each habitat type at Nordic level (C). The highest level of aggregation is a BCI at Nordic level (D).

Fig. 4: Classification tree for Nordic habitat types. N3 Marine is not divided into sub-habitats as marine habitats were not covered in this work. Complete habitat definitions are listed in Appendix A.

Fig. 5: Trends in the area of farmland (N2 Regularly or recently cultivated land) and the abundance of common farmland birds in the Nordic countries. Bird data are indexed with 1990 = 100 (except Iceland where adequate data are not available and Norway where data are indexed with 1995 = 100).

Fig. 6: BCI for farmland (N2 Regularly or recently cultivated land) in Finland, Sweden, Norway and Denmark. BN_t is measured as the area of farmland and BL_t as the abundance of common farmland birds. Units are indexed with 1990 = 100 (except Norway where data are indexed with 1995 = 100).

Fig. 7: BCI for mires (N7 Mires, bogs and fens) in Finland and Sweden. BN_t is measured as the area of all mire types and BL_t as the abundance of mire birds. Units are indexed with 1990 = 100.

Fig. 8: BCI for forest in Finland, Sweden, Norway and Denmark. BN_t is measured as the area of N9 Forest (excluding N9.4 Mountain birch forest due to lack of historical data) and BL_t as the abundance of common forest birds. Units are indexed with 1990 = 100 (except Norway where units are indexed with 1995 = 100).

Fig. 9: BCI for farmland, mires and forest in the Nordic countries in the period 1990-2005. Units are indexed with 1990 = 100 (except Iceland where adequate data is not available and Norway where data are indexed with 1995 = 100).

Fig. 1

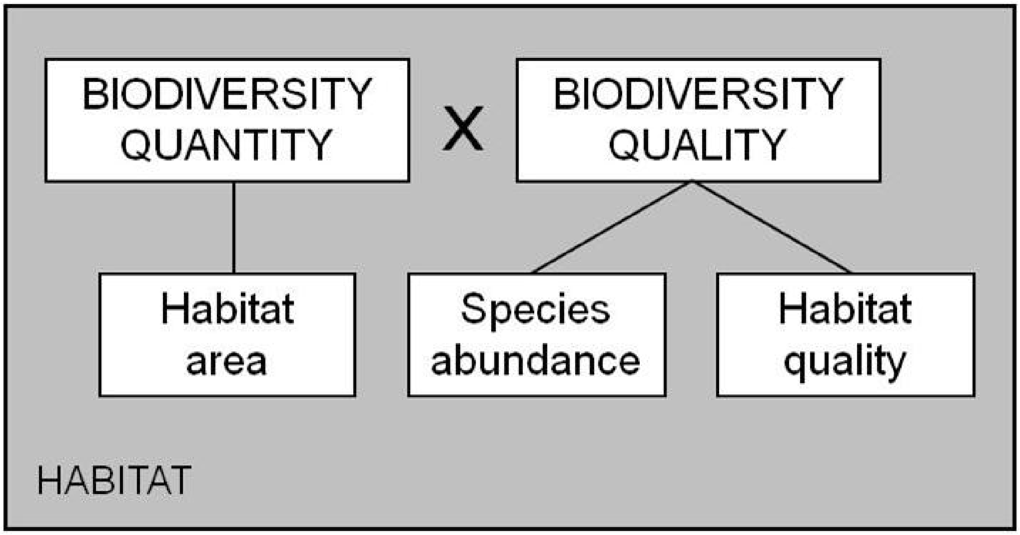
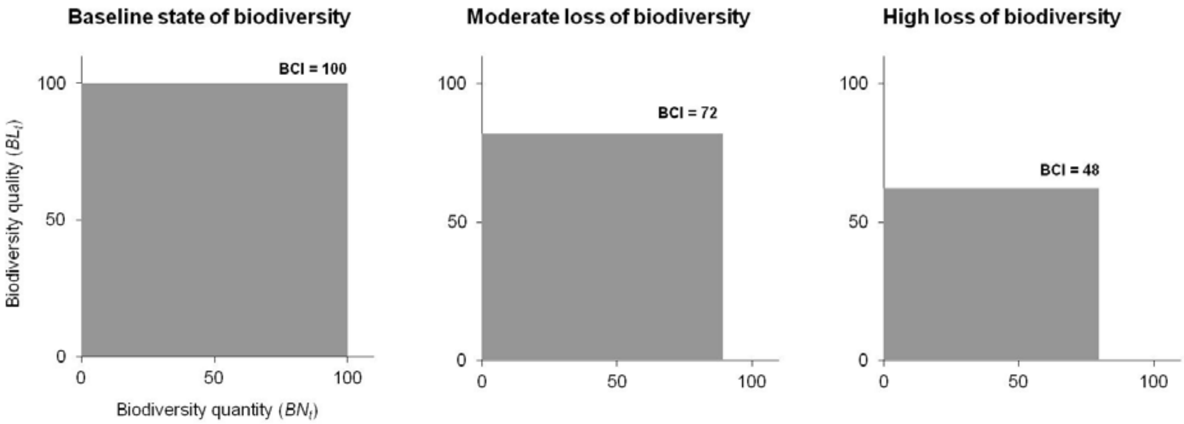

