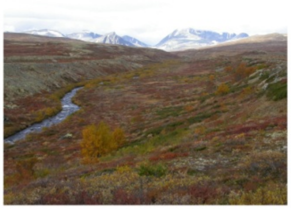
NINA Report 542

Nature Index

General framework, statistical method and data collection for Norway

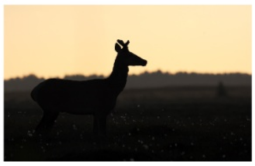
Grégoire Certain
Olav Skarpaas





$$NI_t = \sum_{ijk} S_{ijkt} W_{ijkt}$$




NINA
Norwegian Institute for Nature Research




TEAMWORK ENTHUSIASM INTEGRITY QUALITY

Cooperation and expertise for a sustainable future

NINA Publications

NINA Report (NINA Rapport)
This is a electronic series beginning in 2005, which replaces the earlier series NINA commissioned reports and NINA project reports. This will be NINA's usual form of reporting completed research, monitoring or review work to clients. In addition, the series will include much of the institute's other reporting, for example from seminars and conferences, results of internal research and review work and literature studies, etc. NINA report may also be issued in a second language where appropriate.

NINA Special Report (NINA Temahefte)
As the name suggests, special reports deal with special subjects. Special reports are produced as required and the series ranges widely: from systematic identification keys to information on important problem areas in society. NINA special reports are usually given a popular scientific form with more weight on illustrations than a NINA report.

NINA Factsheet (NINA Fakta)
Factsheets have as their goal to make NINA's research results quickly and easily accessible to the general public. The are sent to the press, civil society organisations, nature management at all levels, politicians, and other special interests. Fact sheets give a short presentation of some of our most important research themes.

Other publishing
In addition to reporting in NINA's own series, the institute's employees publish a large proportion of their scientific results in international journals, popular science books and magazines.

Norwegian Institute for Nature Research

Nature Index

General framework, statistical method and data collection for Norway

Grégoire Certain
Olav Skarpaas

Certain, G. and Skarpaas, O. 2010. Nature Index: General framework, statistical method and data collection for Norway – NINA Report 542. 47 pp.

Oslo, February 2010

ISSN: 1504-3312
ISBN: 978-82-426-2117-7

AVAILABILITY
Open

PUBLICATION TYPE
Digital document (pdf)

EDITION
First

QUALITY CONTROLLED BY
Nigel Yoccoz

SIGNATURE OF RESPONSIBLE PERSON
Research director Erik Framstad (sign.)

CLIENT(S)
The Directorate for Nature Management

CLIENTS' CONTACT PERSON(S)
Signe Nybø

COVER PICTURES
Jan Ove Gjershaug, Espen Dahl Lie, Jarle Werne Bjerke, Olav Skarpaas, Nina Eide, Gro & Terje Van der Meeren, Grégoire Certain.

KEY WORDS
Biodiversity, indicators, Norway

NØKKELORD
Biologisk mangfold, indikatorer, Norge

CONTACT DETAILS

NINA head office
NO-7485 Trondheim
Norway
Phone: +47 73 80 14 00
Fax: +47 73 80 14 01

NINA Oslo
Gaustadalléen 21
NO-0349 Oslo
Norway
Phone: +47 73 80 14 00
Fax: +47 22 60 04 24

NINA Tromsø
Polarmiljøsenteret
NO-9296 Tromsø
Norway
Phone: +47 77 75 04 00
Fax: +47 77 75 04 01

NINA Lillehammer
Fakkelgården
NO-2624 Lillehammer
Norway
Phone: +47 73 80 14 00
Fax: +47 61 22 22 15

www.nina.no

Abstract

Certain, G. and Skarpaas, O. 2010. Nature Index: General framework, statistical method and data collection for Norway – NINA Report 542, 47 pp.

The Nature Index for Norway has been developed to be an aggregated measure of biodiversity in Norway, reflecting the state of terrestrial and marine ecosystems and providing comprehensive information to environmental managers and to the public in a simplified and understandable way. It consists of a set of 310 biodiversity indicators that encompass important aspects of natural biodiversity.

The present report is a general description of the Nature Index framework. It summarises the basic concepts and definitions used, and displays the associated mathematical developments. The report builds on and extends previous pilot studies on concepts and practical implementation (NINA Reports 347, 425 and 426). The final results of the Nature Index will be presented elsewhere (Nybø (ed.) 2010a,b); here we present the data collection process and an analysis of the indicator set collected so far in order to provide information on the ecological significance and on the inferences that can be expected.

Data on indicators were collected from experts who provided estimates of the indicator values at several points in time using expert judgement, monitoring data or models. Experts also provided an estimate of uncertainty with each data point in the form of quartiles, and they were asked to indicate where insufficient information was available to provide an estimate of the indicator value.

To combine the indicators to produce an index, the indicators are scaled by a reference value, *i.e.* their value in a reference state. This serves two purposes: First, the reference state, for each indicator, is supposed to reflect an ecologically sustainable state for the indicator, and the scaled value measures the departure from this state. Second, because the scaled values are all dimensionless numbers between 0 and 1, they can be averaged across, for instance, municipality, major habitat, or taxonomic group. Thus the use of a reference value facilitates a flexible combination of indicators expressed in different measurement units, such as abundance or species richness.

Plain averaging of scaled indicators implies a “complete equivalence” assumption, *i.e.* that no municipality, no major habitat, and no indicator is more important than another. This assumption is not always true. Moreover, despite efforts to balance the indicator set, the indicators are not homogeneously distributed among taxonomic groups, pressures, major habitats etc. In the specific case of Norway, we decided, with the support of the Ecological Reference group for the Nature Index, to apply weighting mainly to deal with heterogeneities within the indicator set. Weights were applied across two axes of the Nature Index: across the spatial axis, so that the index remains area-representative, and across the indicator axis, to solve issues concerning the ecological significance of the index. Equivalence was maintained between major habitats because this ensures that the nature index will be maximised with beta (regional) diversity as well as alpha (local) diversity: complete loss of a major habitat implies a decrease in beta diversity, and this will always result in a decrease of the index under equivalence between major habitats.

In the Nature Index framework data uncertainty and missing data are analysed and actively used in several ways: At the level of individual indicators, information on the source of estimates (expert opinion, data, models), the uncertainty in the estimates, and the cases where there is a complete lack of knowledge, can be used to guide future research. Uncertainty in the indicator estimates is aggregated to the index level using Monte Carlo methods, sampling from distributions fitted to the mean and quartiles of each indicator.

In conclusion, we show that the Nature Index is able to synthesize and compare information coming from all fields of ecological science, encompassing oceanic and terrestrial areas. There are two kinds of information that can be produced by the Nature Index framework: information on the current state of ecosystems, given the current knowledge of the Ecological Research Network; and also information on lack of knowledge and lack of data can be displayed, in order to better inform, and therefore optimise, research and management policies. Information extracted from the Nature index framework can be aggregated or disaggregated across several dimensions, such as spatial units, ecological units or management themes, giving this framework the potential to become an efficient management tool, an efficient catalyst for Ecological Research Network in Norway, and a strong basis for international applications.

Gregoire Certain, Norwegian Institute for Nature Research (NINA), NO-7485 Trondheim, gregoire.certain@nina.no
Olav Skarpaas, Norwegian Institute for Nature Research (NINA), Gaustadalléen 21, NO-0349 Oslo, olav.skarpaas@nina.no

Sammendrag

Certain, G. and Skarpaas, O. 2010. Nature Index: General framework, statistical method and data collection for Norway – NINA Rapport 542. 47 s.

Naturindeksen er et sammensatt mål for biologisk mangfold i Norge som gjenspeiler tilstanden i terrestre og marine natursystemer og formidler denne omfattende informasjonen til miljøforvaltningen og allmenheten på en forenklet og forståelig måte. Den består av 310 indikatorer som dekker viktige aspekter ved biologisk mangfold.

Denne rapporten gir en generell beskrivelse av rammeverket for Naturindeksen. Den gjennomgår grunnleggende begreper og definisjoner, og tilhørende matematiske formuleringer. Rapporten bygger videre på tidligere forslag til rammeverk og pilotstudier (NINA Rapport 347, 425 og 426). Hovedresultatene for naturindeksen presenteres i to kommende DN-utredninger (Nybø (ed.) 2010a,b); her presenterer vi metoder for datainnsamling og en analyse av indikatorsettet for å informere om den økologiske betydningen av naturindeksen og slutningene man kan forvente å gjøre på grunnlag av denne.

Data om indikatorene ble samlet inn fra eksperter som ga estimater av indikatorverdier på flere tidspunkter på grunnlag av ekspertvurderinger, overvåkingsdata eller modeller. Ekspertene ga også et estimat av usikkerheten til hver verdi i form av kvartiler, og de ble bedt om å angi i hvilke tilfeller grunnlaget var for svakt til å gi estimater.

For å kunne kombinere indikatorene til en indeks, ble hver enkelt indikator skalert med en referanseverdi, dvs. verdien av indikatoren i en referansetilstand. Dette tjener to formål: For det første reflekterer referansetilstanden en økologisk bærekraftig tilstand for indikatoren, og den skalerte verdien måler avvik fra denne tilstanden. For det andre kan de skalerte verdiene, som alle er enhetsløse verdier mellom null og en, benyttes til å beregne gjennomsnitt på tvers av for eksempel kommuner, hovedgrupper av natursystemer og taksonomiske grupper. Bruken av en referanse muliggjør dermed fleksible kombinasjoner av indikatorer med ulike måleenheter som bestandsstørrelse eller artsrikdom.

Rene gjennomsnitt av skalerte indikatorverdier kan beregnes under en antagelse om ”fullstendig ekvivalens”, dvs. at ingen kommune, ingen natursystemer og ingen indikatorer er viktigere enn andre. Dette vil ikke alltid være tilfelle. Indikatorene er heller ikke jevnt fordelt mellom taksonomiske grupper, påvirkninger, etc., på tross av forsøk på å balansere indikatorsettet. I implementeringen for Norge har vi derfor valgt, med støtte fra Faggruppen for Naturindeksen, å tilordne vekter langs to akser: den geografiske aksen, slik at indeksen blir arealrepresentativ, og indikatoraksen, for å løse problemer med økologisk representativitet. Mellom hovedgrupper av natursystemer antar vi fullstendig ekvivalens, fordi dette sikrer at Naturindeksen maksimeres med betadiversitet (regional diversitet), i tillegg til alfadiversitet (lokal diversitet): tap av et natursystem medfører reduksjon i betadiversitet, og dette medfører alltid en reduksjon i indeksen under antagelsen om fullstendig ekvivalens.

I Naturindeksen brukes datausikkerhet og manglende data aktivt på flere måter: Informasjon om kilder til indikatorestimater (ekspertvurdering, data, modeller), usikkerheten i estimatene og tilfeller med fullstendig mangel på kunnskap, kan brukes til å målrette framtidig forskning og utredning. Usikkerhet i indikatorestimater aggregeres til indeksnivå ved hjelp av Monte Carlo-metoder: simulering av fordelingene tilpasset gjennomsnitt og kvartiler til hver enkelt indikator.

Naturindeksen kan fange opp og sammenstille informasjon fra ulike økologiske fagfelt, både terrestre og marine, og avlevere to hovedtyper av informasjon: tilstanden til natursystemer, gitt dagens kunnskap, og områder med manglende kunnskap kan begge tydeliggjøres og gi innspill til forvaltning og forskning. Informasjonen i naturindeksen kan aggregeres eller splittes opp langs flere akser, slik som geografiske enheter, økologiske enheter eller forvaltningstema.

Dette gir Naturindeksen et stort potensial som forvaltningsverktøy og katalysator for økologisk forskning og utredning i Norge, og for internasjonal anvendelse.

Gregoire Certain, Norsk institutt for naturforskning (NINA), NO-7485 Trondheim, gregoire.certain@nina.no
Olav Skarpaas, Norsk institutt for naturforskning (NINA), Gaustadalléen 21, NO-0349 Oslo, olav.skarpaas@nina.no

Contents

Foreword

The development of a Nature Index for Norway has progressed rapidly since its initiation by the Norwegian government in 2007. The present report builds on and extends previous studies (NINA Reports no. 347, 425 and 426), and summarizes the methodological development for the Nature Index to be implemented for Norway in 2010, the International Year of Biodiversity.
This is the first report on the Nature Index in English. It has been both inspiring and challenging to work with several nationalities and languages (specifically, Norwegian, English and French), while at the same time communicating well with our main client, Norwegian nature management. We have occasionally been faced with problems of translation when dealing with specific Norwegian concepts (e.g. Naturtyper i Norge) or general English concepts (most of the scientific literature and international agreements like CBD and EU Directives), but we have tried to make translations as precise as possible.
While preparing and writing this report, we have also been heavily occupied with data collection for the Nature Index, which has been a highly demanding and time consuming process involving 120 experts and 310 indicators. It has been challenging to manage this process while keeping a focus on the interesting scientific and applied outcomes of the statistics project. This would not have been possible without the efforts of experts delivering data, infrastructure to handle the data (programmed by Pål Kvaløy, Norwegian Institute of Nature Research), helpful GIS support (Frank Hanssen and Stefan Blumentrath, Norwegian Institute of Nature Research) and many valuable discussions and constructive comments of a large number of participants in the various Nature Index projects.
More specifically, we wish to thank Gro van der Meeren (Institute of Marine Research), for her help to properly integrate the marine systems within the NI framework. We are also grateful to the members of the NI Statistics Reference Group and associated advisors who provided numerous and helpful comments about the methods: Per Arild Gårnasjordet, Iulie Aslaksen and Svein Homstvedt (Statistics Norway), Steinar Engen (Norwegian Institut for Science and Technology), Nigel Yoccoz (University of Tromsø) and Bent Natvig (University of Oslo). We also thank the members of the Ecological group for useful discussions on weighting: Ann Norderhaug (Bioforsk), Eivind Oug and Markus Lindholm (Norwegian Institute for Water Research), Jan Erik Nielsen (Norwegian Forest and Landscape Institute), Ann Kristin Schartau, Frode Ødegaard and Erik Framstad (Norwegian Institute of Nature Research), Gro van der Meeren, Margaret Mary McBride,(Institute of Marine Research), Kristin Thorsrud Teien (Ministry of Environment). We also thanks the management project group: Ingrid Bysveen, Else Løbersli, Knut Simensen, Bård Solberg, Signe Nybø (Directorate for Nature Management), also we wish to thank Sandra Öberg (Norwegian Institute of Nature Research) and Magnar Lillegård (Statistics Norway) for their useful, last minute comments, and of course all the experts that have contributed to feed the project with their time, knowledge and data.
The pictures illustrating the cover page and the Figure 2 of this report have been provided by Jan Ove Gjershaug (lynx, birds and Dovre mountains), Espen Lie Dahl (red deer), Nina Eide (arctic fox), Erling Sölberg (moose), Jarle Werner Bjerke (*Gymnocarpium*, *Cladonia* and Mires), Hans Christian Perdersen (willow ptarmigan), Gro & Terje Van der Meeren (Sugar kelp and Anemone), Olav Skarpaas (*Cortinarius*), and Gregoire Certain (others). Jeanne Certain also provided much help with Figure design.
Finally, we thank our client the Directorate for Nature Management (DN) for funding, and our contact at DN, Signe Nybø, for her great interest and enthusiasm for the work, for pushing us forward, and for being patient when needed. We look forward to further collaboration on the Nature Index.

