European Commission

Technical Guidelines for assessing and monitoring the condition of Annex I habitat types of Directive 92/43/EEC

Summary and Overall Methodology

ATECMA & DAPHNE
November 2025

EUROPEAN COMISSION

Directorate-General for Environment
Directorate D — Biodiversity
Unit D3 — Nature Conservation

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European Commission
B-1049 Brussels

Technical Guidelines for assessing and monitoring the condition of Annex I habitat types of Directive 92/43/EEC

Overall Methodology

2025

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This document must be cited as follows:

Olmeda, C., Šefferová Stanová, V. & Simon, J.C. (2025). Overall Methdodology. In: C. Olmeda & V. Šefferová Stanová (eds.), Technical guidelines for assessing and monitoring the condition of Annex I habitat types of the Directive 92/43/EEC. Luxembourg: Publications Office of the European Union, ISBN 978-92-68-32014-3. https://doi.org/10.2779/8464172

Manuscript completed in September 2025

Luxembourg: Publications Office of the European Union, 2025

PDF ISBN: 978-92-68-32014-3 DOI: 10.2779/8464172 KH-01-25-199-EN-N

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Acknowledgements

This document was prepared in the framework of a European Commission contract with Atecma, Daphne and the IEEP for the elaboration of Guidelines for assessing and monitoring the condition of Annex I habitat types of the Directive 92/43/EEC (Contract nr. 09.0201/2022/883379/SER/ENV.D.3).

Concha Olmeda (Atecma) and Viera Šefferová Stanová (Daphne) coordinated a team of scientific experts that elaborated the guidelines for all habitat types, and provided input during their preparation.

An ad-hoc group of experts nominated by Member States administrations, the European Topic Centre for Biodiversity and Ecosystems, the Joint Research Centre, EuropaBON, the European Environment Agency and the European Commission, provided advice and support throughout the development of these technical guidelines.

Angelika Rubin and Marina Xenophontos (European Commission) and Eleni Tryfoni (European Environment Agency) supported the elaboration of the guidelines and contributed to the preparation of the Overall methodology. They provided particularly useful insights to refine this document. Their contributions are gratefully acknowledged.

Glossary and definitions

Habitats

Natural habitats: are terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (Habitats Directive, Art.1(b)).

Habitat condition: is the quality of a natural or semi natural habitat in terms of its abiotic and biotic characteristics, in particular its structure, function and typical species or typical species composition. In the framework of conservation status assessment under the Habitats Directive, condition corresponds to the parameter "structure and function (including typical species)". The condition of a habitat asset (spatial unit) is interpreted as the ensemble of multiple relevant characteristics, which are measured by sets of variables.

Habitat characteristics: are the attributes of the habitat and its major abiotic and biotic components. They can be classified as abiotic (physical, chemical), biotic (compositional structural, functional) and landscape characteristics (based on the Ecosystems Condition Typology defined in the SEEA-EA; United Nations et al., 2021).

Species

Characteristic species: are species that characterise the habitat type, are used to define the habitat, and can include dominant and accompanying species.

Typical species: are species that indicate good condition of the habitat type concerned. Their conservation status is evaluated under the structure and function parameter. Usually, typical species are selected as indicators of good condition and provide complementary information to that provided by other variables that are used to measure compositional, structural and functional characteristics.

Variables

Condition variables: are describing individual characteristics of a habitat asset that can be measured; they must have clear and unambiguous definition, measurement instructions and well-defined measurement units that indicate the quantity or quality they measure. In these guidelines, the following types of condition variables are included:

- **Essential variables:** describe essential characteristics of the habitat that reflect the habitat quality or condition. These variables are selected on the basis of their relevance, validity and reliability and should be assessed in all member states following equivalent measurement procedures.
- **Recommended variables:** are optional, additional condition variables that may be measured when relevant and possible to gain further insight into the habitat condition, e.g. according to contextual factors; these are complementary to the essential variables, can improve the assessment and help understand or interpret the overall results.
- **Specific variables:** are condition variables that should be measured in some specific habitat types or habitat sub-groups; can thus be considered essential for those habitats, which need to be specified (e.g. salinity for saline grasslands, groundwater level for bog woodlands, etc.).

Descriptive or contextual variables: define environmental characteristics (e.g. climate, topography, lithology) that relate to the ecological requirements of the habitat, are useful to characterise the habitat in a specific location, for defining the relevant thresholds for the condition variables and for interpreting the results of the assessment. These variables, however, are not included in the aggregation of the measured variables to determine the condition of the habitat.

Reference levels and thresholds: are defined for the measured values of the variables (or ranges) that determine whether the habitat is in good condition or not. The value of the reference level is used to re-scale a variable to derive an individual condition indicator.

Aggregation: is defined here as a rule to integrate and summarise the information obtained from the measured variables at different spatial scales, primarily at the local scale (sampling plot, monitoring station or site).

Executive summary

This document presents the overall methodological approach proposed for the assessment and monitoring of Annex I habitat types, which has been developed in further detail in the various technical guidelines elaborated for individual habitat types and habitat groups.

These technical guidance documents are designed to support the 27 EU Member States in producing more harmonised and comparable assessments of the condition of Annex I habitat types in support of the Habitats Directive and the Nature Restoration Regulation.

Habitat condition refers to the overall quality of a habitat unit, considering both abiotic and biotic characteristics and corresponds to the "structure and function (including typical species)" parameter used in the conservation status assessments under the Habitats Directive.

In developing the overall methodology for these technical guidelines, a review of existing international frameworks for ecosystem assessment was carried out. In particular, the United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA), served as an important source of inspiration and reference. Moreover, the elaboration of guidelines for harmonising the assessment and monitoring of habitat condition builds upon the methodologies used by EU Member States for this purpose.

The guidelines have been elaborated following a consistent approach that includes the following main steps and contents:

1. Ecological characterisation of the habitats covered. Identification of key ecological characteristics and processes that determine the habitat condition, and the associated variables to measure those characteristics.
2. Review and analysis of EU national methodologies (and other sources) for assessing and monitoring Annex I habitat condition. Identification of strengths, shortcomings and gaps.
3. Guidance for harmonisation of methodologies for assessing and monitoring habitat condition, including:
    - A proposal of a set of key habitat characteristics and associated variables to measure.
    - Guidance on identification of reference values and thresholds to determine the condition.
    - Guidance for the aggregation of the variables measured (at local scale and biogeographical region scale).
    - Recommendations for the selection and evaluation of typical species as part of the assessment of habitat condition
    - Guidance for the selection of monitoring localities and sampling design.
4. Guidelines to assess fragmentation at appropriate scales.
5. Next steps to promote further harmonisation in the assessment and monitoring habitat condition and to address future needs.

1. Introduction

1.1 Background and context

According to the Habitats Directive (92/43/EEC), Member States shall undertake surveillance of the conservation status of the natural habitats and species (Article 11) and shall report, among others, their status every six years (Article 17). A central component of the assessment of conservation status of a habitat type is the evaluation of the "condition", which corresponds to the "structure and functions (including typical species)" parameter within the monitoring and assessment framework used under the Habitats Directive.

Based on these requirements, Member States have developed different monitoring programmes or used and adapted existing monitoring schemes to comply with these reporting obligations.

While formats and guidelines on reporting and assessing conservation status as part of the obligations under Article 17 of the Habitats Directive are made available via a reference portal[1], no detailed EU guidelines exist today for assessing and monitoring the condition (i.e. the quality) of Annex I habitat types. The latest reporting guidelines (European Commission, 2023; chapter 2.6) provide only a summary description of the Structure and functions parameter and some general guidance on the assessment of habitat condition

Previous analyses (e.g. Ellwanger et al. 2018) detected significant differences in the implementation of monitoring provisions among Member States. Such differences in the monitoring methodologies hamper the achievement of comparable assessments of habitat condition in the national reports of Member States and at a biogeographical level.

The assessment and monitoring of Annex I habitat condition has been identified by the European Commission, the European Environmental Agency (EEA) and Member States as one of the aspects in need of more harmonisation and guidance. This is particularly relevant in the context of the implementation of the EU Biodiversity Strategy for 2030 and the Nature Restoration Regulation (2024/1991) which requires not only improving the knowledge about the habitat condition by 2030 & 2040 (Article 4.9 & 5.7) but also builds quantitative, binding targets and obligations on data relating to habitat condition.

Considering this need, the Commission has promoted the elaboration of technical guidelines to foster harmonisation, with the aim of improving the consistency, quality, comparability and transparency of assessments across Member States and across reporting cycles. These technical guidance documents are designed to support the 27 EU Member States in producing more harmonised and comparable assessments of the condition of Annex I habitat types in support of the Habitats Directive and the Nature Restoration Regulation.

This document presents the overall methodological approach proposed for the assessment and monitoring of Annex I habitat types, which has been further developed and applied in the technical guidelines elaborated for individual habitat types and habitat groups.

1.2 Purpose and role of these Technical Guidelines

The conservation and restoration of natural habitats across the European Union depend on our ability to understand and monitor their condition in a harmonised and scientifically robust manner. These *Technical Guidelines for Assessing and Monitoring Habitat Condition* have

[1] https://cdr.eionet.europa.eu/help/habitats_art17

been developed to support a coherent approach across Member States, addressing the long-recognised need for standardised methodologies and criteria.

The guidelines are intended to serve as a practical reference for competent authorities, conservation practitioners, scientific experts, and agencies involved in habitat assessment, monitoring and reporting under EU legislation. They aim to provide clear, adaptable methodologies that can be applied across different biogeographical regions and habitat types, both terrestrial and marine, while allowing flexibility for regional specificities and existing national monitoring frameworks.

Ultimately, the guidelines seek to enhance consistency and comparability of data on habitat condition, strengthen the scientific basis for conservation and restoration planning, and support the effective implementation of EU biodiversity policy objectives.

The assessment and monitoring of habitat condition are central to the implementation of multiple legal obligations and policy instruments under EU nature legislation. These technical guidelines are particularly relevant in the context of two key legal frameworks: the *Habitats Directive* and the *Nature Restoration Regulation*.

Under the Habitats Directive

Article 11 of the Habitats Directive (92/43/EEC) requires, inter alia, monitoring of the conservation status of habitat types (defined in Article 1 of the directive) listed in Annex I of the Habitats Directive to be carried out by the Member States of the European Union. According to Article 17 of the Directive, Member States report every six years on the conservation status of habitat types of Community interest. In brief, habitat condition describes the quality of a habitat type in a specified spatial unit.

Under the Nature Restoration Regulation

The Nature Restoration Regulation (EU/2024/1991) reinforces and expands the need to monitor and assess habitat condition of the habitat types in its Annex I (terrestrial habitat types, which are identical with habitat types under the Habitats Directive) and II (marine habitat types) by introducing legally binding restoration targets based - among others - on habitat condition. According to Articles 4 and 5, Member States are required to put in place measures to restore terrestrial, coastal, freshwater, and marine ecosystems to good condition by specific target dates. Monitoring and assessing habitat condition and tracking improvements over time is thus essential to guide, prioritise, and evaluate the effectiveness of restoration measures. Furthermore, Article 4.9 calls for an increase in knowledge about the condition of habitats and there are monitoring (Article 20.1 (a) and (h)) as well as reporting (Article 21.2 (c)) provisions that require Member States to have good quality information on habitat condition available.

These technical guidelines have been developed to provide methodological support for assessing and monitoring habitat condition, with the aim of improving the comparability, consistency, quality, and transparency of assessments across Member States and across reporting cycles

1.3 Main tasks performed when elaborating these guidelines

The elaboration of the guidelines was carried out by a multidisciplinary team composed of scientific experts with a specialisation in different habitat groups (marine and coastal habitats, dunes, rivers, lakes, heaths, scrubs, grasslands, bogs, rocky habitats, caves and forests). It was also supported and advised by **an ad-hoc group of experts** nominated by Member States administrations, the European Environment Agency and its Topic Centre for Biodiversity and Ecosystems, the Joint Research Centre and the European Commission.

A first task was the compilation and screening of existing methodologies and guidelines for assessing and monitoring the condition of habitat types from all EU Member States, as well as relevant information from other sources. Based on the analysis of this information and considering relevant gaps and needs to improve comparability and harmonisation of the existing methodologies, technical guidelines for assessing and monitoring the condition of Annex I habitat types were elaborated by the team of scientific and technical experts.

A clustering of habitat types was agreed for the elaboration of the guidelines, considering that some habitat groups share similar ecological characteristics and monitoring requirements. As a result, some of the guidance covers groups of habitats (e.g. coastal dunes, grasslands, forests), while others address single habitat types (see table 1 and annex 1 for further details).