BIODIVERSITY QUANTITY
X
BIODIVERSITY QUALITY
Habitat area
Species abundance
Habitat quality
HABITAT

Fig. 2



Baseline state of biodiversity
Moderate loss of biodiversity
High loss of biodiversity
BCI = 100
BCI = 72
BCI = 48
Biodiversity quality (BL_t)
Biodiversity quantity (BN_t)
0
50
100

Fig. 3

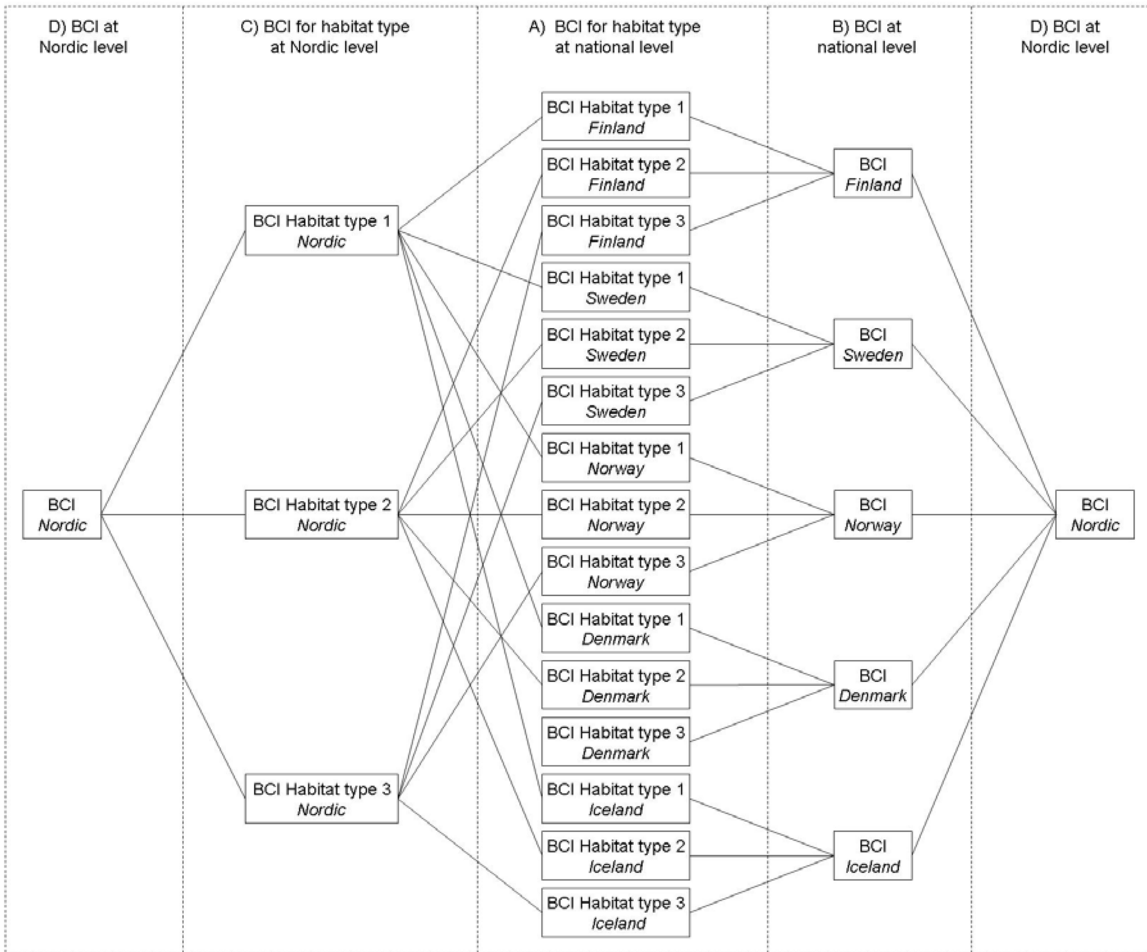
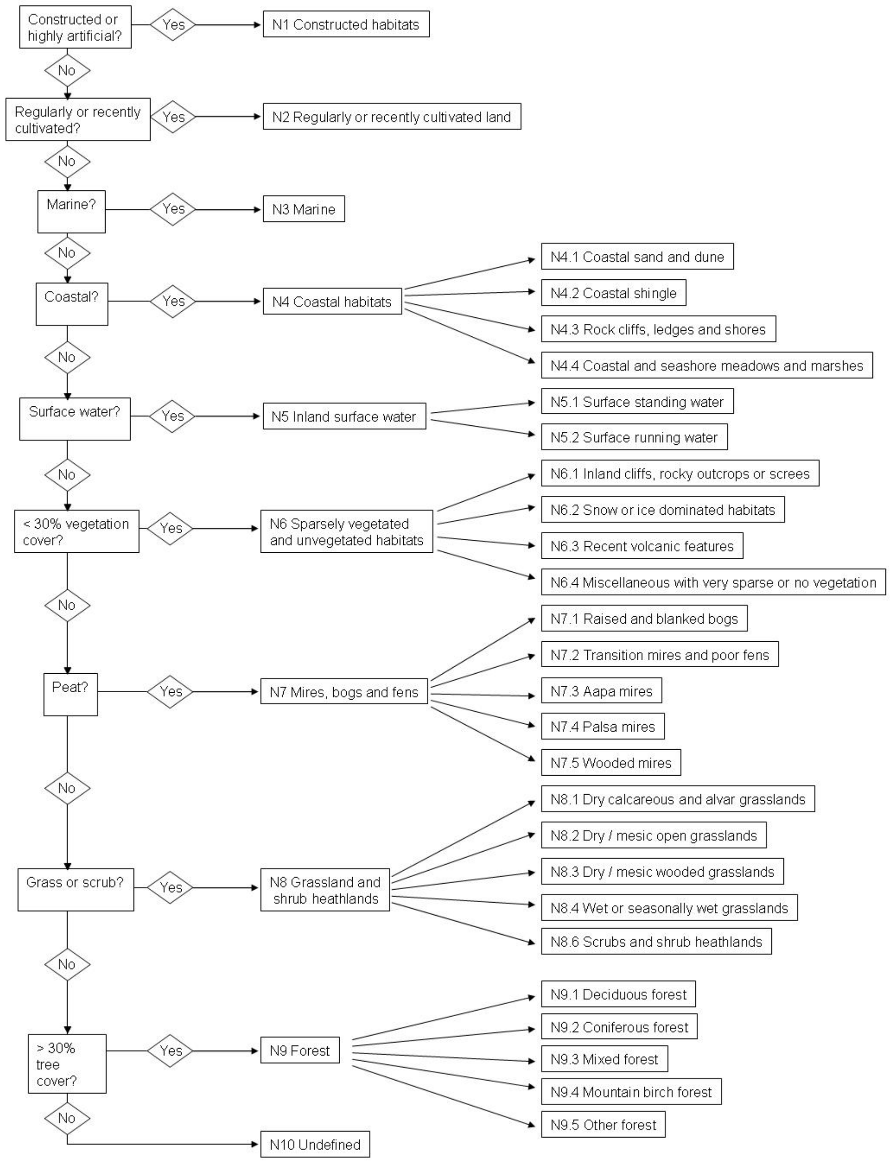

