European Commission

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

Perennial vegetation of stony banks (1220)

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Glossary and definitions

Habitats

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

Habitat condition: is the quality of a natural or semi natural habitat in terms of its abiotic and biotic characteristics. Condition is assessed with respect to the habitat composition, structure and function. In the framework of conservation status assessment, condition corresponds to the parameter “structure and function”. The condition of a habitat asset is interpreted as the ensemble of multiple relevant characteristics, which are measured by sets of variables and indicators that in turn are used to compile the assessments.

Habitat characteristics: are the attributes of the habitat and its major abiotic and biotic components, including structure, processes, and functionality. 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: species that characterise the habitat type, are used to define the habitat, and can include dominant and accompanying species.

Typical species: 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 quantitative metrics describing individual characteristics of a habitat asset. They are related to key characteristics of the habitat that can be measured, 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 MSs 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 help improve the assessment, understanding or interpretation of the overall results.
- **Specific variables:** are condition variables that should be measured in some particular habitat types or habitat sub-groups; they 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, and help characterise the habitat in a specific location, define the relevant thresholds for the condition variables, and interpret the assessment results. These variables 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 values (or ranges) of the variables that determine whether the habitat is in good condition or not. They are set considering the distance from the reference condition (good). The value of the reference level is used to re-scale a variable to derive an individual condition indicator.

Condition indicators: are rescaled versions of condition variables. Usually, they are rescaled between a lower level that corresponds to high habitat degradation and an upper level that corresponds to the state of a reference habitat in good condition.

Aggregation: is defined in this document 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).

Abbreviations

EU**:** European Union

HD – Habitats Directive

IAS – Invasive Alien Species

MS: Member State

EU Member States acronyms:

Austria	(AT)	Estonia	(EE)	Italy	(IT)	Portugal	(PT)
Belgium	(BE)	Finland	(FI)	Latvia	(LV)	Romania	(RO)
Bulgaria	(BG)	France	(FR)	Lithuania	(LT)	Slovakia	(SK)
Croatia	(HR)	Germany	(DE)	Luxembourg	(LU)	Slovenia	(SI)
Cyprus	(CY)	Greece	(EL)	Malta	(MT)	Spain	(ES)
Czechia	(CZ)	Hungary	(HU)	Netherlands	(NL)	Sweden	(SE)
Denmark	(DK)	Ireland	(IE)	Poland	(PL)		

SEEA EA – System of Environmental Economic Accounting- Ecosystem Accounting

UAV: unmanned aerial vehicle

Executive summary

Shingle banks are coastal deposits of large rounded rocky fragments, in areas dominated by wave action, which can be colonised by perennial herbaceous vegetation. This habitat occurs along the coast where shingle (cobbles and pebbles) and gravel have accumulated to form elevated ridges or banks above the high tide mark. Species diversity is determined by the degree of exposure to wave action, and by substrate stability, coarseness and particle size These coastal formations are highly valuable for their ecological diversity, provide diverse habitats for plants and animals, and play an essential role in stabilizing nearby soft sediment environments like salt marshes and mudflats.

The ecological characteristics of this habitat are shaped by factors such as composition of the shingle, accumulation of organic matter, water regime climate conditions, the width of the foreshore, and human activities. The overall functionality of the habitat system depends on the natural accumulation processes that form new shingle strips and the gradual development of vegetation at different successional stages. The mosaics of vegetation present on these shingle systems therefore depends on the high level of dynamism in the accretion/erosion phases to which these shingle strips are subjected.

An analysis of existing monitoring methodologies across EU Member States was conducted detecting some commonalities regarding which habitat characteristics have been considered to describe variables to measure them and which have directly not been included as part of the monitoring of habitat condition. Thus, no chemical nor landscape characteristics are measured in any of the consulted methodologies. The abiotic characteristics present in the consulted methodologies focus on wave exposure and substrate characteristics such as particle size. Composition and structural characteristics are assessed through the presence and coverage of characteristic vascular plant species as well as fauna species.

Thresholds for interpreting these metrics are absent or when provided, is not specify how are they estimated. Those consulted methodologies that describe an aggregation system use in general arithmetic operators or categorical majority rules to the values obtained from the measurement of the variables used in the assessment. Monitoring procedures are based on a combination of transect and plot sampling.

A set of essential, recommended and descriptive variables for monitoring Perennial vegetation of stony banks are proposed. They are categorized into abiotic (e.g. wave exposure, tidal regime, particle size, soil organic matter), biotic (e.g. characteristic vascular plants, characteristic fauna species), structural (e.g. cover of characteristic plant species and communities, cover of invasive alien species), functional (e.g. pollinators, seed bank), and landscape (e.g. coastal trend).

General guidelines for setting thresholds for the variables to measure, and to aggregate the results of local condition assessment are also provided, together with recommendations for the monitoring and sampling design, including for the selection of the monitoring localities.

1. Definition and ecological characterisation

1.1 Definition and interpretation of habitats covered

Shingle banks are coastal deposits of large rounded rocky fragments, in areas dominated by wave action, which can be colonised by perennial herbaceous vegetation. The geomorphology of the shingle coast is highly dynamic and is the result of a balance between shingle inflow and outflow, either through erosion or exploitation (Duhamel et al., 2017).

Globally, shingle coasts are most common in high-latitude regions and temperate coastlines shaped by Pleistocene glaciation. Many of today's significant shingle formations were created during the Holocene marine transgression, beginning at lower sea levels and reaching their current positions around 4000 years ago. Most existing shingle structures are remnants or rely on sediment from erosion rather than glacial deposits (Doody & Randall, 2003), and human use (Doody & Randall ,2003).

Shingle coasts encompass a variety of landforms shaped by their origins, movement, and exposure to oceanic conditions. These coastal formations are highly valuable for their ecological diversity, provide diverse habitats for plants and animals, and play an essential role in stabilizing nearby soft sediment environments like salt marshes and mudflats (Doody & Randall, 2003). When shingle features are relatively stable, vegetation tends to develop, although wave activity typically keeps the middle and lower sections of the beach free of plants. Vegetation on the upper beach depends on factors such as the level of disturbance, the movement of the shingle, the presence of fine sediments filling the gaps between larger particles, and the local water conditions.

Source: De Ramil et al. (2008)
© 2008. Instituto de Biodiversidade Agraria e Desenvolvemento Rural (Galicia, Spain).
Shingle coast in Galicia, Spain.

This habitat occurs along the coast where shingle (cobbles and pebbles) and gravel have accumulated to form elevated ridges or banks above the high tide mark. Species diversity is determined by the degree of exposure to wave action, and by substrate stability, coarseness and particle size (Martin et al., 2017). It is an unstable habitat that can move from year to year (Delaney et al., 2013). Different vegetation types can be present along shingle coast. The pioneer community that can establish on the upper beach is characterized by sparse perennial vegetation, primarily including *Crambe maritima* and *Honkenya peploides*, alternating with bare shingle. Further inland, vegetation becomes more dominant where coastal grasslands, heath and scrubs and communities rich on lichens and bryophytes can appear (Bensettiti et al., 2014). Whereas the pioneer community is rooted in gravel, sand, or organic matter, grassland and scrub communities are rooted in soil. The presence of lichens indicates long term stability (Martin et al., 2017).

This habitat is also important for invertebrates and for nesting and foraging of some breeding birds.

The habitat occurs in the Atlantic, Boreal, Continental and Macaronesian regions and the Interpretation Manual of EU habitats (European Commission, 2013) recognises three subtypes with different characteristic plant communities: Baltic Sea kale communities (*Elymo-Crambetum*), channel sea kale communities (*Lathyro-Crambetum*) and Atlantic Sea kale communities (*Crithmo-Crambetum*). The habitat is present only in 10 EU Member States: Germany (DE), Denmark (DK), Estonia (EE), Spain (ES), Finland (FI), France (FR), Ireland (IE), Latvia (LV), Portugal (PT) and Sweden (SE).

1.2 Environmental and ecological characterization and selection of variables to measure habitat condition

Four environmental factors are responsible for the growth of a shingle beach. There must be an available supply of sedimentary material at the same time as conditions of waves, winds and tidal currents are favourable for its movement. Since this coincidence is unpredictable, conditions without movement occurring may exist for considerable periods, interspersed by times of marked activity resulting in stable and mobile shingle habitats varying both in time and space (Randall, 1988).

The ecological characteristics of this habitat are shaped by factors such as composition of the shingle, accumulation of organic matter, water regime (Davy et al., 2001) climate conditions, the width of the foreshore, and human activities (JNCC, 2004). The overall functionality of the habitat system depends on the natural accumulation processes that form new shingle strips and the gradual development of vegetation at different successional stages. The mosaics of vegetation present on these shingle systems therefore depends on the high level of dynamism in the accretion/erosion phases to which these shingle strips are subjected (Duhamel et al., 2017).

Environmental and ecological characterization should consider the main abiotic, biotic and landscape characteristics that explain the habitat variability and its condition. The description of key characteristics and the corresponding variables that are useful to measure the habitat condition in this section follows the approach to assess ecosystem condition defined in the framework of the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA), adopted by the United Nations Statistical Commission as international standard for ecosystem accounts (United Nations, 2021), which is also integrated and proposed in the EU wide methodology to map and assess ecosystem condition (Vallecillo et al., 2022).

Abiotic characteristics

Physical characteristics

Within the abiotic characteristics, wave exposure, water supply and sediment characteristics are the most influential elements on shaping the habitat.

Wave exposure influences the formation and shape of the foreshore where the first colonizers will establish as well as defining the sediment supply and characteristics. Even though it does not provide information on the condition of the habitat, it provides valuable information to understand the context where the habitat is developing.

Rising sea levels often cause shingle landforms to shift inland, although rapid sea-level rise can submerge these features in place through overstepping (Doody & Randall, 2003).

Water supply is maintained mainly by rainfall, dew and internal dew (Davy et al., 2001). Rainwater percolates into the shingle where some is likely absorbed by plant roots, organic matter, or the other matrix surrounding the pebbles, while some remains as pendular water on the pebbles. Evaporative losses seem to be minimal, as the surface pebbles function like a mulch, helping retain moisture. (Davy et al., 2001).

The **sediment** consists of a mixture of different sizes and materials, as cobbles, pebbles, and gravel. This is a consequence of the temporal and spatial variation of the inputs and wave dynamics. **Shingle** is the term applied to sediments larger in diameter than sand but smaller than boulders. A predominant particle size of over 2mm separates shingle from sand (King, 1972). Over 200 mm diameter they may be considered to be boulders and in ecological terms approximate to cliff habitat. The **particle size** distribution and the nature of the matrix in the fine fraction have considerable effects on the vegetation. Large pebbles with no matrix and subject to strong wave action are barren, but higher on the ridge and landwards where there is a sand, organic or silt / clay matrix the vegetation may be substantial and of a distinctive type (Scott, 1963, cited in Davy et al., 2001). Fine shingle may play a similar role on shingle beaches as sand and humus in providing the rooting medium and moisture for growth (Fuller, 1987, cited in Davy et al., 2001).