Trondheim and Åsgårdstrand, 4 Feb. 2010

Gregoire Certain
Olav Skarpaas

1 Introduction

The magnitude and urgency of the biodiversity crisis is widely recognised within the scientific and political institutions (Jenkins 2003). However, the lack of integrated biodiversity monitoring tools (Teder *et al.* 2005, Loreau *et al.* 2006) has greatly reduced the ability of national and international institution to face the biodiversity crisis, and meet the 2010 objectives of halting biodiversity loss. There are two main reasons for such a reduced ability, according to Loreau *et al.* (2006). First biodiversity is a highly complex notion encompassing several organisation levels (from genes to ecosystems) and several spatio-temporal scales. Second, the CBD and other international agreements concerned with biodiversity do not have the structural means to mobilize the expertise of a large scientific community to inform governments. This latter point does not seems to improve, as the effectiveness of the scientific body that advises the Convention on Biological Diversity (CBD) is being undermined by the increasing dominance of politicians and professional negotiators (Brauer 2005, Laikre *et al.* 2008, Ahlroth and Kotiaho 2009) more concerned with the inclusion of trade, economic growth and public opinion in conservation debates than in operational efficiency and scientific verification. What is lacking is a mechanism that is able to bring together the expertise of the scientific community to provide, on a regular basis, validated and independent scientific information relating to biodiversity and ecosystem services, to governments, policymakers, international conventions, non-governmental organizations and the wider public (Loreau *et al.* 2006).

To provide such an integrated monitoring tool of biodiversity is precisely the aim of the Nature Index (NI) that has been developed and applied in Norway: a general, integrated framework designed to collect and synthesise information from the Ecological Research Network (ERN) to provide a tractable, calibrated and scientifically-based information to management and political institutions on the current knowledge of the state of ecosystems.

The amount of information produced by the ERN each year is extremely voluminous. The enormous number of articles, reports, proceedings, in addition all the oral communications at conferences and all popularization attempts in the media (Internet, TV, Radio, Newspapers etc.), makes the ERN a highly entropic information source (sensu Shannon 1948). However, too complex messages are likely to be misunderstood or even missed by the institutions responsible for decision making. Reducing the complexity of the information source is one way to ease information transfer. Such information transfer from science toward the other part of human societies is the purpose of integrated biodiversity indexes, which are critically needed (Scholes *et al.* 2008, Sachs *et al.* 2009, Wallpole *et al.* 2009).

The Nature Index (NI) is an integrated framework that samples information from the ERN, synthesises this information, and transmits it in a very simple, understandable form, which ensures an unambiguous understanding from environmental managers and policy makers. It allows comparing and following the signals coming from all studied ecosystems, from high mountainous to deep seas, optimises the use of existing information by considering expert estimates, data-based estimates and model-based estimates, and provides a scientifically designed picture to help managers and policy-makers set environmental objectives. It also allows identifying and quantifying the extent to which knowledge on ecosystems is lacking, which is invaluable information to optimise research policies. It relies on exhaustive comprehensive set of scientific experts, each being in turn responsible for one or several biodiversity indicators. The resulting indicator set is supposed to represent the best of our knowledge on the state of biodiversity and ecosystems. In principle, indicators may refer to any natural quantities related to any aspect of biodiversity. To be aggregated together, each indicator must be scaled by their value in a reference state, *i.e.* an expected value in undisturbed or non-significantly impacted ecosystems, which is identified and assessed by the expert. Once observed indicator values are collected, they can be scaled by their corresponding value in a reference state, and aggregated / disaggregated over several axes representing several spatio-temporal dimensions, or thematic groups (see Scholes & Biggs 2005 for a similar process).

The NI framework has been implemented in Norway, and has proven to be an efficient way of collecting information (see also Nybø *et al.* 2008; Nybø & Skarpaas 2008a,b; Nybø (ed.) 2010a,b). It has the potential to constitute an operational, efficient and pragmatic way to monitor the state of biodiversity and ecosystems internationally or even globally.

2 Basic concepts

The present method section gives the major definition of the NI framework. The main ideas from previous studies (Nybø *et al.* 2008; Nybø & Skarpaas 2008a,b) are retained, but with several important improvements. Most of this information, plus a number of guidelines on practical details, were provided to the experts, through several meetings, seminars, discussions, and in the form of a user manual available at the NI website http://naturindeks.nina.no/ (Nybø (ed.) 2010b).

2.1 The biodiversity indicators

The first task in the implementation of the NI was to select a set of Biodiversity indicators. In the NI framework, a **biodiversity indicator** is defined as:

"A natural parameter related to any aspect of biodiversity, supposed to respond to environmental modification and representative for a delimited area. It is a parameter for which a reference value can be estimated. 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 an amount of independent information".

In this current formulation, a biodiversity indicator may refer to a population of a single species, a genetic metric, a functional diversity index, a demographic parameter, a community metric, or any other metric fitting the definition.

The task of identifying biodiversity indicators has involved a succession of meeting groups, organised by taxonomic groups, where experts discussed and selected indicators based on the definition above and on a list of additional criteria specifically designed for the Norwegian implementation of the NI (Nybø & Skarpaas 2008a). Resident species have been prioritized, all the major taxonomic groups should be represented, both common and rare species should be represented, indicators should be complementary with regard to their response to anthropic pressures, keystone species should be included when possible, and a wide variety of ecosystems and habitat should be represented by the indicator set.

More than 120 experts were involved, most of them scientists being the national expert on their indicator or one of the nationals experts. A scientific advisory group were established representing the major habitats and the five research institutions responsible for nature monitoring. For the sake of simplicity during data collection and communication, each indicator was attributed to a single major habitat (see below). The only mathematical constraint on the indicator is that it should be expressed as a positive value.

2.2 The major habitats

The natural systems within the NI framework are discretised in a set of "Major habitats". In accordance with experts, 9 major habitats have been defined: "Mountain", "Forest", "Mires and Wetland", "Freshwater", "Open Lowland", "Coast Pelagic", "Coast Bottom", "Ocean Pelagic", "Ocean Bottom". These major habitats refer to broad ecoregion or landscape entities, defined in accordance with the expert group. These major habitats correspond to a critical level of stratification within the NI framework, used for example to select the Biodiversity Indicators (the number of Biodiversity Indicators should be fairly homogeneous between major habitats). The only parts of nature excluded from these major habitats are intensive cultural landscapes, urban areas, and the permafrost. More specifically, the major habitats were defined as in Table 1, using N50 (e.g. habitat maps with a 1/50 000 resolution) reference maps.

Table 1. *Definitions for the 9 major habitats used within the NI framework.*

Major habitat	**Description**
Mountain:	Open area above the actual forest line, including Tundra, arctic, alpinie and sub-alpine shrub, shrub and/or herbaceous vegetation, open space with little or no vegetation above the forest line
Forest:	Any woodland or wooded land
Open Lowland:	Open spaces below the actual forest line including shrub heathlands and semi-natural grassland, lands dominated by forbs, mosses, lichens, Temperate shrub heathland, Inland unvegetated or sparsely vegetated habitats, coastal cliffs, pastures
Mires and Wetland:	Mires, bogs, fens
Freshwater:	Rivers and lakes, inland surface waters
Coastal Pelagic:	Intertidal areas, Coastal marine area (<1 nautical mile of the coast), estuarine areas, excluding benthic fauna and flora
Coastal Bottom:	benthic fauna and flora of the marine area loacted <1 nautical mile of the coastline
Ocean Pelagic:	Pelagic area in the Economic Area of Norway, that is outside the coastal zone and within 200 nautical miles
Ocean Bottom:	Benthic area in the Economic Area of Norway, and abyssal areas that is outside the coastal zone and within 200 nautical miles

2.3 The reference state

The use of reference state in the NI Framework answers to both a theoretic and a pragmatic need, in the sense that it gives the context within which each observed indicator value will be interpreted, and provides a way to express all observed indicator values on a comparable scale. A **reference state** is defined as follows:

"The reference state, for each biodiversity indicator, is supposed to reflect an ecologically sustainable state for this indicator. The reference value, i.e. the numerical value of the indicator in the reference state, is a value that minimises the probability of extinction of this indicator (or of the species/community to which it is related), maximises the biodiversity of the natural habitat to which it is related, or at least does not threaten biodiversity in this or any other habitat."

In practice, the indicator value in a reference state is used to scale the observed value of each indicator, so that all scaled indicator values are directly comparable. The estimate of the reference value has to be done by each expert in charge of an indicator. There is no need that all indicators share the same reference state. Reference states can be defined specifically for each indicator, according to the current state of knowledge on each indicators and ecosystems. The constraints are that the reference state chosen by the expert does not deviate substantially from the definition above, it corresponds to well formulated hypotheses and assumptions so that it is tractable, and points toward high biological diversity. There are, in practice, several ways to estimate such a reference value. To ease experts estimating these reference values, we provided some examples (Table 2).

Table 2. *Examples of practical definitions that can be used to estimate the reference value.*

Name	**Description**
Carrying capacity	A theoretical value for a population number or density for example, according to the natural limit of a population set by resources in a particular environment. .
Precautionary level	Recommendations provided by scientific and independent group of reflexion. Refers to a value below which the indicator, and therefore the major habitat to which it is related, is endangered
Pristine or near-pristine nature	An estimated value that refers to pristine, untouched or low impacted natural system
Knowledge on past situation	An estimated value derived from a known past situation, when the indicator was in good condition, and a situation that is always ecological relevant today
Traditionally-managed habitat	A value observed under traditionally managed habitat, such as extensive, biological agriculture
Maximum sustainable value	A value below which no detrimental effects are observed for the major habitat to which the indicator is related.
Best theorical value of indexes	If the indicator refers to an already developed index, such as a biodiversity index, it's best (the value corresponding to the "best" state in term of biodiversity) expected value depending on the location and the major habitat
Amplitude of fluctuations observed in the past (for cylcing of fluctuating species)	For fluctuating populations (typically rodents or small pelagic fishes): the amplitude of fluctuations over a given temporal windows that is observed in natural or low impacted conditions (specific case for pristine or past knowledge)

3 Data collection

3.1 The data collection on indicator estimates

The collection of data and expert opinion concerning the biodiversity indicators started in late June 2009, and can be up-dated continuously. It is achieved through a website hosted by NINA, at the following address: http://naturindeks.nina.no/. NI Data are collected at the spatial resolution of the 430 Norwegian municipalities, and at 4 dates: 1950, 1990, 2000, and 2010. The observed value of each indicator, for each municipality and each date, is entered by experts on this website, connected to a SQL database. In addition, for each indicator and each municipality, experts must enter the value of the reference state. For each estimate entered (observed value of an indicator or corresponding reference state) experts must also provide the lower (25%) and upper (75%) quartiles, as a measure of the uncertainty of their estimate (see Garthwaite *et al.* 2005 and the Statistical Section for details). For each estimate, a specific field is devoted to distinguish between "expert opinion", "data calculation" and "model prediction".

For each estimate (*i.e.* each combination indicator*municipality*date), instead of giving a value, experts have the possibility to report a lack of knowledge strong enough to prevent them to provide any information, using a special code ("-1"). If no data are entered, we consider that the indicator is not supposed to occur and that there is nothing to be reported.

3.2 The data collection on indicator characteristics

For each natural parameter identified as a biodiversity indicator for the NI, each expert was asked to report several pieces of information, summarised in Table 3. This information includes broad ecological characteristics of each indicator ("taxonomic group", "trophic group", "keystone species", "specialist/opportunist"), information of conservation or management interest ("red list", "ecosystem service", "quick response", "sensitivity to pressure factor"), and information necessary to assess the inference that can be drawn from each indicator and from the whole set ("presence in broad geographical region", "specificity to major habitat", "population/community", "sub-habitat", "migrating", "reference value"). In particular, the information relative to "specificity to major habitat" has been collected since some indicators could reflect simultaneously the state of several major habitats, especially in marine areas. In the NI framework, this information can be used to calculate thematic indexes, or to weight each indicator according to some aspect (see "Weighting" section for details).

3.3 Data collection on municipality and major habitat properties

Within the NI framework, the municipality is the spatial unit, and the major habitat the ecological unit. Both entities, being respectively administrative and ecologically defined in space**,** are overlapping. We used GIS analyses to extract relevant information at the municipality scale so that both administrative and ecological units can be easily related to each other. Therefore, for each municipality, we calculated the total municipality area, the area of each Major habitat, and the area of land within 200m altitude classes. GIS calculations were made on the basis of Major habitat definition in Table 1, and of the Norwegian topography, digital N50 maps and vegetation maps (Erikstad *et al.* 2009).

In addition, statistics on population density and urbanisation (such as building density and size, road length) were also extracted from Statistics Norway website (www.ssb.no). Information on municipality area can be used for weighting purposes, to give more weight to larger municipalities. Information on urbanisation can be used in the last step of the analysis as covariates, to model the effect of urbanisation on the value of different indicators and on the overall value of the NI.

Table 3. *Summary of the general information collected on the ecological characteristics of each indicator.*

Name	Question	Possible answer
Taxonomic group	In which taxonimic group does the indicator belong?	The taxonomic group of the indicator
Red list	Does the indicator refer to a species or a set of species belonging to the Red list of threatened species?	Categorical variable (No, Vulnerable, Threatened, Critically Endangered)
Presence	Presence/absence of the Indicator in five broad geographical regions in Norway (North, South, Center, East, West)	Categorical variable (present/absent), in each region
Specificity to major habitat	Can your indicator only be found in the major habitat to which it is related?	Categorical variable (yes/no)
Trophic group	To which trophic group does this indicator belong?	Categorical variable (Primary Producer, Mixotroph, Herbivore, Filter-feeder, Intermediate Consumer, Top predator, Detritivore, Omnivore, Scavenger - Carrion feeder, Parasitic, Multitrophic)
Keystone species	The system under study as a high probability of shifting if this indicator change/diseappear	Categorical variable (yes/no)
Generalism	Report a number on a scale between 1 and 5	Discrete variable ranging from 1: completely specialist to 5: completely generalist
Community	indicate if the indicator value refers to a metric measured for populations (e.g. density) or community (e.g. species richness)	Categorical variable (population/community)
Sub-habitat	Can you define a sub-habitat (within the major habitat) that better describes the ecological niche of the indicator ?	Free: any description could be entered by expert, preferably related to NiN units
Ecosystem service	Is this indicator providing any service (resource, pest control, recreative activity…) to human societies?	Categorical variable (yes/no)
Quick response	Is this indicator likely to respond quickly (=<1 YEAR) after any dramatic environmental change?	Categorical variable (yes/no)
Pressure	If the indicator is sensitive to one or several of the pressure listed below, just enter the corresponding code. You may enter several codes.	Categorical variable. Pa: land use changes due to primary activity, Lc: land use change due to other sectors , Cl: climate change, Is: invasive species, Ih: harvesting of animals, Hc: anthropic Hydrological changes, Eu: Eutrophication, Ac: Acidification, Po: other pollution, X: other kind of pressure
Migrating	How much is the indicator migrating between different areas?	Categorical variable (non migrating, migrating within northern europe/Atlantic, migrating within Europe or outside atlantic, migrating other than previously mentioned
Multiple major Habitats	When the indicator value may reflect change in several major habitats, to which major habitats should it be related, and with which weights ?	Any combination of the form major habitat1 (x1), major habitat2 (x2) … where x1, x2 are numbers between 0 and 100 whose sum equals 100
Reference value	Describe shortly the process by which you estimated the reference states (which calculation, which assumption, or a reference to a pre-established level…	A set of example was provided (Table 2), but experts were free to add others.

