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Ecological framework for the Nature Index.

A more rigorous approach to determination of reference values and selection of indicators

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Content

Summary

In this report, we stress that the basic question the Nature Index is intended to shed light on is: Is biodiversity declining, is it stable or is it increasing? The Nature Index does this by summarising in a composite index measurements and assessments made by experts on the state and vitality of a selection of the components which, together, are thought to represent biodiversity.

The Nature Index for Norway initially uses just species as indicators, but in the future the desire is to develop a habitat type component in the index. Indicators that are intended to be included in the Nature Index should therefore at this stage be demographic variables or other population qualities. The indicators should, furthermore, be measurable in nature for delimited areas, and it should be possible to estimate the uncertainty in such measurements. It should also be possible to estimate a reference value for each indicator. One should also have sufficient knowledge to be able to assess trends in the individual indicator. The values reported should be as geographically representative as possible, that is, they should reflect the state of the indicator in the whole area in question. The indicators must respond to environmental changes.

Indirect indicators (surrogates) can be included in the set of indicators if they represent a population variable for a defined species or group(s) of species.

The set of indicators should
- be taxonomically representative
- represent various ecological functions of the species (e.g. trophic level, functional groups)
- include both common and rare species
- include key species
- have indicators that are sensitive to various kinds of environmental pressure (complementary)
- represent different habitat types and natural successional stages in the various major ecosystems
- represent the various main types of microhabitat found in the major ecosystems
- not include alien species

For “natural” major habitats (i.e. all major habitats except “open lowland”), reference values for the indicators are estimated relative to a common reference state that represents intact ecosystems with little or no human impact. A little impacted state means that species richness, the state of the various populations, and the system’s ecological functions are intact. It is suggested that the corresponding reference state for semi-natural ecosystems (i.e. “open lowland”) is defined as a system that is “in good condition” relative to the species diversity normally associated with the type of semi-natural habitat in question.

1 Background

1.1 The purpose of this report is to describe a basis for the revised version of the ecological framework for the Nature Index for Norway. This basis forms a common point of departure and conceptual framework for all the major ecosystems in the next phases of the revision process in which, among other things, the indicator set for each major ecosystem will be reviewed. The report clarifies the conceptual basis on which the Nature Index is founded, criteria are given for which qualities and properties its indicators should have, and guidelines are given for how a selection of indicators should be composed which, together, should describe the state of the ecosystems. In addition, a conceptual foundation and principles for estimating reference values that are intended to be identical for all the indicators are described.

1.2 By ecological framework, we mean the ecological definitions of the terms biodiversity, biodiversity indicator, reference state and reference value as these are used in the context of the Nature Index. The framework also gives meaning to “the state of biodiversity” or “the state of nature”, which are formulations used in the Norwegian Government’s Soria Moria II Declaration (Stoltenberg et al. 2009), and includes the principles chosen to measure these states. The framework also covers evaluations associated with the selection of indicators used to calculate the Nature Index, the choice of the type of scaling function attached to the individual indicator, how the reference value of the individual indicator is estimated based on a defined reference state and the determination of weightings applied to the individual indicator. The ecological framework was presented and discussed by Nybø et al. (2008), Certain and Skarpaas (2010) and Certain et al. (2011), and the various biodiversity indicators are dealt with by Nybø (2010b).

1.3 Certain et al. (2011) defined a flexible framework for the Nature Index which, in practice, permits the inclusion of widely different indicators. The principles for estimating reference values are also very flexible. In practice, Certain et al. (2011) extended the ecological framework as it was defined in the first Nature Index report (Nybø et al. 2008).

1.4 The choice of indicators in the 2010 Nature Index for Norway, however, largely followed the approach used by Nybø et al. (2008), putting focus on species as indicators. Reference values, on the other hand, were estimated in accordance with the broad, general definition in Certain et al. (2011), which gave room for various practical definitions (e.g. sustainable populations, pristine natural conditions, traditional management) even though “intact nature”, as it is defined here (see 8.6), was chosen for the majority of the indicators. This permitted the inclusion of a broader range of indicators, but made interpretation of the Nature Index values and comparison across major habitats more difficult.

1.5 This revision is mainly concerned with two aspects. Which principle should be used to select indicators for the Nature Index? How should the reference values for these indicators be determined?

1.6 Several matters give grounds for this revision. The work leading to the first version of the Nature Index revealed several aspects that needed clarifying and improving, and problems that needed solving. Some of these were mentioned by Skarpaas et al. (2010) and will also be presented and discussed in this Note. The Nature Index has, moreover, been criticised for not using a consistent method or definition to determine the reference state (Bøhn 2010, Sellæg 2010). The main report acknowledges this and points out that the state of different ecosystems must be compared with caution (Nybø 2010a). Following the launching of its first version in September 2010, the Nature Index has received considerable attention in Norway and other countries, resulting in it being used in new ways. Further areas of application have been proposed, but not yet implemented; and new ones are likely to be put forward in the future. This development is taken up in Chapter 2.

1.7 The mathematical framework defines the Nature Index as a composite indicator (OECD 2008), where the index is estimated as a weighted average of scaled biodiversity indicators (Certain and Skarpaas 2010, Pedersen and Skarpaas 2012). Composite indicators are being increasingly recognised as useful aids for evaluating and shaping policy strategies and communicating with the public within many different sectors in society, including environmental management, and economy (Bandura 2006, Saltelli 2007).

1.8 Composite indicators can at best clarify and simplify themes and fields that are complex and difficult to define, like biodiversity, and illustrate the trend within these. In such cases, it will therefore be easier to interpret composite indicators than to identify common developmental characteristics in many separate indicators (OECD 2008). Composite indicators have proved useful and effective for measuring development in such areas relative to fixed objectives and/or references and to raise awareness around particularly relevant themes (Saltelli 2007, Bubb et al. 2010).

1.9 The aim of this revision process is to define the ecological framework for the Nature Index for Norway more precisely than earlier descriptions, thereby achieving a consistent understanding of how indicators are chosen and how their reference values are estimated. A clearer understanding of the ecological framework will simplify the message imparted by the Nature Index to different users, communication will be improved and the index will to a greater extent be able to function as described in 1.7 and 1.8.