D) BCI at Nordic level
C) BCI for habitat type at Nordic level
A) BCI for habitat type at national level
B) BCI at national level
D) BCI at Nordic level
BCI Nordic
BCI Habitat type 1 Nordic
BCI Habitat type 2 Nordic
BCI Habitat type 3 Nordic
BCI Habitat type 1 Finland
BCI Habitat type 2 Finland
BCI Habitat type 3 Finland
BCI Habitat type 1 Sweden
BCI Habitat type 2 Sweden
BCI Habitat type 3 Sweden
BCI Habitat type 1 Norway
BCI Habitat type 2 Norway
BCI Habitat type 3 Norway
BCI Habitat type 1 Denmark
BCI Habitat type 2 Denmark
BCI Habitat type 3 Denmark
BCI Habitat type 1 Iceland
BCI Habitat type 2 Iceland
BCI Habitat type 3 Iceland
BCI Finland
BCI Sweden
BCI Norway
BCI Denmark
BCI Iceland
BCI Nordic

Fig. 4



Constructed or highly artificial?
Yes
N1 Constructed habitats
No
Regularly or recently cultivated?
Yes
N2 Regularly or recently cultivated land
No
Marine?
Yes
N3 Marine
No
Coastal?
Yes
N4 Coastal habitats
N4.1 Coastal sand and dune
N4.2 Coastal shingle
N4.3 Rock cliffs, ledges and shores
N4.4 Coastal and seashore meadows and marshes
No
Surface water?
Yes
N5 Inland surface water
N5.1 Surface standing water
N5.2 Surface running water
No
< 30% vegetation cover?
Yes
N6 Sparsely vegetated and unvegetated habitats
N6.1 Inland cliffs, rocky outcrops or screes
N6.2 Snow or ice dominated habitats
N6.3 Recent volcanic features
N6.4 Miscellaneous with very sparse or no vegetation
No
Peat?
Yes
N7 Mires, bogs and fens
N7.1 Raised and blanked bogs
N7.2 Transition mires and poor fens
N7.3 Aapa mires
N7.4 Palsa mires
N7.5 Wooded mires
No
Grass or scrub?
Yes
N8 Grassland and shrub heathlands
N8.1 Dry calcareous and alvar grasslands
N8.2 Dry / mesic open grasslands
N8.3 Dry / mesic wooded grasslands
N8.4 Wet or seasonally wet grasslands
N8.6 Scrubs and shrub heathlands
No
> 30% tree cover?
Yes
N9 Forest
N9.1 Deciduous forest
N9.2 Coniferous forest
N9.3 Mixed forest
N9.4 Mountain birch forest
N9.5 Other forest
No
N10 Undefined