The assessment of the average textures or the relation shingle/sand is difficult to obtain accurately. Over time, ranker-like alluvial **soils** can develop. These are shallow and loamy, often overlying gravel or coarse material within a short depth. When plants establish themselves, they contribute to the accumulation of material as their roots and above-ground parts decay. Organisms like mites and collembolans aid in breaking down this plant matter, forming a dark, humus-like layer. Additionally, plants trap wind-blown debris, which further increases the build-up of organic litter. The resulting soils are typically very acidic but can be closer to neutral if the shingle contains a significant amount of shell material. This humus layer improves moisture retention and nutrient availability, supporting the growth of more permanent vegetation (Doody & Randall, 2003).

Chemical characteristics

Little is known about the mineral nutrition of plants of shingle, but the **supply of minerals** to plants must be limited by the lack of substrate on the pebbles, particularly in early plant succession on shingle. Where there is substantial seaweed deposition and build-up of humus, the limitation is doubtless less severed (Davy et al., 2011). In particular, short supply of nitrogen and phosphorus may limit plant growth.

Salinity conditions vary strongly, especially dependent on position, on shingle beaches. On the seaward fringe, with high salinity, the plants are halophytic while on the inland margin.

Glycophytes or plants that do not tolerate soil or water of high salinity appear (Davy et al., 2011).

Biotic characteristics

Compositional and structural characteristics

Within the biotic characteristics, composition and cover of characteristic species as well as negative indicator species, are the main factors influencing condition of the habitat (Ramil et al., 2008). Functional processes such as sediment supply and the presence of a seed bank are also relevant factors that influence the development of the habitat.

Vegetated shingle forms on deposits of shingle at or above mean high-water spring tides. The first colonizer species are tolerant to wave exposure and to be covered under water for some periods, being these species mostly annual or short-lived perennial species tolerant of saltwater inundation. On smaller and less dynamic sites, annual vegetation may persist from one year to another but the dynamism normally does not allow this persistence (JNCC, 2004).

Vegetated shingle occurs at or above spring tide mean high-water. The ridges and lows influence plant growth, resulting in zones of vegetated and bare shingle. Vegetation ranges from pioneer plant communities through a lichen-rich turf, to gorse scrub or bramble and, where grazed, to a species-rich turf. Vegetation varies according to: shingle stability; distance inland; pebble size; amounts of fine material; water availability; and site management (Suffolk – priority habitat factsheet[1]).

The EU Habitats Interpretation Manual (European Commission, 2013) lists *Crambe maritima, Honkenya peploides, Leymus arenarius, Lathyrus japonicus* and *Crithmum maritimum* as characteristic species of this habitat.

Martin et al. (2017) describes six types of plant communities on vegetated shingle in Ireland: pioneer community on the upper beach, secondary pioneer communities, grassland communities, mature grassland communities, heath communities and scrub communities characterized by woody species and climbing plants.

Bensettiti et al. (2004) distinguish two subtypes of habitat 1220 in France: perennial vegetation at the top of shingle beaches (1220-1) and vegetation on the inland part of shingle beaches dominated by grasses or other herbaceous vegetation (1220-2). The first subtype extends from the limit of the highest tides to the upper contact with the sea (0 m) where there is slight to no slope and the shingle strip tends to be linear and narrow. Here, the substrate can be occasionally washed by waves during very high tides and it receives regular inputs of decomposing plant debris (sea mud) which accumulate in the interstices between the coarse elements. Dominant species include *Honkenya peploides, Crambe maritima* and *Crithmum maritimum.* This subtype can be found in contact with annual vegetation of drift lines (habitat 1210), with pioneer annual vegetation with Salicornia (habitat 1310) and also with the subtype 1220-2.

The second subtype establishes from the limit of the highest tides up to 1 m where there is also slight to no slope and it is more expansive than the previous subtype. The substrate is characterized by coarser pebbles that can be covered by a sandy-organic film and it is still subject to strong marine influence. Presence of herbaceous species such as *Solanum marinum* and *Silene montana* are dependent on the organic matter content of the substrate

[1] https://www.suffolkbis.org.uk/sites/default/files/images/habitat/Coastal%20vegetated%20shingle%20factsheet%20NEW.pdf

and grass species like *Arrhenatherum elatius* are dependent on the sandy-organic film superimposed on the pebbles. This subtype can be found in contact with other coastal habitats like annual vegetation of drift lines (habitat 1210) and pioneer annual vegetation with *Salicornia* (habitat 1310) in the foreshore part and with fixed dunes with herbaceous vegetation (habitat 2130), dunes with *Hippophaë rhamnoides* (habitat 2160) and lichen and thyme (*Thymus* spp.) in the upper part.

In Galicia, northern Spain, this habitat can be in contact with 1140 during low tides and, punctually, with dry heaths (4030) and coastal heaths of *Erica vagans* (4040) on the upper part (Ramil et al., 2008).

As regards the **fauna**, various species of beetles, ants, spiders and bees can be found in shingle vegetated sites as well as seabird species, which can nest and find foraging resources in shingle vegetated sites. Invertebrate species associated with coastal vegetated shingle sites include Arachnida, Chilopoda, Diplopoda, Isopoda, Orthoptera, Hemiptera, Coleoptera and Hymenoptera. Seabird species such as *Larus argentatus, Sterna albiforns, S. sandvicensis, S. hirundo, Charadrius dubius, C. alexandrinus, C. hiaticula, Anthus spinoletta* and *Heamatopus ostralegus.Charadrius hiaticula* have been reported in this habitat type in various countries (Bensettiti et al., 2004; Krause et al., 2008; Suffolk Biodiversity Information Service).

The presence and coverage of **negative indicator species** such as non-native species and agricultural species indicate certain level of disturbance on the habitat. Martin et al., (2017) indicate *Cirsium arvense, Lolium perenne,* and *Urtica dioica* as negative indicator species in Ireland and Duhamel et al., (2017) mentions *Lycium barbarum, Rosa rugosa* and *Reynoutria japonica* as **invasive species** on the French coast.

Functional characteristics

Regarding functions, the vegetation established on shingle structures are subject to wave action that create different levels of disturbance ranging from substrate erosion, burial under new deposits of shingle, physical abrasion and inundation with sea water. The vegetation can be washed away, buried and damaged. A response to these natural disturbances that ensure the survival of the vegetation and development of the habitat, is the presence of a persistent seed bank in the shingle matrix. Davy et al., (2001) stress the prevalence of seed dormancy on the characteristic perennial species present on vegetated shingle (*Honkenya peploides* or *Glaucium flavum*).

Landscape characteristics

Coastal retreat and erosion have an effect on wave exposure and weathering conditions (precipitation and wind) as well as on the geomorphological characteristics of the coast (Pérez-Alberti et al., 2013). Retreat of the coast affects habitats exposed to coastal dynamism like sandy beaches, shingle sites and rocky cliffs which are influenced by the exposure to extreme forcing conditions.

Habitat deterioration and disturbance

This habitat can suffer a reduction on its distribution due to agriculture, urban and industrial development (JNCC, 2004). Coastal defence infrastructures and related management of shingle structure such as redistribution of sediment material, also poses a great threat to the habitat. Trampling or water abstraction from groundwater also affect shingle vegetation causing physical and drought stress. Extreme climatic events and current climate change, with the rise in sea level, poses a threat to the habitat (Duhamel et al., 2017).

The main ecological characteristics and associated variables that can be used to assess the habitat condition are summarily presented in Table 1 below.

Table 1. Key ecological characteristics and selection of variables to assess the habitat condition

Ecological characteristics	Types	Description of associated variables	Examples of variables
Abiotic characteristics	**Physical state characteristics**	Wave exposure Sediment characteristic and supply	Frequency of storms Proportion of size particles
	Chemical state characteristics	Soil and nutrients available to plants	- N, P - Organic content in substrate
Biotic characteristics	**Compositional state characteristics**	Composition / diversity of ecological communities (Flora and fauna)	- Characteristic vascular plant species presence and abundance - % of surface invasive species - Entomofauna (coleopters)
	Structural state characteristics	Vegetation cover and density	- Herbaceous cover - Shrub/tree cover - Vegetation succession/transition - Proportion (%) of bare sand
	Functional state characteristics	Recovery and regeneration of vegetation Pollination	- Seed bank - Number and abundance of pollinator typical species
Landscape characteristics		Fragmentation and connectivity Coastal trend	- Measurement of the retreat of coastline through remote sensing - Habitat patch extent - Distance between habitat patches
Other characteristics		Habitat alteration, deterioration	- Presence and occupation by infrastructures - Coastal defences

1.3 Selection of typical species for condition assessment

Typical species of the habitat are used to assess the habitat conservation status. The Habitats Directive uses the term ‘typical species’, but it does not give a definition for use in reporting. For a habitat type to be considered as being at favourable conservation status, the Habitats Directive requires that both its structure functions and its ‘typical species’ are in a favourable status (Article 1(e)).

The formulation of Art. 1(e) could suggest that the assessment of typical species could be carried out separately and complement the assessment of structure and function. In this regard, the selection of typical species should be as robust and appropriate as possible. However little guidance has been provided on how to use the typical species in this assessment.

According to the Guidelines for Article 17 reporting (European Commission, 2023), 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, and which are sensitive to changes in the condition of the habitat (‘early warning indicator species’) and may be drawn from any species group. The sum of sites and occurrences of each habitat type should support viable populations within the region being assessed of the typical species on a long-term basis for Structure and functions to be favourable.

Typical species can vary across the habitat range. Given the ecological and geographical variability of the Annex I habitats 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.

All MSs have communicated a list of typical species for each habitat type, although usually they have not provided any justification or rationale for their selection. The variability of the selection of typical species by MSs seems to indicate that different interpretations are done on the concept of typical species. Mostly plants are proposed as typical species (> 90% of the selected species) and in many cases dominant of characteristic species are included. However, species from other taxonomic groups are also considered (e.g., lichens, insects, birds, mammals…). According to the analysis of national methodologies available for the assessment of habitat structure and function, some MSs assess the typical species separately, while other seem to include the typical species in the assessment of the habitat compositional characteristics. However, the use or consideration of typical species in the habitats assessments is not well documented, in general, in the methodologies analysed for the elaboration of these guidelines.

For instance, in Greece and Cyprus, the assessment of typical species is carried out separately (considering species cover and vitality) from the variables used to assess the structure and functions of the habitats, and the results of both assessments are afterwards integrated into one single value for the habitat condition (Dimopoulos et al., 2018).

In the Netherlands, the assessment of conservation status 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 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).

