A technical system for assessing good ecological condition

RECOMMENDATIONS FROM AN EXPERT COMMITTEE

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A technical system for assessing good ecological condition

- A TECHNICAL SYSTEM FOR ASSESSING GOOD ECOLOGICAL CONDITION

Signe Nybø, Per Arneberg, Erik Framstad, Rolf Ims, Anders Lyngstad, Ann Kristin Schartau, Hanne Sickel, Anne Sverdrup-Thygeson, Vigdis Vandvik

CONTENTS

FOREWORD

This report is an English translation of the report that recommends a technical system for assessing good ecological condition in natural ecosystems. The recommendation was done by an Expert Committee appointed by the Norwegian Ministry of Climate and Environment. The English translation includes the first three chapters and Appendix I and II of the original report. The two first chapters explains the background and existing systems that needed to be considered before recommending a comprehensive technical system for assessing good ecological condition. This system itself is presented in chapter three. Appendix I gives the mandate of the Committee while Appendix II defines central terms. The summary is the original summary and includes all chapters.

The non-translated chapters includes chapter 4 and 5 and Appendix III-V. The fourth chapter gives a detailed description of each of the main ecosystems and how the common approach in chapter 3 relates to each of the main ecosystems. Chapter five recommends future work. Appendix III discusses how limits for good ecological status is set in the Water Frame Directive while appendix IV discusses the delimitation of wetlands. This is a complex issues as there are several Norwegian and international standards that is not coherent. Appendix V lists possible indicators for each ecosystem.

We have decided to give an exact translation of the original document and we recommend to use "google translation" on the original document if one want to look closer into these chapter (Nybø & Evju (2017)). As some chapters and appendixes is not included in our translation, the text will sometimes refer to chapters and appendixes which is not included in this translation.

The present translation is not updated with respect to new knowledge and monitoring programmes that have originated after 2017. Thus some text may be outdated. We have included a few footnotes with updated information when relevant. An update on all Ecosystem Condition projects followed after the original document can be found here: Assessment system for ecological condition (nina.no). Also new monitoring programmes on terrestrial vegetation and insects have evolved after 2017.

For readers who do not know Norwegian legislation well: Norway is not a member of the EU. However through the EEA-agreement we are obligated to some EU-legislation, others not. We have implemented the Water Frame Directive, but not the Habitat Directive and the Bird Directive.

The Expert Committee was appointed by the Ministry of Climate and Environment on September 1st 2016. The Committee delivered its recommendations on June 1st in 2017. In addition to the members of the Committee (see chapter 1.3) several experts have been involved in the work: Per Arild Aarrestad, Virve Ravolainen, Åshild Pedersen, Eva Fuglei , Dag-Inge Øien, Jarle Werner Bjerke, Tor Erik Brandrud, Inger Auestad, Liv Guri Velle, Harald Bratli, Olav Skarpaas, Per Fauchald, Normann Whitaker Green, Eva Ramirez-Llodra, Sylvia Frantzen, Cecilie von Quillfeldt and Anne Kirstine Frie.
Marianne Evju has been the secretary of the Committee.
I would like to thank Richard Hedger and Erik Framstad for translation of this report.

Signe Nybø
Leader of the Expert Committee

SUMMARY

The Norwegian action plan for natural diversity has as its main aim that ecosystems shall be in good condition, in order to protect biological diversity and to deliver ecosystem services. Well-functioning ecosystems give a basis for sustainable development.

Based on this, the Department for Climate and Environment (DCE) selected an Expert Committee with a mandate to develop recommendations for a comprehensive technical system for assessing good ecological condition . The technical system should be based on *"scientific indicators"* and "*on existing and accessible scientific knowledge on the condition and development of Norwegian ecosystems, and build further on and supplement existing relevant classification systems".* The technical system covers marine and terrestrial ecosystems not covered by the Water Framework Directive, including on Svalbard. The Water Framework Directive does not apply to Svalbard, and as the technical system does not include coastal and freshwater ecosystems, these must be safeguarded in other ways. This report presents the Expert Committee's recommendations for a comprehensive technical system for the assessment of good ecological condition.

This report reviews existing systems that assemble knowledge concerning biological diversity in Norway, together with existing classification systems assessing ecosystem condition. The review indicated that the Water Framework Directive had many relevant elements a comprehensive technical system can build on. The Nature Index and Marine Management Plans are existing information sources that can deliver indicators, with associated underlying data, for use in a new technical system. The Red Lists for species and nature types, together with the Black List (of invasive species) also systematise important information which can be of use. All of these build on results from monitoring programmes and other available knowledge. Nature in Norway (NiN) classifies nature into various ecosystem/ nature types, and contains comprehensive descriptions of natural variation useful for further work. The basic data collected through NiN surveys is important for mapping nature types in Norway. Mapping focuses on small areal units (natural systems) and does not include important components of the ecosystem (e.g. fauna). The result is that this survey is insufficient for assessing the condition of major ecosystems. In the recommended technical system, designation of a reference condition (intact nature) is a further development of the definitions used in the Water Framework Directive and the Nature Index. Good ecological condition is defined as not diverging significantly from intact nature, in turn defined as nature not significantly affected by modern industry and systemic human effects. Intact nature is defined with respect to a climate and a species assemblage in the 'near past', that is the Normal Period 1960–1990, and extensive traditional land management practices (grazing, haymaking, fire, hunting) defined as integral parts of semi-natural ecosystem types. The Expert Committee has identified seven properties that characterise ecosystems in good ecological condition. These properties relate to primary production, distribution of biomass between trophic levels, diversity of functional groups, important species and biophysical structure, landscape ecological patterns, biodiversity, and abiotic factors.

Whether finer subdivision into 'level 2 units' is necessary has been evaluated for each of the major ecosystems: woodland, mountain, arctic tundra, wetland, semi-natural land, natural open areas below the treeline, and sea. The evaluation was determined from management relevance, concrete disturbance factors, and whether the same indicators can be used in the units or not. For individual level-2 units the ecosystem is described, and what constitutes an intact condition. In addition, a normative description is given of what characterises level 2 units in good ecological condition. A review of recommended indicators is included in the chapters for every level 2 unit. More detailed information on indicators is found in Appendix 5. A total of 336 indicators are proposed for the 18 level 2 units. For 213 of these data exist, and for 123 data are lacking and new monitoring should be developed and implemented.

The Expert Committee recommends dividing further work into two parts, into priorities for achieving an operative system by 2020, and what is needed for an adequate system in the long term. The Expert Committee has laid weight on using existing data, but it is a fact that relevant monitoring data is to a greater or lesser degree lacking. The Committee considers, therefore, that additional monitoring is required. As early as 1995, environmental management identified increased monitoring needs; but only a small part of the recommendations have been followed up so far. Insufficient monitoring results in data inadequate for evaluating central properties of many ecosystems. Ecosystem based monitoring is recommended for all ecosystems, as already established for the Barents Sea and currently being implemented for arctic tundra (COAT). Further, there is a need for area-representative extensive monitoring of land ecosystems based on cost-effective, but well-validated, indicators. Area-representative monitoring coupled with intensive ecosystem monitoring will be capable of producing a basis for understanding changes in ecological condition. Better exploitation of existing remote sensing (LIDAR, satellite recording, time-lapse photography), combined with new ground-based sensor technology, can give better data and a better basis for evaluating ecological condition. The Expert Committee recommends establishing a database solution in the near future, in which condition data can be stored. For simpler and more secure interpretation of ecological condition data, development of new infrastructure that can select and integrate relevant data, including important data from other relevant sectors, is recommended. We also recommend methods how the technical system may be tested and developed within the period to 2020.

1 Introduction

by/ Nybø, S., Arneberg, P., Framstad, E., Ims, R., Lyngstad, A., Schartau, A. K., Sickel, H., Sverdrup-Thygeson, A., Vandvik, V.

1.1 Background and mandate

Biodiversity provides the basis for human life on Earth. Ecosystems produce natural goods that provide us with, among other things, food, clean drinking water, building materials, and experiences. Well-functioning ecosystems contribute to plants being pollinated, providing fruits and vegetables, regulating climate and protecting soil from erosion (NOU 2013). Future generations depend on securing ecosystems through conservation and sustainable use, and a well-functioning nature is a prerequisite for implementing the green shift (Meld. St. 14 (2015-2016)). Through the Convention on Biological Diversity, Norway is at the same time committed to secure genetic diversity, species, and ecosystems, regardless of their importance for human welfare.

The white paper "Nature for life. The Norwegian Action Plan for Biodiversity" was adopted in the Norwegian Parliament in May 2016 (Report to the Norwegian Parliament No. 14 (2015-2016)). The action plan is based on a strategic plan for the Convention on Biological Diversity for 2011–2020, which has specific objectives, the so-called Aichi goals. The goals are set to ensure well-functioning ecosystems and stop the loss of biodiversity. These goals are reflected in national targets.

The action plan "Nature for Life" sets three overarching national targets for biodiversity:

- Ecosystems should have good ecological condition, and they should deliver important ecosystem services
- No species or nature types should be eradicated, and developments for endangered and near endangered species and nature types should be improved
- A representative selection of Norwegian nature should be preserved for future generations.

Hence, there is a focus on both the ecosystems' ability to deliver ecosystem services for the benefit of people, and on the preservation of biodiversity regardless of the usefulness of nature.

The work to fulfil the national goals should be knowledge-based. One of the main approaches for following up the national action plan is to establish criteria and indicators for when ecosystems are in good condition.

The Ministry of Climate and Environment has, based on Meld. St. 14 (2015–2016), established the Expert Committee for Ecological Condition. The committee consists of renowned ecologists, and based on its expertise, the committee will propose a comprehensive system that describes what is good ecological condition in Norwegian ecosystems. This system is referred to as 'the technical system' hereafter. The work covers all Norwegian ecosystems, with the exception of lakes, rivers and coastal waters, which are covered by the Water Framework Directive. Urban ecosystems and intensively managed agricultural land are also not included in the work.

The mandate for the Expert Committee for Ecological Condition, which is available in its entirety in **Appendix 1**, states that the work should be based on existing and available scientific knowledge about the state and development of Norwegian ecosystems. It should build on and supplement existing relevant classification systems, but should be far simpler than the system established to implement the Water Framework Directive (Regulations relating to frameworks for water management, lovdata.no). The technical system should be based on a limited number of indicators that reflect the structure and function of ecosystems and take into account the natural dynamics in ecosystems. The technical system should at least be able to clarify what constitutes

Foto: Odd Terje Sandlund

Box 1. Good ecological condition and management objectives

In this report, we distinguish between the concepts of good ecological condition and management objectives.

Ecosystems in good **ecological condition** are characterized by the fact that ecosystem structure, function and productivity do not differ significantly from intact ecosystems. Scientific knowledge and criteria form the basis for defining both intact ecosystems and good ecological condition.

Management objectives are society's objectives for what ecological condition an area or ecosystem should have. The action plan also uses the term "desired condition" as equivalent of management objectives. The objectives are determined as part of a trade-off between society's need for nature in good ecological condition and society's other needs. Sections 4 and 5 of the Nature Diversity Act discuss management objectives for species, nature types and ecosystems. The Water Framework Directive uses the term **environmental objectives** for the management objectives. In the Water Framework Directive, the objectives coincide with good ecological condition.

good ecological condition in Norwegian ecosystems, and should in the first instance be possible to establish for ecosystems at county/region level, or other scientifically based, appropriate levels.

When the technical system for assessing good ecological condition has been prepared, politicians and the management authorities should determine management objectives for different areas **(see Box 1)**. It is not a given that the management objectives should be good ecological condition everywhere (Meld. St. 14 (2015–2016)). The Action Plan for Biodiversity states that: *"Once the management objectives for ecological status have been established, the Government will organise the use of policy instruments with a view to maintaining ecological status in areas and ecosystems where it is already good enough and improving it in areas where ecological status is poorer than stipulated by the management objectives."* In other words, the terms "management objectives for ecological status" and "where it is already good enough" refer to management objectives, not to good ecological condition. Chapter 1.2 describes the difference between management objectives and good ecological condition in more depth.

Furthermore, the Government will use the knowledge of ecological condition in Norwegian ecosystems "as a tool for making nature management more effective and for setting priorities for restoration projects in accordance with Aichi target 15.." Aichi Goal 15 states that by 2020 we should have robust ecosystems where biodiversity contributes to increased carbon storage, through conservation and restoration, including the restoration of at least 15 percent of degraded ecosystems. The technical system for assessing ecological condition should therefore also be able to form a starting point for assessing whether an area has deteriorated, i.e. whether the ecological condition is poor, to prioritize areas for restoration, and to assess whether the condition is improved after restoration measures.

The Government's ambition is that defined management targets for ecological condition will be a basis for management by 2020.

The Expert Committee for Ecological Condition was appointed with the aim of being a fast-working committee. It was appointed on 1 September, had a start-up meeting on 28 September 2016 and the deadline for delivery of recommendations was on 1 June 2017. According to the mandate, the technical system for assessing ecological condition should be cost-effective and usable and ready to be used by the management authorities by 2020. As the present report shows, the Government's goals for the Expert Committee's work are ambitious, both due to deficiencies in the knowledge base for assessing the limits for good ecological condition and due to a lack of available indicators in many ecosystems (see Chapter 5). In addition, costs and simplifications must be assessed against a requirement that the technical system should be verifiable and reliable.

1.2 Good ecological condition and management objectives

As of today, we lack specific management objectives for ecological condition for terrestrial Norwegian ecosystems. For marine areas, environmental quality objectives have been prepared for individual components through the management plan work, and these are linked to good ecological condition. For coastal waters and fresh water, environmental objectives have been developed for water bodies through the Water Framework Directive. In the Water Framework Directive, the environmental objectives coincides with 'good ecological condition' **(Figure 1)**.

The Expert Committee's mandate, on the other hand, clearly distinguishes between management objectives and tools for determining what constitutes good ecological condition. The technical system should as a minimum clarify what is good ecological condition, where ecological condition is assessed on the basis of the deviation from a norm (intact nature), and where good ecological condition is assessed on the basis of how large the deviation is in relation to this norm (see Chapter 3). The technical system for assessing ecological condition should be based on scientific knowledge. Managers and politicians then set management objectives for areas and ecosystems by making a trade-off between society's need for nature in good ecological condition, which safeguards biological diversity and provides important ecosystem services, and society's other needs (Figure 1).

The figure also illustrates how the distinction between the reference condition 'intact nature', good ecological condition and the management objective provides opportunities for a more flexible and adapted use of objectives and policy instruments. For certain areas and ecosystems, the management objective can be set higher or lower than good ecological condition. The management objective may, for example, be set lower than good ecological condition in areas for which the administration does not prioritize maintaining good ecological condition. An example of such areas could be hay meadows that depend on traditional management. Here it will probably be relevant to prioritize management of the best-preserved hay meadows, but not all. When society does not prioritize the management of (all) hay meadows, the meadows will regrow with woody plants and the ecological condition of hay meadows in a county or region will be reduced.

In other areas, the authorities may choose to set a management objective that is higher than good ecological condition. In nature reserves, for example, with the strictest protection, it would be natural to imagine that the management objective is close to the reference condition, e.g. in coniferous forest reserves with primeval forest character or hay meadows with traditional management. One can further imagine that some areas where the condition today is poorer than good ecological condition, can be protected with a view to improving the condition through restoration, in order to achieve management objectives for good ecological condition in the future.

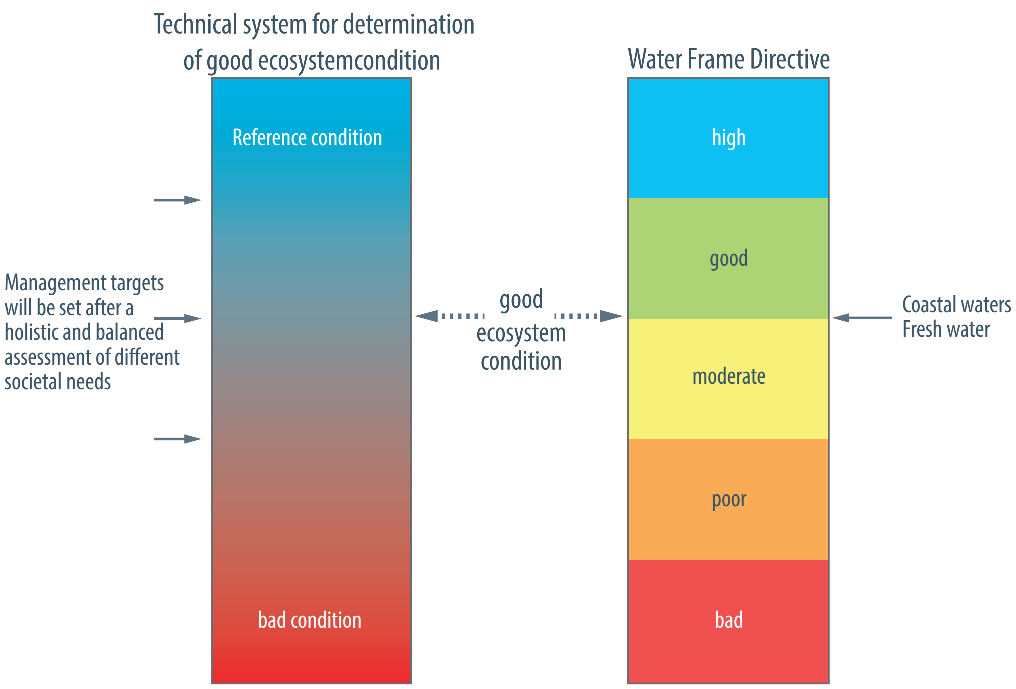

Figure 1. *Illustration of the relationship between the reference condition (top of the column), good ecological condition (dashed arrows) and management objectives (solid arrows). The framework used by the Expert Committee allows these to be different; and thus allows for more flexibility in the relationship between them, based on a balance of society's different needs. For example, the management objective can be set lower than good ecological condition. For comparison, the right column shows the system for fresh water and coastal water based on the Water Frame Directive, where the ecological condition is classified into five classes (right column), and where the management objective is defined to be good ecological condition. Reworked from Nybø (2010).*

1.3 Expert Committee for Ecological Condition

The Expert Committee for Ecological Condition is an independent committee appointed by the Ministry of Climate and Environment.

