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

Sandbanks which are slightly covered by sea water all the time (1110)

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Glossary and definitions

Habitats

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

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

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

Variables

Condition variables: are 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 improve the assessment and help understand or interpret the overall results.
- **Specific variables:** are condition variables that should be measured in some specific habitat types or habitat sub-groups; can thus be considered essential for those habitats, which need to be specified (e.g. salinity for saline grasslands, groundwater level for bog woodlands, etc.).

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

Reference levels and thresholds: are defined for the values of the variables (or ranges) 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)		

MSFD: Marine Strategy Framework Directive

SEEA EA: System of Environmental Economic Accounting- Ecosystem Accounting

WFD: Water Framework Directive

Executive summary

'Sandbanks which are slightly covered by seawater all the time' (habitat 1110) are present in all EU Marine Regions. A general description, is provided by way of introduction, including references to the definition in the Habitats Directive Interpretation Manual, EUNIS habitat types (level 4) and Annex I of the Nature Restoration Regulation. As many of the methodologies used to investigate 1110 overlap with those used to investigate habitat types 1130 (Estuaries), 1140 (Mudflats and sandflats not covered by seawater at low tide) and 1160 (Large inlets and bays) some of the tables in this report bring together information for these four habitat types (1110, 1130, 1140 & 1160) in the review of the monitoring and assessment requirements as presented in Section 3.

A structured framework for the ecological characterization of habitat 1110 and the selection of appropriate variables for assessing their condition is set out in Section 1. Sixteen **key characteristics and corresponding variables essential for evaluating condition of the habitat** have been identified using the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) (United Nations et al., 2021), an international standard for ecosystem accounts adopted by the United Nations Statistical Commission (Section 1.2 and Table 1).

Twenty-one Member States have reported habitat 1110 as present in their jurisdictions (BE, BG, CY, DE, DK, EE, ES, FI, FR, GR, HR, IE, IT, LV, MT, NL, PL, PT, RO, SE, SI). The habitat is present in all the regional sea areas, with the majority fringing coastal areas or around offshore islands. The two main, large exceptions, both of which have been designated Natura 2000 sites, are Hoburgs Bank in the south-central Baltic and the Dogger Bank in the central North Sea.

Whilst some information has been collected about the location and description of the main characteristics of shallow sublittoral sandbanks by all twenty-one the Member States that have reported habitat 1110 as present within their jurisdiction **specific methodologies** for assessing and monitoring this habitat are only available from twelve Member States (DE, DK, ES, FR, HR, IE, IT, MT, NL, PL, RO, SI). There are also reports of sandbank surveys and assessments carried out in these and other EU Member States that are relevant, and that can or have been used to inform such assessments although not directly stated as a reason for the work.

All of the abiotic characteristics identified as being relevant to monitoring structure and function of this habitat type are specified for monitoring by at least two Member States with depth/tidal regime and sediment composition/distribution the most frequently identified physical characteristics. Both water and sediment quality are subject to monitoring by five Member States although there are some apparent differences in the variables measured. All the twelve Member States monitor biotic characteristics with most focus on epifaunal and infaunal assemblages. There is also some monitoring of structural characteristics for example by monitoring variables such as volume or biomass of particular species/species groups (Table 5).

The **reference values and thresholds** applied by Member States to obtain condition indicators for shallow sandbanks are variously; very specific, based on trends, use indices, rely on expert judgement or any combination of these. There is consistent and good coverage of variables used to describe the ecological characteristics of this habitat type across Member States. The exception is functional state characteristics where limited information is available on approaches taken.

In most EU Member States, a generic rather than habitat specific methodology is used to **aggregate data** on variables measured at the local scale to provide a condition assessment at the level of the plot or monitoring locality/site.

There is no standard approach to the identification of a number and distribution of **localities or sampling frequencies** to carry out the assessment and monitoring of shallow sublittoral sandbanks. Practical consideration, such as accessibility are important as are mobility of the feature, size, physical variability and diversity of the associated biological communities. There can be very high levels of natural variability, with substantial small-scale variation in substrates and associated taxa. Ideally monitoring takes place across the sandbank feature trying to record the variety of features.

There is much commonality in **methodologies** across Member States, from initial review of likely locations based on existing geological information and maps, followed by aerial surveys and further reconnaissance from boat and shore to gather more specific locational information. Abiotic and biotic characteristics of the habitat are recorded, as well as aspects such as fragmentation and disturbance which are landscape/seascape characteristics of this habitat type. For example, physical state characteristics frequently recorded include sandbanks dimensions, depth, exposure to wave action, and sediment type; compositional state characteristics typically involve recording epifaunal and infaunal assemblages, their abundance and distribution within across sandbanks habitats as well as the presence, condition and abundance of any macroalgae or eelgrass beds. Variations in the methodologies used to assess and monitoring shallow sublittoral sandbanks are strongly influenced by accessibility, topographical type, hydrographic conditions, as well as the diversity of the habitat and the associated biological communities.

The final part of document is focused on guidance for harmonising methodologies to ensure consistent data collection and assessment criteria across EU Member States. A proposed list of **essential, recommended and specific condition variables** is presented covering abiotic, biotic, and landscape/seascape characteristics (Table 14). Potential approaches for **making assessments of condition** include comparison to undisturbed areas, hindcasting, modelling and expert judgement. Cross reference is also made to EU reference values in the Water Framework Directive and Marine Strategy Framework Directive that may be relevant.

1 Definition and ecological characterisation

1.1 Definition and interpretation of habitats covered

'Sandbanks which are slightly covered by seawater all the time' are shallow sandy accumulations dominated by the action of the tide and waves, usually colonized by diatoms and invertebrates and occasionally by phanerogams. They may be found in open coastal areas or develop inside estuaries and some types of tidal lagoons (Morales et al., 2009). A classification by Dyer & Huntley (1999) which emphasises the formation and present hydrodynamic setting in their long-term development, distinguishes various types including open shelf linear ridges, linear ridges formed at the mouths of estuaries, and banner banks. They can also be distinguished depending on the sediment characteristics (e.g. gravelly and clean sands, or muddy sands), as well as by the associated communities (e.g. eelgrass *Zostera marina* beds, and maërl beds) (JNCC, 2017).

Shallow sandbanks can be mobile features, the rate depending on the type of bank and the stage of development (active or moribund), and therefore display very high levels of natural variability, with substantial small-scale variation in substrates and associated taxa (Noble-James et al., 2018). Different topographical types are sandy mounds and elongated banks.

Sandbanks which are slightly covered by sea water all the time (code 1110) are listed in the Interpretation Manual under COASTAL AND HALOPHYTIC HABITATS and in the subcategory 'Open Sea and Tidal Areas'. The Interpretation Manual (European Commission, 2013) gives the following definition and clarification;

> "Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than on the underlying hard substrata".
>
> "**Slightly covered by seawater all the time**" means that above a sandbank the water depth is seldom more than 20m below chart datum. Sandbanks can, however, extend beneath 20m below chart datum. It can, therefore, be appropriate to include in designations such areas where they are part of the feature and host its biological assemblages

Sandbanks in deeper waters are not being considered in these guidelines.

Shallow sandbanks may be found in association with several other Habitats Directive Annex I types; 'Mudflats and sandflats not covered by seawater at low tide' (1140), underlying '*Posidonia* beds' (1120) and sometimes interspersed with areas of 'Reefs' (1170). Sandbanks may also be a component part of habitat 'Estuaries' (1130) and the habitat 'Large Shallow Inlets and Bays' (1160). There can be considerable overlap in the monitoring and assessment requirements of three of these habitat types in particular 1130, 1140 and 1160. For example:

- Topographical mapping of a shallow subtidal feature, to determine aspects such as location, extent, profile, as well as changes in these parameters over time.
- Investigation of hydrographic conditions (particularly tides and currents) as these can have a major influence on key characteristics of the habitat such the development, changing morphology and associated species.
- Sampling of subtidal sediments to determine sediment characteristics, as well as of the associated infauna and epifauna.

Habitat 1110 is completely subtidal. Habitat 1140 is intertidal and habitats 1130 and 1160 have an intertidal component but may include areas of hard substrate. As many of the methodologies used to investigate 1110 are a subset of those used to investigate habitat types 1130, 1140 and 1160. These four habitat types (1110, 1130, 1140 & 1160) are therefore clustered for the purposes of this review of the monitoring and assessment requirements as presented in Section 3.

Habitat 1120 is not included in the common tables in Section 3 because, even though the underlying sediment needs to be examined for both habitats, there is a strong emphasis on biological monitoring, of the condition, extent, and associated species of *Posidonia* beds. Such elements need to be examined in situations where habitat 1110 is colonised by the seagrass *Zostera* but this is only one of many potential biotopes to be found on shallow sandbanks whereas *Posidonia* will always be present in habitat 1120.

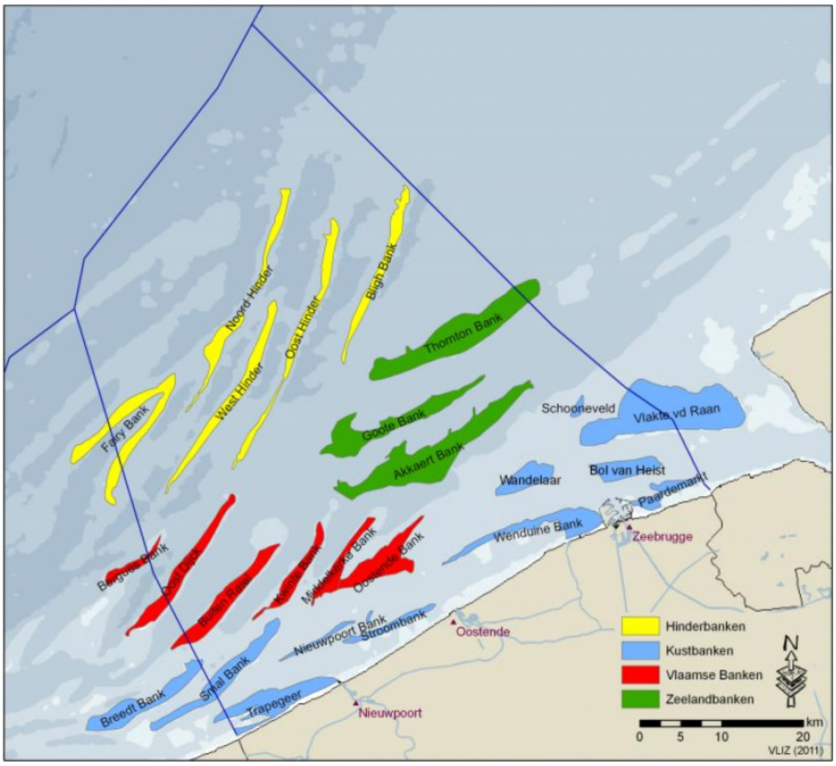
According to the 2022 EUNIS marine habitat classification the following EUNIS habitat types (level 3) may be present as components of habitat type 1110: MB23, MB32 to MB35, MB42 to MB44, MB52 to MB55, MB62, MC23, MC32, MC33, MC35, MC42, MC52, MC53, MC55. Several of these EUNIS level 3 habitats are listed in Group 7 (soft sediments above 1000m) of Annex II of the Nature Restoration Law (MB32, MB42, MB52, MB62, MC32, MC42, MC52).

Diversity across the regions

'Sandbanks which are slightly covered by sea water all the time' have been reported from twenty-one EU Member States; Belgium (BE), Bulgaria (BG), Cyprus (CY), Germany (DE), Denmark (DK), Estonia (EE), Spain (ES), Finland (FI), France (FR), Greece (GR), Croatia (HR), Ireland (IE), Italy (IT), Latvia (LV), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Sweden (SE), and Slovakia (SI). The habitat is present in all the Regional Sea areas, with the majority fringing coastal areas or around offshore islands. The two main large exceptions, both of which have been designated Natura 2000 sites, are Hoburgs Bank in the south-central Baltic and the Dogger Bank in the central North Sea.

Shallow sublittoral sandbanks in the North Sea, are present as features off the coastlines of Denmark, Germany, the Netherlands and Belgium. Some are directly connected to intertidal sand and mudflats of the Waddensea. Others such as Borkrum Reef Ground and Amrum Bank lie further offshore (in German waters) but still function as extensions of the coastal sandy habitats into the offshore region (Beermann et al., 2023). Further offshore the Dogger Bank is a large sublittoral sandbank in the central North Sea. Although physically separated from the coastal sandbanks there is likely to be some connectivity following short term events such as storms and turbulence (Becker et al., 1992; Kröncke & Knust, 1995). Off the Belgian coast this habitat takes the form of a series of parallel sublittoral sandbanks separated by channels 4-6km wide and rising about 25m above the surrounding sea floor (Figure 1). They result from the accumulation of sandy deposits of glacial origin carried down by waters draining from the surrounding land (Vanosmael et al., 2009). A similar situation can be found off the Channel coast of France where sandbanks form linear shore-parallel or slightly oblique sand bodies about 10-30km long and 1-3km wide (Latapy et al., 2019).

Figure 1. Sandbanks in the Belgian EEZ



Source: DEIMS-SDR (Dynamic Ecological Information Management System - Site and dataset registry).

The **Atlantic** facing coasts of France Spain and Portugal have shallow sandbanks which lie close to the coast, sometimes in the mouths of rivers but there are also examples further offshore in Canaries and Madeira. The latter examples tend to be much smaller features compared to than those in the North Sea as there is a less extensive area of continental shelf. In the Irish Sea there are a series of coast-parallel, north-south trending linear sandbanks in the nearshore environment off the east coast of Ireland with four main sub-types identified: gravelly & clean sands, muddy sands, eelgrass *Zostera marina* beds, and maërl beds (composed of free-living Corallinaceae).

In the **Baltic Sea**, habitat 1110 sandbanks are typically elongated, curved, or irregularly shaped shoals permanently submerged in shallow waters, generally at depths less than 20 meters. These sandbanks are mainly composed of sandy sediments, but may also include coarser (boulders, pebbles) or finer (mud) materials depending on local hydrodynamics. In some areas, sandbanks are colonized by seagrasses such as *Zostera marina* and, less frequently, *Cymodocea nodosa*, as well as by other aquatic plants like *Ruppia* sp. and charophytes, especially in sheltered or lower-salinity zones (European Commision, 2013; HELCOM, 2013; Michałek, 2022). The fauna is dominated by burrowing invertebrates such as *Bathyporeia pilosa, Pygospio elegans* and *Cerastoderma glaucum*, which are characteristic of sublittoral sandy bottoms. The exposure to waves and the position away from land-based pollution sources promote highly natural conditions, limiting organic matter accumulation and supporting diverse benthic communities. Sandbanks in the Baltic are important nursery and foraging areas for fish, including demersal species and those feeding on macrozoobenthos, as well as key feeding and wintering grounds for waterbirds such as *Melanitta nigra, Gavia stellata* and *Gavia arctica*. Seals also use these areas for foraging and resting (HELCOM, 2013; Michałek, 2022).

There are numerous shallow sandbanks in the **Mediterranean**. In the Spanish Mediterranean they take the form of terraces (both parallel and perpendicular to the coast) as well as being associated with deltas (e.g. the Ebro and Palancia river deltas), and bays along the coasts of Catalonia, Murcia and Valencia as well as the Balearic Islands (Morales et al., 2009). Around the Maltese islands sandbanks tend to occur in very shallow waters (down to 2m depth) (Knittweis et al., 2017). The shallow sandbanks around the Cetina Estuary (Croatia) support an extensive seagrass bed (*Cymodocea nodosa*) (Mrcelic et al., 2023) however it is not uncommon for several species of seagrass such as *C. nodosa, Zostera marina* and *Z.noltii* to coexist on shallow sandbanks in the Mediterranean such as off the Adriatic coast of Italy (Danovaro et al., 2020).

In the **Black Sea** sublittoral sandbanks are present in shallow waters off the coasts of Bulgaria and Romania including within the Danube Delta. The habitat may take the form of mobile sandbars or shoals, with sediment types including muddy sands, fine sands, coarse sands, shell sands and gravels. Some of the sandbanks in the Black Sea support eel grass beds (*Zostera* spp. and *Ruppia* spp.) (Zaharia, 2013).

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

The **main characteristics** which determine the structure & function of this habitat are;

- Substrate type
- Exposure to currents, tides, wave action, and scour (removal of sediment due to increased water flow).
- Degree of submergence/depth
- Topography
- Stability
- Turbidity/sedimentation
- Nutrient status
- Infaunal and epifaunal biotopes
- Associated fish, seabirds and marine mammals

They can be classified into abiotic, biotic and landscape characteristics as described below.

1.2.1 Abiotic characteristics

Abiotic characteristics describe both the physical and chemical state of the habitat.

Sandbanks are subject to high levels of natural hydrodynamic disturbance, developing where there is abundant sand, and the currents are strong enough to move sediment. Their present-day form and shape is modified by **currents and waves**. Water movement also affect **sediment composition and distribution** (via erosion and deposition) across the sandbank as well as the **turbidity** of the water column. Highly mobile sandbanks will be dominated by coarse sediments as the finer fractions are carried away, whereas finer sands and muddy substrates may be present on sandbanks where there is less disturbance of the sediment (Noble-James et al., 2018).

The mobility of sandbanks will depend on the type of bank and the stage of its development. They may be active or moribund, with the latter typically having gentler slopes, fewer sand waves, and being in deeper water compared to active sandbanks which tend to have a more asymmetrical profile (Kenyon et al., 1981; Belderson et al., 1986).

1.2.2 Biotic characteristics

The **diversity and types of communities** associated with shallow sandbanks are determined particularly by sediment type together with a variety of other physical, chemical and hydrographic factors. These include geographical location (influencing water temperature), nutrient status, the relative exposure of the coast (from wave-exposed open coasts to tide-swept coasts or sheltered inlets and estuaries), the topographical structure of the habitat, and differences in the depth, turbidity and salinity of the surrounding water (JNCC, 2017).

Due to their shallow depth, they show considerable natural sediment dynamics. The movement of sediment, with associated mixing, erosion and deposition is a physical process but also a functional characteristic because it has an influence on the dynamics of the biota, for example, resulting in high species turnover and fluctuation even though there may be an overall specialised species composition as evident from long term monitoring data with the associated benthic communities adapted to natural disturbance (Ellis et al., 2011). Sandbanks in high energy areas are more likely to support species with a short life span, few sedimentary forms and more mobile species.

Where sandbanks are extensions of shallow coastal sediments adjacent to the coast, they may support similar soft sediment communities (Kaiser et al., 2004). A study in the Irish Sea for example, reported that distinct sandbanks were typified by low species diversity and shared indicator species such as the weever fish *Echiichthys vipera*, the shrimp *Philocheras trispinosus* and the hermit crab *Pagurus bernhardus*. The sandbanks considered as extensions of nearshore sediments shared many similarities with the *Pleuronectes platessa–Limanda limanda* assemblage, identified by Ellis et al. (2000) which is widespread in the Irish Sea.

Troughs or areas between banks generally contain more stable gravelly sediments and support diverse infaunal and epifaunal communities. Here sediment movement is reduced and therefore the areas support an abundance of attached bryozoans, hydroids and sea anemones. Any anthropogenic activity affecting benthic organisms (e.g. bottom trawling or dredging) may compromise seafloor integrity and therefore, the condition of habitat 1110 (Jennings et al., 2001).

Biogenic reefs formed by the tube building polychaete worm *Sabellaria spinulosa* may be present on some shallow sandbanks where they can form small aggregations, thin crusts or large encrusting reefs that are several centimetres thick and cover extensive areas (Foster-Smith & White, 2001; Gibb et al., 2014).

Where conditions are suitable, sandbanks also support **plant communities**. In the Mediterranean, these include communities characterised by the marine angiosperm *Cymodocea nodosa, Zostera marina, Zostera noltii* and *Posidonia oceanica* (however, *P. oceanica* is listed as a unique habitat under the Habitats Directive -1120). Although understood as a euryhaline group (sensu den Hartog, 1981), *Ruppia* spp. is also found on some Mediterranean sandbanks (Ruiz et al., 2015). Different photophilic species of algae living on the leaves are associated with *Posidonia* beds. In the Black Sea (Milchakova & Phillips, 2003) four species of seagrasses are known (*Zostera marina, Z. noltii, Ruppia maritima, R. cirrhosa*). Around the Macaronesian islands, *C.nodosa* is the most representative species associated with sandbanks in the Canary Island, and acts a well-known fish nursery area and even as one of the main food resources of juvenile Green turtle (*Chelonia mydas*). Patches of *Z.noltii* may also be present (European Commission, 2013; Ruiz et al., 2015).