In Germany, the assessment of the habitat type in each plot is based on the evaluation of the following components: ‘habitat structures’, ‘typical species’, and ‘pressures and threats’. Usually, the number of typical plant species is considered in the assessment of the habitat compositional characteristics. Animal species are included in the assessment of a few habitat types only (Ellwanger et al., 2018).

As above mentioned, typical species may be drawn from any species group and, although often most species reported were vascular plants, consideration should be given to also selecting lichens, mosses, fungi, and animals, including birds. It can be useful to consider key functional groups for the selection of typical species, taking into account the habitat's ecology, the role of typical species as bioindicators (e.g. pollinators, dispersers, decomposers, trophic and symbiotic relationships, etc.) and their sensitivity to changes. Table 2 provides an illustrative list of species' groups that can be used as indicators to assess perennial vegetation of stony banks habitats condition.

This habitat is important for invertebrates and for nesting and foraging of some breeding birds. Ground beetle species (*Nebria livida*), grey wolf spider (*Arctosa cinerea*) or seabird species like ringed plover (*Charadrius hiaticula*) and little tern (*Sterna albifrons*) are indicated as typical of habitat 1220 by Krause et al. (2008).

Table 2. Selecting typical species for monitoring habitat 1220

Species Group	Ecological role (bioindicator of)	Sensitive to changes in quality
Carabid species (e.g. *Nebria lívida*)	Predators of herbivorous invertebrates and prey for higher trophic levels, including shorebirds, lizards, and small mammals.	Wildly use as indicators of habitat condition (Mossakowski & Imrler, 2023). Carabid assemblages respond strongly to soil and vegetation characteristics as well as disturbance, serving as indicators of habitat stability and succession (Rainio et al., 2003). They also support higher trophic levels by providing prey for shorebirds, lizards, and small mammals.
Arachnids	Top predators of herbivorous invertebrates and prey for higher trophic levels, including shorebirds, lizards, and small mammals.	Wildly use as indicators of habitat condition (Mossakowski & Imrler, 2023). Arachnids regulate insect populations through predation and are sensitive to changes in habitat structure, disturbance, and microclimate, making them useful indicators of habitat quality and succession.
Birds (e.g. *Sterna albifrons*)	Nests in the open substrate.	

2. Analysis of existing methodologies for the assessment and monitoring of habitat condition

The following analysis is made on the methodologies collected from 5 Member States: Germany, Denmark, Ireland, Latvia and Sweden.

A summary of the variables included in the methodologies reviewed is presented in Table 3. A more detailed table with examples of the variables, metrics and methods used by said methodologies is presented in Annex 1.

2.1 Variables used, metrics and measurement methods, existing data sources

Regarding abiotic variables, no chemical variables have been described in the consulted methodologies. Physical variables mainly focus on coastline dynamics and substrate characteristics.

Table 3. Types of variables used in Member States for assessing perennial vegetation on stony banks habitat condition

Variable Group	Variable name	DE	DK	IE	LV	SE
A1. Abiotic - Physical	Wave exposure					■
	Substrate characteristics	■		■		
	Substrate sequence	■				
A2. Abiotic - Chemical	None					
B1. Biotic - Compositional	Typical/characteristic species	■		■	■	
	IAS and negative species				■	
	Fauna inventory	■		■	■	
B2. Biotic - Structural	Typical/characteristic species			■	■	■
	IAS and negative species		■	■	■	
	Expansive species		■		■	
	Trees and shrubs		■		■	■
B3. Biotic - Functional	Sand accumulation				■	
C1 -Landscape	None					
Others - disturbances	Anthropic disturbances	■	■	■	■	■

DE (Germany): Krause et al., 2008. DK (Denmark): Fredshavn and Nygaard, 2014. IE (Ireland): Martin et al., 2017. LV (Latvia): DAP, 2023. SE (Sweden): Hedenås et al., 2020.

Physical variables

Wave exposure is visually categorized into predefined exposure classes (from very exposed to very protected) by means of exposure maps. However, it is not clear where these maps can be retrieved from. This classification helps in understanding the potential impact of wave action on different sections of the coastline. This variable is only indicated in the methodology by Hedenås et al., (2020) and can be understood as a context variable that do not inform on the condition of the habitat but provide a valuable insight on their context.

Krause et al., (2008) describes two variables measuring substrate structure: one aiming at detecting the presence of the typical sequence of formations (beach, walls, depressions) and the other, at assessing the composition and diversity of sediments. Martin et al., (2017) also measures shingle particle sizes by measuring the diameter from a field photography and assess the percentage of pebble in the substrate (a minimum of 60% is required for the habitat to qualify as 1220).

Biotic variables

Wave exposure is visually categorized into predefined exposure classes (from very exposed to very protected) by means of exposure maps. However, it is not clear where these maps can be retrieved from. This classification helps in understanding the potential impact of wave action on different sections of the coastline. This variable is only indicated in the methodology by Hedenås et al., (2020) and can be understood as a context variable that do not inform on the condition of the habitat but provide a valuable insight on their context.

Compositional variables

Assessment of the completeness of species inventories for vascular plants, birds, beetles, and spiders is performed by visual expert knowledge during fieldwork (Krause et al., 2008; Martin et al., 2017). The total number of characteristic species, habitat-associated, habitat-dependent, rare, and specially protected species across different organism groups are also indicated by DAP (2023). This assessment involves visual inspections along belt transects measuring 50 meters long and 10 meters wide. The presence or absence of characteristic, rare, and invasive species is recorded through visual inspections along the same transect. The different community types at each monitoring stop (grassland or pioneer communities) are recorded according to Martin et al., (2017).

Structural variables

Structural variables are indicated in all the consulted methodologies. These variables measure coverage of typical, characteristics or notable species, invasive pr other negative species. Variables measuring coverage of woody and grass species of different height and sizes have also been proposed by the methodologies.

Functional variables

The influence of sand accumulation and presence of groundwater recharge points is also indicated in some methodologies but no explanation is provided in the relevance nor the measurement methods used to assess these variables.

Other variables

Variables under the group of others mostly focused on measuring presence of artificial structures and anthropic activities and how these are affecting the habitat. Artificial structures can significantly alter the natural processes and ecological integrity of these environments. These structures, which are normally part of the management of coastal areas and include sea defences (e.g., rock armour), paths, fences and tracks; can directly impact the cliff structure, vegetation composition, and habitat connectivity. They may lead to habitat fragmentation, increased erosion, altered drainage patterns, and the introduction or spread of invasive species. The presence of these structures can also disrupt natural succession patterns and negatively affect the distribution and abundance of characteristic plant and animal species. Modifications to coastal processes through artificial structures or management practices can also alter erosion and sedimentation patterns, water flow, and overall habitat stability.

Leisure activities, such as trampling by hikers or disturbance from recreational vehicles, can directly damage vegetation, compact soil, and disrupt wildlife. Fertilization and pollution from agricultural or other industrial activities can also have a negative impact on the communities.

2.2 Definition of ranges and thresholds to obtain condition indicators

Some of the consulted methodologies, like Hedenås et al., (2020), do not indicate threshold values. However, those that include them, do not specify how these can be obtained. The threshold values use percentage values, presence or qualitative categories.

Krause et al. (2008) use three qualitative categories associated to favourable or unfavourable conditions (e.g., substrate structure proposed by Krause (2008) can have the following values of A (favourable) = natural unchanged, B (unfavourable-inadequate) = small changes or C (unfavourable-bad) = larger changes. Martin et al., (2017) assess the condition of some variables using one qualitative status indicating good condition, understanding any other possible condition as bad (e.g., regarding the number of notable species, it is considered a Favourable status only if there is no evidence of decline in number of individuals over time.).

The methodologies developed by Fredshavn and Nygaard (2014) or DAP (2023) assign scoring values to the different possible outcomes of the variables. For the variable proportion of landfill area (%) dominated by expansive species (DAP, 2023), a point value from 0 to 2 are given to the possible % values. The use of percentage values of some variables is also used in Krause et al., (2008) combined with the afore-mentioned categories (e.g., species inventory present in a 50-60% corresponds with a B).

2.3 Aggregation at local scale

Some methodologies do not indicate how the aggregation of variables is done at local or plot scale (Hedenås et al., 2020). Those that have described an aggregation system use quantitative rules or categorical majority rules to add up the values of the variables.

Quantitative rules, which apply arithmetic operators, or in some particular case multivariable indices are used in some methodologies developed in Denmark and Latvia

In Denmark, Fredshavn and Nygaard (2014), which calculates a “nature condition index” that considers both structure and function and species partial indices.

The structure index is assessed assigning weighting values to the variables that are grouped in four categories: vegetation structure, hydrology and coastal protection, grazing, impact of agricultural operations and habitat-characteristic structures. The variables described for each category (e.g., coverage of dwarf-scrub) are assigned points from 0 to 100 to each of their possible values, with 100 representing favourable condition for said variable. The variables are weighted according to their importance, and since they are built in a tiered system, the weighting is done at each hierarchical level. The weights are normalized so that the sum of the weights is 1. A weight of 0 means that the variable has no importance for the overall index, while a weight of 1 means that the indicator constitutes the entire contribution of the hierarchical level in question to the structural index. The weights should be assigned on a solid data basis, but in the absence of this, the weighting has been done based on best expert judgment. Each of the four variable categories is also weighted according to its importance in a similar way.

The species index is part of the overall nature condition index and is calculated as a weighted average of the species score index and the species diversity index. Both sub-indices are calculated on the basis of the species composition of the vegetation in a documentation circle with a radius of 5 m, where the centre is placed in a homogeneous area that is characteristic of the habitat type. For each habitat type, the species are divided into contributory species, negative species and null species. The contributory species contribute their species points, which are a score between 1 and 7. High points are awarded to species that are very sensitive to negative impacts on the habitat type, whereas species with low points will be more or less favoured by these impacts. The species score index is calculated as the average of the species' point values, regardless of how many species are included in the species composition. The species diversity index is calculated as the sum of the species' point values adjusted for the average species diversity of the habitat type. Negative species are promoted by a strong negative impact on the habitat type. In both indices, both negative species and invasive species have a score of -1, while null species, which are introduced and non-native species, have a score of 0. Both the structure index and the species index have values between 0 and 1 on the reference scale, where 1 is the best natural condition and 0 is the worst. The two indices are weighted together to form an overall natural condition index that describes the overall natural condition of the habitat type.

On habitat types that occur close to the sea, as the Annual vegetation of drift lines (1220) and perennial vegetation of stony banks (1220), the vegetation is naturally characterised by nutrient-demanding opportunistic species, which in other communities are an expression of an unnaturally high nutrient level. Since the same species scores are used in all habitat types, the weight assigned to species index is considerably lower (0.2) than to the structural index (0.8) in these communities.