3.4 Data collection on indicator values in time

Experts were asked to estimate the observed value of each combination indicator*municipality*date for 1950, 1990, 2000 and 2010, with 2010 supposed to reflect the situation today. These four dates were chosen to cover the second part of the 20th century and the beginning of the 21th century, during which the human civilisation experienced an unprecedented development rate, while the simultaneous effects of global change and of the 6th crisis of mass biodiversity extinction became obvious.

4 Mathematical formulations

4.1 The set of indicators

From a mathematical point of view, the observed value, or “state” S^{obs} of the indicator *i* belonging to the major habitat *j* in the municipality *k* and at the date *t* can be noted S_{ijkt}^{obs} . The corresponding set of values for the reference states can be noted S_{ijk}^{ref} . From this notation, it is clear that the reference state for a given indicator is assumed to be relevant for each date. Both S_{ijkt}^{obs} and S_{ijk}^{ref} are sets of 0 or positive values.

4.2 Statistical formulation of the set of indicators

Within the NI framework, the estimate of the observed state for an indicator *i* is assumed to be randomly drawn from a statistical distribution *L* with maximum two parameters *a* and *b* (maximum two parameters because of the limited information on distributions obtained trough expert elicitation). Therefore, the whole set of indicators is assumed to be drawn from a corresponding set of statistical distributions:

$$S_{ijkt}^{obs} \sim L_{ijkt}\left(a_{ijkt}, b_{ijkt}\right) \tag{1}$$

The estimate of each L_{ijkt} is useful to estimate confidence intervals around each indicator values, and ultimately around the NI values. It has been carried out using the information on the quartiles extracted during the elicitation process. To estimate each statistical distribution, we only rely on three values: the mean observed value of the indicator, and the associated lower and upper quartiles. With this limited amount of information, the process of estimating the statistical distribution can only be very simple.

Practically, depending on whether the indicator is a continuous or a discrete variable, several statistical distributions and couple of parameters were tested. For a given statistical distribution and couple of parameter *L(a,b)*, we calculated the following criterion *C*:

$$C = m^2 + {q_l}^2 + {q_u}^2 , \tag{2}$$

Where *m* refers to the differences between the observed mean estimate of the indicator and the mathematical expectation of the random variable following the distribution *L(a,b)*; and q_l and q_u refer to the differences between the estimated lower and upper quartile of the indicator and the lower and upper quartile of the distribution *L(a,b)*. For each observed indicator value S_{ijkt}^{obs}, we retained the set *L(a,b)* that minimised *C*. The minimisation algorithm has been implemented in the software R 2.8.1, using the function *nlminb()* of the *stats* package (R development core team 2008).

The statistical distribution tested were the Normal, the Gumbel, the Log-normal, the Weibull and the Gamma distribution in the case of an indicator expressed as a continuous variable, and the the Poisson, the Zero-inflated Poisson and the Negative binomial distribution in the case of an indicator expressed as a discrete variable. All these statistical distributions were chosen to cover a broad range of distribution shapes, with varying degree of skewness and kurtosis. They are all implemented and easy to access in the R package GAMLSS of Rigby *et al.* (2008).

4.3 Scaling the set of indicators

According to our indicator definition, each indicator can be expressed in a specific measurement unit, say for example densities, abundance, species richness, or presence probability. Therefore, it is impossible to combine directly indicators together to produce any averaged index across, for instance, municipality, major habitat, or trophic group. To deal with this problem, a convenient solution is scaling. As we require indicators to provide an easy-to-interpret measure of an ecological state, we have scaled observed indicators values by their respective reference state values. This concept is fairly equivalent to the measure of equitability associated to any biodiversity index such as the Shannon index, as it results in a quantity ranging between 0 and 1, 0 being a complete degraded situation, while 1 being an optimal situation.

Because of the several possible ways of estimating a reference state value for a given indicator, three scaling models were used. The “optimal” model (Figure 1a) is defined as follows:

$$S_{ijkt} = \sup\left\{1 - \left|\frac{S_{ijkt}^{obs} - S_{ijk}^{ref}}{S_{ijk}^{ref}}\right|, 0\right\} \quad (3)$$

Where S_{ijkt} is the set of scaled indicator, *i.e.* a set of dimensionless, scaled number that expresses the deviation of the value of the indicator as a proportion of its associated reference state value.

By using the optimal scaling model, we assume that any departure from the reference state results in a degradation of the major habitat to which the indicator is related. This may be useful for example in the case of indicators related to species such as moose, that may experience strong decline (as it was the case in the past) but whose increase in large numbers may also be detrimental to the ecosystem (trough grazing pressure) (Veiberg *et al.* 2007, Nilssen *et al.* 2009).

When the reference state refers to a low, precautionary level, as in marine management of small pelagic fishes for example (Kell *et al.* 1999), the “minimal” scaling model (Figure 1b) has been used:

$$S_{ijkt} = \inf\left\{\frac{S_{ijkt}^{obs}}{S_{ijk}^{ref}}, 1\right\} \quad (4)$$

When scaling the indicator by the “minimal” model, we assume that a deteriorated state for the indicator only corresponds to a decrease below the reference level, and that any value above this reference level corresponds to an optimal situation.

When the reference state refers to a maximal value, for example a maximal limit for the density of a proliferating species above detrimental effects on ecosystems are observed, the “maximal” scaling model (Figure 1c) can be used:

$$S_{ijkt} = \sup\left\{1 - \frac{S_{ijkt}^{obs} - S_{ijk}^{ref}}{S_{ijk}^{ref}}, 0\right\} \text{ if } S_{ijkt}^{obs} > S_{ijk}^{ref} \text{ and } S_{ijkt} = 1 \text{ if } S_{ijkt}^{obs} < S_{ijk}^{ref} \quad (5)$$

Despite that these scaling models correspond to different interpretation of a reference state, they remain extremely simple, for the sake of tractability and interpretation, and they all results in a dimensionless quantity varying between 0 and 1 (Figure 1). For a given indicator, the choice of the scaling model to be applied belongs to the expert in charge of that indicator, to ensure a proper ecological significance of the resulting scaled value.

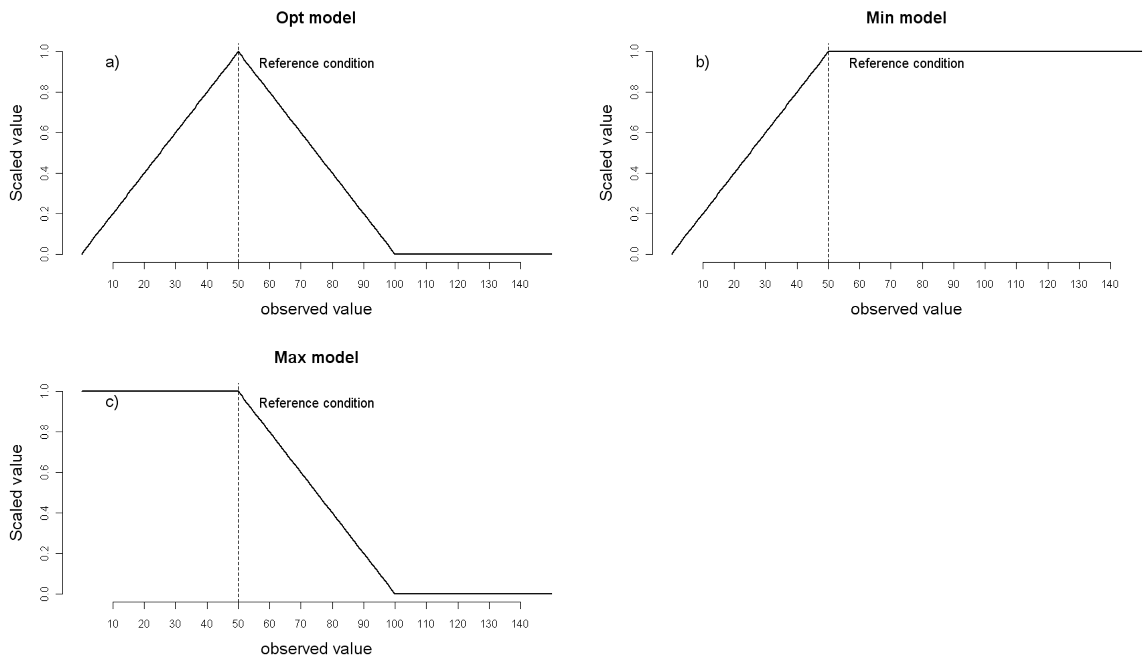


Figure 1. Scaling models: Scaled value when the observed value of a hypothetical indicator is ranging between 0 and 150 and when the value in a reference state is 50.

4.4 Averaging the index

Once the set of scaled indicators is calculated, it can be averaged across any of its axes *i*, *j, k* or *t,* or any combination of these. In addition, since the set of indicators *i* can be grouped according to a large number of themes, such as trophic group, taxonomic groups, or endangered species, averaged thematic indexes can be produced and compared the same way. For example the NI over time is expressed:

$$NI_t = \frac{\sum_{ijk} P_{ijkt} S_{ijkt}}{\sum_{ijk} P_{ijkt}} \qquad (6)$$

Where $P_{ijkt} = 1$ if a value for the indicator *i* in habitat *j* in municipality *k* and year *t* is present, and $P_{ijkt} = 0$ otherwise.

There is a very large number of themes over which the NI can be calculated, and it would be useless to cite them all here. However, as an example of its flexibility, it can be calculated across time and major habitats, across time and trophic group, across time and conservation groups, and across time and two spatial scales, the municipality and the county.

4.5 Estimating confidence interval for the nature index

Since the set of statistical distributions from which the observed value of the indicator are drawn have been estimated, we have simulated 999 realisations of our data collection process for the observed indicator values, using a classical Monte-Carlo simulation procedure. This process resulted in 999 sets of scaled measures that can be used to compute 95% confidence intervals for any NI estimate. Note that the values estimated by the expert for the reference state were kept constant during these simulations.

4.6 Weighting the nature index

4.6.1 General formulation

In all the previous developments, no particular weights were applied to the indicator or to the municipality for example, so that every calculation was made under a “complete equivalence” assumption, *i.e.* that no municipality, no major habitat, and no indicator is more important than the other. But depending on the spatial unit and on the indicator chosen, this assumption can easily be falsified. In our case, there may be large discrepancies among municipality areas for example, and one may want to give more weight to the larger municipalities. Similarly, more weight may be attributed to indicators related to a wide range of species, or to indicators reflecting a major component the food web.

In the specific case of Norway, we decided to apply weighting across two axes of the NI: across the spatial axis, so that the index remains area-representative, and across the indicator axis, to solve issues concerning the ecological significance of the index. In general formulation, introducing any set of weights W_{ijkt} within the NI formula is straightforward.

$$NI_t = \sum_{ijk} S_{ijkt} W_{ijkt} \qquad (7)$$

with the condition $\sum_{ijk} W_{ijkt} = 1$ for any date t, and $W_{ijkt} = 0$ if the indicator *i*, in the major habitat *j*, the municipality *k* and the date *t* has not been documented in the database.

4.6.2 Calculating the weights

Weighting the indicators is a very difficult question that has been considered with special attention. If our indicator set was perfectly chosen according to the criteria (ch. 2.1), was ideally representing the biodiversity of our study area (Norway), and if all indicators could be documented in at all dates and all spatial locations, there would be no need for weights. However, despite the attention paid at the building stage of the indicator list, some discrepancy appeared quickly, for example with near 70% of indicators being vertebrates (birds, fishes, mammals), while most species in nature are invertebrates (Chapman *et al.* 2009). Also, some indicators were only documented in a given geographical area, or at a given date, creating further dissimilarities in the data set, with regions well described, and other poorly represented. Indeed, most of these discrepancies are due to the structure of the ERN, with research on birds, fish and mammals attracting the most part of the societal interest, and with some field areas recurrently sampled while data in other regions are never collected.

The decision on the weighting process for the indicators was the object of a specific Ecological Reference group meeting between more than 20 experts representing all 9 major habitats, and the solution presented here (Figure 2) results from a collegial decision. Five sequential steps (ABCDE) have been defined to calculate the weights of the NI:

(A) At the smallest level, within a trophic group in a major habitat and in a municipality (Figure 2a), indicators should be weighted according to their specificity of the major habitat. To do so, a basic weight is attributed to each indicator. This basic weight is a relative measure of how much this indicator relates to the major habitats (using information collected on “multiple habitat”, Table 3). For example, an indicator such as benthic macrofauna whose state depends exclusively on Freshwater gets a basic weight of 1 in Freshwater and 0 in the other major habitat. On the other hand, the indicator referring to *Salmo salar* population, whose life cycle encompass several major habitats gets a weight of 0.4 in Freshwater, 0.3 in Coastal Pelagic and 0.3 in Ocean Pelagic.

(B) At the level of a major habitat within a municipality (Figure 2b), some indicators were identified by the expert as important indicators whose value strongly correlates with the state of the ecosystem. It has been decided that these “extra-representative” indicators should account for half of the NI value. The criterions for selecting an extra-representative indicators were: (i) representative for hundreds of species, (ii) representative for a broad area (encompassing several county in the specific case of Norway), and (iii) documented by data that allow estimation of the indicator for several dates and for the reference state.

The other indicators should be weighted so that when calculated within each major habitat at the municipality level, the different trophic groups documented contribute equally to the NI value (Figure 2b). Eight trophic groups were considered: primary producer generalist, primary producer specialist, decomposer of organic matter, primary consumer and filter feeder, intermediate predator specialist, intermediate predator generalist, top predator specialist, top predator generalist. These groups were established according to information provided by the experts on trophic levels and level of specialism/generalism (Table 3).

(C) At the municipality level (Figure 2c), it has been decided to give equal weights to all the major habitats present in the municipality. Therefore, weights were defined to achieve this complete equivalence.

(D) At the County level (Figure 2d), weights should be given according to municipality area, in order to ensure the area-representativity of the index.

(E) At the national level (Figure 2e), the process is the same than at the County level, but using County area as weights.

4.6.3 From one general index to several specific indexes

The ability to produce one general number for the NI value in Norway is one mathematical properties of the NI, if we choose to follows all the steps from a) to e). But apart from communication purpose, the usefulness of such a global measure may be very limited. Instead, one may be interested on sub-indexes focused on a given trophic or taxonomic group, on a given region or even on a given problematic.

From the Figure 2, it is easy to understand that some steps can be dropped to produce more specific indexes that can be useful to managers. One can choose to focus on one trophic group, and therefore drop step (B). One may want to focus on a major habitat, and drop step (C). One can focus on maps at the county level, and therefore drop step (E). One may want to focus on a subset of indicators that relates to a given problematic, such as global change, acidification, or harvesting. Such an approach will be referred as the construction of a “thematic index”, and could implies to drop the steps (B) and (C), perhaps by using different weights more specific to the chosen theme. In this latter case, one may also want to restrict the NI calculation to a given area, or to compare two broad areas. A great number of thematic indexes can be designed within the NI framework. In the case of building a new thematic index, expert consultation is indispensable.