Table 1. Clustering of habitat types for the elaboration of the guidelines

Habitat groups	Technical Guidelines for	Habitat types covered
Marine and coastal habitats	Sandbanks which are slightly covered by seawater all the time	1110
	Posidonia beds (habitat code)	1120*
	Estuaries	1130
	Sandflats and mudflats not covered by seawater at low tide	1140
	Shallow inlets and bays	1160, 1650
	Reefs	1170
	Submarine structures made by leaking gases	1180
	Perennial vegetation of stony banks	1120
	Vegetated sea cliffs (habitat codes	1230, 1240, 1250
	Salt marshes and salt meadows	1310, 1320, 1330, 1630, 1340, 1410, 1420, 1430
	Submerged or partially submerged sea caves	8330
Coastal dunes	Coastal sand dunes	1210, 2110, 2120, 2130*, 2140*, 2150*, 2160, 2170, 2210, 2220, 2230, 2240, 2250*, 2260
Freshwater habitats	Standing water	3110, 3120, 3130, 3140, 3150, 3160, 3170*, 3180*, 3190, 31A0*, 1150, 2190
	Running water	3210, 3220, 3230, 3240, 3250, 3260, 3270, 3280, 32A0, 329
Temperate heath and scrub and sclerohyllous scrub	Heaths and scrub	4010, 4020, 4030, 4040, 4050, 4060, 4070, 4080, 40A0*, 40B0, 40C0*, 1510, 1520, 4090, 5110, 5120, 5130, 5140, 5210, 5220, 5230, 5310, 5320, 5330, 5410, 5420, 5430
Natural and semi-natural grasslands	Grasslands	2330, 2340*, 6110*, 6120*, 6130, 6140, 6150, 6160, 6170, 6180, 6190, 6210, 6220*, 6230*, 6240*, 6250*, 6260*,6270*, 6280*, 62A0, 62B0*, 62C0*, 62D0, 6310, 6410, 6420, 6430, 6440, 6450, 6460, 6510, 6520, 6530*, 6540, 9070.

Habitat groups	Technical Guidelines for	Habitat types covered
Peatlands	Mires: bogs and fens	7110*, 7120, 7130*, 7140, 7150, 7160, 7210*, 7220*, 7230, 7240*, 7310*,7320*
Rocky habitats	Scree	8110, 8120, 8130, 8140, 8150, 8160
	Rocky slopes with chasmophytic vegetation	8210, 8220, 8230, 8240
	Caves not open to public	8310
	Fields of lava and natural excavations	8320
	Permanent glaciers	8340
Forest habitats	Forests	All forest habitats included in group 9 of the Habitats Directive, except wooded pastures (9079), and wooded dunes (2180 and 2270).

1.4 Approach and contents of the Guidelines

These technical guidelines for assessing and monitoring the condition of Annex I habitats are inspired and build on the ecosystems condition approach proposed in the System for Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) adopted by the United Nations Statistical Commission in 2021 (United Nations et al., 2021).

All the guidelines have been elaborated following a consistent approach and cover the following main sections:

1. Ecological characterisation of the habitats covered. Identification of key ecological characteristics and processes that determine the habitat condition. Selection of associated variables to measure those characteristics.
2. Review and analysis of EU national methodologies (and other sources) for assessing and monitoring Annex I habitat condition. Identification of strengths, shortcomings and gaps.
3. Guidance for harmonisation of methodologies for assessing and monitoring habitat condition:
   - Selection of key habitat characteristics and associated variables to measure those characteristics.
   - Guidance on identification of reference values and thresholds to determine the condition.
   - Guidance for the aggregation of the variables/indicators (for local scale and biogeographical region scale).
   - Guidance for the selection of monitoring localities and sampling methods
4. Guidelines to assess fragmentation at appropriate scales. Fragmentation relates to spatial properties of the habitat distribution which can affect its functionality and persistence. Consequently, it is considered a component of the habitat condition and will be covered in the guidelines.
5. Next steps to address future needs. This section will identify the needs that shall be addressed to promote further harmonisation in the assessment and monitoring habitat condition, research needs, etc.

2. Understanding habitat condition and key elements for its assessment

2.1 Habitat condition definition

The Habitats Directive defines natural habitats as terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (Article 1). Habitat types of Community interest are listed in Annex I of the directive and are described in the Interpretation Manual of European Union Habitats (current version EUR 28, April 2013)[2]. The Nature Restoration Regulation in its Annex I targets the same terrestrial habitat types as the Habitats Directive. Annex I habitats are characterised by their physical features (topography, soil characteristics, water quality, etc.) and by the species of plants and animals that live there. A habitat or a group of related habitats can be considered an ecosystem (EEA, 2023[3]; Keith et al., 2013).

By analogy, we can address the habitat condition with reference to ecosystem condition, which is now well established and applied in international frameworks, especially in the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA)[4] adopted by the United Nations Statistical Commission in 2021, but also other frameworks described below. Ecosystem condition is the overall quality of an ecosystem type within a basic spatial unit. This ecosystem approach can be applied to the assessment of habitat types or groups, as appropriate. ~~E~~

The term "condition" that applies both to habitats and ecosystems can therefore be understood as a measure of their overall quality, encompassing both biotic (living) and abiotic (non-living) characteristics. This quality reflects the ability to maintain their structure and function.

However, monitoring habitat condition poses a significant number of conceptual and practical challenges, since habitat types included in the Directive are mostly conceptual constructs and not really natural biological units like species. Habitats are assemblages that are unique to a given location, although community assembly rules and abiotic factors make these assemblages similar across sites and regions. Moreover, habitats are naturally dynamic and not static in composition, and this poses an additional challenge to determine condition. This requires recognition of the great variability that may occur across the range of habitat types in the characterisation of a given habitat, which creates a challenge for the definition of reference values and thresholds for condition. These challenges suggest the need to plan broad and extensive monitoring systems that capture, as far as possible, the ecological diversity associated with the habitat types and environmental gradients existing in the different biogeographic regions.

In the assessment and reporting of conservation status of habitats according to Art 17 of the Habitats Directive, habitat condition corresponds to one of the four parameters used to assess conservation status: the structure and functions (including typical species) parameter. It is defined in the Directive in relation to the favourable status, which is achieved where *'the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future'*. According to the reporting guidelines, Member States must assess what proportion of the area of a habitat type is in good and in not-

[2] https://circabc.europa.eu/ui/group/3f466d71-92a7-49eb-9c63-6cb0fadf29dc/library/37d9e6d9-b7de-42ce-b789-622e9741b68f/details
[3] https://www.eea.europa.eu/en/topics/in-depth/biodiversity/an-introduction-to-habitats
[4] https://seea.un.org/ecosystem-accounting

good condition to determine the conservation status of each habitat type in each biogeographical region. According to the assessment matrix for habitat types, which is part of the reporting format of Art.17 reports, it is recommended to use for most cases an indicative value of 90% of the habitat type area in 'good' condition as the threshold to conclude on 'favourable' structure and functions parameter. On the other hand, if more than 25% of the habitat area type is reported as 'not in good condition', then the 'structure and functions' parameter is 'unfavourable-bad'".

In the Nature Restoration Regulation, the definition of 'good condition' for habitat types is harmonised with the one in the Habitats Directive. *'Good condition means, as regards an area of a habitat type listed in Annex I of the Habitats Directive, a state where the key characteristics of the habitat type, in particular its structure, functions and typical species or typical species composition reflect the high level of ecological integrity, stability and resilience necessary to ensure its long-term maintenance and thus contribute to reaching or maintaining favourable conservation status'* (Art. 3(4)). I.

2.2 International frameworks and approaches to the assessment of ecosystems and biodiversity

General frameworks have been developed internationally, including the GeoBON Essential Biodiversity Variables (EBV) and the United Nations' System of Environmental-Economic Accounting — Ecosystem Accounting (SEEA EEA) or the IUCN methodology developed to establish red lists of ecosystems. Globally, but also in the EU, the assessment of ecosystem condition has gained increasing attention from biodiversity policy in the last decade.

In developing these technical guidelines, existing international frameworks for ecosystem assessment were considered to ensure methodological alignment and complementarity. In particular, the United Nations System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA), served as an important source of inspiration and reference. The SEEA EA is a spatially-based, integrated framework for organising biophysical information about ecosystems, adopted as a global statistical standard by the United Nations.

The concept of ecosystem condition used in the SEEA-EA is based on long-standing ecological knowledge and is strongly rooted in the concept of ecosystem integrity, which is defined as the ecosystem's capacity to maintain its characteristic composition, structure, functioning and self-organisation over time within a natural range of variability (Pimentel & Edwards, 2000).

Ecosystem condition is often defined by measuring the similarity (or the distance) of a current ecosystem to a reference state, such as minimally impacted by people or a historical state. Ecosystem condition can be described by assessing combinations of physical, chemical and biological indicators and their changes over time.

Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic, biotic and landscape characteristics. Condition is assessed with respect to an ecosystem's composition, structure and function which, in turn, underpin the ecosystem integrity. Measures of ecosystem condition may reflect multiple values and may be undertaken across a range of temporal and spatial scales (United Nations et al., 2021).

Different ecosystem types (and habitat types) have different relevant characteristics, which can be described by different indicators. In order to facilitate communication, as well as comparisons and aggregation across ecosystem types, an Ecosystem Condition Typology

(SEEA ECT) has been adopted under the SEEA-EA Framework. It is a hierarchical classification consisting of six classes grouped into three main groups: abiotic (physical and chemical), biotic (compositional, structural and functional) and landscape-level ecosystem characteristics. This typology can be applied for ecosystem characteristics, as well as for ecosystem condition variables and indicators, to create a reporting and aggregation structure.

The SEEA-EA uses a **three-stage approach** to account for ecosystem condition. The first stage involves defining and selecting ecosystem characteristics and associated **variables**. The selected variables and indicators reflect changes over time in the key characteristics of each ecosystem asset. The second stage involves identifying **reference levels**, which correspond to the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable. This allows determining whether, for a given variable, ecosystem condition can be considered high (close to the reference level) or low (distant from the reference level). The third stage involves the **aggregation** of ecosystem condition variables that are meaningful at the level of individual ecosystem assets (spatial units). The resulting aggregate indicators are therefore average measures reflecting the condition of the constituent ecosystem assets.

The System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) has been used as a reference in the development of other relevant frameworks. In particular, the **EU wide methodology for assessment of Ecosystems** (Vallecillo et al, 2022) has adopted the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) as a reference framework. The SEEA EA is also the reference framework under the Regulation (EU) 2024/3024, adopted in December 2024, amending **Regulation (EU) 691/2011 on European environmental economic accounts**, by introducing as new environmental account modules, forest accounts, ecosystem accounts, and environmental subsidies accounts.

2.3 Lessons learned from reviews and analyses of studies on ecosystem condition assessment

There is ample literature on experiences and approaches regarding the assessment of biodiversity and the condition of ecosystems at various scales. Several reviews and analyses have been published that are useful to identify relevant issues, best practices and gaps in the assessment of ecosystems and habitat condition.

A selection of variables or indicators that measure specific ecosystem characteristics are generally reported in order to make inferences about the overall condition of ecosystems. All studies include biotic indicators and among those species-based indicators are very frequent (Maes et al., 2020). Commonly used biodiversity metrics such as species abundance, species richness or species-based indices measure aspects of ecosystem condition, in particular composition (Rendon et al., 2019).

Physical and chemical characteristics are also measured, more often in the assessment of freshwater and marine habitats than in terrestrial habitats. Environmental condition indicators covered by the WFD and the MSFD that determine the chemical and ecological status of water bodies and marine ecosystems based on physical, chemical and biological analyses were often found in the literature relating to the EU. Such indicators provide information on oxygenation conditions (e.g. dissolved oxygen), nutrient conditions (e.g. nitrates, phosphates and ammonium concentrations), salinity and acidification status (Rendon et al. 2019).

Soil characteristics and processes were also covered in some studies. The most common indicators related to soil condition were soil nitrogen and carbon, carbon-to-nitrogen ratio, soil organic matter, phosphorus compounds, evaporation/transpiration, nitrogen mineralisation, and nitrogen balance (Rendon et al., 2019).

A recent review of studies on ecosystem condition (Nicholson et al., 2025) detected a prevalence of indicators of structural, physical, and chemical state characteristics, with limited examples of indicators of functional state and landscape characteristics, which comparatively remain underexplored. This analysis also revealed that none of the reviewed assessments addressed all the 6 indicator classes (physical, chemical, compositional, structural, and functional state, and landscape characteristics). In addition, notable differences in the ecosystem characteristics covered were observed across the main ecosystem types recorded, with a bias towards indicators of structural state applied in forest ecosystems and chemical state in rivers and lakes, as the studies focused on the latter tended to equate ecosystem condition with water quality. In forest ecosystems, structural state indicators like the Normalized Difference Vegetation Index (NDVI), above-ground biomass, and forest height were prevalent. In rivers and lakes, chemical state indicators, such as chlorophyll-a concentration and Secchi depth were often used.

Pressure indicators have also been used in the assessment of ecosystem condition as they provide insight into the reasons why an ecosystem is in a certain state (Maes et al., 2018). Pressures are often considered as an “indirect approach” for measuring ecosystem condition. If there is little data available that describe the condition, then pressures can be considered a useful surrogate or proxy, ensuring that the relationship between the two is well understood and justified (Bland et al. 2018; Czúcz et al., 2021). Indicators related to human disturbance and pollution are commonly found in the assessment of ecosystems condition (Rendon et al., 2019). However, treating pressures as condition variables is not fully in line with the usual definition of condition, which expressly focuses on the state (quality) of the studied system.

Furthermore, the selection of indicators for assessment is often driven by data availability, which is prioritised over thematic relevance (Maes et al., 2020).