In Madeira, *C.nodosa* is the only seagrass species reported, but its occurrence is very scarce and mostly anecdotal (Schäfer et al., 2021). In the Baltic Sea, *Zostera marina* is the most common marine angiosperm (known as Nordic eelgrass), although *Potamogeton* spp. and *Ruppia* spp. are also present; in the North Sea *Zostera marina* is also a well-known species. Where eelgrass beds are established, they can stabilise the sediment as well as having a role in carbon storage and sequestration when carbon is incorporated into the underlying sediment (Johannessen & Macdonald, 2016).

Maërl beds, which are sometimes present on shallow sandbanks, have an even greater capacity for carbon storage and sequestration (Burrows et al., 2014). As defined by OSPAR (Hall-Spencer et al., 2010; Barberá et al., 2003), maërl or rhodolite beds is a collective term for various species of non-jointed coralline red algae (mostly Corallinaceae but also Peyssonneliaceae) that live unattached. These species can form extensive beds, mostly in coarse clean sediments of gravels and clean sands or muddy mixed sediments, which occur either on the open coast, in tide-swept channels or in sheltered areas of marine inlets with weak current. As maërl requires light to photosynthesize, the depth of live beds is determined by water turbidity, from the lower shore to 40 m or more. Maërl beds may be composed of living or dead maërl or varying proportions of both. In addition, two of the main maërl-forming species *Lithothamnion corallioides* and *Phymatolithon calcareum* are included in Annex V of the Habitats Directive.

Shallow sandy sediments, including shallow sandbanks can act as nursery areas for fish (both commercial and non-commercial species): e.g. Botheidae, Soleidae or *Heteoconger longissimus*. They also act as feeding grounds for seabirds such as puffin, guillemot and razorbill (Coveney Wildlife Consulting Ltd., 2004[1]). They may be used as foraging areas by seabirds feeding on small pelagic fish and macrobenthos that are associated with the sandbanks or around the frontal systems which develop in their vicinity (e.g. Skov et al., 1995; Camphuysen et al., 2011; Boedeker et al., 2006; Skov et al., 2016; Degraer et al., 1999; Kröncke, 2011). These features can also attract foraging seals (e.g. Thompson & Miller, 1990).

The main ecological characteristic of habitat type 1110 and a selection of relevant examples of variables used to measure these characteristics when reporting on the habitat condition are summarised in Table 1.

[1] https://www.npws.ie/marine/marine-habitats/sandbanks (accessed 05/02/25)

Table 1. Ecological characterisation and selection of condition variables

Ecological characteristics	Types	Description	Examples of associated variables
Abiotic characteristics	**Physical state characteristics**	Degree of submergence/ depth, tidal regime	Depth in relation to chart datum Tidal range
		Topography	Physical dimensions, extent, longitude and latitudinal gradients, elevation, form and features e.g. sandbanks, islands from a standardised list
		Hydrodynamics – Exposure to current, wave action, scour & surge	Current speed, direction, height, seasonal extremes
		Turbidity	Suspended particles, Light transmission through water, Secchi disk depth
		Sediment composition/ distribution/dynamics	Sediment particle size, thickness of oxidised layer (for silt). Deposition/erosion rates and location
	Chemical state characteristics	Water quality	Various substances including chemicals listed in the WFD and EQSD, nitrates & phosphates, oxygen, chlorophyll, dissolved solids
		Sediment quality	Inorganic and organic chemical contaminants, organic carbon
Biotic characteristics	**Compositional state characteristics**	Invertebrates – Epifaunal & infaunal assemblages including biogenic structures	Abundance and diversity of characteristic species from standardised lists
		Vertebrates – Associated fish, birds & marine mammals	Abundance and diversity of characteristic species from standardised lists
		Macrophytes, macroalgae, eelgrass	Type, abundance, extent
	Structural state characteristics	Characteristic species including biogenic structures	Volume, biomass, estimated % cover, fragmentation, condition
		Macrophytes, macroalgae, eelgrass	Condition, biomass, estimated % cover
	Functional state characteristics	Primary production	Phytoplankton blooms (frequency/ longevity) Macroalgae (growth rates, dry weight/m^2)
		Food webs	Number of species/functional groups and qualitative links Average energy transfer between trophic levels (%) Stable isotopes (^{13}C, ^{15}N, ^{34}S) Stomach content analysis
Landscape/ seascape characteristics		Connectivity / Fragmentation	Continuous, fragmented, presence of anthropogenic structures and their % cover
Other		Disturbance	Footprint of activity, number and intensity of negative pressures

1.2.3 Ecological processes that are relevant regarding proper functioning.

Currents, waves, tides, sediment availability and transport as well as the interactions between morphology, hydrodynamic processes and sediment transport are key to the location, formation and stability of sandbanks. They define physical characteristics of the habitat, such as mobility, longevity, and sediment composition but also the associated species and biotopes.

Some sandbanks may be relict, formed under different hydraulic conditions than those existing presently and therefore not being affected actively in modern sedimentary process. The physical character of these sandbanks is unlikely to change significantly, even over decades. Others may be active where there is dynamic interaction between banks and the present hydrodynamic regime, like the shallow sandbanks in the southern North Sea (Jones, 2001).

Sandbanks can go through a cycle from an active to moribund state, for example as sea level rises and they are left stranded in weak currents (Kenyon & Cooper, 2005). It is also the case that although the main feature may not change over human time there can be regular changes in the topography of the crest and superimposed bedforms (Vanaverbeke et al., 2000). They can play an important role in the protection of the coast by dissipating incoming wave energy and consequently acting as natural coastal defences as well as supplying or storing sediments.

1.3 Selection of typical species for condition assessment

Typical species of the habitat are used to assess whether a habitat is at Favourable Conservation Status. The assessment of typical species is included as **part of the assessment of the structure and function** parameter, although a **full assessment** of the conservation status of **each typical species is not required**.

According to the guidelines for reporting under Article 17 (European Commission, 2023), the selection of ‘typical species’ should include species which are good indicators of favourable habitat quality. They should include species sensitive to changes in the condition of the habitat (‘early warning indicator species’). Moreover, assuming that the habitat’s structure and function are already being monitored, it is important that they provide any useful additional information.

Given the ecological and geographical variability of Annex I habitat types, different species can be selected as typical species for a habitat type in different marine regions. Indeed, even within one Member State **different typical species may be present in different parts of the range of the habitat type or in different subtypes**. On the other hand, **many species may be typical for several habitats** and not dependent on a single Annex I habitat type (EC, 2023).

Shallow sandy sediments are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms (see example from German North Sea EEZ in Table 2) (Beermann et a., 2023). Mobile epifauna at the surface of the sandbank may include mysid shrimps, gastropod molluscs, crabs and fish. Sand-eels *Ammodytes* spp., an important food for birds, live in sandy sediments. Where coarse stable material, such as shells, stones or maërl, is present on the sediment surface species of foliose seaweeds, hydroids, bryozoans and ascidians may form mixed communities (Johnston et al., 2002; JNCC, 2017).

Garden eels (*Heteroconger longissimus*) are also found in sandbanks occupying great extensions in the Macaronesia (Ribeiro et al., 2005). Usually, these communities are described to occur between 10 and 60 m depth, however; they have been found deeper than 80 m depth (Ricardo Aguilar, OCEANA, pers. comm).

Table 2. Examples of characteristic species of infauna on sandy seafloor habitats, including sublittoral sandbanks, in the German North Sea EEZ

Note that the criteria for the selection of characteristic species are given in material and methods of Beermann *et al*. (2023)

Group	Species
Bivalvia	*Crobula gibba, Euspira nitida, Fabulina fabula, Kurtiella bidentata, Nucula nitidosa*
Gastropoda	*Turritellinella tricarinata*
Polychaeta	*Lanice conchilega, Magelona johnstoni, Nephtys cirroa, Nephtys hombergii, Owenia fusiformis, Oxydromus flexuosus, Spiophanes bombyx, Scoloplos armiger*
Crustacea	*Bathyporeia elegans, Callinassa subterranean, Harpinia antennaria, Urothoe poseidonis*
Nemertea	Nemertea indet.
Phoronida	Phoronidae
Echinodermata	*Amphiura filiformis, Echinogardium cordatum*

Typical species **may be drawn from any species group**. The species used to monitor the condition of this habitat type differ depending on the geographical location and characteristics. Table 3 indicates frequently present groups from which species for monitoring may be selected, and the types of changes in quality they could be used indicate. Physical disturbance can reduce extent, displace and/or damage species from the groups indicated, while increased nutrient levels can be reflected in the species present and affect productivity.

Table 3. Potential species groups from which to select typical species for monitoring habitat 1110 (sandbanks)

Species group	Ecological notes	Sensitive to changes in condition
Angiosperms	Seagrass beds may be present on some sandbanks. They help to stabilize the sediment as well as capturing carbon in the root systems, particularly in the case of long-established beds. Seagrass beds act as nursery areas for some species of fish and invertebrates.	Physical disturbance, for example associated with anchoring and demersal fishing gears can uproot seagrasses and fragment beds, while nutrient levels can enhance growth but not if this results in the smothering of the plants by encouraging the growth of epiphytes. Increases in turbidity can have a negative effect on seagrass growth and condition by reducing photosynthesis.
Corallinaceae	Maërl is a slow-growing unattached coralline algae which can be found on sandbanks where light levels are sufficient and there is little disturbance of the seabed. Maërl beds (comprised of both living and dead maërl) can support high densities of species and act as nursery areas of fish, crabs and molluscs.	Smothering by fine sediment, lowered oxygen concentrations and the presence of hydrogen sulphide, are particularly damaging to maërl-forming algae. Abrasion and physical disturbance, for example associated with anchoring and demersal fishing gears, can bury living maërl and reduce the diversity of associated species (Wilson et al., 2004; Jones et al., 2000)

Species group	Ecological notes	Sensitive to changes in condition
Molluscs	Both infauna and epifauna. Benthic macrofauna have a pivotal role in the mixing, ventilation, oxygenation and irrigation of sediments (bioturbation). This improves nutrients cycling, substrate permeability, redistribution of food resources, buffering against nutrient enrichment and benthic-pelagic coupling (Di Camillo et al., 2022).	Physical disturbance and changes in nutrient/organic matter levels can be indicated by monitoring species from this group. Molluscs have been used as biotic tools for ecological status assessment in the context of WFD status classification (Leshno et al., 2016; Nerlović et al., 2011), as ecological indicators (La Valle et al., 2011) and bioindicators of environmental contamination (Coelho et al., 2014; Mahmoud et al., 2010; Velez et al., 2016). For example, the bivalve *Corbula gibba* has been proposed as a proxy of eutrophication with distribution influenced by Chl a concentrations (Moraitis et al., 2018).
Polychaetes	Reef building species (*Sabellaria spinulosa*) may be present as well as infauna with species preferences depending on grain size, organic matter, oxygen levels Vanosmael et al., 1982).	Physical disturbance and changes in nutrient/organic matter levels can be indicated by monitoring species from this group.
Echinoderms	Both infaunal and epifauna species of echinoderms are present in this habitat. They include bioturbators and bioirrigators such as the sea potato *Echinocardium cordatum* which rework organic matter into the sediment. Besides the general permeability of sediments, the constant movement of these large-bodied infaunal burrowers can have profound influence on sediment-bound biochemical processes, benthic nutrient fluxes and, thus, on local benthic and pelagic primary production (Huettel et al., 2014; Lohrer et al., 2005; Wrede et al., 2017). These are essential ecosystem functions (Beerman et al, 2023).	Physical disturbance and changes in nutrient/organic matter levels can be indicated by monitoring species from this group.
Fish	Shallow sandbanks are important feeding grounds as well as nursery and spawning areas for some species of fish such as the Lesser weever *Echiichtyhys vipera* (Ellis et al., 2011), plaice and dab (Atalah et al., 2013). Sandeels *Ammodytes* spp. where present are an important food source for seabirds.	Physical disturbance, productivity. Indicators of change include variation in the abundance of the population of one or more species. This can be measured as a decrease or increase in the number of individuals, their biomass, their average size and age, as well as an expansion or contraction of their distribution range over time.
Seabirds	Shallow sandbanks are important feeding grounds, in particular for fish feeding birds.	

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

Some information has been collected about the location and description of the main characteristics of shallow sublittoral sandbanks by all twenty-one the Member States that have reported habitat 1110 as present within their jurisdiction[2] but specific methodologies for assessing and monitoring this habitat are only available from twelve Member States (DE, DK, ES, FR, HR, IE, IT, MT, NL, PL, RO, SI). There are also reports of sandbank surveys and assessments carried out in these and other EU Member States that are relevant, that can or have been used to inform such assessments although not directly stated as a reason for the work (e.g. surveys carried out in Estonia (Vaher et al., 2022)). All these methodologies have been considered in the following review albeit distinguishing between what is being done by Member States for reporting on habitat condition under Article 17 and what has been done as part of other initiatives.

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

A summary of the ecological characteristics and main variables used to measure habitat condition of habitat 1110 is presented in Table 1 (Section 1). Examples of the characteristics and variables used by Member States as part of the assessment of conservation status are presented in Table 4 and a summary analysis is given in Table 5, which indicates the twelve Member States that have published methodologies specifically relating to this habitat.

Table 5 shows that whilst the monitoring and assessment programmes from twelve Member States cover abiotic, biotic, landscape and other characteristics there are differences in emphasis. All of the abiotic characteristics identified as being relevant to monitoring structure and function of this habitat type are specified for monitoring by at least two Member States. For physical characteristics depth and tidal regime are most frequently identified followed by the sediment composition and distribution across shallow sublittoral sandbanks. Both water and sediment quality are subject to monitoring by five Member States although there are some apparent differences in the variables measured. All the twelve Member States monitor biotic characteristics with most focus on epifaunal and infaunal assemblages (which would include any biogenic structures if present). Aside for reporting on presence and diversity of species, there is also monitoring of structural characteristics through condition, for example by monitoring variables such as volume or biomass. Macrophytes and macroalgae are specifically identified in the programmes of seven Member States whereas associated fish, birds and marine mammals are only specified in two cases (Ireland and Slovenia). Of the two functional state variables identified for this habitat (primary production and food webs) there is no indication of monitoring food webs and only one Member State specifically referring to monitoring primary production.

[2] as evidenced by the submitted Standard Data Forms for designated sites where 1110 is a feature as well as Article 17 reporting.

Table 4. Examples of variables used by Member States to assess condition of habitat 1110 (sandbanks)

Description	Examples of variables used by Member States	Notes
1. Abiotic characteristics		
1.1 Physical state characteristics		
Degree of submergence/depth/tidal regime	NL - Tidal dynamics (speed, direction) RO - Water depth (m)	Whilst not necessarily highlighted in all assessment methodologies, these characteristics are usually included in the descriptions of Natura 2000 sites where habitat 1110 is present (e.g. in the SDFs) and can still be useful to understand and interpret possible changes in condition.
Topography	IT – Morphobathymetry (m)	The gross morphology of habitat 1110 provides an overview of the feature and can also give some insight into formation, stability, and dynamics. These characteristics are usually included in the initial descriptions of the protected habitats as well as providing context for what might constitute "natural change" in the future even if they are not specifically mentioned in the methodologies.
Hydrodynamics - Exposure to current, wave action, scour & surge	DE - Hydrology and morphology	Whilst not necessarily highlighted in all assessment methodologies, these characteristics are usually included in the descriptions of Natura 2000 sites where habitat 1110 is present (e.g. in the SDFs) and can still be useful to understand and interpret possible changes in condition.
Turbidity	RO - Water transparency (average light attenuation)	Measurements of this variable are not specifically mentioned in all the methodologies examined but may be included as part of water quality sampling.
Sediment composition / distribution/ dynamics	DE - Sediment composition distribution and dynamics FR - Characteristics of soft substrates IE - Changes in proportion of grain size classes MT - Sediment composition	The distribution of soft sediments on sublittoral sandbanks may not be static. This can not only lead to changes in the gross morphology of the sandbank but also has a major influence on the associated infauna and epifauna.
1.2 Chemical state characteristics		
Water quality	DE - Input of hazardous substances RO – Nutrient status/concentration (extent and seasonal abundance of macroalgal mats within the habitat), average concentration of phytoplankton (Chlorophyll a)	There is frequent mention of water quality sampling for assessments of this habitat type. Much of the published guidance is general in nature although specific variables are mentioned in some cases.
Sediment quality	FR - Thickness of oxidised layer of silt (cm) IT - Nutrients in sediments PL - Redox (bottom sediments)	Much of the published guidance is general in nature but specific parameters are mentioned in some cases.

Description	Examples of variables used by Member States	Notes
2. Biotic characteristics		
2.1 Compositional state characteristics		
Invertebrates - Epifaunal & infaunal assemblages including biogenic structures	DK - Fauna on sandy habitat types IE - Number of marine community types MT - Species richness PL - Typical macrobenthic species IT – Characterisation of macrobenthos RO – Specific structure of biocenosis (number and abundance of identified species), abundance of characteristic species (average density of characteristic species), biocenoses types (identification of biocenoses types) SI - Stony coral *Cladocora caespitosa* and *Geodia cydonium* density and size fractionation (density = individuals/100m2; colony size fractionation = cm of colony diameter)	These characteristics are widely investigated but the methodologies examined reveal some variation in the level of detail. In some cases, there is reference to compiling species lists, for example and in others to recording biocenosis or keystone communities.
Vertebrates -Associated fish, birds & marine mammals	SI - Density of fish species and size distribution (number of recorded individuals/100 m)	These characteristics are not necessarily mentioned specifically in assessment methodologies but may be covered during surveys to record species and biocenoses present.
Macrophytes, macroalgae, eelgrass	DK - Maximum depth limit, spread and % cover of eelgrass and other flowering plants ES - Characteristic species of eelgrass SI - Presence of characteristic plant species	
2.2 Structural state characteristics		
Characteristic species including biogenic structures	HR - Abundance and coverage of species NL - Number of qualifying structural elements	The methodologies examined reveal some variation in the variables measured. Abundance measures (e.g. % cover or biomass).
Macrophytes, macroalgae, eelgrass	RO - Extent of macroalgae/seagrass (area within the habitat), density of *Zostera noltii* (average density)	Several Member States make specific mention of monitoring variables for this characteristic and provide detailed methodologies. It may also be picked up under reporting of the 'abundance and condition of characteristic species' (see above).
2.3 Functional state characteristics		
Primary production	RO – Extent of phytoplankton	

Description	Examples of variables used by Member States	Notes
3. Landscape/seascape characteristics		
Connectivity / Fragmentation	NL – Nursery function for North Sea fish species	
4. Other		
Disturbance	FR - Reworking of sediment by dragnet fishing, sand extraction dredging etc. IE - Number of negative pressures DE – Sediment extraction	

Table 5. Main ecological characteristics and associated variables monitored in the assessment of structure and function of habitat 1110 (sandbanks) by EU Member States

Ecological characteristics	Variables	Metrics	DE	DK	ES	FR	HR	IE	IT	MT	NL	PL	RO	SI
1. Abiotic characteristics														
1.1 Physical state characteristics														
Degree of submergence / depth / tidal regime	Depth in relation to chart datum; tidal range	Metres (m), maximum & minimum (m) with seasonal patterns		■		■			■	■	■	■	■	
Topography	Physical dimensions; extent; longitude and latitudinal gradients; elevation, form and features (e.g. ridges and troughs in the sandbank)	Area (ha) of different sandbank physical features, degrees of slope (°), physical features from a reference list				■			■					
Hydrodynamics – Exposure to current, wave action, scour & surge	Current speed; direction; height; seasonal extremes	Current speed (Knots) direction, height and extremes (m)	■							■				
Turbidity	Suspended particles; light transmission through water; Secchi disk depth	Nephelometric turbidity units (NTU), formazin turbidity units (FTU), Secchi disc depth (m)								■			■	
Sediment composition / distribution / dynamics	Sediment particle size; thickness of oxidised layer (for silt); deposition/erosion rates and location	% of three classes of particle size (mm), oxidised layer (mm) sediment size distribution, and rates of change (mm/year, -g/m^2)	■			■		■					■	
1.2 Chemical state characteristics														
Water quality	Various substances (including chemicals listed in the WFD and EQSD, nitrates & phosphates, oxygen, chlorophyll, dissolved solids)	pH, Chromophoric dissolved organic matter (CDOM), fluorescent dissolved organic matter (FDOM), total dissolved solids (TDS), dissolved oxygen (mg/l), oxygen saturation (%)	■						■	■	■		■	
Sediment quality	Inorganic and organic chemical contaminants; organic carbon	Redox potential in bottom sediment, traces of hydrocarbons, hydrogen sulphide concentration in the sediment (µM), organic carbon % dry matter, g MO(MS)/ m^2/day	■			■			■	■		■		