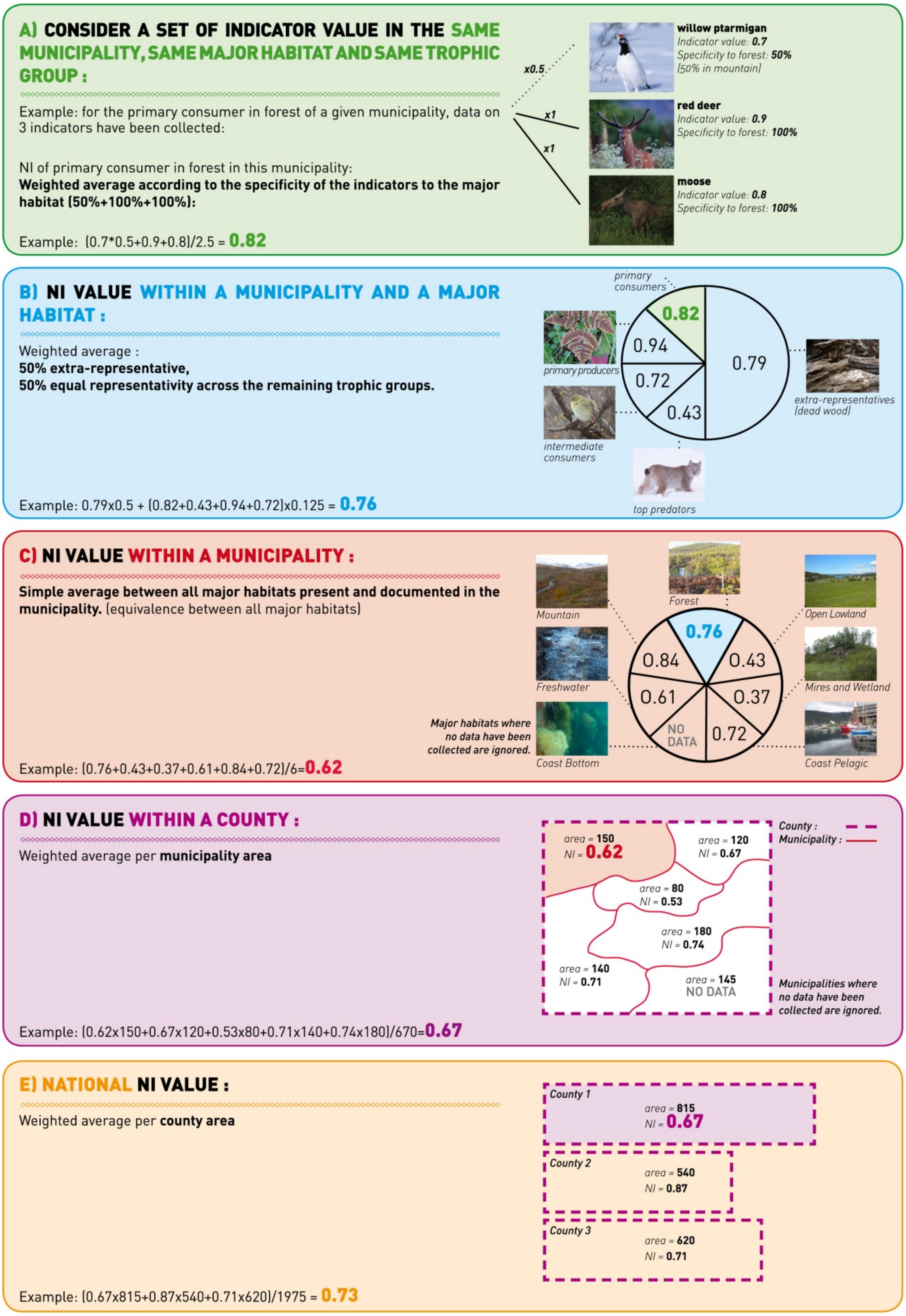


Figure 2. *Illustration of the sequential process used to define weights for the NI. Note that all values given here are hypothetical example and do not refer to a real situation.*

4.7 Extracting information from missing data

As a tool of reporting and synthesising the current knowledge on nature state, the NI framework offers a unique possibility to easily point toward lack of data, or to compare the levels of knowledge reached between major habitats for example. Several simple statistics can be extracted from the NI database to study lack of knowledge.

During the data collection process, experts were asked to discriminate between estimates obtained from expert opinion, from field data or from a model. These three categories correspond to three levels in the knowledge of the ecological process governing the value of each indicator, from informed belief to explicit model formulation. Therefore, examining the occurrence and contribution of expert opinion estimates among indicators and across spatial area is a convenient way to identify areas or indicators where knowledge is lacking, and were data collection is needed. This is all the more true when experts have explicitly pointed toward a lack of knowledge, by using a specific code when entering data. We can therefore map across spatial units the contribution of expert relative assessment compared to data or model-based assessment, and also the number of indicators that should be documented but are not because of pure lack of knowledge. These statistics can have two distinct uses: they can first be used together with NI values to evaluate their robustness, and they can help managers and stakeholders to take measure so that to reduce efficiently this lack of knowledge.

5 Preliminary results on data collection

5.1 The indicator set

The process of data collection is up to now nearly finished. Among the 310 indicators identified by the expert groups, only a few (3) are not documented yet, which gives a rate of data entering of 99% at the date of the 01/02/2010. For these 3 missing indicators, solutions have been found so that the data will be entered during February 2010. The data entered by the experts have not been analysed yet. Therefore, this result section will only focus on the indicator set, so that to better understand which kind of inference can be drawn from it. Please note that since the NI is constantly updated, numbers given in this section may be slightly different in the future, as the number of indicators is constantly increasing and the ecological knowledge constantly improving. The Indicator list is available as an appendix of this report, and further informations will be available in Nybø (ed.) 2010b.

5.1.1 Basic statistics

Descriptive statistics on the set of biodiversity indicators are provided in Table 4. 310 indicators were identified, among which 236 are specific to a major habitat, which means that their value only refers to the state of one major habitat, and 74 being representative of several major habitats. When these are duplicated into the major habitats they represent, the total indicator set is composed of 400 indicators. It is clear from Table 4 that the indicator set covers extensively several aspects of nature and ecosystems, and that all these aspects are represented by at least one indicator into each major habitat. The most important heterogeneity concerns the specificity to major habitat, with more specific indicators in terrestrial habitats than in marine habitat where a significant number of indicators represent at least two major habitats. Some heterogeneity may also be due to the different level of knowledge between major habitats: for example, much more red-listed indicators are found in terrestrial major habitat, not only because they are many at risk, but maybe also because of the fundamental differences in the research tradition between terrestrial and marine ecosystems. In general, the indicators considered as “Extra-representatives” were indicators related to a community measure, or indicators related to a keystone species or habitat.

Table 4. *Number of indicator per major habitat and thematic group.* ***Tot****: total number of indicator.* ***Spe****: indicator specific to only one major habitat,* ***Key****: indicator related to a keystone species,* ***Red****: indicator related to vulnerable, endangered of critically endangered species on the red list,* ***Comm****: indicator related to a community,* ***Serv****: indicator related to the provision of ecosystem service, and* ***Ext****: indicator considered as “Extra-representative” by the experts.*

	Tot	***Spe***	***Key***	***Red***	***Comm***	***Serv***	***Ext***
Coast Bottom	48	26	6	5	8	35	8
Coast Pelagic	37	9	6	4	2	29	4
Ocean Bottom	31	10	5	6	3	26	5
Ocean Pelagic	41	14	8	7	2	33	6
Forest	74	61	11	12	6	23	6
Freshwater	42	35	14	14	9	21	11
Mountain	30	22	7	6	2	16	3
Mires and Wetland	40	29	6	10	1	22	4
Open Lowland	57	30	7	12	2	30	4

5.1.2 The reference state

Table 5 allows examining the frequency, in terms of number of indicators, at which different kinds of reference states have been used. These classes of reference state corresponds to those defined in Table 2, except “amplitude of fluctuation” which is considered as a special case of (and therefore included in) “past knowledge”. Focusing on which kind of reference state has been used across major habitats allows a better understanding of the inference that can be drawn from the indicator set.

For most terrestrial habitats, the main contribution will come from indicators with reference states established under “Pristine” natural conditions (e.g. no impact of human activity). This is obvious in non-exploited systems that may therefore suffers from artificial conversion into other more “productive” systems, (e.g. Mires and Wetland), and/or when there is some access to nearly pristine locations that can serve as a reference (e.g. Forest, Mountains, Coast Bottom, Mires and Wetland). In several harvested habitats (Open Lowland, Coastal Pelagic and Ocean Pelagic), the use of “Pristine nature” as a reference is much less important, and it is replaced by the concepts of “Traditional management” (Open Lowland), “Precautionary level” and “Past knowledge” (marine habitats). These two last notions are much more used in the marine habitats than in the terrestrial habitats, which highlights the differences in the research practice in these two areas: Direct observations are much more used in terrestrial systems, whereas in marine systems most studies focus on long time series of indirect observations for management purposes. Indeed, since marine science is much more influenced by the management of resources such as fish stocks, a high number of reference states in marine systems relate to precautionary harvesting levels, which are the outputs of stock- and recruitment-oriented demographic models. The use of already developed theoretical or empirical indexes, the reference being the best possible value for these indicators, is restricted to Freshwater systems, where it has a long tradition in research. The concept of Carrying capacity has been used for a few indicators in nearly all major habitats (except Mires and Wetland), and mainly concern very-well studied indicators such as moose or salmon.

Table 5. *Number of indicators per major habitat and per method used to define the reference state. Columns.* ***CC****: Carrying capacity,* ***Sust****: Maximum sustainable value,* ***Past****: Knowledge on past conditions,* ***Prec****: Precautionary level,* ***Prist****: Pristine or near-pristine nature,* ***Best****: Best theoric values of indexes,* ***Trad****: Traditional Management (1850-1950). Rows: Major habitats.*

	CC	*Sust*	*Past*	*Prec*	*Prist*	*Best*	*Trad*
Coast Bottom	4	0	12	5	23	0	4
Coast Pelagic	2	0	5	23	6	0	1
Ocean Bottom	4	0	12	6	4	0	5
Ocean Pelagic	3	0	17	15	3	0	3
Forest	8	2	19	1	40	0	3
Freshwater	1	2	4	0	27	8	0
Mountain	5	0	5	0	19	0	0
Mires and Wetland	0	1	4	0	32	0	3
Open Lowland	1	1	8	17	24	0	6

5.1.3 Pressures

Table 6 shows the number of indicators that are sensitive to different kinds of pressures in different major habitats, according to the information gathered on the sensitivity of indicators to the list of pressures in Table 3. We see that most of the pressures are represented by at least one indicator in each major habitat, except primary activity in Ocean Bottom, invasive species in Mountain, Forest and Ocean Bottom, harvesting in Mires and Wetland, hydrologic changes in Coast Pelagic and Ocean Bottom, and eutrophication in Mountain. Indeed, most of these pairs pressure/habitat, except maybe those related to invasive species, are just irrelevant.

Highly documented pressures will be the effect of primary activity (mainly agriculture/fishing, depending of the major habitat), land use change (building, infrastructure) mainly in terrestrial area, but it can also have implications in marine ecosystems when modifying the terrestrial habitats of seabirds for example. Indicators related to climate change and other pollution are found in nearly all habitats, and indicators related to harvesting are mainly found in marine habitats. Indicators related to invasive species, eutrophication or acidification, although less numerous than for the other pressures, are nonetheless present in nearly all major habitats.

Table 6. *Summary of the number of indicators related to a given kind of pressure per major habitats. Columns.* ***Pa****: land use changes due to primary activity,* ***Lc****: land use change due to other sectors ,* ***Cl****: climate change,* ***Is****: invasive species,* ***Ih****: harvesting of animals,* ***Hc****: anthropic Hydrological changes,* ***Eu****: Eutrophication,* ***Ac****: Acidification,* ***Po****: other pollution,* ***Ab****: Abandonment of land use*

	Pa	***Lc***	***Cl***	***Po***	***Is***	***Ih***	***Hc***	***Eu***	***Ac***	***Ab***
Coast Bottom	3	7	28	30	4	29	3	11	2	0
Coast Pelagic	19	1	29	32	13	25	0	2	1	0
Ocean Bottom	0	3	14	27	0	28	0	1	2	0
Ocean Pelagic	8	1	24	40	5	32	0	1	1	0
Forest	56	26	11	6	0	8	8	4	5	0
Freshwater	6	14	7	18	8	8	19	10	6	0
Mountain	8	5	12	2	1	5	2	0	1	0
Mires and Wetland	19	17	7	5	1	0	16	9	6	0
Open Lowland	30	16	22	19	13	14	2	7	4	6

5.2 Effect of the weights

In Figure 3, we calculated preliminary weights on the set of indicators, according to criteria listed in section 4.6.2. Because data analysis is not finished yet, this set of weights has been calculated for a fictive municipality where all the major habitats and all the indicators are present and documented. Although this case study is hypothetical, it nonetheless illustrates the change induced by the weighting process in the relative contribution of the indicators, compared to a situation without weights.

The global contribution of extra-representative indicators has been multiplied by nearly 4 in the weighted situation (Figure 3b) compared to the unweighted situation (Figure 3a), while the contribution of the remaining indicators has been equated among trophic groups (Figure 3c) at the major habitat level. Note that in our example, equal contribution of trophic groups is expected at the major habitat level (Figure 3c), but not at a global scale (Figure 3b). This is because the relative contributions of the trophic groups depend on their relative frequencies in each major habitat. For example, since indicators related to decomposers have only been defined in three major habitats, their global contribution to the present NI is lesser than for a trophic group being found in every major habitat such as intermediate predator generalist.