One of the key concepts – and thus also key challenges in the assessment of ecosystem condition is the use of a **reference condition** (Jakobsson et al., 2020). It is usually defined as intact ecosystems with negligible human impact (Karr, 1981, Stoddard et al., 2006).

The definition and use of a reference condition or reference levels for specific indicators against which the reported condition can be evaluated is not a standard practice. It was, however, applied in about half of the studies in a review carried out by Maes et al., 2020. In a recent review covering 302 ecosystem condition studies from more than 50 countries (Nicholson et al., 2025), most indicators (80%) were not compared to reference levels or reference conditions, essentially remaining as unscaled variables. When reference levels or conditions were used, and sufficiently described for reviewers to classify the approach, the reference was mostly set using an expert-based approach, followed by a simple data-driven approach, or using a natural reference condition. The limited comparisons to reference levels, along with the lack of validation and uncertainty analysis, remain key barriers to the applicability of ecosystem condition indicators and should be prioritised in future research (Nicholson et al., 2025).

Some assessments and monitoring projects make use of baseline years instead of the conceptual idea of a reference condition (Keith et al., 2020), where subsequent estimations of ecological condition are assessed relative to the condition during the baseline year. This approach however does not allow quantitative comparison of ecological condition assessments across geographical areas, and therefore using limits for good ecological condition seems more appropriate (Jakobsson et al., 2020).

The **aggregation of indicators** into a single composite index (or in a few composite sub-indices) was not a standard practice either, but applied also in about half of the studies (Maes et al., 2020). Other studies have stressed the need for appropriate aggregation approaches in ecological condition assessments (Jakobsson et al., 2021).

The **methods used and the sources of data** varied in the studies reviewed. Most often, the studies used biological, physical and chemical analyses, direct measurements and monitoring data of different ecosystems and their components, while modelling approaches and remote sensing were less commonly used to assess ecosystem condition. (Rendon et al, 2019). However, a recent literature review (Nicholson et al., 2025) observed that remote sensing (particularly multispectral imagery from Landsat and Sentinel satellite missions) is widely used to develop spatially explicit and continuous indicators at appropriate scales. In particular, the use of vegetation indices (including Normalised Difference Vegetation Index (NDVI) and various adjusted spectral indices such as Modified Red Edge NDVI and Soil Adjusted Vegetation Index (SAVI)) derived from satellite imagery is widespread across ecosystem types. In rivers and lakes, chemical state indicators, such as chlorophyll-a concentration and Secchi depth were mainly derived from multispectral imagery but in many cases also incorporated field data.

More frequently, indicators of compositional state relied on the use of direct measurement data interpolated from point locations to produce spatially explicit values as defined by the inclusion criteria (e.g. Pompeu, 2022).

In the EU, there has been an increase in the variety and frequency of methods to assess ecosystem condition since 2005, which corresponds to the adoption of environmental directives (Rendon et al., 2019). The use of biological, physical and chemical approaches is in line with the requirements of these directives. However, in recent years, GIS methods, models and scenarios have been gaining more importance in the estimation of ecosystem condition.

The results of these studies and analyses reveal the importance of properly identifying 1) which characteristics are relevant in the monitoring of condition, 2) what variables are most relevant to quantify ecosystem characteristics, 3) how indicators can be measured relative to a reference condition and 4) how ecosystem condition indicators can be aggregated across ecosystem types or across accounting areas (Maes et al., 2020).

All of these are key aspects that need to be considered when developing guidelines for assessing and monitoring the condition of Annex I habitat types.

2.4 Analysis of existing methodologies for assessing and monitoring the condition of Annex I habitats in the EU

The elaboration of guidelines for harmonising the assessment and monitoring of habitat condition must consider and build upon the methodologies used by EU Member States for this purpose.

A previous analysis carried out in 2018 (Ellwanger et al., 2018) revealed a variety of different approaches amongst the Member States in the implementation of monitoring programmes tailored to the reporting obligations of Article 17 of the Habitats Directive. Some Member States used a special standardised monitoring programme, while others used data from already existing programmes (e.g. habitat mapping, large-scale forest inventories, landscape monitoring). Most Member States used monitoring based on samples but the data collection, sample sizes and level of statistical certainty differed considerably. The analysis also revealed that consideration of animal species was a weak point in monitoring schemes of habitat types in almost all Member States.

For the purpose of these technical guidelines, a compilation and review of methodologies available from EU MSs for assessing and monitoring habitat condition was carried out in 2023 and 2024 in consultation with Member States authorities and the ad-hoc group that provided support and input to the elaboration of the guidelines. This compilation revealed a significant progress and increase, since 2018, in the number of monitoring programmes and methodologies available for assessing and monitoring Annex I habitats in the EU. National methodologies were available from 26 MSs, for at least some habitat types, totalling 190 main references that were analysed (a list is provided in Annex 2).

A screening of the national methodologies and collection of the relevant data for subsequent analysis were carried out using an online database. The review of each methodology was based on an analysis of the main steps defined for assessing the habitat condition, which are described in the following section. The analysis of all the information extracted from the database was then used for the elaboration of guidelines for harmonisation of existing methodologies after identifying their strengths, best practices, shortcomings and gaps. A summary overview of the compiled information and general results from the analysis are presented below.

Some MSs have developed specific methodologies for individual habitat types while others have focused their methods more broadly on habitat groups (e.g. forests, rivers, dunes, etc.). The methodologies available from some MSs do not cover all the habitat types present in the country, but only some of them (further development seems to be ongoing in some MSs). Some MS focus their habitat monitoring only or mainly within Natura 2000 sites (e.g. Cyprus, France, Poland and Hungary)

Abiotic and biotic variables or indicators are used to a different extent by the Member States depending on the habitat groups. Abiotic characteristics and associated variables are in general less frequently used for assessing and monitoring the habitat condition, particularly for terrestrial habitats (e.g. grasslands, heaths and scrubs, forests). Around 25-30% (depending on the habitat groups) of the national methodologies targeting terrestrial habitats measure biotic variables only, mostly those related to the composition and structure of the habitats, while functional variables in general receive less attention. On the other hand, abiotic variables, including physical and chemical indicators are more systematically included in the assessment and monitoring of freshwater, peatland and marine habitats.

Information concerning the method for setting **reference values and thresholds** for condition assessment is not always described. This limits the ability to perform a complete analysis of commonalities and differences among the methodologies available from Member States. In general, the criteria for establishing thresholds that determine the condition for each variable (good/nor good) are insufficiently documented. It appears that such values are frequently established according to expert opinions. Moreover, there are different approaches concerning the number of threshold values used, with some methodologies setting a single threshold to determine good condition (any other values would indicate not good condition), while other include ranges or three categories (e.g. A-excellent, B-good, C-poor, or good, medium, low).

Aggregation methods to summarise the information obtained from the measured variables at a local scale (plots, monitoring stations) are described in most of the methodologies analysed. In some MSs these methods are currently being developed. Different approaches can be identified, including the use of majority rules, which are most commonly applied, as well as scoring and additive rules. Some methodologies apply the 'one out - all out' rule or, in some cases, it is required that a number of characteristics that are important for the habitat must be in good condition. Aggregation by groups of variables is applied in some methodologies, and some countries calculate indexes assigning a weight to each variable.

A detailed assessment of national methodologies available is presented in the technical guidelines addressing each of the various habitat groups or habitat types.

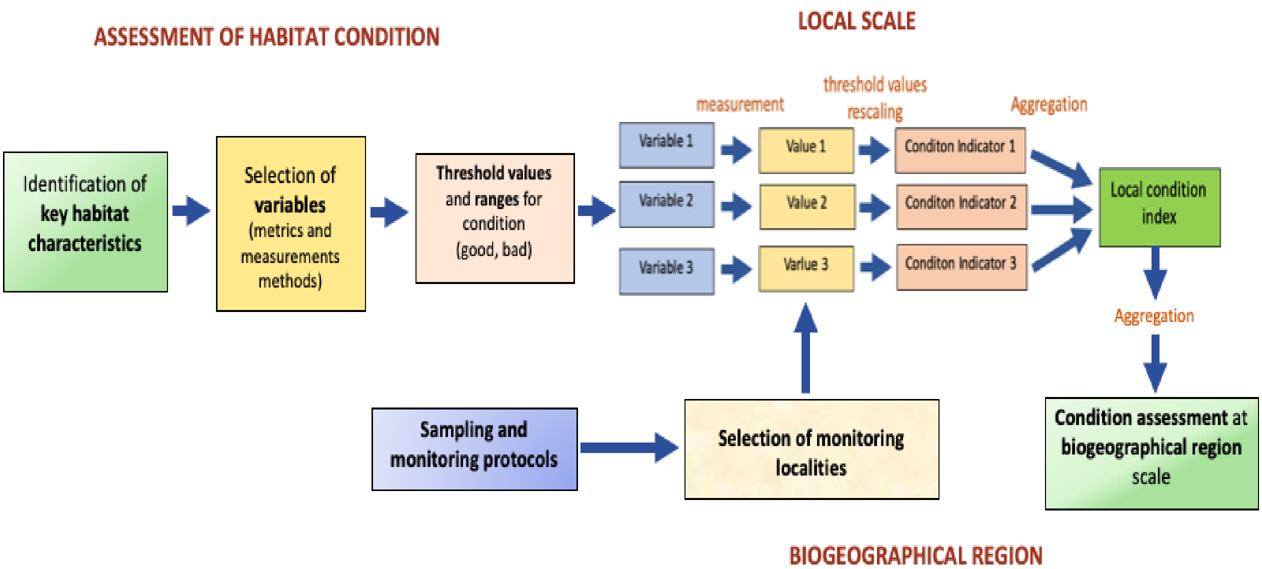
In addition to existing national methodologies developed for assessing and monitoring Annex I habitats, other relevant methodologies and monitoring programmes relating to EU Directives (e.g. WFD, MSFD), international conventions and cooperation frameworks (e.g. OSPAR, the Barcelona Convention, MedPan) are also considered as far as they provide relevant and useful information for the assessment and monitoring of the condition of habitat types.

Finally, also other relevant sources were compiled and reviewed, including methodologies developed in non-EU countries for ecosystem condition assessment (e.g. from USA, Australia, Norway, UK), as well as scientific publications and technical reports, which provided useful information on the use of new technologies, modelling, definition of thresholds, etc. This information was further completed during the elaboration of the Guidelines.

3. General methodological approach for assessing and monitoring habitat condition

The three-stage approach to determining ecosystem condition defined in the SEEA-EA provides a suitable framework for assessing habitat condition. Following this approach, a step by step procedure is recommended to assess habitat condition at two levels: the local scale and the biogeographical region scale. This procedure considers that measuring habitat condition requires, as a core element, the selection of a consistent set of variables that cover all the relevant ecological characteristics of each habitat type, and a series of subsequent steps which are described in this section. The proposed main steps for assessing habitat condition are described below.

Figure 1. Stepwise procedure for assessment of Annex 1 habitat condition



This section will provide general guidance on all these steps for assessing and monitoring the condition of habitat types or habitat groups listed in Annex I of the Habitats Directive.

These guidelines also aim to guide on the selection and use of typical species in the context of habitats condition assessment, as described in a dedicated section below (see section 3.6).

3.1 Identification of key habitat characteristics and selection of associated variables to assess their condition

A critical first step in assessing the condition of habitats (and ecosystems) is the selection **of the relevant characteristics and associated variables** that are appropriate for the assessment. Generally, the focus in assessing condition is on characteristics that can show a directional change over consecutive reporting periods in a scientifically coherent manner. The most essential characteristics need to be identified and the selection of variables associated to those characteristics shall properly reflect their condition.

In the elaboration of these Technical Guidelines we followed the Ecosystem Condition Typology defined in the SEEA-EA for classification of characteristics and variables, which provides a meaningful structure for habitat condition assessment, facilitating its standardisation and broad application (see table 1)

Table 1. Framework for identification of ecological characteristics and selection of variables to measure habitat condition (examples)

Ecological characteristics	Types	Description	Examples of variables (for some habitat groups)
Abiotic characteristics	**Physical state characteristics**	Physical descriptors of abiotic components of the ecosystem (soil, water, air), (e.g., soil structure, water availability)	- Soil thickness (grasslands, forests) - Height of dune - Temperature, amount of light (caves) - Water colour, water transparency (lakes)
	Chemical state characteristics	Descriptors of the chemical composition of the abiotic ecosystem components (e.g. nutrients in soil, water, or air.	- Nitrogen concentration - pH of soil, water - Organic matter content (forest) - C/N ratio of peat (bogs)
Biotic characteristics	**Compositional state characteristics**	Composition / diversity of ecological communities at a given location and time (e.g., presence and number of key species)	- Number of amphibian and reptile species (standing waters) - Species richness (grasslands) - Number of tree species (forests)
	Structural state characteristics	Aggregate properties (e.g. mass, density) of the ecosystem or its main biotic components (e.g., total biomass, canopy coverage, annual maximum NDVI)	- Canopy cover, amount of deadwood (forest) - Helophytic species cover (lakes) - Grass height (grasslands) - litter cover, peat/moss cover (bogs) - Proportion of area (%) with hummocks developed by wind (dunes)
	Functional state characteristics	Summary statistics (e.g. frequency, intensity) of the biological, chemical, and physical interactions between the main ecosystem compartments (e.g. primary productivity, community age, disturbance frequency)	- Regeneration density, stand age (forests) - Hydroperiod: water permanence period in the water body; Phytoplankton biomass (standing waters) - Regeneration of dominant shrub species (scrub) - Grazing pressure (grasslands) - Invasive species cover - Presence of strong algal growth or algae "blooms" (lakes)
Landscape/seascape characteristics		Metrics describing mosaics of ecosystem types at coarse (landscape/seascape) spatial scales (e.g. landscape diversity, connectivity, fragmentation)	- Distance among habitat patches - Degree of fragmentation of the dune system - Habitat fragmentation by infrastructures (roads, etc.)