The members (see below) are appointed on the basis of their expertise in various fields of ecology, with special expertise in the ecosystems covered by the committee's work. The experts therefore represent themselves and not the institution they are associated with in this work. Signe Nybø is the leader of the committee. The secretariat for the Expert Committee has been assigned to NINA and consists of technical secretary Marianne Evju and administrative secretary Eivind Aronsen.

The management authorities have had observers who have followed the Expert Committee's work: the Norwegian Environment Agency (Else Løbersli), the Norwegian Biodiversity Information Centre (Arild Lindgaard), the Norwegian Directorate of Mining with the Commissioner of Mines at Svalbard (Marte Kristoffersen), the Directorate of Fisheries (Modulf Overvik), the Norwegian Defence Estates Agency

Composition of the Expert Committee:

Signe Nybø
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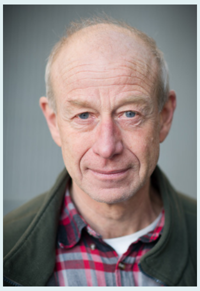
Position: Research Director, Terrestrial Department, NINA

Main work area: Nature index, biodiversity, ecosystem services, renewable energy, project management

Has also worked with: Ecotoxicology, acid rain, the Water Freamwork Directive



Rolf Ims
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Position: Professor, UiT – Arctic University of Norway

Main work area: Climate change and ecosystem dynamics; northern boreal forest and Arctic tundra

Has also worked with: Landscape Ecology

Per Arneberg
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Position: Researcher, Institute of Marine Research

Main work area: Ecosystem-based management, status assessment of marine ecosystems, food web ecology, ecology of infectious organisms

Has also worked with: Molecular methods in ecology

Anders Lyngstad
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Position: Researcher, NTNU University Museum, Department of Natural History

Main work area: Management-oriented research in mires and cultural landscapes: Mapping, climate effects, biodiversity, regional variation, management, investigations

Erik Framstad
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Position: Research Director, NINA

Main work area: Indicators and monitoring of biological diversity, forest ecology

Has also worked with: High mountain ecology

Anne Sverdrup-Thygeson
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Position: Professor, Norwegian University of Life Sciences – NMBU and Scientific Advisor, NINA

Main work area: Conservation biology, forest ecology, insect ecology

Has also worked with: Monitoring of species, hotspot habitats

(Line Stabell Selvaag), the Norwegian Railway Directorate (Per Fjeldal), the Directorate of Agriculture (Jostein Torstrup), the Norwegian Polar Institute (Øystein Overrein) and the Norwegian Public Roads Administration (Astrid Skrindo). The observers have been present in several of the Expert Committee's meetings and have been informed about the process along the way. Øyvind Andreassen (Ministry of Climate and Environment) has attended some meetings. Else Løbersli (Norwegian Environment Agency) has been the committee's contact person for the client.

Ann Kristin Schartau
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Position: Senior Researcher, NINA

Main area of work: Water Directive, Nature Index, Biodiversity, Freshwater

Has also worked with: Monitoring, acid rain

Hanne Sickel
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Position: Researcher, Department of Landscape Ecology, NIBIO

Main area of work: Vegetation ecology, vegetation mapping and monitoring, grazing studies of cattle and sheep in the semi-natural habitats

Has also worked with: Management and restoration of semi-natural ecosystems

Vigdis Vandvik
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Position: Professor of plant ecology and head of SFU bioCEED, University in Bergen

Main area of work: Vegetation ecology, biodiversity, coastal heathland, mountain vegetation, plant interactions, climate effects

Has also worked with: Advice and investigation for nature management and work with alien species in Norway and internationally

The mandate for the Expert Committee stipulates that the development of scientific criteria for good ecological condition in the sea should be carried out as part of the work on the management plans for Norwegian marine areas. The work on the sea has been carried out by a subgroup consisting of researchers from the research institutions who participate in the Monitoring Group during the work on the sea management plans. This subgroup has been led by Per Arneberg (Institute of Marine Research), who also heads the Monitoring Group and who has been appointed to the Expert Committee. The subgroup is also composed of the following researchers appointed by the Norwegian Polar Institute (NP), the Norwegian Institute for Nature Research (NINA), the Norwegian Institute for Water Research (NIVA), the Institute of Marine Research (HI) and the National Institute for Nutrition and Seafood Research (NIFES): Per Fauchald (NINA), Sylvia Frantzen (NIFES), Anne Kirstine Frie (HI), Normann Whitaker Green (NIVA), Eva Ramirez-Llodra (NIVA) and Cecilie von Quillfeldt (NP). The Norwegian Environment Agency (Anne Britt Storeng) and the Norwegian Directorate of Fisheries (Modulf Overvik) have participated as observers in this work.

1.4 The Expert Committee's approach to a cost-effective system

The technical system for ecological condition should have an orientation that *"is cost-effective and applicable to the management authorities so that it can be used by these authorities by 2020."* (Appendix 1). At the same time, the mandate emphasizes that *"The system should be far simpler than the system established for follow-up of the Water Framework Directive. The focus should be on what is good condition, and not other class boundaries. The technical system must also be based on a limited number of indicators that reflect the structure and function of the ecosystems, and which take into account the natural dynamics of the ecosystems".*

The Water Framework Directive covers all water bodies in fresh water, coastal water and groundwater in mainland Norway (not Svalbard). The Water Framework Directive is described in more detail in Chapter 2.2.2. The Water Framework Directive divides ecological condition into five condition classes (very good, good, moderate, poor and very poor), and the scientific assessments of ecological condition in water bodies are based on a set of indicators. At the same time, the work includes major administrative measures related to the preparation of water management plans and the establishment of water regions in collaboration between various county authorities, municipalities and various sectors.

The Expert Committee will not give recommendations on how the technical system for good ecological condition should be used by the management authorities but should only assess relevance and applicability related to scientific aspects. The Committee emphasizes that the system for good ecological condition must be easy to understand and easy to apply. It is, among other things, a conscious move that the proposals are based on recognizable principles from existing classification systems that the management authorities are used to apply, see Chapter 2.

The Expert Committee takes as a starting point that:

1. The technical system should build on, and supplement existing relevant knowledge and classification systems, see Chapter 2.
2. The technical system should be based on indicators of ecological condition supported by data that is already collected through existing monitoring and knowledge, as far as there are relevant datasets, see Chapter 4 and Appendix 5. Already collected, but not interpreted, data is used to the degree it is appropriate.
3. It is proposed that any need for new data be incorporated into existing and planned monitoring programs, see Chapter 5.

Monitoring programs provide a basis for assessing trends in nature over time. The Expert Committee therefore bases its indicators for assessing ecological condition on established monitoring programs with relevant indicators as far as possible and where this exists. At the same time, the Expert Committee, like a number of previous studies (Direcktoratet for naturforvaltning 1995, 1998, Framstad & Kålås 2001, Halvorsen 2011, Framstad 2015), points out that the monitoring of Norwegian nature is inadequate. This applies to both spatially representative monitoring that provides a basis for assessing changes on a larger geographical scale, and ecosystem-based monitoring that will provide a good basis for comprehensive condition assessments. Establishment or expansion of relevant long-term monitoring is necessary for several main ecosystems. At the end of each ecosystem chapter, the need for knowledge is summarized, and in Chapter 5, the Expert Committee gives some general recommendations on priorities for knowledge building so that the ecological condition can be assessed in a sound manner. The recommendations are based on existing proposals for expanding existing programs and establishing new monitoring programs. The Committee's recommendations cover which indicators should be prioritized in existing and new monitoring to provide information on ecological condition. Furthermore, the Expert Committee points to data from other sectors of society, such as agriculture, which have the advantage that they could be used as a basis for developing indicators for certain habitat types. Making data available and used across sectors of society is an important goal in the Government's digital agenda (Report to the Norwegian Parliament 27 (2015-2016)), and the Expert Committee points to specific proposals that can help make data available and provide a basis for better analyses of ecological condition (Chapter 5).

1.5 Structure of the report

This report has five chapters. Each chapter describes the overall delimitations for the work, and all the individual parts of the mandate are dealt with in different subchapters. Chapter 1 discusses the mandate and the composition of the Expert Committee. Then the fundamental differences are described between setting management objectives and the determination of good ecological condition according to scientific criteria. Finally, the Expert Committee gives a general discussion of how the technical system can be made cost-effective and simpler than the Water Framework Directive, cf. the mandate in Appendix 1. Key concepts are defined in Appendix 2.

The Expert Committee's recommendations should be based on existing and available scientific knowledge. Chapter 2 discusses relevant established knowledge and classification systems used in Norway and internationally. The DPSIR framework, the Water Framework Directive, the Nature Index for Norway, the marine management plans and the classification system Nature in Norway (NiN) are discussed here, as well as the Red Lists and how restoration measures and effects of measures are classified. A brief description is given of the biodiversity indicators GLOBIO and Living Planet Index, as well as a description of Natura 2000 and the EU's Marine Strategy Directive. The last two are not used in Norway but have approaches that may be relevant to the work with ecological condition. The chapter provides a brief summary of the existing approaches on which the proposed technical system is based.

Chapter 3 describes the Expert Committee's proposal for a comprehensive, ecosystem-based technical system for good ecological condition for the main ecosystems covered by the Committee's work. First, the status of the knowledge is presented about the connection between ecological condition, biological diversity and well-functioning ecosystems. Furthermore, a normative value for intact nature (reference condition) is discussed alongside how this should be assessed in the light of previous human pressures and in the Anthropocene - the human age. The Expert Committee provides a normative description of intact nature and characteristics of ecosystems in good ecological condition, followed by a proposal on how indicators can be used to measure the condition. The chapter further discusses limit values for good ecological condition for the indicators, how information from several indicators can be combined to make comprehensive assessments of ecological condition, and how uncertainty can be taken into account when determining ecological condition. The update frequency for the technical system is proposed. How to assess the ecological condition of areas that change from one nature type to another is also briefly discussed.

Chapter 4 describes the characteristics of the various main ecosystems and the most important natural and human pressures. Furthermore, the main ecosystems are divided into more uniform ecosystems, and what characterizes each individual ecosystem given the normative criteria for good ecological condition as defined in Chapter 3. Indicators related to ecological condition in these ecosystems are discussed, and data sources are described. For each main ecosystem, a discussion is given of how the recommendations are based on existing technical systems, and the deficiencies in knowledge and data that can limit the condition assessment and its reliability. Appendix 5 provides an overall overview of proposed indicators.

Chapter 5 provides recommendations for further work.

2 Relevant knowledge and classification systems

by/ Nybø, S., Arneberg, P., Framstad, E., Ims, R., Lyngstad, A., Schartau, A. K., Sickel, H., Sverdrup-Thygeson, A., Vandvik, V.

The work for establishing good ecological condition in marine and terrestrial ecosystems should be *"based on existing and available scientific knowledge about the condition and development of Norwegian ecosystems, and build on and supplement existing relevant classification systems".* This chapter provides an introduction to the most important knowledge and classification systems on which the development of the technical system for good ecological condition is based.

2.1 Classification of drivers, pressures, states and responses

The DPSIR approach is a simple framework for explaining to the general public and management why and how environmental problems arise (OECD 1994). It makes it possible to sort between underlying causes (drivers, pressures), what effect the causes have (states, impacts), and responses **(Figure 2).** In order to use the framework, various indicators should be used to measure drivers/pressures, states/impacts and responses. The DPSIR approach facilitates a transparent and unambiguous understanding of different aspects of environmental challenges. The approach is used in Miljøstatus.no and by the European Environment Agency (EAA).

Drivers are underlying driving forces, such as population growth, economy, technology or social structure. The term "indirect drivers" and "driving forces" is used in some contexts equivalent to drivers. The present report uses the term "drivers".

Pressures are the actual factors that affect the environment, e.g. emissions of acidifying substances and pollutants, land use changes or alien species. The term "direct drivers" is used in some contexts. The present report uses the term "pressures". The scale of pressures is a result of the drivers. Developing environmentally friendly technology (a driver),

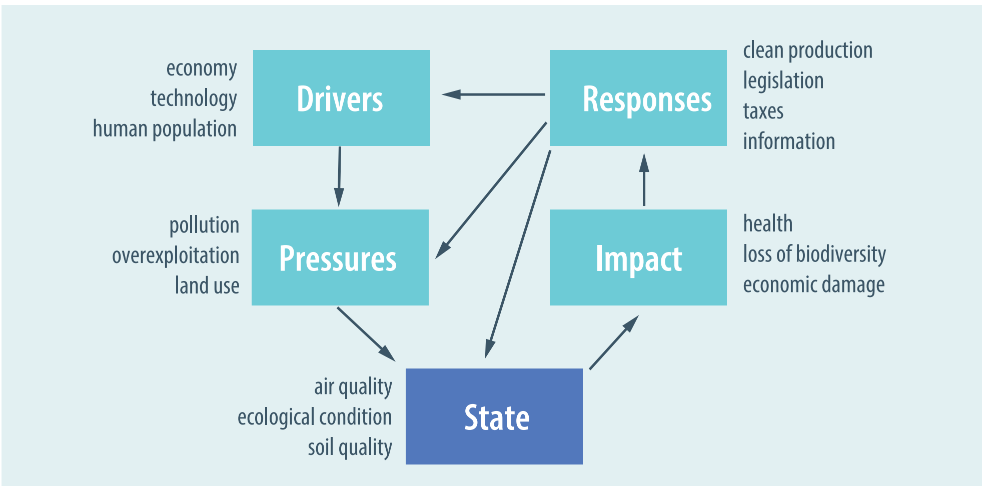

Figure 2. *The DPSIR concept is used to show what affects the condition of ecosystems, and what responses can be taken to change the condition (from EEA http://www.eea.europa.eu/publications/TEC25)*

for example, may reduce emissions of pollutants (pressure), while more gentle trawling tools will reduce the negative effect of trawling on marine benthic systems.

The pressures lead to changes in the **state** or condition of the environment, e.g. through changes in air or water quality, quality or amount of resources for species, population level of species or level of other ecosystem components. This condition in turn has an **impact** or effect on the functioning of ecosystems or the viability of species. The distinction between state and impact for ecosystems can be difficult, but these two concepts can be roughly linked to the structure and function of ecosystems, which together can be understood as **"ecological condition"** as the Expert Committee' mandate is designed.

Management responses can be implemented with a view to improving the condition. The responses can, for example, be aimed at changing the scope of drivers (e.g. technology development), reducing pressures directly (e.g. emissions of sulphur to air) or improving the state (e.g. liming of lakes, restoration of degraded nature).

It is not always easy to distinguish between pressures, states and impacts; e.g. in ecosystems, established alien species are a factor that both affects and represents the ecosystem's condition. As a starting point, however, the Expert Committee strives for indicators of ecological condition that should represent the structure and functioning of ecosystems, not the pressure factors that influence them. This is discussed more thoroughly in Chapter 3.5.

The DPSIR approach is used in the technical system to distinguish between drivers, pressures, states, impacts and responses. Ecological condition is understood in the technical system as a combination of states and impacts as described above.