1.10 The two central topics in this revision are dealt with in Chapters 7 and 8 in this report. Chapters 2 to 6 are intended to give a background for these problems. Chapter 2 presents relevant areas of application for the Nature Index and discusses, in principle, the challenges development in this area has for the construction of the Nature Index and its framework. Chapter 3 describes the principles of how the Nature Index measures the state of biodiversity, and Chapter 4 proposes a demarcation of the parts of biodiversity the Nature Index should measure the state of. Chapter 5 deals with the mathematical framework, and Chapter 6 explains how and to what extent this framework provides flexibility to tackle the challenges brought by new areas of application.

2 How is the Nature Index intended to be used?

2.1 Two of the premises for the Nature Index to be able to function as described in 1.7 and 1.8 are that its relevant areas of application are described and its relevant users are identified. A description of users and areas of application form the basis for identifying and formulating those questions which the Nature Index is intended to answer, preferably in the shape of a key question. This can then be used as a standard and reference when developing and evaluating the ecological framework (cf. Bubb et al. 2010).

The original commission

2.2 In its Soria Moria Declaration, the Second Stoltenberg Government (2006-2009) stated that: "The Government will introduce a Nature Index for Norway to obtain an impression of how nature, including the cultural landscape, is developing" (Stoltenberg et al. 2005). The intention was that the Nature Index would help to measure whether Norway was attaining her international obligations to halt the loss of biodiversity by 2010, and be in a position to compare the development towards the same target in other relevant countries. The Ministry of the Environment clarified the utility value of a Nature Index in its requisition to the Directorate for Nature Management; it should have educational value, be able to provide early warning of changes, be a standard for nature management and enhance our understanding of the need to map and monitor biodiversity. This clarification has had consequences for the shaping of the framework, particularly the need to make it a standard for nature management, which is also closely tied to international reporting.

2.3 The Third Stoltenberg Government (2010-) confirmed the Nature Index in its Soria Moria II Declaration. "The Government wishes to introduce a Nature Index for Norway that will be able to present the state of nature in Norwegian municipalities" (Stoltenberg et al. 2009). The Nature Index is thus intended to be an instrument for management authorities, enabling them to measure the state of, and changes in, biodiversity in a lucid manner.

Further development and proposed new areas of application

2.4 Both the national targets and indicators and those of the Convention on Biological Diversity (CBD) have changed since the Nature Index was launched.

2.5 The CBD established new international targets for 2020 and 2050 (Convention on Biological Diversity 2011), and indicators linked to these are being developed. The Nature Index, with associated thematic indices, can be used for national reporting for these new CBD targets. This particularly applies to indicators linked to Strategic Goal C, "To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity" (Convention on Biological Diversity 2011). Indicators attached to this strategic goal are in Appendix 1. Thematic indices based on the Nature Index framework can be used to show the development in these "Aichi Targets".

2.6 Biodiversity management in Norway received better legislation when the Nature Diversity Act came into force on 1 July 2009. Its purpose is to protect biological, landscape and geological diversity, and ecological processes. The Act states that decisions must be taken on the basis of the precautionary principle (§ 9) and public decisions affecting nature diversity must, as far as is reasonable, be based on scientific knowledge of the population status of species, the range and ecological state of habitat types, and the effect of environmental pressures (§ 8). Moreover, pressure on an ecosystem must be assessed on the basis of the cumulative environmental effect on the ecosystem now or in the future (§ 10).

2.7 Prioritised species and selected habitat types are specific, new targets for management. The task of implementing associated measures for these targets is carried out in several sectors. There will probably be a need to give an overall assessment of whether these measures produce the desired effect. It is natural that the Nature Index contributes here. At present, it seems that the Nature Index may be used in relation to prioritised species, but the NI ecological framework also paves the way for assessing selected habitat types as these become better described and mapped.

2.8 In autumn 2011, the Nature Index was accepted as an indicator of sustainable development and will figure in the annual Norway Statistics report on sustainable indicators and in the national budget (Finansdepartementet 2011).

2.9 The Ministry of the Environment also changed its priority areas in 2011, and focus is now directed at ecosystems (Miljøverndepartementet 2011). This approach makes it easier to acquire an overall ecosystem approach like that on which the Norwegian Nature Diversity Act focuses. The subdivision of ecosystems into types broadly follows the Nature Index subdivision of major habitats. For the new priority areas, the Nature Index is envisaged as being an overarching indicator for measuring the development of biodiversity in the ecosystems. Sub-goals are defined in each priority area. For many of the ecosystems, sub-goals are formulated for prioritised species and selected habitat types, sustainable management of various harvestable stocks and the trend in the populations of endangered species. Possible thematic indices based on Nature Index data can be constructed to indicate the trend in such targets for management within each priority area. However, management authorities must themselves define the areas for which it is relevant to develop such indices.

2.10 Separate sectorial goals for work related to biodiversity are laid down in Miljøverndepartementet (2001). These goals have been further developed, partly as a consequence of the Nature Diversity Act. Sectors, commercial organisations and NGOs working on biodiversity were invited in spring 2012 to form a group of Nature Index stakeholders. The work in this group will be able to uncover additional requirements for reporting the effects of measures implemented by the sectors to safeguard biodiversity. The framework for the Nature Index takes into account that thematic indices for such sub-goals can be developed provided the NI data base contains indicators that are relevant for them.

2.11 Both the institutions for environmental management and the sectors have responsibility to report the national development in biodiversity to the CBD. In most cases, they will wish to report the same figures as are reported nationally. It will therefore be important to harmonise the national indicators with international ones (see 2.5). The Directorate for Nature Management is now endeavouring to clarify the relationship between the Nature Index, thematic indices and these reporting requirements. Preliminary evaluations indicate good agreement (see also Appendix 1). The Norwegian Institute of Marine Research is also seeking to harmonise its reporting of the status in the sea to various fora.