In Latvia, according to DAP (2023), each variable has three rating classes, where ratings are expressed as "0" or "1" or "2". Parameter ratings are summed within a transect. The result is used to assess the quality of the habitat. The final assessment algorithm is still under development in the frame of LatViaNature LIFE Integrated project “Optimising the Governance and Management of the Natura 2000 Protected Areas Network in Latvia[2] ”.

Categorical majority rules, which establishes the habitat condition according to pre-established combinations of ordinal condition categories (i.e., favourable, non-favourable, bad condition) are sued, for instance, in Germany and Ireland.

In Germany, Krause et al. (2008) group the variables in three groups: 1) completeness of the typical habitat structures, 2) completeness of the habitat typical species inventory, and 3) impairments. A categorical status is given to each of these variable groups: Excellent, Good and Medium-poor. Subsequently, the following rules are applied: if all three groups share the same status, they have a common status condition; two criteria share the same status, in general, they result in the most common status condition. For example, two Excellent and one Good, results in Excellent. If there is a C rating, an overall rating of A is no possible, but for two Excellent and one Medium-Poor partial results, the overall result is still a Good status.

In Ireland, according to Martin et al. (2017), the data from all of the monitoring stops and the relevant mapping data contributed to a habitat-scale assessment. The main source of information regarding Structure and Functions was the monitoring stop, wehre a number of variables were assessed according to defined thresholds and the number of variables that did not reach the threshold (failed) was noted. If no variable failed, then the Structure and Functions for the site were assessed as Favourable. If one or two criteria failed, the Structure

[2] https://latvianature.daba.gov.lv/en/

and Functions were assessed as Unfavourable-Inadequate. If three or more criteria failed, they were assessed as Unfavourable-Bad. Failure to pass three or more criteria indicates that several aspects of the Structure and Functions are impaired, irrespective of how many criteria are assessed.

2.4 Aggregation at biogeographical scale

Most MSs adhere to the guidelines from Article 17 reporting for the period 2013-2018, which state that the 'structure and functions' parameter is considered 'favourable' if 90% of the habitat area is in 'good' condition. It is classified as 'unfavourable-bad' if more than 25% of the habitat area is reported as 'not in good condition,' and 'unfavourable-inadequate' for intermediate percentages. Consequently, in most cases, the aggregation of variables to assess structure and functions at a biogeographical scale involves weighting local scale assessments according to the corresponding occupied area.

2.5 Selection of localities

Most methodologies do not indicate which locations have been selected or the criteria followed to select them.

In Martin et al., (2017), surveys were conducted in 30 sites out of which 1220 was present in 27. The sites were chosen to be representative of the range of habitat types and geographic locations of 1220 Vegetated shingle sites within Ireland and. For 11 of the 30 sites ecologists had digital and printed baseline maps derived from the maps generated during the Sand Dunes Monitoring Project (Delaney et al., 2013) and Coastal Monitoring Project (Ryle et al., 2009); for the other 21 sites there was no baseline mapping and the site survey was guided by the field notes and positioning of vegetation transects recorded by the National Shingle Beach Survey (Moore & Wilson, 1999).

The identification and selection of monitoring localities described in DAP (2023), relies on the Natura 2000 Standard Data Form (SDF) information submitted and approved by the European Commission. It is based on the results of the Emerald/Natura 2000 inventory project (2001-2004), on previously available published information no older than 1990, on the most recent monitoring data and on the most recent habitat mapping data (Nature Census project 2017-2023, nature conservation plans, etc.). All habitat mapping data is stored in the nature data management system "Ozols" containing geospatial data. This geospatial data layer is a basis for site selection.

Selection of monitoring localities is based on following steps:

1) For all habitat types, the list of sites to be surveyed shall include all sites with entries A and B in the Natura SDF for particular habitat type;
2) for habitat type for which A and B together account for at least 20% of the total number of sites, all those sites shall be monitored; in case when A + B < 10 sites, C sites should be selected randomly to add the required number of sites (at least 10);
3) For habitat type where C sites > 80%, the C sites to be visited shall be selected by randomly selecting 20% of all C sites. Ensure that each habitat type has at least 10 sites. If the total number is less than 10, all sites shall be visited, whether they are A, B or C;
4) check that there are no Natura 2000 sites left outside the list that would not have been visited even once (this is possible in case of random selection and should also be checked in the context of the Natura 2000 species monitoring sites). Identify these sites;
5) analyse which habitats occur in these remaining sites. Remove all habitats that are already well represented with more than 20 sites included into the monitoring plan

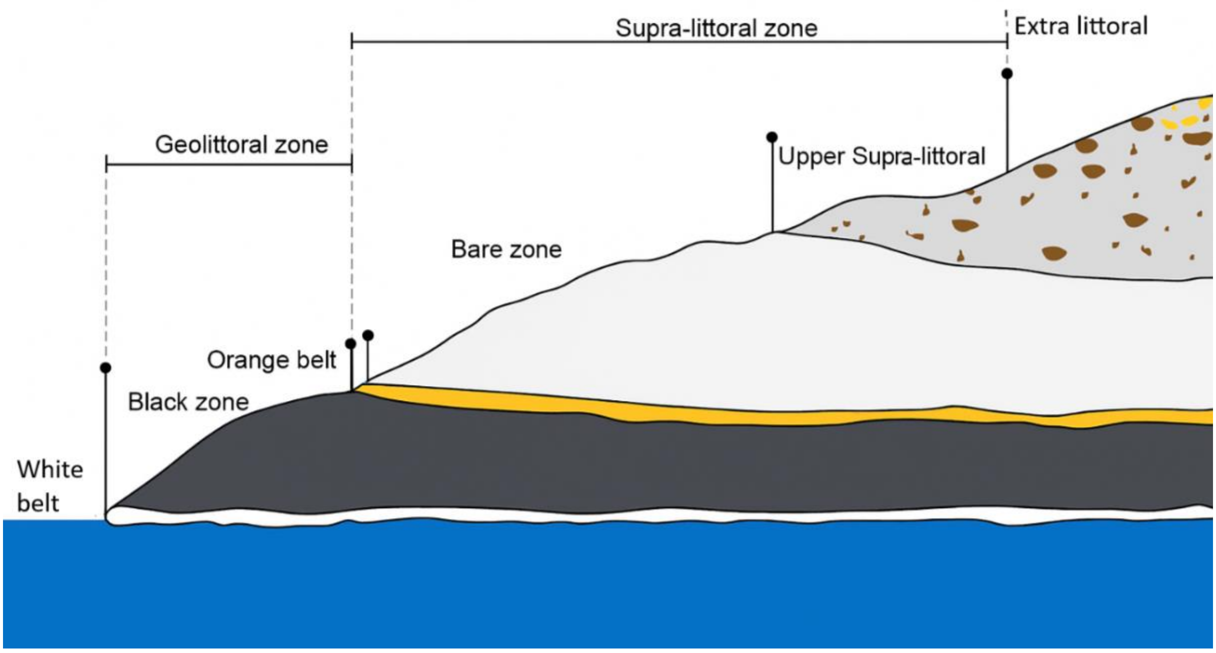
(selected previously in steps 1-3). For remaining habitat types include one to three habitat types to be monitored for each site.

2.6 General monitoring and sampling methods

In Fredshavn and Nygaard (2014), a circular sample plot with a radius of 5 meters (with and area of 78.5 m2) is used for recording species composition but no more information on sampling protocols is provided.

In the methodology developed by Hedenås et al., (2020), a field inventory based on a 10 m wide transect is used to monitor presence and characteristics of different coastal habitats (Figure 2). The transect is divided in zones (geolittoral, supralittoral and extra littoral) and extends from the water line to the extra-littoral forest, in order to capture the following habitats: sea cliffs (1210,1220 and 1230), meadows (1310, 1330), boreal coastal habitats (1610, 1620, 1630, and 1640), dune habitats (2120, 2130, 2140, 2170, 2180, 2190) and upland forest (9030). Photointerpretation is used to define the limits of each zone. Detailed inventory in the extra littoral is only carried out in cases where stone and gravel banks (1220), sea cliffs (1230 incl. 1239), dunes (2100) or upland forest (9030) is found above the supralittoral. In this case, the transect continues on the extra littoral area until the habitat ceases. The exception is sea cliffs (1230) which are included even if they occur further away without direct contact with the end point of the beach zone.

Figure 2. Assessment of costal habitats on a rock/cliff beach



The geolittoral consists of a zone dominated by barnacles at the bottom, known as the white belt, followed by a zone dominated by either cyanobacteria (sl. soaps, sl. *Calothrix*) or black lichen (*Verrucaria maura*), known as the black zone. The supralittoral zone consists of a zone dominated by orange lichens (*Caloplaca* spp.), known as the orange belt, followed by the bare zone, which in turn is followed by an area with a well-developed lichen community, known as the ‘upper supralittoral zone’, which is mainly affected by spray. The extra littoral zone continues until the rock/sill ends and another plant community takes over, which shows no signs of being affected by aerosols.
Source: Adapted from Hedenås et al. (2020).

The minimum mapping unit estimated for coastal habitats is 0.1 ha. When this criterion is not met, meaning that the area occupied by a habitat inside the transect is lower than its minimum area, the habitat is assigned as the next habitat type that has reached the minimum required area.

Occurrence of the species listed on the species protocol is recorded and for some species the number of plants, number of tufts or coverage must also be noted. The coverage is stated in m^2 with $0.1m^2$ as the smallest area allowing for listing. Shrub coverage is recorded along with their length (m), width (m) and density (in %) determining the distance from the starting point for each found shrub (of each species).

In Martin et al., (2017) a 167 monitoring stops were recorded within the 1220 Vegetated shingle, with 111 stops (67%) within the pioneer community, 48 (29%) within the grassland community, 6 (4%) within the scrub community and 2 (1%) within other communities. Maps from previous projects were used as baseline maps for selecting the monitoring spots. 11 of the 30 sites had been previously surveyed by the CMP or SDM; the location of the VSM monitoring stops followed those of the most recent survey and the same numbers for the stops were utilised.

Transects perpendicular to the coastline were surveyed at regular intervals along the foreshore and transitions between habitats were noted. Each habitat mapped was represented as a closed, labelled polygon on the field map. In cases where complex habitat mosaics were detected and the minimum mapping area was too large to allow proper and easy representation, the habitat with the most cover within a polygon was called the primary habitat and other habitats were recorded as the secondary and tertiary habitats.

Recording of structure and function variables was conducted at monitoring stop level. A minimum monitoring area of 0.04 ha. Monitoring stops were divided among the different 1220 Vegetated shingle communities based on the area each community covered and the diversity within each.