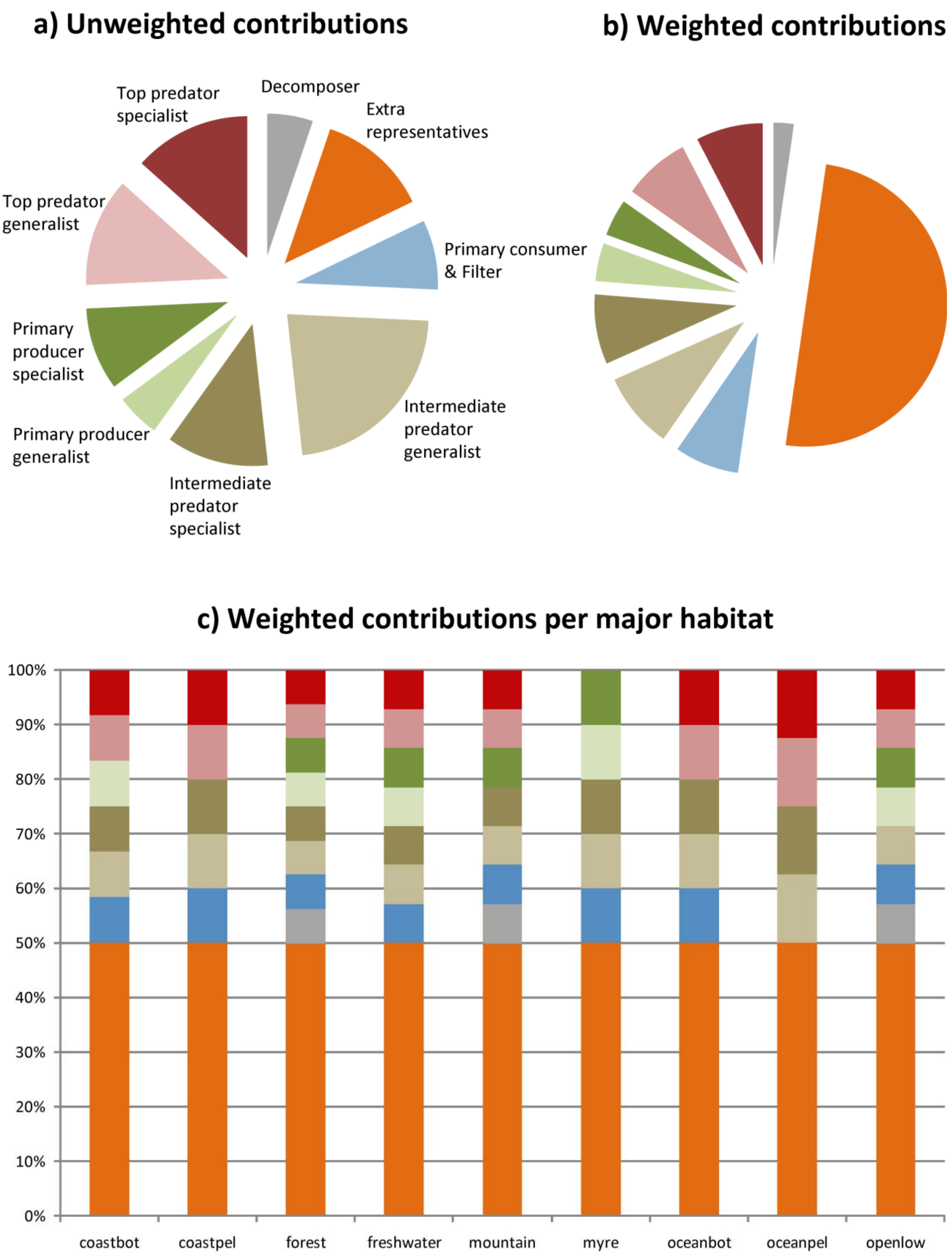


Figure 3. *Relative contribution of each trophic group a) without weighing, b) using weights, and c)using weights and for each major habitat in a fictive municipality where all the major habitats and all the indicators are present and documented.*

6 Discussion

6.1 Estimating the reference state: examples and discussion

The use of a reference state is not new in the context of biodiversity management. Scholes & Biggs (2005) uses “populations in a large protected area in the same ecosystem type” while Nielsen *et al*. (2007); Nybø *&* (2008a,b) proposes an empirical approach (e.g. statistical modelling based on field data) to set the reference. In the first case, the presence of large protected areas is required, and one assumes that values observed in these areas are representative from all others. In the second case, one should rely on a consequent dataset. It is unlikely that all indicators fulfill the same criterions in the same time. We therefore opted for a more flexible definition of a reference state in order to adapt to several aspects and traditions within the ERN, such as marine and terrestrial ecology. Indeed, our definition of the reference state (section 2.3) can be met by several practical situations (Table 2) depending on the indicator and the major habitat (Table 5). We therefore discuss each in the following sections.

6.1.1 Pristine condition

The concept of pristine nature, defined as untouched or undisturbed natural systems, has been widely applied, especially to all indicators and major habitat that were not subject to strong human activities. This concept is one of the most widely used in other international indicators (ten Brink & Tekelenburg 2002, Scholes & Biggs 2005, Alkemade *et al.* 2009). In Norway, some areas can be considered as pristine, offering therefore a basis for comparison (see for example Morissette *et al.* 2009). In Forests, which are heavily exploited in Norway, an extensive network of 17 000 monitoring sites are surveyed every 5 years in the National Forest Inventory. Among these, it has been possible to identify near 900 sites corresponding to “pristine” forests, *i.e.* monitoring sites where no trace of human activity were reported, no invasive species were present, no harvesting activity occurred in the last 50 years, and several vegetation layer were simultaneously observed: On the basis of these 900 sites, it has been possible to estimate the value of several Forest indicators in pristine conditions, an empirical-based approach similar to Nielsen *et al.* (2007).

Another example of the use of the “pristine” concept within the NI framework is on terrestrial birds. 96 indicators relate to land bird species in the NI, and all are associated to a reference state expressed in term of pristine conditions. Here, most of these estimates were expert-based and involved a meeting amongst several ornithologists to estimate, species per species, the population size of each indicator in the reference state, which is an approach similar to Scholes & Biggs (2005).

6.1.2 Carrying capacity

The concept of Carrying capacity has been used in all major habitats except Mires and Wetland, but most extensively in Mountains where indicators whose reference states are related to carrying capacity contribute 33% of the NI value. Ecological carrying capacity has been defined as the natural limit of a population set by resources in a particular environment (Caughley & Sinclair, 1994, Hayward *et al.* 2007). In most systems, the carrying capacity is a high limit, since emigrations or density-dependent effects may occur even when populations are below this carrying capacity (Plumb *et al.* 2009).

In the NI framework, most reference states related to carrying capacity have been estimated using GIS-based modelling of resource and/or habitat area, using ecological parameter such as territory size, density in undisturbed areas or resource consumption levels to estimate the potential population size given available habitat (see for example Støbet-lande *et al.* 2003). This approach has been used for several indicators in Mountains, such as arctic fox, rock ptarmigan, wolverine, lynx, bear and wolf. For large herbivores populations such as wild reindeer or moose, both bottom-up (resource availability) and top-down (browsing impact) control mechanisms have been considered to set the reference state.

6.1.3 Maximum sustainable level

Some of our indicators in terrestrial habitats focus on metrics (either at the species or the community level) that should have a low value, and whose any increases above a given threshold is interpreted as a negative effect. The typical example is the Critical load of Nitrogen (Larssen *et al.* 2008), used as an indicator in Mires and Wetland and considered as "extra-representative" in this major habitat, due to the sensitivity of mires to pollution in rainfalls. For these indicators, the estimate of the maximum sustainable level has been identified by each expert, and the associated scaling model is systematically the MAX model (Figure 1c). Another typical example is the abundance of planktonic algae which indicates eutrophication when they exceed a threshold level.

6.1.4 Past knowledge

A large number of indicators, especially in the marine habitat, are associated with a reference pointing at a particular, past situation. For example the krill abundance, an indicator identified as "extra-representative" for the Ocean Pelagic major habitat, has a reference that relates to the earliest data available (Dalpadado *et al.* 2009) rather than a theoretic value derived from a model. The main reason here is that such models are inexistent or in early stage of development in the marine system, mostly because of the high variability joint to the difficult observation of these systems. The choice of a past value as a reference often reflects a lack of knowledge on the current ecosystem within which the indicator is found, that prevents the estimation of a reference state relevant for the today's ecosystem and matching our definition in section 2.3. The alternative is therefore to use values observed in the past, under the hypothesis that environmental and anthropogenic pressures have increased over the last decades. Therefore values observed in the past correspond to values observed in much less disturbed ecosystems, more likely to sustain higher levels of biodiversity than today. For example in the case of marine systems where some indicators related to fish stocks have collapsed, the "past knowledge" reference state refers to the pre-collapse situation.

6.1.5 Precautionary level

For numerous marine indicators related to harvested species, the reference state corresponds to precautionary level established in a management framework: ICES recommendation (ICES 2008). The ICES precautionary level indicates a population size where it is assumed that the population is below biological safe limits when it drops below this limit. The use of Precautionary level directly leads to the application of the MIN model (Figure 1b). For some indicators where this limit was considered very low by the expert, it has been multiplied by 1.5 to provide a more relevant picture. Herring and cod are the most known example where ICES precautionary levels have been set. Both are considered as "extra-representative", of the state of the pelagic habitat (coast and ocean) for herring, and of the state of Ocean Bottom for cod.

Another application of the Precautionary level concept is found with indicators related to seabird's colony growth rate, were the reference state corresponds to a demographically stable colony, and where any negative growth rate could ultimately result in the extinction of the colony. Therefore, a growth rate of 0% (e.g. a stable colony) has been defined as a precautionary level.

6.1.6 Maximum theoric value of indexes

In a few cases, indexes (mostly empirical indexes focusing on a metric at the community level) developed for theoretic or management purposes are already available. Several of these indexes were developed under the Water Frame Directive where the reference states are pristine conditions, and they can be understood as a specific case of the “pristine” reference state. Research in freshwater Ecology in Norway has a long tradition in working with these indexes, focusing on phyto- and zoo- plankton community, as well as on benthic macro-invertebrates (for example Ptacnik *et al.* 2009). However, the very nature of these empirical indexes probably requires further considerations. First, as these index are often related to several hundred of species and more generally to pollution or stress level within an ecosystem, they were all treated as “extra-representative” in the Freshwater habitat. But further developments may make a distinction between pressure-oriented indexes and biotic or ecosystemic indexes. Pressure-oriented indexes mostly present a theoretic construction and a spatial distribution designed according to the pressure they are supposed to measure- in a sense, they are ad-hoc indexes with very specific interpretation. On the other side, general biodiversity indexes such as Shannon index, or the shape of Species-Abundance Distribution (SAD) curves early developed by Fisher (1943, but see also Engen 2007) are indexes that focus on general properties of the ecosystems, and are by essence sensitive to any pressure or disturbance.

6.1.7 Traditional management

The use of the concept of “traditional management” as a reference has most often been applied in the “human-driven” major habitat “open lowland”. Indeed in these systems, human activity has constantly shaped the landscape for centuries or even millennia, giving the time for a broad community of organisms to co-evolve with the human society practice. It is only recently, following the shift toward intensive, mono-cultural practices on one side, and the abandonment of traditional management resulting in tree and shrub encroachment on the other side, that this whole part of biodiversity is under threat. It has been recently demonstrated that the “pristine” concept applied to lowland areas would result in Forest to the long term, and that only management policies focused on the sustainability of the ‘natural heritage’ (*i.e.* the community of co-evolved organism) lead to an optimisation of diversity (Fonderflick *et al.* 2010). Therefore, the “traditional management” is a reference state that refers to a time when this ‘natural heritage’ was prospering, when traditional human management had been stable over a long time. It mostly refers to the agricultural practice of the beginning of the past century (1900), where extensive and poly-culture was used, leading to a wide and complex mosaic of open-habitat suitable for biodiversity.

6.1.8 So what is the reference for Norway?

By challenging the ERN to produce indicators for which reference states should be estimated, using our theoretic definitions of these two within the NI framework (see section 2.1 and 2.3), we are now able to better synthesize what would be the reference state for the Norwegian nature. It would be a nature where no harvested stocks are at extinction risk, where most of the species or community present abundance, density, biomass or area of distribution close to the pristine conditions, or alternatively close to the carrying capacity of their respective ecosystems, and where most of the agricultural practice ensures a good equilibrium between service production and biodiversity.

This multi-criterion definition reflects the complexity of both natural and societal systems that a framework such as the NI must consider. Indeed, one unique concept such as “pristine nature” cannot be applied uniformly to all major habitat, since human society are part of nature and the definition of “pristine” deliberately exclude the impact of human society on natural system. However it still can be applied in a wide number of ecosystems that are not either habitat for human society, or a massive source of services such as biological resource.

If we had a unique model encompassing all the ecosystems, all the trophic groups and all species throughout the entire Norwegian territory, including both terrestrial and marine systems, all kind of spatial, temporal, inter-ecosystems and inter-trophic interactions, including the dynamic of species at all spatio-temporal scales (and probably other processes presently unknown to us), then and only then would we be able to propose a model-based reference state of all indicators that points toward the same situation. But the current state of knowledge in the ERN is very far away from this ideal situation.

Therefore, to face the complexity of the different major habitats, as well as the complexity in research practices and traditions, we opted for the use of slightly different reference states that all share the same properties regarding biodiversity, and for the use of three different scaling models. We think that this combination allows incorporation of any pieces of ecological knowledge within the NI framework; at least it has successfully integrated most of the knowledge of the ERN in Norway.

6.2 Quantifying the lack of knowledge

As we briefly state it in section 3.1, the NI framework provides a unique chance to quantify the lack of knowledge existing within the ERN. In the NI framework, uncertainties will be dealt with according to three levels: (i) measurement uncertainty; (ii) uncertainty of data source; (iii) missing knowledge.

6.2.1 Measurement uncertainty

Each of the experts is asked to give a 50% confidence interval for each estimate and for the reference state. This confidence interval reflects both measurement error and natural variability. These confidence intervals will allow producing confidence intervals around the NI values and the different thematic indexes in a very classical way, using Monte-Carlo simulations. Although confidence intervals is a very convenient numeric way of expressing uncertainty, these confidence intervals do not include every kind of uncertainty within the NI. Rather, they only reflect the numerical uncertainty existing around a known or an estimated value. Note that we do not plan to use Monte-Carlo simulations to estimate confidence intervals around the reference, because this uncertainty is already contained in the statistical distribution of the observed value. But the confidence intervals given by the expert around the reference condition can be used as a measure of the precision of the indicator.

6.2.2 Data source and missing knowledge

Another level of uncertainty is the type of data source: experts, data, or models. Model and data-based estimates can often be considered as comparable (models are preliminarily calibrated with field data), while expert-based estimates must be regarded with more caution. Indeed, estimates based on known and repeatable measures in the field are much more trustable than any expert estimate, and are a better support for any management decision.

The same reasoning, perhaps with an even more important implication, can be applied to the last uncertainty level: missing knowledge. Missing knowledge occurs when an expert is unable to give any estimate on the value of an indicator that should be present at a spatial location. This “missing knowledge” is maybe the most important source of uncertainty within the ERN.

Therefore, both the relative contribution of expert-based estimate, and the numbers of indicators where knowledge is missing must be used as indirect measures of the uncertainty of the NI value, and must be communicated in the same time than maps or time series produced within the NI framework.

6.3 The weighting process

Defining a weighting system for the NI has been a difficult task, first to find a set of criteria that improves the significance of the index, and second to reach a compromise between all the experts involved. This experience highlighted how difficult and arbitrary it can be to attribute numerical weights to a set of highly diverse indicators. The chosen approach seems to be a good compromise for several reasons.

6.3.1 Complete equivalence between major habitats

First complete equivalence between all the major habitats conceptually ensures that the NI will be maximised with both increase in alpha (local) and beta (regional) diversity (see Godfray *et al.* 2001 for definitions). It ensures that the disappearance of a major habitat- and therefore a decrease in beta diversity will automatically result in an irremediable decrease of the index. Any Approach that weight per major habitat area will be sensitive to any change in area, would require up-dated GIS maps of the different major habitat anda “reference” map of the different major habitats, which is obviously a very complex task. By contrast, the complete equivalence approach does not focus much on the potential variation in extent, either natural or due to land use change, of each major habitat. These variations are implicitly taken into account in each indicator value. However, our approach can nonetheless be affected by the complete disappearance of a major habitat from our smallest spatial unit, in our case the municipality, but only if such disappearance is also included in the reference state: A major habitat that has disappeared may always be considered as present in the reference state, leading to 0 values for all the indicators being associated to this habitat. Although this is not likely to occur at a global scale, it may be relevant at a local scale with a major habitat sensitive to global change such as Mires. The complete equivalence approach also solves the bias of heterogeneous number of indicators between major habitats.