Ecological characteristics	Variables	Metrics	DE	DK	ES	FR	HR	IE	IT	MT	NL	PL	RO	SI
2. **Biotic characteristics**														
2.1 Compositional state characteristics														
Invertebrates - Epifaunal & infaunal assemblages including biogenic structures	Abundance and diversity of characteristic species from standardised lists	Number of biocenosis/taxa, presence & abundance of species (SACFOR scale), diversity index, (Shannon-Wiener diversity index, AMBI index) biomass, estimated % cover												
Vertebrates - Associated fish, birds & marine mammals	Abundance and diversity of characteristic species from standardised lists	Number, distribution, population structure (e.g. length distribution of fish), trophic composition (e.g. % omnivores/piscivores)												
Macrophytes, macroalgae, eelgrass	Type; abundance; extent	Biomass, estimated % cover												
2.2 Structural state characteristics														
Characteristic species, including biogenic structures	Abundance & condition; volume; biomass	Percentage cover, biomass, density, Synthetic indicators (M-AMBI, BENTIX etc)												
Macrophytes, macroalgae, eelgrass	Disease/necrosis extent; biomass; estimated % cover	Spatial extent (area and depth), taxonomic composition, % cover of substrate, density (no/m^2), biomass (dry weight/m^2) eelgrass average leaf length & width, leaf & rhizome biomass.												
2.3 Functional state characteristics														
Primary production	Frequency/longevity/strength of plankton blooms	Concentration of chlorophyll a (µg/ l), phytoplankton species, cyanobacteria volume												

Ecological characteristics	Variables	Metrics	DE	DK	ES	FR	HR	IE	IT	MT	NL	PL	RO	SI
3. Landscape/Seascape characteristics														
Connectivity / Fragmentation	Continuous/fragmented	Area (ha), % area directly affected by human activity, distance to other similar habitats												
4. Other														
Disturbance	Footprint of activity	Presence/absence, Length of modified banks (m), % area directly affected by human activity (e.g. by demersal fisheries, sand extraction or anthropogenic structures)												

Methodologies used for assessment and monitoring of habitat condition and existing data sources

Accessibility/location, exposure, size and depth have a major influence on data gathering, including the level of detail in which the variables are recorded. Table 6 lists some of the typical methodologies used to gather information on the key characteristics of this habitat type.

Table 6. Examples of survey methods used to investigate some of the key characteristics of habitat 1110 (sandbanks)

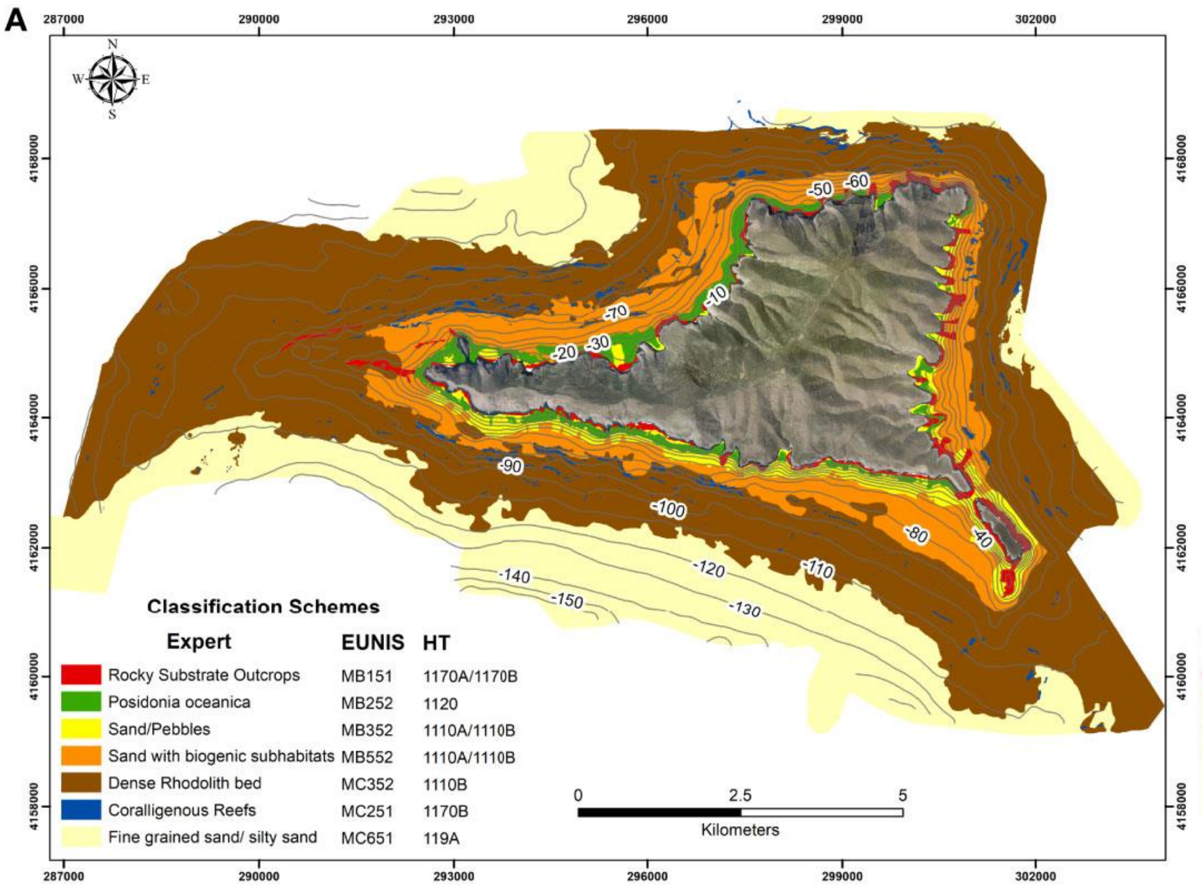
Abbreviations: ACDP - Acoustic Doppler Current Profiler, AGDS – Acoustic Ground Discrimination Systems, DDV – Drop-drown video, LIDAR – Laser Induced Detection and Ranging, MBES – Multibeam Echo Sounders, ROV – Remotely Operated Vehicle, SSS - Side Scan Sonar

Key characteristics	Methodologies
Degree of submergence/ depth	Diving, boat-based surveys, Acoustic methods, AGDS
Topography	Aerial survey (Satellite/Drone imagery/LIDAR), Acoustic surveys (SSS, AGDS, MBES), geological maps, modelling
Sediment composition/ distribution	Sediment sampling/profiling (core, grab), particle size analysis, DDV, video transects, geological maps. Multicorer or boxcorer for biological components and organic matter composition
Hydrodynamics - Exposure to current, wave action, scour and surge	Hydrographic charts, modelling, Aerial survey (Satellite/Drone imagery), Current meters (ADCP), time-lapse photography
Turbidity/ sedimentation / sediment dynamics	Water sampling, Secchi disc, satellite data, sediment sampling, sediment traps
Water quality	Temperature, salinity, water chemistry data loggers
Macrophytes, macroalgae, eelgrass	Photographic quadrats, video transects, visual census, direct sampling
Invertebrates - Epifaunal & infaunal assemblages	Photographic quadrats, video transects, visual census, direct sampling (grab, core, trawl), ROV or DDV. Multicorer or boxcorer (depending on water depth) to collect sediment samples for quantitative biological and trophic analyses. Diver-operated corer for meiofauna. Biogenic reefs formed by the ross worm *Sabellaria spinulosa* have been located using a combination of high resolution MBES and SSS as well as photography.
Vertebrates - Associated fish, seabirds & marine mammals	Visual census, aerial and boat-based surveys

Abiotic characteristics

Abiotic characteristics describe both the physical and chemical state of the habitat. In some cases, aerial surveys provide useful information about the general location and shape of shallow sandbanks but more detailed investigation by acoustic methods (e.g. SSS, AGDS, MBES) is generally desirable to get a picture of range and extent (Figure 2). The latter also provides more detail on bedforms on sandbanks such as mega ripples, as well as fine-scale topography. Sediment sampling (e.g. core, grab) is used to collect material for particle size analysis enabling more detailed mapping of the physical characteristics of sandbanks.

Figure 2. The classification map of Gyaros seafloor (South Aegean, Greece) by combining different acoustic methods

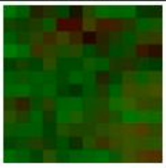
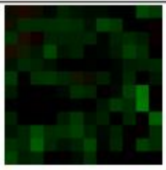
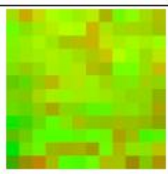
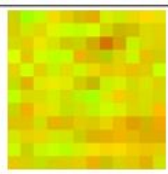
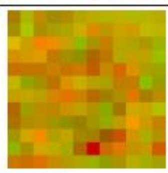
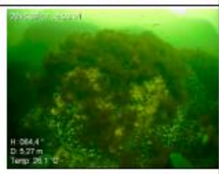
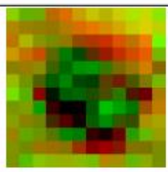
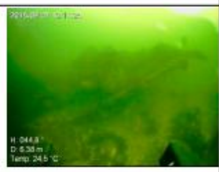


Source: Dimas et al., (2022).

Biotic characteristics

Acoustic methods used to record abiotic characteristics along with photography (video and still transects, drop down cameras) also provide information on the biotopes present and can be used in parallel. In the Belgian part of the North Sea, for example, cross-tabulation of acoustic data from Multibeam images with biological ground truthing data has been used to identify the likely occurrences of different microbenthic communities on shallow sandbanks. An example of benthic habitat mapping based on MBES can be found on Figure 3.

Figure 3. Acoustic facies, their descriptions and the corresponding backscatter and seabed images of the Rowy area (Baltic Sea, Poland)

Class ID/Color	Backscatter Image (9 × 9 m)	Image Description	Seabed Image	Seabed Composition
VFS		Dark green homogenous areas		Bare, flat area of very fine sand with worm burrows
S		Very dark homogenous areas		Sand or slightly gravelly sand with ripple marks
SG_GS		Green to orange areas		Slightly gravel or gravelly sand, rare boulders with barnacles and *Mytilus Trossulus*
B		Light yellow to orange heterogenous areas with patchy patterns		A high concentration of *Mytilus Trossulus* on dense boulder substratum
R		Dark orange areas with red patches		Large, dense patches of red algae with a high concentration of *Mytilus Trossulus* on boulder substratum
A		Very dark areas of undefined sharp transition with other areas		Artificial structures, such as a shipwreck

Source: Janowski et al., (2018)

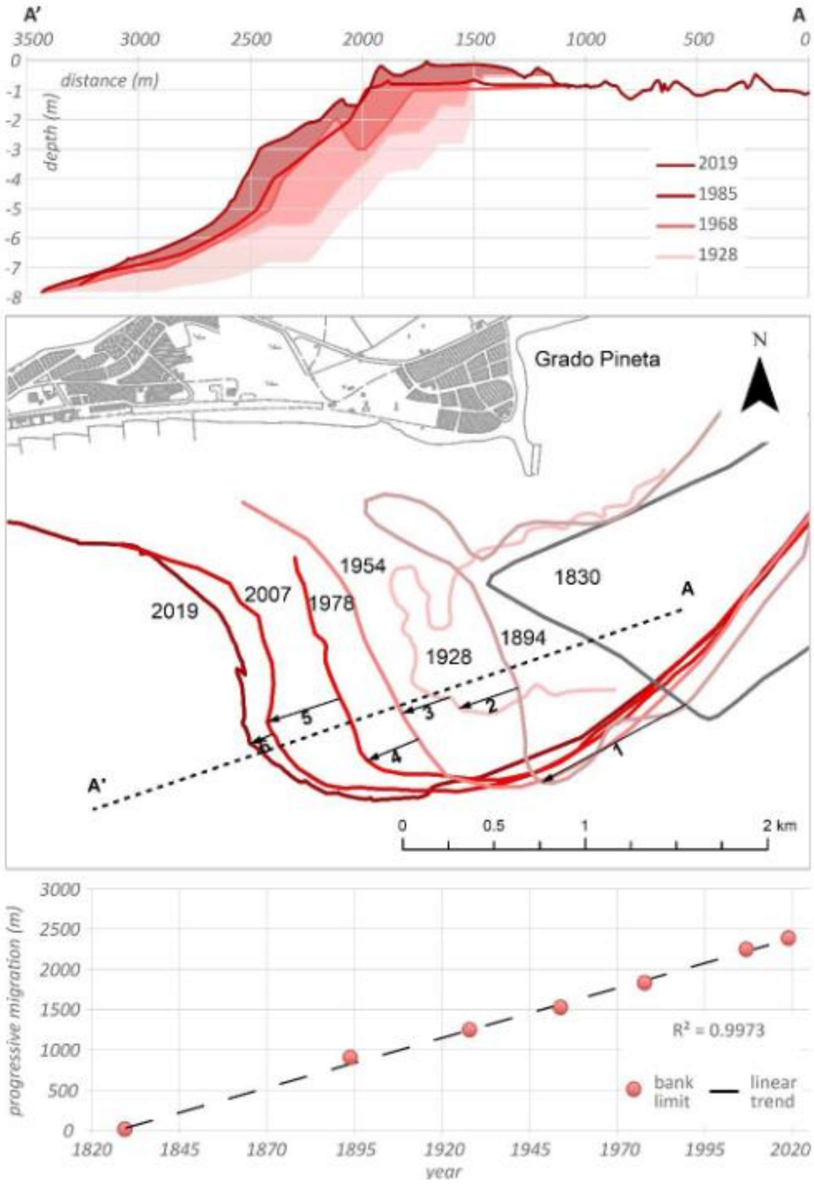
Visual census/aerial surveys including using photography provide information on seals and seabird numbers, distribution, and use of exposed and shallow sandbanks as feeding, resting, breeding and moulting areas while acoustic data can be interpreted to show the distribution and abundance of schooling fish such as sandeel. The existing knowledge base is also a factor. For example, there is a long-term data set of changes in the marine benthos on five selected fishing grounds over 60 years at the Dogger Bank (southern North Sea) enabling repeat sampling to detect trends (Frid et al., 2000).

Landscape/seascape characteristics

Acoustic survey methods using MBES, AGDS and side scan sonar are widely used to gather landscape characteristics of this habitat type. The data collected enables Member States to get an overview of the extent, topography and changing form of shallow sandbanks. This is typically combined with sampling which provides details of the sediment characteristics, infauna and epifauna. Sampling strategies vary, depending on the location, depth, size and hydrographic conditions.

In contrast geological and biological data from the habitats around Aland in Finland are relatively recently (Rinne et al., 2019). Historical changes in the morphology of sandbanks have also been investigated in order to detect trends. For example, the morphological evolution of Mula di Muggia Bank (northern Adriatic, Italy) over a 200-year period has been reconstructed using historical cartography, topographic maps, aerial phots, nautical maps and bathymetric surveys over time period from 1798 to the present data. The quality and reliability, particularly of early sources, needed to be carefully considered, after which it was possible to describe the most significant morphological changes (Figure 4) (Bezzi et al., 2021).

Figure 4. Detail of the bank migration analysed on the western front at Mula di Muggia Bank (northern Adriatic, Italy)



Source: Bezzi et al., (2021)

2.2 Definition of ranges and thresholds to obtain condition indicators

The reference values and thresholds applied by Member States to obtain condition indicators for shallow sandbanks are variously, very specific, based on trends, use indices, rely on expert judgement or any combination of these. Table 7 gives examples of specific reference values used in **Poland** to record condition of shallow sandbank habitats (Michałek et al., 2022).

Table 7 Examples of reference values used in Poland to record condition of shallow sandbank habitats

Condition of sediment Variable type	Variable	Metric	Reference level / threshold / indicator
Chemical	Organic carbon in bottom sediments	% dry matter	FV < 2% < U1 < 8% < U2
	Nitrogen in bottom sediments	% dry matter	FV < 0.25% < U1 < 0.5% < U2
	Phosphorus in bottom sediments	% dry matter	FV < 0.10% < U1 < 0.20% < U2
Biotic	Typical species	Number from list of typical species	FV >=4, U1 2-3, U2 1 or 0

FV=Favourable; U1=Unfavourable; U2=Unfavourable-declining

The **Netherlands** has developed a Benthic Indicator Species Index (BISI) for the Dutch North Sea as part of a benthos monitoring programme under the MSFD (e.g. Wijnhoven & Bos, 2017). This approach is also being used to inform quality assessments under the Habitats Directive (Wijnhoven & Van Avesaath, 2019). The focus is on assessment of sensitivity to disturbance and/or eutrophication using indicator species. The BISI measures the occurrence and/or density of a list of specified indicator species and compares this to a reference condition at a certain time. Reference values and indicator values are specified for different causes or functions (Table 8) but the species and reference conditions are area specific (Wijnhoven & Bos, 2023).

Table 8 Categories against which indicator species are assessed to determine sensitivity to disturbance and/or eutrophication

Categories against which indicator species are assessed
Sea floor disturbance
Ecological alteration (combining possible effects of pollutants and toxicants, hypoxia and temperature increases)
Intensity of sea floor disturbing fisheries (based on size of species)
Frequency of sea floor disturbing fisheries (based on age of species)
Recovery (based on frequency of recruits)
Characteristic species
Food web structure (importance for higher trophic levels)
Habitat diversity (species creating permanent structures)
Biological activation of sea floor top layer (bioturbating and bioirrigating species)
Habitat Directive typical species, when relevant

In other cases, assessments are based on trends rather than setting numerical thresholds or reference values. In **Germany**, for example, "loss of space or impairment of water quality, the soil and its flora and fauna" is one of the variables used to assess the condition of typical species of sublittoral sandbanks (Krause et al., 2008). This approach is considered useful for a habitat which is characterised by high natural dynamic geomorphological, hydrophysical and hydrochemical processes and consequently that favourable conservation status can only be achieved if natural processes are as undisturbed as possible within the framework of their natural dynamics. Expert judgement is also used such as "fairway maintenance or hydraulic engineering measures that do not permanently impair the structure and functions of the sandbank" (Krause et al., 2008).

In **Ireland** the assessment maërl-dominated communities, a community found associated with habitat type 1110, uses both trends (reference values linked to previously recorded condition) and a combination of negative indicators as a threshold/target to pass (Table 9) (Scally et al., 2020).

Table 9. Maërl-dominated community complex assessment of Structure & functions

*Previous survey results refer to the surveys of sensitive subtidal communities carried out between 2006 and 2009 (MERC, 2006, 2007a, 2008a and 2009)

Attribute	Assessment criteria	Target for pass
Physical quality indicators		
% Live: dead maërl	Gross change in ratio from previous survey results*	No gross change
Fragmentation	Gross change in cover (appearance of areas of sediment) from previous survey results*	No gross change
Negative indicators		
Physical damage e.g. evidence of dredge marks	Evidence of physical damage	A score of 2 (out of the 5 negative indicator attributes) or less for any combination of negative indicators.
Siltation or pseudofaeces	Presence of siltation or cover of pseudofaeces over maërl	
Invasive Alien Species (IAS) Algal cover	Presence of IAS within the bed Presence of abundant/smothering macro-algal cover	
Opportunistic species	Superabundance or covering of smothering opportunistic species	
A fail in either the physical quality or negative indicator assessment results in an overall fail for the polygon.		

In **France** reference values can be determined based on consultation and work with relevant experts with a recognition that they can correspond to historical values, potential values or modelled/co constructed values according to the experts (Lepareur, 2011).