At each 2 m x 2 m stop within the 1220 Vegetated shingle habitat three digital photographs were taken: one of the 2 m x 2 m monitoring stop area, a landscape photograph to put the stop in the context of its surroundings, and if exposed shingle was visible a third with a 30 cm ruler placed on the shingle substrate to allow particle size to be recorded through digital images. For a monitoring stop to qualify as 1220 Vegetated shingle habitat at least 60% of the substrate had to be classified as either gravel, pebble or cobble, or a combination. Cover scores were recorded to the nearest 5% except for covers of less than 10%; to provide increased detail and consistency, these were recorded as 0.1%, 0.3%, 0.5%, 0.7%, 1%, 3%, 5% or 7%.

Similar to the methodology described by Martin et al., (2017), DAP (2023) uses a combined route-point-transect method to select monitoring areas. Monitoring planning is based on previous monitoring period, optimising their number and location according to the occurrence of the monitored habitat, influencing factors, accessibility and other aspects. A route (or several routes) shall be established along the coast (parallel to the coast) within or outside the Natura 2000 site concerned. The route shall cover the majority of each coastal habitat to be monitored in the area. The length of a single route shall be approximately 500-1000 m.

The route map marks the points where the expert must first identify which habitats are present perpendicular to the shoreline (seaward-landward) and which of these are to be monitored. In each habitat strip, a habitat questionnaire is completed using transects (parallel to the coastline) 50 m long and 10 m wide. Where the habitat is narrower than 10 m, the transect shall include the full width of the habitat. If the transect size is less than 50x10 m, the length and width of the transect shall be indicated in the notes to the questionnaire.

The optimum time for monitoring is July and August, but it is also possible to monitor in September. For most coastal habitats, monitoring should be carried out at least once every six years. In cases where severe storms or other factors lead to significant changes in habitat area and structure, monitoring should be more frequent.

2.7 Other relevant methodologies

Regarding other relevant methodologies, JNCC (2004) lists five broad criteria that should be used to assess the status of the 1220 Vegetated shingle habitat. These are:

- habitat extent: current extent recorded in the field that is then compared with previous survey data or aerial photographs
- physical structure: functionality and sediment supply, identifying anthropogenic processes (e.g. coastal defences) that may be having a negative impact
- vegetation structure: natural zonation of vegetation important in a dynamic habitat such as 1220 Vegetated shingle
- vegetation composition: characteristic/typical species (for each vegetation zone) and presence of notable species such as *Crambe maritima*
- negative indicators: negative indicator species, such as non-native species and agricultural species, and signs of disturbance.

In addition to these broad criteria JNCC (2004) also recommends that factors such as transitions to other habitats (e.g., saltmarsh) are recorded.

The methodology jointly monitors habitats 1210 (annual vegetation of drift lines) and 1220, as they form the two main vegetated shingle zones. Variables are to be assesses by means of a structured walk (e.g., a W shaped walk) with at least 10 stops within each assessment unit. The general routes with stops should be pre-selected by consulting maps or aerial photographs before the field survey is conducted. At each stop, the variables (e.g., percentage cover and/or presence of relevant species) should be assessed within approximate 4 m^2 sampling units. Visual estimates are recommended and considered sufficient.

The number of recommended monitoring locations is also considered to be a decision based on the assessors' overview of the state of the site.

The methodology provides the following frequencies for defining dominant, abundant, frequent, occasional and rare species:

- Dominant: the species appears at most (>60%) stops and it covers more than 50% of each sampling unit.
- Abundant: species occurs regularly throughout a stand, at most (>60%) stops and its cover is less than 50% of each sampling unit.
- Frequent: species recorded from 41-60% of stops.
- Occasional: species recorded from 21-40% of stops.
- Rare: species recorded from up to 1-20% of stops.

One or more transects are recommended to assess the width of the shingle zones and to detect the zonation and possible intrusion of adjacent habitats. The use of photography and LIDAR is recommended.

2.8 Conclusions

The consulted methodologies present some commonalities regarding the habitat characteristics and associated variables to measure. No chemical nor landscape characteristics are measured in any of the consulted methodologies. The reason behind this decision can be explained by the nature of vegetated coastal shingles, a habitat which is heavily influenced by coastal dynamics and marine water, and which is naturally fragmented, being formed by shingles of different sizes that are subject to wave and coastal dynamics.

Substrate physical characteristics are measured by two of the three methodologies (Krause et al., 2008; Martine et al., 2017; Hedenås et al., 2020). Only one of the methodologies analysed methodology consider wave exposure, despite this factor plays a major role in the habitat natural dynamics (Hedenås et al., 2020). The measurement of compositional and structural variables focusing on characteristic species, as well as on invasive alien species or other negative species, is found across all the consulted methodologies. Lastly, all methodologies monitor anthropic disturbances.

Thresholds for the variables are provided in the majority of the methodologies and these are based on percentage values, presence or qualitative categories. However, it is not specified how these values are obtained. When a system for the aggregation of variables is provided, these are based on quantitative rules, indices or categorical majority rules. Only one methodology does not indicate the aggregation of variables (Hedenås et al., 2020).

The criteria used for selecting localities aim to ensure that they are representative of the full range of habitat types, based on sites chosen in previous monitoring programs. Sampling methodologies are similar among the consulted methodologies and are based on a combination of transects and sampling plots.

Overall, the strong similarities among the consulted methodologies and with other monitoring approaches implemented outside the EU lend support to their reliability and suitability as sampling methods. However, there is limited application of emerging technologies that could significantly improve monitoring efficiency and reduce manual effort.

3. Guidance for the harmonisation of methodologies for assessment and monitoring of habitat condition

3.1 Selection of condition variables, metrics and measurement methods

As shown in the previous section, there are some commonalities in the methodologies used by the various EU Member States to assess the condition of perennial vegetation of stony banks but also significant differences in the specific variables and metrics used. Common procedures would be desirable to obtain comparable habitat assessments across Member States. In order to harmonise the selection of condition variables for the assessment and monitoring of habitat 1220, several general principles should be considered:

- Any habitat type can be described with a set of key characteristics, which can be measured with relevant variables.
- There are contextual factors operating in the different MS, which influence the values of the variables that determine whether the habitat is in good or not good condition.
- For a given habitat, the final assessment of habitat condition, based on the relevant variables associated to key characteristics of the habitat, should be equivalent for the different MS, after accounting the contextual factors of each MS.

Moreover, the harmonization of the use of relevant variables requires a set of common requirements:

- For any habitat type, the main characteristics must be measured in all MSs using a set of common variables, applying the same measurement procedures.
- The description of the condition variables, metrics and measurement procedures must be clearly defined and perfectly understandable so that they can be applied in all the MS.
- The number of common condition variables should be the minimum needed to determine the habitat condition.
- The common variables should meet the criteria of validity, reliability, availability, simplicity and compatibility (Czúcz et al., 2021).

This section presents a proposal for a common set of variables, recommended metrics, and measurement procedures for perennial vegetation of stony banks, classified as follows:

Essential variables (E) correspond to characteristics that are vital for the habitat, describe the distinctness of the habitat or its condition. **Recommended variables** (R) correspond to additional variables which are relevant but that can be neglected to be measured in some contexts. In addition, a number of **descriptive variables** (D) are also proposed, which inform on the context of the habitat and can be relevant to understand the processes that can influence their ecological status, but do not directly inform of such condition. This structured framework ensures scientifically robust and context-specific habitat assessments.

A proposed list of condition variables for perennial vegetation of stony banks is summarized in Table 4. The list is based on the main characteristics described in Section 1.2, on the methodologies used by the Member States for habitat condition assessment (see section 2), and available literature on these habitats. The proposed metrics and measurement methods are designed to be easily and reliably obtained.

The characteristics and proposed condition variables are classified according to the Ecosystem condition typology from SEEA-Ecosystem Accounting (United Nations, 2021).

Regarding **physical variables**, exposure to wave action and tidal dynamics influence sediment supply and vegetation composition. Classifying the coastal shingle site according to exposure classes (e.g. protected or very exposed) can help in the characterization of the habitat and provide information to interpret the other variables (e.g. sediment supply) but do not directly inform about the condition. For this reason, it is proposed as a descriptive variable. A similar reasoning is behind the proposal of storm surges and tidal regime; these variables will determine the sediment characteristic and supply and, therefore, plant colonization but a certain frequency of stormy events or high tides cannot be linked to a certain habitat condition. Thus, these variables are presented as descriptive.

Particle size and proportion of particle classes is proposed as an essential variable since particle size determines soil development, water retention and plant colonization. This variable is also included in the methodologies of two of the consulted methodologies (Krause et al., 2008; Martin et al., 2017), which supports its reliability. Digital imagery can be used to assess diameter size and composition of the sediment.

Regarding **chemical variables**, accumulation of organic matter (from shells, seaweed, pioneer species) influences plant colonization and development of shingle communities. Measured as the percentage of organic matter or soil organic carbon (SOC), soil organic matter content is proposed as an essential variable and can be assessed using the methods presented in Table 4.

As **compositional variables**, the presence of characteristic and typical plant and fauna species, as well as invasive and negative species, are proposed as essential variables.

Characteristic species are key ecological indicators that reflect habitat quality and specific environmental conditions, playing a major role in defining ecosystems' composition, structure and functioning. Changes in species richness (the number of species) or abundance (the distribution of individuals among species) can signal habitat degradation or recovery. Metrics for assessing this variable include **species richness**, which quantifies the total number of species in a given area, and evenness, which measures the relative abundance of different species (properly called **species diversity** and usually measured through the Shannon index or the Simpson index) (Roswell et al., 2021). Monitoring methods for characteristic species include field surveys, which involve direct observation and data collection on species composition, and remote sensing technologies, which allow for detecting and mapping characteristic species over large areas. Presence of fauna species is also proposed as an essential variable, which will rely on local species inventories and typical species list specific of each MS. Invasive and negative species (e.g., *Lolium perenne* and *Urtica dioica* as indicated by Martin et al., 2017) presence is also proposed as an essential variable since their presence indicates a level of disturbance that can affect the condition of the habitat.

Regarding **structural variables**, the presence and coverage of characteristic vegetated shingle community types has been proposed as an essential variable based on Martin et al., (2017). According to the results obtained by said study, the pioneer community hold the largest coverage values (52% of their survey area), followed by the grassland community (42%). The scrub community was much less present than the other two (4%) and the other potential communities are less frequent (2%). It can be deduced that a higher proportion of scrub communities and lower of pioneer communities is a sign of unfavourable condition but exact percentages or ratios cannot be provided within the scope of this project since they should be set according to the region characteristics.

Coverage of characteristic vegetation, as well as invasive species and negative species are also proposed as essential variables since they define the structure of the habitat. Metrics for vegetation cover include the percentage or fractional vegetation cover, which quantifies the proportion of ground covered by vegetation. These metrics help identify trends in ecosystem stability and resilience over time. Monitoring methods include remote sensing, which uses satellite or aerial imagery to analyse vegetation patterns over large areas, and ground-based vegetation cover surveys, where direct observations and measurements are made in the field.