6.3.2 Extra-representative indicators

Second, the distinction between “Extra-representative” indicators and the others allows highlighting some very important indicators, such as keystone species, or already developed community indicators thought to summarise important ecosystem characteristics. Rather than attributing some arbitrary weight to each of them, the use of the 50% criterion (the extra-representative indicators must account for half of the NI value in each major habitat) is a more flexible way to emphasize them. Indeed, this approach is a way to deal with (i) heterogeneities in the number of extra-representative indicators between major habitat: whatever these heterogeneities, the contribution of extra-representative indicators is the same, and (ii) redundancies of extra-representative indicators within a given habitat: whatever the number of extra-representative indicators in a major habitat, their overall contribution is the same. Of course, even though it resulted from a consensus with the expert, the choice of the value 50% remains arbitrary.

6.3.3 The use of trophic groups

Third, our classification of indicators according to their trophic group together with explicitly contrasting between specialist and generalist indicators is an attempt to take into account ecosystem structure and function into the NI, to reflect the increasing importance given to functional diversity (Tilman 2001). It also allows controlling for the over-representation of similar, well studied organisms, such as birds and fish. Emphasis was put on trophic structure since it is a part of the current debate on the interplay between biodiversity and ecosystem functions (Hillebrand & Matthiessen 2009) and since this information was easily accessible for each of our indicators. Indeed, more advanced information at the level of some functional traits would have been difficult to collect homogeneously across all the biodiversity indicators.

6.4 Comparison with other indexes

Some of the concepts used within the NI framework match the concepts used in other approaches. Our definition of the reference state, focused on biodiversity, allows comparison with the Biodiversity Intactness Index (BII). A significant proportion of reference state refers to pristine nature, as does the BII (Scholes & Biggs 2005) and also the GLOBIO framework (Alkemade *et al.* 2009). Furthermore, bridges between these two approaches and the NI can probably be established, since data collected within the NI framework may be used to calibrate the models used to investigate scenarii of biodiversity loss in the future (Biggs *et al.* 2008, Alkemade *et al.* 2009). In addition the flexibility of the NI framework allows to present the results in a form similar to other aggregated indexes, such as the BII or the Natural Capital Index (ten Brink & Tekelenburg 2002).

6.5 Usefulness of the Nature Index to policy makers

There are at least two main ways of using the information provided by the NI. First, trying to increase the NI value can be the starting point of various management policies that may for example launch conservation programmes in areas or ecosystems where one or several indicators face serious threats. But the ability of the NI to measure explicitly uncertainty and lack of knowledge within the ERN is a novel opportunity to increase the efficiency of research policies, by directing funds towards the areas or systems where gaps in knowledge are the most important.

In other words, management policies may seek to increase the NI value, while research policies may use the information concerning uncertainty to optimise the gathering of information on natural systems and reduce uncertainty.

6.6 The need for validation and calibration

Indexes based on expert knowledge are useful, because they use pieces of information that were previously neglected or only implicitly used in other approaches. Of course, this purely expert-based approach is more likely to be biased compared to a more classical, empirical approach. However, it allowed synthesizing a huge amount of knowledge which is now available within the NI framework. Furthermore, calibration experiments attempted on similar expert-estimate collection process showed a reasonable accuracy of expert performances (Scholes & Biggs 2005).

However, in order to be trusted and regularly used for management and policy design, we should stress that the use of expert-estimates within the NI framework should be challenged and submitted to a calibration process (see Garthwaite *et al.* 2005 for methodological details). It may be not possible in all cases, but calibration should be used (for example simultaneous collection of expert estimate and field data) to assess the relevance of expert-based estimates and maybe refine the numerical expression of associated uncertainty. Furthermore, the explicit distinction between expert-based and data-based estimates already offers a first way to control for expert-induced biases.

7 Conclusion

Reducing complexity of information may lead to over-simplistic schemes (see for example Röckstrom *et al.* 2009, commented by Samper 2009). However reducing complexity is also a key to increase information transfer (Shannon 1948). We do believe that the NI framework corresponds to a near-optimal trade-off between these two needs.

By integrating all kinds of ecosystems, terrestrial and marine, all kinds of metrics obtained in nature (population, community, demographic parameters), and several sources of knowledge (expert opinion, field data, model outputs) the NI present the key properties to become a milestone in the management of norwegian ecosystems. The use of reference states is a framework to quantify what could be the “best” ecological state. It is a challenging and difficult task, but it can also be viewed as a catalyst within the ERN. As soon as new scientific results are published, the reference states may be up-dated accordingly, offering a way to constantly improve the relevance of the NI. The use of thematic indexes allows providing information on very well defined topics, and prevents the NI to be only a very general and hard to interpret measure. The ability of highlighting gaps in knowledge is also a key point to inform management and funding of future research needs. There is currently no limit to the number of indicators that can be included within the NI framework, and the current definition of an indicator allows including a very wide diversity of metric collected in nature. Therefore, the transposition of the NI framework within other countries can be straightforward.

Given the high expectancy concerning the halt of biodiversity loss at the global scale in 2010, a framework such as the NI has the potential to significantly contribute to estimate of trends in biodiversity and design management policies accordingly, therefore increasing the efficiency of the societal response to the global change threat.

8 References

Alkemade R, van Oorschot M, Miles L, Nellemann C, Bakkenes M, ten Brink B. 2009. GLOBIO3: A framework to investigate options for reducing global terrestrial biodiversity loss. *Ecosystems*. 12:374-390

Ahlroth P, Kotiaho J. 2009. Route for political interests to weaken conservation. *Nature*. 460:173.

Biggs R, Simons H, Bakkenes M, Scholes RJ, Eickout B, van Vuuren D, Alkemade R. 2008. Scenarios of biodiversity loss in Southern Africa in the 21st century. *Global Environmental Change*. 18: 296-309.

Brauer J. 2006. Establishing Indicators for Biodiversity. Science. 208:791.

ten Brink BJE, Tekelenburg T. 2002. Biodiversity: how much is left? The Natural Capital Index framework (NCI). RIVM report 402001014. Bilthoven

Caughley GC, Sinclair ARE. 1994. Wildlife Ecology and Management. Blackwell Science, Cambridge, Massachusetts.

Chapman AD. 2009. Numbers of Living Species in Australia and the World. CSIRO report. 2nd ed. 78pp.

Dalpadado P, Bogstad B, Eriksen E, Rey L. 2009. Distribution and diet of 0-group cod (*Gadus morhua*) and haddock (*Melanogrammus aeglenus*) in the Barents Sea in relation to food availability and temperature. *Polar Biology*. 32:1583-1596.

Engen S. Heterogeneous communities with lognormal species abundance distribution: Species–area curves and sustainability. 2007. Journal of Theoretical Biology. 791:803.

Erikstad L, Bakkestuen V, Hanssen F, Stabbetorp OE, Evju M, Aarrestad PE. 2009. Evaluering av landsdekkende Satellitbasert Vegetasjonskart. *NINA Rapport* 448. 82pp.

Fonderflick J, Lepart J, Caplat P, Debussche M, Marty P. 2010. Managing agricultural change for biodiversity conservation in a Mediterranean upland. *Biological Conservation*. in press.

Fisher RA, Corbet AS, Williams CB. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology. 12:42–58.

Garthwaite PH, Kadane JB, O'HAgan A. 2005. Statistical methods for eliciting probability distributions. *Journal of the American Statistical Association*. 100(470):680-701.

Godfray CJ, Lawton JH. Scale and species numbers. 2001. *Trends in Ecology & Evolution*. 16(7):400-404.

Hayward MW, O'Brien J, Kerley GIH. 2007. Carrying capacity of large african predators: predictions and tests. *Biological Conservation*. 139:219-229

Hillebrand H, Matthiesen B. 2009. Biodiversity in a complex world: consolidation and progress in functional biodiversity research. *Ecology Letters*. 12:1405-1419.

ICES Advisory Committee. 2008. ICES advice. 320pp.

Jenkins M. 2009. Prospects for Biodiversity. *Science*. 302(2003):1175-1177.

Kell LT, O'Brien C, Smith MT, Stokes TK, Rackham BD. 1999. An evaluation of management procedures for implementing a precautionary approach in the ICES context for North Sea plaice (*Pleuronectes platessa L.*). ICES Journal of Marine Science. 56:834-845.

Laikre L, Jonsson B, Ihse M, *et al.* 2008. Wanted: scientists in the CBD Process. *Conservation Biology*. 22(4):814-815.

Larssen T, Lund E, Høgåsen T. 2008. Overskridelser av tålegrenser for forsuring og nitrogen for Norge. NIVA.

Loreau M, Oteng-yeboah A, Arroyo M, *et al.* 2006. Diversity without representation. *Nature*. 442(July):245-246.

Morissette L, Pedersen T, Nilsen M. 2009. Comparing pristine and depleted ecosystems: the Sørfjord, Norway versus the Gulf of St Lawrence, Canada. Effects of intense fisheries on marine ecosystems. *Progress in Oceanography*. 81:174-187.

Nielsen E, Bayne M, Schieck J, Herbers J, Boutin S. 2007. A new method to estimate species and biodiversity intactness using empirically derived reference conditions. *Biological Conservation*. 137:403-414.

Nilsen EB, Skonhoft A, Mysterud A, Milner JM, Solberg EJ, Andreassen HP, Stenseth NC. 2009. The role of ecological and economic factors in the management of a spatially structured moose *Alces alces* population. *Wildlife Biology*. 2009;15(1).

Nybø, S. & Skarpaas, O. 2008[a] (eds.). Nature Index. A test of methods in central Norway – NINA Report 425, 45 pp.

Nybø, S. & Skarpaas, O. 2008[b] (eds.). Nature Index. Background documents for the pilot study in Central Norway – NINA Report 426. 69 pp.

Nybø (ed.) 2010[a]. Naturindeks for Norge 2010. DN-utredning x- 2010, in prep.

Nybø (ed.) 2010[b]. Datagrunnlaget for Naturindeks 2010. DN-utredning x-2010, in prep.

Nybø, S., Skarpaas, O., Framstad, E. & Kålås, J.A. 2008. A Nature Index for Norway: suggestions for a conceptional framework – NINA Report 347, 68 pp.

Ptacnik R, Solimini AG, Brettum P. 2009. Performance of a new phytoplankton composition metric along an eutrophication gradient in nordic lakes. *Hydrobiologia*. 633:75-82.

Plumb GE, White PJ, Coughenour MB, Wallen RL. 2009. Carrying capacity, migration, and dispersal in Yellowstone bison. *Biological Conservation*. 142:2377-2387.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rigby RA, Stasinopoulos DM, Akantziliotou C. 2008. A framework for modelling overdispersed count data, including the Poisson-shifted generalised inverse Gaussian distribution. *Computational Statistics and Data Analysis*. 53:381-393.

Rockström J, Steffen W, Noone K, *et al.* 2009. A safe operating space for humanity. *Nature*. 461:472-475.

Sachs JD, Baillie JE, Sutherland WJ, *et al.* 2009. Biodiversity Conservation and the Millennium Development Goals. *Science*. 325:1502-1503.

Samper C. 2009. Rethinking biodiversity. *Nature*. 3:118-119.

Scholes RJ, Biggs R. 2005. A biodiversity intactness index. *Nature*. 434:45-50.

Scholes RJ, Mace GM, Turner W, *et al.* 2008. Toward a Global Biodiversity Observing System. *Science*. 321:1044-1045.

Shannon C. 1948. A Mathematical theory of Communication. The Bell System Technical Journal. 27:379-423.

Støbet-Lande U, Linnel JD, Herfindal I, *et al.* 2003. Potensielle leveområder for store rovdyr i Skandinavia: GIS – analyser på et økoregionalt nivå. NINA fagrapport 64. 32pp.

Teder T, Moora M, Roosaluste E, *et al.* 2007. Monitoring of Biological Diversity: a Common-Ground Approach. *Conservation Biology*. 21(2):313-317.

Tilman D. 2001. Functional diversity. In S. A. Levin (Ed.), Encyclopedia of biodiversity. 109–120. San Diego: Academic Press.

Veiberg V, Loe LE, Mysterud A, Solberg EJ, Langvatn R. 2007. The ecology and evolution of tooth wear in red deer and moose. *Oikos*. 116:1805-1818.

Walpole M, Almond REA, Besancon C, *et al.* 2009. Tracking progress toward the 2010 Biodiversity Target and beyond. Science. 325:1503-1504.

9 Appendix- List of Indicators

Major habitat	Indicator english name	Indicator scientific name	responsible institution in Norway	Trophic group	Reference State	Scaling Model
Freshwater	Algae growth on river sub-strate eutrofication index	*NA*	NIVA	Ext	Best index value	MAX
Freshwater	Macrofauna, rivers	*NA*	NIVA/NINA	Ext	Pristine	MIN
Freshwater	Zooplancton composition	*NA*	NINA/NIVA	Ext	Best index value	OPT
Freshwater	Noble Crayfish	*Astacus astacus*	NINA	IC gen	Pristine	OPT
Freshwater	freshwater pearl mussel	*Margaritifera margaritifera*	NINA	PCF	Pristine	MIN
Freshwater	Aure	*Salmo trutta*	NINA	TP gen	Pristine	OPT
Freshwater	Silver bream	*Abramis bjoerkna*	NINA, redlist	IC gen	Pristine	OPT
Freshwater	zander	*Stizostedion lucioperca*	NINA, redlist	TP spe	Pristine	OPT
Freshwater	fourhorn sculping	*Myoxocephalus quadricornis*	NINA, redlist	IC gen	Pristine	OPT
Freshwater	european bullhead	*Cotus gobio*	NINA, redlist	IC gen	Pristine	OPT
Freshwater	Atlantic salmon	*Salmo salar*	NINA	Ext	Carrying capacity	MIN
Freshwater	moss-Herbertus dicranus	*Herbertus dicranus*	VM/ redlist	PP spe	past knowledge	MIN
Freshwater	moss-Herbertus stramineus	*Herbertus stramineus*	VM/ redlist	PP spe	past knowledge	MIN
Freshwater	moss-Hygroamlystegium fluviatile	*Hygroamlystegium fluviatile*	VM/ redlist	PP spe	past knowledge	MIN
Freshwater	moss-Isothecium holtii	*Isothecium holtii*	VM/ redlist	PP spe	past knowledge	MIN
Freshwater	Otter in freshwater area	*Lutra lutra*	NINA	TP spe	Pristine	OPT
Freshwater	Critical load acid exceedance	*NA*	NIVA	Ext	Max sustainable level	MAX
Freshwater	Lake phytoplancton	*NA*	NIVA	Ext	Best index value	MAX
Freshwater	aquatic flora of lake	*NA*	NIVA	Ext	Best index value	OPT
Freshwater	chlorophyll-a in lakes	*NA*	NIVA	PP gen	Best index value	MAX
Freshwater	Asp	*Aspius aspius*	NINA, redlist	TP spe	Pristine	OPT
Freshwater	ASPT index bottomfauna	*NA*	NIVA	Ext	Best index value	MIN
Freshwater	Salmon ssp.	*Salmo salar ssp.*	NINA, redlist	IC gen	Pristine	OPT
Freshwater	Atlantic salmon ssp.	*Salmo salar ssp.*	NINA, redlist	IC gen	Pristine	OPT
Freshwater	Acidification index bottomfauna	*NA*	NIVA	Ext	Best index value	MIN
Freshwater	Algae growth on river sub-strate acidification index	*NA*	NIVA	Ext	Best index value	MIN
Freshwater	common gull	*Larus canus*	NINA	IC gen	Pristine	MIN
Freshwater	Osprey	*Pandion haliaetus*	NINA	TP spe	Pristine	MIN
Freshwater	dipper	*Cinclus cinclus*	NINA	IC spe	Pristine	MIN
Freshwater	black-headed gull	*Podiceps auritus*	NINA	IC gen	Pristine	MIN
Freshwater	Whooper swan	*Cygnus cygnus*	NINA	PCF	Pristine	MIN

