Common Standards Monitoring Guidance

for

Littoral Sediment Habitats

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Contents

NOTE: It is essential that the "Introduction to the marine guidance" found at the start to the marine section should be read prior to this littoral sediment guidance when setting attributes.

1 Definition of littoral sediment

Littoral sediment covers all sedimentary habitats located between high and low water – it does not cover saltmarsh, sand dune or vegetated shingle habitats. The prevailing physical environmental conditions and geomorphological processes determine the structure, function and biological composition of littoral sediment. Condition assessment of littoral sediment must include a consideration of both physical and biological components of the system.
Littoral sediment often displays considerable spatial heterogeneity in their topography, sediment structure and sediment composition resulting in corresponding heterogeneity in their associated biological composition.

The term 'littoral sediment' includes the habitats listed in Box 1.

Box 1 Habitat types included in the term 'Littoral sediment'

Habitats Directive	BAP Broad habitat type[1]	BAP Priority habitat/Action Plan[1]	OSPAR Threatened Habitats[2]
Mudflats and sandflats not covered by seawater at low tide	Littoral sediment	Mudflats	Intertidal mudflats
Estuaries (in part)		Sheltered muddy gravels	*Ostrea edulis* beds
Large shallow inlets and bays (in part)		Seagrass beds	*Zostera* beds

A condition assessment of littoral sediment should be based on the attributes[3] and their associated targets derived from the generic attributes table (Table 1, Section 6).

Section 2 and Table 1 (Section 6) list the generic attributes that are considered most likely to represent the condition of the feature. It will be necessary to develop a site-specific expression of some or all of these generic attributes to represent the conservation interest of the feature properly, fully reflecting any local distinctiveness.

Littoral sediment often forms part of very dynamic systems and interacts with other adjacent features such as subtidal sandbanks, saltmarshes and sand dunes. The shape and functioning of the littoral sediment is determined both by the coastal processes acting upon it and the influence of these adjacent habitats. The overarching objective for all of these features, including littoral sediment, is to allow their natural evolution in response to the prevailing coastal processes. Features will change their morphology over time in response to factors such as sea level rise or the evolution of an estuary

[1] These are derived from both the Biodiversity: The UK Steering Group Report - Volume II: Action Plans and the *UK Biodiversity Group Tranche 2 Action Plans - Volume V: Maritime species and habitats.* Further information on these habitat types can be found on the UK Biodiversity web site at http://www.ukbap.org.uk/habitats.htm

[2] These are derived from a provisional list agreed by the OSPAR (Convention for the Protection of the Marine Environment of the Northeast Atlantic) Biodiversity Committee at their Leiden Workshop, 5-9 November 2001, and therefore may change when the final list is agreed.

[3] The Common Standards text defines an attribute as: a *characteristic of a habitat, biotope, community or population of a species which most economically provides an indication of the condition of the interest feature to which it applies.*

to dynamic equilibrium. This is an acceptable part of the functioning of the feature and should be encompassed within the attributes and targets. These principles should form an essential component of the conservation objective.

Evaluating the biological quality of a feature often requires a quantitative measure of the number of species and individuals (of those species) present. Some littoral sediment have relatively few species present, so quantitative sampling would be a waste of resources. Consequently, the need for quantitative measures of species abundance to assess the condition of littoral sediment should be considered on an individual site basis.

2 Background, targets and monitoring techniques for individual attributes

Table 1 (Section 6) lists ten attributes, four of which (*Extent, Biotope composition, Sediment character and Distribution of biotopes*) are mandatory for all sites. The rest are site-specific attributes used to highlight local distinctiveness when assessing the overall conservation value of a site and may therefore not be applicable to all sites.

2.1 Extent

Extent of the littoral sediment is an essential structural component of the feature and therefore **must be assessed for all sites**.

2.1.1 Background to the attribute

Littoral sediment features are generally dynamic, and their actual extent will vary on diurnal, lunar and seasonal cycles, driven by tidal regime, prevailing weather conditions, coastal and geomorphological processes.

Natural changes may be attributable to the following:

- *Saltmarsh encroachment.*

This is the colonisation of the littoral sediment by saltmarsh plants. Succession is typically led by the pioneer *Salicornia* species, which stabilises the sediment and facilitates the colonisation of perennial species. Unfavourable colonisation may occur from the non-native cord-grass *Spartina anglica*, considered to be an invasive species and may impact on intertidal mud flats, pioneer and low-mid marsh communities, in which case a monitoring programme would be triggered and there may be a need for management action.. An indicative target for Spartina has been set of less than 10 % expansion to pioneer saltmarsh in the last 10 years, but this figure may have to be revised following consultation.

Encroachment by *Spartina* is considered a contentious issue and there is a need to be cautious about advocating *Spartina* control when its presence is considered to be a natural process. Specialist advice is required when dealing with this issue.

- *Erosion following winter storms or floods*

Storm events are becoming increasingly frequent, and wave energy or high tides/river levels may cause erosion of the littoral sediment, or changes to river/drainage channel patterns. These should generally be perceived as acceptable changes, although some erosion may be exacerbated by coastal defences, and should be treated similarly to ‘coastal squeeze’ (see below). However, natural re-establishment through sediment accretion may occur over time and sediment flats are therefore expected to appear in some areas as they disappear elsewhere.

- *Changes in estuary morphology.*

Estuaries have a natural tendency to accumulate sediment (Roger Morris, English Nature, *pers comm*.), thereby changing their form from their original Holocene morphology to a state where tidal energy is dissipated by sub- and inter-tidal sediment banks. The width and depth of the estuary will therefore change over time towards a state of dynamic equilibrium or "most probable state". The velocities of currents passing through the mouth are determined partly by the tidal range and partly by the cross sectional area of the mouth itself. If these velocities are higher than the sediment erosion threshold, erosion will widen the channel and lower velocities will ensue. If velocities are lower than the sediment depositional threshold, deposition will narrow the mouth and higher velocities will ensue. In this way, an equilibrium cross section will evolve which balances tidal prism, velocities and erosion/depositional thresholds. Sea level rise means that estuaries will show a natural tendency to translate inland (roll-over) and may erode at the mouth. Such changes will influence the extent of sediment flats within an estuary. Where this process is constrained by hard sea defences, then this would be considered as coastal squeeze (see below).

Extent will not be a static measure and therefore some change must be anticipated during a monitoring cycle. Where changes are observed, the cause of the change is important to establish, since this will determine the final assessment of condition.

Where the field assessment judges extent to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes, the final assessment will require expert judgement to determine the reported condition of the feature. The feature's condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change outside the expected variation or a loss of the conservation interest of the site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable. Staff should refer to the flow diagrams in the introductory text to the marine features for more information on these issues.