As **functional variables**, the presence of a seed bank is indicated as an essential variable due to the importance of species capacity to re-emerge and survive the natural disturbances of the habitat. The use of soil eDNA is proposed to assess the presence of taxa in the soil. The presence of pollinator species is proposed as a recommended variable due to their role as bioindicators of ecosystem health and their natural presence in this habitat.

Regarding **landscape variables**, changes in coastal trend including coastal retreatment rate and coastal width directly influences reduction of the area currently or potentially occupied by the habitat, and it is proposed as an essential variable. Coastal retreatment rate is the speed at which a shoreline moves landward due to erosion, sea-level rise, or human activities. It is typically measured in meters per year (m/yr). The trend of the coastline over the last ten years should be measured by comparison of aerial photographs covering approximately this period or as close as possible. The photographs should be georeferenced. The measurement will be made perpendicular to the coastline along representative transects. Once the coastlines at different dates have been obtained from the digitalization of the indicators, the comparison between them and the quantification of the change rates can be carried out using GIS (Ojeda et al., 2002). For the monitoring of this parameter, it is recommended to use the "Digital Shoreline Analysis System" tool from ArcView, which is a stand-alone application associated with a GIS that calculates the change in coastline or boundary over time. DSAS allows you to calculate exchange rate statistics from multiple historical positions on the coast. It provides a system for setting measurement transects, performs rate calculations and other types of information associated with exchange rates.

Number, size and distances between habitat patches are also proposed as an essential landscape variable. These will shape the habitat connectivity and will inform on the relation with adjacent habitats. Monitoring methods include GIS tools and habitat mapping, which allow for precisely measuring and analysing patch size and spatial patterns.

Regarding **disturbances of anthropogenic origin** such as pollution from industrial or agricultural activities, trampling derived from recreational activities, fragmenting infrastructures, coastal defence are indicated as essential variables. Their presence and surface occupied can be recorded and estimated using remote sensing or aerial photography.

Table 4. Proposal of condition variables for assessing and monitoring perennial vegetation of stony banks habitat (1220)

Application (App): D - descriptive/contextual; E: essential; R: recommended.

Variables	Metrics	App	Measurement procedure	Ecological relevance
1. Abiotic characteristics				
1.1 Physical state characteristics				
Wave Exposure	Exposure classes	D	Use of current coastal exposure maps or development of models.	Influences sediment supply and vegetation composition and dynamics.
Tidal regime and range	Tidal prism	D	Data can be retrieved from meteorological stations.	Influences sediment supply and vegetation composition and dynamics
Storm surge incidence	d y-1	D	Data can be retrieved from meteorological stations.	Influences sediment supply and vegetation composition and dynamics
Particle size and composition	Size diameter and of each class proportion (%)	E	Field assessment of particle sizes and proportion. Assessment can be performed with digital photography.	Determines soil development, water retention and plant colonization.
1.2 Chemical state characteristics				
Soil organic matter content	Soil Organic Carbon (SOC) (% or g/kg), Loss on Ignition (LOI), carbon-to-nitrogen ratio	E	SOC: Walkley-Black method (wet oxidation, % or g/kg) or dry combustion with a CHN analyser (g/kg). LOI: by heating soil at 500-550°C (%). The C:N Ratio evaluates the carbon-to-nitrogen balance.	Accumulation of organic matter (from shells, seaweed, pioneer species) influences plant colonization and development of shingle communities.
2. Biotic characteristics				
2.1 Compositional characteristics				
Species richness	Number of plant species per monitoring plot surface	E	Visual assessment of the number of species observed within a monitoring plot.	
Species diversity	Shannon diversity index (H´), Simpson Diversity Index (D),	E	These indices rely on precise species counts from field surveys, and the specific formulas available in any ecology textbook should be used. H´: determine the proportion of individuals for each species and assesses how evenly they are distributed within the community. D: by calculating the likelihood that two randomly selected individuals belong to different species	Includes the number of species and their relative abundances, offering a fuller view of the community

Variables	Metrics	App	Measurement procedure	Ecological relevance
Characteristic vegetation species	Presence	E	Visual assessment of presence during field work based on species inventories.	
Characteristic fauna species	Presence	E	Visual assessment of presence during field work based on species inventories.	
IAS and negative species	Presence	E	Record of presence during field work based on species inventories.	Their presence and abundance can displace characteristic and typical vegetation of the habitat, indicating a degradation of the habitat condition.
2.2 Structural characteristics				
Coverage of shingle habitat community types	Percentage of the monitoring plot area covered by community types.	E	Assessed at the monitoring plot using photographic digital analysis and visual inspection on site. Community types: Scrub communities, Heath communities, Grassland communities, Mature grassland communities, Secondary pioneer communities, and Pioneer communities	Presence and dominance of the different community types allow to characterized the successional stage of the habitat or degradational stage.
Coverage of characteristic species	Percentage of the monitoring plot area covered	E	Assessed at the monitoring plot using photographic digital analysis and visual inspection on site.	
Coverage of scrub and woody species	Percentage of the monitoring plot area covered	E	Assessed at the monitoring plot using photographic digital analysis and visual inspection on site.	An elevated coverage of woody vegetation indicates a more mature successional stage, deviating from the characteristic pioneer and grassland communities.
Coverage of IAS and negative indicator species	Percentage of the monitoring plot area covered	E	Assessed at the monitoring plot using photographic digital analysis and visual inspection on site.	Their presence and abundance can displace characteristic and typical vegetation of the habitat, indicating a degradation of the habitat condition.
2.2 Functional characteristics				
Pollinators number and abundance	Presence and number of pollinator typical species	R	Visual assessment of presence during field work based on species inventories.	
Seed bank	Presence and composition	E	Assessed through eDNA of soil samples.	Species capacity to re-emerge and survive natural disturbances influences the survival of the habitat.

Variables	Metrics	App	Measurement procedure	Ecological relevance
3. Landscape characteristics				
Coastal trend	Meters/year	E	Remote sensing -DSAS	Coastal width and coastal retreatment rate directly influence reduction of the area currently or potentially occupied by the habitat.
Fragmentation / patchiness	Number, size (m2 or ha), and distance (m or Km) among patches	E	Remote sensing	Patch sizes and the relation between them and mosaic with other habitats.
4. Other characteristics				
Anthropogenic disturbances: pollution, trampling	Presence and visible impacts. Percentage of surface occupied at monitoring plot level.	E	Visual assessment in the field or through remote sensing.	Disturbances can degrade the condition of the habitat.

3.2 Guidelines for the establishment of reference and threshold values, and obtaining condition indicators for the variables measured

The measured values of the condition variables need to be compared with reference values and critical thresholds to assess the condition of each variable. 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 level represents its distance from the reference condition.

Reference levels should be defined consistently across different variables within a given ecosystem type, and for the same variable across different ecosystem types. This ensures that derived indicators are compatible and comparable, and that their aggregation is ecologically meaningful (United Nations et al., 2021).

Reference levels are typically defined with upper and lower values reflecting the endpoints of a condition variable's range, which can then be used in re-scaling. For instance, the highest value may represent a natural state, while the lowest value may represent a degraded state where ecosystem processes fall below the threshold required to maintain function (Keith et al., 2013, in: United Nations et al., 2021). 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.

Establishing reference values and thresholds is essential for determining whether habitats are in good condition or have become degraded. Reference values represent the desired state of an ecosystem, typically reflecting intact or minimally disturbed conditions. These values serve as benchmarks for assessing habitat condition.

These guidelines do not aim to prescribe specific threshold values. Rather, they outline the main approaches and provide guidance for establishing reference values that support the determination of good or not-good condition, while accounting for the ecological variability of habitats across their range.

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.

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.

All approaches should be grounded in scientific literature. Methods that use values from a single baseline year as a reference for good condition are not recommended, as the selected year may not reflect favourable conditions, and historical data may be unreliable or incomplete (Jakobsson et al., 2020). The use of historical period (e.g., pre-industrial) as a reference state, as proposed by Stoddard et al. (2006) and Keith et al. (2020) aligns with the baseline approach but also overlaps with comparisons to undisturbed cases (see below). If conditions during a specific baseline year are well documented as favourable, they may be useful for trend analyses. Likewise, where historical pristine conditions are clearly documented, they may serve as valid reference states under the undisturbed comparison approach.

Absolute biophysical boundaries

These refer to situations in which observed values of variables exceed 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.

- Advantages: This approach provides robust and transparent criteria that are clearly linked to the ecological integrity of the habitat.
- Disadvantages: 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). While this method may appear straightforward, it is often limited by the scarcity of suitable sites, especially in landscapes that have been historically modified.

- Advantages: 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.
- Disadvantages: Methodological challenges arise due to the difficulty of identifying a sufficient number of suitable reference sites in historically altered environments.

Comparison to cases 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. This assumption is generally valid in human-modified landscapes and can be linked to historical reference conditions when human pressures were less pronounced (Stoddard et al., 2006). However, disturbances that are part of a natural disturbance regime 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, as found in “primary” forests (sensu Sabatini et al., 2017), and are often directly connected to climax communities such as old-growth or primeval forests (Wirth et al. 2009; Burrascano et al. 2013; Buchwald, 2005), which are typically assumed to be in good condition. However, in regions with long-standing anthropogenic pressure, it may be difficult to identify unaltered or naturally disturbed habitats for certain 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 (Alfaro-Sánchez et al. 2019).

- Advantages: 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.

- Disadvantages: The assumption that any disturbance reduces habitat quality may not always be valid. Moreover, identifying sufficient undisturbed or naturally disturbed reference areas can be challenging for some habitat types.

Modelling the relationships between variables and condition

This approach assumes a relationship between variable values and habitat condition. When determining threshold and reference values, models that describe these relationships 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 examples can be extrapolated to other contexts, such as 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). For instance, deadwood volume in pristine forests can be modelled along productivity gradients to establish reference values in climatic conditions where unaltered forests no longer exist (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. It is also possible to create models in which condition is inferred from variables other than the condition variable itself – for example, biodiversity-related condition variables may be inferred from pollution levels. However, this approach should be used with caution to avoid tautological inferences involving variables that reflect pressures.

- Advantages: 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.
- Disadvantages: 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 et al., 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 of good condition, but on statistical inferences subject to the constraints of the sampling used to build the reference database.

- Advantages: This approach can be applied with reasonable ease by users with statistical training. It is transparent, replicable, and minimally subjective.
- Disadvantages: 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 level of expertise may be insufficient 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.

- Advantages: This approach is easy to apply and is commonly used.
- Disadvantages: It entails a high degree of subjectivity and low transparency, which limits replicability and reliability. Its use may also be constrained by the scarcity of suitable experts for particular habitats and Member States.

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

Habitat condition assessments are based on determining whether the variables used indicate good or not good condition, according to defined threshold or ranges. 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 MSs. 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; or good, medium and bad) 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 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.