2.12 In February 2013, the United Nations Statistics Division will complete a manual for ecosystem accounting for statistical bureaus around the world (United Nations 2013). This is referred to as an experimental manual, that is, it lays down the basic principles for how such accounting should be implemented, but the nations can try out different methods to achieve this. The manual paves the way for the Nature Index being one such method that can be tested.

2.13 Natural benefits, or ecosystem services, are closely linked with biodiversity. The Government has appointed a committee of experts to evaluate ecosystem services in Norway. It may be envisaged that the Nature Index can help to quantify the potential for ecosystem services. The conceptual model for this is being drawn up. Later, there will be a need to prepare examples based on this model.

2.14 Desires for future use of the Nature Index are appearing all the time. Several new possibilities are outlined above (2.5-2.13). These can be realised if various sectors become involved, particularly with a view to which indicators can enter into the Nature Index given the set of criteria for selecting new indicators (Chapter 7) and acquiring knowledge about them. This paves the way for producing various thematic indices which can be used to assess our own management, and be re-used for international reporting when this is relevant.

2.15 The Nature Index is also an appropriate instrument for the press and other media, special interest organisations and the general public (see e.g. Seippel and Strandbu 2012). It will thus be able to raise awareness for topics and problems associated with biodiversity in Norway, contribute knowledge that can form a basis for public debate surrounding these, and initiate such debate.

2.16 As proposals are put forward to extend the area of application of the Nature Index, it will always be timely to ask whether the index and its framework are relevant for, or capable of, answering the questions that are posed and covering the requirements that are in demand. Is the framework sufficiently flexible to provide answers to many different questions? We return to these issues in Chapters 4 and 6.

2.17 Items 2.4-2.16 underline the importance of transparency around the Nature Index as regards how it is constructed, which questions it is meant to answer, how it gives answers and the reasoning used to provide the answers (i.e. the theoretical basis).

The key question

2.18 The key question the Nature Index is intended to answer can be inferred from item 2.2: *Is biodiversity declining, is it stable or is it increasing?* The formulation ”how nature … is developing” in the Soria Moria I Declaration can be made more precise as: “how biodiversity is developing”.

2.19 In the remainder of this report, the concept of “Nature Index” is limited to cover just composite indicators which are developed to answer the key question posed in 2.18. However, the fundamental data and the ecological and mathematical frameworks can also be used to estimate other composite indicators. Such indices will hereafter be referred to as thematic indices or something else.

The Nature Index is an index of the state and development of biodiversity in the major ecosystems.

A thematic index is composed of a smaller selection of indicators that form part of the Nature Index.

A thematic index reflects a particular management theme or the development in a group of species.

2.20 The European Environment Agency (EEA) uses the DPSIR approach (Bosch and Gabrielson 2003) when it defines what an indicator must reflect. D stands for “drivers” and points to the underlying anthropogenic causes of environmental change (e.g. population growth, economic development and technological development). The drivers are the cause of the various “pressures” (P), which include the direct anthropogenic pressures that change the environment (e.g. acid precipitation and climate change). S stands for “state” and I for “Impact” – the effect of the pressure. These two elements, S and I, are often regarded as two sides of the same issue since the current state is a result of the total pressure. Finally, R is used for “response” which includes legal and economic measures applied to change the state.

2.21 The Nature Index measures the state (S) in the ecosystems given the total pressure from various impact factors. Since the Nature Index does not estimate impact factors, only state, the Nature Index value will reflect the effect of the total negative impact applied by mankind on biodiversity in a major habitat given that the indicators are sensitive for the pressures concerned.

2.22 Indicators of state may have key functions in effective decision processes and in management that should be accommodated to relevant challenges. They can describe the extent to which different management strategies have an effect and attain their targets, and also form part of an early-warning system to learn of detrimental developments. They can also be used to enhance awareness of a theme. However, indicators of state do not automatically supply information on cause and effect relationships, but they will be natural starting points for suggesting theories and hypotheses about them.

2.23 If a composite index that describes state is to be transparent, and the content it communicates is to be unambiguous, one should avoid mixing indicators for pressure and state in one and the same index, as OECD (2008) also emphasises. A mixture will undermine the function of the index (cf. 2.22) because potential causes would be confused with potential effects, and responses (which are often directed at the impact factors) would potentially be confused with target attainment (which should be in the shape of positive changes in state).

2.24 Knowledge of drivers and impact factors is, however, important if causes of changes in the Nature Index are to be understood and/or inferred, and to design and execute targeted responses which might be essential to attain management goals. Information on important negative impact factors is collected for each indicator and will by degrees be analysed in relation to changes in the value of the Nature Index.

3 Biodiversity – what does the Nature Index measure?

3.1 "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and aquatic ecosystems and the ecological complexes which they are part of; this includes diversity within species, between species and of ecosystems" (United Nations 1992).

3.2 The Norwegian Nature Diversity Act defines biological diversity as "ecosystem and species variability and intra-species genetic variability, and the ecological relationships between ecosystem components". Nature diversity is a broader concept and includes "biodiversity, landscape diversity and geological diversity which, for the most part, are not a result of human impact".

3.3 These definitions contain several elements. They identify biological *variation* as the central element in the concept of biodiversity. They emphasise variation at three different levels, *within species* (which includes genetic variation within and between populations), *between species* (for example, species richness) and *between ecosystems* (including variations in habitat type and landscape). They also include the diversity that arises when individuals and populations form components in complex ecological systems; ecological interactions both result in and are a result of biodiversity (Mace et al. 2012).

3.4 The definitions, however, are not explicit regarding how far they refer to the *extent* of the biological variation or biological variation *per se*, or how the concept of biodiversity relates to spatial variation (Mace et al. 2012). The definitions do not include measurements and amounts that are solely based on quantity or abundance (cf. Balmford et al. 2003, Mace 2005).

3.5 The basic question which the Nature Index must answer (2.18) is, however, not "how large is biodiversity in Norway?" Rather, it concerns (2.18) the state and development of biodiversity, and whether the changes are proceeding in a positive or a negative direction.

3.6 To be able to evaluate the development towards the 2010 goals, the Convention on Biological Diversity pointed out that the concept "loss of biodiversity" should embrace "the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels" (Convention on Biological Diversity 2004).