Changes in extent may be attributable to anthropogenic effects, where defence works interrupt natural coastal processes. Changes in extent would be considered unfavourable and by default the feature would also be declared unfavourable, if attributable to *coastal squeeze*, which is the term applied to the effect hard defences (including beaches fixed in position by control structures) have when they interrupt the natural response of the shoreline to sea level rise. Sea walls or other embankments are often too steep to allow natural encroachment, restricting the natural landward retreat and resulting in the intertidal zone being 'squeezed', with a loss in the extent of intertidal habitat as a result of the higher levels of energy occurring in the intertidal zone.

2.1.2 Setting a target

In principle the target should be set at no loss of area of the littoral sediment during the monitoring cycle accommodating any geomorphological trajectory. It may be necessary to set a target that declines each monitoring cycle where there is an established natural loss of extent, or sufficient data available to predict (via a model) a downward trend in extent[4]. Departure from this predicted target then would be a trigger for investigation and the feature may be considered unfavourable.

The target should indicate the recognised area of the feature measured in hectares. It is important that targets set for this attribute are flexible enough to relate to the natural coastal processes involved with this feature (see above).

[4] It may also be possible to predict and increase in extent for littoral flats where sediment accumulation occurs.

When measuring extent, the following issues should be considered:

- Check that all aerial photographs and broadscale biotope maps have the same upper and lower boundaries, are at the same scale and to the same datum.
- Determine whether watercourses (rivers, drainage channels, creeks etc.) have shifted position. An increase in depth or width of such water courses may consequently lead to a loss of the feature's extent.
- Storm events and flood water can transport sediment into the system. This may lead to sediment deposition and an increase in extent.
- Storm events can lead to sediment flat erosion and consequent loss of extent.
- Anthropogenic factors such as coastal protection schemes can lead to extent loss or increase.

An example of how a target for this attribute might be expressed is shown in Box 2

Box 2 A site-specific target for the attribute 'Extent'

Target	Comments
No decrease in extent of littoral sediment at 279 ha.	Baseline data from Bunker, Moore & Perrins (2001) estimated extent at 279 ha. Condition would be judged unfavourable if loss in extent due to factors other than cyclical natural processes or geomorphological trajectory is considered to have had an adverse effect on site integrity.

*Taken from Plymouth Sound and Estuaries SAC

2.1.3 Suggested techniques

Extent can be measured in absolute terms, using estimates from aerial imagery or an index approach such as point sampling over a grid, or by inference. The type of measure used should be linked to the known or likely threats posed by anthropogenic activities and take into account necessary consideration of dynamic processes.

In most cases the area will be derived from aerial photographs of the site. Broadscale biotope maps may also be useful, showing distribution and extent of littoral sediment. It is important that all the photographs and maps show the same lower and upper shore boundary. When establishing the extent of littoral sediment habitats, the definition of the lower boundary is problematic. Where littoral sediment is adjacent to a sub-tidal area, the boundary would most likely be defined by the mean low water mark accepting that this is difficult to identify in the field, but some other datum may be appropriate. Please ensure the upper/lower limit data are documented with the target value.

The Marine Monitoring Handbook (Davies *et al.*, 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the extent of the feature are:

- 1-1 Intertidal resource mapping using aerial photographs

Other proposed methods, not as yet detailed in the handbook are:

- Satellite and airborne multi-spectral remote sensing (Remote imaging);
- Aerial photography and photogrammetry (Air photo interpretation);

2.2 Biotope composition

Biotope composition is an essential component of the feature and therefore **must be assessed for all sites**.

2.2.1 Background to the attribute

The biotope composition attribute of littoral sediment should encompass the variety of biological communities present within the feature, and should reflect the conservation interest of the particular site.

The attribute may address a subset of the biotopes identified for the following:

- overall biotope composition where the feature supports a diverse range of communities
- specific biotopes indicative of the character of the site or of conservation interest[5]
- biotopes, which may be indicative of the condition of the feature with respect to the level of anthropogenic activity or input.

The resolution to which biotopes are expressed in the target will have to be considered with regard to their use in condition assessment. It may be appropriate to use higher level biotopes (e.g. biotope complexes) in preference to the more detailed ones that are difficult to identify in the field.

It is important to understand cyclical succession of littoral sediment biotopes. Biotopes are often defined by differing abundance of species, and under natural conditions certain biotopes will cycle about each other, and may disappear and reappear over time. These cycles are an acceptable part of the interest of the feature and must be considered when phrasing a target value (see Section 2.2.2). A suite of the biotopes expected at the site should be listed with their "cyclical partners".

Where the field assessment judges biotope composition to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes, the final assessment will require expert judgement to determine the reported condition of the feature. The feature's condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change outside the expected variation or a loss of the conservation interest of the site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable.

The present attribute aims to measure the overall variety of communities throughout an entire site and is distinguished from the attribute *Distribution of biotopes* discussed below which measures the presence or absence of biotopes at specific locations.

2.2.2 Setting a target

It is intended that either:

- a subset of the biotopes should be identified where the feature supports a diverse range of communities, or
- the overall biotope composition be determined and specific notable biotopes highlighted where appropriate.

This information can be derived from biotope maps or from other more detailed survey records.

[5] Examples would be nationally rare or scare biotopes, or biotopes supporting species of conservation value.

Targets should be set that require the determination of the presence of the named subset of biotopes from selected areas within a site over the monitoring cycle (sampling locations are also likely to be governed by access and health and safety issues[6]). It is important that the targets and measures set are clear and unambiguous. The targets and measures should determine the resolution (i.e. whether the assessment is based on biotope complex, biotope or sub-biotope level) and the scale of the assessment (i.e. intensity of sampling). The targets should also clearly identify what must be achieved in order to pass or fail (i.e. biotopes X, Y, Z must be present within the feature).

Note the following general points when defining targets for the biotope composition of littoral sediment features:

- *Biotopes may change in natural cycles*

If an area changes from one biotope to another, this may be a natural process, possibly part of a natural cycle. It is important not to over specify targets ("biotope x must be present at site y"), to avoid the possibility of an area being deemed unfavourable where biotopes have changed as part of a natural process. For example, natural shifts in biotopes are likely to occur on beaches of clean, coarse mobile sand. Seasonal changes in wave exposure can be significant and winter storms may reduce or remove the infauna that were present during the summer months, or alter species composition. A shift from one sub-biotope of LS.LSA.MOSA.AmSco[7] to another would not normally indicate a decline in the condition of the feature; even a shift from LS.LSA.MOSA.AmSco to barren sands (LS.LSA.MOSA.BarSa) can be the result of natural processes. In this particular example, it may be suitable to set the target at the biotope complex level ("biotopes within biotope complex LS.LSA.MOSA must occur within the site"). Knowledge of local conditions is necessary when setting targets: some beaches may virtually disappear during stormy winters and re-appear during calm summer months.