2.2 Systems used in Norway

2.2.1 Nature in Norway (NiN)

NiN as a basis for classifying and describing nature

The Norwegian Parliament has decided that the a classification and description system for nature, Nature in Norway, of the Norwegian Biodiversity Information Centre, will form the core of the work on mapping Norwegian nature. Nature in Norway (NiN) is a system that describes Norwegian nature and divides it into ecosystem types **(Figure 3).** NiN has three main dimensions: 1) The nature diversity levels in NiN relate to scale, 2) the typology divides nature into types and 3) the description system provides the opportunity to describe variation in nature, e.g. variation along climatic gradients or as a result of different pressures. Nature can be divided into types at different spatial scales, termed levels of nature diversity **(Figure 3).**

The three levels are; landscape types, ecosystem types[1] and habitat component are all-encompassing, i.e. all nature in Norway can be assigned types at each of the three levels. A landscape type is a larger geographical area with a uniform visual character, while the habitat component allows

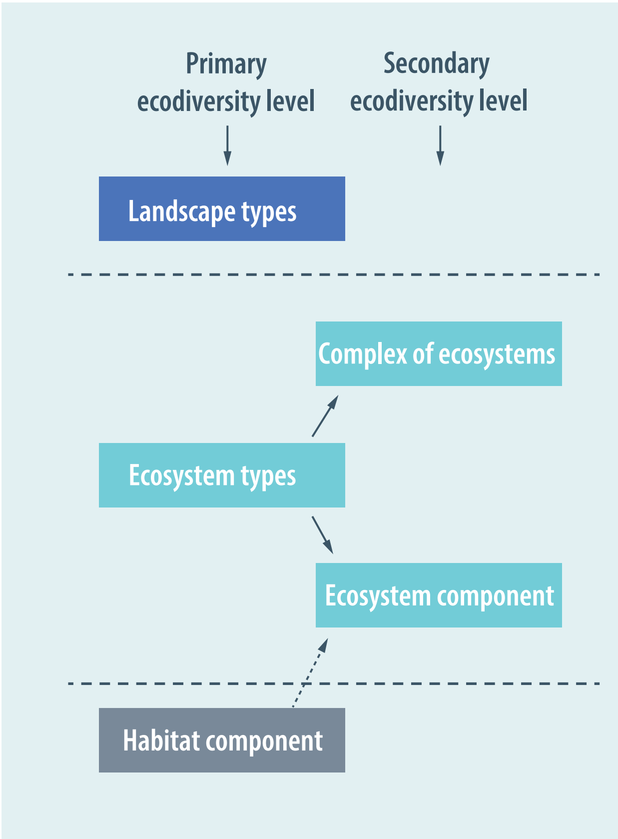

Figure 3. *The nature diversity levels in NiN relate to variation at different scales (Artsdatabanken 2015).*

[1] *Ecosystem types is also named as "nature systems" in some settings.*

us to characterize species' living conditions at the smallest spatial scale. The ecosystem types in NiN is defined by "all organisms within a more or less uniform, delineable area, the total environment in which they live and are adapted, and the processes that regulate the relationships between organisms and between organisms and the environment (including human activity)." The ecosystem types level addresses natural variation at the ecosystem level, but at a relatively fine spatial scale.

Mapping of nature in Norway takes as a main starting point the ecosystem type level. Mapping units are adapted for different spatial scales, i.e. the details in mapping are adapted to a given spatial scale (e.g. 1:5 000 or 1:20 000, Bryn &Halvorsen 2015), and is currently developed for terrestrial nature systems.

The ecosystem type level is one of the biodiversity levels that is most well worked through in NiN 2.0. The link between mapping units and the ecosystem type level also makes it appropriate to assess the main ecosystems in the technical system for ecological condition against the ecosystem type in NiN. However, in most cases, ecosystem type consist of small spatial units, which may have too fine a scale to characterize ecological condition, so that a collection of ecosystem type is a more relevant unit. For some nature types, e.g. mires, complexes of ecosystems (landscape part in NiN 1) are more relevant units than the nature system level for some purposes.

Table 1. *Overview of the typology of the ecosystem type level in NiN 2, with major type groups, major types and minor types[2].*

Major type groups	Number of major types	Number of minor types
Marine seabed systems	15	196
Freshwater bottom systems	8	48
Terrestrial systems	45	351
Wetland systems	13	91
Marine waterbody systems	4	18
Limnic waterbody systems	5	35
Snow and ice systems	2	2

The typology of the ecosystem type level is hierarchically structured, with major type groups, major types and minor types. There are 92 major types of natural systems, divided into seven major type groups **(Table 1).** The major types of nature systems are further divided into minor types (a total of 741), based on variation along one or more "local environmental complex gradients".

Data from the NiN mapping as a basis for assessing ecological condition

The description system in NiN also allows for a more detailed description of the variation in nature, and together with the typology, the description system makes it possible to characterize natural areas in more detail. The description system includes nine groups of variables (sources of variation), in addition to subordinate local environmental complex variables, and has about 90 (compound) variables (Halvorsen et al. 2016). One of the groups is condition variation. Condition variation is defined by a set of 16 variables that describe the scope and type of pressures on nature or ecological processes. Eight of the condition variables focus on the extent of various impacts, e.g. the extent of ditching or tracks from traffic with heavy vehicles. Six variables focus on ecological processes – i.e. changes in species composition – as a result of the impact **(Table 2).** Condition variables for ecological processes in NiN are therefore best suited for assessing ecological condition, while condition variables for degree of impact, are less suitable. The variables for ecological condition in NiN are based on changes in species composition and vegetation structure, which coincides with several of the indicators proposed in the technical system. However, methodology has not been developed for these indicators, and method development is needed. In cases where the condition variables in NiN are relevant as indicators of ecological condition, the reference condition is defined as the "zero state" of the variable. This is a condition characterized by little negative pressure from anthropogenic activity, i.e. pressures are absent or changes in species composition are negligible. For semi-natural ecosystems, the zero state presupposes extensive management. Other variables in the description system may also be relevant to consider as indicators of ecological condition, e.g. natural objects where standing and downed dead wood are included.

A number of different nature mapping projects have been initiated, both operational mapping and testing, based on NiN methodology. The projects have different objectives, and the

[2] *The NiN typology is evolving over time, and table 2 shows the typology as used in 2017.*

mapping is a comprehensive and long-term work. Examples of objectives are: Forest mapping to assess new protected areas, selective mapping to delimit red-listed habitat types and habitat types of national management interest, and full mapping of protected areas. Such mapping is in part very detailed and takes place at the local level. For most projects, however, there are no plans to repeat the mapping of the same areas, which is necessary for monitoring. The usefulness for assessing development in ecological condition in the areas over time is therefore limited. However, the results of the mapping may be relevant for assessing the ecological condition on a local scale in an area.

The ecological condition system is based on the classification of nature in NiN, but some adjustments have been made (Chapter 4.1). Furthermore, some indicators have been chosen from the NiN description system to assess ecological condition (Appendix 5). At the same time, the concept of condition variation in NiN is somewhat challenging as this term is not fully consistent with the definition of ecological condition. This is discussed in Chapter 5.1. For condition variables relevant to assessing ecological condition, the "zero state" is in accordance with the intact nature/reference condition as defined in the technical system. An area representative monitoring program (AKO) has been proposed for mapping habitat types according to NiN (Strand 2016). The Expert Committee proposes that certain indicators of ecological condition and/or data that can be used for calculating such indicators are incorporated into such monitoring, see Chapter 5 and Appendix 5.

2.2.2 Water Framework Directive

The Water Framework Directive covers all surface water (coastal waters, lakes and rivers) and groundwater in mainland Norway (www.vannportalen.no/). The ecological condition is assessed for all water bodies of a certain size.

The Water Framework Directive divides ecological condition into five condition classes (very good, good, moderate, poor and very poor), and the scientific assessments of ecological condition in water bodies are based on a set of indicators. The work also includes major management measures related to the preparation of water management plans and the establishment of water regions in cooperation between several county authorities, municipalities and various sectors.

The reference condition is natural/untouched conditions with little pressure from human activity. The indicators that measure the condition are a set of biological parameters/indices representing the quality elements phytoplankton, aquatic plants, benthic macro invertebrates and fish. These parameters are sensitive to different types of pressures (e.g.

Table 2. *Condition variables in NiN 2; two classes where the ones named "effect" and "natural dynamics" below is in line with the definition of condition in this technical system.*

Effects of pressures on species composition	Human pressures
Eutrophication	Ditching/trenching [3]
Acidification	Agriculture
Alien species component	Excessive harvesting
Quick succession	Forestry
Forest stand dynamics	Tracks from benthic trawling
Environmental toxins and other pollution	Tracks from traffic with heavy vehicles
	Tracks from wear and wear-dependent erosion
Natural dynamics/pressures	Effects of watercourse regulation[1]
Natural stand reduction in forests	
Imbalance between trophic levels [4]	

[3] *The condition variable includes both units linked to condition (effect of pressure) and units linked to the magnitude of the pressure.*
[4] *Primarily used where the cause of change is unknown, e.g., extensive grazing by sea urchins.*
[5] *Was established in 2019*

eutrophication, acidification, hydromorphological changes). Physicochemical and hydromorphological measures are supporting parameters, while changes in the area of water bodies are not included in the assessment of ecological condition. The Water Framework Directive also has requirements for environmental quality standards for pollutants in water bodies, see also the Miljødirektoratet (2016).

Good ecological condition is defined as minor deviations from the reference condition: *"The values for biological quality elements for the relevant type of surface water body show levels that are slightly altered as a result of human activity, but differ only slightly from those normally associated with this type of surface water body under pristine conditions"*. The classification is the process that determines the ecological condition of each water body. A five-step scale is designed to determine ecological condition. The classification is based on the values measured for the various biological quality elements. The overall state is assessed on the basis of the indicator with the worst condition (the "one-out, all-out" principle, with some modifications).

For heavily modified water bodies, good ecological potential is defined. Modified water bodies are, for example, rivers with extensive changes in water flow due to regulation for energy purposes. Maximum ecological potential is assessed in relation to the comparable physical environment in natural water bodies. Good ecological potential is defined as small changes in relation to maximum ecological potential.

The same approach for determining ecological condition is used in all EU-countries, and the limit values are very good/good and good/moderate ecological condition (which delimits the definition of good ecological condition) intercalibrated between countries that have the same water type **(Appendix 3).** County governors and municipalities are trained in the concept through work on Water Management Plans. An orientation of the Expert Committee's work on ecological condition that is in line with the Water Directive may therefore make the system more easily understood and used by management authorities.

The Water Framework Directive classification system is an important basis for the Expert Committee's proposed technical system (Chapter 3). The definition of intact nature/reference condition is in accordance with the approach of the Water Framework Directive, and indicators are scaled between 0 and 1. The system for setting the limit value for good ecological condition is inspired by the Water Framework Directive.

2.2.3 Norwegian Marine Management Plans

Good environmental conditions should be ensured in Norwegian sea areas through comprehensive management plans. The management plans are prepared and followed up by the responsible authorities in cooperation with experts. Management plans are now available for all Norwegian sea areas; for the Barents Sea with Lofoten, for the Norwegian Sea, and for the North Sea with Skagerrak.

As part of the follow-up of the overall management plans, an indicator-based monitoring system has been established for the three sea areas in the Barents Sea, the Norwegian Sea and the North Sea. So far, around 120 indicators have been developed in this system. The indicators describe the state of the different groups of organisms in the ecosystems, the state of the physical environment, as well as pollution and the pressure of human activity in the areas. The indicators are reported on miljostatus.no, and most are updated annually. The work is organized through the Monitoring Group.

Limits have been set for environmental quality targets for some of the indicators. How this is done varies. For fish stocks, the limit values prepared by the International Council for the Exploration of the Sea (ICES) are used, i.e. Bpa and Fpa (precautionary biomass and precautionary fishing mortality). For other indicators, change is applied over time, where the limit value is an upper limit for acceptable change, i.e. the environmental quality measure.

An important application for the indicators is to assess whether the environmental quality targets in the management plans have been achieved or not. Good ecological condition is indirectly described through these environmental quality goals. They largely imply the same criteria as described in the 11 descriptors of the EU marine strategy (Chapter 2.3.1).

The management plan work is considered relevant for the work on ecological condition. Through the environmental goals, much has been said indirectly about what is put into the concept of good ecological condition for Norwegian sea areas. Furthermore, parts of the extensive set of indicators are

[6] *These are threshold values where the spawning biomass is so large and fish mortality so low that one can say with high certainty that the reproductive capacity of the population is not negatively affected by the fisheries.*

relevant for assessing whether or not one has a good ecological condition in an area of the sea, and as described in Chapters 4.8-4.11, the system can be established as an extension of the Monitoring Group's work.

The work of the Expert Committee will contribute to a comprehensive technical system where the reference condition, good ecological condition and the choice of indicators will strengthen the work on indicators used in the management plans.

2.2.4 Nature Index for Norway

The Nature Index is developed for terrestrial, marine and limnic ecosystems and indicates the state and evolution of biodiversity in Norwegian ecosystems (http://www.naturindeks.no/). The reference condition in the Nature Index is defined as nature with little pressure from human activity. For semi-natural ecosystems on land, the reference condition is defined as nature in good condition, i.e. the extensive management that defines the type of nature, such as grazing, mowing and heather burning. Pressures other than traditional management are minimal.

Good ecological condition is not assessed in the Nature Index. The state of biodiversity is measured by deviations in the indicators relative to the reference values, on a scale from 0 to 1, where 1 indicates nature in the reference condition and 0 indicates the absence of the indicators included in the Nature Index. Natural variation is taken into account when setting the reference values. The overall state (Nature Index value) of an ecosystem is presented as a weighted average of the various indicators.

Indicators in the Nature Index are species indices, population level of species, or surrogates for these. There are about 300 indicators in the Nature Index. Important species (e.g. small rodents) and other key elements (e.g. dead wood) have a greater weight than other indicators.

A Nature Index value of 0.7 means that the indicators are on average 70% of the values in the reference condition. Since most indicators are species, it can be simplified to say that the populations of the species are on average 70% of what is found in the reference condition.

The Nature Index is a further development of the Natural Capital Index (see Chapter 2.3.5), and it relates to the reference condition in the same way as the Water Framework Directive. On the other hand, the method for assessing the overall state of the Nature Index (weighted average) is different from the method used in the Water Framework Directive classification system.

2.2.5 The Red List for Species

The Red List for Species assesses the extinction risk for individual species. Extinction risk at the national level is assessed on the current population size, as well as the development of the population in the near past or future. The risk of extinction is assessed in accordance with a quantitative set of five criteria, against which the species are assessed. The criteria and minimum requirements for a species to be considered endangered are related to: A: strong population reduction, B: limited distribution area, C: limited population size, D: very few reproductive individuals, or E: quantitative analysis of the risk of extinction ¬(Henriksen &Hilmo 2015).

The Red List assessments are based on data and expert assessments of how large today's population is compared to the maximum over the past 100 years. The Red List for Species is the most complete overview of developments for known Norwegian species and their risk of extinction. The Red List is designed at the national level. Information at the county or regional level about species can be found in part in the Red List database. The Red List database also has information about important negative pressures on the species.

Red List work and knowledge of development will be useful if species are used as indicators of ecological condition. The Red List does not operate with the terms reference condition or ecological condition

2.2.6 The Red List for Ecosystems and Habitat Types

The Red List for Ecosystems and Habitat Types includes terrestrial, limnic and marine ecosystems. The Red List assesses the risk of ecosystems types or habitats disappearing. Although the methodology allows for assessments based on expected future changes, the assessments are mainly based on knowledge of the current state and historical developments. The first national Red List followed its own set of criteria, as no international criteria yet had been developed for Red List of Ecosystems and Habitat Types (Lindgaard &Henriksen 2011). In criterion 1, the change in the area of the ecosystems and habitat types within a 50-year perspective and the near future was assessed. In criterion 2, the ongoing decline of types with a limited number of sites was assessed, where the ongoing decline is not expected to cease unless measures are implemented. Ecosystems and habitat types assessed according to criterion 3 are naturally rare. Landscape ecological assessments are included here. Criterion 4 is related to the proportion of area of a nature type that has a reduced condition. Reduction in condition is the dominant cause of red-listing of nature types, followed by a reduction in area (Lindgaard & Henriksen 2011). As with the Red List for Species, the Red-listed ecosystems and habitat types are documented in a separate Red List database with an overview of the most important pressure factors.

A new national Red List for Ecosystems and Habitat Types will be prepared and published in 2018. International criteria have now been developed under the auspices of the IUCN (Keith et al. 2013), and the new Red List will be based on the new IUCN criteria. European red lists for habitats can be consulted here. The five IUCN criteria have many similarities with the criteria used in 2011. The A criterion is related to a reduction in geographical distribution of an ecosystem or a habitat type. In the Norwegian Red List for Ecosystems and Habitat Types in 2011, 40 per cent of the red-listed types were assessed according to criterion 1, which coincides with the IUCN criterion A. Criterion A is suitable for assessing ecological condition at county or regional level where area reduction in a larger area is important. Criterion A is relevant when assessing ecosystems on a coarser scale, e.g. county or region level, cf. property no. 5 (see Chapter 3.4). The B criterion is related to ecosystems or habitat types with limited geographical distribution or occurrence, and where there is also a reduction in area or condition. The C criterion includes abiotic degradation of ecosystems, e.g. altered hydrology or flood regime, while the D criterion includes biological degradation of ecosystems. The C and D criteria are relevant for the work on ecological condition and coincide with the characteristics the Expert Committee has developed for good ecological condition, see Chapter 3.4. The E criterion involves doing a quantitative analysis that estimates the probability of habitat/ecosystem collapse in the future. Criterion E is thus not relevant for assessing ecological condition today but is relevant if future developments are to be considered.