3.7 Examples of such components of biodiversity are the individual species/population or habitat type/ecosystem (cf. Millennium Ecosystem Assessment 2005). However, the concept is generally used in a much broader sense (e.g. Certain and Skarpaas 2010, Certain et al. 2011, McDonald 2011).

3.8 The basic question can therefore be answered in different ways (McDonald 2011). For instance, by measuring the amount of biological variation in the form of different measures for genetic variation, species richness, or diversity indices, and with the help of these measures of variation describe how the diversity changes over time (e.g. Fleishman et al. 2006). Alternatively, one could measure the state and vitality of the components which, together, constitute the biodiversity and summarise them in one or more component-based, composite index (e.g. Noss 1990).

3.9 Such data on the amount of total biological variation in the individual municipality at different times are not currently available, nor are they thought to be obtainable in the foreseeable future due to inadequate scientific and financial capacity.

3.10 Recognised, international indices for biodiversity, such as the Natural Capital Index (ten Brink 2000), and the Biological Intactness Index (Scholes and Biggs 2005), are based on components.

3.11 *The Nature Index is an index for biodiversity that summarises the state and vitality of a selection of the components which, together, represent biodiversity* (cf. Certain et al. 2011).

3.12 Component-based indices can be simply broken down into thematic indices or their separate components. This is valuable in an active and adaptive management of biodiversity because our knowledge of how potential drivers affect diversity is first and foremost concerned with the individual components and less with the extent of the biological variation.

4 Which components of biodiversity should the index represent?

4.1 Certain et al. (2011) described a flexible framework to develop a composite index for biodiversity. The Nature Index for Norway (Nybø 2010a, b) is one (of many possible) realisation(s) of this framework.

4.2 In the present version of the Nature Index framework (Certain and Skarpaas 2010, Certain et al. 2011), the intention is that the selection of indicators should cover all aspects of biodiversity in a homogeneous manner. The index aims to summarise the development of all aspects of biodiversity. In principle, this framework enables us to have a still wider coverage by including indicators which represent other kinds of nature diversity (landscape, geodiversity).

4.3 Evaluation and further development of the selection of indicators in relation to such a goal presupposes a description of what all the different aspects of biodiversity (or nature diversity) are, which aspect is represented by the individual indicator, and that, for each aspect, an evaluation is made of the extent to which it is adequately represented in the selection and taken into account when the Nature Index is calculated. This places great demands on documentation, argumentation, presentation and dissemination of what the Nature Index is. So far, very little documentation of this kind has been collected and presented in a Nature Index context. The following paragraphs clarify and demarcate the aspects of biodiversity which the Nature Index is intended to represent. This demarcation implies a simplification of the intention of the Nature Index compared with the descriptions given by Certain and Skarpaas (2010) and Certain et al. (2011).

4.4 A clarification of which aspects of biodiversity the Nature Index is intended to cover should be based on what the index is envisaged to be used for. As mentioned earlier, its area of application has widened since it was first commissioned. With the enactment of the Norwegian Nature Diversity Act (with its Provisions on prioritised species and selected habitat types) and the performance measures set by the Ministry of the Environment, species and habitat types stand out as two elements of nature diversity that are important to cover. So far, most of the indicators are species, but the index also includes indicators of a ”habitat type” character (community indices, habitats) in the majority of the ecosystems.

4.5 There are several good reasons to concentrate on species (cf. McDonald 2011): a) species are the topic of most international agreements and national policy strategies concerned with biodiversity, b) species are comparatively conspicuous and easy for the public to relate to, c) estimated index values and changes in these are easier to impart if species alone are included, d) considerable research on species and populations has been taking place for many decades, and it includes long-term monitoring programmes, e) species are often used as a surrogate for biodiversity in general, f) ecosystems consist of populations and the abiotic environment, and g) a species indirectly represents its own gene pool.

4.6 Species/populations and habitat types/ecosystems are the most likely levels for biodiversity that will be included in environmental accounts and valuations of ecosystem services (Cosier and McDonald 2010, McDonald 2011).

4.7 In the very first version of the framework for the Nature Index, species based indicators were envisaged to be the sole components, and Nybø et al. (2008) suggested that the indicators for state in a major habitat should preferably be population parameters for a set of species (which also indirectly represent genetic variation). Alternatively, surrogates for the species (indirect indicators) could form part of the indicator set where the relationship between surrogates and the state of the populations of one or more species was documented and data for the surrogates were more easily available.

4.8 There were two reasons for this proposal. The most important one was that insufficient data on the distribution and state of ecosystem- and habitat types were available to undertake assessments by experts, nor did plans exist to begin comprehensive mapping and monitoring of this (Nybø et al. 2008). Mapping of selected ecosystem- and habitat types has now begun, but as of 2012 there are no plans to undertake general mapping and monitoring of ecosystem- and habitat types in Norway, neither common nor rare ones.

4.9 The second reason was that the Norwegian Parliament had requested that the Nature Index should be able to be used to compare the development of biodiversity in Norway with that in other countries (Miljøverndepartementet 2006). Recognised, international indices for biodiversity like the Natural Capital Index (ten Brink 2000), GLOBIO (Alkemade et al. 2009), Biological Intactness Index (Scholes and Biggs 2005) and Living Planet Index (Loh 2000) are based on species. They mostly evaluate population trends and rarely or never diversity changes. Some indices, however, report areas of “rapid change” and “major habitats”, while the Biological Intactness Index weighs habitat types by their original species richness.

4.10 The 2010 Nature Index includes species and indirect indicators for species, which cover many aspects of taxonomical and functional diversity, but it is extremely unclear how far the degree of ecosystem- and habitat type variation is covered by the “habitat type” indicators. The inclusion of both species and habitat types in the 2010 Nature Index means that the interpretation and, hence, the imparting of the estimated index values will be difficult. The representation in the index of the total diversity of species and habitat types becomes unclear and varying, and thus difficult to impart. One should therefore consider having the species and habitat type components of the Nature Index in two separate indices.

4.11 *The Nature Index for Norway will initially only be based on species*. This will have consequences for the choice of indicators to be included in the index.