Ideally, the condition assessment should ensure that for each habitat type (or groups of habitats), at least one variable is selected for each of the six classes of characteristics (physical, chemical, compositional, structural, functional, landscape). This rule of thumb aims to ensure a minimum level of comprehensiveness in the full set of condition variables, acknowledging that there might be situations where it is not possible to cover each class. A set of well-selected variables for a given habitat type should provide sufficient information to assess the condition of an ecosystem (or habitat) asset.

Selection criteria should guide the identification of **variables**. For example, variables that are more sensitive to change should be preferred for inclusion within a condition assessment method. The general principles and criteria for the selection of variables have been outlined by Czúcz et al. (2021). A summary of the most relevant criteria proposed is:

- Intrinsic relevance: characteristics and associated variables should reflect scientific understanding of habitat (habitats structure and function) integrity & quality.
- Directional meaning: variables and their metrics[5] should allow a clear interpretation of changes; it should be clear if a change indicates improvement or deterioration of habitat condition.
- Sensitivity to human influence: characteristics and metrics should be responsive to key pressures, management options, etc.
- Reliability: metrics need to be accurate, reliable, and reproducible, with potential sources of error explored and documented.
- Simplicity: metrics should be as simple as possible.
- Comprehensiveness: the final set of variables, as a whole, should cover all of the relevant characteristics of the habitat type, while at the same time it should try to avoid redundancy among the selected variables.
- Cost effectiveness: in terms of human resource and time needed for the measurement of the selected variables and implementation of the monitoring protocols.

These selection criteria aim to ensure that the variables selected give a balanced overview of the quality of a habitat and address a relevant aspect of the condition of said habitat.

In these Technical Guidelines a careful choice of essential variables to be measured in all the MSs concerned for a particular habitat type or habitat group should be made to achieve comparable assessments and allow proper aggregation of data at the EU level.

The selection of variables and metrics should be based on existing ecological knowledge and monitoring systems, with ecologists directly involved in the selection process. When developing guidance for harmonising the methodologies for assessing and monitoring habitat condition across the EU, the variables and indicators used in the various Member States need to be carefully considered to detect common practices, differences and possible gaps.

Variables should have a clear and unambiguous definition (short but clear names are useful to communicate effectively), well-defined measurement units that indicate the quantity or quality they measure, and detailed measurement instructions.

Likewise, two main types of **condition variables** are distinguished: **essential** variables and **recommended** variables. **Essential** variables correspond to key habitat characteristics and are crucial for addressing the condition of the habitat type/group. If essential variables are only suitable for a habitat type or subgroup, then they are called specific. Recommended variables are those considered to provide additional complementary information.

In addition, some environmental characteristics (e.g. climate, topography, lithology) that relate to the ecological requirements of the habitat, are useful to characterise the habitat in a specific location, and relevant variables can be selected and measured in their regard. These are called **contextual variables** and are useful to define relevant thresholds for the condition variables

[5] A variable is an attribute that can be measured and have different values, while a metric is a specific measurement used to track and evaluate a variable. An example of a variable can be water temperature, and for a metric associated to this variable it could be the average monthly temperature at certain depth.

and for interpreting the results of the assessment, but are not included in the aggregation of the condition variables, which are measured to determine the condition of the habitat.

Attention to not only the ecological relevance of the condition variables but also to the availability and continuity of data over time is needed, as these factors affect their suitability for detecting temporal trends and supporting long-term monitoring.

Concerning the data sources for the variables to measure, it may originate from direct field observations, while some data could be sourced from other monitoring programmes, environmental data and remote sensing, including satellite data.

Main steps in the identification of key characteristics and selection of variables to assess habitat condition

- Identification of the **main characteristics** (abiotic, biotic and landscape characteristics) that define and characterise the structure and function of the habitat type/group addressed, considering ecological processes involved in their functioning and the ecological diversity and variability of the habitat type/group across its range.
- Selection of **variables to measure** the condition for the key habitat characteristics identified.
- Definition of **metrics, measurement units and measurement procedures** for each variable.

A synthetic example of common variables proposed for broad habitat groups (terrestrial, freshwater and marine habitats) are presented in the following tables (Tables 2, 3 and 4). These examples have been compiled from the proposed sets of variables included in the technical guidelines elaborated for the various habitat types and groups.

Once the relevant set of variables are identified for each habitat group/habitat type, as appropriate, the subsequent steps involve the establishment of reference values and thresholds for good/nor good condition, and their aggregation to obtain an overall assessment of the habitat condition at the appropriate scales.

General guidelines on the approaches and methods to follow in these subsequent steps are presented in the following sections.

Table 2. Variables proposed for terrestrial habitats

G: Grasslands; H: Heaths and scrubs; F: Forest habitats

Characteristics	Main common variables	Proposed variables in terrestrial habitats
Physical state characteristics	Soil physical properties: soil moisture, water availability, temperature, texture, bare soil, soil disturbance.	- Soil moisture, (G, H) - Groundwater level (G, F) - Soil structure and texture (H) - Soil disturbance (G) - Bare soil (F) - Topsoil temperature (G)
Chemical state characteristics	Soil chemical properties: pH, organic matter, nutrients, salinity	- Soil pH (G, H, F) - Organic matter content (H, F) - Soil C/N ratio (G) - Soil Nutrient content: N, P (G, H, F) - Soil electrical conductivity (G) - Contaminants (H)
Compositional state characteristics	Characteristic species (vascular plants, bryophytes, lichens), invasive, alien, harmful species, animal species, pollinators.	- Characteristic species richness: vascular plants, bryophytes, lichens) (G, H, F) - Characteristic animal species presence (G, H, F). - Invasive, non-native species presence (G, H, F) - Species that indicate habitat degradation (G, H, F) - Tree and shrub species richness (F) - Pollinator species presence (G)
Structural state characteristics	Horizontal and vertical structure: vegetation cover, height, layers	- Vegetation cover and height (G, H) - Canopy cover and height (F) - Vertical stratification - number & cover of layers (F) - Shrubs and trees density (H) - Cover of shrubs and trees (G) - Cover of ruderal plant species (G) - Cover on neophytes (G) - Living veteran trees (F, Wooded grasslands) - Deadwood, coarse woody debris (F, Wooded grasslands)
Functional state characteristics	Productivity, regeneration, succession, phenology, decomposition, pollination	- Primary production (H) - Successional stage (G, H, F) - Litter accumulation, cover, depth (G, F) - Regeneration of trees (F, wooded grasslands) - Canopy health, signs of decay, defoliation (F) - Pollinator activity (H) - Livestock grazing, mowing, burning (G, H) - Browsing (F) - Human-driven impact (F)
Landscape characteristics	Patch size, fragmentation, connectivity	- Patch size – extent (G, H, F) - Habitat fragmentation (G, H, F) - Habitat heterogeneity in the patch (G, H) - Continuity of riparian forests (F)

Table 3. Variables proposed for freshwater habitats

R: Running water (rivers); S: Standing water (lakes, lagoons, ponds)

Characteristics	Main common variables	Proposed variables in freshwater habitats
Physical state characteristics	Physical, hydromorphological variables, substrate and sediment features	- Water temperature (R, S) - Light, water transparency, turbidity (R, S) - Water flow (R) - Hydroperiod/hydrological regime (S) - Fluctuation of water level/ flooding (S) - Mean lake depth (S) - Type and cover of substrate (R, S) - Sediment load (R, S) - Shoreline features and modifications (R, S)
Chemical state characteristics	Water chemical characteristics: basic chemical parameters, dissolved gases, inorganic nutrients, dissolved ions, organic matter.	- pH (R, S) - Salinity/electrical conductivity of water (R, S) - Alkalinity (R, S) - Dissolved Oxygen (R, S) - Nitrogen, Phosphorous, Ammonium (R, S) - Sulphate, Chloride (R, S) - Organic matter in water and sediments (R, S)
Compositional state characteristics	Characteristic species: aquatic and riparian vegetation, animal species	- Characteristic species richness: macrophytes, riparian vegetation (R, S) - Macroinvertebrates (R, S) - Fish species (R, S) - Other animal species: birds, reptiles, amphibians, mammals (R, S) - Phytoplankton community composition (S)
Structural state characteristics	Horizontal and vertical structure of vegetation	- Cover of aquatic vegetation (R, S) - Width and cover of riparian vegetation (R, S) - Height and strata of riparian vegetation (R) - Cover of invasive alien species (R, S)
Functional state characteristics	Organic load, trophic status, indicator species for eutrophication and acidification.	- Biological Oxygen Demand (R, S) - Chemical Oxygen Demand (R, S) - Abundance of phytobenthos (R, S) - Presence of algal growth or blooms (R, S) - Presence of indicator species for eutrophication (R, S) - Woody debris and decomposition (R) - Cover of species indicating acidification (S) - Phytoplankton biomass / chlorophyll-a (S)
Landscape characteristics	Habitat area (extent) Connectivity Conditions in surrounding area	- Number of water bodies with habitat presence (S) - Distance between habitat patches (S) - River continuity: number, type and permeability of transversal and lateral barriers (R) - Degree of channelisation (R) - Vegetation in catchment area (R, S) - Land use, human activities in surrounding area (R)

Table 4. Variables proposed for marine habitats (1110, 1120, 1130, 1140, 1160, 1170, 1180)

Characteristics	Main common variables
Physical state characteristics	- Degree of submergence/ depth - Tidal regime: tidal range - maximum and minimum with seasonal patterns - Topography: physical dimensions, longitude and latitudinal gradients, elevation, form and features. - Hydrodynamics, exposure to current, wave action, scour & surge. - Turbidity: Suspended particles, light transmission - Water temperature - Sediment composition: particle size, thickness of oxidised layer (for silt)
Chemical state characteristics	- Salinity/freshwater influence/stratification - Water quality: various substances, including chemicals listed in the WFD and EQSD, nitrates & phosphates, oxygen, chlorophyll, dissolved solids. - Sediment quality: -Inorganic and organic chemical contaminants, organic carbon. - Oxygen levels measured at surface and depth
Compositional state characteristics	- Invertebrates: abundance of characteristic species from standardised lists. - Vertebrates: associated fish, birds & marine mammals - Abundance of characteristic species from standardised lists. - Opportunistic/ invasive species: presence, distribution, abundance.
Structural state characteristics	- Characteristic species cover - Biogenic structures: type, extent, cover, volume/biomass, Fragmentation. - Macrophytes, macroalgae, eelgrass: spatial extent (area and depth), taxonomic composition, % cover of substrate, density. - Vegetation zones: abundance, extent, depth.
Functional state characteristics	- Primary production - Food webs - Nutrient load: Phytoplankton blooms – frequency, longevity, strength.
Landscape characteristics	- Habitat area (extent) - Connectivity, fragmentation (- Presence of anthropogenic structures and their % cover - Affected/ modified length of linear habitats

3.2 Establishment of reference values and thresholds

Assessing habitat condition is based on determining whether the variables used in the assessment indicate good or not good condition. Establishing reference values and thresholds or limits for those variables that signal whether habitats are in good condition or have become degraded is therefore essential.

The measured values of the condition variables need to be compared with reference values and critical thresholds. A reference level is the value of a variable under reference conditions, against which it is meaningful to compare past, present or future measurements. The difference between a variable's measured value and its reference value represents the distance from the reference condition for that variable.

Upper and lower values reflect the endpoints of a condition variable's range, which can then be used in re-scaling (see further details for rescaling in section 3.3.2). For instance, the highest value may represent a natural state, while the lowest value may represent a degraded condition where ecosystem (or habitat) processes fall below the threshold required to maintain function (Keith et al., 2013). For example, pH values in freshwater ecosystems clearly indicate whether biological life can be sustained, while soil nutrient enrichment beyond a certain threshold can lead to the loss of sensitive species.

These guidelines outline the main approaches and provide guidance for establishing thresholds that support the determination of good or not-good condition, while accounting for the ecological variability of habitats across their range. The harmonisation of reference values and thresholds for the variables used in the assessment of habitats condition should consider some **common requirements** (based on Czúcz et al., 2021 and Jakobsson et al., 2020):

- For a given habitat, the final assessment of its condition over time – based on the reference values and thresholds of the variables characterising the habitat – should be coherent across Member States (MSs), after accounting for the contextual factors specific to each MS (e.g., climate).
- Thresholds must account for the natural variability of habitats across their range. Consequently, different threshold or reference values for the same habitat type may be appropriate in different MSs or in different regions within a single MS
- Thresholds and reference values should be tested using sufficiently robust datasets that represent the full range of habitat conditions, from degraded to high-quality sites.
- Each MS should provide a clear, justified, and comprehensible description of the methodology used to establish threshold and reference values for each variable.
- The methodologies should be designed for regular evaluation and improvement, based on the best available scientific knowledge. Any modifications made – and their implications for past monitoring data – must be communicated transparently.
- Exchange & joint activities on setting threshold and reference values should take place among experts from the different MSs in order to achieve ensure harmonised approaches.