These values are normalised using reference levels and reference conditions, allowing comparison across variables. Measurement values are thus scaled in relation to their reference levels, thereby normalised to a common scale and 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 level

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 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 habitat type area in good/not good condition is the key information needed for evaluating the conservation status of structure and functions 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), two main aggregation approaches can be distinguished: the one-out, all-out rule (minimum aggregation) and additive aggregation (e.g., addition, arithmetic mean, geometric mean). Further information on aggregation approaches and methods is provided below.

Minimum aggregation, or the One-out, all-out rule

For the 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

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.

Simple additive methods and averaging approaches

Simple additive methods calculate an aggregated value as the sum of the n values (vi) of the variables. Averaging approaches are among the most commonly used methods for aggregating indicators. These include straightforward calculations such as the arithmetic mean, weighted average, median, or combinations thereof, to produce an overall assessment value.

Weighting

Differential weighting of 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 ecosystem. Ideally, the approach should be supported by a clear scientific rationale and informed by input from ecologists with expertise in the relevant ecosystem types.

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.

Normalization of variables values (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, the measured values of variables 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 3).

Figure 3. Example of deriving condition indicators by rescaling the values obtained for variables, based on upper and lower reference levels

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

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)

3.3.2 Proposal for the aggregation of measured variables

A quantitative aggregation method should be applied to integrate all essential and specific variables measured to assess the habitat condition. The method should be applied consistently across the habitat range in order to obtain comparable results. The main steps for aggregation are described below.

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). Thus, each variable's value will be in the range 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, and considering the difficulties to suggest a more complex method or index, we describe here a preliminary proposal for aggregation based on the **arithmetic mean**, which 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 result, the aggregated value would range between 0 and 1.

An alternative method would be to use the weighted average, in which the weight of each variable should be decided, justified and agreed upon for each habitat type by all the MSs that would apply the method. This method can be formulated with the following equation:

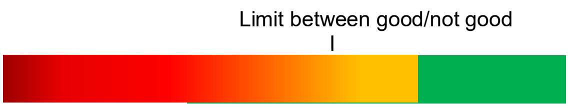
$$Local\ condition = \sum_{1}^{n} v_i * w_i/\mathrm{n}$$

Where n is the number of variables, v_i is the rescaled value of the corresponding variable (between 0 and 1) and w_i the corresponding weight, with ∑ wi =1. The aggregated value would 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 a robust scientific knowledge. It also requires reaching a consensus on the weights assigned to the variables measured for each type of habitat, among all the countries that must 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.



3.4 Guidelines for aggregation at the biogeographical region scale

Following Art. 17 guidelines, each monitoring station must be classified as either in 'good condition' or 'not in good condition' based on aggregating the variables used to assess the habitat structure and function at this local scale. The next step at the **biogeographical region level** is to calculate the proportion of habitat in 'good condition'. If 90% or more of the habitat area is in good condition, the structure and functions parameter is classified as 'favourable'; If more than 25% is not in good condition, it is classified as 'unfavourable-bad'. Results between these thresholds (90%-75% in good condition) are classified as 'unfavourable-inadequate.'

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 better prioritization of conservation efforts. This methodology provides a consistent yet flexible framework for scaling up local assessments to the biogeographical region, ensuring compliance with Art. 17 requirements and supporting more detailed conservation insights.

3.5 Guidelines on general sampling methods and protocols

Field surveys remain the cornerstone of most assessment methodologies, providing detailed, ground-level data essential for understanding the dynamics of coastal ecosystems. These surveys typically employ a multi-faceted approach.

Transects perpendicular to the coastline are used to monitor coastal habitats, detecting zonation and establishing limits between the different habitat types. Transect-based sampling parallel to the coastline, corresponding with habitat strip, is typically used, with DAP (2023) indicating transects 50 m long and 10 m wide. Complementing this, plot-based vegetation sampling is applied, involving fixed or random plots. These plots serve as focal points for detailed floristic and structural assessments, offering insights into species composition, vegetation cover, and structural diversity. The sizes of these plots can be defined according to the extent and diversity of the habitat. The methodologies applied by the MS, use monitoring plots of 2m x 2m (Martin et al., 2017) or circular plots of 5m diameter (Fredshavn & Nygaard, 2014). These plots will be georeferenced using GPS and documented with photographs to facilitate relocation and provide visual records of baseline conditions.

Additionally, field surveys often include mapping of visible pressures and disturbances, which is crucial for identifying immediate threats and management needs. Most methodologies utilized by the MS, monitor vegetated shingle along with other coastal habitats (beaches, dunes) using a transect perpendicular to the coastline and monitoring plots. Surveys are typically conducted during July and August (Martin et al., 2017).

Coastal habitats present unique challenges for monitoring due to their dynamic nature. Natural To enhance the scope and efficiency of the monitoring, remote sensing and GIS analysis are increasingly being integrated into assessment protocols. These technologies complement field data by providing landscape-scale perspectives and facilitating the analysis of changes over time. Satellite imagery and aerial photography can reveal broad patterns of coastal width and retreatment rate, vegetation cover changes, and human impacts. Where available, existing habitat maps serve as valuable baseline data, allowing for comparative analyses and the tracking of long-term trends.

Monitoring of presence and coverage variables (vegetation, anthropic disturbances), as well as landscape variables, should be conducted annually whereas other variables such as coastal trend can be assessed over longer periods of time. Other studies have analysed shoreline retreatment rates over periods of 20 to 10 years (Aga et al., 2024; Pérez-Alberti et al., 2012) and it has been detected an acceleration on these rates. In order to adjust the monitoring frequency to the reporting period, coastal retreatment rate and wid0ht are proposed to be assessed every six years.

Regarding data collection, to sample soil organic matter at least 2-3 soil sampling points per plot should be collected to capture the heterogeneity of the soil and it can be measured every 3 to 5 years. The use of remote sensing (Unoccupied Aerial Vehicles) has been proved to accurately map plant communities and topsoil organic carbon concentration in coastal wetlands (Villoslada et al., 2022), thus, this technique can replace field sampling.

By combining these diverse monitoring approaches, researchers and conservation managers can gain a holistic understanding of habitat conditions, dynamics, and threats. This comprehensive methodology enables more informed decision-making in conservation efforts, helping to preserve these vital and dynamic coastal ecosystems for the future.

3.6 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:

- 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. Understanding these patterns is essential for developing strategies to mitigate the negative impacts of habitat fragmentation.
- 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 data.

The number of sampling areas considered statistically adequate should be determined according to the habitat type distribution in each region. This estimation should take into account the specific characteristics and variability of the habitat, ensuring that the sampling design is robust enough to capture the full range of conditions present.

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:

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.

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.

3.7 Use of available data sources, open data bases, new technologies

Remote sensing (RS) techniques have emerged as invaluable tools for acquiring spatial environmental information, enabling the monitoring of large areas with consistent temporal resolution (Macintyre et al., 2020).

Despite their broad applicability, free satellite products are constrained by limited spectral, spatial, and temporal resolutions, hindering detailed ecological process modelling (Hossain et al., 2015; Nex & Remondino, 2014). Unmanned aerial vehicles (UAVs) are bridging this gap, offering high-resolution, rapid, and cost-effective methods. UAV sensors include high-resolution photogrammetry cameras and other advanced techniques like thermography, multispectral, LiDAR, and hyperspectral sensors.

UAV products, combined with satellite-derived vegetation presence/absence data, accurate digital terrain models (DTM), and sea-level rise (SLR) modelling, offer significant opportunities for monitoring habitat conditions and temporal changes in saltmarshes and salt meadows.

4. Guidelines to assess fragmentation at appropriate scales

As coastal areas face increasing pressure from human activities, particularly tourism and urban development, coastal habitats have become increasingly fragmented. This fragmentation poses several challenges for the conservation of these habitats. Coastal defences and other infrastructures affect the sediment supply and vegetation structure of the habitat.

Different methods exist for assessing fragmentation at the local scale, especially for terrestrial habitats, which integrate remote sensing, spatial analysis, and landscape ecology tools to assess fragmentation (e.g., Moreno-de las Heras et al., 2011, for shrubs). There are important differences between habitat 1220 and other habitats, especially because habitat 1220 is a naturally fragmented habitat exposed to highly energetic coastal dynamics. However, the assessment of the size and distribution of vegetation patches, proposed by other methodologies, as the one cited above, can be applied to this habitat.

The approach focuses on detecting changes in vegetation patterns, which serve as key indicators of ecosystem health. The main steps are identifying areas with different levels of fragmentation, including reference zones (undisturbed) and disturbance zones (e.g., affected by infrastructures), and patch size analysis using mathematical tools to describe how patch sizes are distributed in a landscape. Finally, landscape-scale fragmentation is estimated by analysing the differences in patch size distributions between undisturbed and disturbed areas. Identify changes in the overall distribution pattern, such as a shift from power-law to truncated or exponential forms, which indicate fragmentation.

Remote sensing technologies have emerged as powerful tools for assessing and monitoring habitats fragmentation:

- Satellite-based assessment: Satellite imagery provides a broad-scale view of coastal habitats, allowing researchers to track changes in vegetation cover and land use over time. Multispectral sensors on satellites can detect different vegetation types and their health, which is crucial for identifying fragmentation patterns. For instance, the Normalized Difference Vegetation Index (NDVI) derived from satellite data can be used to quantify vegetation cover and its changes, indicating areas of habitat loss or fragmentation.
- LiDAR and UAVs technology: LiDAR has become an invaluable tool for assessing habitat morphology and vegetation structure in three dimensions. This technology offers several advantages. It can create detailed digital elevation models (DEMs) of coastal habitats, revealing subtle changes in morphology that may indicate fragmentation. LiDAR can also penetrate vegetation canopies, providing information on understory structure and vertical complexity, which are important indicators of habitat quality and fragmentation. Finally, repeated LiDAR surveys allow for the detection of changes in height, shape, and vegetation cover over time, helping to identify fragmentation trends.
- Hyperspectral data: to classify vegetation species and sand cover using linear spectral mixture analysis (LSMA) and identify invasive species and halophytic colonization in deflation zones.

While remote sensing offers powerful tools for assessing habitat fragmentation, the following challenges remain:

1. Scale considerations: Balancing the need for broad-scale assessment with fine-scale detail remains a challenge, often requiring multi-scale approaches.

2. Temporal resolution: Increasing the frequency of data collection, especially with LiDAR, can improve our understanding of short-term changes in coastal habitats.
3. Data integration: Developing methods to effectively combine data from multiple sensors and platforms is crucial for comprehensive fragmentation assessment.
4. Automation: Machine learning and artificial intelligence techniques are being developed to automate the detection and mapping of coastal habitats, potentially improving the efficiency and accuracy of fragmentation assessments.