The Norwegian Environment Agency has initiated efforts to evaluate sites with red-listed ecosystems and habitat types of national management interest (Evju et al. 2017). In this work, which will be based on mapping of sites according to NiN, relevant variables for condition variation in NiN, meaning the occurrence of negative pressures (or absence of positive ones in semi-natural nature types) will be recorded in the field. Mapping and valuation of nature types of national management interest will be a good basis for future red list assessments.

2.2.7 The Black List for Species

In the work on black-listing of species, alien species are assessed in Norway, i.e. species that occur outside their natural distribution area and dispersal potential, and that have come to Norway by passive or active help of people. The species are assessed in relation to ecological risk, i.e. how likely the species is to spread to and establish itself in nature, and what effect the species may have on indigenous species and nature types. Black-listed species are species with a very high risk, i.e. species with a strong negative effect on Norwegian nature, and species with high risk, i.e. species with wide distribution and some ecological effect, or species with a limited distribution but great ecological effect (Gederaas et al. 2012). The Black List and associated risk assessments are updated regularly, and will be a useful knowledge base for assessing the effects of alien species in ecosystems.

2.2.8 Environmental monitoring for Svalbard and Jan Mayen (MOSJ)

The Norwegian Polar Institute is responsible for monitoring ecosystems in and around Svalbard, and assessment of indicators and condition changes takes place under the auspices of the environmental monitoring system MOSJ (Environmental Monitoring of Svalbard and Jan Mayen; https://www.mosj.no/en/). MOSJ collects data from relevant monitoring programs and presents temporal trends for a selection of species in terrestrial and marine ecosystems. Assessments of the condition of ecosystems are made by expert panels in the form of special reports approximately every 10 years (Fauchald et al. 2014b, Ims et al. 2014). These condition assessments take place on the basis of all available monitoring data and research literature, and the condition of the environment (terrestrial and marine) is qualitatively assessed against the State Environmental Goals for the High North (miljøstatus.no). The development of the Climate Ecological Observation System for the Arctic Tundra (COAT) will contribute to increased data access for relevant indicators for Svalbard and Arctic parts of mainland Norway.

2.3 International systems of Interest

2.3.1 EU's Marine Strategy Framework Directive

The EU Marine Strategy Framework Directive, was adopted on 17 June 2008 (2008/56/EC), but is not incorporated into the EEA Agreement. The goal is to achieve good ecological condition in the EU's marine areas by 2020 and protect the resources on which marine economic and social activities depend. All EU countries will develop strategies to achieve this. Norway is not bound by the EU marine strategy, and the directive is not implemented in Norway, but the way the directive is implemented in other countries may benefit Norway.

The EU Marine Strategy Framework Directive (MSFD) has defined normative criteria for good environmental status, related to 11 descriptors: biodiversity, alien species, commercially exploited species, food web, eutrophication, integrity of the seabed, hydrographic conditions, pollution, food safety, marine litter and energy, including underwater noise. Separate sets of indicators have been developed for each of the 11 descriptors. Based on the descriptor every single country has specified what good ecological condition means for its own sea areas. The monitoring system is designed to assess the state of the marine areas. Several of the descriptors focus not on the ecological condition, but on the extent of pressures.

The Marine Strategy Directive does not define reference conditions, only good ecological condition.

2.3.2 Natura 2000

Natura 2000 is a network of areas to protect rare and endangered species and nature types. This applies to all 28 EU member states, and includes both land and sea areas. In 2017, the network covers over 18% of the EU's land area and almost 6% of the marine area. Most of the network is also protected after each country's own national legislation to protect nature. The aim of the network is to ensure the survival of Europe's most valuable and endangered species and habitats. These are listed in the EU Bird Directive and in the Habitats Directive. Implementation of Natura 2000 areas is an obligation under the EU Habitats Directive.

The conservation status of habitats and species listed in the Habitat and Bird Directives is evaluated regularly, normally every 6 years. The reference condition against which conservation status is assessed is the level of occurrence and distribution (for the habitats) or distribution and population size (species) that are considered necessary for the habitats/species to achieve good conservation status. The level of reference can never be set lower than it was the year a country joined the EU. What is good enough (necessary) is assessed for each type of species/habitat per biogeographic and marine region. For the species, the assessments rely on the IUCN's criteria for how much is needed of a species in order for it to no longer be threatened. For habitats, among other things, the populations of species and historical maps are used to assess how much is good enough. Since the reference condition is not unambiguously defined, it is difficult to compare conservation status between countries, areas and habitats.

The conservation status of the habitats is measured by indicators related to a habitat's area, distribution, quality (ecological structures and functions, both species and abiotic factors) and future prospects (threats today and expected threats in future).

The terms good/favourable, inadequate and poor conservation status are used. The criteria for good conservation status of a habitat are:

- Area: stable/increasing and no less than the reference and no changes in the distribution of the habitat
- Distribution: stable/increasing and not less than the reference
- Quality: structure and function: good condition, no negative impact

The criteria for good conservation status vary slightly for the different categories (area, distribution, quality and future prospects). There is the greatest variation in the category of quality, since what is important varies among the different types of habitats, e.g. the amount of dead wood is important in forests, while for a meadow it is important that the nutritional status is natural (no fertilization except for what the grazing animals may add).

Many of the indicators used in the evaluation of the Natura 2000 areas are relevant for the work on ecological condition. This applies in particular to area (and fragmentation) and quality. The concept for determining the reference condition varies between species and between habitats and is not considered a good starting point for determining the reference condition in the technical system for good ecological condition.

Norway is not obliged to implement Natura 2000, as the EEA Agreement does not include the EU Habitats Directive. However, the Bern Convention, which Norway has ratified, has a parallel obligation; the Emerald Network. Norway is thus obliged to establish the Emerald Network, as are the EU and other non-EU countries that have ratified the convention. Norway has proposed a number of candidate areas for the Emerald Network. Relevant areas are stated in the official list (T-PVS/PA (2016) 11) from the party meeting in 2016. All candidate areas are already protected by Norwegian law. The requirements for reporting the state and development of Emerald areas under the Bern Convention have not yet been determined. Nevertheless, there is reason to believe that they will resemble similar requirements established under EU regulations for the Habitats and Bird Directives, as well as Natura 2000. Norway has so far not established a special system for such knowledge acquisition and possible reporting to the Berne Convention.

2.3.3 Restoration, how to measure improvements in condition?

The EU biodiversity strategy towards 2020 aims, among other things, to restore at least 15% of degraded ecosystems (Aichi target 15). This is in accordance with the objectives of the Convention on Biological Diversity. In Norway, Parliament has decided that "the Government shall clarify what is in good condition and which areas are considered to be degraded ecosystems and step up efforts to improve the condition of the ecosystems, with the aim of restoring 15% of degraded ecosystems by 2025." In Norway, a few scattered restoration measures have been implemented in various nature types, and in 2015 a national plan for the restoration of wetlands (Miljødirektoratet & Landbruksdirektoratet 2016) was adopted, but there has been no development of a common method for measuring the ecological condition of the area to be restored. The work to develop a technical system for determining the ecological condition should also be a starting point for assessing whether an area has deteriorated, i.e. whether the ecological condition is poor, and whether it improves after restoration.

In the work to implement the EU strategy, a theoretical framework has been developed to prioritize efforts and measure the effects of restoration measures (Lammerant et al. 2013). In this framework, the quality of an area is assessed in relation to a given year (the reference condition). The assessment of the quality of the area is done with indicators that are strongly linked to the state of the area (the extent of degraded area). Which indicators measure quality vary between countries, making comparison very difficult. An assessment of specific state indicators for the Nordic countries shows that there are also major differences between countries and different nature types (Hagen et al. 2015a). Two main approaches are used to assess the degree of deterioration:

- ability to deliver products/ecosystem services, and
- ecological function and ability to restore condition (resilience).

The EU restoration framework has not been operationalized and tested in practice. Since it should be a tool for assessing goal achievement in relation to restoration, great emphasis is placed on practical feasibility. The choice of indicators is largely recommended to be pragmatic, based on available data, existing legislation, etc. The EU framework does not appear to have been worked through enough to provide good advice for use in the work of the Expert Committee. However, we would assume that some of the abiotic and biotic indicators to be measured coincide with indicators used in the Natura 2000 work and in the work on red-listing of ecosystems and habitats. These indicators may be relevant to assess in the technical system for ecological condition.

There is great variation in different restoration measures, and restoration projects can have very different goals, from the establishment of populations of individual species to landscape shaping. Within the field of restoration ecology, there is a lot of focus on finding good indicators, i.e. characteristics that describe development towards the goal of the restoration measure. Proposals have been developed for an international standard for the implementation of restoration measures, and which characteristics are important. The main groups of characteristics in this proposal are the absence of threats, abiotic conditions, species composition, ecosystem function, and function and exchange with other systems (McDonald et al. 2016). Scale is a major challenge in measuring the effects of restoration. Most measures take place at a small scale and can have a large local effect but will not have an impact on national or regional statistics. Different indicators are thus relevant depending on whether one wants to measure the effect of overall programs or details of individual measures.

Once the EU's work on the restoration framework has been further developed and accepted, a review may be required to assess whether this can contribute to the technical system for good ecological condition.

2.3.4 Living Planet Index

measures the state of global biodiversity based on population trends for vertebrates. The database on which the index is based has data on over 14,000 populations of more than 3,600 species of mammals, birds, fish, reptiles and amphibians. Reference years, against which the condition is measured, are set to 1970, and, like the Nature Index, relative population level is used as a measure of the state of biodiversity. No management targets have been set for LPI.

A reference condition as it was in 1970 is not relevant for use in the technical system for good ecological condition. This is due to the fact that such an approach would automatically classify areas that were already deteriorating in 1970 as having good ecological condition.

2.3.5 GLOBIO og Natural Capital Index

GLOBIO-modellen has been used to give an overview of the state of biodiversity in different contexts. The reference condition in GLOBIO is natural ecosystems with native vegetation or primary vegetation. The Natural Capital Index (NCI), on which the GLOBIO model is based, uses pre-industrial time (interpreted as "pristine conditions") as a reference condition. For semi-natural ecosystems, the reference condition is defined as areas that are in a good management state. NCI uses biological data on species to calculate the state of biodiversity, while GLOBIO bases its state assessment on information on different pressures and known dose-response relationships between pressures and populations of species. The GLOBIO model includes information on pressures from nitrogen deposition, land use changes, land use intensity, infrastructure and fragmentation, and climate change, but does not include harvesting, hunting, and alien species. The condition being modelled is "Mean Species Abundance (MSA)" – i.e. the relative population level of species. Since input data in the GLOBIO model are pressures and have not been verified against real population data, the model can in many ways be considered a weighted impact map on Earth's terrestrial ecosystems. It is unclear whether the weighting is correct in terms of assessing changes in species quantities. The GLOBIO model has been tested in the northernmost parts of Norway (van Rooj et al. 2017) but is based only on impact information. Dose-response correlations between pressures and their effects on species are mainly established for regions other than Fennoscandia and have not been verified against real data on population changes in Norway. As the GLOBIO model is based on data on impact factors and treats species and ecosystems indirectly through dose-response conditions, it is not considered relevant to the work on ecological condition.

The Natural Capital Index is based on population data of species and is therefore relevant. NCI was tested in the Netherlands in the 1990s but is not in use today. The Nature Index is described in more detail in Chapter 2.2.4.

2.4 Summary

The chapter summarizes how proposals for a "technical system for ecological condition" are based on existing knowledge and established systems:

- The technical system is based on the typology for nature as defined in Nature in Norway, but also on the division in the Norwegian Action Plan for Biodiversity. This has been done with some adjustments (see Chapter 4.1).
- The technical system uses the term reference condition as defined in the Water Framework Directive and the Nature Index, i.e. intact nature, and is based on normative descriptions of good ecological condition as described in the Water Framework Directive, but with concrete descriptions of characteristics for good condition.
- Classification of good ecological condition builds on, but is a simplified version of, the classification process in the Water Framework Directive.
- Relevant indicators from the marine management plans, the Nature Index, Nature in Norway, Environmental Monitoring Of Svalbard and Jan Mayen (MOSJ) are relevant as condition indicators. The Red List for Species and the Red List for Ecosystems and Habitat Types may contribute with up-to-date knowledge of some indicators.
- The knowledge basis for the indicators is obtained from monitoring programs and other relevant sources of information (see Chapters 4 and 5, as well as Appendix 5).

3 Technical system for assessing good ecological condition

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This chapter presents the proposal for a technical system for assessing good ecological condition and justifies the choices made. Participants in the subgroup Sea (Per Fauchald, Normann Whitaker Green, Eva Ramirez-Llodra, Sylvia Frantzen, Cecilie von Quillfeldt and Anne Kirstine Frie) have contributed significantly to developing the characteristics that provide a normative description of good ecological condition in Chapter 3.4.

3.1 Definition of ecological condition

The technical system for ecological condition should be based on *"a limited number of indicators that reflect the structure and function of the ecosystems and take into account natural dynamics in the ecosystems* (Expert Committee mandate, **Appendix 1**). In the Nature Diversity Act, ecological condition is defined as *"Status and development of functions, structure and productivity in the localities of a nature type in light of current pressure factors".* The definition of ecological function includes productivity, and the mandate therefore also covers productivity. The criteria set for the selection of indicators (Chapter 3.5) includes that the overall set of indicators should be sensitive to the most important pressure factors in the ecosystem. The technical system thus covers the Nature Diversity Act's definition of ecological condition.

Ecosystem structure is the biophysical structure of an ecosystem (TEEB 2010). The term encompasses biodiversity, including the composition of species in an ecosystem, and also number, quantity (abundance) and quantity distribution of different species. The term also encompasses an ecosystem's trophic structure; how many trophic levels (links in the food web, e.g. plants, herbivores and predators) exist, or how the biomass in an ecosystem is distributed between different trophic levels. Furthermore, ecosystem structure can describe how the composition of the biotic parts of the ecosystem shapes the ecosystem's biophysical architecture, such as trees, coral reefs and kelp forests (NOU 2013). Central to the concept of ecosystem structure is biodiversity.

Ecosystem function, including productivity, is synonymous with the concept of ecosystem processes, which describe inherent features of the ecosystem that enable the ecosystem to maintain its integrity or health, and provide ecosystem services (Millennium Ecosystem Assessment 2005). Ecosystem processes can be physical, such as transport of water or sediments, or biological, e.g. photosynthesis/primary production, decomposition or grazing. Ecosystem function also includes ecological functional areas for species. In the Nature Diversity Act (§3), functional areas are defined as being an *"area – with delimitation that may change over time – that fulfils an ecological function for a species, such as spawning area, recruitment area, larval drift area, migration routes, grazing area, denning area, moulting area, day or night resting area, lekking or mating area, nesting or reproduction area, over-wintering area and home range."*

Ecological condition is assessed on the basis of these definitions of the structure and function of ecosystems. Important concepts used in this report are defined in **Appendix 2.**

3.2 Ecosystem condition and well-functioning ecosystems

In the Norwegian Action Plan for Biodiversity, the national goal is that "Ecosystems should be in good condition and deliver ecosystem services" (Meld. St. 14 (2015-2016)). This sub-chapter provides a status of knowledge for the relationship between the condition of ecosystems, i.e. their function and structure, and the capacity to deliver basic ecosystem services, as well as supplying and regulating ecosystem services. The sub-chapter deals specifically with the importance of biodiversity, which is central to the structure of the ecosystem.

The relationships between biodiversity and ecosystems' ability to deliver ecosystem services are a relatively new field of ecology, which accelerated in earnest after the meeting of the Convention on Biological Diversity in Rio in 1992. Over the past 25 years, a large number of field experiments have provided new knowledge and established that the importance of biodiversity for the functions of ecosystems is real and significant (Hooper et al. 2005, Braat & de Groot 2012, Cardinale et al. 2012). Loss of diversity may in itself have effects on ecosystem functions that are as great or larger than climate change, increased nitrogen supply and other environmental changes (Hooper et al. 2012, Tilman et al. 2014). Accelerating environmental changes and continued loss of global biodiversity therefore threaten the function and condition of ecosystems, as well as their ability to deliver ecosystem services (Dirzo et al. 2014, Oliver et al. 2015).
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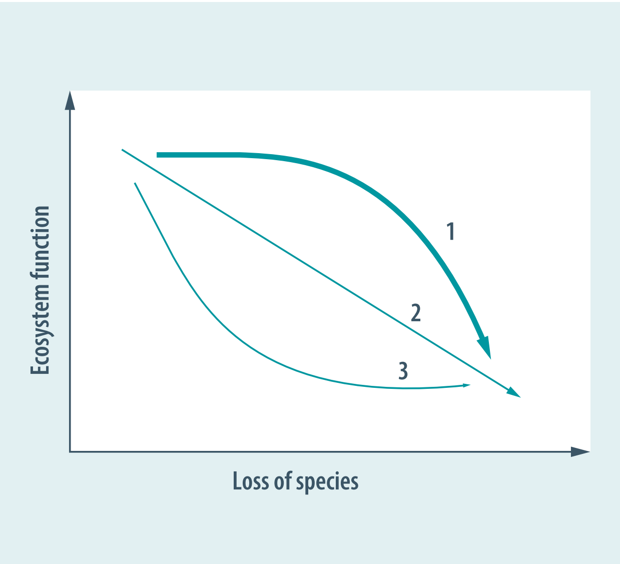


Species diversity is important for basic ecosystem functions

Species diversity is an important factor in ecosystem productivity, stability, resistance to invasive species and nutrient turnover, i.e. factors that describe the condition of the ecosystem.