Several approaches have been recognised for estimating reference values to assess habitat condition (Stoddard et al., 2006, Jakobsson et al., 2020, Keith et al., 2020). These can be broadly synthesised into six categories: (1) absolute biophysical boundaries, (2) comparison to reference empirical cases - i.e., areas or communities considered to be in good condition, (3) comparison to undisturbed cases, (4) modelling and extrapolation of variable-condition relationships, (5) statistical assessments, and (6) expert judgement. These approaches are briefly described below, indicating their advantages and possible drawbacks.

Absolute biophysical boundaries

These refer to situations in which the observed value of a variable exceeds the physical and chemical limits (e.g., pH, bare soil cover, critical loads for eutrophication or acidification) or biotic limits (e.g., presence of alien species) that define the habitat. When such limits are exceeded, the habitat cannot be in good condition (Jakobsson et al., 2020). These thresholds therefore indicate negative impacts on the favourable condition of the habitat.

This approach provides robust and transparent criteria that are clearly linked to the ecological integrity of the habitat. However, it is applicable to a limited number of variables, typically those with direct negative impacts on habitat condition.

Comparison to empirical cases considered to be in good condition

This approach is based on identifying areas or communities considered to be in good condition (Stoddard et al. 2006, Jakobsson et al. 2020, Keith et al. 2020). These serve as reference cases from which the reference values can be derived. Therefore, their careful selection – and the availability of a sufficient number of such cases – is essential for ensuring the reliability of the reference value estimates (Soranno et al., 2011). This method, while valuable, it is often limited by the scarcity of suitable sites, especially in landscapes that have been historically modified. Providing that sufficient data from high-quality cases are available, this approach offers empirical validity and reliability by directly linking variable values to habitat condition.

Comparison to undisturbed cases (or sites with a natural disturbance regime)

This approach is closely related to the previous one, based on the assumption that most human-induced disturbances reduce habitat quality (except in cases of management of semi-natural habitats). This assumption is generally valid in human-modified landscapes and can be linked to historical reference conditions when human pressures were less pronounced (Stoddard 2006). However, disturbances that are part of a natural disturbance regime (e.g. storms, regular, non-catastrophic flooding) may actually indicate naturalness and thus good habitat condition. In fact, a certain level of disturbance can be beneficial, supporting microhabitat formation, enhancing biodiversity, and promoting regeneration of habitat-characteristic species (Keith et al., 2020).

Historical reference criteria may include the absence of human intervention or management, and are often directly connected to climax communities, such as old-growth or primeval forests, which are typically assumed to be in good condition. However, in regions with long-standing anthropogenic pressure like most of the EU, it may be difficult to identify unaltered or naturally disturbed cases for certain habitat types (Keith et al. 2020). Additionally, defining the undisturbed state based on a relatively short time period may overlook disturbance legacies that persist over longer timescales.

This approach provides transparent and empirically grounded criteria for defining reference conditions and can benefit from large-scale information on disturbance and land-use history. However, the assumption that any disturbance reduces habitat quality is not always valid. Moreover, identifying sufficient undisturbed, or naturally disturbed or adequately managed reference areas can be challenging for some habitat types.

Modelling the relationships between variables and condition

This approach assumes a relationship between measured values and habitat condition. When determining threshold and reference values, models that describe this relationship share a conceptual basis with methodologies based on dose-response curves. Such models assume that certain cases of good condition correlate with specific levels of a condition variable.

The advantage of modelling is that it allows reference values to be inferred where empirical examples of good condition or undisturbed condition are lacking. In these situations, information from known empirical cases can be extrapolated to other contexts, such as, for example, locations along a climatic gradient.

Various modelling procedures are available. Functional relationships – linear, saturated, or humped – can be applied (Stoddard et al. 2006, Jakobsson et al. 2020). Correlative climate niche models can also be used to estimate the suitability of species sets (i.e., variables that characterise the habitat) at different points along the climatic gradient (Jakobsson et al. 2020). Although these approaches offer a functional basis for establishing reference values, they involve several assumptions that often require expert judgement.

Modelling approaches are flexible, transparent, and encompass a variety of procedures based on functional relationships between variables and condition (validity), drawing on scientific knowledge from multiple disciplines. They can also be applied to obtain reference values when empirical examples of good or undisturbed condition are lacking. However, the information available to build models is often insufficient or unreliable for many variables. Outputs are highly sensitive to the chosen modelling procedure and underlying assumptions, and expert judgement is ultimately required at multiple stages of the modelling process.

Statistical assessments

This approach is based on quantitative data from databases, such as habitat inventories, which report the distribution of variables within a given habitat. It assumes that higher values of certain variables correspond to good condition when a positive relationship exists, and vice versa. For such variables, high percentile values or confidence intervals (e.g., 95%, Jakobsson et al. 2020), or differences from the maximum observed values (Storch et al. 2018), may be used.

For variables with a negative impact on habitat condition, low (e.g., 5%) or minimum values are applied, while for variables that show a hump-shaped (non-linear) relationship with condition – peaking at intermediate values (e.g., gap occurrence, browsing) – a combination of high and low percentiles may be used.

This approach is particularly suited to variables obtainable from forest inventories (Storch 2018, Pescador et al. 2022), and is useful when empirical examples of good condition are lacking. However, it may provide limited insight into the state of habitats that are in poor condition throughout the entire assessed territory. In other words, this approach is not directly based on reference situations that reflect good condition, but on statistical inferences subject to the constraints of the sampling used to build the reference database.

This approach can be applied with reasonable ease by users with statistical training. It is transparent, replicable, and minimally subjective. The existence of appropriate, quantitative datasets representing the reference state is essential for this method. Its reliability depends on the distribution of condition classes (from bad to good) in the dataset and on how well this distribution corresponds to empirical situations of good condition. As a result, it may lead to under- or overestimation of good condition and may be less reliable for habitats that are poorly represented in the dataset.

Expert judgement

Setting of reference values and thresholds based on expert judgement is common practice, particularly where other sources of information are lacking – for instance, in certain non-abundant habitats where experts have developed empirical knowledge of habitat condition. However, this approach is often criticised for its limited transparency, and the risk of relying on an insufficient level of expertise in some cases. For this reason, it is sometimes considered a last-resort option for many variables.

Nonetheless, for certain variables – such as assemblages of characteristic species, successional stages, the presence of microhabitats, or regeneration characteristics – expert judgement may be appropriate for establishing thresholds and reference values. In other cases, it can also serve as a complement to other approaches.

In all situations, it is advisable to apply expert judgement through protocols based on consensus and consultation with multiple experts of comparable experience. This should include clear procedures (e.g., standardised questionnaires) and transparent documentation of how conclusions were reached (Stoddard et al. 2006). A further limitation is the lack of available experts for certain habitats, which can hamper the correct application of this approach.

This approach can be applied where the expertise required is available and appropriate procedures are used to avoid a high degree of subjectivity. Its use may however be constrained by the scarcity of suitable experts for particular habitats and Member States.

Thresholds and reference values must be tested against sufficiently broad data sets, covering the full range of habitat conditions – from degraded to high-quality examples.

Given the uncertainties involved in setting reference levels, a combination of approaches is generally recommended to improve reliability. The approaches described are not mutually exclusive, and frequently used in combination. For example, expert judgement is typically required when defining reference cases for good condition or when making modelling decisions about the relationship between variables and condition. Similarly, modelling-based approaches can complement those based on empirical cases of good or undisturbed condition and may also be integrated with statistical methods.

Habitat condition assessments focus on determining whether the variables used indicate good or not good condition. However, it is common practice to define more than two categories for each variable – e.g., good, medium, and bad – as observed in the analysis of methodologies used by some member states. In such cases, there must be a clear distinction between good and not good condition; for instance, in the above example, good would correspond only to the first category, while the other two would indicate “not good” condition, with some nuances.

The criteria for assigning these condition categories vary depending on the characteristics of each variable. For example, categorical variables may involve thresholds such as “no alien species allowed”, while quantitative variables may follow linear or non-linear relationships with condition (Jakobsson et al. 2020).

This classification of variable values – whether quantitative or categorical – into condition categories (e.g., good and not good) corresponds to the scaling process needed for joint evaluation through aggregation procedures, as described in the following section. Condition categories can be translated into numerical values (e.g., good = 2, medium = 1, bad = 0). Alternatively, where quantitative values for the variables are available, these can be directly standardised for use in aggregation.

In habitat condition assessments, each characteristic and its associated variable is likely to be measured in a different unit. Owing to the different metrics and magnitudes used for the variables that characterise the habitats, the values obtained from their measurement require some form of standardisation – e.g., through re-scaling – in order to build indicators that combine multiple variables. Measurement values are thus scaled in relation to their reference levels, thereby normalised to a common scale and an aligned direction of change. They can then be combined to form a composite index or used to obtain an overall condition result through appropriate aggregation approaches (see further details in Section 3.3. on Aggregation).

3.3 Guidelines for the aggregation of variables at the local scale

Ecological assessments require the integration of physical, chemical, and biological quality elements. The choice of aggregation method for combining these partial assessments into an overall evaluation has been widely discussed within the scientific community, as it can significantly influence the final outcome. Various approaches can be used to integrate the values of the measured variables into an overall index reflecting the condition of habitat types at the local scale (e.g., monitoring plot, station, or site).

Applying appropriate aggregation approaches is essential for categorising condition at the local scale as good or not good, since the proportions of the area in **good/not good condition** is the key information needed for assessing the conservation status of structure and functions of the habitat at the biogeographical level.

3.3.1 Overview of aggregation methods

Based on the literature (e.g., Langhans et al. 2014, Borja et al. 2014), several aggregation approaches can be distinguished: the one-out, all-out rule (minimum aggregation), conditional rules, averaging approaches (including weighted, non-weighted and hierarchical operations), multi-metric indices and high-level integration.

For minimum aggregation, the aggregated value is calculated as the minimum of the values of the measured variables. The **one-out, all-out (OOAO) rule** has been recommended for assessing ecological status under the Water Framework Directive (CIS, 2003). The principle behind this minimum aggregation method is that a water body cannot be classified as having good ecological status if any of the measured quality elements fail to meet the required threshold. This is considered a precautionary and rigorous approach, but it has also been criticised for potentially underestimating the true overall status. A precautionary OOAO approach is also used in the aggregation of parameters when assessing conservation status under the Habitats Directives, the IUCN Red List of Species and the IUCN Red List of Ecosystems.

Conditional rules require that a certain proportion of variables meet their respective thresholds in order for the overall assessment to achieve a good condition rating. For example, the overall status may be considered as not good when a specific number of variables fail to meet their thresholds. **Averaging approaches** are among the most commonly used methods for aggregating indicators. These include straightforward calculations such as the arithmetic mean, weighted average, median, sum or combinations thereof, to produce an overall average.

Differential **weighting** of variables or indicators may be applied when calculating sums, means, or medians. The choice of weighting system should reflect the relative importance of each indicator in determining the overall condition of the habitat. Ideally, the approach should be supported by a clear scientific rationale and informed by input from ecologists with expertise in the relevant habitat type of group of habitats. However, a robust basis for assigning weights is not always available. In such cases, weighting often relies on expert judgment, which can be subjective, as expert opinions may differ considerably.

Multimetric indices are used to integrate multiple indicators into one value (e.g. as those developed for different biological elements within the Water Framework Directive), which may result in more robust indicators, compared to indicators based on single parameters. However, scaling of a multimetric index may be less straightforward, and ideally the various parameters should not be inter-correlated.

High-level integration approaches require that assessment results obtained for groups of indicators related to several ecosystem components ecosystem (e.g. biological, physic-chemical, disturbance indicators) are aggregated into final assessment indicators applying the OOAO rule. This approach can include the selection of an agreed reduced set of indicators and agreed weighting rules, which could be considered a pragmatic compromise, reducing the risks associated with OOAO.

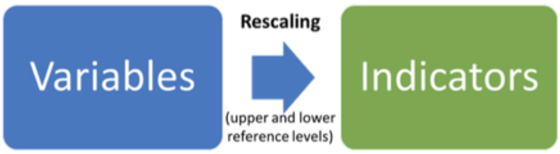
Multivariable indices to aggregate individual variables in the assessment of habitat condition of habitat types at a local scale, is common across EU MSs, especially for inland water habitats (freshwater habitats). This aggregation is usually performed through a combination of weighting loads and different approaches such as indices, specific statistics, etc. The aggregation system depends on carefully chosen indicators, well-calibrated weighting, and effective combination algorithms. The weighting for each component is determined by its ecological significance and how accurately its associated metrics reflect the effects of key environmental pressures.

3.3.2 Normalisation of variables (rescaling)

In the assessment of habitat condition, each characteristic and associated variable is likely to involve the use of different measurement units. To ensure comparability, in particular when averaging approaches are used for aggregation of the variables, the measured values are often normalised to a common scale (e.g., 0 to 1 or 0 to 100). This involves rescaling the raw data based on reference values or thresholds that define the boundary between good and not good condition for each variable.