In **Bulgaria**, this habitat is not currently included in the guidelines of assessment matrices due to limited data to determine exact parameters and threshold values (Zingstra et al., 2009).

Relevant data collected under other programmes (e.g. WFD, MSFD and any regional/national schemes) are also used as and when they become available and include some thresholds. For example, Descriptors 1 and 6 for reporting on 'Good Environmental Status' under the MSFD (see Box 1).

Box 1: Descriptors 1 & 6 under the Marine Strategy Framework Directive

Descriptor 1; Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions;

Descriptor 6; sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

For benthic [seabed] habitats (relating to Descriptors 1 and 6), the GES Decision provides the following criteria to be used to assess the extent to which GES is achieved:

- **D6C1** Physical loss of the seabed
- **D6C2** Physical disturbance to the seabed
- **D6C3** Adverse effects of physical disturbance on benthic habitats (spatial extent)
- **D6C4** Benthic habitat extent (extent of habitat loss from anthropogenic pressures)
- **D6C5** Benthic habitat condition (extent of adverse effects from anthropogenic pressures

Threshold values for a seabed habitat to be considered in Good Environmental Status (GES), were agreed in 2023. This states that no more than 25% should be adversely affected by human pressures, including no more than 2% that should be irreversibly lost[3]. A benthic broad habitat type is adversely affected in an assessment area if it shows an unacceptable deviation from the reference state in its biotic and abiotic structure and functions, e.g. typical species composition, relative abundance and size structure, sensitive species or species providing key functions, recoverability and functioning of habitats and ecosystem processes. It is however noted that these recommendations should not be considered by Member States as alternative conservation values for these habitat types under for example, the Habitats Directive.

An assessment of GES on the Hinder Banks, a sandbanks habitat in Belgium waters and the nearby Natura 2000 site of Flemish Banks, is example of a combined monitoring programme with the MSFD monitoring providing relevant data for Habitats Directive monitoring (Van Lancker et al., 2017).

A summary of the types of approach used by Member States regarding reference values and examples of the variables used are presented in Table 10.

[3] https://environment.ec.europa.eu/topics/marine-environment/descriptors-under-marine-strategy-framework
directive_en#descriptor-6-seabed-integrity

Table 10. Examples of reference values and approaches used for habitat 1110 (sandbanks)

Approach	Example of variable used	Method/metric and reference values	Reference
Quantitative	Chemical characteristics of sediment	Sampling, % dry matter	Poland: Michałek et al., 2022
Indices/Additional	occurrence/density of indicator species	Compared to site specific species list and site-specific reference condition	Netherlands: Wijnhoven & Bos, 2017
Scoring	Not specified but will cover, faunal and floristic components, state of health and character of sediment for soft substrates	Indicator compared to a threshold value to get a score which is then subtracted from a starting score of 100.	France: Delavenne & de Bettignies, 2023.
Linked to other programmes - e.g. WFD, MSFD, EOBV	Ecological, oceanographic and pressure variables relevant to monitoring seagrass beds		Adriatic: Manea et al., 2022
Trend	Loss of space or impairment of water quality, the soil and its flora and fauna	Evidence of change	Germany: Krause et al., 2008
	Fragmentation of maërl dominated communities	Evidence of gross change in cover (appearance of areas of sediment) compared to previous survey results	Ireland: Scally et al., 2020
Expert judgment		Consultation and work with relevant experts, including potential/modelled values	France: Lepareur, 2011
Under development		Limited data at present to determine parameters and thresholds values	Bulgaria: Zingstra et al., 2009

2.3 Aggregation methods at the local scale

In most EU Member States, a common rather than habitat specific methodology is used to aggregate data on indicators at the local scale to provide a condition assessment at the level of the plot or monitoring locality. For example, a general approach taken in France is illustrated in Box 2.

The approach used in **Poland** is to rate individual parameters (FV, U1, U2) and with the lowest grading determining the aggregated result (see Michałek et al., 2022 for more details).

In **Ireland**, it is proposed that a site level assessment set both for 1110, and for 1130, 1140 and 1160. It is based on the analysis of the structure and functions with regard to Marine Community Types (MCTs), sediment composition, keystone species, negative species and unique communities for which targets had been set in the site-specific conservation objectives (Table 11). A combination of those indicators provides an overall site assessment as shown in Table 13.

Box 2. Aggregation of indicators at a local scale - France

In France, for evaluation at the scale of Natura 2000 sites three parameters (surface, structure and functions and alterations) are assessed against several criteria, themselves represented by one or more indicators filled in or calculated from metrics collected in the field. In this "PatriNat" method, each indicator assessed is compared with a threshold value.Then each indicator is given a score (negative or zero) which is subtracted from the starting score of 100. A good indicator score will result in few points being subtracted, and a bad indicator score will result in more points being subtracted. Final scores indicate the overall status along a gradient (Table 11 & Figure 5 below).

Table 11. Example of scoring for three indicators A, B, C presenting different response modalities (from Delavenne & de Bettignies, 2023 and Lepareur et al., 2018).

PARAMETERS	CRITERIA	INDICATORS	MODALITIES (threshold values)	GRADE
Parameter 1	Criterion X	A	0-3	0
			3-6	-5
			6-9	-10
Parameter 2	Criterion Y	B	80%-100%	0
			20%-80%	-10
			0%-20%	-15
		C	>1	0
			<0	-20
			Final score (example)	100-0-15-20 = **65**

Figure 5. Determination of conservation status based on its overall score

Source: Delavenne & de Bettignies (2023) and Lepareur et al. (2018)

Table 12. Site level assessment of Structure & functions based on individual indicators and targets (Scally et al., 2020)

Indicator	Target	Notes	Assessment
Number of MCTs	The number of MCTs in a site should remain as specified in the conservation objectives	Any change from this should be taken as a fail unless the change can be attributed to improving environmental conditions or natural processes or a likely artefact of sampling*.	Favourable = all community types listed in the site-specific guidance document are present
			Unfavourable-Inadequate = increase or decrease in MCTs present
			Unfavourable-Bad = ≤50% of MCTs are present
Negative species	No increase in numbers of negative indicator species	Increase in presence and/or abundance of group IV or V species (Ambi Index**) in stations within the MCTs.	Favourable = absent from ≥75% of stations
			Unfavourable-Inadequate = absent from 74-51% of stations
			Unfavourable-Bad = absent from ≤50% of stations
Sediment	No significant change in the proportion of grain size classes	Change in the proportion of grain size classes that would result in change in the classification of the sediment type. Other than through Natural process***.	Favourable = ≥75% of stations with no change
			Unfavourable-Inadequate = 74-51% of stations with no change
			Unfavourable-Bad = ≤50% of stations with no change
Keystone communities	Area of the keystone communities	A change, other than through natural processes, in the area of these communities as defined in the conservation objectives.	Favourable = ≥90% of area shows no change
			Unfavourable-Inadequate = 90-76% of area shows no change
			Unfavourable-Bad = ≤75% of area shows no change
	Quality of the keystone communities	A change in quality elements, other than through natural processes, of these communities as defined in the conservation objectives.	Favourable = >90% with no change
			Inadequate = 90-76% with no change
			Unfavourable-Bad = ≤75% show no change

*As described in the text above, sampling artefacts can arise due to the physiographic structure of a site and location of sampling stations. **Ambi Index: AZTI marine biotic index (Borja et al., 2000; 2003). ***Storm events can lead to coarsening of the sediment composition while deposition is associated with an increase in the proportion of fine particles (Huisman et al., 2016)

Table 13. Overall site level assessment of Structure & functions (from Scally et al., 2020)

MCT: Marine Community Types

Attribute	Favourable	Inadequate	Bad
Structure & functions	All attributes stable	Loss of a single sediment MCT (unless due to an artefact of sampling), or Significant change in sediment grain size classes other than through natural processes, or Increase in numbers of negative indicator species, or Any decline in area of keystone communities, or Reduction in quality of keystone communities	Loss of more than a single MCT (unless due to an artefact of sampling), or Loss of keystone community, or Any combination of three or more attributes classed as 'Inadequate'

2.4 Aggregation at biogeographical scale

To assess the conservation status at a biogeographical scale, the area, quality and trends in the habitat need to be assessed. There is a lack of information on how Member States have undertaken aggregation at the biogeographical scale specifically for this habitat type, but it is expected that the relevant guidance is followed. The most recent recommendation (for the reporting period 2019-2024) is that if 90% of habitat area is considered as in ‘good’ condition’, then the status of ‘structure and functions’ parameter is ‘favourable’. If more than 25% of the habitat area is reported as ‘unfavourable, then the ‘structure and functions’ parameter is ‘unfavourable-bad’ (European Commission, 2023).

2.5 Selection of localities

There is no standard approach to the identification of a number and distribution of localities to carry out the assessment and monitoring of shallow sublittoral sandbanks. Practical consideration, such as accessibility are important as are mobility of the feature, size, physical variability and diversity of the associated biological communities. There can be very high levels of natural variability, with substantial small-scale variation in substrates and associated taxa. Ideally monitoring takes place across the sandbank feature trying to record the variety of features.

In **Italy**, for example, it is specified that survey sites across shallow sandbanks are selected to be representative of different environmental conditions and impacts of different intensities, taking account of existing monitoring under WFD, MSFD and within any designated MPAs.

In **Poland**, since there are only two Natura 2000 sites where habitat 1110 is recorded, it is proposed to monitor both of them. Within the habitat patches, monitoring stations are randomly selected. In **Romania**, selection of localities is done within protected natural areas where the habitat has been recorded. Sampling locations should be spread over the entire area to ensure adequate examination of spatial variation. A single sampling station cannot be assumed to be representative of the entire habitat. The actual number of stations needed to describe the full range of species present needs to be determined through a pilot study. A sampling strategy should consist of several stations, with only a few replicates per station (even a single one), when considering attributes related to biological description. In **Slovenia**, the four most representative areas for the habitat 1110 have been selected for monitoring.

In **Spain**, in order to select localities for monitoring of coastal habitats, eleven criteria were developed and applied to each biogeographical region (Aranda et al., 2019):

- Representativeness within the Natura 2000 Network and the Protected Area Networks.
- Statistical significance. A minimum number of monitoring locations is necessary so that the assessment can be extrapolated from local to regional level.
- Number of types of habitat of community interest present in the location.
- Range/Occupied surface area
- Representative presence within the coastal province.
- Threat status (danger of disappearance) and conservation status. Includes habitat types with a certain degree of degradation or threat, which have a current tendency to decrease or have had a historical tendency in this sense.
- Reference ecosystems.
- Ecological significance and national/community uniqueness.

- Environmental-ecological diversity.
- Distance to other monitoring points.
- Representativeness within the autonomous communities.

Sampling protocols, including the number of samples to be taken at each sampling station are relevant to the analysis but with no standardised approach. In **Poland**, it is stated that at each site samples should be taken from 5 stations evenly distributed within the habitat.

2.6 General monitoring and sampling methods

A six yearly cycle of reporting, as specified under Article 17, is required under the Habitats Directive. This includes reporting on the conservation status of habitats listed in Annex 1 of the Directive. It applies throughout the territory of the Member State concerned, not only where the habitat occurs within Natura 2000 sites. To inform this reporting, six-yearly monitoring of the relevant habitats would be the minimum required. In practice, monitoring specifically for the Habitats Directive may be more frequent, as well as using relevant data collected under other programme (e.g. WFD, MSFD and any regional/national schemes) as and when they become available. Seasonal patterns also need to be taken into account and will affect the timing of monitoring. In the case of sandbanks this would be especially relevant where there are associated ephemeral algal communities but also to pick up significant changes in the overlying water column.

On the **Polish** sandbanks, for example the monitoring programme states that the optimal time for examining zoobenthos is spring (April-May) before the organisms start reproducing (Michałek et al., 2022). Macrozoobethos samples are collected in accordance with the methodology described in Osowiecki & Błeńska et al. (2020) which is based on the guidelines of the Helsinki Commission (HELCOM, 2017).

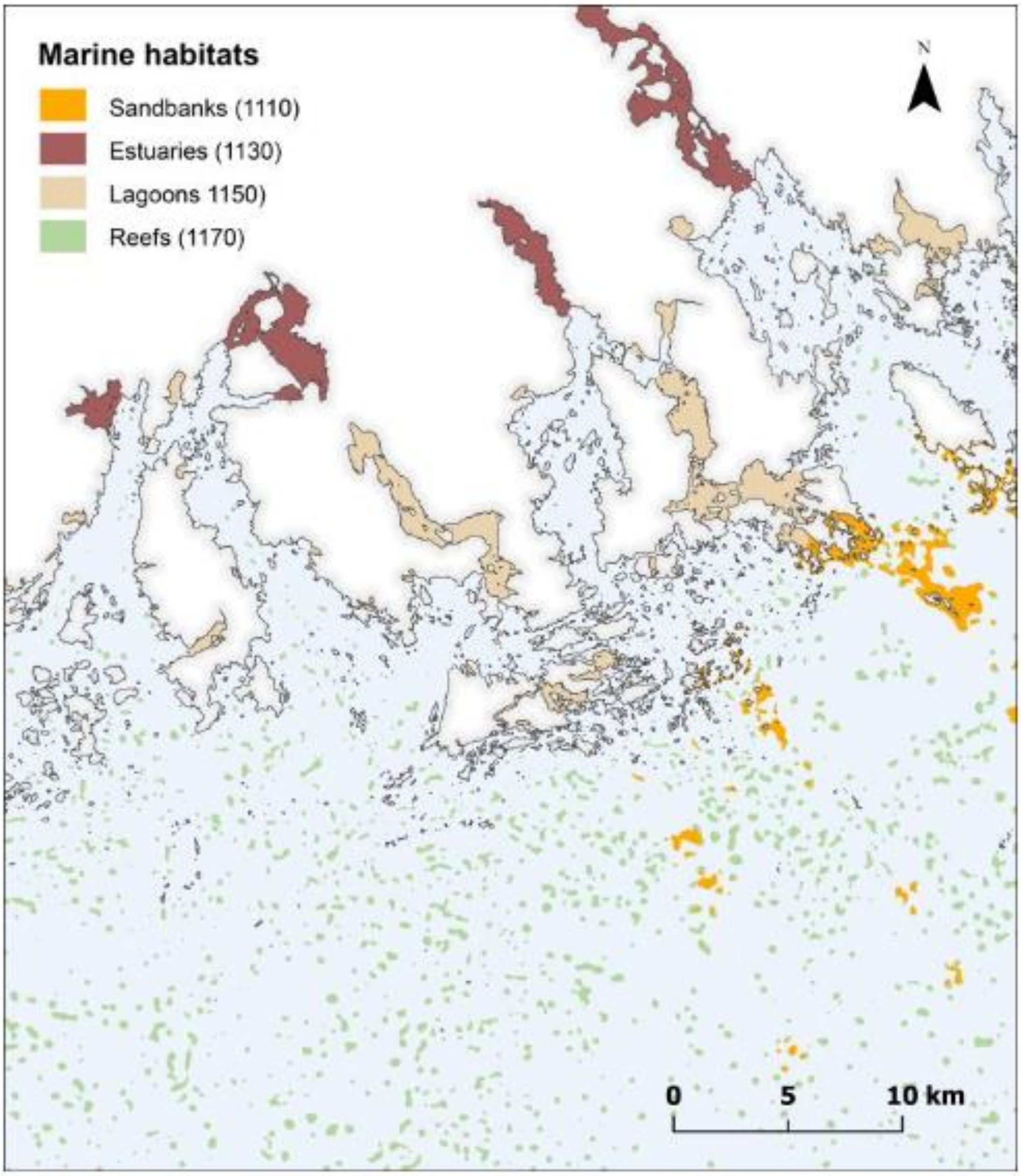
In **Italy**, surveys are carried out every 3 years, to evaluate the surfaces, their temporal variation and possible colonisation by species. This is done by drone, aerial or satellite images with field checks. Macrophytes and benthic macrofauna species verified with sampling always on a 3-year basis. To control variation in the area occupied by the habitat it is suggested that photogrammetric surveys are carried out from early May to late October during exceptional low tides. This is also a good time to study the fauna as it is much reduced during winter. The survey frequency for fauna is annual, varying the position of the survey areas from year to year but returning to the same area every 3 years. At each station four samples are taken, three for faunal studies and a fourth for analysis of grain size (La Mesa et al., 2019).

In **France** where possible, it is stated that site monitoring should rely on existing protocols and monitoring for the MSFD and WFD although it is recognised that some indicators calculated from protocols used on a national scale are not easily affordable and do not necessarily serve local management questions within a Natura 2000 site. Site scale assessments are to be carried out every 6 years to feed into the European reporting cycle. However, there is a recognition that interannual variability can be significant for certain habitats and therefore an increased frequency may be necessary. These should be determined based on best available knowledge of the different habitats (Delavenne & de Bettignies, 2023).

In **Denmark**, the National Monitoring Program for Aquatic Environment and Nature (NOVANA) monitors the condition of the aquatic environment and nature within areas prioritized according to politically established economic frameworks. In the **Netherlands**, the type of monitoring and the expected number of samples to be taken with 3 yearly intervals is specified.

Finland has an inventory programme for underwater marine diversity VELMU (started in 2004)[4]. This is not a monitoring program set up to directly provide data for Habitats Directive reporting but the outputs, together with indicators from MSDF and WDF, provides some information to report on structure and function of marine habitats as part of the Article 17 reporting. Furthermore, while some of the surveys focus on shallow sandbanks it is also the case that relevant data may not be habitat specific but collected during marine surveys of geographical areas. This is an effective approach where the same methodologies are used. Habitat types are then distinguished following subsequent interpretation of the data (Figure 6).

Figure 6. Distribution of the EBHAB habitats in the study area



Numbers denote the code of the habitat types described in supporting text.
Source: Finnish Inventory Programme for Underwater Marine Diversity (Velmu)

[4] https://www.ymparisto.fi/en/nature-waters-and-sea/natural-diversity/conservation-and-research-programmes/velmu-programme

2.7 Other relevant methodologies

A variety of methodologies and projects provide valuable information on assessing the structure and function of shallow sandbanks even though they may not be specifically aimed at Article 17 reporting.

They include:

- Work carried out under Regional Seas Programmes such as the Quality Status Reports prepared by OSPAR[5] (e.g. Eutrophication Thematic Assessment) and HELCOM[6].
- Reporting under other EU Directives, in particular the Water Framework Directive and the Marine Strategy Framework Directive[7].
- Scientific research/databases e.g. assessing cumulative impacts of human pressures on sandbanks in the northeastern Baltic Sea (Vaher et al., 2022).
- Surveys/monitoring of offshore developments/human activities/EIAs (Van Lancker et al., 2017).

In the case of the **North Sea**, for example, some areas of sandbank have been subject to decades of research which have generated a solid understanding of the large-scale structuring of the seafloor as well as the composition and distribution of major benthic faunal associations in the southeastern North Sea (Hagmeier, 1925; Neumann et al., 2013; Salzwedel et al., 1985). Additionally, specific habitats have been identified, which often represent spatially restricted derivates of the broad associations, potentially characterized by unique structural and functional features (Gutow et al., 2022).

In the **United Kingdom** the recommendation for monitoring shallow sandbanks is to develop a stratified monitoring strategy based on an initial inventory of the entire sandbank resource. Where sandbanks are categorised, for example based on sediment type or topographical structure, all categories should be sampled. For individual sandbanks sample sites should be spread throughout to ensure adequate consideration of spatial variation. The sampling strategy should consist of many stations with a few replicates per station (Davies et al., 2001).

Examples from outside Europe include studying the geomorphology of sandbanks using multibeam sonar together with sediment sampling, and modelling of the current regime (the Bay of Fundy, Canada e.g. Todd et al., 2014); macrofauna and sediment sampling to examine the diversity and structure of microbenthic assemblages and how community structures vary with season and environment parameters (Louisiana, USA) (Dubois et al., 2009); and using video and side-scan, transect sampling by video and point sampling of fauna using quadrats and cores to monitor subtidal soft-sediments (Tamaki Strait, New Zealand, Chiaroni et al., 2010).