- *Species composition of biotopes*

It is not possible to apply a level in the classification hierarchy at which all targets should be set: in some cases a shift from one biotope (or even sub-biotope) to a similar one may signal a decline in environmental quality. For example, within the fine clean sand polychaete biotope (LS.LSA.FISA.Po), there are three sub-biotopes, two of which are dominated by polychaetes (LS.LSA.FISA.Po.Pful, LS.LSA.FISA.Po.Ncir) and one of which contains significant numbers of the bivalve *Angulus tenuis* (LS.LSA.FISA.Po.Ang). As the bivalve can live for longer than a year and requires a certain degree of sediment stability throughout its life, a shift from the *Angulus* sub-biotope to one of the other two may signal a significant change in the sediment dynamics of a site. Similarly, a shift from muddy sand biotopes with large numbers of long-lived bivalves (e.g. LS.LSA.MUSA.CerPo; LS.LSA.MUSA.HedMacEte) to biotopes with low numbers of bivalves (e.g. LS.LSA.MUSA.BatCare) may signal a reduction in environmental quality and should trigger further investigation.

- *Data type and quality*

For many littoral sediment features, the biotope composition cannot reliably be identified at the biotope or sub-biotope level during broadscale mapping surveys, since quantitative sampling is required to identify the characterising species. It is very important to bear this in mind, especially where habitat maps based on Phase I surveys are available for a particular site: subsequent quantitative surveys may lead to different habitat assignments even if there was no change to the feature. Similarly, if data from an initial quantitative survey were available to establish a target condition, subsequent rapid assessment surveys will not necessarily deliver the same level of detail.

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[6] Information on health and safety issues can be obtained in the Marine Monitoring Handbook **http://www.jncc.gov.uk/marine** or from appropriate country agency risk assessments.

[7] These biotope codes are taken from the revised biotope classification published in Spring 2003 and can be found at **http://www.jncc.gov.uk/marine/biotopes/default.htm**

Where condition assessments will be based on data from rapid surveys, it is important not to set the target at too detailed a level in the biotope classification, as the field data will not deliver the required level of resolution. It may be necessary to set targets at the biotope complex or habitat complex level if resources will not allow for quantitative surveys to be carried out in future.

SSSI citations, SAC Regulation 33 packages, biotope maps or more detailed survey records should help to determine the biotopes of nature conservation importance within a site, which in turn will determine the target list of biotopes. Due consideration should also be given to activities occurring within sites where they may impact important biotopes.

When setting target values, it is important to consider the following issues:

- An agreed level of biotope discrimination must be clearly established in relation to the national biotope classification scheme. You may wish to use a higher level in the classification where biotopes are difficult to differentiate without detailed sampling;
- A subset of biotopes of importance may be identified and listed, omitting ephemeral biotopes and biotopes considered to be of low conservation importance. You may only wish to choose biotopes considered to be of conservation importance within the site;
- Some biotopes occur in a natural cycle and may disappear and reappear over time. These cycles are a vital part of the interest of the feature and must be considered when phrasing a target value. Too tightly defined targets could lead to a false judgement of unfavourable condition.

An example of how a target for this attribute might be expressed is shown in Box 2.

Box 3A site-specific target for the attribute 'Biotope composition'

Target	Comments
Maintain the variety of biotopes identified for the site, allowing for natural succession/known cyclical change. Biotopes present are: LMS.MacAre (and with *Enteromorpha* sp.); LMS.Znol; SLR.MytX; LGS.AP.Pon and LGS.AEur LMS.MacAre may cycle with LMS.MacAe.Are and LMS.PCer. This would be due to a change in sediment accretion and/or wave-exposure. LMS.Znol may cycle with LMS.PCer where there is a decline in the abundance of *Zostera* spp. These biotopes have a similar infauna. LGS.AP.Pon may cycle with LGS.AP.P where sediment alternates its stability e.g. channel movement may influence this cycling. LGS.AEur may cycle with LGS.AP.Pon if wave exposure/ tidal streams change/ fluctuate. SLR.MytX would not be expected to cycle with other biotopes.	Expect to find the suite of target biotopes within the site. Derived from site citations, aerial photographs and Allen *et al* (1999) data. Condition should be judged unfavourable if the biotopes highlighted as being of importance are not found on the site.

* Taken from Lindisfarne NNR/Budle Bay SAC

2.2.3 Suggested techniques

Sampling locations should be distributed throughout each site so that an assessment of overall site condition can reasonably be made. However, because of the large and complex nature of many sites it is likely that a degree of sub-sampling will be essential in most cases, which makes the risk of missing a biotope much greater (due to shifts in sediment, particularly in estuaries) to beyond the sampling area.

It is likely in such cases that emphasis is placed on assessing the continued presence of those biotopes of greatest conservation value. Within some sites these biotopes may be clumped disproportionately within a small section of a larger site and here it would be important to also include biotopes and sampling locations representative of the remainder of the site. More detailed sampling effort should focus on those biotopes of highest conservation value.

The Marine Monitoring Handbook (Davies *et al.*, 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the biotope composition of the feature are:

- 1-1 Intertidal resource mapping using aerial photographs; with ground validation
- 3-1 *In situ* intertidal biotope recording (effort-limited biotope identification techniques)
- 3-6 Quantitative sampling of intertidal sediment species using cores

Other proposed methods, not as yet detailed in the handbook are:

- Satellite and airborne multi-spectral remote sensing (Remote imaging); validated with effort-limited biotope identification techniques
- Point sample mapping using effort-limited biotope identification techniques

2.3 Sediment character: sediment type

Sediment character:sediment type is an essential component of the feature and therefore **must be assessed for all sites**.

2.3.1 Background to the attribute

Sediment character defined by sediment type is key to the structure of the feature and reflects all of the physical processes acting on it. Particle composition of the sediment has a direct bearing upon the distribution and extent of infaunal communities. Recognised assemblages of species are directly related to the sediments in which they occur. A change in the particle size parameters will lead to changes in associated infaunal/epifaunal communities.

Wave and tidal energy has a direct influence on the prevailing sediment types present. High-energy areas such as wave-exposed shores would be expected to have a larger grain size than sediments at the head of estuaries, which are very sheltered systems. Any change in the prevailing environmental conditions will result in a change in sediment type.

Where the field assessment judges sediment type to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes (e.g. winter storm/flood events, changes in supporting processes or the natural shifting of watercourses throughout a site), the final assessment will require expert judgement to determine the reported condition of the feature. The feature's condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change outside the expected variation or a loss of the conservation interest of the

site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable.

2.3.2 Setting a target

It is intended that average sediment parameters for the feature should be set. In setting the target the distribution of known sediment types across the feature should be determined and the target should distinguish between the need to retain a range of sediment types throughout the feature, or the maintenance of a spatial juxtaposition of specific sediment types, possibly at a defined number of sites. Sediment type may be important because, for example, the site may have an unusual prevalence of sandy communities. This information can be derived from biotope maps, geological maps, or previous detailed survey. A target condition must be based on detailed sample data to ensure future assessments can be compared to actual baseline data.