Fig. 5

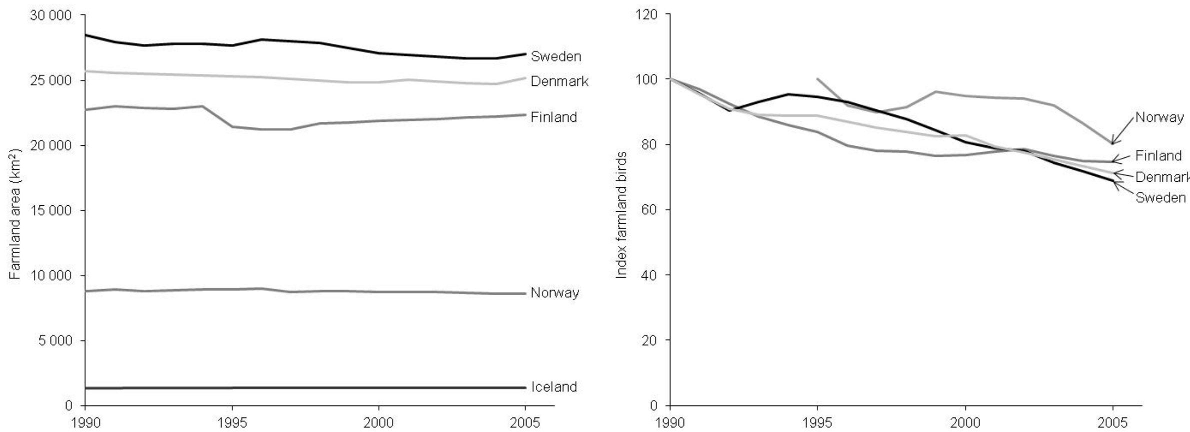
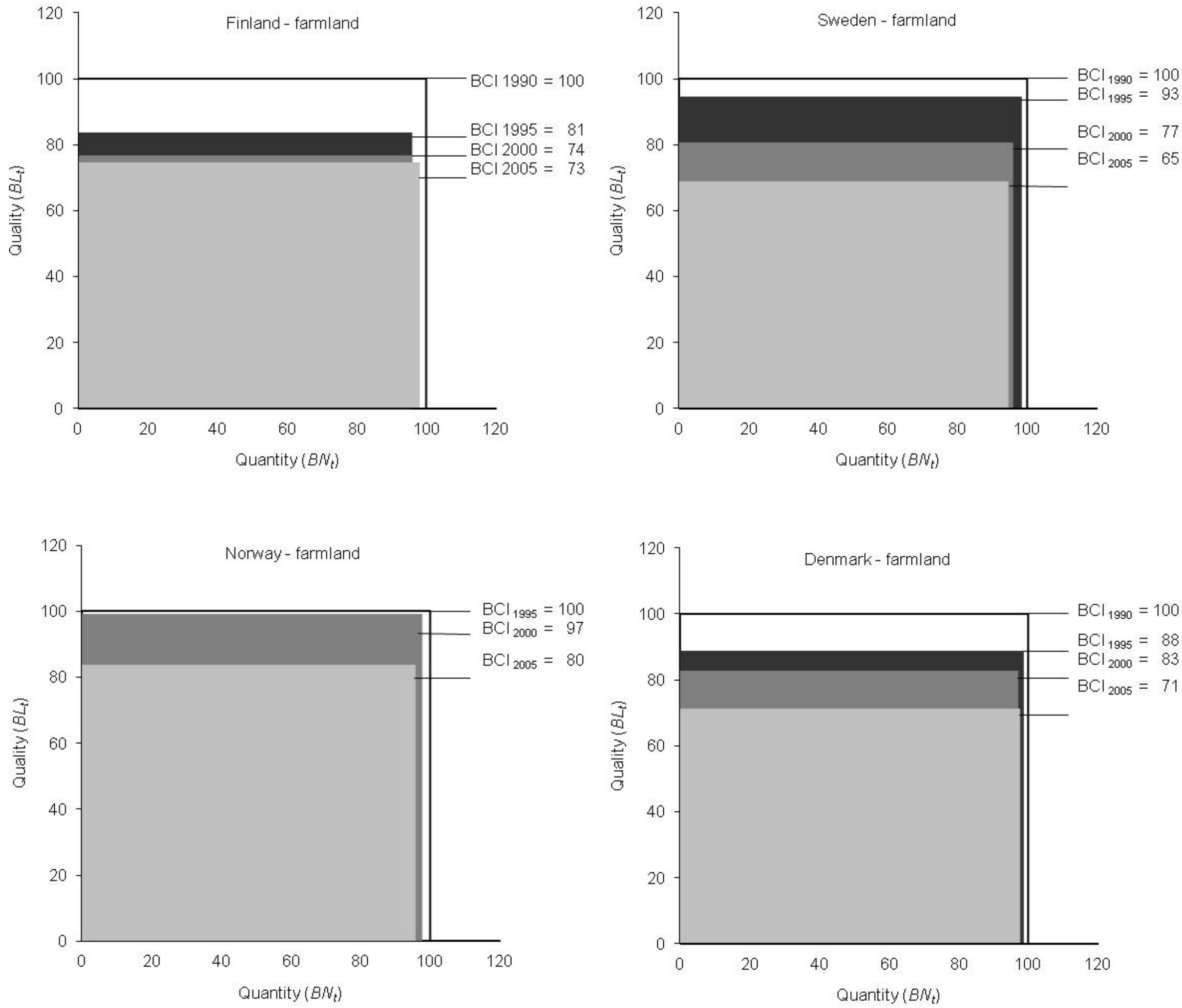

30 000
25 000
20 000
15 000
10 000
5 000
0
Farmland area (km²)
1990
1995
2000
2005
Sweden
Denmark
Finland
Norway
Iceland
120
100
80
60
40
20
0
Index farmland birds
1990
1995
2000
2005
Norway
Finland
Denmark
Sweden

Fig. 6



Finland - farmland
BCI 1990 = 100
BCI 1995 = 81
BCI 2000 = 74
BCI 2005 = 73
Quality (BL_t)
Quantity (BN_t)
Sweden - farmland
BCI 1990 = 100
BCI 1995 = 93
BCI 2000 = 77
BCI 2005 = 65
Norway - farmland
BCI 1995 = 100
BCI 2000 = 97
BCI 2005 = 80
Denmark - farmland
BCI 1990 = 100
BCI 1995 = 88
BCI 2000 = 83
BCI 2005 = 71