2.8 Conclusions

Some information has been collected about the location and description of the main characteristics of shallow sublittoral sandbanks by all twenty-one the Member States that have reported habitat 1110 as present within their jurisdiction[8] but specific methodologies for

[5] OSPAR Eutrophication Thematic Assessment https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/eutrophication/

[6] HELCOM estuaries metadata catalogue https://metadata.helcom.fi/geonetwork/srv/api/records/1b3802d8-c23b-4d69-8575-c9eadda71619

[7] Summaries available on the Marine Information System for Europe; https://water.europa.eu/marine/data-maps-and-tools/map-viewers-visualization-tools/dashboards-on-marine-features-under-other-policies

[8] as evidenced by the submitted Standard Data Forms for designated sites where 1110 is a feature as well as Article 17 reporting.

assessing and monitoring this habitat are only available from twelve Member States (DE, DK, ES, FR, HR, IE, IT, MT, NL, PL, RO, SI). Reports of sandbank surveys and assessments carried out in these and other EU Member States are also relevant and can be or have been used to inform such assessments.

All of the abiotic characteristics identified as being relevant to monitoring structure and function of this habitat type are specified for monitoring by at least two Member States. Depth/tidal regime and sediment composition/distribution are the most frequently identified physical characteristics. Both water and sediment quality are subject to monitoring by five Member States although there are some apparent differences in the variables measured. All the twelve Member States monitor biotic characteristics with most focus on epifaunal and infaunal assemblages. There is also some monitoring of structural characteristics for example by monitoring variables such as volume or biomass of particular species/species groups.

There is much commonality in methodologies across Member States, from initial review of likely locations based on existing geological information and maps, followed by aerial surveys and further reconnaissance from boat and shore to gather more specific locational information. Abiotic and biotic characteristics of the habitat are recorded, as well as aspects such as fragmentation and disturbance which are landscape/seascape characteristics of this habitat type. For example, physical state characteristics frequently recorded include sandbanks dimensions, depth, exposure to wave action, and sediment type; compositional state characteristics typically involve recording epifaunal and infaunal assemblages, their abundance and distribution within across sandbanks habitats as well as the presence, condition and abundance of any macroalgae or eelgrass beds. Variations in the methodologies used to assess and monitoring shallow sublittoral sandbanks are strongly influenced by accessibility, topographical type, hydrographic conditions, as well as the diversity of the habitat and the associated biological communities.

The reference values and thresholds applied by Member States to obtain condition indicators for shallow sandbanks are variously; very specific, based on trends, use indices, rely on expert judgement or any combination of these. There is consistent and good coverable of variables used to describe the ecological characteristics of this habitat type across Member States. The exception is functional state characteristics where limited information is available on approaches taken.

A number of approaches are used to aggregate data to provide an assessment at local and national scales. There is no information on the biogeographical scale.

There is no standard approach to the identification of a number and distribution of localities to carry out the assessment and monitoring of shallow sublittoral sandbanks. Practical consideration, such as accessibility are important as are factors such as mobility of the feature, size, physical variability and diversity of the associated biological communities. Ideally monitoring takes place across the sandbank feature trying to record the variety of features.

A six yearly cycle of reporting, as specified under Article 17, is required under the Habitats Directive. This includes reporting on the conservation status of habitats listed in Annex 1 of the Directive. It applies throughout the territory of the Member State concerned, not only where the habitat occurs within Natura 2000 sites. To inform this reporting, six-yearly monitoring of the relevant habitats would be the minimum required. In practice, some monitoring of sandbank habitats specifically for Habitats Directive reporting is more frequent (e.g. 3 yearly) but in many cases relevant data collected under other programme (e.g. WFD, MSFD and any regional/national schemes) are also used as and when they become available.

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

3.1 Selection of condition variables, metrics and measurement methods

Variables identified for monitoring programmes need to be robustly associated to the key characteristics and processes (functions) that determine habitat condition and must be sensitive to natural threats or human pressures that decrease favourable condition (Maes et al., 2023). A set of variables associated with all types of characteristics (abiotic physical and chemical, biotic compositional, structural and functional, landscape variables) should be measured.

The description of the condition variables, metrics and measurement methods need to be informed and clear so that they can be applicable in all Member States.

The ecological characteristics, methodologies, variables and metrics used to investigate and assess the condition of habitat types 1110 (sublittoral sandbanks), 1130 (estuaries), 1140 (mudflats & sandflats) and 1160 (inlets and bays) are rather similar. This section therefore presents joint proposals for a minimum common set of variables, recommended metrics, and measurement procedures for all four of these habitat types (1110, 1130, 1140 & 1160). A proposed list of essential, recommended and specific condition variables is presented in Table 14. 'Essential' variables describe the common essentials of the habitat, 'recommended' variables are relevant but can be neglected in some contexts, while 'specific' variables are those which should be measures in some circumstances.

- **Essential** condition variables describe essential characteristics of the habitat, reflecting its conservation quality. They are selected on the basis of intrinsic and instrumental relevance, validity, reliability, availability, simplicity and compatibility, and should be assessed in each MS, following equivalent procedures.
- In addition, a set of **Recommended** condition variables are proposed as optional, additional or complementary variables that may need to be applied in some cases, according to contextual factors operating on habitats in the different MSs.
- There are also **Specific** condition variables which are more suitable to be measured on some habitat subtypes or which may be particularly relevant in some Member States.

Some **descriptive or contextual variables** are included in this section. These variables define environmental characteristics (e.g. climate, topography, lithology) that can influence the habitat condition, are useful to define thresholds for the condition variables and interpret the results of the assessment but are not used in the aggregation of variables to determine the condition of the habitat.

There are contextual factors operating in the different Member States, which may determine the values of the variables characterizing the habitat condition as favourable, particularly biogeographical as good condition of the same habitat may vary across biogeographical regions. Salinity is a good example of this given the different salinity profiles of the different Regional Seas.

Table 14 uses the main characteristics of the four different habitats (described in section 1.2.1 of each habitat report), together with the information provided by Member States about the assessment the condition of these habitats and habitat specific literature. The proposed metrics are intended to be easily but reliably obtained.

The main **abiotic characteristics** are physical (describing the form, influencing factors such as tidal range, exposure to currents, temperature, turbidity and sediment composition /distribution) and chemical (related to water and sediment quality). Only one of the physical characteristics (exposure to current, wave action, scour & surge) does not appear to be routinely monitored for condition assessment across all four habitats. The exception is estuaries, potentially because of prevailing sheltered conditions. However, it should be noted that this variable can have a significant influence on condition around the mouths of estuaries and within exposed channels therefore it is proposed as essential.

In the case of chemical characteristics, salinity/freshwater influence/stratification will have a significant influence on the condition of habitats 1130 & 1140, less so for 1160, and potentially not an issue for examples of 1110 which lie offshore. For this reason, monitoring has been proposed as recommended (although essential in the Black Sea after justification by some Member States). Water quality needs to be monitored across all habitat types, however there will be differences in the variables that are measured. In estuaries with industrial facilities along the shoreline for example, monitoring of heavy metals would be highly relevant but not in the case of offshore sandbanks, hence the recommendation that monitoring is essential but with recommended elements.

The main **biotic characteristics** are compositional (associated species), structural (presence and condition of species) and functional (influencing factors such as sedimentation and phytoplankton blooms). All of these are already subject to monitoring by Member States however monitoring biogenic structures has been listed in Table 14 as recommended as such structures are not always present. The same applies to macroalgae/eelgrass presence and condition. Monitoring the presence of opportunistic/invasive species is also recommended as the risk may be higher in some locations/habitats, and it may be considered precautionary measure so that any potential effects on habitat condition can be picked up at an early stage.

The main **landscape/seascape characteristics** are connectivity, form and extent, and a single variable, 'disturbance', has been proposed for monitoring in the category '**other'**. Extent and disturbance would be the minimum required to get an overview of the condition of the site at both large and small scales, and they are therefore proposed for essential monitoring. Connectivity and form provide more detail and are therefore recommended monitoring variables.

Table 14. Proposals for essential, recommended and specific condition variables for habitats 1110, 1130, 1140, and 1160

The variables are included in the types recognized in the SEEA EA methodology (United Nations et al., 2021). Metrics may show several options. including current monitoring for each habitat type across Member States (*), metrics and measurement procedures. Abbreviations: ACDP - Acoustic Doppler Current Profiler, AGDS – Acoustic Ground Discrimination Systems, CTD - Conductivity, temperature and depth, DDV – Drop-drown video, LIDAR – Laser Induced Detection and Ranging, MBES – Multibeam Echo Sounders, ROV – Remotely Operated Vehicle, SBES – Single Beam Echo Sounders, SSS - Side Scan Sonar)

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
1. Abiotic characteristics									
1.1 Physical characteristics									
Degree of submergence/ depth	**- Depth in relation to chart datum**	- Metres (m)	*	*	*	*	Essential if not positionally stable	SBES, MBES, AGDS, LIDAR, Hydrographic charts, modelling, Aerial survey (Satellite/Drone imagery), Tide gauges	Depth, together with topographical characteristics and tidal regime have a significant influence on the form and extent of these habitat types as well as on the development and stability some of the features within them such as beaches, channels and tidal pools. The associated biota will also be affected by the degree and length of time of submergence/ emergence as determined by the tidal regime.
Tidal regime	**- Tidal range**	- Maximum & minimum (m) with seasonal patterns	*	*	*	*	Essential in tidal areas for 1130, 1140 and 1160. Recommended for 1110.	Tide gauges, modelling, Aerial survey (Satellite/Drone imagery).	Depth, together with topographical characteristics and tidal regime have a significant influence on the form and extent of these habitat types as well as on the development and stability some of the features within them such as beaches, channels and tidal pools. The associated biota will also be affected by the degree and length of time of submergence/ emergence as determined by the tidal regime

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
Topography	**- Physical dimensions - Extent - Longitude and latitudinal gradients - Elevation, - Form and features (eg. banks, islands, troughs)**	- Area of features (km^2) - Tidal prism/cross-sectional area relationship - Degrees of slope (°) - Physical features	*	*	*	*	Essential if not positionally stable for 1110, 1130 and 1140. Recommended for 1160.	SSS, MBES, SBES, AGDS, LIDAR Aerial survey (Satellite/Drone imagery) Geological maps	Most appropriate methodology will depend on issues such as the size of the area to be mapped, resolution required, object detectability, and the depth range over the survey area. For baseline broad scale mapping where relatively large geological features such as sand waves or reefs are present, MBES may be more cost effective. For the identification of small habitat features, a combination of MBES and SSS can give both quantitative bathymetric data (1m resolution) and qualitative, high-resolution habitat relief data but is costly. For small scale habitat mapping, high resolution SSS, underwater photography, ROVs, and grab sampling data can be combined for habitat mapping. Satellite imagery, LIDAR is particularly useful in shallow waters although affected by turbidity of the water.
Hydrodynamics - Exposure to current, wave action, scour & surge	**-Current speed -Direction -Height -Extremes**	- m/s - Metres (m)	*	*	*	*	Essential	Hydrographic charts Modelling Aerial survey (Satellite/Drone imagery) Current meters (ADCP).	Seasonal changes and storm events will be apparent when recording these variables. Species composition is an indirect indicator of these variables.
Temperature	**- Water temperature**	-Temperature (ºC)	*	*	*	*	Essential	CTD	Temperature is usually recorded as part of water quality sampling programmes.
Turbidity	**-Suspended particles -Light transmission through water samples -Secchi disk depth**	- Nephelometric turbidity units (NTU) - Formazin turbidity units (FTU) - Secchi disc depth (m)	*	*	*	*	Essential	Turbidity sensor, Secchi disc, water chemistry data loggers, satellite data, sediment sampling, sediment traps	Different turbidity unit depending on tools used, therefore the same instrument should be used for comparability of data. Turbidity caused by resuspension of sediments results in associated effects of increased oxygen demand, release of nutrients and potentially toxic substances.

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
Sediment composition/ distribution	**- Sediment particle size and distribution** **- Thickness of oxidised layer (for silt)** **- Deposition/ erosion locations**	- % of three classes of particle size (mm; Folk diagram) - Oxidised layer (mm) - Rates of change (mm/year, -g/m^2)	*	*	*	*	Essential	Benthic grab/core sampling, suction sampling, sediment profile camera Video/photographic transects MBES Aerial imagery Modelling	Variation in sediment composition can occur over both small and large distances. A systematic and consistent approach to sampling will therefore be required to give sufficient overview of this characteristic across the habitat as well as identifying boundary areas and any locations with particularly different/distinctive sediment compositions characteristics.
1.2 Chemical characteristics									
Salinity/ freshwater influence/ stratification	**- Salinity** **- Conductivity**	- Parts per thousand Sodium and Chloride (0/00) - Depth/ boundaries (m) of different water bodies	*	*	*	*	Essential in the Baltic Sea, Specific in all other Seas	CTD, Water chemistry data loggers	Changes in salinity within and across the habitat are a major natural characteristic of estuaries as well as across mudflats/sandflats and islets and bays due to tidal movements and freshwater runoff. The resulting variation may be apparent diurnally, seasonally or as pulses in response to events such as storms and flooding. Salinity gradients can also lead to stratification of the water column which has chemical, physical and biological implications for the associated biota.
Water quality	- Various substances (including chemicals listed in the WFD and EQSD, nitrates & phosphates, oxygen, chlorophyll, dissolved solids)	- pH - Chromophoric dissolved organic matter (CDOM) - Fluorescent dissolved organic matter (FDOM) - Total dissolved solids (TDS) - Dissolved oxygen (mg/l) - Oxygen saturation (%)	*	*	*	*	Essential but with specific elements as variables will depend on depending on habitat type, pressures and threats.	CTD with sensors to measure oxygen (saturated in % and dissolved in mg/l), pH, nitrate, chlorophyll, turbidity currents	Numerous parameters may be recorded under the variable "water quality". The standards set under the WFD for transitional waters are particularly relevant and are already being used as reference values/thresholds for a number of parameters. These include general parameters such as oxygenation, nutrients, nitrogen, phosphorus, as well as chemical and physio-chemical quality elements.

Characteristics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
Sediment quality	- Inorganic and organic chemical contaminants - Organic carbon	- Redox potential in bottom sediment - Traces of hydrocarbons - Hydrogen sulphide concentration in the sediment (µM) - Organic carbon (% dry matter)	*	*	*	*	Essential	Sediment sampling/profiling (core, grab), particle size analysis, DDV, photographic record of samples	Variation in sediment quality can occur over both small and large distances. A systematic and consistent approach to sampling will therefore be required to give sufficient overview of this characteristic across the habitat as well as identifying boundary areas and any locations with particularly different/distinctive sediment qualities.
Oxygen levels	**- Oxygen levels measured at surface and depth.**	- Concentration/ dissolved oxygen (% saturation)		*			Specific	Dissolved oxygen meters, optical sensors	
2. Biotic characteristics									
2.1 Compositional state characteristics									
Invertebrates - Epifaunal & infaunal assemblages	**- Abundance of characteristic species from standardised lists. - Diversity of characteristic species from standardised lists.**	- Number of taxa - Presence & abundance of species (SACFOR scale) - Diversity index, (Shannon-Wiener index, AMBI index) - Biomass, - Estimated % cover - Density (ind./10 cm^2) and Shannon-Wiener for meiofauna	*	*	*	*	Essential, although recommended for meiofauna	Macrofauna: Photographic quadrats, video transects, visual census, direct sampling (grab, core, dredge, suction), ROV or DDV. Meiofauna: Diver-operated corer (3 replicates in floor sediment)	Allows quantitative data on macro and meiofauna. Allows identification of mega epibenthos. Non-destructive methods are likely to be favoured and the methodology will depend on the species as well as factors such as the extent, location, and any seasonality.
Vertebrates - Associated fish, birds & marine mammals	**- Abundance and diversity of characteristic species from standardised lists.**	- Number - Population structure - Trophic composition (e.g. % omnivores/ piscivores) - Distribution	*	*	*	*	Essential for some groups, specific for some others	Aerial/boat-based surveys photographic/satellite imagery, in situ observations, eDNA Fish: nets & traps	Methodology will depend on the species.
Biogenic structures	**- Type - Extent**	- Biomass - Estimated % cover - Condition	*	*	*	*	Specific but essential if present	Photographic quadrats, video transects, visual census, direct sampling (grab, core), ROV or	Methodology will depend on the species. Non-destructive methods are likely to be favoured

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
								DDV, aerial photography for intertidal areas.	
Opportunistic/ invasive species	**- Presence** **- Distribution** **- Abundance**	- Number - Biomass - % cover - Population structure.	*	*	*	*	Recommended	Benthic/pelagic sampling methods as well aerial imagery if intertidal.	Methodology will depend on the species and whether it is present intertidally or subtidally. Opportunistic/invasive species can cause very significant changes in the biotic composition of any of the habitats in this cluster as well as some potential impacts on their physical structure. Examples include Pacific Oyster *Crassostrea gigas*, forming reefs on intertidal flats, dense meadows of the alga *Caulerpa cylindracea* smothering areas of rock, sand, mud and seagrass beds within inlets and bays, and Chinese Mitten Crab *Eriocheir sinensis* undermining soft sediment banks in estuaries.
2.2 Structural state characteristics									
Characteristic species	**- Condition**	- Percentage cover - Biomass - Density - Synthetic indicators (M-AMBI, BENTIX etc)	*	*	*	*	Essential	Birds, marine mammals, fish: Visual census, aerial and boat-based surveys. Epifaunal and infaunal assemblages: Photographic quadrats, video transects, visual census, direct sampling (grab, core, trawl) ROV or drop-down video data	Methodology will depend on the species. For example, some may be visually dominant and therefore can be surveyed by visual means whereas more cryptic species or infauna may require direct sampling. The monitoring schedule will need to take account of any seasonal changes.
Biogenic structures	**- Abundance** **- Extent** **- Condition**	- Volume/ biomass - Fragmentation - Ecological volume	*	*	*	*	Specific	Photographic quadrats, video transects, visual census, direct sampling (grab, core) ROV or DDV, AGDS, SSS, aerial/satellite imagery. For ecological volume: Photogrammetry 3D; integration of SSS and MBES; quadrants and transects; ROVs.	Non-destructive methods are likely to be favoured and the methodology will depend on the reef forming species as well as factors such as the extent and location.

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
Vegetation zones	**- Abundance - Extent - Condition**	- Area (ha) - Depth (m) limit of angiosperms - Biomass (dry weight/m^2) - Ecological volume	*	*	*	*	Specific	Visual and acoustic surveys (e.g. covering presence, density, extent) photographic quadrats, video transects, visual census, direct sampling. For ecological volume: Photogrammetry 3D; integration of SSS and MBES; quadrants and transects; ROVs.	Comparisons of recording data will reveal temporal changes in the presence and/or condition of macroalgae/eelgrass. Any such changes may be part of a natural cycle e.g. seasonal changes in macroalgal cover. Alternatively, they may be an indicator of anthropogenic impacts directly (e.g. removal) or indirectly (e.g. increasing turbidity of the water column).
Macrophytes, macroalgae, eelgrass	**- Abundance - Extent - Condition**	- Spatial extent (area and depth) - Taxonomic composition - % cover of substrate - Density (no/m^2) - Average leaf length & width - Leaf & rhizome biomass. - Ecological volume	*	*	*	*	Specific	Visual and acoustic surveys (e.g. covering presence, density, extent), photographic quadrats, video transects, visual census, direct sampling. For ecological volume: Photogrammetry 3D; integration of SSS and MBES; quadrants and transects; ROVs.	Comparisons of recording data will reveal temporal changes in the presence and/or condition of macroalgae/eelgrass. Any such changes may be part of a natural cycle e.g. seasonal changes in macroalgal cover. Alternatively, they may be an indicator of anthropogenic impacts directly (e.g. removal) or indirectly (e.g. increasing turbidity of the water column).
2.3 Functional state characteristics									
Primary production	**- Frequency of plankton blooms - Longevity of plankton blooms - Strength of plankton blooms - Angiosperms/ macroalgae**	- Concentration of chlorophyll a (µg/ l) - Phytoplankton species - Growth rates - Dry weight/m^2	*	*	*	*	Specific	Plankton sampling, spectrophotometry, flurometry, high performance liquid chromatography.	This variable is an indicator of factors such as nutrient load, seasonality, and water temperature and it can also be one of a number of significant markers of changes associated with climate change. Research undertaken for this project suggests that it is not typically recorded for all the habitats in this cluster however this may be misleading as it may be included in water quality and macroalgae/eelgrass sampling.
Food webs	**- Energy transfer between tropic levels**	- Number of species/functional groups and qualitative links - Average energy transfer between trophic levels (%) - Stable isotopes (^{13}C, ^{15}N, ^{34}S) -Stomach content analysis	*	*	*	*	Specific	Combined trophic analyse (both stomach analysis, stable isotope analysis and DNA analysis as barcoding/metabarcoding)	Use standardized methods to collect samples of benthic organisms, plankton, and fish across multiple fixed stations and depth zones. This ensures representative data on all food web components. Measure environmental parameters (sediment type, water quality) and implement quality control procedures (replicates, reference standards) to ensure data reliability and comparability between sites.