By rescaling the condition variables, indicators are standardised to the same scale, making it possible to aggregate them into condition indices that reflect the overall condition at a given plot or location.

Figure 2. Normalisation by rescaling the values obtained for variables, based on upper and lower reference levels



$$Condition\ indicator = \frac{(V-VL)}{(VH-VL)} \quad \text{[Equation 1]}$$

Where:

- V is the measured/observed value of the variable,
- VH is the high condition value for the variable (upper reference level),
- VL is the low condition value (lower reference level).

Source: Vallecillo et al. (2022)

3.3.3 Recommendations for the aggregation of measured variables

Applying appropriate aggregation approaches for the variables measured at the local scale (e.g. on a sampling plot or monitoring station) is crucial to determine the habitat condition.

A quantitative aggregation method should be applied to integrate all the essential and specific variables measured to assess the habitat condition. The method should be applied consistently across the habitat range, within the EU, to obtain comparable results.

Averaging approaches could be used as a common basic method for determining habitat condition at the local scale. These approaches are particularly suitable and often applied to **terrestrial habitats**. In some cases, it may be appropriate to apply different weights to the essential variables in the aggregation procedure, as long as there is a consensus regarding the assignment of these weights to the variables measured in all habitat assessments across the European Union (see Box 1 below).

Aggregation approaches based on **conditional rules** or on the application of the **one-out, all-out rule** on a selection of variables that have particular relevance to determine habitat condition may be more appropriate for some habitat groups, such as **freshwater water and marine habitats.** This approach is preferred when there is a good understanding of the key ecological characteristics and processes of the habitat type (see Box 2 below).

On the other hand, in the assessment of some habitat groups, especially freshwater habitats, it is also common to use **multivariable indices** that integrate the individual variables measured, usually assigning different weights to them. An appropriate selection of indices, weighting and combination criteria (or algorithms) is required to ensure a robust assessment that accounts for the status of the main habitat characteristics. The assessment in these last approaches often involves a first aggregation of groups of variables related to different components of the habitat condition (e.g. biotic, physic-chemical, landscape). The results of these partial aggregations are then combined into an overall assessment.

Box 1. Implementation of averaging approaches to aggregate the variables measured in terrestrial habitats

Step 1 – Normalisation of the variables

The quantitative values obtained for each variable should be normalised by rescaling based on reference values (as described above). The value of each variable will be thus in a range from 0 to 1.

Step 2 – Aggregation of normalised variables

The aggregated value is then calculated by the aggregation of the normalised values of the variables. For the sake of simplicity, considering the limitations to suggest the use of a more complex method or index, we describe here a preliminary proposal for aggregation based on the arithmetic mean with normalisation of the values obtained for each of the measured variables. This method could be used to determine the habitat condition at the local scale, as summarised in the following equation:

$$Local\ condition = \sum_{1}^{n} v_i/\mathrm{n}$$

Where n is the number of variables and *vi* is the rescaled value of the corresponding variable (between 0 and 1). As a consequence, the aggregated value should range between 0 and 1.

Another possible method would be to use the weighted average. Here, the weight of each variable should be decided, justified and agreed upon for each habitat type by all the MSs that would decide to apply this method. It can be formulated with the following equation:

$$Local\ condition = \sum_{1}^{n} v_i * w_i/\mathrm{n}$$

Where n is the number of variables, v_i the rescaled value of the corresponding variable (between 0 and 1) and w_i the corresponding weight, with $\sum wi = 1$. As a consequence, the aggregated value should range between 0 and 1.

This second method, however, presents some difficulties when assigning weights to the variables, which must be based on a proper evaluation of their importance and influence on the habitat condition, based on robust scientific knowledge. It also requires a consensus on the weights assigned to the variables measured for each habitat type among all the countries that assess its condition. This is a crucial aspect to obtain comparable results in the assessments carried out by all the Member States.

Step 3 – Identify the threshold to determine good/not god condition at the local scale

Finally, a threshold must be applied to the aggregated value to distinguish between good and not good overall condition. This is a crucial step and, wherever possible, this threshold should be established based on empirical data from reference localities in good condition and from localities showing a degraded state. Where such reference localities are not fully available, modelling to obtain such thresholds could be applied.

Box 2. Aggregation approach suitable for freshwater and marine habitats

The determination of habitat condition is based on the results obtained from the aggregation of the variables corresponding to three main components of the habitat: biotic, abiotic and landscape characteristics.

In a **first step**, a set of variables linked to each of these groups of characteristics are aggregated using a conditional rule, whereby a selection of essential variables should meet the threshold values for considering that habitat component (biotic, physicochemical, landscape) in good status. The selection of the set of variables that must reach the threshold is made considering their indicator value, i.e. their relative importance or relevance to determine whether the habitat is in good condition or not. These should be variables for which a clear threshold can be defined to distinguish good and not good condition. If any of those selected variables does not reach/exceed the minimum thresholds, the condition cannot be considered good for the corresponding component of the habitat (biotic, abiotic, landscape).

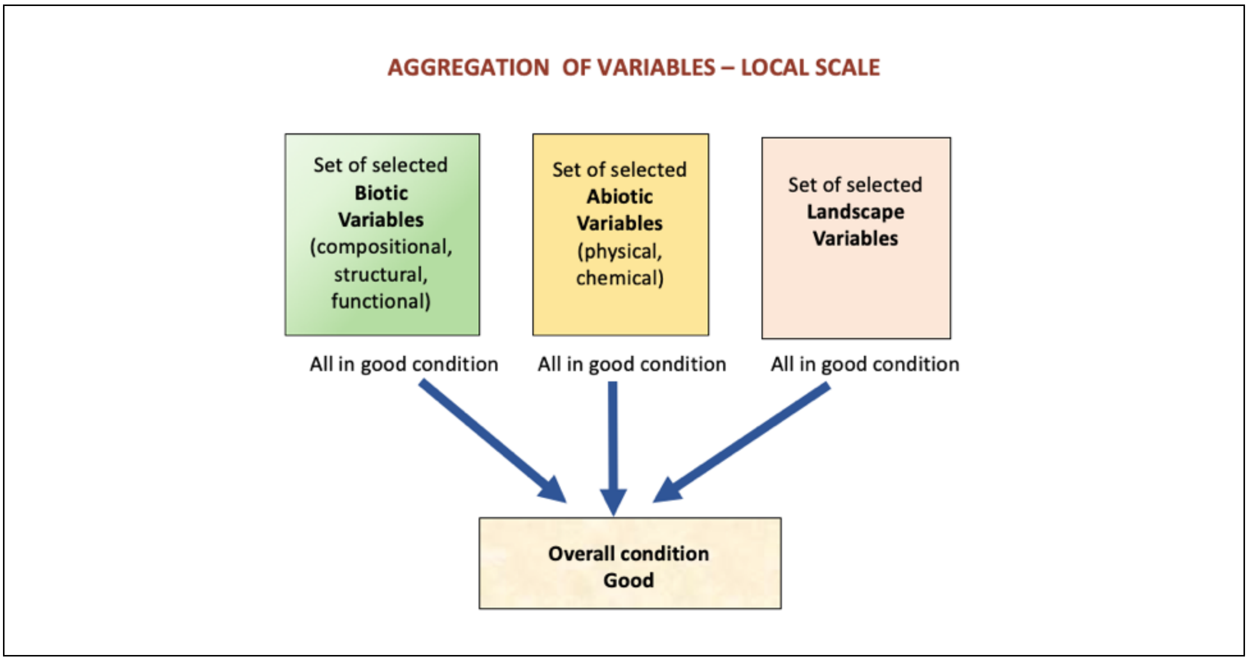
Then, in a **second step**, the results achieved in each the three components (or groups of characteristics) should be aggregated following the “one-out, all-out” rule, i.e. if any of these components does not reach an overall good status, the condition of the river habitat at the local scale cannot be considered good. This aggregation approach is currently used in several EU Member States.

Step 1 – Aggregation of the variables measured in each group of characteristics

Aggregation is done by groups, following a conditional rule, a minimum set of variables in each group must reach/exceed the threshold for good condition.

Step 2 – Aggregation of the variables measured in each group of characteristics

The results obtained in each group of characteristics (abiotic, biotic, landscape) in the above step are aggregated following the "one-out, all-out", which requires that all the three components have been assessed in good status in the previous step for the overall condition of the habitat at the local scale to be considered good.



3.4 Guidelines for aggregation at the biogeographical region scale

The aggregation of the condition values obtained at the local scales need to be done in order to upscale the overall condition to the entire biogeographical region.

According to Art. 17 reporting guidelines, the following **general rules must be applied for the assessment at the biogeographical region scale**: if more than 25 % of the habitat type area within the assessed biogeographical region is not in good condition, the status of Structure and Function is classified *unfavourable-bad*.

Ideally, the entire area of a habitat type should be in good condition for structure and functions to be considered *favourable*. In practice, however, this is rarely achievable. It is, therefore, acceptable for a proportion of the habitat type area to be in not-good condition, while still assessing structure and functions as favourable.

An indicative threshold of 90% of the habitat type area in good condition is recommended as a benchmark for concluding *favourable* structure and functions. This indicative threshold may be adapted according to the rarity or abundance of the habitat type – e.g., closer to 100% for rare habitat types with restricted distribution, this could require that their entire area be in good condition.

These rules highlight the importance of a sample design that ensures a statistically sufficient representation of the total habitat area and diversity.

Addressing spatial heterogeneity within large or ecologically diverse regions can further improve assessments. This process can be achieved by evaluating habitat conditions in sub-regions (e.g., ecozones or management units) to capture spatial variation accurately. This will enable more nuanced assessment and prioritisation of conservation efforts. This methodology provides a consistent yet flexible framework for scaling up local assessments to the biogeographical region, ensuring compliance with Article 17 requirements and supporting more detailed conservation insights.

3.5 Selecting monitoring localities and sampling design

The selection of sampling localities - along with the **sample size** (number of plots) and power - is essential to ensure that the results of assessment and monitoring are representative for each habitat type at the biogeographical scale.

Identifying and selecting localities for sampling requires a systematic approach to ensure that the chosen sites provide comprehensive and representative data on habitat condition within the biogeographical region. Sampling localities should reflect the full range of habitat diversity, as well as environmental gradients, including variations in elevation, soil types and climate.

Moreover, sites should be selected both inside and outside protected areas. This requires a sound understanding of the distribution and variability of each habitat across its range, including the identification of ecotypes or subtypes, where relevant. The main criteria for selecting monitoring localities are summarised below.

Criteria for selecting monitoring localities

Ecological variability: Localities must represent the full range of ecological diversity and variability within the habitat type. Selection should include different ecotypes or subtypes, successional stages, and reflect key environmental gradients such as altitude, soil type, moisture levels, geomorphological features, and topography.

Spatial Coverage: Adequate spatial coverage is essential to capture habitat heterogeneity. Localities should be selected across the full geographical range of the habitat type within the region, ensuring they are well distributed and represent a significant proportion of the habitat's total occupied area.

Degree of conservation and exposure to pressures and threats: The selection of monitoring localities should include areas with varying degrees of conservation and degradation, in order to capture the full range of habitat condition across its distribution. This includes both well-conserved areas with minimal human impact, and areas affected by degradation and subject to different pressures. To reflect the diversity of pressures acting on the habitat, localities should span a range of intensity levels – from low to high – and account for different sources of disturbance, such as urbanisation, agriculture, and climate change.

Presence inside and outside Natura 2000 sites: The assessment and monitoring of habitat conservation status must be carried out both inside and outside Natura 2000 sites. This requires selecting localities – and an appropriate number of plots – that reflect the proportion to the habitat's distribution within and outside the Natura 2000 network.

Habitat fragmentation at landscape scale: Localities should be selected based on landscape metrics such as patch size and connectivity. Including both isolated and well-connected sites allows for the assessment of fragmentation effects on habitat condition.

Lack of Information: Including areas where data are lacking contributes to building a more comprehensive dataset. Selecting localities in historically under-sampled regions ensures a more balanced and complete understanding of habitat condition across its range. This helps to address data gaps and supports more informed conservation planning.

Accessibility and practicality: Monitoring localities should be accessible for regular field visits, taking into account logistical factors such as distance from roads and ease of access. Practical considerations also include the safety of field personnel and the feasibility of transporting equipment to and from the site.

Historical Data and existing monitoring sites: Making use of existing monitoring sites with historical data can strengthen the understanding of long-term trends and changes in habitat condition. Such sites provide valuable baselines for comparison and support more robust trend analyses over time.

Once sampling localities have been identified for each habitat type, the minimum number of plots per locality – and across the biogeographical region – must be calculated to balance sampling effort with the need for representative and statistically robust data.

The **size of the sample** influences two statistical properties: 1) the precision of the estimates and 2) the power of the assessment to draw meaningful conclusions. The number of plots must be **statistically sufficient** to detect changes and trends with the desired level of confidence. Appropriate statistical methods should be applied to determine an adequate sample size.

Considering the heterogeneity of habitat types, it is highly recommended to consult a sampling statistician when determining sample size – that is, the minimum number of plots required to ensure representativity and statistical significance. Some key elements for ensuring proper representation of habitat condition in the sample are summarised below.