Measuring the spatial arrangement of sediment types is more complex, since it requires a mapping approach, whereas identifying the presence of a sediment type can use a simple point sample/observation technique. To ensure a consistent approach for future assessments expressions of sediment types can be made using mean phi values or proportions of sediment grades such as 'mud' 'muddy sand' etc, as used in the Folk classification scheme (Folk, 1954). Alternatively, in situ assessments could be made across a site using cruder visual assessments of sediment grades.

It is important, therefore, when setting a target, to clarify the difference between a target to represent the range of sediment types over a feature and a specific requirement for a single sediment type (i.e. silt content of clean sandy biotopes).

An example of how a target for this attribute might be expressed is shown in Box 4

Box 4A site-specific target for the attribute 'Sediment character: sediment type'

Target	Comments
Maintain distribution of mud and sandy mud across the feature, allowing for natural processes 100% of the feature to be mud or sandy mud	Baseline data from Bunker, Moore & Perrins (2002) indicated the feature comprised mud and sandy mud. Condition should be judged unfavourable if a shift in sediment type is detected and not attributable to natural processes

*Taken from Plymouth Sound and Estuaries SAC

2.3.3 Suggested techniques

The established method for assessing sediment type normally involves coring of the sediment followed by laboratory analysis to determine the percentage composition of different particle sizes (particle size analysis). A rough *in situ* field method involving a 'by eye' assessment of sediment type may also be used; contact Paul Brazier (P.Brazier@CCW.gov.uk) who devised field guidance for sediment particle size.

The NMMP Green Book describes approved techniques. The Marine Monitoring Handbook (Davies *et al.*, 2001) will provide a procedural guideline in the future.

2.4 Distribution of biotopes

Distribution of biotopes is an essential component of the feature and therefore **must be assessed for all sites**.

2.4.1 Background to the attribute

Assessing the distribution of biotopes throughout the feature should highlight any progressive loss or change in the biological integrity of the feature. This attribute complements an assessment of the biotope composition attribute by ensuring that the distribution of the conservation interest is maintained throughout the feature.

The issues described under *Biotope composition* in relation to specifying biotopes equally apply to the present attribute. Unlike *Biotope composition*, this attribute is concerned with the presence or absence of biotopes at specific locations.

It is important to understand that not only do sediment biotopes show cyclical succession but they also have no clearly defined perimeters in the field. There is a transition from one biotope to its neighbour with this "boundary" consisting of a mixture of the two adjoining biotopes. It is important for the target to indicate (or make reference to) the likely succession between biotopes and highlight any differences expected in "transitional" biotopes. Specific discreet biotopes found within the feature will be easier to assess than the wide ranging examples (e.g. eelgrass beds and cockle beds may have a small area of distribution within the feature and are recognisably distinct from other sediment features). Conversely, in the field it may be hard to determine boundaries/transitions between different mud biotopes dominated by polychaetes that cannot be distinguished 'by eye' due to their small size and therefore a more pragmatic approach of using biotope complexes would be recommended.

Where the field assessment judges biotope distribution to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes (for example due to a movement of a drainage channel), the final assessment will require expert judgement to determine the reported condition of the feature. The feature's condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change in biotope distribution outside the expected variation or a loss of the conservation interest of the site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable .

2.4.2 Setting a target

In principle the target should be set at no change in distribution of the biotopes during the monitoring cycle. The target must however consider any expected shift(s) in distribution. It is possible to use either an absolute measure or an index approach to measuring biotope distribution.

There are strong links between the physical parameters of the littoral sediment and the associated infaunal and epifaunal communities. Therefore the dynamic nature of the system will affect the biotope distribution. The target must consider any expected shift(s) in distribution. For example, the movement of a drainage channel may lead to an increase in the mud component of the sediment, which may change the biotope. The issues described under *Biotope composition* in relation to specifying biotopes equally apply to the present attribute.

Additional issues to consider when specifying site-specific targets include:

- Biotope distribution may change in response to extreme low frequency events such as increased storm/flood occurrence.

- Some biotopes will change their distribution naturally over time, in a cycle with other biotopes (and the target should identify these if possible).
- The precise location of sediment biotopes will change, particularly in dynamic environments.

An example of how a target for this attribute might be expressed is shown in Box 5

Box 5A site-specific target for the attribute 'Distribution of biotopes:'

Target	Comments
Maintain the distribution of the biotope subset, allowing for natural succession/ known cyclical change in biotope distribution. LMS.MacAre, LMS.Znol, LGS.AP.Pon, LGS.AEur, SLR.MytX.The distribution should correspond with Allen *et al* (1999). See distribution of biotopes attribute for expected cyclical partners.	Expect to identify the biotope subset in the field at positions derived from the baseline biotope map (Allen *et al* 1999). Cross-reference with aerial photographs. LMS.Znol should be present across the same area. Approx. 594 ha site has *Zostera* spp. (32% of feature extent). SLR.MytX should be present across the same area. Approx. 80 ha site has *Mytilus edulis* on mixed substrata (4% of feature extent).

*Taken from Lindisfarne NNR/Budle Bay SAC

2.4.3 Suggested techniques

It is possible to use either an absolute measure or an index approach to measuring biotope distribution.

The Marine Monitoring Handbook (Davies *et al.* 2001) contains details of the techniques appropriate for monitoring the condition of designated features.
Possible methods provided in the handbook for measuring the distribution of biotopes of the feature are:

- 1-1 Intertidal resource mapping using aerial photographs
- 1-2 Fixed viewpoint photography;

Other proposed methods, not as yet detailed in the handbook are:

- Satellite and airborne multi-spectral remote sensing (Remote imaging);

2.5 Extent of sub-feature or representative/notable biotopes

Extent of sub-feature or representative/notable biotopes is considered a site-specific attribute used to highlight local distinctiveness when assessing the overall conservation value of a site and may therefore not be applicable to all sites.

2.5.1 Background to the attribute

This attribute may highlight important structural and functional components of the feature, depending on the biotopes/sub-features chosen. The biotopes chosen should reflect the site-specific interest of the feature. Actual extent may vary on seasonal cycles and the presence or absence of a biotope can change the results quite significantly. It is important to understand cyclical succession of littoral sediment biotopes, and to take this into account when choosing biotopes to reflect this

particular attribute. The target also needs to identify biotopes that would be expected to be part of that natural cycle.

The advice concerning judgement of the feature condition provided under Extent (*Section 2.1.1 Background to the attribute)* equally applies to this section and should be consulted.