In general, there is a positive correlation between the number of species and basic ecosystem functions such as primary production and decomposition. A greater species diversity makes the system more efficient at capturing resources – a larger share of solar energy, water and nutrient access can be exploited as more species fill more niches (Cardinale et al. 2012, Tilman et al. 2014).

Tilman concludes that terrestrial, limnic and marine systems with high species diversity have about twice the primary production (i.e. they produce twice as much biomass per unit of time) as monocultures of the same species, and that the difference increases with time (Tilman et al. 2014). Several different explanations come into play, but an important point is that different species complement each other, and that systems with high species diversity are better able to exploit available resources, even over time.
Continued investigation is needed to clarify exactly how species diversity is related to ecosystem function in different systems. Both theory and experiments suggest that the relationship is not linear, e.g. that there is often a saturation effect with increasing diversity. In this case, the effect of lost

Figure 4. *There are three main hypotheses for ecological consequences of loss of species diversity. (1) One hypothesis states that the loss of the first species will have minor effect on ecosystem functions, because some species are "superfluous" in the sense that other species have a similar ecological role in nature. However, at some point, a continued loss of species will lead to a rapid reduction in ecological functions. This hypothesis is sometimes called the "airplane rivet hypothesis" based on a parallel that removing rivets from a fuselage will have little effect on flight capacity at first, but if enough rivets are removed it will cause the aircraft to fail. (2) Another hypothesis suggests that ecosystem functions are reduced proportionally to species loss. (3) A third hypothesis states that even a small species loss will lead to an abrupt decline in the functions of the ecosystem. A summary of 350 different studies concludes that most of them best correspond to the first hypothesis. Reworked from Cardinale et al. (2011).*

species diversity is small at first but increases after a certain loss has been reached **(Figure 4).** Alternatively, if the system is controlled by a key species, the effect can be great if it disappears, while the absence of other species has less effect. A study that summarizes the knowledge in more than 350 individual experiments with manipulation of plant-species diversity found a predominance of studies with patterns that supported the hypothesis that loss of species diversity has serious effects after passing a threshold (Cardinale et al. 2011).

The relationship between ecosystem function and the capacity to deliver ecosystem services is also not trivial. We need more studies and good syntheses that connect biodiversity, via ecosystem function, to a delivery in the form of an ecosystem service. Many of the field studies that have been done so far have looked at simple systems with a limited number of species. There is therefore a need for field studies that are scaled up to real conditions and scales (Ricketts et al. 2016). The way we measure ecosystem service can also be important. In his review of more than 500 studies, Ricketts et al. show that there is not always a correlation between the effect of species diversity on the delivery of a service (e.g. increased number of pollinators) and the resulting production as we measure it as relevant to humans (e.g. increased crop).

Species functions are more important than the number species

New research tones down the focus on species numbers because the number of species alone can obscure essential nuances. For example, both the distribution of individuals (i.e. how many individuals there are of each species) and the functions of the species that are actually present are of crucial importance for how the system works.

Therefore, the necessity of looking at the functions of the species is emphasized, which in turn is reflected in their functional features. Functional features describe both how an organism responds to pressures and how the organism affects the ecosystem's delivery of ecosystem services (Violle et al. 2007, Enquist et al. 2015). Examples are body size, diet, habitat association, dispersal ability and growth form. In practice, the provision of ecosystem services often depends on interactions between a number of different functional features, across several different levels in the food web. Various studies also point out that both common (Hooper et al. 2005) and rare species (Mouillot et al. 2013, Leitão et al. 2016) can fill unique functional roles in the ecosystem. Thus, it is difficult to predict which species are the most important for maintaining the functioning of ecosystems..

"Key features" link the impact and delivery of ecosystem services

A recent compilation of studies that looked at the link between impact factors and ecosystem services via functional traits points out that there are some "key features"; traits that clearly respond to pressure and at the same time affect the provision of various ecosystem services (Hevia et al. 2017). In their study material, they find examples of such possible traits – such as size or diet. For example, a US study (Larsen et al. 2005) shows that body size in the bee community is affected by intensification in agriculture, in that the large bee species are the first to disappear. At the same time, large bees are better pollinators, so the loss of the large bees can result in a lower crop. Body size here is a useful key feature that can say something about the ecological condition of the system. Such key features that link response and effect are good candidates for robust indicators when monitoring changes in biodiversity and the effect on the condition of the ecosystem and ecosystem services.

A high biodiversity provides stability

Increasingly, the focus is on ecosystems delivering services in the future under changing environmental conditions, and it is therefore important to have knowledge about how robust the systems are. Robustness in ecology is a broad concept that entails both resistance again change ("resistance"), and the speed at which the system recovers after disturbances ("recovery").

The robustness of ecosystems is governed by factors acting at different levels in the organization of biodiversity; species, communities and landscapes. Since these ecological levels are interrelated, changes at one level may affect the other levels, triggering an avalanche of other effects (cascade effects) (Oliver et al. 2015).

The researchers find increasing support for that an intact, high biodiversity makes ecological functions more stable over time. It also means that the capacity to deliver ecosystem services is probably more stable over time in such systems

(Cardinale et al. 2012, Oliver et al. 2015). The mechanisms are several. Among other things, it will be the case that in a system with higher biodiversity, the species will represent several different varieties of ecological functions. Thus, the ecosystem has several variants to "play on" in the face of upcoming environmental changes. Intact species diversity and good ecological condition can thus serve as a "life insurance" that ensures stability in ecological functions and continues provision of ecosystem services with increasing man-made pressures (Chapin et al. 2000, Braat & de Groot 2012).

3.3 Intact nature in an Anthropocene world?

In order to assess the ecological condition, one must be able to assess the condition of the ecosystem against a norm, the reference condition. The conceptual approach for determining the reference condition is subject to recurrent and extensive professional discussions. The discussions are primarily related to whether to assess the reference condition in relation to nature's "pristineness" or whether there are other factors, such as species diversity and the dynamics and functions of the ecosystem, that define 'intact' nature. How do we even establish a reference condition when we know that nature is constantly changing, influenced by natural as well as man-made processes? These issues are related to the discussion in Chapter 2 on whether it is the pressure (in this case, the human pressure) or the ecosystem's total response to all pressures (the structure and function of the ecosystem) that should be decisive and are discussed further below.

The first question we can ask ourselves is this: What is the relationship between the reference condition and management objectives? The Nature Index describes the role the reference condition is intended to play in the framework as follows:

"The reference condition in the Nature Index is comparable to the magnetic North Pole that acts as a reference when setting out on the correct course. The North Pole (the reference condition) is not the objective, but one must know where the North Pole is, in order to get to where one wants (the management objective). Consequently, the reference condition differs from the management objective, perhaps with the exception of some protected areas where one wants the condition to be as unaffected by human activity as possible. Knowledge of the reference condition is therefore important to know whether a change is positive or not. When the Nature Index shows increased values over time, this implies a positive development for biodiversity. Conversely, declining Nature Index values over time will indicate a negative development for biodiversity." (Nybø et al. 2015).

In addition to acting as a compass for the correct course, the reference condition is also used to scale the indicator values, which is necessary in order to compare developments of different indicators. The scale makes it possible to compile different indicators measured using different units of measure.

Below we discuss how the reference condition 'intact nature' is defined and understood by the Expert Committee. Next, we present how this builds on and supplements existing classification systems.

Human impact on nature in a long-term perspective

In recent centuries, we have witnessed a dramatic increase in human impact on nature. In the year 1700, about half of the earth's surface was untouched nature, without human settlements or detectable utilization. Most of the remaining land areas were semi-natural (45%), while only small areas were cultivated or settled. In the year 2000, this picture was turned upside down: more than half (55%) of the Earth's ice-free land areas are now affected or heavily pressured by humans, less than 20% are semi-natural, and less than 25% untouched (Ellis et al. 2010). This dramatic increase in human impact on nature has consistent effects on the Earth's ecosystem at the macro level; the biogeochemical cycles such as carbon and nitrogen cycles, climate, many ecological processes and functions in ecosystems, and thus the important drivers behind loss of and changes in biodiversity are now dominated by human pressures (see e.g. Steffen et al. 2007, Newbold et al. 2015, Newbold et al. 2016). This upheaval has led many to now consider that we have moved into a new geological era, the Anthropocene (the Age of Humans), in which humans are the dominant factor for the Earth system, more important than astronomical, geological and biological processes (see Crutzen &Stoermer 2000). There is discussion on when the transition from the Holocene to the Anthropocene occurred. While it was originally proposed that the distinction should correspond with the Industrial Revolution, since it was this that initiated the processes that have led up to today's human-dominated globe, the second start of the Anthropocene is timed to the point when over half

[7] *The effect on the ecosystem functioning given cumulative pressures*

of the Earth's area and/or biogeochemical cycles were seized by human activities, implying that we set the limit in the early 20th century (Steffen et al. 2007).

The Anthropocene model carries in it a thought of a distinction between nature and humanity, and often also a notion of human influence as exclusively negative, which destroys nature and natural values, so that it is in the interest of nature that all human influence must be limited and preferably reduced. The problem with this mindset is that it assumes a distinction between 'broken' and 'untouched' nature, and not least that it assumes that pristine nature is something we can have knowledge of, partly because there is still untouched nature that we can study, and partly because it has been a relatively short time since nature was largely untouched (cf. Ellis et al. 2010). However, it turns out that both of these assumptions are relatively problematic.

Recent research suggests that the prehistoric human impact on ecosystems and the Earth system is probably greater than we have so far thought. Early models of human pressure built on assumptions that over the past 7,000 years pre-industrial people have had roughly the same technology, and that the population has therefore occupied a constant area per human being (Ruddiman 2013). However, historical ecological data and archaeological databases show that prehistoric people used far larger areas than modern humans. Thus, their pressure on nature, and the earth system, was greater than we have previously assumed. The differences are huge. While the 'industrial' model assumes that 2/3 of the forest disappeared after the Industrial Revolution, the 'early Anthropocene' hypothesis concludes that the majority, perhaps 3/4, of the forest disappeared before the Industrial Revolution. In the early stages, humans pressured the forest not by clear felling and cultivation, but through the manipulation of fire regimes, hunting for large grazing animals and predators (Ruddiman 2013, Scott et al. 2014). These are diffuse pressures that can be difficult to detect and not least quantify, but which may nevertheless have had a major effect on the functioning and dynamics of the ecosystem. Roughly speaking, this new data suggests that humans have pressured the Earth's ecosystem, i.e. nutrient and substance cycles, carbon, climate and distribution of biomass in ecosystems, quite extensively in the last 3000–8000 years (Ruddiman 2013).

An important consequence of this 'long perspective' on human impact on nature is that none of the ecosystems or the species diversity we have today can be seen as 100% natural. They have arisen and been formed through an interaction between natural processes and diversity and the long-term, diffuse human pressures. Some of these pressures have been clearly negative, such as the loss of large mammals such as mammoths and saber tooth tigers (megafauna) and the ecological consequences this has had on biodiversity and ecosystem functions (Mahli et al. 2016). At the same time, the biodiversity we have today consists of species, nature types and ecological processes that have survived, and in part also been shaped and conditioned by pressure from humanity. Such nature types can have high biodiversity, partly because human pressure has taken over for natural disturbance regimes and processes (e.g. by livestock grazing slowing down natural succession processes), and partly through the fact that naturally occurring species have adapted to human disturbance regimes (such as altered fire regimes). This interaction between natural processes and diffuse human pressures over a long period of time is the reason why semi-natural habitats such as hay meadows, pastures, coastal heathland or boreal moors may have characteristic and an often high diversity of naturally occurring species (Bratli et al. 2011). One consequence of this high diversity is that semi-natural habitats are covered by Norwegian politics and international obligations when it comes to safeguarding biodiversity (see e.g. Regulations relating to selected habitat types pursuant to the Nature Diversity Act).

There has been considerable variation in how humans affect nature in different areas, and Scandinavia has always been an area of relatively moderate pressure. Nevertheless, we have documentation of ecosystem impacts that date back thousands of years. The European heathlands, for example, are a semi-natural system. The heathlands have been transformed from original forests over the past 6,000 years using fires imposed by humans and grazing from livestock (summarized in Vandvik et al. 2014). The same pressure factors have been connected with peat growth and mire formation in oceanic regions, e.g. blanket bogs along the coasts of Western Norway and mid-Norway (Solem 1994) and oceanic mires in sloped terrain in the British Isles (Anderson et al. 2008). The mechanism most often highlighted is lower evaporation from vegetation due to deforestation through logging, burning and grazing. This may provide a basis for peat growth. Gallego Sala et al. (2016), however, emphasizes climate fluctuations as the cause of the emergence of oceanic mires in the British Isles, and there is no consensus on whether human pressure can cause mire formation. Most likely, it is enough that human use of nature is one of several factors that can contribute to the formation of mires. Also in the Scandinavian forests, fire regimes have varied considerably over time and space, and it is difficult to determine how much this is due to natural variation and how large a role humans have played (Tryterud 2003, Ohlson et al. 2006, Ohlson et al. 2009, Ohlson et al. 2011). Human pressure also goes way back in time for the ocean areas. For example, hunting has been a dominant factor for coastal seal population dynamics for thousands of years, and the life history of Northeast Arctic cod may have been pressured by fishing for 1000 years (Heino et al. 2015). Whaling has had a major impact on population levels for more than 400 years. In addition to the direct impact on the hunted groups, we must assume that there have been wider ripple effects that have contributed to changing the structures of ecosystems.

These different understandings of human importance for the types of nature that exist today have major consequences for our perception and interpretation of nature and ecosystems, and thus for the determination of the 'reference condition'. If the human pressure is from a relatively new date, and if seemingly unaffected nature is really as 'natural' as it appears, and if this applies to both species composition and ecological function and dynamics, it makes sense to look for or define the reference condition as an imaginary or real unaffected state. But if the pressure has been more pervasive, albeit diffuse, over a long period of time, setting such a boundary will be difficult. On a more general basis, this raises questions about how relevant today's 'pristine' nature is as a reference system, including among other things how the trophic structure of the ecosystem (via, for example, hunting and eradicating megafauna and apex predators and historical fisheries), productivity (via nitrogen fallout and climate change) and landscape structures (via land use changes) have pervasively changed.

These new recognitions have implications for how the reference condition must be defined in order to be relevant to nature management, in the sense that it can be made operational as a reference for developments in ecosystems over time, and that it can be used to set management goals.

The Expert Committee recommends, as a pragmatic approach, to draw a distinction between pre-industrial pressure and the current situation. As discussed above, the massive pressures we have seen since the Industrial Revolution are fundamentally different from the diffuse pre-industrial pressures. The modern pressures are often of a different intensity and character and in many cases have a clear negative effect on ecosystems. An operational reference condition can be defined by the absence of such "new", pervasive human pressures, i.e. that they do not significantly change the condition (resistance), or by the ecosystem's own internal processes being able to easily restore this condition (resilience). As for the pre-industrial impacts on ecosystems, the Expert Committee chooses a pragmatic approach. Instead of trying to define an 'unaffected' reference condition so that we can assess and quantify the effect of these pressures, we focus on biodiversity and the structure and function of ecosystems, and define the reference condition as nature where the processes and structures necessary/beneficial to maintaining the diversity and functioning of indigenous species over time are safeguarded.

Such an approach also makes sense in relation to the role of the Expert Committee, which is to provide the management authorities with a tool for assessing whether nature is degraded or not. Thus, the assessment of ecological condition must take its starting point in the nature we will manage now and in the future, and in variables we can have knowledge of. Consequently, the Expert Committee focuses on defining and assessing the ecological condition based on:

- Species diversity in the near present, where we disregard species that are extinct or extirpated, and where species introduced before 1800 are considered naturally occurring in line with the definition in the Black List 2012 (Gederaas et al. 2012).
- The climate in the near present, defined as the previous normal period (1961–1990, see below).
- Absence of modern (post-industrial) and pervasive human pressures.
- The focus is on developing a technical system that provides the management authorities with tools to assess whether the ecological condition is good enough to support the species, species diversity and ecosystem functions found in each type of nature, as described for the seven key characteristics of ecosystems (see Chapter 3.4), cf. also the Biodiversity Act's management goals for species and nature types **(Box 1)**.