Characteris-tics	Variables	Metrics	1110	1130	1140	1160	Application	Standardised measurement procedures	Considerations relating to Methodologies
3. Landscape/seascape characteristics									
Connectivity/ Fragmentation	**- Continuous/ fragmented** **- Presence of anthropogenic structures and their % cover** **- Affected/ modified length of linear habitats**	- % cover, patch size		*	*	*	Recommended	Visual survey and mapping, aerial/satellite imagery.	Ecological impact assessment can be used to assess species richness and composition in fragmented versus continuous patches, or changes in hydrology due to fragmentation. Patch size and the scale at which the assessment is carried out are important considerations Trend analysis comparing current fragmentation levels with historical data can identify trends over time but will need comparable data.
4. Other									
Disturbance	**- Footprint of activity**	- Presence/ absence -Modified banks length(m) -% area directly affected by human activity (e.g. by demersal fisheries or sand extraction, anthropogenic structures)	*	*	*	*	Essential	Visual survey and mapping, aerial/satellite imagery. SSS and MBES for physical disturbance on sublittoral areas from activities such as trawling and dredging.	Many different "types" of disturbance may be reported, and they can be categorised in a variety of ways e.g. physical/chemical/biological; presence/absence. The significance of any disturbance on the structure and function of the habitat may be related to aspects such as frequency, permanence, level and type of impact.

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

The observed measurements of the condition variables need to be compared to reference values and critical thresholds, in order to assess the condition for each variable. A reference level is the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable. The difference between the value of a variable and its reference level represents the distance to the reference condition.

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

Reference levels are usually set with high and low levels reflecting the limits or endpoints of the range of a condition variable that can be used in re-scaling. For example, the high level may refer to a natural state and the low level may refer to a degraded state where ecosystem processes are below a threshold for maintaining function (Keith et al., 2013, in United Nations, 2021).

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

These guidelines do not intend to provide specific rules or values for these thresholds, but to define the main criteria and guide on the establishment of reference values that would help determining good or not good condition, considering the ecological variability of the habitats across their range.

In a review of approaches for setting reference conditions for assessing marine ecosystem quality, Borja et al. (2012) recommend that they should be defined/described with reference to:

(1) Multiple sites with similar physical characteristics within an ecoregion or habitat type.
(2) Ideally represent minimally impaired or undisturbed conditions (i.e. absence or minimal human pressure).
(3) Provide an estimate of the variability in biological communities and habitat quality due to natural physical and climatic factors.

They identified four main approaches: crossing referencing pristine areas, hindcasting, modelling and best professional judgement.

Pristine areas: Reference values set against “pristine” areas could be developed with knowledge of either undisturbed habitats or habitats that are considered to be in good condition. However, for this to be credible, it would require comprehensive knowledge of the pressures and impacts on the different habitats, and the implications for their condition. Finding such locations is also likely to be problematic, especially as many examples of the habitats which are being assessed are adjacent to the coast or within territorial waters and therefore likely to have been subject to many pressures/impacts sometimes over significant periods of time.

Hindcasting: Using hindcasting to set reference levels requires cross reference to some historical reference condition. This may be a condition which is considered unimpacted (see above) or a set date (as with the Habitats Directive where 1994 is used as a baseline). Issues will arise around deciding when to set any baseline, the reliability and availability of historic data, and how to account for any natural oscillations in condition. For example, a habitat may not be in favourable condition in the selected baseline year, there may be a lack of sufficient data to inform decisions on the most appropriate baseline year, and global changes in recent decades could alter the former reference conditions making any comparisons with datasets from 50, or 100 years ago impossible.

Modelling: Modelling by extrapolating biological attributes can be used to summarise/simplify, visualize and explain actual or predicted situations e.g. the Driver-Pressure-State-Impact-Response (DPSIR) framework (OECD, 1993). There are, however, many considerations with developing and applying such models (Patricio et al., 2016). They include data availability, the level of confidence in the outcomes, how to scale up interpretations, for example from a site to a region, and how to assess cumulative impacts. There is an additional consideration that modelling approaches can be complex with less transparency and comprehensibility for stakeholders and policymakers.

Expert judgement: This is widely used when there is limited data but should ideally be underpinned by some clearly stated criteria and it has less transparency and comprehensibility for stakeholders.

The analysis carried out by Borja et al. (2012) (summarized in Table 15) considered that whilst using pristine or minimally impacted conditions was the best single method, others were also adequate when combined with expert judgement. Setting targets was seen as an alternative approach where none of the traditional reference conditions approaches were applicable, which implicitly indicates conditions where the indicator in question is not adversely affected or only slightly affected. Their conclusions, looking specifically at assessing benthic ecological status, were that a combination of methods in setting reference conditions is more adequate in obtaining final quality assessments related to the pressures on a habitat than one method alone.

Also relevant is the consideration that, regardless of the approach, there may be existing relevant thresholds and reference values set within legal obligations. For marine habitats this is the case at a European level, under the Marine Strategy Framework Directive and the Water Framework Directive.

Finally, the lack of experts in certain habitats can pose an additional difficulty for the correct use of this approach. The analysis carried out by Borja et al. (2012) (Table 15) was that whilst using pristine or minimally impacted conditions was the best single method, others were also adequate when combined with expert judgement.

Table 15. Evaluation of target and reference condition setting methods, regarding different issues

Methods / issues	Reference conditions			Expert judgement	Targets		
Main issues	**Pristine areas**	**Historical data**	**Modelling**	**Best professional judgement**	**Baseline set in the past**	**Current baseline**	**Directional/ trends target**
Legislation using/ proposing it	WFD, CWA	WFD, CWA, OSPAR	WFD, CWA	WFD, CWA	OSPAR	HD	OSPAR
Data needs	Moderate (2)	High (1)	High (1)	Low (3)	Moderate (2)	Moderate (2)	Moderate (2)
Scientific robustness	High (3)	Moderate (2)	Moderate/ high (2.5)	High (3)	High (3)	High (3)	High (3)
Confidence of the method	High (3)	Moderate (2)	Moderate/ high (2.5)	High (3)	Moderate (2)	High (3)	Moderate (2)
Applicability	High (3)	Low (1)	High (3)	High (3)	Moderate (2)	Moderate (2)	Moderate (2)
Practicality of the method within available time scales	High (3)	Moderate (2)	High (3)	High (3)	Moderate (2)	Moderate (2)	Moderate (2)
Transparency and comprehensibility	High (3)	High (3)	Low (1)	Low (1)	High (3)	High (3)	High (3)
Total scores	17	11	13	16	14	15	14

Source: Borja et al. (2012)
Note that scores are high: 3, moderate: 2, and low: 1, except in the case of data needs, which are opposite (the lowest data need the highest score). WFD: Water Framework Directive; HD: Habitats Directive; CWA: Clean Water Act; OSPAR: Oslo-Paris Convention.

General guidance on setting environmental thresholds is included in The Marine Strategy Framework Directive (MSFD) which requires that Good Environmental Status (GES) should be achieved in EU marine waters as described by eleven environmental Descriptors. At the core of the GES assessment lies the need for threshold values which enable a quantitative assessment of environmental status for the indicators and elements used for each GES Criterion.

Principles and guidelines on how these thresholds should be set are specified in Article 4(1) of Commission Decision (EU) 2017/848 (EU, 2017) (Box 3)[9].

[9] Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU) Article 13.

Box 3. Article 4 of Commission Decision (EU) 2017/848 (EU, 2017)

Article 4 - Setting of threshold values through Union, regional or subregional cooperation

1. Where Member States are required under this Decision to establish threshold values through Union, regional or subregional cooperation, those values shall:

(a) be part of the set of characteristics used by Member States in their determination of good environmental status;

(b) be consistent with Union legislation;

(c) where appropriate, distinguish the quality level that reflects the significance of an adverse effect for a criterion and be set in relation to a reference condition;

(d) be set at appropriate geographic scales of assessment to reflect the different biotic and abiotic characteristics of the regions, subregions and subdivisions;

(e) be set on the basis of the precautionary principle, reflecting the potential risks to the marine environment;

(f) be consistent across different criteria when they relate to the same ecosystem element;

(g) make use of best available science;

(h) be based on long time-series data, where available, to help determine the most appropriate value;

(i) reflect natural ecosystem dynamics, including predator-prey relationships and hydrological and climatic variation, also acknowledging that the ecosystem or parts thereof may recover, if deteriorated, to a state that reflects prevailing physiographic, geographic, climatic and biological conditions, rather than return to a specific state of the past;

(j) be consistent, where practical and appropriate, with relevant values set under regional institutional cooperation structures, including those agreed in the Regional Sea Conventions.

A review of the state of play with thresholds for MSFD criteria used by Member States, published in 2022, shows the progress made (e.g. Table 16 for Descriptor 5, Eutrophication) but it also indicates there is still some way to go before this is achieved for all eleven descriptors (Vasilakopoulos et al*.,* 2022). No thresholds have been agreed as yet for D6 (sea floor pressures and impacts), for example.

Table 16. Agreed thresholds setting methods and values for Descriptor 5 (Eutrophication) criteria

D5 Criterion	Compartment	Agreed threshold methods	Threshold Values available	Comments	Related regulations
D5C1	Coastal waters	Nutrient concentration in surface water or in the water column	From 10 to 13 MSs reported TVs for the nutrient categories	Strong input of WFD in coastal waters, some MSs TVs still missing, especially in the open sea.	WFD
	Open sea		From 7 to 14 MSs reported TVs for the different nutrient categories		
D5C2	Coastal waters	Chlorophyll-a in the water column	15 MSs reported TVs	Strong input of WFD in coastal waters.	WFD
	Open sea		17 MSs reported TVs		
D5C3	Coastal waters	Harmful algal blooms in the water column	Only Baltic MSs reporting a cyanobacteria bloom index	No index (e.g. red tides) in other marine regions	
	Open sea				
D5C4	Coastal waters	Photic limit (transparency) of the water column	11 MSs reported TVs		WFD
	Open sea		11 MSs reported TVs		
D5C5	Coastal waters	Dissolved oxygen at the bottom of the water column	12 MSs reported TVs	For some regions, TVs from project results and WFD are combined with expert evaluation. D5C5 may be substituted by D5C8.	WFD
	Open sea		14 MSs reported TVs		
D5C6	Coastal waters	Opportunistic macroalgae of benthic habitats	3 MSs reported TVs		WFD
	Open sea		None		
D5C7	Coastal waters	Macrophyte communities of benthic habitats	5 MSs reported TVs	Availability of TVs across regions is challenging	WFD
	Open sea		None		
D5C8	Coastal waters	Macrofaunal communities of benthic habitats	9 MSs reported TVs A	Availability of TVs across regions is challenging	WFD
	Open sea		None		

The colour in fourth column indicates the degree of achievement in setting threshold; green: high, yellow: moderate, red: low.
Source: Vasilakopoulos et al., 2022.

The Water Framework Directive (WFD) requires Member States to protect and where necessary restore water bodies in order to reach good status (chemical and ecological) and to prevent deterioration. Standards for priority substances and certain other pollutants are set out in the Environmental Quality Standards Directive (2008/105/EC)[10].

All the variables identified for assessing the structure and function of habitats 1110, 1130, 1140 and 1160 are covered in some way by the MSFD GES descriptors. Some WFD Environmental Quality Standards are also directly applicable. A consistent approach, cross-referencing agreed thresholds for MSFD descriptors and WFD thresholds, with those that are also relevant to assessing the condition of the structure and function of marine and coastal habitats covered by the Habitats Directive is clearly desirable.

The harmonization of reference values and thresholds regarding the variables used for the assessment of habitat condition should consider the following **common requirements**:

- Thresholds need to consider the natural variability of the habitats across their range, and different threshold or reference values for the same habitat in different Member States or regions within a MS can be appropriated.
- Thresholds, limits and reference values need to be tested with sufficient data sets, which include full range of habitat conditions – from degraded habitats to best quality ones.
- The reference values should fulfil the criteria of validity (connection to relevant ecological integrity), robustness (reliability), transparency, and applicability (Czúcz et al., 2021; Jakobsson et al., 2020).
- A description of the methodology for establishing the threshold and reference values applied by each MS for each variable must be provided, justified and perfectly understandable.
- The methodologies should be suitable to be regularly evaluated and improved according to the best available scientific knowledge and any modifications made, and the impact these may have on previous monitoring work, must be communicated.
- Common training or guidance on setting threshold and reference values should be programmed for experts from the different MSs in order to achieve full harmonisation.

Table 17 makes some initial recommendations for setting reference/threshold values for the proposed variables for assessing and monitoring the condition of habitats 1110, 1130, 1140 and 1160.

[10] Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

Table 17. Considerations for setting reference/threshold values for habitats 1110, 1130, 1140 and 1160

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
1. Abiotic characteristics					
1.1 Physical state characteristics					
Degree of submergence / depth	**-Depth in relation to chart datum**	Quantitative, Trend	Depth is not static but subject to both diurnal and seasonal variation, as well as across the habitat being monitored. The existing status is therefore in equilibrium with the prevailing conditions. If this were to be disrupted to a significant degree, there can be major changes in both the physical and biological characteristics of the habitats.	QE2 (QE2-1, QE2-3)	D7
Tidal regime	**-Tidal range**	Quantitative, Trend	Tidal range is not static but subject to both diurnal and seasonal variation, the existing status is therefore in equilibrium with the prevailing conditions. If this were to be disrupted to a significant degree, there can be major changes in both the physical and biological characteristics of the habitats. One example would be potential increases or decreases in the extent of marginal vegetation such as saltmarsh. Issues are likely to arise if the changes are either sudden and/or permanent for example due to the creation of barriers/dams which hold back water permanently inundating areas previously subject to tidal fluctuations or, at the other extreme, land claim/infilling. Also relevant are the parameters/ status/ environmental quality standards recorded under WFD which include morphological conditions, as well as hydrological or tidal regime.	QE2 (QE2-1, QE2-3)	D7

EQS: Environmental Quality Sandards. WFD Quality Elements: QE1 – Biological Quality Elements, QE1-1 – Phytoplankton, QE1-2-1 - Macroalgae, QE1-2-2 - Angiosperms, QE1-2-3 – Macrophytes, QE1-2-4 – Phytobenthos, QE1-3 - Benthic invertebrates, QE1-4 - Fish, QE2 – Hydromorphological quality elements, QE2-1 – Hydrological or Tidal regime – QE2-3 – Morphological conditions, QE3 - Chemical and physico-chemical quality elements, QE3-1 – General parameters (Transparency, thermal, oxygenation, salinity, acidification, nutrient, Nitrogen, Phosphorus conditions), QE3-1-1 – Transparency, QE 3-1-3 – Oxygenation conditions, QE3-1-4 - Salinity conditions.

MSFD Descriptors: D1 – Marine biodiversity, D2 – Non-indigenous species, D3 – Commercial fish and shellfish, D4 – Food webs, D5 – Human-induced eutrophication, D6 – Seabed integrity, D7 – Hydrographical conditions, D8 – Contaminants, D10 – Marine litter, D11 – Energy, including underwater noise.

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
Topography	**- Physical dimensions** **- Extent** **- Longitude and latitudinal gradients** **- Elevation, form and features (eg. sandbanks, islands)**	Quantitative, Qualitative, Expert judgement	Comparisons of imagery data over time can reveal gross changes in topography of the habitat however, for the purposes of setting thresholds and reference values, any changes will need to be viewed in the context of "natural" changes as these habitats are naturally subject to erosion and deposition as well as patterns of erosion and deposition which are the consequence of human activity. Threshold values will need to be set in the context of and with regard to knowledge of such changes where the habitat is in a state of dynamic equilibrium. Where historical data are available these could be used to set a reference value relative to a specific point in time. Also relevant are the parameters/ status/ environmental quality standards recorded under WFD which include morphological conditions, as well as hydrological or tidal regime.	QE2 (QE2-1, QE2-3)	D7
Hydrodynamics - Exposure to current, wave action, scour & surge	**- Current speed** **- Direction** **- Height** **- Extremes**	Quantitative, Trend	Seasonal changes (eg. in freshwater run off, onshore winds from winter storms, tidal currents/range) are part of the natural variation. If this were to be disrupted to a significant degree, there can be major changes in both the physical and biological characteristics of the habitats.	QE2 (QE2-1)	D7
Temperature	**- Water temperature**	Quantitative	Reference values for temperature might be carefully defined for each habitat subtype and according to depth and annual cycle, since thermal stress varies within species, assemblages and other physical (e.g. depth, surge) or geographical parameters (e.g. latitude/longitude, currents).	QE3 (QE3-1-2)	D1, D5, D7
Turbidity	**- Suspended particles** **- Light transmission through water samples** **- Secchi disk depth**	Quantitative, Trend, Indices	Estuaries have zones of high turbidity known as turbidity maxima, often located in the zones of low salinity. The size of the turbidity maximum could be a useful focus for monitoring purposes. Increases in turbidity levels by activities such as dredging, and disposal may have an adverse effect on filter feeds and may also reduce the growth rate of organisms dependent on sunlight for photosynthesis	QE3 (QE-3-1, QE3-1-1)	D5

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
Sediment composition / distribution / dynamics	**-Sediment particle size** **-Thickness of oxidised layer (for silt)**	Quantitative, Trend, Indices	Sediment deposition is controlled by the type, direction and speed of the currents and size of the particles. The patterns of sediment movement in and around the habitats in this cluster not only have a major influence on their form and the associated biota but also characterise the natural cycles which either sustain, erode or extend sedimentary features within the habitat. Any reference values or thresholds therefore need to be based on an understanding of what constitutes "natural change" and over what time periods. Whilst this may be possible in some locations that have been studied for decades it is difficult to set a single figure/level across the board either for all Member States or across a biogeographical region.	QE2 (QE2-1, QE2-3)	D7
1.2 Chemical state characteristics					
Salinity / freshwater influence / stratification	**- Salinity** **- Conductivity**	Quantitative, Trend	Changes in salinity attributed to human activity are the most relevant when setting thresholds and reference levels. This may be the result of ongoing activities and/or one-off events e.g. industrial discharge. Targets could be selected to represent the limits of the range of the characteristic species/biotope in key locations.	QE3 (QE3-1-4)	D7
Water quality	**- Various substances (including chemicals listed in the WFD and EQSD, nitrates & phosphates, oxygen, chlorophyll, dissolved solids)**	Quantitative, Trend, Indices, linked to WFD	The parameters and Environmental Quality Standards that apply under the WFD for transitional waters (e.g. in relation to chemical and physico-chemical quality elements) are particularly relevant to determining water quality for this cluster of habitats and are already being used as reference values/thresholds by Member States.	QE3 (QE3-1)	D5, D8
Sediment quality	**- Inorganic and organic chemical contaminants** **- Organic carbon**	Quantitative, Trend, Indices, Scoring			D8
Oxygen levels	**- Oxygen levels measured at surface and depth.**	Quantitative,	The parameters and Environmental Quality Standards that apply under the WFD for transitional waters (eg. in	QE3 (QE3-1-3)	D5