2.5.2 Setting a target

In principle, the target should be set at no loss in extent of the sub-feature or representative/notable biotope during the monitoring cycle. The target needs to identify biotopes that would be expected to be part of that natural cycle.
It may be necessary to set a target that declines each monitoring cycle where there is an established natural loss of extent, or sufficient data available to predict (via a model) a downward trend in extent. Departure from this predicted target then would be a trigger for investigation and the feature may be considered unfavourable.

Information from aerial photographs and biotope maps can be used to highlight areas that are of interest within the feature. Good examples are discreet biotopes within the sediment flat such as seagrass *Zostera noltii*, mussel *Mytilus edulis* or cockle *Cerastoderma edule* beds. These notable biotopes usually have quite distinct boundaries with a measurable area. It is expected that the target for the attribute would be given in hectares or square metres. It should not decline from this baseline unless as a result of natural processes.

The following issues should be considered:

- The number of representative/notable biotopes present within the assessed feature.
- The natural "cyclical partners" for the identified biotopes must be listed with the target.
- Check that all aerial photographs and broadscale maps have the same upper and lower boundaries, are at the same scale and to the same datum.
- Determine whether watercourses (rivers, drainage channels, creeks etc.) have shifted position. An increase in such watercourses could lead to a loss of the biotope's extent.

An example of how a target for this attribute might be expressed is shown in Box 5.

Box 5 A site-specific target for the attribute 'Extent of sub-feature or representative /notable biotope(s)'

Target	Comment
No reduction in extent of *Zostera noltii* bed.	Baseline data from Bunker, Moore & Perrins (2002) estimated extent of the *Zostera* bed at 12 ha.

*Taken from Plymouth Sound and Estuaries SAC

2.5.3 Suggested techniques

Extent can be measured in absolute terms, using an index approach such as point sampling over a grid, or by inference. The type of measure used should be linked to the known or likely threats posed by anthropogenic activities and take into account natural variation in extent or in cyclical succession between biotopes.

The Marine Monitoring Handbook (Davies *et al.*, 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the extent of sub-feature or representative or notable biotopes of the littoral sediment are:

- 1-1 Intertidal resource mapping using aerial photographs with;
- 3-1 *In situ* intertidal biotope recording (grid sampling using effort-limited biotope identification techniques)

Other proposed methods, not as yet detailed in the handbook are:

- Satellite and airborne multi-spectral remote sensing (Remote imaging);
- Aerial photography and photogrammetry (Air photo interpretation);
- Measuring spatial pattern using transect survey techniques (transect survey using effort-limited biotope identification techniques).

2.6 Species composition of representative or notable biotopes

Species composition of representative or notable biotopes is considered a site-specific attribute used to highlight local distinctiveness when assessing the overall conservation value of a site, and may therefore not be applicable to all sites.

2.6.1 Background to attribute

Species composition is an important contributor to the structure of a biotope. A determination of species composition gives an indication of the quality of the biotope, and a change in composition may indicate a cyclic change/trend in sediment communities.

Any change in species populations should be assessed as an overall measure of community structure of the biotope, rather than as an individual or indicator species. An assessment of species composition may be restricted to only measure the characterising species of a targeted biotope where the overall species composition of that biotope is poorly understood and subject to measurement error. These species can be identified from the MNCR biotope classification using species with a typical abundance of common or above (using SACFOR abundance scale from MNCR classification). The target should include a list of these characterising species.

Where the field assessment judges species composition to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes such as mass recruitment and dieback of characterising species, the final assessment will require expert judgement to determine the reported condition of the feature. The feature’s condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change in species composition outside the expected variation or a loss of the conservation interest of the site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable

Examples of notable biotopes would be nationally rare or scarce biotopes, biotopes that are indicative of the 'health' of the feature or the level of anthropogenic activity or input.

2.6.2 Setting a target

Species composition can be measured in absolute terms (number of species, density of a species), using an index (evaluating the overall number of species even if exact species compliment changes) or in terms of presence/absence. The type of measure will depend on the context in which the attribute is used.

The following issues should be considered:

- The biotope for which a species composition measure is required must be clearly stated in the attribute table and identifiable in the field.
- Biotopes may be selected for different reasons, for example their overall diversity or because they contain species of conservation importance. The reason for selection will determine what species should be measured and hence the way a target is phrased.
- It may be appropriate to select a subset of the species present, avoiding species whose presence is ephemeral, difficult to sample or difficult to identify.
- It may be appropriate to develop a checklist of species for a biotope, for example those species that make important structural and functional contributions to the biotope's continued existence.
- For biotopes that have a high turnover of species, it is more appropriate to use an index measure, although careful consideration must be given to the choice of index. Note, indices have specific requirements in terms of the type of data used, and its method of collection.
- Species selected could be: nationally rare or scarce; species that have an important functional or structural role in the feature; species indicative of the 'health' of the feature; species indicative of the level of anthropogenic activity; non-native species (where their presence is considered unfavourable).
- Species targets could be derived from existing records for that biogeographic region.
- Careful consideration must be given to the use of species that are known to have a high turnover or fluctuation in abundance.
- Species recording has significant quality assurance issues in relation to the sampling methodology and particularly the taxonomic competence of the recorders. It may therefore be appropriate to select species that are capable of a relatively simple assessment. If necessary a pre-assessment visit may help to identify or check the ease of recording. Target condition should be established with regard to these QA issues.

An example of how a target for this attribute might be expressed is shown in Box 6

Box 6A site-specific target for the attribute 'Species composition of representative or notable biotopes'

Target	Comments
No decline in quality of LMS.PCer biotope due to change in species composition or loss of the characterising species detailed below, allowing for natural succession/known cyclical change. Expect to find the following characterising species at SACFOR scale abundance of "common" or greater: *Cerastoderma edule,* *Hydrobia ulvae, Macoma balthica, Scoloplos armiger, Pygospio elegans.*	Example taken from Perrins & Bunker, 1998. This attribute will require specialist information and the results will need to be provided to conservation officers before the site unit can be assessed.

*Taken from North Norfolk cSAC

2.6.3 Suggested techniques

The species composition of infaunal biotopes is measured by quantitative sampling of the sediment, which is both expensive and destructive. Whilst a measure of species composition is important to give an indication of feature quality, its use should be balanced against the effect of destructive sampling on the condition of the target biotope.

Note, assessing this attribute will require specialist taxonomic expertise.

The Marine Monitoring Handbook (Davies *et al.*, 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the species composition of representative or notable biotopes of the feature are:

- 3-2 *In situ* survey of intertidal biotopes using Abundance scales and Checklists at Exact locations (ACE)
- 3-6 Quantitative sampling of intertidal sediment species using cores

2.7 Species population measures

For littoral sediment, species population measures such as *Population structure of a species* or the *Presence/abundance of specified species* are considered site-specific attributes used to highlight local distinctiveness when assessing the overall conservation value of a site, and may therefore not be applicable to all sites.