5. Next steps to address future needs

These guidelines recommend standard methods for assessing and monitoring of perennial vegetation of stony banks habitat condition with the goal of promoting harmonised procedures across the EU Member States. To ensure that habitat condition assessments are comparable across countries, it is essential to define a common set of variables/indicators with well-defined metrics and standard measurement procedures. These should include physical, chemical, compositional, and functional variables to comprehensively evaluate the health of mire habitats.

To implement these guidelines, the following next steps are suggested:

- **Test the proposed set of variables** with agreed measurement procedures and monitoring methods. Use common protocols for sampling, while considering the particularities of different habitats and the existing contextual factors at local and country level; this testing would be useful to identify gaps of knowledge, flaws of applicability and robustness and reliability of results. The evaluation should provide recommendations to be further integrated in the harmonised procedure, as needed.
- Develop further, test and standardise the methods for the establishment of **reference values and thresholds** to determine good condition. Defining ecological thresholds based on proper habitat characterisation is essential. These thresholds will indicate the health and quality of perennial vegetation of stony banks, aiding in the monitoring of changes over time. They will also facilitate the assessment of impacts of climate change, human activities, and invasive species, providing critical insight for conservation efforts.
- Develop further, test and standardise the methods for the **aggregation of results** obtained from all the variables measured at the local scale and for each biogeographical region.
- **Develop further and test the criteria for the selection of monitoring localities and sampling design** to ensure a sufficiently representative sample that allows for proper implementation of the aggregation of results at the biogeographical region level.
- **Promote harmonised methods for the use of typical species**: Typical species provide a practical way to evaluate habitat status, reflecting specific ecological conditions. Clear criteria should be defined for selecting these species, along with the methodologies to assess their status and integrate the results into overall condition assessment for each habitat.
- Common **training on the measurement of the condition variables** should be programmed for experts from the different MSs in order to achieve full harmonisation.

The current proposal should be viewed as a starting point and may be adapted where more suitable alternatives are identified based on national experience or ecological requirements.

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Annex 1. Examples of variables included in the methodologies available from EU MSs

DE (Germany): Krause et al., 2008. DK (Denmark): Fredshavn and Nygaard, 2014. IE (Ireland): Martin et al., 2017. LV (Latvia): DAP, 2023. SE (Sweden): Hedenås et al., 2020.

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
Physical variables				
Wave Exposure	Categories of exposure	Wave exposure maps are used to identify which exposure class corresponds with the transect location.	1. Very protected, 2. Extremely protected, 3. Moderately protected, 4. Protected, 5. Moderately exposed, 6. Exposed, 7. Very exposed.	SE: Hedenås et al., 2020
Substrate spectrum	Presence of natural composition	Visual assessment and expert judgement of site-typical substrate diversity as well as processes that are recognizable. Natural range and diversity of gravel, stones, rocks, sand, silt and other sediments	A = Completely preserved, considering natural/ undisturbed dynamics B= Slightly modified. Preserved on the majority of the coastal section. C= More strongly modified. Natural substrate spectrum only limited or on part of the coastal section preserved	DE: Krause et al., 2008
Shingle particle size	Percentage	If exposed shingle was visible a photograph with a 30 cm ruler placed on the shingle substrate was taken to allow particle size to be recorded through digital images. Particle Type (Diameter size in mm): Boulder (>256), Cobble (>64-256), Pebble (>16-64), Gravel (2-16)	A minimum of 60% of the substrate must be cobble/pebble/gravel for the habitat to be classified as the 1220 habitat	IE: Martin et al., 2017
Structural sequence	Presence	Visual assessment and expert judgement of site-typical structural sequence (beach, sea wall, depressions).	A = Typical structural sequence and corresponding natural vegetation formations structures are completely preserved. B = Slightly changed / largely present on the majority of the coastal section.	DE: Krause et al., 2008

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
			C = More strongly modified. Natural structural sequence only limited to a part of the coastal section.	
Compositional variables				
Shingle habitat community types	Presence/absence	Visual inspection of 1220 community types at monitoring stop.	Required to pass: No evidence of decline in 1220 community diversity over time. Ideally both pioneer and more stable 1220 communities (e.g. grassland on shingle) are present.	IE: Martin et al., 2017
Native species	Presence/absence	Visual inspection.	No evidence of a decline over time in the diversity of typical species within 1220 communities present. Consider additional typical species observed outside	IE: Martin et al., 2017
Total number of characteristic species	Number of species	Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Every 6th year.	3-point scale according to which 0, 1 or 2 points are assigned. 0: <=1; 1: 2; 2: >=3	LV: DAP, 2023 Appendix D
Notable species	Presence/absence	Visual inspection of 1220 community types at monitoring stop. Notable species: *Crambe maritima Glaucium flavum Lathrus japonicus Mertensia maritima*	Required to pass: No evidence of decline in number of individuals over time. Individuals both within and outside stops should be counted	IE: Martin et al., 2017
Characteristic, rare and invasive species	Presence/absence	Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Every 6th year.	Presence/absence of predefined species list.	LV: DAP, 2023 Appendix D

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
Species inventory - vascular plants, birds, beetle, spiders	Percentage of inventory species detected	Completeness of typical species inventory of vascular plants. Also breeding birds: C*haradrius hiaticula, Sterna albifrons*, others. Beetle: *Nebria livida*. Spiders: *Arctosa cinerea, Arctosa perita*.	A = inventory (almost) completely (more than 90%) B = inventory mostly present (50-90 C = inventory only partly present (less than 50%)	DE: Krause et al., 2008
Inventory of species of different groups of organisms	Number of species	Habitat-associated, habitat-dependent, rare and specially protected species. Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Every 6th year.	3-point scale according to which 0, 1 or 2 points are assigned. 0: 0, 1: 1, 2: >1	LV: DAP, 2023 Appendix D
Structural variables				
Coverage of grass, herbaceous vegetation	Percentage	Visual inspection.	Asign values between 0-100 to different percentage values. Highest score is assigned to grass/herbaceous vegetation 10-30%.	DK: Fredshavn & Nygaard, 2014
Coverage of dwarf shrub	Percentage	Visual inspection.	Assign values between 0-100 to different percentage values. Highest score is assigned to 0-5%.	DK: Fredshavn & Nygaard, 2014
Coverage of invasive species	Percentage	Visual inspection.	Assign values between 0-100 to different percentage values. Highest score is assigned to 0%.	DK: Fredshavn & Nygaard, 2014
Negative indicator species	Percentage	Non-native species and agricultural species, and signs of disturbance Record % cover - *Cirsium arvensea, Cirsium vulgare Lolium perenne Pteridium aquilinum Senecio jacobaeab, Urtica dioica*	Required to pass: Option (a) No species present in more than 60% of monitoring stops or Option (b) The combined cover in any individual stop 25% or less	IE: Martin et al., 2017

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
Proportion of area (%) with at least one characteristic plant species	Percentage	Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Every 6th year.	3-point scale according to which 0, 1 or 2 points are assigned 0: <20%, 1 :20-60%, 2: >60%.	LV: DAP, 2023 Appendix D
Cover (%) of trees and shrubs	Percentage		3-point scale according to which 0, 1 or 2 points are assigned. 0: >25, 1: 5-25, 2: <5	LV: DAP, 2023 Appendix D
Proportion of area (%) dominated by expansive species	Percentage		3-point scale according to which 0, 1 or 2 points are assigned. 0: >50, 1: 1-50, 2: <1	LV: DAP, 2023 Appendix D
Proportion of area (%) dominated by invasive species	Percentage		3-point scale according to which 0, 1 or 2 points are assigned. 0: >50, 1: 1-50, 2: <1	LV: DAP, 2023 Appendix D
Coverage of field vegetation	Percentage	Visual assessment during fieldwork. Includes all herbs, ferns, rice and graminids within the entire transect divided into geolittoral, supralittoral and extra littoral.	Not provided	SE: Hedenås et al., 2020
Coverage of shrub species	Percentage	During fieldwork, measurements of length (m), width (m) and density (in %) determining the distance from the starting point for each found shrub (of each species)	Not provided	SE: Hedenås et al., 2020
Functional variables				
Sand blowing or accumulation	Scoring system	Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Expert judgement. Every 6th year.	3-point scale according to which 0, 1 or 2 points are assigned. 0: no accumulation; 1: minimal, 2: little	LV: DAP, 2023 Appendix D

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
Other variables				
Presence of coastal defences	Presence/absence	Visual inspection.	Required to pass: Option (a) None built pre-designation which currently affect the habitat due to modification of the shingle habitat or changes to the sediment cycle at the site. Option (b) post-designation anthropogenic impacts on the substrate/mobility of the system (e.g. new stabilisation works, sediment extraction)	IE: Martin et al., 2017
Coastal protection	Presence/absence	Visual inspection.	Assign values between 0-100 to different percentage values. Highest score is assigned to absence of structures.	DK: Fredshavn &Nygaard, 2014.
Disturbance from infrastructures	Presence/absence	Presence of any kind of fence or stone wall within the transect	Not provided	SE: Hedenås et al., 2020
disturbance indicator: infrastructure affecting natural processes	Presence/absence	Visual assessment and expert judgement during field work.	A = not noticeable B = present but not significant C = significant impacts	DE: Krause et al., 2008
Anthropogenic disturbance	Percentage	Visual inspection of impacts derived from heavy trampling, vehicle damage, removal of substrate.	Required to pass: No more than 20% of 1220 habitat affected by disturbance	IE: Martin et al., 2017
Proportion of area (%) with negative anthropogenic impact	Percentage	Visual inspection along a 50 m long and 10 m wide belt transect, 6 or more transects per Natura 2000 site. Every 6th year.	3-point scale according to which 0, 1 or 2 points are assigned. 0: >50, 1: 1-50, 2: <1	LV: DAP, 2023 Appendix D. IE: Martin et al., 2017

Variable names	Metrics	Measurement methods	Examples of thresholds	MS and references
Disturbance from recreational activities	Presence/absence	Impacts derived from recreational activities detected in the transect are noted.	Not provided	SE: Hedenås et al., 2020
Disturbance indicator: recreational use	Presence/absence	Visual assessment and expert judgement during field work.	A = not noticeable or negligible B = affecting up to max 20% of coastline and low intensity (with larger sections of coast undisturbed) C = high intensity in some sections or with lower intensity along larger sections of coastline (more than 20%)	DE: Krause et al., 2008
Drainage and water abstraction	Presence/absence	Visual inspection.	Assign values between 0-100 to different percentage values. Highest score is assigned to absence of activity.	DK: Fredshavn & Nygaard, 2014.
Disturbance indicator: agricultural use	Presence/absence	Visual assessment and expert judgement during field work.	A = none B = negligible C = significant impacts	DE: Krause et al., 2008
Disturbance indicator: rubbish or other pollution	Presence/absence	Visual assessment and expert judgement during field work.	A = none B = present but no significant impacts C = significant or long-term damage or disturbance	DE: Krause et al., 2008

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