Freshwater	red-throated loon	*Gavia stellata*	NINA	IC gen	Pristine	MIN
Freshwater	eurasian coot	*Fulica atra*	NINA	IC gen	Pristine	MIN
Freshwater	black-throated loon	*Gavia arctica*	NINA	IC gen	Pristine	MIN
Freshwater	common sandpiper	*Actitis hypoleuca*	NINA	IC gen	Pristine	MIN
Freshwater	tufted duck	*Aythya fuligula*	NINA	IC gen	Pristine	MIN
Freshwater	mallard	*Anas platyrhynchos*	NINA	PCF	Pristine	MIN
Mountain	Moss	*Aulacomnium turgidum*	VM/ redlist	PP spe	past knowledge	MIN
Mountain	Arctic Fox	*Vulpes lagopus*	NINA	TP spe	Carrying capacity	OPT
Mountain	rock ptarmigan	*Lagopus mutus*	NINA	PCF	Carrying capacity	MIN
Mountain	Arctic Poppy	*Papaver radicatum*	NINA	PP spe	Pristine	MIN
Mountain	Alpine Azalea	*Loiseleuria procumbens*	NINA	PP spe	Pristine	MIN
Mountain	Glacier Crowfoot	*Beckwithia glacialis*	NINA	PP spe	Pristine	MIN
Mountain	Gyrfalcon	*Falco rusticolus*	NINA	IC spe	Pristine	MIN
Mountain	Wolverine	*Gulo gulo*	NINA	TP gen	Carrying capacity	OPT
Mountain	Moss	*Anastrophyllum joergensenii*	VM/ redlist	PP spe	past knowledge	MIN
Mountain	Moss	*Anastrophyllum donnianum*	VM/ redlist	PP spe	past knowledge	MIN
Mountain	Reindeer forage lichens	*Cladonia & Cetraria spp.*	NINA	PP spe	Pristine	MIN
Mountain	Moss	*Atractylocarpus alpinus*	VM/ redlist	PP spe	past knowledge	MIN
Mountain	Moss	*Scapania nimbosa*	VM/ redlist	PP spe	past knowledge	MIN
Mountain	Willow shrub	*Salix sp. area*	NINA	Ext	Pristine	MIN
Mountain	wild reindeer	*Rangifer tarandus*	NINA	Ext	Carrying capacity	OPT
Mountain	greater scoup	*Aythya marila*	NINA	IC gen	Pristine	MIN
Mountain	eurasian dotterel	*Charadrius morinellus*	NINA	IC gen	Pristine	MIN
Mountain	purple sandpiper	*Calidris maritima*	NINA	IC gen	Pristine	MIN
Mountain	shore lark	*Eremophila alpestris*	NINA	PCF	Pristine	MIN
Mountain	Rough-legged Buzzard	*Buteo lagopus*	NINA	IC gen	Pristine	MIN
Mountain	long-tailed duck	*Clangula hyemalis*	NINA	IC spe	Pristine	MIN
Mountain	eurasian golden plover	*Pluvialis apricaria*	NINA	IC gen	Pristine	MIN
Mountain	NA	*Anthus pratensis*	NINA	IC gen	Pristine	MIN
Mountain	lapland longspur	*Calcarius lapponicus*	NINA	PCF	Pristine	MIN
Mountain	snow bunting	*Plectrophenax nivalis*	NINA	PCF	Pristine	MIN
Mountain	northern wheatear	*Oenanthe oenanthe*	NINA	IC gen	Pristine	MIN
Mountain	small rodents	*NA*	NINA	Ext	Pristine	MIN
Ocean Pelagic	Greenland halibut	*Reinhardtius hippoglossoides*	IMR	TP gen	past knowledge	MIN

Ocean Pelagic	Zooplankton	*NA*	IMR	Ext	Pristine	OPT
Ocean Pelagic	Fin whale	*Balaenoptera physalus*	IMR	IC spe	past knowledge	OPT
Ocean Pelagic	Harp seal	*Phoca groenlandica*	IMR	TP gen	Traditional management	OPT
Ocean Pelagic	Hooded seal	*Cystophora cristata*	IMR	TP spe	Traditional management	OPT
Ocean Pelagic	Humpback whale	*Megaptera novaeangliae*	IMR	IC gen	past knowledge	OPT
Ocean Pelagic	Blue whiting	*Micromesistius poutassou*	IMR	IC gen	Precautionary level	MIN
Ocean Pelagic	Capelin	*Mallotus villosus*	IMR	Ext	Pristine	MIN
Ocean Pelagic	European Hake	*Merluccius merluccius*	IMR	IC spe	Carrying capacity	MIN
Ocean Pelagic	Mackerel	*Scomber scombrus*	IMR	IC spe	Precautionary level	MIN
Ocean Pelagic	Phytoplankton	*NA*	IMR	Ext	past knowledge	OPT
Ocean Pelagic	Polar cod	*Boreogadus saida*	IMR	IC spe	past knowledge	MIN
Ocean Pelagic	Lumpfish	*Cyclopterus lumpus*	IMR	TP spe	Traditional management	MIN
Ocean Pelagic	Saithe	*Pollachius virens*	IMR	IC spe	Precautionary level	MIN
Ocean Pelagic	sperm whale	*Physeter macrocephalus*	IMR	TP spe	past knowledge	OPT
Ocean Pelagic	Herring	*Clupea harengus*	IMR	Ext	Precautionary level	MIN
Ocean Pelagic	Atlantic horse mackerel	*Trachurus trachurus*	IMR	IC spe	Precautionary level	MIN
Ocean Pelagic	Sand eel	*Ammodytes sp.*	IMR	IC spe	Precautionary level	MIN
Ocean Pelagic	Minke whale	*Balaenoptera acutorostrata*	IMR	IC gen	past knowledge	OPT
Ocean Pelagic	Silver smelt	*Argentina silus*	IMR	IC gen	past knowledge	MIN
Ocean Pelagic	Basking shark	*Cetorhinus maximus*	IMR	TP spe	past knowledge	MIN
Ocean Pelagic	Porbeagle	*Lamna nasus*	IMR	TP gen	past knowledge	MIN
Ocean Pelagic	Krill	*Meganyctiphanes norvegica*	IMR	Ext	past knowledge	OPT
Ocean Bottom	Blue ling	*Molva dypterygia*	IMR	TP spe	Traditional management	MIN
Ocean Bottom	Northern wolffish	*Anarhichas denticulatus*	IMR	TP gen	past knowledge	MIN
Ocean Bottom	index of benthic fauna species	*NA*	NIVA/HI	Ext	Pristine	MIN
Ocean Bottom	Angler fish	*Lophus piscatorius*	IMR	TP gen	Carrying capacity	MIN
Ocean Bottom	Tusk	*Brosme brosme*	IMR	TP spe	Traditional management	MIN
Ocean Bottom	Spotted wolffish	*Anarhichas minor*	IMR	TP gen	past knowledge	MIN
Ocean Bottom	Wolffish	*Anarhichas lupus*	IMR	TP gen	past knowledge	MIN
Ocean Bottom	Iceland scallop	*Clamys islandica*	IMR	PCF	past knowledge	OPT
Ocean Bottom	Whiting	*Merlangius merlangus*	IMR	IC gen	Precautionary level	MIN
Ocean Bottom	Haddock	*Melanogrammus aeglefinus*	IMR	TP gen	Precautionary level	MIN
Ocean Bottom	Northern coral reef	*Lophelia pertusa*	IMR	Ext	Pristine	OPT
Ocean Bottom	Atlantic halibut	*Hippoglossus hippoglossus*	IMR	TP gen	past knowledge	MIN

Ocean Bottom	Ling	*Molva molva*	IMR	TP gen	past knowledge	MIN
Ocean Bottom	Norway pout	*Trispoterus esmarkii*	IMR	IC spe	Precautionary level	MIN
Ocean Bottom	Northern deep sea shrimp	*Pandalus borealis*	IMR	Ext	Carrying capacity	OPT
Ocean Bottom	Plaice	*Pleuronectes platessa*	IMR	IC spe	Precautionary level	MIN
Ocean Bottom	Norway lobster	*Nephrops norvegicus*	IMR	IC gen	Carrying capacity	MIN
Ocean Bottom	Deep sea redfish	*Sebastes mentella*	IMR	IC spe	past knowledge	MIN
Ocean Bottom	Sponges	*Spongiformes*	IMR	Ext	Pristine	OPT
Ocean Bottom	Atlantic cod	*Gadus morhua*	IMR	Ext	Precautionary level	MIN
Ocean Bottom	Golden redfish =Ocean perch	*Sebastes marinus*	IMR	IC spe	past knowledge	MIN
Ocean Bottom	Onion-eye grenadier	*Macrourus berglax*	IMR	TP spe	Traditional management	MIN
Ocean Bottom	Roundnose grenadier	*Coryphaenoides rupestris*	IMR	TP spe	past knowledge	MIN
Ocean Bottom	Rays, skates	*NA*	IMR	TP gen	Traditional management	MIN
Coast Bottom	European Eel	*Anguilla anguilla*	IMR	IC gen	Pristine	MIN
Coast Bottom	Labrus bergylta	*Labrus surmuletus*	IMR	IC spe	Pristine	MIN
Coast Bottom	Goldsinny	*Ctenolabrus rupestris*	IMR	IC spe	Pristine	MIN
Coast Bottom	Blue mussel	*Mytilus edulis*	NIVA/HI	PCF	Pristine	MAX
Coast Bottom	index of benthic fauna spe-cies	*NA*	NIVA	Ext	Pristine	MIN
Coast Bottom	index of benthic fauna sensi-tivity	*NA*	NIVA	Ext	Pristine	MIN
Coast Bottom	Atlantic ditch shrimp	*Palaemonetes varians*	NIVA/ redlist	IC gen	Pristine	MIN
Coast Bottom	Green sea urchin/northern sea urchin	*Strongylocentrotus droebachiensis*	NIVA/HI	PCF	Pristine	MAX
Coast Bottom	wetland sedges	*Eleocharis parvula*	NIVA/ redlist	PP gen	Pristine	MIN
Coast Bottom	Natural anoxic fjords	*NA*	NA	PP gen	past knowledge	OPT
Coast Bottom	Corkwing wrasse	*Symphodus melops*	IMR	IC spe	Pristine	MIN
Coast Bottom	Iceland scallop	*Clamys islandica*	IMR	PCF	past knowledge	OPT
Coast Bottom	macroalgae intertidal index	*NA*	NIVA	Ext	Pristine	MIN
Coast Bottom	macroalgae lower limit of growth	*NA*	NIVA	Ext	Pristine	MIN
Coast Bottom	European lobster	*Homarus gammarus*	IMR	IC gen	Traditional management	OPT
Coast Bottom	King scallop	*Pecten maximus*	IMR	PCF	past knowledge	OPT
Coast Bottom	Northern coral reef	*Lophelia perfusa*	IMR	Ext	Pristine	OPT
Coast Bottom	Atlantic halibut	*Hippoglossus hippoglossus*	IMR	TP gen	past knowledge	MIN
Coast Bottom	Pollack	*Pollachius pollachius*	IMR	IC gen	Pristine	MIN
Coast Bottom	European oysters	*Ostrea edulis*	IMR	PCF	past knowledge	OPT
Coast Bottom	Otter	*Lutra lutra*	NINA	TP spe	Pristine	OPT
Coast Bottom	Plaice	*Pleuronectes platessa*	IMR	IC spe	Precautionary level	MIN

Coast Bottom	Sand gaper	*Mya arenaria*	NIVA / redlist	PCF	past knowledge	MIN
Coast Bottom	Cuvie	*Laminaria hyperborea*	NIVA/HI	Ext	Carrying capacity	MIN
Coast Bottom	Europan shore crab	*Carcinus maenas*	IMR	IC gen	Pristine	OPT
Coast Bottom	Sugar kelp	*Saccharina latissima*	NIVA/ redlist	Ext	past knowledge	MIN
Coast Bottom	Sponges	*Spongiformes*	IMR	Ext	Pristine	OPT
Coast Bottom	Edible crab	*Cancer pagurus*	IMR	IC gen	past knowledge	OPT
Coast Bottom	Atlantic Cod	*Gadus morhua*	IMR	TP gen	Pristine	MIN
Coast Bottom	Gobidae	*NA*	IMR	IC gen	Pristine	MIN
Coast Bottom	Dogfish	*Squalus acanthias*	IMR	TP gen	past knowledge	MIN
Coast Bottom	black guillemot	*Cepphus grylle*	NINA	TP spe	Precautionary level	MIN
Coast Bottom	common eider	*Somateria mollissima*	NINA	IC gen	Precautionary level	MIN
Coast Bottom	velvet scoter	*Melanitta fusca*	NINA	IC spe	Pristine	MIN
Coast Bottom	steller's eider	*Polysticta stelleri*	NINA	IC spe	Pristine	MIN
Coast Bottom	common scoter	*Melanitta nigra*	NINA	IC spe	Pristine	MIN
Coast Pelagic	Sprat	*Sprattus sprattus*	IMR	Ext	past knowledge	MIN
Coast Pelagic	Zooplankton	*NA*	IMR	Ext	Pristine	OPT
Coast Pelagic	Hooded seal	*Halichoerus grypus*	IMR	TP spe	Pristine	OPT
Coast Pelagic	Jellyfish	*Scuphozoa sp*	IMR	IC spe	Pristine	MAX
Coast Pelagic	Phytoplankton	*NA*	NIVA/HI	Ext	past knowledge	MAX
Coast Pelagic	Lumpfish	*Cyclopterus lumpus*	IMR	TP spe	Traditional management	MIN
Coast Pelagic	Herring	*Clupea harengus*	IMR	Ext	Precautionary level	MIN
Coast Pelagic	Killer whale	*Orcinus orca*	IMR	TP spe	past knowledge	OPT
Coast Pelagic	Harbour seal	*Phoca vitulina*	IMR	TP gen	past knowledge	OPT
Coast Pelagic	Sand eel	*Ammodytes sp.*	IMR	IC spe	Precautionary level	MIN
Coast Pelagic	northern fulmar	*Fulmarus glacialis*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	northern gannet	*Morus bassanus*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	great cormorant ssp carbo	*Phalacrocorax carbo carbo*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	great cormorant ssp sinensis	*Phalacrocorax carbo sinensis*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	european shag	*Phalacrocorax aristotelis*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	great skua	*Stercorarius skua*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	common gull	*Larus canus*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	lesser black-backed gull ssp fuscus	*Larus fuscus fuscus*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	lesser black-backed gull ssp intermedius	*Larus fuscus intermedius*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	herrring gull	*Larus argentatus*	NINA	TP gen	Precautionary level	MIN