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
		Trend, linked to WFD	relation to chemical and physico-chemical quality elements) are particularly relevant to determining water quality for this cluster of habitats and are already being used as reference values/thresholds by Member States.		
2. Biotic characteristics					
2.1 Compositional state characteristics					
Invertebrates - Epifaunal & infaunal assemblages	**- Abundance of characteristic species from standardised lists. - Diversity of characteristic species from standardised lists.**	Quantitative, Indices/ additional, Scoring		QE1 (QE1-2-4, QE1-3)	D1, D4, D6
Vertebrates – Associated fish, birds & marine mammals	**- Abundance of characteristic species from standardised lists. - Diversity of characteristic species from standardised lists.**	Quantitative, Indices/ additional, Scoring.		QE1 (QE1-4)	D1, D3, D11
Biogenic structures	**- Type - Composition**	Quantitative, Indices/ additional, Scoring.	Reference values will need to take into account natural cycles of change, and to distinguish these from changes which are the result of human activity. For example, physical damage of some types of biogenic structures (e.g. *Sabellaria* worm reefs) may be the result of storm events or demersal trawling.		D1, D6
Opportunistic / invasive species	**- Presence - Distribution - Abundance**	Quantitative, Indices			D1, D2
2.2 Structural state characteristics					
Characteristic species	**- Condition**	Quantitative, Indices/ additional, Scoring, linked to WFD		QE1 (QE1-2-4, QE1-3)	D1, D4, D6

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
Biogenic structures condition	**- Abundance** **- Cover** **- Health**	Quantitative, Indices/ additional, Scoring, linked to WFD	Reference values and thresholds need to take account of changes that may be due to natural variation (e.g. burial by sediment, responses to cyclical changes in predator/prey levels) including specific natural events such as damage caused by storms or flooding.	QE1 (QE1-3)	D1, D6
Vegetation zones	**-Abundance** **-Extent** **-Condition**	Quantitative, Indices, linked to WFD		QE1 (QE1-2-2)	D1, D5, D6
Macrophyte, macroalgae, eelgrass	**-Abundance** **-Extent** **-Condition**	Quantitative, Indices/ additional, Scoring, linked to WFD	Reference values and thresholds for good condition will not only vary according to biogeographical region but also from location to location because of the factors such as depth, location, species etc. (see variables). Two types of thresholds should be considered. A threshold relating to extent, and a threshold relating to condition. Extent - change in distribution AND in the density/diversity of the relevant species. Condition - change in key features (e.g. length, biomass) and other evidence of declining condition such increasing prevalence of disease.	QE1 (QE1-2-1, QE1-2-3, QE1-2-4)	D1, D5, D6
2.3 Functional state characteristics					
Primary production	**-Frequency of plankton blooms** **-Longevity of plankton blooms** **-Strength of plankton blooms** **-Angiosperms/ macroalgae**	Quantitative, Indices/ additional, Scoring, linked to WFD	An understanding of primary production (phytoplankton and macrophytes) and/ and/or species composition within the habitat and how it affects the structure and function is needed to set any targets and reference levels. In some cases, there may be long term data sets. WFD has a classification of status including nutrient status, hydromorphological parameters and phytoplankton.	QE1; (QE1-1)	D1, D5

Characteristics	Variables	Reference/ Threshold type	Considerations relating to Reference Values	Relevant WFD EQS for Reference Values / Thresholds	Relevant MSFD Descriptors
Food webs	**-Energy transfer between tropic levels**	Quantitative, Indices	An understanding of food webs within the habitat and how it affects the structure and function is needed to set any targets and reference levels. In some cases, there may be long term data sets. WFD has a classification of status including nutrient status, hydromorphological parameters and phytoplankton	QE1	D1
3. Landscape/Seascape characteristics					
Connectivity/ Fragmentation	**-Continuous/ fragmented** **-Presence of anthropogenic structures and their % cover** **-Affected/ modified length of linear habitats**	Qualitative, Expert judgement	Comparisons of imagery data over time can reveal any habitat fragmentation. However, for the purposes of setting thresholds and reference values, any such changes will need to be viewed in the context of "natural" variation as these habitats are naturally subject to erosion and deposition (seasonally as well as associated with spring neap tide cycles and storm events). These need to be distinguished from patterns of erosion and deposition which are the consequence of human activity. Threshold values will need to be set in the context of and with regard to knowledge of such changes. Where historical data are available these could be used to set a reference value relative to a specific point in time.		D6
4. Other					
Disturbance	**-Footprint of activity**	Quantitative, Qualitative, Expert judgement	For sites which are considered to be in favourable condition, the current state could be used as the reference value. Threshold values could be declines in condition or declines/changes which have an impact on the structure and function. Each location should characterise the major types of disturbance first and then for each of these consider what is considered significant.		D6, D8, D10

Table 18 indicates possible approaches for establishing thresholds and reference values applicable to the proposed variables, based on the procedures followed by Member States and the existing literature. A combination of approaches is suggested to better inform the setting of reference levels or thresholds, given the degree of uncertainty when setting reference levels. The different approaches described are not exclusive, they are often combined. For example, expert judgement is necessary when establishing reference cases for good condition or for certain decisions on modelling the relationship between variables and condition. Modelling-based approaches complement those based on good condition or undisturbed cases and can also be combined with statistical approaches.

The evaluation of the condition of the habitats is based on determining whether the variables used in the assessment indicate 'good' or 'not good' condition. Different criteria are applied to attribute these condition categories according to the characteristics of each variable, for example, whether they are definitive (e.g. no alien species allowed), or quantitative variables which may obey linear or non-linear relationships with the condition (Jakobsson et al., 2020). Some can be directly standardized to apply aggregation procedures.

Owing to the different metrics, measurement units and magnitudes applied to the variables that characterise the habitats, the values obtained from their measurement require some form of standardisation, e.g. by re-scaling, to build indicators combining different variables. The values obtained from the measurement of the variables can be scaled according to their reference levels, thus normalised to a common scale and direction of change, and can then be combined to form a composite index or to obtain an overall result of the assessment using appropriate aggregation approaches (see further details below in Section 3.3 on Aggregation).

Table 18. Some initial recommendations for setting thresholds for the proposed variables

Description	Comparison to undisturbed areas	Comparison to good condition areas	Hindcasting	Modelling	Expert judgement	EU Relevant existing reference values
1. Abiotic characteristics						
1.1 Physical state characteristics						
Degree of submergence / depth						WFD, MSFD
Tidal regime						WFD, MSFD
Topography						WFD, MSFD
Hydrodynamics - Exposure to current, wave action, scour & surge						WFD, MSFD
Temperature						WFD, MSFD
Turbidity						WFD, MSFD
Sediment composition / distribution						MSFD

Description	Comparison to undisturbed areas	Comparison to good condition areas	Hindcasting	Modelling	Expert judgement	EU Relevant existingreference values
1.2 Chemical state characteristics						
Salinity / freshwater influence / stratification						
Water quality						WFD, MSFD
Sediment quality						MSFD
Oxygen levels						
2. Biotic characteristics						
2.1 Compositional state characteristics						
Invertebrates -Epifaunal & infaunal assemblages						WFD, MSFD
Biogenic structures						MSFD
Vertebrates - Associated fish, birds & marine mammals						WFD, MSFD
Opportunistic/ invasive species						MSFD
2.2 Structural state characteristics						
Characteristic species						WFD, MSFD
Biogenic structures						WFD, MSFD
Vegetation zones						WFD, MSFD
Macrophytes, macroalgae, eelgrass						WFD, MSFD
2.3 Functional state characteristics						
Primary production						WFD, MSFD
Food webs						WFD, MSFD
3. Landscape/Seascape characteristics						
Connectivity / Fragmentation						MSFD
4. Other						
Disturbance						MSFD

Dark grey: Preferred approaches; Light grey: additional approaches

*: Check Table 14 for further information

3.3 Guidelines for the aggregation of variables at the local level

Ecological assessments require the integration of physical, chemical, and biological quality parameters. The choice of the aggregation method of such partial assessments into an overall assessment has been widely discussed within the scientific community, since the methodology can have a considerable influence on the outcome of the assessment. Different approaches can be used to integrate the values of the measured variables to give an overall value that indicates the overall condition of habitat types at the local scale, i.e. the monitoring plot, station or site.

An appropriate aggregation method is crucial to categorising local-scale condition into good/not good. This is because the proportion of the habitat type in **good/not good condition** is the main information required for assessment of the structure and function of the habitat type at the biogeographical level.

3.3.1 Overview of aggregation methods

In a review of methods for aggregating and integrating information when assessing the status of marine ecosystems under the MSFD, focusing mostly on the descriptors related to biodiversity, Borja et al. (2014) discussed the advantages and disadvantages of several different approaches used to combine a number of variables into an overall assessment. A review and discussion of advantages and disadvantages of several different aggregation methods for marine biodiversity status assessments has also been carried out by Barnard & Strong (2014).

The main approaches are summarised below.

One-out, all out (OAOO)

The OOAO rule has been recommended for assessment of Ecological Status under the Water Framework Directive (CIS, 2003). The logic behind this is that a water body could not achieve good ecological status if any of the quality elements measured fail. This means that an OOAO approach using the "worst case" scenario for its assessment. This can be viewed as a rigorous precautionary approach. One criticism, however, is that it could lead to an underestimation of the true overall status.

A precautionary one-out, all-out approach is also used in the aggregation of the parameters used in the assessment of conservation status under the Habitats Directives and the IUCN Red List of Species and the IUCN Red List of Ecosystems.

The OOAO rule is a rigorous and conservative approach which follows the precautionary principle, and works well where all the necessary information is available. In the marine environment, where there may be significant data gaps it is important to clarify the extent to which such an approach may be "preliminary", "partial" or "incomplete" due to lack of data.

Averaging approach

The averaging approach is the most commonly used method to aggregate indicators (Shin et al., 2012) and consists of simple calculations, using methods such as arithmetic average, hierarchical average, weighted average, median, sum, product or combinations of those rules, to come up with an overall assessment. Differential weighting applied to the various indicators can be used when calculating means or medians. An adequate basis for assigning weights is not always available and assigning weights often involves expert judgment: However, expert opinions applied in such a way can show important differences.

This approach needs a normalisation of the obtained data to be used.

Conditional rules

Conditional rules are an approach where indicators can be combined in different ways to generate an overall assessment, depending on specified criteria. For instance, it can be formulated in a way that requires that specific proportion of the variables to achieve good status or if a certain number of variables do not meet the threshold, the overall status fails.

Scoring or rating

In this method different scores are assigned to a particular status for a number of different elements, e.g. ranging from 1 to 5 for poor to good). The scores may then be summed to derive a total score which is then rated according to the number of elements taken into account. Different weights can be assigned to the various elements.

Multimetric indices to combine indicators

Within the WFD there are many examples of multimetric indices developed for different biological elements. Within the MSFD, the use of multimetric indices or multivariate techniques for integrating indicators of seafloor integrity have been recommended (Rice et al., 2010). Multimetric methods that are used to combine multiple parameters in one assessment may result in robust indicators, but ideally the various parameters should not be inter-correlated.

Multidimensional approaches

Multivariate methods, such as Discriminant Analysis or Factor Analysis combine parameters in a multi-dimensional space. Multivariate methods have the advantage of being more robust and less sensitive to correlation between indicators. However, interpretation is less intuitive than other methods, as information on individual indicators in each ecosystem is lost and links to management options are less obvious.

Decision tree

Decision trees provide the opportunity to apply different, specific, rules to combine individual assessments into an overall assessment. A decision tree allows implementing individual rules at each of its nodes and thus incorporates decisions at each step within the decision tree. The decision rules can be quantitative or qualitative as well as based on expert judgment. This gives room for a high degree of flexibility in reaching the final assessment.

Probabilistic approach

In some cases the results for each indicator may be uncertain due to several factors e.g., natural variation in the sampling sites, random variation in the samples, insufficient scientific understanding about what should be the reference value for good status, etc. If these uncertainties can be approximated, this gives rise to the possibility of taking this information into account when integrating the indicators. The more uncertain indicators will get less weight in the integrated assessment, while the more certain ones will be more reliable and hence get more weight.

High level integration

This approach, which includes the selection of an agreed reduced set of indicators and agreed weighting rules, could be considered a pragmatic compromise, reducing the risks associated with OOAO while still giving an overall assessment. An example of a high-level integration, where assessments for several ecosystem components are merged into a final assessment, is the HELCOM-HOLAS project (HELCOM, 2010).

As seen in Section 2.3, across EU Member States, the aggregation at local-scale assessments relies on integrating information from multiple variables, though specific approaches varying by country and habitat. Several MSs however apply a conditional rule, whereby a number of relevant variables measured must reach or pass the defined thresholds for good condition, or even the one-out, all-out rule, which requires that all the variables reach the threshold, for the overall habitat condition at the local scale to be considered good.

3.3.2 Recommendations for the aggregation of the measured variables to determine the habitat type condition at the local scale

A common aggregation method to integrate all essential and specific variables measured to assess the habitat should be applied consistently across the habitat range in the EU in order to obtain comparable results.

Considering the various approaches described above and with the aim of harmonising the assessment of marine habitat types at the local scale, we suggest a two-step approach, in which a first aggregation is carried out separately for each group of variables associated to abiotic, biotic and landscape characteristics, and then, the results of such partial assessments are then integrated into the overall local assessment of the habitat condition following a one-out , all-out rule, as described below but being clear about where data is limited or insufficient to make such an assessment (Figure 7).

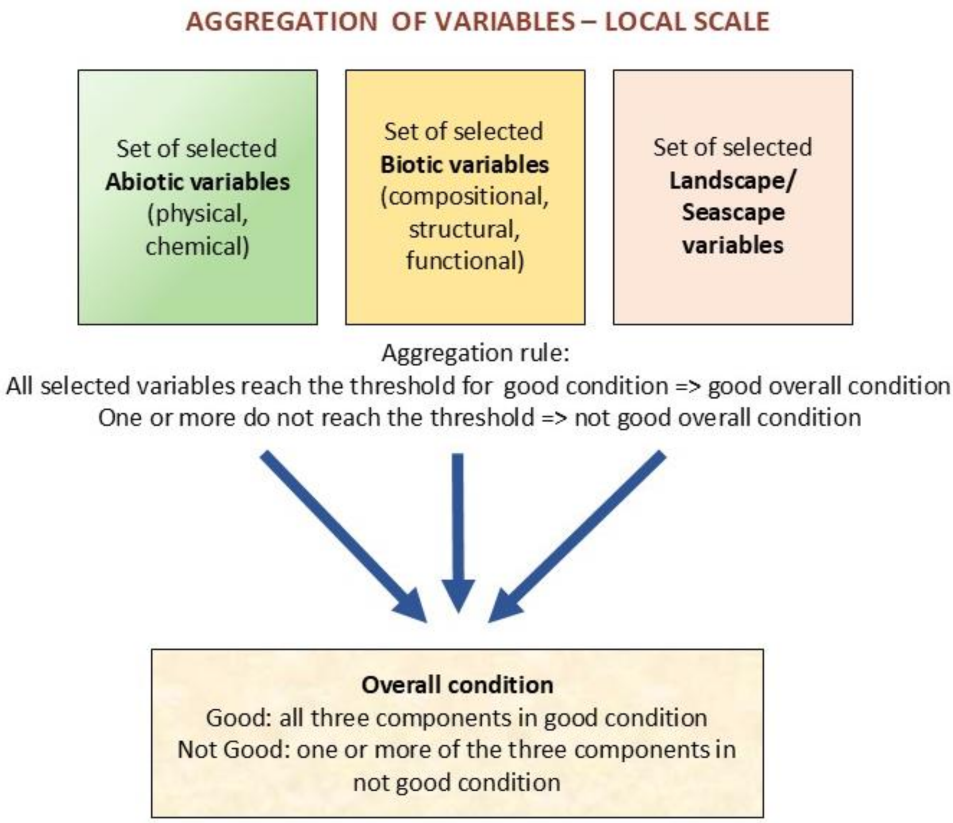
Step 1 – Aggregation of the variables measured in each group of characteristics

A first step would involve using a conditional rule. This would aggregate the variables for each group of characteristics whilst noting that a minimum set of essential variables in each group must reach/exceed the defined threshold for good condition. This would be done for each habitat component (abiotic, biotic, landscape). The selection of the set of variables that must reach the threshold is made considering their indicator value, i.e. their relative importance or relevance to determine whether the habitat is in good condition or not. These should be variables for which a clear threshold can be defined to distinguish good and not good condition. If any of those selected variables do not reach/exceed the minimum thresholds, the condition cannot be considered good for the corresponding component of the habitat (abiotic, biotic, landscape). If there are insufficient data on any particular variables to make such an assessment this should be noted.

Step 2 – Aggregation of the three groups of variables or habitat components

In a second step, the results achieved in each the three components or groups of characteristics (abiotic, biotic, landscape) would be aggregated following the “one-out, all-out” rule, which requires that all the three components have been assessed in good status for the overall condition of the habitat at the local scale to be considered good. If any of these components do not reach an overall good status, the condition of the habitat at the local scale cannot be considered good. Where there are data gaps on any of the habitat components (biotic, abiotic or landscape), a clarification should be provided to show that the assessment is incomplete or preliminary.

Figure 7. Scheme of the proposed aggregation of variables at the local level



3.4 Guidelines for aggregation at the biogeographical region scale

As a minimum requirement Member States must follow the recommendations from the Art. 17 reporting guidelines for the period 2013-2018, which states that "if 90% of habitat area is considered as in 'good' condition, then the status of 'structure and functions' parameter is 'favourable'. If more than 25% of the habitat area is reported as 'not in good condition', then the 'structure and functions' parameter is 'unfavourable-bad'".

This rule highlights the importance of a sampling design that ensures sufficient representativeness of the total habitat area and diversity (see section 3.6 below).

3.5 Guidelines on general sampling methods and protocols

Harmonized monitoring protocols are crucial for assessing habitat conditions across Europe. These protocols should offer standardized methods for data collection, analysis, and interpretation to ensure consistency and comparability over time and across regions. This section includes recommendations on sampling designs and monitoring protocols.

Large-scale survey techniques (e.g. Charts, remote sensing) can be used to provide data for the whole feature across its range and assist with developing a stratified sampling programme to select a few locations to be investigated in detail. If so, the ability to relocate these sampling stations is essential (JNCC, 2004).

As the features across this habitat will not be uniform, for example, in varying stages of development or activity, a single sample for a physical-chemical characterisation is unlikely to provide a reliable description of the habitat as a whole. Multiple sampling and analysis may therefore be required, for example along transects and using quadrats to adequately record such heterogeneity.

Article 17 of the Habitat Directive requests a maximum period of 6 years to coincide with reporting. However, this period can be completed through different approaches depending on the resources of Member States. For example, not all plots and not all variables need to be measured each 6 years. Regarding plots, Member States may establish a large number of monitoring sites, selecting a small number of them to be surveyed every season in order to gather a suitable number of plots with a complete monitoring at least every six years.

Within the six-year period, seasonality needs to be considered to avoid comparison of different time frameworks as the biotic and any associated macroalgae can change with seasons. Regarding variables, most variables are recommended to be seasonally surveyed (or at least annually), except tidal ranges with respect to LAT, that can be surveyed every 6 years. Adaptive monitoring is always recommended, allowing flexibility in frequency based on initial findings.

3.6 Selecting monitoring localities and sampling design

The identification and selection of localities for the assessment and monitoring of this habitat requires a systematic approach to ensure that the selected sites provide comprehensive and representative data. The selection of localities for sampling along with the sample size (number of plots) and power (statistical significance) are crucial to ensure the representativity of the results obtained in the assessment and monitoring of each habitat at the biogeographical scale.

Different approaches are recommended:

- **Geospatial Analysis**: remote sensing techniques (e.g. Acoustic surveys - side scan sonar, AGDS, MBES) as well as geographic information systems are essential tools to identify, analyse and integrate spatial data (e.g. extent, topography, and changes over time) and to identify areas of interest based on various criteria such as biodiversity, threats, and ecosystem services.
- **Field Surveys**: initial visits to potential sites are advisory to gather on-the-ground information about zonation patterns, accessibility, and logistics.
- **Review of existing data/knowledge**: reviews can help prioritise areas based on scientific knowledge.

Selecting a minimum number of localities for monitoring involves balancing several criteria to ensure comprehensive and effective coverage:

1. **Biogeographical or marine heterogeneity**: this habitat is present in all marine biogeographic regions but with different characteristics especially because of differences in tidal range and salinity profiles. Monitoring sites should be distributed across the entire area to represent the full range of ecological diversity and capture regional variations as well as habitat heterogeneity.
2. **Spatial Distribution**: monitoring sites must be distributed across the full geographical range of the habitat (subject to accessibility constraints) to avoid geographical bias and

to capture regional variations and ensuring they represent a significant proportion of the habitat's area.