4.12 As the Nature Index is developed, imbalances in the selection of indicators can be rectified by including more species from under-represented groups. Some information on individual species is also present in the community indices (e.g. the indicators “aquatic vegetation” and “encrusting algae in fresh water”), which can perhaps be split up.

4.13 *We suggest that an ecosystem- and habitat type component is developed for the Nature Index*.

4.14 This calls for a great deal of planning and must be organised as a separate project. A Nature Index for habitat types is now closer to realisation than when the Nature Index work began five years ago. Parallel with the development of the Nature Index, considerable effort was made to clarify terms and categories when "Nature types in Norway" (NiN), a system for typification and description of ecological variation (Halvorsen et al. 2009), was being prepared. Work is now taking place to suggest how the task of monitoring the state of these “nature types” may be undertaken (Framstad, Halvorsen et al. in prep.). If and when such monitoring is actually implemented, the current framework for the Nature Index will be sufficiently flexible to make use of such data (Certain et al. 2011). The database that is presently being established can also be used to collect data on habitat types.

4.15 In the longer term, it will, if desirable, also be possible to combine the species and habitat type components in a single index.

4.16 The remainder of this Note focuses on developing an index as described in 4.11.

4.17 The establishment of alien species, which, at the same time, do not pose a threat to the established diversity, could locally increase the biodiversity in Norway. However, viewed in a wider geographical perspective than the national one, the spreading of alien species represents a homogenisation and, hence, a reduction of the biodiversity (Millennium Ecosystem Assessment 2005).

4.18 *At the outset, alien species do not form part of the biodiversity with which the Nature Index is concerned.* However, using the framework of the Nature Index as its starting point, work has started to look into the possibility of preparing a separate index for alien species that shows their potential for having negative impacts on biodiversity (van Dijk et al. 2012).

4.19 The Nature Index is currently calculated for nine major types of ecosystem (= major habitats): seabed, sea – pelagic, coastal waters – seabed, coastal waters – pelagic, freshwater, open lowland, forest (including both woodland and forest), mire-spring-flood plain and mountain. These are described in more detail by Nybø (2010a).

4.20 The Nature Index focuses on the ”state” or quality of the major habitats (cf. Natural Capital Index, ten Brink 2000) within the area they cover at any one time.

4.21 Changes in the surface area taken up by the individual major habitat therefore constitute (essential) complementary information for the index by describing trends in biodiversity. Updating surface area information is also essential for SEEA Ecosystem Experimental Accounting (United Nations 2013).

5 The mathematical framework

Very simplified, a scaled indicator value of 0.7 can be interpreted as follows:

The population of the species is 70 % of what it would have been in the reference state (LOW model), measured either by the species itself or by an indirect indicator.

The population of the species is 70 % of what it would have been in the reference state, measured by an indirect indicator (MAX model).

Very simplified, a nature index value of 0.7 can be interpreted as follows:

The average population of the indicator species is 70 % of that found in an intact natural environment.

5.1 The mathematical framework consists of the mathematical definition of the Nature Index as a weighted average of scaled biodiversity indicators, and models for scaling the indicators where the reference values are included as "parameters".

5.2 A framework has also been constructed to estimate the Nature Index, and this contains routines for how the index is estimated from data reported with uncertainty.

5.3 Agreement must exist between the ecological and the mathematical frameworks in the sense that definitions of reference state and biodiversity indicators are in accordance with their function in the mathematical framework and *vice versa* and the mathematical framework defines an index which measures the state of biodiversity as diversity is defined in a Nature Index context.

5.4 The 2010 Nature Index has three scaling functions: LOW, MAX or OPT, where the reference value is the only parameter. The LOW model is used when there is a positive relationship between the indicator and biodiversity, the MAX model when the relationship is negative and the OPT model when it is unimodal.

5.5 Recent research on location displacement linked to calculation of the Nature Index means that the OPT model will hereafter be omitted from the mathematical framework (Pedersen and Skarpaas 2012). It will therefore not be further discussed here.

5.6 In general, the LOW model must therefore be used as default, while the MAX model is used only for indirect indicators which are assumed to have a negative correlation with the species for which it is supposed to have statistical significance. For instance, moose will be able to function as an indirect indicator for deciduous trees (rowan, aspen and goat willow) when the moose populations are large and above the reference value. Moose-indirect therefore says something about the trend in the population of deciduous trees and will be assigned to the MAX model. The direct indicator, "deciduous tree", is to be preferred to the moose-indirect indicator. Moose can also be used as a direct indicator, where they represent themselves. In this context, they may be given a different reference value and be scaled with the LOW model. In practice, this means that every indicator that has been assigned to the OPT model in the 2010 Nature Index must be reviewed and a decision must be taken as to whether it must be replaced by two new indicators. Note that the reference value for the two indicators need not be the same.

5.7 The reference value plays two different roles in the scaling functions LOW (Figure 1) and MAX. Firstly, it defines a scaling constant which is equal to the inverse of the reference value (1/ref). In this way, the reference values define for the various indicators which values prior to scaling should give the same indicator value after scaling.

5.8 The reference values also represent boundaries between intervals in the definition area of the indicators, where the scaling functions behave differently. In LOW and MAX, the reference value sets the boundary between intervals where the Nature Index is sensitive to changes in the indicator and intervals where it is not sensitive. In the latter intervals, all the values of the indicator are scaled to 1 (also to 0 in MAX). For these two scaling models, this means that there is a non-linear relationship between indicator and index. The Nature Index is thus a composite indicator based on non-linear aggregation of the individual indicators (cf. OECD 2008).

5.9 In this way, the reference values set a limit for how much an improvement in one indicator, which at the outset is in a good state, can compensate for negative development in other indicators. In practice, this means that if one gets very high populations of an indicator, this will not be able to cancel out a low value in another indicator. For instance, an increase in the local moose population to twice the reference value will not compensate for a local extinction of the wolf. After scaling, moose is assigned a value of 1 irrespective of how much higher than the reference value the population gets. The moose-wolf index in such a case will be assigned a value of 0.5.