2.7.1 Background to attribute

The species selected should serve an important role in the structure and function of the biological community. The method for measurement will vary depending on the species, and how it is contributing to the structure and function of the littoral sediment. Changes in presence and abundance or population structure of a species (which may eventually lead to a change in abundance of longer-lived species) can critically affect the physical and functional nature of the littoral sediment, leading to unfavourable condition.

Population measurements are made to assess whether there is continuing recruitment of a species into a population (i.e. to ensure whether the population is being maintained). This is an important measurement for the longer-lived species such as molluscs, which form dense populations (e.g. mussel beds/cockle beds). The condition of the feature may be considered unfavourable if there is a sizeable shift in the age/size class structure (for instance there may be a loss of mature adults or recruitment failure), which would cause a collapse in the population, leading to loss of the species altogether from the feature.

Presence or abundance of positive indicator species may also be indicative of the condition of the littoral sediment. These species may be of nature conservation importance, or particularly fragile or sensitive to disturbance. The condition of the feature would be considered unfavourable if the species is lost, or there is a significant reduction in abundance.

Increased abundance of negative indicator species may also be indicative of the condition of the littoral sediment. For example, some polychaete worms are indicative of stressed habitats usually associated with pollution. The condition of the feature would be considered unfavourable if there is a significant increase in abundance, which is detrimental to the feature as a whole.

2.7.2 Setting a target

Population structure of a species and the presence or abundance of specified species can be measured in absolute terms (numbers of individuals within age classes, density of species), using an index or in terms of presence/absence. The type of measure will depend on the context in which the attribute is used.

The following issues should be considered:

- The species for which the attribute measure is required must be clearly stated in the attribute table and identifiable in the field.
- The reason for selection will determine what should be measured and hence the way a target is phrased. A target of 'maintain age/size structure' should be used where one species is long lived and is providing a structural/functional role within the habitat.
- Representative species should be apparent from the site documentation, the SSSI citation or previous surveys. Species could be; nationally rare or scarce; species that have an important functional or structural role in the feature; species indicative of the 'health' of the feature; species indicative of the level of anthropogenic activity; non-native species (where their presence is considered unfavourable).
- Species targets could be derived from existing records for that biogeographic region.
- Careful consideration must be given to the use of species that are known to have a high turnover or fluctuation in abundance.
- Species recording has significant quality assurance issues in relation to the sampling methodology and particularly the taxonomic competence of the recorders. It may therefore be appropriate to select species that are capable of a relatively simple assessment. If necessary, a pre-assessment visit may help to identify or check the ease of recording.

An example of how targets for this attribute might be expressed is shown in Box 7.

Box 7 A site-specific target for the attributes under 'Species population measures'

Attribute: *Population structure of a* species i.e the characteristic species: common mussel *Mytilus edulis.*

Target	Comments
Percentage of sexually mature mussels and newly recruited mussels on beds should not fall below Sea Fisheries Committee targets.	Mussels are a key structuring component of the littoral sediment and play an important role in the functioning of the ecosystem. A range of age classes is an important indicator of mussel recruitment and growth. Abundance and age/size class profile of mussels, assessed annually, using a quantitative technique.

Attribute: *Presence/abundance of specified species*

Target	Comments
Extent of *Enteromorpha* sp. should not increase above 25% of feature area – approx. 465 ha.	Increase in extent of *Enteromorpha* sp. above 465 ha (> 25% of feature extent) will result in unfavourable condition for feature. Assess the extent of *Enteromorpha* spp. using GIS & aerial photos.

*all taken from the Wash and North Norfolk Coast European Marine Site Reg. 33(2) package

2.7.3 Suggested techniques

The Marine Monitoring Handbook (Davies *et al.,* 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the population structure of a species and the presence and abundance of specified species are:

- 3-2 In situ survey of intertidal biotopes using Abundance scales and Checklists at Exact locations (ACE)

- 3-6 Quantitative sampling of intertidal sediment species using cores

2.8 Topography

Topography is considered a site-specific attribute to highlight local distinctiveness when assessing the overall conservation value of a site, and may therefore not be applicable to all sites.

2.8.1 Background to attribute

Topography is defined as the flatness/steepness of littoral sediment, which is fundamental to the structure of the feature and bears a direct influence on the associated fauna. The topography of littoral sediment generally reflects the prevailing energy conditions and overall stability of the feature (e.g. flatter shores dissipate wave energy and are generally more stable in nature), which is in turn reflected in the composition of the infaunal community. A shore's profile should be allowed to respond naturally to prevailing conditions. Changes in overall topography will occur seasonally, but may also be as a response to changes in the supporting hydrodynamics, and may be an early indicator of accretion/erosion due to changes in coastal processes. Obvious changes in topography in terms of an overall lowering (shallowing) of the shore slope (such that bed features such as clay or archaeological remains are exposed) may act as a trigger for further investigation into the hydrodynamics of the system. This will be most evident where wave energy is reflected and intensified by hard sea defences, causing a scouring effect adjacent to the defences, which lowers the shore slope. This will consequently expose the foot of sea walls leading to major lowering and eventual erosion of the sea defence.

The factors known to influence extent such as erosion following winter storms or floods, will also affect topography. See Section 2.1.1 for further information.

2.8.2 Setting a target

In principle, the target should be set at no overall change to the topography during the monitoring cycle, but the target should reflect any seasonal changes that might be expected, and in some areas relate to the variation in expected weather and storm activity from one year to the next. Target topographic conditions may be linked to the degree of wave action that is fundamental in defining a particular dynamic community type. There will be fluctuations in the shore profile over time, but it is easy to detect a trend in one direction after a series of measurements have been taken. The target should reflect the fact that a continual reduction in the angle of shore slope would be a trigger for further investigation.

An example of how a target for this attribute might be expressed is shown in

Box 8

Box 8A site-specific target for the attribute 'Topography'

Target	Comments
No trend resulting in a net lowering of shore profiles over a 5 year period	Topography reflects the energy conditions and stability of the sediment, which is key to the structure of the feature. Shore profiles will be determined using data derived from the Environment Agency Wash Monitoring Programme.

*taken from the Wash and North Norfolk Coast European Marine Site Reg. 33(2) package

2.8.3 Suggested techniques

Shore slope can only be measured using shore profiling techniques (or, more recently, remote sensing techniques such as LIDAR) to produce shore profile diagrams. These profiles are generally measured at fixed points within a system and monitored over time.

The Marine Monitoring Handbook (Davies *et al.*, 2001) contains details of the techniques appropriate for monitoring the condition of designated features.

Possible methods provided in the handbook for measuring the topography of the feature are:

- 1-2 Fixed viewpoint photography

Other proposed methods are:

- LIDAR (Light Detection and Ranging System)
- Measuring the vertical distribution of species or biotopes using levelling.