3. **Statistical Criterion**: It would be advisable to ensure that the number of sites is statistically sufficient to detect changes and trends with desired confidence levels (e.g., 95%). Multiple sites within similar ecological contexts should be included for data reliability and robustness.
4. **Existing data and monitoring sites**: Due to potential limitations in surface area and/or budget, previous research can help determine a more realistic number of monitoring locations. Making use of existing monitoring sites with historical data can also strengthen the understanding of long-term trends and changes in habitat condition. Such sites provide valuable baselines for comparison and support robust trend analyses over time.
5. **Degree of conservation and exposure to threat levels**: Monitoring locations should include both protected and high-risk areas experiencing significant threats. The selection should include areas that show different degrees of conservation or degradation to capture the existing variation in the habitat condition across its range. This requires including localities representing well-conserved habitat areas, with minimal human impact, as well as areas subjected to degradation and different pressures and threats. To capture the range of pressures affecting the habitat, localities should be selected across a spectrum of threat levels, from low to high and considering different sources of threats, such as water quality, disturbance/accessibility and resource extraction.
6. **Presence inside and outside Natura 2000 sites**: The assessment and monitoring of habitats conservation status must be done both inside and outside Natura 2000 sites, which requires selecting localities – and an appropriate number of sampling stations/transects – that reflect the proportion to the habitat's distribution within and outside the Natura 2000 network.
7. **Accessibility and practicality**: Monitoring localities should be accessible for regular visits, taking into account logistical factors and ease of access. Practical considerations also include the safety of field personnel and the feasibility of transporting equipment to and from the site.

Once the sampling localities have been identified for each habitat type, the minimum number of sampling stations in each locality and across the biogeographical region must be calculated in order to balance the sampling effort with representative data.

The **size of the sample** influences two statistical properties: 1) the precision of estimates and 2) the power of the assessment to draw conclusions. The number of sampling stations must be **statistically sufficient** to be able to detect changes and trends with desired confidence levels. Appropriate statistical methods should be used for determining an adequate sample size.

Considering the heterogeneity of habitat types, it is highly recommended to consult with a sampling statistician regarding the sample size, i.e. the minimum number of sampling stations/transects etc. required to ensure representativity and statistical significance.

Some key elements to ensure a proper representation of the habitat condition in the sample are summarised below.

Key elements for statistical representation

Sample size and distribution:

- The number of localities/transects etc. should be sufficient to provide a statistically robust sample size. This ensures that the data collected can be generalized to the entire habitat type within the region.
- Statistical methods such as stratified random sampling are often used 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 benthos, infauna, mobile species and other ecological indicators. The distribution and number of sampling stations depend on the variability and size of the habitat patch. Sampling areas (plots, transects) are laid out considering the existing main ecological gradients, e.g., exposure to waves/currents/tides, depth, sediment characteristics.

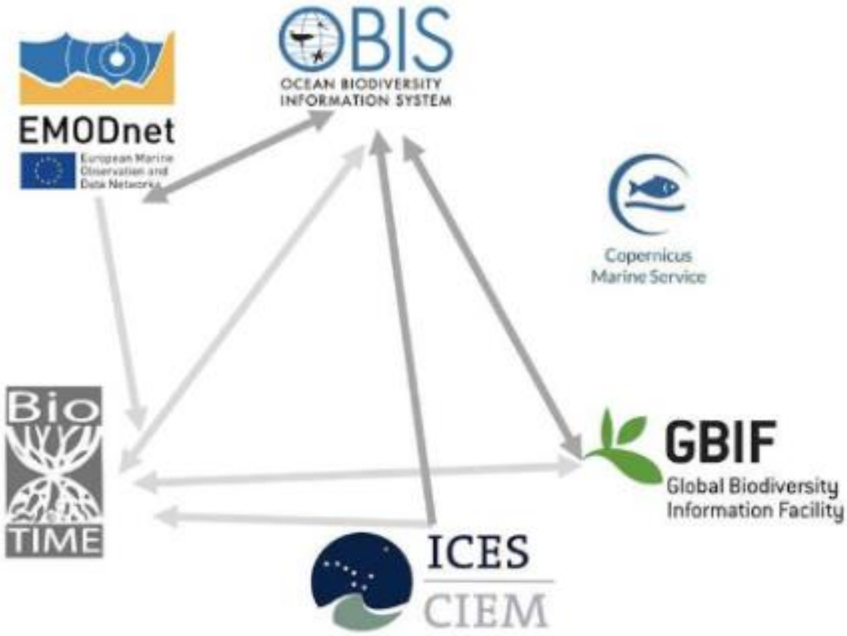
Replication and randomization:

- Replication of sampling units within each locality and randomization of sampling plots location help to reduce bias and increase the reliability of the data.
- Randomized plot locations ensure that the sampling captures the natural variability within the habitat.

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

Data collection frameworks that integrate data from monitoring programmes are a useful source of monitoring data. Examples that focus of marine biodiversity and therefore relevant to monitoring all four of the habitats in this cluster (sandbanks, mudflat & sandflats, large inlets & bays and estuaries) are shown in Figure 8 (European Commission, 2023).

Figure 8. Data collection frameworks relevant to marine biodiversity in European Waters



Source: European Commission, 2023
© European Union, 2023

Three relevant initiatives that provide an overview of research programs, types of data and methodologies used for marine monitoring are:

- **Biodiversa+**[11] European Biodiversity Partnership 'Mapping' the current state of research on biodiversity and associated ecosystem services in Europe in terms of projects, programmes and funding. This includes research projects on biodiversity and associated ecosystems services funded through research programmes in Europe.
- **EuropaBON**[12] current monitoring efforts to identify gaps, data and workflow bottlenecks, and analyse cost-effectiveness of different schemes. The results of this assessment will be used to inform the design of improved monitoring schemes able to integrate in-situ and remote sensing data through models, and using novel technologies, to deliver more complete and less biased biodiversity information with multiple benefits to users and society.
- **MarBioME**[13] **– Marine Biodiversity Monitoring in Europe**. A holistic and global review of European marine biodiversity projects and monitoring programmes, and collated information on marine biodiversity research gaps. Identifies 647 distinct monitoring programmes conducted in EU marine waters, the majority of which target assemblages or communities (European Commission, 2023).

Databases:

SeaAroundUs[14]: developed a preliminary global database of estuaries, the first to be designed at a global scale. It contains over 1,200 estuaries (including some lagoon systems and fjords),

[11] https://www.biodiversa.eu/
[12] https://europabon.org/
[13] https://op.europa.eu/en/publication-detail/-/publication/a09868c3-b721-11ed-8912-01aa75ed71a1/language-en
[14] SeaAroundUs estuaries database: https://www.seaaroundus.org/about-estuaries-database/

in over 120 countries and territories. Currently, our database is also available and viewable via the UNEP-WCMC Ocean Data Viewer.

Portuguese Coastal Monitoring Network (CoastNet): dataset from Mondego, Tejo and Mira estuaries, including multiparametric measurements during 2020 (Castellanos *et al.,* 2021)

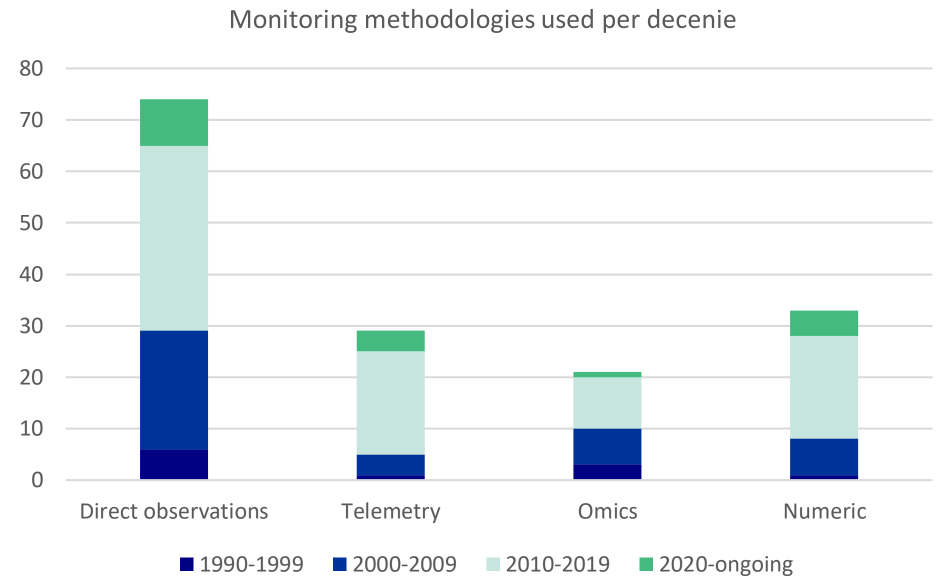
The Estuary Guide[15]: The Estuary Guide aims to provide an overview of how to identify and predict morphological change within estuaries in the UK, as a basis for sound management. It is not yet possible and, indeed, may never be possible to make absolute predictions. Rather, it is necessary to identify probable/possible outcomes, as a basis for guiding management actions.

Other countries as the United States[16], Australia[17] or New Zealand[18] have also developed their own estuaries related databases.

New technologies:

A review of the main methodologies used for the study of marine biodiversity monitoring since 1990 shows a dominance of direct observation but in recent years, an increase in the use of telemetry, omics[19] and numeric models (Figure 9) (European Commission, 2023).

Figure 9. Main categories of methodologies identified in relevant research projects for the study of marine biodiversity monitoring (European Commission, 2023)



The height of each column represents the total amount of research projects that used each category of methodology. Stacked coloured categories depict the number of studies used in each category of methodology per specific decade. Research projects that used more than one methodological category are represented in multiple counts.

[15] The Estuary Guide (UK): https://www.estuary-guide.net/search/estuaries/
[16] Estuarine Species Database (United States): https://coastalscience.noaa.gov/project/estuarine-species-database-noaa-estuarine-living-marine-resources-program/
[17] Australian Estuaries Database (Australia): https://fed.dcceew.gov.au/datasets/erin::australian-estuaries-database-camris/explore?location=-24.518198%2C-46.449988%2C4.51
[18] Estuaries Spatial database (New Zealand): https://www.doc.govt.nz/nature/habitats/estuaries/estuaries-spatial-database/
[19] Studies that focus on the structure, function and dynamics of molecules, such as genomes.

- **Optical fibre sensors:** have become extremely attractive for use in natural environments to monitor different parameters of biological interest, due to their intrinsic small weight and size and low reactivity to chemical and biological parameters (Pereira et al., 2005).
- **Real-time monitoring systems:** in the Hudson River estuary (United States), a new real-time monitoring system is being developed using multiparameter and multiscale real-time environmental monitoring. The system incorporates a complex array of sensor technologies encompassing the physical, chemical, and biological measurement domains (Kolar et al., 2009).
- **Unmanned Aerial Vehicles (UAVs):** To analyse changes, UAV is used to collect very high-resolution images in sandbanks from Taiwan (Andaru et al., 2022). Also, they analyse potential, problems and challenges of using AUVs in monitoring. UAV offers new opportunities for scale-appropriate measurements of corridor-shaped study areas. UAV utilization for mapping purpose has recently emerged since it offers operational flexibility, high spatial and temporal resolutions, and low-cost budget with acceptable accuracy. In particular, to map sandbank morphologies, the common photogrammetry structure-from-motion multiview stereo (SfM-MVS) algorithm can be applied. In the Seine Estuary (France), Jaud et al. (2016) aims to show the potential of light UAVs for monitoring sedimentary hydrodynamics at different spatial scales. For each UAV mission an orthophotograph and a Digital Elevation Model (DEM) are computed. From repeated surveys the diachronic evolution of the area can be observed via DEM differencing.
- **Remote sensing:** 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). Traditional platforms, including satellite and aerial systems, have been extensively employed for regional studies such as mapping tidal marshes (Byrd et al., 2018). Optical satellite remote sensing can gather critical data for understanding historical changes into coastal decision-making. These satellites collect reflectance data across the visible and infrared spectrum, which is used to calculate spectral indices (SIs). For instance, water indices combined with hydrodynamic modelling have successfully mapped digital elevation models (DEM) in intertidal areas (González et al., 2023).

  AV sensors include high-resolution photogrammetry cameras and other advanced techniques like thermography, multispectral, LiDAR, and hyperspectral sensors. Three RS techniques show great promise for high-quality monitoring of saltmarshes: photogrammetry, which produces topographic products via Structure-from-Motion (SfM) (Westoby et al., 2012); Light Detection and Ranging (LiDAR) (Brock & Purkis, 2009), which generates reliable 3D point clouds for high-resolution topography and DEM creation; and multispectral techniques, which provide critical data for vegetation mapping. The combination of multispectral and LiDAR sensors mounted on UAVs yields excellent results for assessing the extent, cover, and canopy height of halophytes in intertidal environments at a landscape scale (Curcio et al., 2024).
- **Review of technology in marsh ecology** (Kimball et al., 2021)**:** This perspective highlights current and potential applications of novel research technologies for marsh ecology. These are summarized under several themes: (1) imagery — sophisticated imaging sensors mounted on satellites, drones, and underwater vehicles; (2) animal tracking — acoustic telemetry, passive integrated transponder (PIT) tags, and satellite tracking, and (3) biotracers — investigation of energy pathways and food web structure using chemical tracers such as compound-specific stable isotopes, isotope addition experiments, contaminant analysis, and eDNA.

4 Guidelines to assess fragmentation at appropriate scales

Fragmentation is a significant ecological issue resulting from both human activities and natural processes potentially leading to habitat loss and altered hydrology as well as changes in biodiversity and carbon storage capacity.

Lawrence et al. (2021), considering fragmentation of terrestrial Natura 2000 habitats, define it as a landscape-scale process that includes (a) reduction in total habitat area, (b) increase in the number of habitat patches, and (c) decrease in sizes of habitat patches. This would lead to a progressive deterioration of the habitat and, therefore the reduction of occupied surface (Mariotti & Fagherazzi, 2010; Kirwan & Megonigal, 2013).

Responses to habitat fragmentation in marine systems may be expected to differ to those in terrestrial systems. For example, many marine species have a relatively open population structure due to the large dispersal distances of marine organisms during their larval life stages. Also, energy and nutrients may be readily carried across habitat boundaries by water flow (Yeager et al., 2020)

A review and analysis carried out by Yeager et al. (2020) found that the effects of fragmentation were highly variable across marine ecosystems. Habitat fragmentation that restricts the movement of water could lead to rapid shifts in environmental conditions within remaining fragments was most notable for having a negative effect. Some positive effects were reported in relation to species abundance/diversity but there is need for further research on this topic including examining differences between patch scale and landscape scale effects of fragmentation.

Fragmentation metrics

Habitat fragmentation can be assessed statically to characterize fragmentation at a specific point in time or dynamically by comparing fragmentation indices based on past data with the same indices based on the current data. Forman (1995) uses as the minimum spatial unit the patch, which is defined as a homogeneous area (polygon in GIS) that differs from its surroundings The landscape metrics used for the assessment of fragmentation can be divided into three groups (Hargis et al., 1998, Wang et al., 2014):

1. **Patch-level metrics** measure characteristics of individual habitat patches. Common patch-level metrics include:
    - Patch area: calculate the size of individual mire patches. Smaller patches are generally more vulnerable to degradation and edge effects.
    - Patch perimeter: The length of the patch boundary.
    - Edge density: The length of the patch edge per unit area.
    - Shape Metrics
    - Shape index: Compares the patch perimeter to the perimeter of a circle with the same area. A higher value indicates a more complex shape.
    - Fractal dimension: Measures the complexity of the patch boundary.
2. **Class-level metrics** assess fragmentation at the landscape level. They provide a broader perspective on habitat fragmentation by considering the overall distribution and configuration of habitat patches within a landscape. They include:
    - Landscape shape index: Measures the complexity of the landscape configuration. Higher values indicate a more complex and fragmented landscape.

- Fractal dimension: Quantifies the complexity of the landscape pattern. Higher values suggest a more irregular and fragmented landscape.
- Patch density: The number of patches per unit area. Higher density indicates greater fragmentation.
- Patch size distribution: Describes the distribution of patch sizes within the landscape. This information can reveal whether there are a few large patches or many small ones.
- Edge density: The total length of edges per unit area. Higher values indicate a more fragmented landscape with increased edge effects.

3. **Connectivity metrics** evaluate the degree of connectivity between habitat patches. They include:

    - Mean patch isolation: The average distance between patches. Higher values indicate greater isolation.
    - Connectivity index: Measures the degree of connectivity between patches. Higher values suggest better connectivity.

Fragmentation may be assessed in a variety of ways. These include;

- Ecological impact assessment to assess species richness and composition in fragmented versus continuous patches, or changes in hydrology due to fragmentation.
- Trend analysis comparing current fragmentation levels with historical data to identify trends over time. Determine if fragmentation is increasing, decreasing, or stabilizing
- Assessing the role of human activity in driving fragmentation and evaluating the impact

Based on fragmentation assessments, it may be possible to identify hotspots i.e. priority areas for conservation, restoration, or connectivity enhancement, determine where restoration efforts could reconnect fragmented patches, improve habitat quality, or re-establish hydrological processes and develop policy recommendations to mitigate further fragmentation and protect existing ecosystems, including conservation strategies at a landscape scale to maintain and enhance connectivity.

5 Next steps to address future needs

This document provided an analysis of the methodologies used for monitoring sublittoral sandbanks in the EU member states, comparing them with the main ecological characteristics of sublittoral sandbanks and proposed a common approach for the harmonisation of habitat monitoring across the EU. Although this proposal is based on extensive information and a review of experiences included in the national habitat monitoring manuals, it is not meant to be definitive and prescriptive. It is highly recommended that this is evaluated by national experts and practitioners in habitat monitoring for its feasibility and appropriateness in different EU member states and different contexts.

Given the ecological and geographical variability of the Annex I habitat types, it is not realistic to have recommended lists of **typical species**, even for a biogeographical or marine region. 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 or even presents different biogeographical regions within the country, with the need to adapt the thresholds to every region in order to have a reliable methodology. Furthermore, given the variability of habitat types across their range, even within a single biogeographical marine region, it is also very unlikely that all typical species will be present in all examples of the habitat. For this reason, the report only identifies potential groups from which to select typical species for monitoring sandbanks. Further work is needed to identify the most relevant typical species for the task. This may take place at a national level but should also reflect any biogeographical and regional differences and ideally link to relevant existing monitoring programmes.

When making such a selection it should also be borne in mind that the priority is for good indicators of favourable structure and function and that as such, they may not be the most dominant species. Species selected also need to reflect the variety of biological communities/subtypes often found within sandbanks given that they may be made up of a mosaic of marine communities rather than being uniform.

A summary of the **ecological, physical, chemical characteristics** and **main variables** used to measure the habitat condition of shallow sublittoral sandbanks is presented in this report together with a review and an analysis of variables which are specified in the national habitat monitoring manuals of EU Member States. There is much commonality but also potential to explore whether this can be standardized across Member States in at least some cases. Equally important is to make sure that there is consistency with variables being used for reporting of MSFD descriptors and the Nature Restoration Law whilst noting that there are differences in the scale of the habitats to be assessed. Also relevant are the metrics which are used to monitor the different variables. Many considerations make it unlikely that the metrics could be standardized even for commonly agreed variables (e.g. due to the variations in this habitat across its range, practical considerations, measurement methods) but it is worth exploring whether there is any scope for intercalibration.

The **reference values and thresholds** applied by Member States to obtain condition indicators for sublittoral sandbanks are variously; very specific, based on trends, use indices, rely on expert judgement or any combination of these. Given the variability of habitat across its range, even within a single biogeographical marine region, it is unlikely that the same ranges and thresholds can be applied in all circumstances. The scope to have a common or favoured approach to setting reference values and thresholds for particular variables could usefully be investigated. Equally important is to make sure that there is consistency with ranges and thresholds being used for reporting of MSFD descriptors and the Nature Restoration Law.

Finally, although there are many well established methods for **monitoring and sampling** sandbanks new techniques are constantly being developed. It is particularly important to keep alert to these for harder to access locations (depth, conditions, nature of habitat, etc.) which is where many advances may be made.

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