Based on these assessments, the Expert Committee has provided a normative definition for intact nature (the reference condition) in Chapter 3.4, which largely coincides with the approach given in other classification systems, including the Water Framework Directive and Nature Index.

3.4 Normative description of good ecological condition

The Expert Committee has put emphasis on that the technical system should be holistic with a common approach for all main ecosystems, and has created a common definition of good ecological condition and intact nature/reference condition. A more detailed description of the characteristics of good ecological condition in each main ecosystem is discussed in Chapter 4. The descriptions are based on these seven characteristics.

Definition of good ecological condition

A. Good ecological condition in Norwegian ecosystems is defined by the fact that the structure, function and productivity of ecosystems do not differ significantly from the reference condition, defined as intact ecosystems..

Justification: *In the case of good ecological condition, anthropogenic pressure is possible, but not to a greater extent than that structure and function are still close to the reference condition. The definition of good ecological condition implies that the ecosystem is either so robust that the anthropogenic pressure does not significantly change the condition (resistance), or that the ecosystem's own internal processes can easily restore this condition (resilience). .*

Definition of intact nature/reference condition

B Intact semi-natural and natural ecosystems are characterized by the maintenance of the ecosystem's important ecological structures, functions and productivity. Intact ecosystems are further characterized by having complete food chains and nutrient cycles. Naturally occurring species make up the bulk of the entire food web and are dominant within all trophic levels and functional groups. Species composition, population structure and genetic diversity of naturally occurring species are a product of natural processes of change throughout the ecological and evolutionary history of the ecosystem. Intact ecosystems have characteristics that do not change systematically over time, but that vary within the boundaries of the natural dynamics of the system.

Human pressures may occur, but should not be pervasive or dominant, or be a factor that changes the structures, functions and productivity of the ecosystem. This means that the effect of human pressures should be on a scale and of an extent that does not exceed the effect of natural drivers of change or dominant species in the ecosystem (disturbances, apex predators, etc.). Furthermore, the human pressure should not lead to changes that are faster or more pervasive than natural drivers of change in the ecosystem. In semi-natural ecosystems, the man-made activities that define the system (e.g. mowing, grazing) are considered an integral part of the ecosystem.

How to deal with climate change when assessing ecological condition?

The technical system for good ecological condition should be used as a basis for future management of Norwegian ecosystems. We are primarily aware of natural processes and dynamics in intact terrestrial ecosystems in Norway, but have a weaker understanding of many marine ecosystems. Nevertheless, we do not have sufficient knowledge to predict the dynamics under known environmental conditions. We also have limited information about the distribution of ecosystems and individual species and ecological processes in time and space, and how these are affected by environmental variation (dose-response relationships). In its work on specific assessments of the condition of ecosystems, the Expert Committee has therefore chosen to use the distribution of ecosystems and their composition of naturally occurring species for a period close to the present. We have therefore based our work on the climate during the normal period 1961–1990.

C. The climate that forms the basis for assessments of intact ecosystems is that described in the climate normal for 1961–1990

D. The technical system is based on the distribution of ecosystems and their composition of naturally occurring species for a period close to the present

The following characteristics distinguish an ecosystem in good ecological condition:

1. The ecosystem's primary production does not differ significantly from production in an intact ecosystem

   Justification: *Too high or too low primary production indicates an affected system with regard to, for example, nutrients, over-grazing or drought.*

2. The distribution of biomass between different trophic levels does not differ significantly from the distribution in an intact ecosystem

   Justification: *A significant shift in the biomass distribution between trophic levels indicates an affected ecosystem and can, for example, result from decimation of apex predators.*

3. Functional composition within trophic levels does not differ significantly from the composition of an intact ecosystem

   Justification: *A significant change in functional composition within trophic levels indicates an impacted ecosystem. Examples include decline of groups of pollinating insects, increase in shrub growths at the expense of other plants in semi-natural ecosystems, and the dominance of jellyfishes in marine ecosystems.*

4. The functioning of functionally important species, habitat-building species and biophysical structures does not differ significantly from an intact ecosystem

   Justification: *Functionally important species, habitat-building species and biophysical structures are of great importance for population size for many other species. The change in the amount of these species/structures will thus affect many other species and functions in ecosystems. Examples of functionally important species, habitat-building species and biophysical structures are corals, kelp forests, small rodents, bilberries and dead wood.*

5. Landscape ecological patterns are compatible with the survival of species over time and do not differ significantly from an intact ecosystem.

   Justification: *Human-induced pressures can lead to altered landscape ecological patterns, which can affect the species' population size and structure, e.g. when harvesting, logging and fragmenting species' habitats. The remaining habitats must therefore be large enough and close enough to each other to ensure long-term survival of the species. Climate change, land use changes, pollution and alien species can also affect population sizes and age composition.*

6. The genetic diversity, species composition and species replacement of the ecosystem do not differ significantly from an intact ecosystem.

   Justification: *Loss of biodiversity can make the ecosystem less robust against impacts, thereby affecting the structure, function and productivity of ecosystems. Changes in species replacement rates, i.e. colonization and extinction, may indicate an impact on the ecosystem.*

7. Abiotic conditions (physical and chemical conditions) do not differ significantly from an intact ecosystem.

   Justification: *Human-induced pressures, such as pollutants, the supply of nutrients, altered hydrology or acidification, can lead to changes in the physical/chemical structure and function of ecosystems, which in turn can have consequences for the composition, function and dynamics of ecosystems.*

3.5 Criteria for choosing indicators that reflect ecological condition

The technical system for ecological condition should be based on a limited number of indicators that reflect the structure and function of ecosystems and take into account natural dynamics in ecosystems. In this context, an indicator can be defined as a variable, or a value derived from the variable, that provides information about the state of one or more of the seven characteristics that describe key properties of the ecosystem (Chapter 3.4). This chapter discusses criteria that should form the basis for the selection of indicators.

General requirements for good indicators

The use of indicators reduces the number of variables and measurements that would otherwise be necessary to provide a good overview of a situation, e.g. the ecological condition of an ecosystem. The use of indicators also allows for easier communication about the state of situation(OECD 2003).

The OECD (2003) has defined a set of basic criteria for environmental indicators **(Box 2)**, collected under three main categories: 1) relevance and usefulness, 2) analytical prudence and 3) measurability. The criteria describe the ideal indicator, and in practice it will be difficult to find indicators that meet all the criteria. In total, the indicators should cover as many criteria as possible, and do this as best as possible .

Box 2: Criteria for selecting environmental indicators

Policy relevance and utility for users

- Provide a representative picture of environmental conditions, pressures on the environment or society's responses
- Be simple, easy to interpret and able to show trends over time
- Be responsive to changes in the environment and related human activities
- Provide a basis for international comparisons
- Be either national in scope or applicable to regional environmental issues of national significance
- Have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.

Analytical soundness

- An environmental indicator should:
- Be theoretically well founded in technical and scientific terms
- Be based on international standards and international consensus its validity
- Lend itself to being linked to economic models, forecasting and information systems

Measurability

- Data needed to support the indicator should be:
- Readily available or be made available at a reasonable cost/ benefit ratio
- Adequately documented and of known quality
- Updated at regular intervals in accordance with reliable procedures

OECD (2003) OECD Environmental Indicators. Development, measurement and use. – OECD Reference Paper. OECD, Paris.

Criteria for the selection of indicators reflecting ecological condition

The Expert Committee has defined seven characteristics that describe key properties of an ecosystem in good ecological condition. Selected indicators to describe ecosystem condition:

- must reflect important features of the structure, function, and productivity of ecosystems, in accordance with important characteristics of good ecological condition (Chapter 3.4),
- can be biotic or abiotic variables

At the same time, the set of indicators should be sensitive to the supposed effects of the main human pressures on the ecosystem.

Relevant biotic indicators can be direct or indirect (surrogate) measures of a number of different biotic and abiotic factors and processes such as population level, extinction and immigration of different species, species composition, functional composition, biomass relationship between trophic levels, biodiversity, process rates such as production and decomposition of biomass, or resources such as amount of dead organic matter (e.g. dead wood). Knowledge of dose-response relationships between pressures and indicators increases the possibility of taking targeted management measures. Population levels of some species and resources (such as dead wood) may be sensitive to changes in the environment, are in principle measurable, and may have available time series data that are easy to communicate. At the same time, many such indicators may be needed to capture the important ecological functions, especially in species-rich systems where many species play similar roles, where each individual species may be rare (complementarity), or when they do not capture the effect of biodiversity.

Species richness per se can be difficult to use as an indicator because such data depends on monitoring efforts and experts with special expertise and is costly.

For species groups with many species, e.g. invertebrates and vascular plants, the composition of species within a trophic level can however often provide a precise, sensitive, robust and more easily measurable (in both time and space) estimate of ecological condition than the number of species or population level of individual species. This will be the case, for example, if many different species can contribute to an ecological function, or when the species respond equally to a pressure (see **Figure 4,** Cardinale et al. 2011). In the Water Framework Directive, species indices representing the relationship between sensitive and tolerant species are used for different pressures, often in the same way as described in Box 3. Here, dose-response relationships between pressure and effect on species composition are known. For terrestrial ecosystems, Ellenberg's indicator values for plant species are a useful framework **(Box 3)**. Another example is species indices established with data from ecosystem expeditions in the Barents Sea, where species occurrences

Box 3. The **Ellenberg** value of a plant community is determined from registrations of a large number of plant species in a monitoring location. Each plant species' value is based on the species' tolerance along important environmental gradients such as light, soil pH, moisture, nitrogen availability and environmental salinity (Diekmann 2003, Ewald 2003). The species' value reflects the species' realized ecological niche, i.e. an estimate based on the species' dose-response curves.

Ellenberg values can be calculated for entire plant communities as a weighted average, based on the Ellenberg value of the species and their relative quantity ratio. Such weighted averages can be good indicators of the community's response to specific influence factors. Ellenberg values for plant communities have been shown to be sensitive to environmental changes (Diekmann 2003) and at the same time robust to the omission of rare species (Ewald 2003). The use of Ellenberg values can therefore be an easy and cost-effective way to monitor a plant community, compared to following all individual species over time. Registration of vascular plants, focusing on relatively common species, can in this way provide indicators that provide a clear statement about changes in temperature, humidity, acidification, nitrogen degradation and salt impact. Ellenberg values must be validated for the ecosystems for which they will be used as they do not necessarily apply across different ecosystems (Diekmann et al. 2015).

are examined using standardized methods in a network of around 200 sampling stations in the area, an approach that allows robust estimation of species richness at a local and regional scale (Certain & Planque 2015). Functional features (Violle et al. 2007, Enquist et al. 2015) can similarly be used to compare information about the species' overall ecological responses and functions, across entire species communities of plants or animals.

Abiotic indicators should be directly linked to ecosystem function. One example of such an abiotic indicator is the ratio of nitrogen to carbon in the soil. The ratio, which increases with increasing nitrogen decomposition, has an impact on the functioning and structure of ecosystems. Other examples are water temperature, ocean currents and extent of sea ice, natural hydrology in wetlands, features of the snow cover, or the thickness of the active layer in the permafrost.

By choosing a few indicators to reflect good ecological condition, it is important to be aware that this results in greater uncertainty in the results than if many indicators are included (Siddig et al. 2016). This applies in particular to indicators used to assess the state of ecosystems with complex characteristics and partly unknown dynamics (Lindenmayer &Likens 2011, Beroya-Eitner 2016). However, the importance of the number of indicators depends on how much uncertainty there is associated with each indicator and whether the state of the indicators is combined through the "one-out, all-out" principle or a weighted average or by other methods.

The indicator set must be sensitive to the main human pressures

Using the DPSIR framework, we can distinguish between societal driving forces, the pressures resulting from these driving forces, the state of the environment, the impacts this has on nature and humans, and responses taken to reduce impacts or mitigate the effects (see Chapter 2.1).

The definition of good ecological condition is based on the fact that the pressure of anthropogenic activity can lead to a change in ecological condition when the pressure is extensive enough. Measures to improve the ecological condition are usually implemented by reducing the pressures. Knowledge of the most important pressures and their effects on the condition must therefore be in focus when indicators are selected. This means that the ecological condition indicator set must be sensitive to pressures.

Anthropogenic pressures are divided into five main categories;

- Land use and fragmentation (e.g. forestry, agriculture, infrastructure, grazing)
- Population harvesting (e.g. fishing and other harvesting, population regulations, illegal harvesting)
- Pollution (e.g. eutrophic and acidifying substances, pollutants, pharmaceuticals)
- Alien species
- Climate change (e.g. changes in precipitation, growing season, temperature, drought)

The division of pressures follows the most commonly used division of pressure factors for biodiversity. The units above are included in the same main categories as defined in the Norwegian Standard for Pressures, with the exception of logging, which is placed here together with forestry.

Several of these pressure factors can be both natural and anthropogenic (e.g. climate, acidifying substances), but knowledge of the cause of the pressures must be included in a comprehensive assessment when any measures are to be proposed. Knowledge of pressures is necessary in order to understand the reasons why ecosystems are changing.

At the same time, it is important to be aware that it is often difficult to develop indicators in which changes can be easily traced to specific pressures. This is, for example, a central experience from over 10 years of work on indicator development for the overall management plans for the marine areas (von Quillfeldt & Dommasnes 2005, Dommasnes et al. 2008, van der Meeren et al. 2012). Moreover, there are often several different factors that affect the same element of an ecosystem. What is then measured by an indicator will be the result of the combined pressure of the various factors (Barton et al. 2015). Understanding such overall effects can be very difficult and in marine ecology is considered the most important research question for the development of sustainable management (Rudd 2014). This means that by focusing only on indicators that are thought to be sensitive to a single type of known pressure, one may risk not being able to record unexpected results of more complex effects (Lindenmayer et al. 2010). In practice, we must therefore make trade-offs between indicators that capture development in the seven characteristics of good ecological condition, while also seeking indicators that can identify and distinguish the effects of pressure factors.

Alien species do not belong to intact ecosystems. Alien species can, but must not necessarily, have an impact on the ecological condition. Relevant state indicators will be the effect that alien species have on indigenous species diversity, ecosystem processes, etc. In some cases (especially during climate change), however, alien species will eventually be able to dominate the ecosystem's characteristics to the extent that they must be included as indicators of condition. For pollutants, it is difficult to find good biological condition indicators as clear dose-response relationships are often lacking in nature. The concentration of pollutants in organisms is usually considered a pressure factor, but, in the absence of good condition factors, it can possibly be used because high concentrations can lead to reduced fertility and survival, especially in apex predators.

The effect on the condition of an ecosystem can be amplified or reduced through interaction between pressure factors. For example, climate change can affect the occurrence and distribution of alien species. Another example of interacting effects is the construction of infrastructure in mountains that entails more human activity, littering and disturbances of wild fauna species.

Indicators of ecosystem robustness

Robustness means the system's ability to maintain its distinctive characteristics within normal limits under external pressures. Robust systems change relatively little with a given impact (have great resistance), and to the extent that change occurs, the system has a great ability to recover (has great resilience). It is initially demanding to measure the robustness of an ecosystem, and research has not found an unambiguous operationalization of this concept (Mumby et al. 2014). It is also worth noting that great robustness itself does not have to be beneficial, because severely degraded systems can be more robust than intact (pristine) systems, in that they show little sensitivity to further disruptions (Standish et al. 2014). In principle, robustness can be estimated using time series data that include experimental manipulations, or by model analyses when ecosystem functions and their relationships to pressure factors are so well known that they can be formulated mathematically. Such knowledge is largely lacking for Norwegian ecosystems. Nevertheless, on a generally theoretical basis, it is possible to give certain qualitative assessments of robustness based on certain system characteristics (Levin & Lubchenco 2008). For example, robustness can be expected to be related to characteristics such as functional diversity (number of functional groups) and redundancy (number of species with overlapping functions) (see Chapter 3.2). In addition, the complexity of the food web is an important characteristic; e.g. how many and how diverse the relationships are between the species. Reductions in these characteristics, relative to the intact condition, indicate that the ecosystem has become less robust. However, it is notoriously difficult to determine limit values for such characteristics/indicators because they usually have unknown nonlinear relationships to the overall condition of the system (Standish et al. 2014).