Coast Pelagic	great black backed gull	*Larus marinus*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	black-legged kittiwake	*Rissa tridactyla*	NINA	TP gen	Precautionary level	MIN
Coast Pelagic	common tern	*Sterna hirundo*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	arctic tern	*Sterna Paradisaea*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	razorbill	*Alca torda*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	common murre	*Uria aalge*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	thick-billed murre	*Uria lomvia*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	atlantic puffin	*Fratercula arctica*	NINA	TP spe	Precautionary level	MIN
Coast Pelagic	yellow-billed loon	*Gavia adamsii*	NINA	IC gen	Pristine	MIN
Coast Pelagic	red-breasted merganser	*Mergus serrator*	NINA	IC spe	Pristine	MIN
Mires and Wetland	moss	*Hamatocaulis vernicosus*	VM/ redlist	PP spe	past knowledge	MIN
Mires and Wetland	Atlantic raised bog	*NA*	NINA	Ext	past knowledge	MIN
Mires and Wetland	Carabidae sp.	*Elaphrus uliginosus*	NINA, redlist	IC spe	Pristine	MIN
Mires and Wetland	Carabidae sp.	*Cicindela maritima*	NINA, redlist	Ext	Pristine	MIN
Mires and Wetland	moss	*Cinclidium arcticum*	VM/ redlist	PP spe	past knowledge	MIN
Mires and Wetland	Marsh Fern	*Thelypteris palustris*	NINA	PP spe	Pristine	MIN
Mires and Wetland	Critical load N exceedance	*NA*	NIVA	Ext	Max sustainable level	MAX
Mires and Wetland	Palsa mire	*NA*	NINA	Ext	Pristine	MIN
Mires and Wetland	Bladder Sedge	*Carex vesicaria*	NINA	PP gen	Pristine	OPT
Mires and Wetland	Smooth Newt	*Lissotriton vulgaris*	NINA +VM	IC gen	Traditional management	MIN
Mires and Wetland	moss	*Meesia longiseta*	VM/ redlist	PP spe	past knowledge	MIN
Mires and Wetland	Great Crested Newt	*Triturus cristatus*	NINA +VM	IC spe	Traditional management	MIN
Mires and Wetland	Few-flowered Sedge	*Carex pauciflora*	NINA	PP spe	Pristine	MIN
Mires and Wetland	Early Marsh-Orchid	*Dactylorhiza incarnata ssp.incarnata*	NINA	PP spe	Pristine	MIN
Mires and Wetland	Common Frog	*Rana temporaria*	NINA +VM	IC gen	Traditional management	MIN
Mires and Wetland	ruff	*Philomachus pugnax*	NINA	IC gen	Pristine	MIN
Mires and Wetland	great snipe	*Gallinago media*	NINA	IC spe	Pristine	MIN
Mires and Wetland	common snipe	*Gallinago gallinago*	NINA	IC gen	Pristine	MIN
Mires and Wetland	broad-bill sandpiper	*Limicola falcinellus*	NINA	IC gen	Pristine	MIN
Mires and Wetland	greenshank	*Tringa nebularia*	NINA	IC gen	Pristine	MIN
Mires and Wetland	wood sandpiper	*Tringa glareola*	NINA	IC gen	Pristine	MIN
Mires and Wetland	yellow wagtail	*Motacilla flava*	NINA	IC gen	Pristine	MIN
Mires and Wetland	bar-tailed godwit	*Limosa lapponica*	NINA	IC gen	Pristine	MIN

Mires and Wetland	dunlin	*Calidris alpina*	NINA	IC gen	Pristine	MIN
Mires and Wetland	common redshank	*Tringa totanus*	NINA	IC gen	Pristine	MIN
Mires and Wetland	sedge warbler	*Acrocephalus schoenobaenus*	NINA	IC gen	Pristine	MIN
Mires and Wetland	reed bunting	*Emberiza schoeniclus*	NINA	PCF	Pristine	MIN
Mires and Wetland	whimbrel	*Numenius phaeopus*	NINA	IC gen	Pristine	MIN
Mires and Wetland	Red-necked Phalarope	*Phalaropus lobatus*	NINA	IC gen	Pristine	MIN
Mires and Wetland	common crane	*Grus grus*	NINA	PCF	Pristine	MIN
Mires and Wetland	white beak-sedge	*Rhynchospora alba*	NINA	PP spe	Pristine	MIN
Mires and Wetland	brown beak-sedge	*Rhynchospora fusca*	NINA	PP spe	Pristine	MIN
Mires and Wetland	Great sundew	*Drosera anglica*	NINA	PP spe	Pristine	MIN
Mires and Wetland	oblong-leaved sundew	*Drosera intermedia*	NINA	PP spe	Pristine	MIN
Forest	algae on Birch	*NA*	NINA	PP spe	Max sustainable level	MAX
Forest	Scots Elm	*Ulmus glabra*	NINA	PP gen	Pristine	MIN
Forest	NA	*Cortinarius nanceiensis*	NINA, redlist	PP spe	past knowledge	MIN
Forest	NA	*Artomyces pyxidatus*	NINA, redlist	Dec	past knowledge	MIN
Forest	brown bear	*Ursus arctos*	NINA	TP gen	Pristine	OPT
Forest	Length of growing season for natural vegetation	*NA*	NINA	PP gen	Pristine	OPT
Forest	bilberry	*Vaccinium myrtillus*	Skog og landskap	Ext	Pristine	MIN
Forest	NA	*Antrodia albobrunnea*	NINA, redlist	Dec	past knowledge	MIN
Forest	old leaf successions	*NA*	Skog og landskap	Ext	Pristine	MIN
Forest	moose	*Alces alces*	NINA	PCF	Carrying capacity	OPT
Forest	Stair-step Moss	*Hylocomium splendens*	Skog og landskap	PP gen	Pristine	OPT
Forest	NA	*Scapania apiculata*	VM/ redlist	PP spe	past knowledge	MIN
Forest	NA	*Gomphus clavatus*	NINA, redlist	PP spe	past knowledge	MIN
Forest	Oak Fern in alpine birch for-est	*Gymnocarpium dryopteris*	NINA	PP gen	Pristine	MIN
Forest	Oak Fern in spruce forest	*Gymnocarpium dryopteris*	Skog og landskap	PP gen	Pristine	MIN
Forest	Old trees, MiS	*NA*	Skog og landskap	Ext	Pristine	MIN
Forest	Lynx	*Lynx lynx*	NINA	TP spe	Carrying capacity	OPT
Forest	NA	*Albatrellus cristatus*	NINA, redlist	PP spe	past knowledge	MIN
Forest	NA	*Plagiosterna aenea*	NINA, redlist	PCF	Pristine	OPT
Forest	red deer	*Cervus elaphus*	NINA	PCF	Carrying capacity	OPT
Forest	NA	*Sphagnum wulfianum*	VM/ redlist	PP spe	past knowledge	MIN
Forest	Bay Willow	*Salix pentandra*	NINA	PP gen	past knowledge	MIN
Forest	NA	*Geastrum sp.*	NINA, redlist	Dec	past knowledge	MIN

Forest	NA	*Cortinarius cupreorufus*	NINA, redlist	PP spe	past knowledge	MIN
Forest	Wild Primrose	*Primula vulgaris*	NINA	PP gen	Pristine	MIN
Forest	No	*Hypogymnia physodes*	NINA	PP gen	Max sustainable level	MAX
Forest	NA	*Amylocystis lapponicus*	NINA, redlist	Dec	past knowledge	MIN
Forest	deadwood, laying "timber"	*NA*	Skog og landskap	Ext	Pristine	MIN
Forest	Willow grouse	*Lagopus lagopus*	NINA	PCF	Carrying capacity	MIN
Forest	Lobaria-species in forests	*Lobaria spp.*	NINA	PP spe	past knowledge	MIN
Forest	NA	*Neckera pennata*	VM/ redlist	PP spe	past knowledge	MIN
Forest	NA	*Orthotrichum rogeri*	VM/ redlist	PP spe	past knowledge	MIN
Forest	One-flowered Wintergreen	*Moneses uniflora*	NINA	PP spe	Pristine	MIN
Forest	NA	*Frullania bolanderi*	VM/ redlist	PP spe	past knowledge	MIN
Forest	European Roe Deer	*Capreolus capreolus*	NINA	PCF	Carrying capacity	OPT
Forest	NA	*Notorhina punctata*	NINA, redlist	PCF	Pristine	MIN
Forest	Soil vegetation	*NA*	Skog og landskap	Ext	Pristine	MIN
Forest	Epiphytic vegetation	*NA*	Skog og landskap	PP spe	Pristine	MIN
Forest	NA	*Tayloria splachnoides*	VM/ redlist	PP spe	past knowledge	MIN
Forest	NA	*Cujucus cinnaberinus*	NINA, redlist	IC spe	Pristine	MIN
Forest	NA	*Harminius undulatus*	NINA, redlist	IC spe	Pristine	MIN
Forest	Wayvy Hairgrass - subalpine birch forest	*Avenella flexuosa*	NINA	PP gen	Pristine	OPT
Forest	Wayvy Hairgrass - spruce forest	*Deschampsia flexuosa*	Skog og landskap	PP gen	Pristine	OPT
Forest	NA	*Melanohalea olivacea*	NINA	PP gen	Precautionary level	MIN
Forest	deadwood, standing	*NA*	Skog og landskap	Ext	Pristine	MIN
Forest	Western Capercaillie	*Tetrao urogallus*	NINA	PCF	Carrying capacity	MIN
Forest	NA	*Sarcodon sp.*	NINA, redlist	PP spe	past knowledge	MIN
Forest	NA	*Cantharellus melanoxeros*	NINA, redlist	PP spe	past knowledge	MIN
Forest	NA	*Phellinus nigrolimitatus*	NINA, redlist	Dec	past knowledge	MIN
Forest	trees with bryoria sp	*Bryoria sp.*	Skog og landskap	PP gen	Pristine	OPT
Forest	Wolf	*Canis lupus*	NINA	TP gen	Carrying capacity	OPT
Forest	Mistle Thrush	*Turdus viscivorus*	NINA	IC gen	Pristine	MIN
Forest	Lesser Spotted Woodpecker	*Dendrocopos minor*	NINA	IC gen	Pristine	MIN
Forest	Parrot Crossbill	*Loxia pytyopsittacus*	NINA	PCF	Pristine	MIN
Forest	willow tit	*Parus montanus*	NINA	IC gen	Pristine	MIN
Forest	Common Chiffchaff	*Phylloscopus collybita*	NINA	IC gen	Pristine	MIN
Forest	goshawk	*Accipiter gentilis*	NINA	TP gen	Pristine	OPT

Forest	Hazel Grouse	*Bonasa bonasia*	NINA	PCF	Pristine	MIN
Forest	golden eagle	*Aquila chrysaetos*	NINA	TP gen	Pristine	OPT
Forest	Willow Warbler	*Phylloscopus trochilus*	NINA	IC gen	Pristine	MIN
Forest	Song Thrush	*Turdus philomelos*	NINA	IC gen	Pristine	MIN
Forest	Blackcap	*Sylvia atricapilla*	NINA	IC gen	Pristine	MIN
Forest	Pied Flycatcher	*Ficedula hypoleuca*	NINA	IC gen	Pristine	MIN
Forest	Crested Tit	*Parus cristatus*	NINA	IC gen	Pristine	MIN
Forest	Eurasian Three-toed Woodpecker	*Picoides tridactylus*	NINA	IC gen	Pristine	MIN
Forest	*Loxia curvirostra*	*Loxia curvirostra*	NINA	PCF	Pristine	MIN
Forest	*Icterine Warbler*	*Hippolais icterina*	NINA	IC gen	Pristine	MIN
Open Lowland	Purple Moore Grass	*Molinia caerulea*	NINA	PP gen	Pristine	OPT
Open Lowland	NA	*Meligethes norvegicus*	NINA, redlist	PCF	Pristine	MIN
Open Lowland	NA	*Geotrupes stercorarius*	NINA, redlist	Dec	Traditional management	MIN
Open Lowland	NA	*Porella obtusata*	VM/ redlist	PP spe	past knowledge	MIN
Open Lowland	NA	*Geoglossum sp.*	NINA, redlist	Dec	past knowledge	MIN
Open Lowland	NA	*Clavaria sp.*	NINA, redlist	Dec	past knowledge	MIN
Open Lowland	Small White Orchid	*Pseudorchis albida*	NINA	PP spe	Pristine	MIN
Open Lowland	clouded apollo	*Parnassius mnemosyne*	NINA, redlist	PCF	Pristine	MIN
Open Lowland	NA	*Hypnum jutlandicum*	VM/ redlist	PP spe	past knowledge	MIN
Open Lowland	NA	*Meloe violaceus*	NINA, redlist	Ext	Traditional management	MIN
Open Lowland	NA	*Entoloma bloxami*	NINA, redlist	Dec	past knowledge	MIN
Open Lowland	NA	*Hygrocybe sp.*	NINA, redlist	Dec	past knowledge	MIN
Open Lowland	Oxeye Daisy	*Leucanthemum vulgare*	NINA	PP gen	Pristine	MIN
Open Lowland	Bell Heather	*Erica cinerea*	NINA	PP spe	Pristine	MIN
Open Lowland	NA	*Encalypta vulgaris*	VM/ redlist	PP spe	past knowledge	MIN
Open Lowland	Arnica	*Arnica montana*	NINA	PP spe	Pristine	MIN
Open Lowland	Semi-natural grasslands state	*NA*	Bioforsk	Ext	Traditional management	OPT
Open Lowland	Coastal heathland state	*NA*	Bioforsk	Ext	Traditional management	OPT
Open Lowland	peat moss sp.	*Sphagnum strictum*	VM/ redlist	PP spe	past knowledge	MIN
Open Lowland	house sparrow	*Passer domesticus*	NINA	PCF	Pristine	MIN
Open Lowland	yellowhammer	*Emberiza citrinella*	NINA	PCF	Pristine	MIN
Open Lowland	white-tailed sea eagle	*Haliaeetus albicilla*	NINA	TP gen	Carrying capacity	OPT
Open Lowland	eurasian eagle owl	*Bubo bubo*	NINA	TP gen	Pristine	OPT
Open Lowland	NA	*Anthus cervinus*	NINA	IC gen	Pristine	MIN

Open Lowland	sand martin	*Riparia riparia*	NINA	IC gen	Pristine	MIN
Open Lowland	skylark	*Alauda arvensis*	NINA	PCF	Pristine	MIN
Open Lowland	NA	*Pica pica*	NINA	IC gen	Pristine	MIN
Open Lowland	rock pipit	*Anthus petrosus*	NINA	IC gen	Pristine	MIN
Open Lowland	common starling	*Sturnus vulgaris*	NINA	IC gen	Pristine	MIN
Open Lowland	eurasian curlew	*Numenius arquata*	NINA	IC gen	Pristine	MIN
Open Lowland	peregrine falcon	*Falco peregrinus*	NINA	IC gen	Pristine	MIN
Open Lowland	northern lapwing	*Vanellus vanellus*	NINA	IC gen	Pristine	MIN

ISSN: 1504-3312
ISBN: 978-82-426-2117-7

NINA Report 542

Norwegian Institute for Nature Research
NINA head office
Postal address: NO-7485 Trondheim, NORWAY
Visiting address: Tungasletta 2, NO-7047 Trondheim, NORWAY
Phone: + 47 73 80 14 00
Fax: + 47 73 80 14 01
Organisation number: NO 950 037 687 MVA

www.nina.no

Graphic design: NINA
Cover photos: Per Jordhøy, Børre Dervo, Knut Kringstad, Tycho Anker-Nilssen