Key elements for statistical representation

Sample size and distribution:

- The number of localities and plots should be sufficient to provide a statistically robust sample size. This ensures that the collected data can be generalised to the entire habitat type within the region.
- Statistical methods such as stratified random sampling are often applied to ensure that all habitat subtypes and environmental gradients are adequately represented.

Sampling design:

- Within each sampling area or locality, multiple plots are established to collect detailed data on vegetation, soil, and other ecological indicators. The number and distribution of plots depend on the size of the habitat patch and its internal variability.
- Sampling areas (e.g., plots, transects) should be laid out with consideration of the main ecological gradients, such as altitude, moisture, and exposure to sea influence. It is also important to determine the minimum sampling areas that capture the main compositional and structural features of the habitat types.

Replication and randomisation:

- Replicating sampling units within each locality and randomising the location of sampling plots help reduce bias and increase the reliability of the data.
- Randomised plot locations also ensure that sampling captures the natural variability within the habitat.

3.6 Selecting and assessing typical species in the condition assessment

The term 'typical species' is part of the definition of Favourable conservation status for a habitat type given in Article 1(e) of the Habitats Directive. However, the directive does not give a definition for the term 'typical species.

> ***Habitats Directive - Article 1(e)***
>
> *The conservation status of a habitat will be taken as 'favourable' when:*
>
> - *its natural range and areas it covers within that range are stable or increasing; and*
> - *the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future; and*
> - *the conservation status of its typical species is favourable as defined in (i)*[6]*.*

The formulation of Art. 1(e) could suggest that the assessment of typical species could be carried out separately from the assessment of structure and functions. The reporting format and its assessment matrix that was agreed with Member States, as well as the guidelines for Art.17 reporting ask to assess the parameter structure and functions including typical species, i.e. have merged these two aspects into one parameter.

3.6.1 Selection of typical species

The selection of typical species should be as robust and appropriate as possible. However little guidance has been provided so far on how to use the typical species in this assessment.

The Guidelines for Article 17 reporting provide some definitions and interpretations regarding typical species:

- The assessment of typical species is part of the assessment of the structure and function parameter; however, a full assessment of the conservation status (as for species listed in Annexes II, IV and V) of each typical species is not required.
- Typical species should include species which are good indicators of favourable habitat quality, they should include species sensitive to changes in habitat condition ('early warning indicator species').
- The dominant species may not be a good choice for monitoring typical species, as they do not provide any additional information on structure and functions (being usually assessed as part of the habitat composition and structure).
- Typical species may be drawn from any species group and, although often most species reported are vascular plants, consideration should be given to also selecting lichens, mosses, fungi and animals.
- Given the ecological and geographical variability of Annex I habitat across their range, even within a single biogeographical or marine region, it is very unlikely that all typical species will be present in all examples of a given habitat type, particularly in large Member States. Indeed, even within one Member State different species may be present in different parts of the range of a habitat type or in different subtypes.

[6] (i) *conservation status of a species* means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the territory referred to in Article 2;
The *conservation status* will be taken as 'favourable' when:
— population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
— the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
— there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Therefore, the set of typical species for a habitat type should consider the ecological diversity (or subtypes) of the habitat across its range.

- Some species may be typical for several habitats (including non-Annex I habitats) and not dependent on a single Annex I habitat type.
- The occurrence of typical species should guarantee the conservation of viable populations of the species within the species range. This requires that the species is maintaining itself on a long-term basis as a viable component of its natural habitats.
- The sum of sites and occurrences of each habitat type should support viable populations of the typical species within the region being assessed on a long-term basis for structure and functions to be favourable. However, it must be taken into account, as mentioned above, that some species may be typical for several habitat types; this would require considering all the habitat types for which a species is indicated as a typical species, to assess the viability of its populations.

All MS have communicated a list of typical species for each habitat type[7], but the rationale for their selection is not available. The variability detected in the selection of typical species reported by MSs seems to indicate a difference in the interpretation of the typical species concept (e.g. some member states have reported a high number of typical species for the habitat types present in their territory while other have been more selective, indicating a small number of species). For the most part, plants are proposed as typical species (> 90% of the reported typical species) and in many cases dominant or characteristic species are included. However, species from other taxonomic groups are also being considered (e.g., lichens, insects, birds and mammals).

As a general rule, it would seem advisable that for each habitat type, an equivalent number of typical species would be selected in each of the member states where the habitat occurs. Criteria and methodologies for the selection of typical species should be agreed upon by MSs for each habitat type. For instance, species with similar ecological valence and characteristics should be selected (e.g. species that share similar environmental conditions, occupy comparable ecological niches, have similar indicator roles, etc.).

3.6.2 Assessment of typical species

According to the analysis of available national methodologies for the assessment of habitat structure and function, some MS assess the typical species separately from structure and functions, while others seem to include typical species in the of the compositional characteristics' assessment. However, the use or consideration of typical species in habitat condition assessments is generally not well documented in the methodologies analysed for the elaboration of these guidelines.

For instance, in the protocols used in Greece and Cyprus for the 2013-2018 reporting period, the assessment of the habitat structure and functions considered two components 'typical species' and 'specific structure and functions'. The typical species' conservation status or conservation degree was assessed based on the cover or abundance and the vitality of each typical species at the plot monitored. On the other hand, the assessment of 'specific structure and functions' was based on the proportion of indicators whose threshold values for good condition were reached in each sampling locality (e.g., cover by shrub species >40%; species composition similar to that of the typical communities, etc.). Then the results of both assessments were combined to obtain the "conservation degree" of the structure and function

[7] The list (for all habitat types and MS) is available at: https://cdr.eionet.europa.eu/help/habitatsart17

parameter. The rule was that both assessments, typical species and specific structure and functions' conditions were in a good condition at the sampling locality to be assessed as favourable (Dimopoulos & Tsiripidis, 2013; Dimopoulos et al., 2018).

In the Netherlands, the assessment of the condition of habitat types is carried out by aggregating the assessments of two sub-parameters: 'structure and functions (without typical species)' and 'typical species' at biogeographical level according to the EU evaluation matrix. The determination of the status of the sub-parameter 'typical species' at a biogeographical level is based on the proportion of species belonging to different categories of the Red List and subsequent aggregation with the sub-parameter 'structure and functions' (Ellwanger et al. 2018). Such condition assessment is not locality based.

In Germany, the number and coverage of habitat-typical plant species are used to assess the completeness of the habitat-typical inventory of species, as part of the assessment of the structure and functions parameter at a monitoring plot, which indicates that typical species are integrated into the assessment of the habitat structure and functions. In addition to flowering plants, ferns, mosses and lichens are included, as relevant. For some habitat types, additional selected groups of animal species are surveyed and evaluated (BfN, 2017). Furthermore, other two components or criteria are used in the assessment of the habitat structure and function in a plot, the 'Completeness of the habitat-typical structures', 'and the 'Coverage of disturbance or damage' present in the habitat (BfN, 2017).

The assessment of typical species has not been sufficiently addressed in the Guidelines for reporting under Art. 17 and in the national methodologies used by the MSs (according to the methodologies analysed). These guidelines try to provide some recommendations in this regard, but this issue shall better be addressed in greater depth and detail in the future.

The Guidelines for reporting under Article 17 state that a full assessment of the conservation status (as for species listed in Annexes II, IV and V) of each typical species is not required. The assessment matrix for habitat types as regards the parameter structure and functions (incl. typical species) also makes it clear that a spatially explicit condition assessment is required (i.e. condition can be assessed in specific sites /monitoring plots, locally).

The assessment of species conservation status is partly based on the status of the species' habitat. The evaluation matrix states that for the habitat of a species to be considered in favourable status, the area of the habitat must be sufficiently large (and stable or increasing) and habitat quality must be suitable for the long-term survival of the species. The guidelines also acknowledge that area, quality and spatial organisation are important elements for assessing the habitat for a species.

The quality and suitability of the habitat for a typical species is something that can be assessed locally in a single habitat type where the typical species occurs. In this regard, it can be considered that the habitat for a typical species should cover the ecological requirements of the species (feeding, reproduction, shelter) and the assessment should consider these needs. For example, saproxylic insects should have a sufficient amount of dead wood and mature trees, dispersing birds should have a good supply of fruits/seeds, larval host plants should be available for butterflies, dragonflies require floating aquatic plants on which they lay their eggs, etc.

The evaluation should determine how the habitat type in question meets these requirements. The compliance with these requirements could thus be assessed as part of the assessment of structure and functions of the habitat type at the level of the locality / monitoring plot. This also points to the importance of selecting typical species for which the habitat quality and suitability can be assessed with condition variables, which can be included in the assessment protocols.

It must also be taken into account that some of the ecological requirements of a typical species can be met in different places, as the same habitat type can provide different resources for the species, e.g. suitable sites for nesting, refuge and feeding resources in different places across its range. This must be considered in the local assessment of the habitat quality and suitability for typical species.

Moreover, some typical species are not fully dependent on a single habitat type, they occur in various habitats. It would be necessary to consider the role of the typical species for the specific habitat under evaluation. Then, it would be possible to assess in the sampling plot a) if the typical species are present as expected (structurally) including in terms of abundance, and b) if the specific habitat of the typical species is of good quality.

The suggestions and argumentations presented above highlight the complexity involved in the evaluation of typical species. Appropriate methodologies for the evaluation of typical species (e.g. based on habitat suitability and quality) should be developed and agreed for each habitat type.

3.7 Guidelines on general sampling methods and protocols

It is important to use common monitoring protocols for a given habitat type to obtain comparable results from the assessments across the Member States.

These guidelines provide recommendations on sampling and monitoring protocols adapted to each habitat type/group, considering the different spatial scales (biogeographical scale, Natura 2000 network, site level scale) at which the condition must be assessed. This includes guidance on monitoring frequency, periods, minimum surface for sampling, number of sampling areas, etc. and ways to identify monitoring trends.

As regards the data recorded on the field, the scale at which the variables will be measured is critical for the design of the **monitoring protocols**. Some variables will need to be measured in **sampling plots or transects**, with shape and sizes adapted to the habitat type/group features.

The type, number and distribution of sampling plots is adapted depending on the complexity and variability of the habitat, and considering the environmental heterogeneity in the sampling area. For instance, in habitats that exhibit zonation patterns, it may be recommended to use transect-based sampling designs that allow assessing the habitat condition within each zone or band and across the full environmental gradient.

The use of permanent plots is recommended in some habitats, as it allows for the detection of changes and trends over time with greater precision and reliability.

As regards the frequency of measurements, Article 17 of the Habitat Directive requests a maximum period of 6 years. However, this period can also be adapted to the specific needs of each habitat and also considering the available resources. It may be the case that not all the sampling plots and not all variables need to be measured every 6 years depending on the ecology and dynamics of the habitat. Equally, some habitat characteristic and their associated variables may require a more frequent monitoring, as is the case in areas where seasonality needs to be considered.

For variables that can be obtained from available data sources and remote sending, the monitoring frequency can be adapted to the data available over relevant periods, without representing an increase in the monitoring effort.

3.8 Use of available data sources, open data bases, new technologies and modelling

These guidelines will address and promote the use of available data sources (e.g., reporting under Water Framework Directive, Marine Strategy Framework Directive, forest inventories and other relevant monitoring programmes), and the possible use of new technologies (e.g. remote sensing) and modelling, when relevant, in combination with direct field records to obtain the data required for all the selected variables. Recent and ongoing developments in the availability and use of satellite imagery and other remote sensing data at a standardised quality across the EU will be particularly considered.

4. Guidelines to assess the degree of fragmentation at appropriate scales

Habitat fragmentation is a landscape-scale characteristic that reflects the loss of surface area and decrease in the size of patches. The effects of fragmentation on the habitat condition depend on the spatial distribution and dynamics of each type of habitat.

The consideration of fragmentation is different in terrestrial, freshwater and marine habitats. The significance of fragmentation is also different for zonal and azonal habitats[8]. Zonal habitats distribute along environmental gradients and their distribution can be affected by fragmentation effects due to human interventions across their range. Azonal habitats are defined by local or specific edaphic factors, geological processes, flooding, salinity or other particular features that are present only in specific locations. Human induced fragmentation can occur in these habitats on a more local scale.

Landscape characteristics are considered in the selection of condition variables that can be measured in the assessment of habitat condition. These characteristics may need to be considered at different spatial scales, depending on the habitat types.

The assessment of habitat fragmentation shall be integrated in the assessment of habitat condition. Fragmentation refers to spatial properties of the distribution of a habitat type that can affect its functionality and persistence. From this perspective, fragmentation is considered a component of the habitat ecological condition along with its status and trends.

The guidelines review the existing methodologies to assess habitat fragmentation in the context of habitat condition assessment and monitoring, as available from the compilation of information on national methodologies and other sources. This issue is considered mostly for terrestrial habitats and is particularly relevant for some habitat types (e.g. forests, dune systems, etc.).

The objective is to provide guidance on the implementation of standard methods and procedures to assess the degree of fragmentation for the habitat type/group considered. The guidelines should identify gaps and best practices in this regard, when possible.