3.6 Limit values for the indicators at good ecological condition

In this report, good ecological condition in Norwegian ecosystems is defined by the fact that the structure, function and productivity of ecosystems do not differ significantly from intact ecosystems. Good ecological condition is further described using seven characteristics of ecosystems, and Chapter 4 provides a more detailed description of how these characteristics are expressed in each ecosystem. Indicators representing the different characteristics have been chosen to assess ecological condition. An indicator will then represent good ecological condition if the indicator value does not differ significantly from its value in the reference condition (the reference value). When determining reference values, the definition of intact nature is based on Chapter 3.4 and the Expert Committee's approach to intact nature as described in Chapter 3.3, as well as in ecosystem-specific descriptions in Chapter 4. In many cases, there will not be sufficient knowledge to set empirical values for the indicators in the reference condition. This knowledge must be developed over time so that reference values can be set. Given that reference values can be set for an indicator, it is an important part of the work to assess what constitutes a "not significant deviation". This chapter describes the Expert Committee's proposal for how to determine values for good ecological condition for individual indicators, and provides further suggestions for methodology for scaling the indicators so that the limits for good ecological condition can be represented by a number that is comparable across indicators.

Determination of limit values for individual indicators
In the work of the Water Framework Directive, dose-response relationships are used to set limit values between different condition classes (Appendix 3). In dose-response models, there is a clear understanding of the relationship between the extent of the pressure and the value of the indicator, which will be helpful in setting limit values. Another important precondition for setting limit values is that the functional relationship between the indicator and the characteristic in the ecosystem it reflects is known.

The limit value for good ecological condition for an indicator is set so that it corresponds to the normative descriptions of good condition. In this work, however, we have a lack of knowledge about dose-response relationships between pressures and indicator values for most indicators, so that a procedure in line with the Water Framework Directive is difficult to implement (Appendix 3). At the same time, many of the indicators chosen in this technical system respond to several pressures at the same time. Thus, the focus on dose-response relationships for these indicators is also less relevant for setting limit values. The development of reference values and limit values for indicators must be carried out in further work with the technical system and build on experience and knowledge from other work.

When data and knowledge are inadequate, and one cannot estimate the value of good ecological condition for an indicator, but the reference value is known, the Expert Committee proposes, as a first approach, that the biological knowledge one has about the system is used to set up an assumption of what the limit value is. The assumption must be accompanied by a justification, so that the assessment is transparent.

In cases where it is not possible to set limit values based on the knowledge one has today, it must be reported that the limit value is unknown. Further data collection and analyses will thus be required to determine the limit value for these indicators. Practical use of such indicators will therefore lie somewhat in the future. The use of expert assessments is discussed in more detail in **Box 4.**

Box 4. Assessment of uncertainty and use of expert judgement.

The Expert Committee sees the necessity of knowledge-based management of our ecosystems, where results from monitoring and research are central to our management. The established technical system shall provide the best possible basis for assessing ecological condition, effects of anthropogenic pressures and trends over time. Ecosystems are complex, and the Expert Committee recognizes that establishing both threshold values and reference values for indicators is associated with a lot of uncertainty, both now and in the longer term. At the same time, the Expert Committee sees that the management needs an operational system that can form the basis for management objectives and decisions.

The Expert Committee believes that operationalization of the technical system must be a dynamic process, with testing, evaluation and adjustment of the choice of indicators and their associated reference and threshold values.

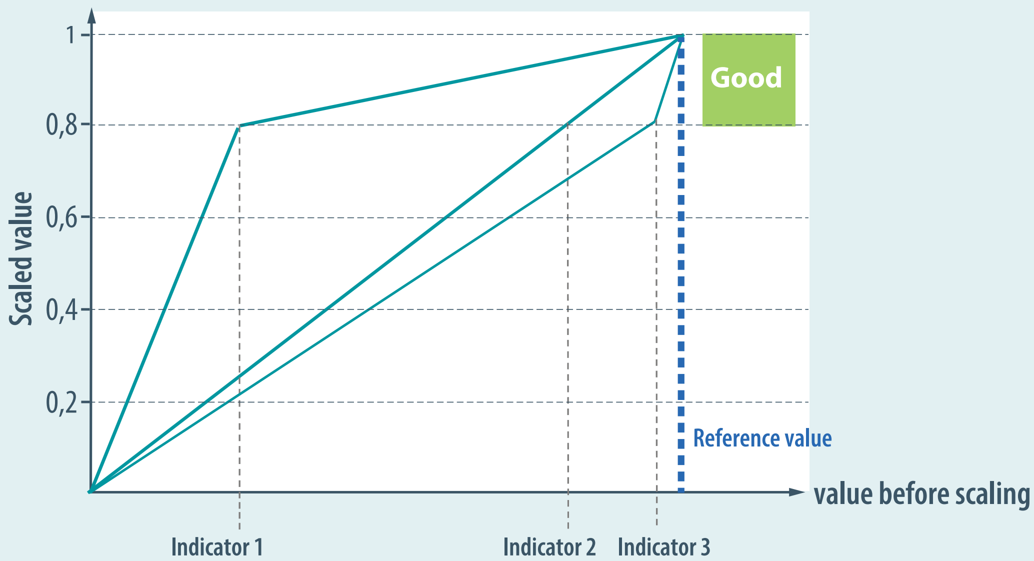
The use of experts in further work is therefore necessary. Expert assessments are used in the implementation of the Water Framework Directive, the Nature Index, the Red List work for species and nature types and in the Black List work, in the Norwegian Scientific Committee for Food and Environment and in the assessment of fish stocks under the EU Ocean Directive. Expert assessments are based on known data, e.g. observations, field data, research and monitoring, but where "modelling" takes place in an expert's head and not through structured mathematical models. It is therefore important that the quality of the experts is good, and that good agreed criteria form the basis for how the expert assessments should be conducted.

Suggested method for scaling limit value for individual indicators

The Expert Committee wishes to present a simple and transparent method for determining the ecological condition. We therefore build our approach on the Water Framework Directive and by focusing on numerical values for good ecological condition. By using numerical values, it is easier to test, refine and improve the proposed technical system than one that is based only on a qualitative (textual) description of the condition. The Expert Committee considers it necessary that the system is tested and improved over time.

Scaling (standardization) of the values of the indicators included in the technical system for ecological condition makes it possible to compare the state of different indicators across measurement scales in the same way as in the Water Framework Directive, Nature Index and, for example, international work assessing the state of different marine areas (Halpern et al. 2012). Scaling indicator values is necessary if several indicators are to be combined into an index, either as one index of ecological condition in an ecosystem or as separate indices for each of the seven characteristics of good ecological condition (see example in 3.8). Scaling can also help to highlight which pressure factor produces the greatest deviation from good ecological condition by presenting scaled values for indicators sensitive to given pressures. Scaling also simplifies the communication about the content of the technical system.

In the Water Framework Directive, a five-step scale is used to assess the ecological condition: very good, good, moderate, poor and very poor (Chapters 2.2.2 and Appendix 3), and as a general rule, the scaling functions require five parameters: the limit values between the state classes very poor/poor, poor/moderate, moderate/good and good/very good, in addition to the reference value. The Expert Committee proposes a simplification of the Water Framework Directive's approach, in which two values for an indicator must be stated: a reference value and a limit value for good ecological condition. The indicator is then scaled so that the scaled reference value is 1 and the scaled value for good ecological condition is 0.8.[9] When the indicator is absent, the scaled value is 0. Such an approach ensures that an indicator value of 0.8 reflects good ecological condition for all indicators, for those indicators where limit values for good ecological condition are set.



Figur 5. *Good ecological condition is assessed on the basis of knowledge of the indicator's reference value and limit value (value with good ecological condition). The indicator is scaled so that the reference value is set to equal 1, the limit value is set to 0.8 and the absence of the indicator to 0. In the example, the relationship between unscaled and scaled indicator values is given for three indicators of equal value in reference condition (red line), but different values in good ecological.*

[9] *The scaled limit for good ecological condition was changed to 0.6 after this report was launched*

The scaling function proposed by the Expert Committee is illustrated in **Figure 5**. The scaling model is linear for the interval between the reference value and the limit value for good ecological condition, and for the interval between the limit value and the absence of the indicator. As the chart shows, the scaling function allows for the deviation between the reference value and the limit value for good ecological condition to vary for different indicators. The proposed model implies that if one knows only the indicator value in good ecological condition, and not the exact reference value, this may nevertheless provide a basis for assessing whether the indicator is in good ecological condition.

The Expert Committee's proposed scaling function means that the scaled value 0.8 will reflect an indicator of good ecological condition for all indicators in the technical system where the limit value can be set. The scaling function can be further developed to include limit values between several state classes, cf. Water Framework Directive.

There can however be a challenge in that the relationship between the indicators and the characteristics of the ecosystem they are to reflect (Chapter 3.4) is either complex, so that they cannot be easily represented with such simple functions (Barton et al. 2015), or is unknown. The Expert Committee recognizes this, and the proposed scaling function is a simplification of reality. With increased knowledge of the relationships between pressures, indicator values and ecological condition, it should be considered whether more scaling functions should be developed. In later versions of the technical system, it must in this case be specified which scaling function is best suited for each indicator.

It is emphasized that the proposals for limit values and scaling must be tested in practice on a wide range of indicators before the final method can be determined. As in the Water Framework Directive, testing must assess whether the limit values are in accordance with the normative description of good condition **(Appendix 3).**

Furthermore, a method must be developed to assess each of the seven characteristics in cases where they will be based on multiple indicators and finally a method for assessing the overall ecological condition based on all relevant characteristics that will apply to an ecosystem. Chapter 3.8 describes some approaches to this, and provides some illustrations on how the condition of an ecosystem can be visualized (Chapter 3.9).

3.7 Management of uncertainty

Scientific uncertainty can be characterized along a gradient from certain knowledge, where everything is known, to total ignorance, where nothing is known and one does not even know what one does not know (Walker et al. 2003, Gillund & Myhr 2007). One often operates with two sources of scientific uncertainty: limited knowledge and natural variation in the system being studied. Uncertainty due to limited knowledge can be reduced by more research; more observations, better procedures for data collection, conducting controlled experiments, better models, etc. Uncertainty due to natural variability and complexity (e.g. stochastic variability) can often be understood as an inherent characteristic of the systems studied (Walker et al. 2003). Stochastic variability in the systems can hardly be reduced with more research, but through the creation of time series data, variability can be quantified.

The uncertainty associated with limited knowledge can be handled with different strategies. Below we describe the classification systems where the management of uncertainty has been well worked out.

The Nature Index integrates uncertainty into all indicator values in the index presented; for details see Pedersen &Nybø (2015). Simplified, the uncertainty of each indicator is indicated by quartiles, i.e. the interval in which the indicator value is 50% probability. This information is used in probability distributions where the spread of the distribution represents the uncertainty and the distribution's position on the line of possible valuesindicates the indicator value used in further calculations of the Nature Index. The uncertainty of the individual indicators is integrated by bootstrapping.

In the Water Framework Directive, uncertainty is assessed individually for indicators that determine the class limit for the water body. The uncertainty in the classification is based on where the mean of the indicator is relative to the class boundaries, and how large the standard deviation around the individual indicator's mean is. If the mean is close to a class boundary, the water body is just as likely to belong to the best of the two classes. If the mean is in the middle of a class and has a small standard deviation, it is very likely that the water body is in that class. If the standard deviation is greater, the distribution will more easily overlap one or more class boundaries, and the uncertainty in the classification will thus increase.

Reduction of uncertainty in the classification (pursuant to the Water Framework Directive) is particularly important if the condition is close to the good/moderate limit, as moderate condition triggers measures. A general recommendation is that the probability of misclassification should not exceed 20% if misclassification has an impact on whether action should be triggered. Where one has good measurement data, one will often also be able to indicate the uncertainty in the form of a distribution curve – how likely it is that the condition of a water body is very good, good, moderate, etc.

The reliability of the classification of each water body should be set to high, medium or low.

- high reliability: the classification is based on monitoring data for at least one biological quality element and some supporting parameters, as well as other criteria, such as the use of intercalibrated indices and class boundaries, many samples, low standard deviation, and a mean that is nowhere near a class boundary
- medium reliability: the classification is based on solid monitoring data for at least one biological quality element, and that all but one of the criteria required for high reliability are met
- low reliability: the classification is done without monitoring data, is based on expert assessments, or sparse data for one quality element exists, but where none of the criteria required for high reliability are met

The classification of a water body must always be assessed based on what is considered reasonable from the local conditions. Inadequate data, delayed biological response, as well as other locality-specific conditions may also explain any discrepancies between condition based on expert assessment and a classification result calculated from available data. For example, water bodies on the boundary between two or more water types are assumed to have a more uncertain classification than water bodies far from type limits, and classification based on one year's measurement data or where the condition varies widely between years will be more uncertain than classification based on several years of measurement data or/and where the condition varies little between years.

The Expert Committee has not concluded how uncertainty should be handled when setting reference values and limits for good ecological condition, see also Chapter 3.6.

3.8 Overall assessment of ecological condition based on multiple indicators

The Expert Committee shall propose scientific indicators and criteria for ecological condition in Norwegian ecosystems that, at a minimum clarify, what is "good ecological condition". Good ecological condition is assessed on the basis of ecosystem characteristics and is based on selected indicators that reflect these characteristics (Chapter 3.5). At the same time, these indicators should be sensitive to important human pressures on the ecosystem. Management authorities will then be able to target measures to reduce negative impacts. In the long term, lower impact will improve the condition of the indicator. In addition to presenting the state of each individual indicator, all indicators must be assessed collectively for a comprehensive assessment of the ecosystem's condition. From other classification systems, we know two different approaches to assess the overall ecological condition based on several indicators. The two approaches are:

1. The indicator with the lowest scaled value indicates the condition of the ecosystem. This is referred to as the "one-out, all-out principle" (Water Framework Directive and the IUCN Red List of Ecosystems; Keith et al. 2015).
2. A weighted average of scaled indicator values (Nature Index).

Approach 1 works so that the worst indicator value determines how good the overall ecological condition is in each water body. For the management of water, this can be an advantage, as it is immediately possible to recognize where measures must be taken and against what impact. This is possible because the indicators representing the biological quality elements (as well as physicochemical and hydromorphological supporting parameters) in the Water Framework Directive are designed to respond to specific pressures. The "one-out, all-out" principle is sensitive to the number of indicators included in the technical system; the probability of an indicator falling below the limit value for good ecological condition must be assumed to increase with increasing numbers of indicators.

Approach 2 is used in the Nature Index. It includes many more indicators than the Water Framework Directive, and it should be representative of large geographical units, not for small areas such as water bodies. The Nature Index presents the total Nature Index value as a weighted average of the indicators, where the value 1 shows that the ecosystem is in the reference condition (intact nature) and the value 0 indicates a broken ecosystem where naturally occurring species have more or less disappeared. A weighted average means that functionally important species and important biophysical elements are given greater weight than other indicators (see characteristic 4, Chapter 3.4). These indicators should be based on good datasets. The Nature Index value is followed by text describing which parts of biodiversity contribute to the Nature Index value, and what is known about the causes of the condition and changes in development. Supporting information on the extent of pressures is used in this process. An argument against an aggregate index is that it can be inappropriate to present ecosystem conditions – a genuinely complex characteristic – with a single number (Burgass et al. 2017).

A third alternative approach entails that, rather than determining ecological condition using a stringent mathematical framework such as in the Nature Index, one uses experts who jointly determine the ecological condition. The experts can then take into account that there is a different degree of knowledge and data about the ecosystem's characteristics. For characteristics where one has data on reference and limit values, one uses the number-based system for individual indicators and supplements with qualitative expert assessments for the indicators for which data are sparse, so that this includes a comprehensive overall assessment. Such an expert assessment must be carried out according to stringent and established methods that must be developed. Finally, a comprehensive assessment of the condition of the ecosystem is given which is clearly justified on the basis of the varying knowledge base and weighting based on the assessments for significance of each of the different characteristics for the current ecosystem. This can be done, for example, by specifying how many characteristics the condition is good for and how many it is not good for.

Assessment of developments in the ecosystem over time is an important part of the assessment of ecological condition, regardless of the choice of approach for overall assessment.

The Expert Committee has not concluded which approach is best suited for assessing good ecological condition. Which approach is best for assessing the importance of uncertainty in the datasets must be considered in concrete testing of the ecological condition indicator set.

3.9 How to visualize good ecological condition?

Both the Water Framework Directive and Nature Index visualize the state of ecosystems on a colour scale from blue (condition near the reference condition) to red (highly degraded ecosystems). The Water Framework Directive operates with five condition classes, each represented by its colour; blue (very good condition), green (good condition), yellow (moderate condition), orange (poor condition) red (very poor condition), while the Nature Index has a continuous colour scale from blue to red. Two alternative ways of presenting the ecological condition are shown below **(Figure 6)**. Both options visualize the state of the seven characteristics discussed in Chapter 3.4. The data is fictitious.