2.9 Sediment character: organic carbon content

Sediment character: Organic carbon content is considered a site-specific attribute to highlight local distinctiveness when assessing the overall conservation value of a site, and may therefore not be applicable to all sites.

2.9.1 Background to attribute

Organic carbon can be derived from many sources, but predominantly from sewage effluent or nutrient enrichment. Increases in organic content in combination with the deoxygenation of the feature can cause a chemical shift within the sediment. This creates an increase in the microbial activity, which can produce toxic substances such as hydrogen sulphide or methane. A shift to these conditions causes a change in the infaunal community of the sediment, either due to the fauna not being tolerant of reduced oxygenation or as a direct toxicity effect. In either case, a change in species composition will be observed. Generally numbers of species will decrease. This changes the functioning of the littoral sediment and should be considered unfavourable.

A change in the organic content of the sediments can indicate a wider shift in the system dynamics. Changes may be due to natural events such as floods (which will increase the organic load of the system) or storms (which may aerate the sediment and lead to the breakdown of organic content) it will be necessary to clearly identify the level of change prior to reporting the condition of the feature.

2.9.2 Setting a target

Organic carbon should be measured where there is a threat from sewage or nutrient enrichment, which will have an impact on the structure or functioning of the littoral sediment. It has the most detrimental effect on very stable areas, where there is poor flushing of the organic material of the system. It will have less of an effect on the higher energy, mobile sediments.

Currently there is no example of how a target for this attribute might be expressed.

2.9.3 Suggested techniques

The NMMP Green book describes approved techniques for measuring organic carbon. A suite of laboratory techniques is available, but the most common procedure comprises a measure of loss on ignition (at 600ºC).
Organic carbon content is will most likely need to be assessed by specialist staff or contractors.

2.10 Sediment character: oxidation-reduction profile (Redox layer)

Oxidation-reduction profile should only be used where there is a clearly identified need, because it is very difficult to measure correctly. The *oxidation-reduction profile* (represented visually by the redox discontinuity or 'grey' layer) of the sediment is considered a site-specific attribute to highlight local distinctiveness when assessing the overall conservation value of a site, and may therefore not be applicable to all sites.

2.10.1 Background to attribute

Organic materials settle onto the surface of littoral sediment and are gradually incorporated into the sediment itself both by physical environmental processes and through biological activity. Micro-organisms decompose this organic material either aerobically where oxygen is present, or anaerobically where the rate of oxygen consumption exceeds the rate at which oxygen can diffuse down into the sediment from the overlying water. The redox discontinuity layer, known as the 'grey layer', is found between the areas of aerobic and anaerobic decomposition within the sediment. The anoxic region is easily recognised as a black layer within the sediment and is an indicator of the functioning of the system. Its depth below the surface is a function of the quantity of organic material and the rate of oxygen diffusion into the sediment. Muds are relatively impermeable to water and therefore once the oxygen is removed from the water it is only slowly replaced. The black layer may only be a few millimetres below the surface of the mud. The larger grain size of sands (that results in a greater porosity), coupled with the fact that sand generally occurs in more dynamic environments, result in greater mixing of the upper layers of sand flats. This leads to high oxygenation. Typically, sands also have a lower organic content. Permeable sands with a low organic content may have aerobic conditions for several decimetres below the surface.

The degree of oxygen availability critically influences the infaunal community and the mobility of chemical compounds. Macro-organisms can only survive below the redox discontinuity layer if they can oxygenate their surroundings. Large infaunal organisms construct burrows with an opening to the surface that allows the passage of oxygenated water down into the sediment. Such burrowing activity will help to maintain aerobic conditions in the upper layers of sediment. Removal of burrowing infauna animals will therefore have a wider impact on littoral sediment beyond the simple loss of a species from the community.

A change in the distance from the surface of the sediment to the top of the black layer is considered an indicator of a change in the supply of organic material to the littoral sediment. In general, it is of greater concern where the top of the black layer moves closer to the surface of the sediment, since this may indicate an increase in organic material entering the system. It is important to emphasise that the distance to the top of the black layer can vary on a seasonal basis as a consequence of both a varying supply of organic material and/or seasonal changes in the tidal/wave regimes. A trend in the distance to the top of the black layer that is independent of, or corrected for, seasonal variation would lead to a feature being assessed as unfavourable.

2.10.2 Setting a target

The target should be set as no deviation from a range of values, giving depth of the redox layer in centimetres from the surface. A change in the presence/absence of the layer can indicate a shift in the dynamics of the littoral sediment. Such a change will have a knock-on effect on the infaunal

communities present. Changes due to natural events such as floods (which will increase the organic load of the system) or storms (which may aerate the sediment and breakdown the redox layer) will be acceptable.

The average black layer depth Eh should not deviate in relation to baseline.

For sandy muds the rpd layer should be at 2-5 cm depth. For muds the rpd layer should be at 1-3 cm depth.
The following issues should be considered:

- Is a redox layer present?
- If so, how deep (in cm) is it?
- Have there been any recent natural events (storms/floods) which could have washed away the layer (by aerating the sediment to a greater depth than normal) or deposited extra organic material?
- If the redox layer has shifted, is it moving towards the surface or getting deeper?
- Is there any perceptible change in infaunal communities due to a shift in the redox layer? (e.g. sometimes dead bivalve shells can be found below the black layer.)

An example of how a target for this attribute might be expressed is shown in Box 9.

Box 9A *hypothetical* example of a site-specific target for the attribute 'Sediment character: Oxidation-reduction potential (Redox layer)'

Target	Comments
Average black layer depth/ Eh should not deviate in relation to baseline. For sandy muds the rpd layer should be at 2-5 cm depth. For muds the rpd layer should be at 1-3 cm depth.	Degree of oxidation/reduction reflects the oxygen availability within the sediment that critically influences the infaunal community and the mobility of chemical compounds. It is an indicator of the structure of the feature. The measure should accommodate seasonal changes in organic levels and temperature and should provide a mean figure for the year /season

2.10.3 Suggested techniques

Possible methods of assessing the oxidation/reduction profile are:

- visual measurement of the depth of the Redox (grey) layer below surface of the sediment

- depth to the top of the black layer below the surface of the sediment
- *in situ* measurement of redox potential using a redox probe.

3 Other environmental and physical parameters

Although condition assessment will focus on the attributes within the condition tables, in some cases the results may be difficult to interpret without some additional evidence in the form of data on environmental and physical parameters. Environmental and physical parameters are considered to be site-specific and should only be used as supporting information to highlight local distinctiveness when assessing the overall conservation value of a site, where they are considered to be fundamental to the condition of the feature. For example, an attribute reflecting sediment supply may be considered where erosion may result in a loss of the feature.

It should be emphasised that if an attribute for an environmental or physical parameter is selected as part of the definition of favourable condition for the feature, it must be considered during the assessment process. It is therefore essential that a realistic target can be established, taking account of known inherent variation, and a reliable method of measurement is available, since a failure to meet the target condition will render the condition of the feature unfavourable.