These guidelines will consider the descriptive metrics (patch size, distance between patches) that indicate the extent to which fragmentation can determine a change in the condition of the habitat. A challenge remains however to define a conceptual framework that enables the definition of thresholds for fragmentation considering minimum viable areas for habitats and connectivity among habitat patches or fragments.

This issue is also considered in a separate document on Guidelines to assess habitat fragmentation.

[8] Zonal habitats are shaped by regional climate, broad soil patterns, topography, and other abiotic and biotic factors. Azonal habitats are determined by by specific environmental factors such as the type of soil or presence of water.

5. Next steps to address future needs

The considerable biodiversity of the European Union and the different ecological and environmental conditions in its various biogeographical regions, stress the importance of implementing a harmonisation strategy when monitoring and assessing the condition of habitat types to obtain robust and comparable results at the regional and European level.

An extensive monitoring system should be implemented, including a significant number of monitoring locations and sampling plots, both within and outside Natura 2000 sites in each biogeographical region.

Testing common monitoring protocols consistently using a selected set of variables for each habitat type or habitat group is a key recommendation. In addition, further work will be needed to identify reference conditions and define thresholds, and to agree on the best aggregation methods at a local scale.

Collaboration among Member States should be promoted to identify reference locations, using common methods, and covering the different habitat subtypes across the habitat range. This, in turn, requires the development of detailed mapping appropriate to their specific ecological characteristics, adapted to the scales at which the different habitat types occur.

The use of national inventories and other monitoring programmes (e.g. forest inventories, water monitoring programmes) for the assessment and monitoring of habitat condition should be further explored.

Finally, harmonised methods for the evaluation of typical species should be promoted, including the definition of criteria for selecting these species, along with methodologies to assess their status and integrate the results into overall condition assessment for each habitat type.

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Annex 1. Clustering of habitats for the elaboration of the guidelines

To ensure clarity, usability, and ecological relevance, the technical guidelines for the assessment and monitoring of habitat conditions have been organised according to major thematic habitat groupings. These groups are based on the classification of Annex I habitat types under the Habitats Directive, further refined by their ecological characteristics, structural similarities, and shared monitoring needs. This clustering facilitates a more efficient and harmonised development of condition indicators and monitoring approaches across similar habitat types.

Each group contains a set of habitat types for which tailored technical guidelines were developed, focusing on the most relevant structural and functional attributes, typical species, and pressures affecting their condition. The main habitat groups and associated guidelines include:

1. Coastal and Halophytic Habitats

Coastal and halophytic habitats represent some of the most dynamic, complex, and ecologically diverse systems within the Annex I habitat types. These habitats are shaped by the interplay of marine and terrestrial processes, highly variable salinity regimes, tidal dynamics, sediment transport, and exposure to extreme weather events. To ensure ecological and methodological relevance, individual technical guidance documents were developed for most Annex I habitat types in this group. However, in several cases, a single guidance document covers multiple closely related habitat types. This approach was taken when habitats share similar ecological characteristics, condition indicators, pressures, and monitoring requirements—allowing for a harmonised methodology without compromising ecological specificity. Such grouping also reflects how these habitats often co-occur in the field, form part of ecological gradients, or require joint management approaches. The technical guidelines for this group are following:

- Technical guidelines for sandbanks which are slightly covered by seawater all the time (habitat code 1110)
- Technical guidelines for Posidonia beds (habitat code 1120*)
- Technical guidelines for estuaries (habitat code 1130)
- Technical guidelines for sandflats and mudflats not covered by seawater at low tide (code 1140)
- Technical guidelines for large shallow inlets and bays (habitat code 1160)
- Technical guidelines document for reefs (habitat code 1170)
- Technical guidelines for submarine structures made by leaking gases (habitat code 1180)
- Technical guidelines for perennial vegetation of stony banks (habitat code 1220)
- Technical guidelines for vegetated sea cliffs (habitat codes 1230, 1240, 1250)
- Technical guidelines for salt marshes and salt meadows (habitat codes 1310, 1320, 1330,1340, 1410,1420, 1430 & 1630)
- Technical guidelines for submerged or partially submerged sea caves (habitat code 8330)

2. Coastal Sand Dunes

Coastal sand dunes represent a functionally and ecologically coherent group of habitats shaped by wind, sand movement, salinity, and coastal dynamics. These habitats form a continuous succession along a land–sea gradient, from embryonic dunes near the shoreline to fixed and wooded dunes further inland. Because of their close ecological interdependence, similar pressures, and shared monitoring requirements, a single technical guidance document was developed to cover this entire group of dune habitats. This grouping reflects how, in most landscapes, these dune types occur together as a mosaic or gradient.

- Technical guidelines for coastal sand dunes (habitat codes 1210, 2110, 2120, 2130*, 2140*, 2150*, 2160, 2170, 2210, 2220, 2230, 2240, 2250*, 2260)

3. Freshwater Habitats

Freshwater habitats encompass a diverse range of aquatic ecosystems, which are fundamentally shaped by the presence or absence of flowing water. For the purpose of developing technical guidelines for condition assessment, freshwater habitats have been divided into two main groups: standing waters (lentic systems) and running waters (lotic systems). This division reflects well-established differences in ecological functioning, hydrological regimes, and monitoring approaches, and is consistent with the typology used under the EU Water Framework Directive (WFD).

- Technical guidelines for standing water (habitat codes 3110, 3120, 3130, 3140, 3150, 3160, 3170*, 3180*, 3190, 31A0*, 1150, 2190)
- Technical guidelines for running water (habitat codes 3210, 3220, 3230, 3240, 3250, 3260, 3270, 3280, 32A0, 3290)

4 & 5. Heaths and Scrub

Heaths and scrub habitats include a diverse range of structurally similar vegetation types dominated by shrubs and low woody plants. Despite their diversity in floristic composition, climatic setting, and biogeographical distribution, these habitats share many common ecological and functional characteristics—such as low nutrient availability, extensive land-use history, and dependence on disturbance regimes (e.g. grazing, fire, or clearance). For these reasons, a single technical guidance document was prepared for the entire group of heath and scrub habitats, with the aim of ensuring methodological coherence and efficient application of monitoring principles. Within this document, however, two distinct ecological subgroups are recognised:

- Subgroup 1: Heaths and Temperate Scrublands (Habitat codes: 4010, 4020, 4030, 4040, 4050, 4060, 4070, 4080, 40A0*, 40B0, 40C0*). This subgroup includes heathlands, subalpine scrub, and temperate scrub systems found mainly in Atlantic, Boreal, Continental, and Alpine regions.
- Subgroup 2: Sclerophyllous Scrub (Habitat codes: 1510, 1520, 4090, 5110, 5120, 5130, 5140, 5210, 5220, 5230, 5310, 5320, 5330, 5410, 5420, 5430). This subgroup comprises thermo-Mediterranean and sclerophyllous scrub types, commonly referred to as matorral, garrigue, or maquis.

- Technical guidelines for heaths and scrubs

6. Grasslands

Grassland habitats represent one of the most ecologically and structurally coherent groups of Annex I habitat types. They are characterised by the dominance of herbaceous vegetation, strong dependence on traditional or extensive land management practices (such as low-intensity grazing or mowing), and exceptionally high biodiversity—especially in species-rich semi-natural grasslands. Despite their floristic and biogeographical diversity, these habitats share fundamental ecological processes, similar anthropogenic pressures, and comparable monitoring needs. This ecological and methodological coherence provides a strong rationale for developing a single technical guidance document for the condition assessment of all grassland habitat types.

Compared to the classification under the Habitats Directive, three additional habitat types were included in the grassland guidance document. Two habitats from the group *Coastal sand dunes*, representing inland dune grasslands (2330 Inland dunes with open *Corynephorus* and *Agrostis* grasslands and 2340 Pannonic inland dunes), were included under the dry grasslands. Although these habitats occur on inland dune substrates, they are structurally and ecologically similar to other inland dry grasslands and may occur alongside them. Therefore, it was more appropriate to group them with inland grasslands rather than with coastal dune habitats, which have distinct monitoring requirements due to their dynamic coastal environment.

Under the wooded grasslands habitat “9070 Fennoscandian wooded pastures”, which been moved from the *Forest group* to grassland habitat types, due to its narrow relationship with habitat “6530 Fennoscandian wooded meadows”.

For practical purposes, grassland habitats were grouped into the following ecological subtypes within the guidance:

- Dry grasslands (habitat codes 2330, 2340*, 6110*, 6120*, 6130, 6190, 6210, 6220*, 6240*, 6250*, 6260*, 6280*, 62A0, 62B0*, 62C0*)
- Mesic grasslands (habitat codes 6180, 6230*, 6270*, 6510, 6520)
- Wet grasslands (habitat codes 6410, 6420, 6430, 6440, 6450, 6460, 6540)
- Alpine grasslands (habitat codes 6140, 6150, 6160, 6170, 62D0)
- Wooded grasslands (habitat codes 6310, 6530*, 9070).

    - Technical guidelines for grasslands

7. Mires: bogs and fens

Peatlands represent a functionally unified group of Annex I habitats defined by the accumulation of peat under water-saturated, low-oxygen conditions and the presence of specialised vegetation adapted to these environments. Despite regional and floristic differences, peatland habitats share key ecological processes, hydrological dependencies, and condition attributes, which justify the development of a single technical guidance document for their assessment and monitoring.

- Technical guidelines for mires: bogs and fens (habitat codes 7110*, 7120, 7130*, 7140, 7150, 7160, 7210*, 7220*, 7230, 7240*, 7310*,7320*)

8. Rocky Habitats

Rocky habitats encompass a diverse range of Annex I habitat types associated with extreme abiotic conditions, such as steep slopes, unstable substrates, rock crevices, caves, lava fields, and glacial environments. These systems typically have low vegetation cover, are shaped by geophysical rather than biotic processes, and often support specialised or endemic flora and fauna adapted to harsh conditions. The development of technical guidelines for these habitats followed a flexible approach, with some documents covering grouped habitat types and others dedicated to individual habitats, depending on ecological coherence and monitoring requirements.

- Technical guidelines for screes (habitat codes 8110, 8120, 8130, 8140, 8150, 8160)
- Technical guidelines for rocky slopes with chasmophytic vegetation (habitat codes 8210, 8220, 8230, 8240)

- Technical guidelines for caves not open to public (habitat code 8310)
- Technical guidelines for fields of lava and natural excavations (habitat code 8320)
- Technical guidelines for glaciers (habitat code 8340)

9. Forest Habitats

Forests are among the most widespread and ecologically significant habitat types in Europe, providing essential ecosystem services, supporting high biodiversity, and playing a key role in climate regulation. Annex I forest habitats reflect the remarkable ecological diversity of Europe’s forested landscapes, shaped by variations in climate, geology, altitude, and biogeographical history. They range from extensive boreal coniferous forests in northern Europe to thermophilus deciduous woodlands in central and southern regions, and from humid alluvial forests along river systems to dry sclerophyllous and pine forests in Mediterranean and Macaronesian areas. This diversity is further enriched by mountain forests, ravine and scree woodlands, and wood-pasture systems that result from centuries of low-intensity human management. In total, over 70 forest habitat types are listed under Annex I of the Habitats Directive, each with specific structural features, typical species, and ecological functions. Their distribution spans all biogeographical regions, including Alpine, Atlantic, Continental, Boreal, Mediterranean, Macaronesian, and Pannonian zones, making forest habitats one of the most structurally and functionally varied groups within the Natura 2000 network.

Since most methodologies used for monitoring forest condition are broadly similar across biogeographical regions and forest habitat types, all forest habitats have been clustered together in this work. This approach allows for a harmonised set of monitoring principles, with adaptations applied where necessary based on ecological specificity. The forest habitat types have been grouped into the following categories based on their biogeographical and ecological characteristics:

- Boreal forests (habitat codes 9010, 9020, 9050, 9060, 9080)
- Temperate deciduous broadleaf forests (habitat codes 9110, 9120, 9130, 9140, 9150, 9160, 9170, 9180*, 9190, 91A0, 91B0, 91C0, 91D0*, 91E0*, 91F0*, 91G0, 91H0*, 91I0*, 91J0, 91K0, 91L0, 91M0*, 91N0, 91P0, 91Q0, 91R0, 91S0, 91T0, 91U0, 91V0, 91W0, 91X0, 91Y0, 91Z0, 91AA, 91BA, 91CA)
- Mediterranean deciduous forests (habitat codes 9210, 9220, 9230, 9240, 9250, 9260, 9270, 9280, 9290, 92A0, 92B0, 92C0, 92D0)
- Mediterranean sclerophyllous forests – 8 habitat types (habitat codes 9310, 9320, 9330, 9340, 9350, 9360, 9370, 9380)
- Temperate mountainous coniferous forests (habitat codes 9410, 9420, 9430)
- Mediterranean and Macaronesian mountainous coniferous forests (habitat codes 9510, 9520, 9530*, 9540, 9550, 9560, 9570, 9280, 9590, 95A0)

In addition, two habitat types (2180 – Wooded dunes of the Atlantic, Continental and Boreal region and 2270 – Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*) are classified under forest habitats, despite occurring in the habitat group Coastal dune systems, because their dominant vegetation form is woodland, not herbaceous or shrubby dune vegetation typical of dune succession stages.

- Technical guidelines for forests

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KH-01-25-199-EN-N

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