3.10 How to assess the ecological condition of an area that changes from one habitat type to another

An area can change from one nature type to another. This can happen quickly, for example by developing a new motorway in a wooded area, or slowly, for example by trees and bushes invading a coastal heathland. At some point, coastal heathlands will transition to being forest, or forest to highway. Conversely, some greatly altered habitats can be changed to natural ecosystems, e.g. from quarries to wetlands, or aquatic ecosystems can be converted into terrestrial ecosystems by hydropower development. Mountain areas may be converted into forests under future climate change, and sea level rise can convert coastal areas into marine areas. In some cases, it is also conceivable that "new ecosystems" (Hobbs et al. 2014) may occur below levels or combinations of pressures that do not have historical or geographical analogues. Areas can therefore both change the main ecosystem (from water to land) and from one level 2 ecosystem to another.

This sub-chapter describes how one imagines that the ecological condition should be assessed in areas that are converted from one type of nature to another. We illustrate this with an example from coastal heathland. A coastal heath where the management ceases will regrow and turn into forest. The indicators describing the ecological condition will show that

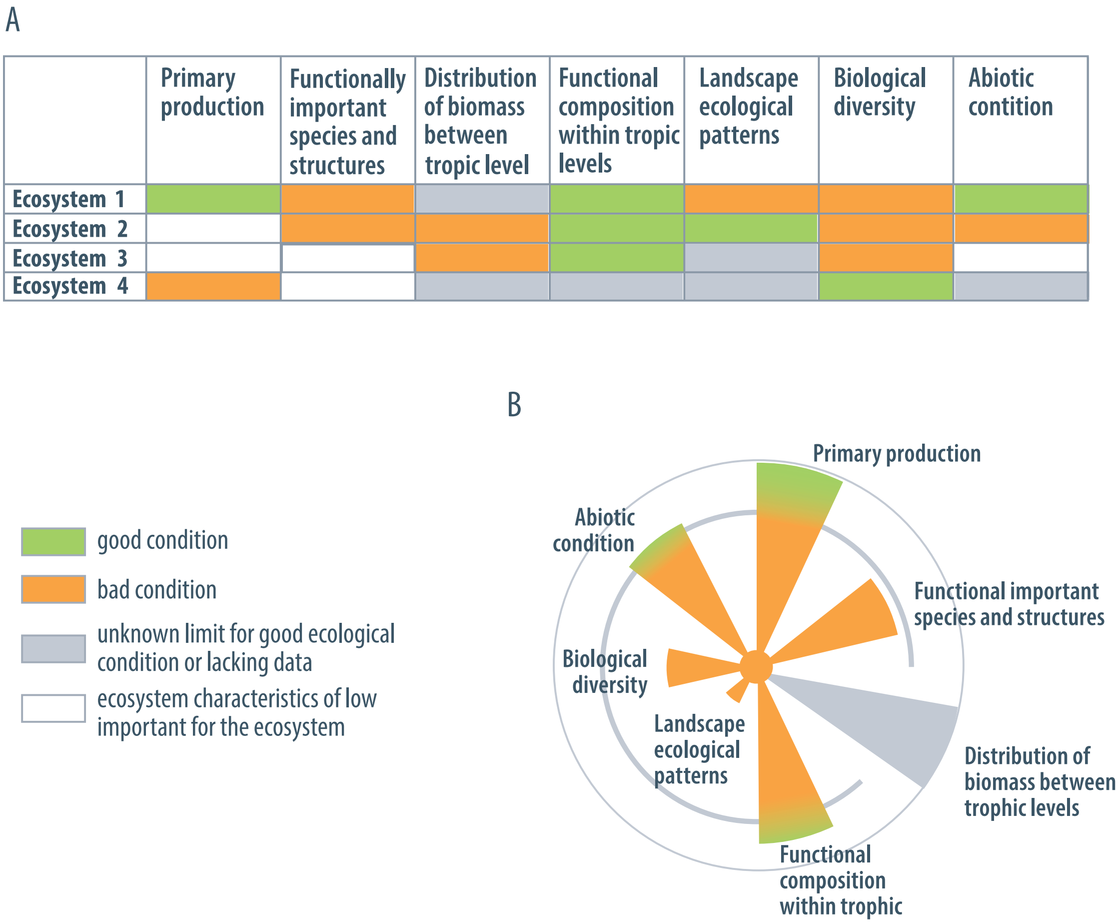


Figure 6. *Figure 6. Visualization of the state of the seven characteristics that characterize good ecological condition. A. Green: good condition, orange: poor condition. White indicates that the property is less relevant for assessing the ecosystem. Grey indicates that indicators have been proposed, but they are not operational due to lack of data or lack of limit values. B. The condition of ecosystem 1 visualized with a star chart. Thick circle line represents the limit value for good ecological condition (0.8) and the reference value (1) is the outer circle. The colour green shows which characteristics are in good or better condition than the limit of good ecological condition, while orange indicates a condition inferior to good. For characteristics where known limit values are missing, this is marked by the removal of the thick circle for good condition. Grey indicates that there are insufficiently data to evaluate condition for this characteristic.*

<u>Exception from a member of the Committee</u>: Per Arneberg takes exception to the proposal for the use of the star chart as an illustration of the ecological condition of the various characteristics. The star chart cannot be used if the rating for each characteristic is to estimate whether the condition is good or not without specifying a numerical value.

over time, coastal heathland develops into an increasingly poor ecological condition **(Figure 7)**. When the condition is so poor that it can no longer be defined as a coastal heathland, the condition of the area will be assessed according to indicators of the ecological condition in forests.

For rapidly changing areas, e.g. from forest to highway, one will not see a gradual change. For greatly changed habitats such as paved areas, principles for good ecological condition have not been developed. Figure 7 reflects changes in an area with a limited extent, i.e. a local assessment. When assessing ecological condition on a coarser scale, e.g. at county level, landscape ecological conditions (Hobbs et al. 2014) must also be considered. Fragmentation and area loss may affect population size and/or survival of species (Characteristic 5, Chapter 3.4). If larger areas of coastal heathland disappear, assessments related to Characteristic 5 will show that the ecological condition of coastal heathland is poor.

3.11 Updating frequency

For terrestrial systems, it is recommended that the work on assessing ecological condition is done every 5 years.

Efforts must be made to provide a common knowledge base for the indicators (including species and species composition, and data from other sectors) that will be assessed. Today, extensive work is carried out under the auspices of the Nature Index to obtain data on indicators from different databases, and to model developments in the indicators at the most detailed relevant geographical scale. This knowledge may benefit both the Red List work and the work on ecological condition.

The Nature Index and the Red List for Species are compiled every 5 years. A five-year refresh rate coincides with the originally planned frequency of ongoing aerial photography. However, the Norwegian Mapping Authority has announced that this has now been increased to seven years per survey. The aerial photography covers mainland Norway. Other types of remote sensing data, such as satellite monitoring and LIDAR data, are either updated so often or have not so comprehensive geographical coverage that it should currently govern ecological condition refresh rates.

For indicators that are not included in the Nature Index or other programs that are updated, work on obtaining data must begin as soon as possible, so that it is possible to use the technical system from 2020.

For marine systems, it is recommended that the work on determining the ecological condition coincides with the work on updating the management plans. In the updated management plan for the Norwegian Sea (Notification to the Norwegian Parliament to be considered by the Norwegian Parliament in June 2017), it is proposed that each management plan be updated every 4 years and revised every 12 years.

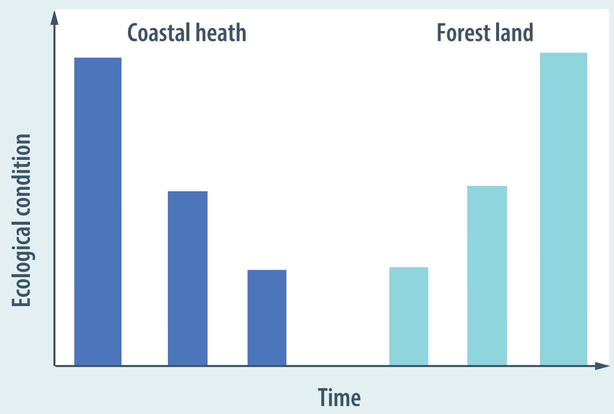


Figure 7. *A sketch of how the ecological condition of coastal heathland decreases in line with regrowth, and where at a given time it changes its nature type to forest. The ecological condition of coastal heathland is assessed according to indicators selected for this ecosystem (dark blue pillars), while the condition of forest is assessed according to indicators selected for forest (turquoise pillars).*

4 References

This reference list contains only references used in the first three chapters. Norwegian documents is referred in Norwegian language as in the original report. The reference list of the original document is 21 pages. Many of those references are ecosystem specific (i.e. in chapter 4).

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Appendix

Appendix 1 Mandate for the Expert Committee for Ecological Condition

The task of the Expert Committee will be to, by 1 June 2017, with the exception of areas that fall under the follow-up of the Water Frame Directive Regulations, propose scientific indicators and criteria for ecological condition in Norwegian ecosystems that at least clarify what is "good ecological condition".

The Expert Committee shall propose a technical system that initially can be established for ecosystems at county/ region level, or other professionally based, appropriate levels, with an approach that is cost-effective and usable for the management authorities such that it can be taken into use in management by 2020.

The system shall be far simpler than the system established for follow-up of the Water Frame Directive Regulations. The focus should be on what is good condition, and not other class boundaries. The technical system shall also be based on a limited number of indicators that reflect the structure and function of ecosystems and take into account natural dynamics in ecosystems.

In the ecosystem "open seas", the development of scientific criteria for "good ecological condition" shall be carried out as part of the work on the management plans. The criteria for good ecological condition in ecosystem "open seas" shall be included in an overall proposal for a technical system from the Expert Committee for Ecological Condition so that a comprehensive technical system with a common framework for ecological condition can be established in all ecosystems.

The Expert Committee shall also make recommendations on how often the state of the various ecosystems should be assessed and classified, and point out which approach and degree of detail should be an aim for a technical system in the longer term.

The committee's work will be based on existing and available scientific knowledge about the condition and development of Norwegian ecosystems, and build on and supplement existing relevant classification systems.

The Expert Committee shall submit its proposed system to KLD by 1 June 2017. A secretariat in NINA is established for professional and administrative assistance to the Expert Committee. The Expert Committee may seek assistance from relevant academic communities on specific topics. Representatives from the Norwegian Environment Agency and other directorates participate as observers in the Expert Committees' meetings.

Appendix 2 Definition of key concept

Classification: the process that determines the ecological state of each individual water body (in the Water Framework Directive)

DPSIR model: a conceptual framework that highlights the interactions between society and the environment, contains five components:

- Drivers: underlying driving forces, such as population, economy, technology, social structure. The term "indirect drivers" is used in some contexts equivalent to drivers. This report uses the term "drivers".
- Pressures: the actual factors that affect the environment, e.g. emissions of acidifying substances and pollutants, land use changes or alien species. The term "direct drivers" is used in some contexts. The present report uses the term "pressures"
- State: changes in the environment as a result of influences, e.g. changes in air or water quality, quality or amount of resources for species, population level for species or level of other ecosystem components.
- Impacts: effect on the functioning of ecosystems or the viability of species. The distinction between state and impact for ecosystems can be difficult, but these two concepts can be roughly linked to the structure and function of ecosystems, respectively, which can collectively be understood as **"ecological condition"** as the Expert Committees' mandate is designed.
- Responses: policy or measures can be implemented with a view to improving the condition. The responses can, for example, be aimed at changing the scope of drivers (e.g. technology development), reducing influences directly (e.g. emissions of sulphur to air) or improving the condition (e.g. liming of lakes, restoration of degraded nature).

Ecological condition: "Status and development of functions, structure and productivity in the localities of a nature type in light of current influence factors" (Nature Diversity Act §3).

Ecological functional area for species: an "area – with delimitation that may change over time – that fulfils an ecological function for a species, such as spawning area, recruitment area, larval drift area, migration routes, grazing area, denning area, moulting area, day or night resting area, lekking or mating area, nesting or reproduction area, over-wintering area and home range." (Nature Diversity Act §3)

Ecosystem: "a more or less well-defined and uniform natural system in which communities of plants, animals, fungi and microorganisms interact with the non-living environment" (Nature Diversity Act §3).

Ecosystem function: synonymous with the concept of ecosystem processes, which describes inherent features of the ecosystem that allow the ecosystem to maintain its integrity or health (Millennium Ecosystem Assessment 2005). Ecosystem processes can be physical, such as transporting water or sediments, or biological, e.g. photosynthesis, decomposition or grazing. Ecosystem function also includes ecological functional areas for species.

Ecosystem structure: is the biophysical structure of an ecosystem (TEEB 2010). The term encompasses biodiversity, including the composition of species in an ecosystem, and also number, quantity (abundance) and quantity distribution of different species. The term also encompasses an ecosystem's trophic structure; how many trophic levels (links in the food web, e.g. plants, herbivores and predators) exist, or how the biomass in an ecosystem is distributed between different trophic levels. Furthermore, ecosystem structure can describe how the composition of the biotic parts of the ecosystem shapes the ecosystem's biophysical architecture, such as trees, coral reefs and kelp forests (NOU 2013). Central to the concept of ecosystem structure is biodiversity.

Ecosystem type/ nature type: "a uniform type of nature that encompasses all living organisms and the environmental factors that act there, or special types of natural deposits such as ponds, non-arable outcrops or similar, as well as special types of geological formations" (Section 3 of the Nature Diversity Act).

Functionally important species: a species whose population is of great importance for the occurrence of a range of other species, either by virtue of its dominance or by virtue of being a key species.

Good ecological condition: the structure, function and productivity of ecosystems do not differ significantly from the reference state, defined as intact ecosystems. A well-functioning ecosystem, where the natural ecological functions are maintained and most species and ecological functions are in place, will have a good ecological condition (see ecological condition). Good ecological condition is not necessarily the same as the natural condition (Meld. St. 14 (2015–2016)). In good ecological condition, anthropogenic influence is possible, but not to a greater extent than that structure and function are still close to the reference state. The definition of good ecological condition implies that the ecosystem is either so robust that the anthropogenic influence does not significantly change the condition (resistance), or by allowing the ecosystem's own internal processes to easily restore this condition (resilience).

Indicator and variable: An indicator is a characteristic of a phenomenon one is interested in (e.g. wanting to map or monitor). A variable is basically any quantitative or qualitative expression of a given characteristic. An operational indicator must be based on one or more specific variable(s) that best represent the characteristics of the phenomenon of interest or by derivation from such variables.

Intact ecosystems: natural or semi-natural ecosystems where important ecological structures, functions and productivity are safeguarded, food chains and substance cycles are complete, naturally occurring species make up the bulk of the entire food chain and are dominant within all trophic levels and functional groups. Species composition, population structure, and genetic diversity of naturally occurring species are a product of natural processes of change throughout the ecological and evolutionary history of the ecosystem. In intact ecosystems, ecological resistance and resilience are relatively constant over time, with natural dynamics. Anthropogenic pressure may occur, but should not be a pervasive, dominant, or a factor that changes the structures, functions and productivity of the ecosystem. This means that the effect of the anthropogenic pressure should be on a scale and of an extent that does not significantly exceed the effect of natural impact factors or dominant species in the ecosystem (disturbances, top predators, etc.). Furthermore, the anthropogenic pressure should not lead to changes that are faster or more pervasive than natural pressure factors in the ecosystem. In semi-natural ecosystems, the anthropogenic activities that define the type of nature (e.g. grazing, mowing) are considered an integral part of the ecosystem.

Key species: species whose impact on ecosystem function and diversity is disproportional with the quantity of the species in the ecosystem. Although all species interact, the interactions between some species are more pervasive than others, so that if the species are removed from the ecosystem, it often has cascade effects with direct and indirect changes at more than one trophic level, often with loss of habitats or other species (Soulé &Noss 1998)

Management objectives: society's goal for the ecological condition an area or ecosystem should have. The management objective can be either higher, lower or equal to good ecological condition. The action plan also uses the term "desired state" in management objectives. (Report to us St. 14 (2015–2016)).

Productivity: the rate of biomass production in an ecosystem, expressed per area and time unit.

Reference value: The value an indicator would have in the reference condition. The condition of an indicator is assessed against the reference value. The greater the deviation from the reference value, the poorer the condition is reflected by the indicator.

Reference condition: see Intact ecosystems
Robust ecosystems: Used to describe ecosystem resistance and resilience to climate change and disruption. Resistance describes the ecosystem's ability to withstand climate change and natural and anthropogenic disturbances and remain within a certain condition. Resilience describes the ecosystem's ability to recover from climate change and natural and anthropogenic disturbances. Although the terms are not strictly defined scientifically, both concepts are closely related to the ecological condition and maintaining the variability, structure and function of the ecosystem. (Meld St. 14 (2015–2016)).

Robustness: robustness means the ecosystem's ability to maintain its characteristic properties within normal limit values under external influences.

Semi-natural ecosystems: ecosystems that require, and to such a great extent are characterized by, anthropogenic disturbance that ecosystem function, ecosystem structure and ecosystem services change significantly, but without the system being pervasively altered and without it being a holistic ecosystem (Halvorsen et al. 2016b). In practice, this means ecosystems that are predicated on long-term extensive use.

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