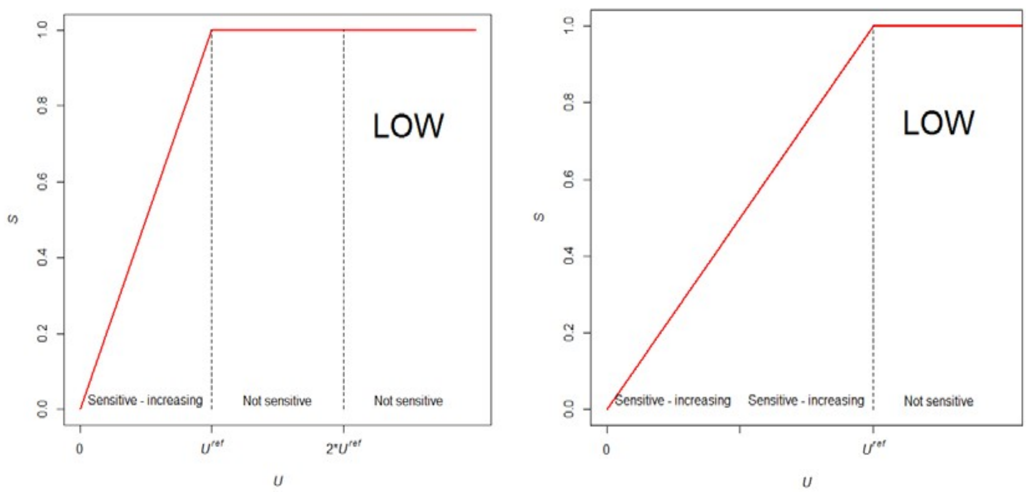

*Figure 1. When the reference value (U^{ref}) is changed, both the slope value (i.e. the scaling constant) of the scaling function (S) in the "sensitive" interval and the size of the intervals where the Nature Index is sensitive or not sensitive to changes in the indicator (U) are changed, here illustrated for the LOW model, where the new reference value (right-hand figure) is 2.0. * old reference value (left-hand figure).*

5.10 The Nature Index is thus a summary of negative departures (in the state of biodiversity) from the reference values, where positive departures lack significance (Figure 1). An index value of 0.7 means that the (weighted) average, negative departure from the reference state corresponds to an indicator (population) that is 70 % of the reference state.

5.11 Non-linear aggregation seems to be a precondition if a composite index which summarises the state and/or vitality of the diversity components (see 3.8) is to be able to represent biodiversity.

5.12 Estimating reference values balances functions like sensitivity and compensation limits. A higher reference value gives a larger interval where the index is sensitive to changes. The value of 1 is more difficult to attain, but it gives an indicator greater opportunities to compensate for negative trends in other indicators.

5.13 In its present form, the Nature Index is estimated at different levels of aggregation. At the lowest level, it is estimated for an individual functional group in one ecosystem in a municipality. These can then be combined into indices at higher levels by aggregating across functional groups, ecosystems and/or municipalities (Certain and Skarpaas 2010, Certain et al. 2011).

5.14 Different weightings are used when aggregating from one level to another depending upon which “factor” the aggregation takes place across. When aggregating across functional groups, the groups are, as a starting point, weighted equally, but extra weighting is assigned to key indicators, which Certain et al. (2011) called extra-representative indicators. When aggregating across major ecosystems, these are weighted equally, i.e. they are regarded as having equivalence. However, one very rarely wishes to present a single figure for nature in Norway or a region. The reason for this is that any cause and effect relationships will be difficult to communicate without splitting the figure up again into major ecosystems. When aggregating across municipalities, the weightings reflect their surface area.

6 The framework and flexibility

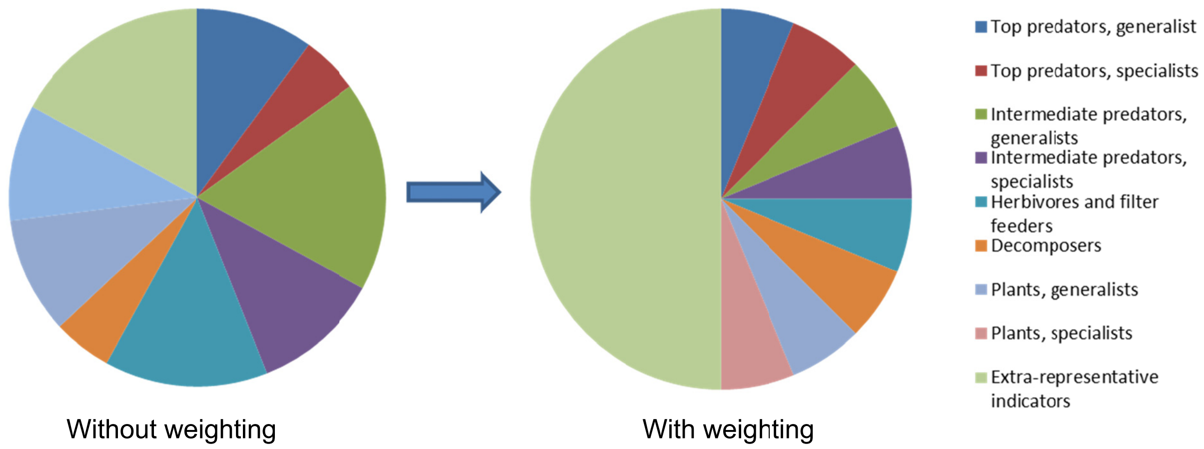

Figure 2. Schematic overview of weighting across functional groups

6.1 The principles for weighting and aggregating can be accommodated to new requirements when developing new thematic indices. The principles for calculating the Nature Index across functional groups and assigning extra-representative indicators 50 % of the weightings were agreed upon by the experts for the Nature Index and apply to all major ecosystems (Figure 2). The criteria for regarding an indicator as an extra-representative indicator are: i) the indicator has statistical significance for populations of one hundred or more species, ii) it occurs over a large area, and iii) at the same time, the index has good data for it (Nybø 2010a). This means that key species like capelin, herring, rodents and bilberries, which are very important for other species, will be weighted as extra-representative indicators. The present weighting system was primarily introduced to correct for imbalances in the selection of indicators which was, and still is, dominated by vertebrates (Nybø 2010a).