Fig. 7

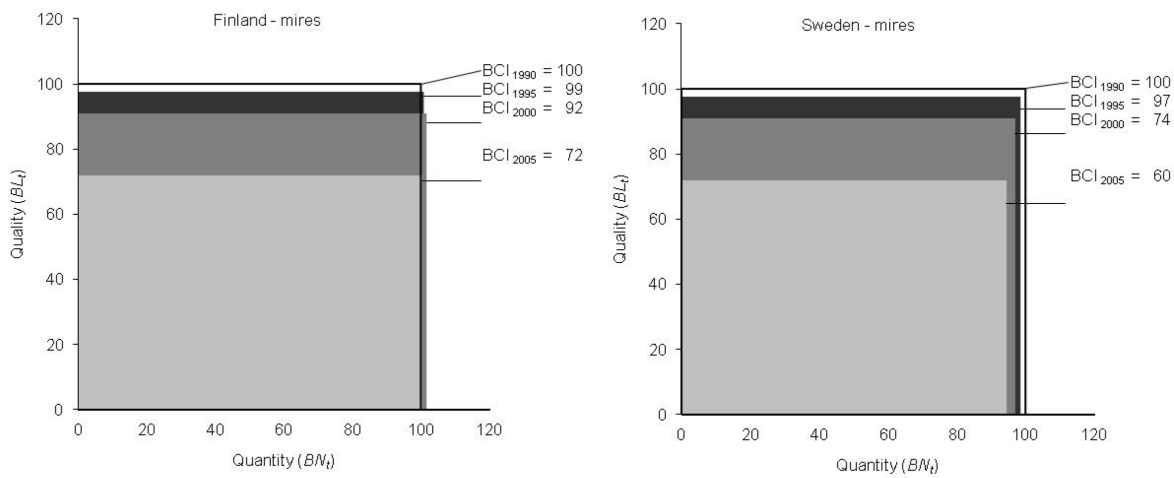

Finland - mires
Quality (BL_t)
Quantity (BN_t)
BCI_{1990} = 100
BCI_{1995} = 99
BCI_{2000} = 92
BCI_{2005} = 72
0
20
40
60
80
100
120
Sweden - mires
Quality (BL_t)
Quantity (BN_t)
BCI_{1990} = 100
BCI_{1995} = 97
BCI_{2000} = 74
BCI_{2005} = 60