6.2 An indicator may represent several factors. It can be characterised on the basis of which ecosystem and habitat type(s) it belongs to, its ecological function, its microhabitat, its taxon and to which impact factors it is sensitive, etc. This paves the way for constructing various thematic indices and for analyses that will shed light on cause and effect relationships.

6.3 By using other principles for weighting and for the composition of the indicator selection, the data used in the Nature Index and its framework can be used to answer other questions than the key question (2.18).

7 Which indicators should be included in the Nature Index?

Which qualities must a biodiversity indicator have?

7.1 In the last version of the framework for the Nature Index (Certain and Skarpaas 2010, Certain et al. 2011), a biodiversity indicator was defined as “a natural variable related to any aspect of biodiversity, supposed to respond to environmental modification and representative for a delimited area. It is a variable for which a value in a reference state can be estimated“ (Certain et al. 2011, p. 2).

7.2 This implies that each individual indicator should, in principle, be measurable in nature and it must be possible to link each measurement to a specific, delimited area. The purpose here is not to exclude judgements by experts, but it should be possible to validate these in the future and preferably to replace them by monitoring in the longer term. An indicator must also be able to respond to changes in the environment, and it must be possible to estimate a reference value.

7.3 Other premises are that an indicator must be able to be linked to one or more major ecosystem(s). For each major ecosystem in which a species indicator occurs, and for each areal unit an indicator is measured, it is to be expected that the species can maintain a persistent population when the ecosystem is in its reference state (this is necessary if the reference value is to be above zero). There must be sufficient knowledge to be able to estimate trends in the indicator.

7.4 The values for each indicator in the database must be geographically representative for the area assessed, that is, excessive focus must not be placed on good or poor areas in a municipality, county or region. This criterion is difficult to satisfy, but an effort should be made to do so for all indicators. If geographically representative measurements are not available, an alternative is to rely on the judgement of experts. This is an important reason why many indicators in the 2010 Nature Index were reported as assessments by experts.

An indicator should meet the following criteria:

1. *It should be measurable in nature*
2. *The measurements must be able to be linked to a specific, delimited area*
3. *It must be possible to estimate a reference value*
4. *It must be able to be linked to one or more major ecosystem(s)*
5. *For each of these major ecosystem, it is to be expected that the indicator can maintain a persistent population when the ecosystem is in its reference state*
6. *There is sufficient knowledge to be able to estimate trends in the indicator*
7. *The indicator should preferably be a population quality*
8. *It must respond to changes in the environment*

7.5 As mentioned above, the species component is initially the only one used in the Nature Index, based on the approach proposed by Nybø et al. (2008), which focused on species indicators.

Indirect indicators

7.6 About 1/8 of the indicators now used in the Nature Index (estimated in the 2012 Nature Index) are strictly speaking not species indicators. This is a heterogeneous group of indicators.

7.7 A large proportion of these are based on observations of a taxonomically and/or ecologically defined group of species rather than individual species. Examples of such indicators are *Clavaria* fungi, phytoplankton, skates, small rodents and the sponge genus *Geodia*.

7.8 An equally large proportion of the indicators can be characterised as “community indices”. They have in common that observations of individual species are synthesised or aggregated into an index value that characterises the composition of the community which the individual species together constitute. It is the index value, not the observations of each species, which forms the basis for estimating the Nature Index. Such indices have been developed for benthos fauna, communities of macro-algae and freshwater vegetation, etc. Estimating community indices from observations of species is a parallel to estimating the Nature Index from species indicators. Community indices can therefore form part of the selection of biodiversity indicators without violating the concept of a species-based Nature Index. However, these indices often represent other ways of synthesising the species observations which one believes are more appropriate for the communities concerned.

7.9 The remainder of the 15 indicators are either surrogates like the MIS indicators, standing and lying dead wood, indicators based on habitat types like the areas of palsa mire and Atlantic raised bog, or individual species like wavy hair-grass which are used as surrogates for other species which co-vary negatively with the observed species and are therefore scaled with the MAX model.

7.10 The indicators mentioned in 7.8 (community indices) and 7.9 (surrogates) are here called indirect indicators.

7.11 Surrogates can be used in the species index if they represent a development of the population of one or more species. Such a correlation must be shown to be probable. Surrogates may be chosen among biotic indicators which say something about the occurrence of a species. In practice, habitat types can only be used if they represent given species or groups of species.

7.12 Indicators that are direct measures of the development in abiotic impact factors, such as pollution or climate variables, must not be used. The principles in question are discussed in 2.23. Moreover, dose-response curves between pressure and populations are seldom known, and there is usually some recovery time lag between a change in the abiotic factors and demographic changes. Indirect indicators based on pressures will therefore often show a more rapid response than the actual population changes. Hence, an index based on this type of indirect indicator will give an excessively positive impression of the state of nature when measures have been implemented.

7.13 We also wish to examine whether the community indices that are included in the Nature Index (e.g. the Water Framework Directive indices) should be split up into individual species. Focusing on population changes in individual species will make it easier to utilise and communicate the information in these indices, in part by using a selection of the species for thematic indices.

Composition of indicator set – former approach

7.14 The Nature Index will necessarily be based on a limited selection of all the relevant indicators. Practical limitations mean that random selection of indicators is impossible. The strategy should therefore rather be to make a selection which one believes is representative to describe the state of diversity.

7.15 “The set of indicators should cover as homogeneously as possible all aspects of biodiversity, and any addition of a new indicator should result in the addition of information. Thus, a biodiversity indicator might refer to a population of a single species, a genetic measure, a functional diversity index, a demographic or behavioral parameter, a community metric, or any other natural parameter fitting the definition." (Certain et al. 2011, p. 2).

7.16 The approach used by Certain and Skarpaas (2010) therefore sets limits on which indicators can enter into the selection. At the same time, an effort is made to have very many different kinds of indicators in the selection so as to cover as many aspects of biodiversity as possible. The approach also places restrictions on how many indicators will be included in the index, because complementary information is required.