Fig. 8

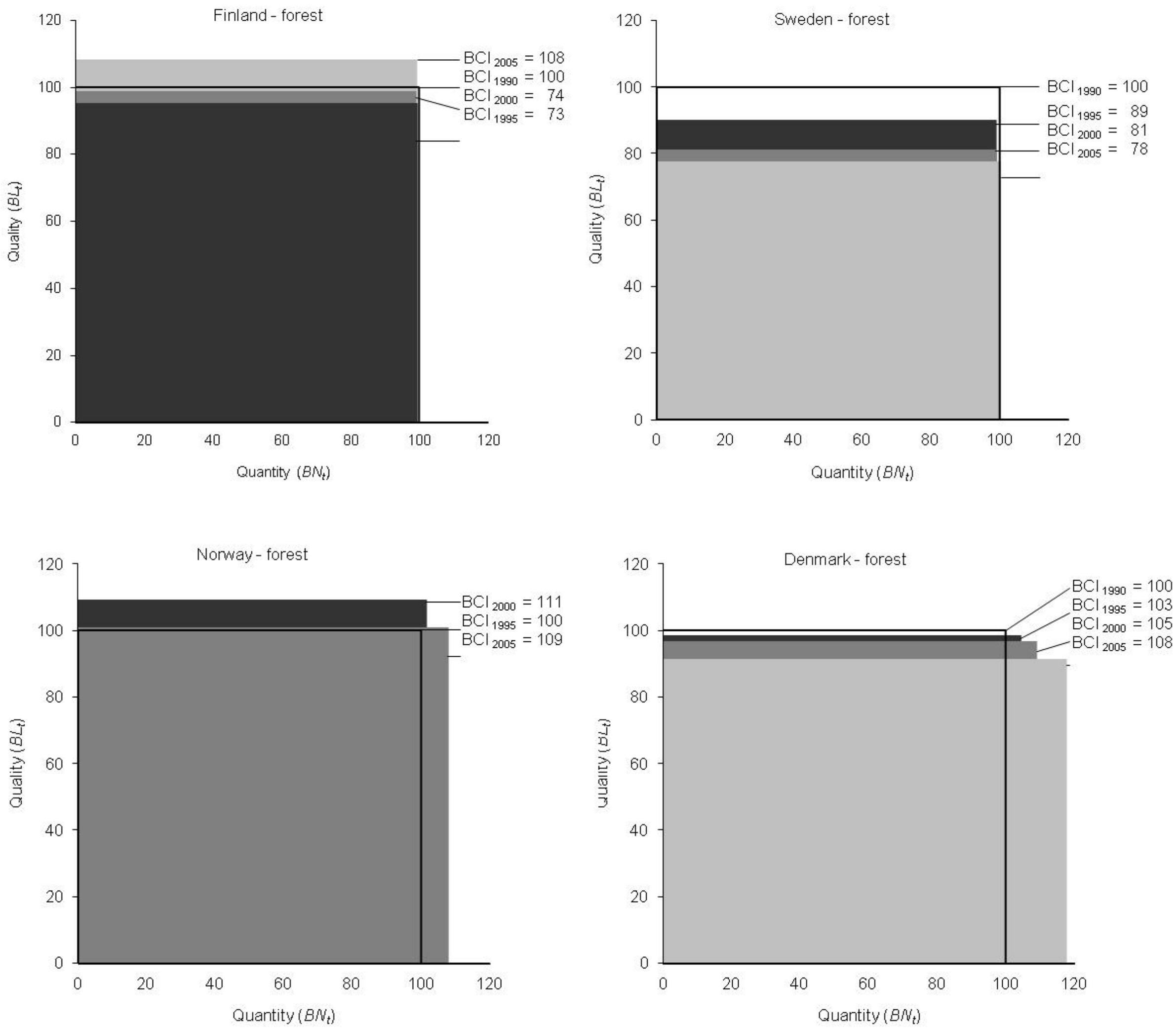
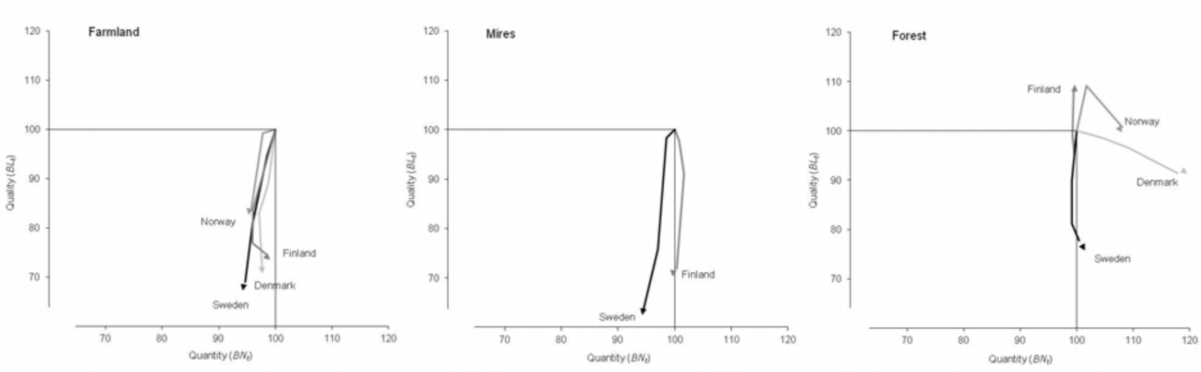

Finland - forest
BCI 2005 = 108
BCI 1990 = 100
BCI 2000 = 74
BCI 1995 = 73
Quality (BLt)
Quantity (BNt)
Sweden - forest
BCI 1990 = 100
BCI 1995 = 89
BCI 2000 = 81
BCI 2005 = 78
Quality (BLt)
Quantity (BNt)
Norway - forest
BCI 2000 = 111
BCI 1995 = 100
BCI 2005 = 109
Quality (BLt)
Quantity (BNt)
Denmark - forest
BCI 1990 = 100
BCI 1995 = 103
BCI 2000 = 105
BCI 2005 = 108
Quality (BLt)
Quantity (BNt)

Fig. 9


Farmland
Mires
Forest
Quality (BL_d)
Quantity (BN_t)
Norway
Finland
Denmark
Sweden