Composition of indicator set – revised approach

7.17 In the practical implementation of the 2010 Nature Index for Norway, a set of criteria was used to select indicators which, when the points listed in 7.15 were elaborated upon, was close to the approach used in the first framework (Nybø et al. 2008). Focus is placed there on population changes for species or indirect indicators for these and that the set of indicators must provide a representative selection of indicators with respect to taxonomical and functional distribution.

7.18 Based on this, we suggest that the set of indicators should

a. be taxonomically representative
b. represent the different ecological functions of the species (e.g. trophic level and functional groups)
c. include both common and rare species
d. include key species
e. contain indicators which, together, are sensitive to various kinds of environmental pressure
f. represent the various habitat types and natural stages of succession within the different major ecosystems
g. represent the various main types of microhabitats found within the different major ecosystems
h. not include alien species (cf. 4.18).

7.19 It will be difficult to satisfy all these criteria, but 7.18 will, nevertheless, serve as a starting point to identify gaps and imbalances in the existing knowledge for the Nature Index.

Specification of criteria for selection of indicators for a habitat type index

7.20 As we have suggested above, an ecosystem- and habitat type index should be planned based on the framework of the Nature Index. In this connection, a practical set of criteria must be devised to select indicators which are in correspondence with the general points in Certain et al. (2011).

8 Determining reference values

8.1 The mathematical framework means that the Nature Index measures the current state in nature relative to a reference state. The reference state is described conceptually by the definition and quantitatively by the reference values of the various indicators.

8.2 As explained in 5.7 - 5.12, the reference values are used for scaling and non-linear aggregation of biodiversity indicators. They therefore have fundamental functions in the mathematical framework.

8.3 Only negative departures from the reference values will affect the Nature Index.

8.4 According to ten Brink (2006), the reference state and reference values have the following functions in an index for biodiversity:

- give meaning to raw data
- allow aggregation of different indicators into coherent composite indicators
- make biodiversity indicators comparable within and between countries
- simplify communication with politicians and the public
- provide a fair and common denominator for all countries, being in different stages of economic development

8.5 Reference values are determined on the basis of a reference state that is defined for an entire major habitat. The reference value of the individual indicator is determined on the basis of the common reference that applies for all indicators in the ecosystem. This means that the reference values are tied to a reference state, not a given year.

8.6 Determining reference values for indicators from the same natural ecosystems (i.e. all major ecosystems except open lowland) must be based on a common reference state for that system. The state must represent an intact ecosystem with little or no human impact. A little impacted state means that the species richness, the state of the various populations and the ecological functions are intact. Thus, in practice, the reference value is set on the basis of the populations in what would have been an intact ecosystem today, given the climate at a specific point in time (e.g. the mean for 1961-1990, which is used as the “climate normal” by the Norwegian Meteorological Institute) with a species composition that would have existed in intact nature at that time.

8.7 The reference state for semi-natural ecosystems is defined as a system that is “in good condition” relative to the species diversity normally associated with the type of semi-natural habitat type in question.

8.8 One advantage of this approach is that the Nature Index is then sensitive to all negative departures from the common reference state.

8.9 Another advantage is that a value of 1 in the Nature Index is given a specific content. The index becomes more readily understood and simpler to impart. A value of 1 means that all the indicators are in their reference state.

8.10 The original commission (2.2) clearly stated that the Nature Index must report the development characteristics for both natural and semi-natural ecosystems.

8.11 The simplest way to construct sensitive indices (a premise for reporting development characteristics) which describe the development in both natural and semi-natural systems is: 1) at one level or another of the aggregation, to combine biodiversity indicators from the same ecosystem which refer to a common reference state, and 2) on that level, differentiate between natural and semi-natural ecosystems.

8.12 Open lowland is the only major habitat in the Nature Index that is now described as semi-natural.

8.13 Thematic indices for semi-natural habitat types within other major ecosystems than open lowland (e.g. grazed woodland) or natural habitat types in open lowland (e.g. lime-rich shallow soil) can be developed. For these indicators, the same definition for the reference state is used as for semi-natural systems (open lowland, 8.7) and natural systems (8.6), respectively. Data from indicators from these thematic indices are not included in the Nature Index, but are presented separately.

8.14 Both definitions of reference state must be elaborated for each individual major habitat.

8.15 The precise definition of the reference state for natural, major habitats should be incorporated and be consistent with the fact that successions take place in such systems (e.g. following a forest fire).

8.16 Both definitions pave the way for comparing existing, intact, major habitats with states at an earlier point in time when reference values for the individual indicator are to be determined. Historical data, monitoring data from intact ecosystems in Norway, studies of intact ecosystems in countries which can be compared with Norway or models can be used to set reference values.

8.17 An alternative way of approaching this is to base the determination on explicitly specified factors which affect the value of the indicators negatively in relation to their reference state. Such factors will be various kinds of harvesting, climate change, various kinds of pollution, cessation of traditional land-use, and grazing by sea urchins or moose, etc. The reference value indicates the state of the indicator (indicator value) in situations where these factors are either absent, have no negative effect on the indicator, or are themselves in a reference state, depending on what is relevant for the individual environmental factor. Such a procedure, however, presupposes that the relationship (dose-response) between the indicator and the impact factors is well documented.

Determining reference values for indicators from the same major habitat must be based on a common reference state for the system.

The reference state for natural major habitats must represent an intact habitat, with little or no human impact. Little impact means that the species richness, the state of the various populations and the ecological functions are intact.

The reference state for semi-natural habitats is defined as one that is "in good condition" relative to the species diversity normally associated with the habitat type in question.

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Appendix 1

Aichi Targets where the NI methodology could be useful:

4 Population trends of utilized species, including species in trade
5 Degradation of natural habitats; population trends of habitat dependent species in each major habitat type

6 Population trends of target species and by catch of aquatic species
7 Population trends of forest and agriculture dependent species in production systems

9 (Impacts of invasive alien species on extinction risk trends)
12 Trends in abundance of selected species

15 Status and trends in species that provide ecosystem services

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