The following parameters, from which site-specific attributes may be derived, are known to influence the status of littoral sediment flats and/or their associated communities. This is not an exhaustive list and additional parameters may be appropriate, taking into consideration the comments in the preceding paragraph on the need for a strong justification for an attribute's use in condition assessment.

It will be necessary to relate any local measurements of physical parameters to contextual information for a wider geographical area when interpreting the data. Local changes may reflect a regional trend rather than any site-based anthropogenic activity and judgement needs to be made whether or not extra environmental attributes are needed. It may be necessary to seek expert advice.

3.1 Water density (salinity regime and temperature)

Temperature and salinity are characteristic of the overall hydrography of the area. Any changes in the prevailing temperature and salinity regimes may affect the presence and distribution of species (along with recruitment processes and spawning behaviour).

Where changes in temperature or salinity through adverse impacts (e.g. thermal discharge plumes, industrial discharges, water abstraction etc.) cause a severe loss or shift in community structure such that the conservation interest is adversely affected, then this should be judged as unfavourable. Where changes in temperature or salinity are due to natural processes such as severe winter temperatures, then this may be judged as an acceptable change to the feature unless the key conservation interest is lost.

3.2 Sedimentation rate

Where adverse anthropogenic impacts such as cockle dredging, disposal of dredge spoil or changed water flows due to artificial structures cause a change in sedimentation rate leading to severe loss of habitat, or an adverse shift in community structure, then this should be judged as unfavourable. Where changes in sedimentation rate are attributable to natural processes such as storm events, changed tidal movements or dynamics, or natural erosion, then this may be judged as an acceptable change to the feature, unless the key conservation interest is adversely affected.

3.3 Nutrient enrichment

One of the central aims of The Convention for the Protection of the Marine Environment of the Northeast Atlantic, 1992 (known as the OSPAR Convention) is the prevention and elimination of pollution, and for Contracting Parties (Countries) to take the necessary measures to protect the

maritime area against adverse effects of human activities[8]. The Contracting Parties adopted a Strategy to Combat Eutrophication[9] that sets out to tackle problems attributable to nutrient enrichment of marine systems. A Common Procedure for the Identification of the Eutrophication Status of the Maritime Area (known as the *Common Procedure*) will be used to characterise each part of the maritime area as a problem area or a potential problem area or a non-problem area with regard to eutrophication. OSPAR established a Eutrophication Committee to implement the eutrophication strategy. There are many papers from meetings of this committee containing relevant material to monitoring and assessing the nutrient status of marine waters. In particular, the summary document of EUC 2001[10] includes the 'Draft Common Assessment Criteria their Assessment Levels and Area: Classification within the Comprehensive Procedure of the Common Procedure (Source: ETG 2001 Summary Record – ETG 01/7/1, Annex 5)'. This document sets out the process for assessing the status of marine waters (known as 'classification'). Nutrient and/or chemical status will be monitored and assessed as part of the implementation of the Water Framework Directive, such work will be an important source of data for Common Standards Monitoring.

Nutrients are measured annually by the National Marine Monitoring Programme (NMMP). Information on the sampling and analytical procedures are available in the *Green Book,* which is available from the NMMP web site.[11]

Ecological Quality Objectives (EcoQOs) are proposed for nutrient status of marine waters in relation to the protection of biodiversity: see "Revised Proposals for EcoQOs for nutrients and eutrophication effects for inclusion in the BDC (Biodiversity Committee) draft background document on the development of Ecological Quality Objectives for the North Sea as in BDC 01/12/1, Annex 5." This draft text includes background reference conditions for nutrients, oxygen concentrations and phytoplankton indicator species.

Within the OSPAR process over the next few years, there will be a considerable research effort focused on setting standards and developing tools to monitor against these standards for eutrophication. The OSPAR web site should be consulted to determine the most up-to-date advice on assessing eutrophication.

Historically, the presence, absence or extent of green algal mats has often been considered an indication of the nutrient status of littoral sediment systems, and hence could be used as an indicator of the favourable condition of this feature. Much of the algal growth within littoral sediment is attributed to nitrogen inputs, despite the fact that there has been no *direct* correlation found between nitrogen inputs to a system and green algal mat growth. This is due to many additional factors interacting with each other, which influence both initiation and rates of growth of algal mats. The growth of algal mats tends to be governed by distinct temperature and light intensity ranges (Khan J. N. 1998). Generally, the nitrogen content measured within green algae can be used to reflect the availability of nutrients to the system (i.e. an indicator of raised inputs). Overall it is thought that although the initiation of the algal growth can be due to factors such as temperature and light, the maintenance and extent of these mats is determined by nutrient *inputs* to the system. To a point this may be true but it is possible that the inputs to maintain the mats are *naturally* derived and that nutrient-poor systems are able to produce extensive green algal mats.

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[8] See the section on the Convention on the OSPAR web site: **http://www.ospar.org**

[9] In this context, 'Eutrophication' means the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life, to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. It therefore refers to the undesirable effects resulting from anthropogenic enrichment by nutrients, as described in the Common Procedure

[10] Available on the OSPAR web site – see [8]

[11] See **http://www.cefas.co.uk/monitoring/page-b3.asp** for information on the NMMP and for the NMMP Green book **http://www.marlab.ac.uk/FRS.Web/Uploads/Documents/GBMain%20Text%201103.pdf**.

Before proceeding with using green algal mats as indicators of the nutrient status of the littoral sediment the relationship between the nutrient and the algae should be understood, especially:

- sources of nutrients to the system
- relationships between the nitrogen in the sediments and its transference to macroalgae.
- internal fluxes of nutrients within algal mats for the maintenance of biomass (Janet Khan *pers comm*.)

Also, the nutrient content of the algae at the beginning of the mat formation (April/May) may be used to indicate whether the nutrients are being recycled within the system, based on a *sediment-algal mat-sediment cycle* system, or whether the nutrients are being derived from an external input (Jeffrey *et al.* 1995) . Nutrient content will be measured using the guidelines under in the NMMP Green Book and OSPAR Joint Assessment and Monitoring Programme (JAMP).

The Environment Agency's Environmental Monitoring Manual (EA in prep-Roger Proudfoot, *pers comm*.) suggests a trigger point of 25% cover before management action is required.

3.4 Suggested techniques

Routine measurement is required to determine temporal trends, where the frequency will depend on the characteristic in question. Remote measurement and data logging devices will most likely be required to sample efficiently at an appropriate frequency.

Lack of surveillance of physical attributes during a monitoring cycle will dictate that any change noted by the biological monitoring are likely to have inadequate evidence to assess whether the change is natural or anthropogenic. Some changes in biology may be large but not part of a natural cycle and this can only be assessed if there is adequate surveillance of certain physical attributes and any significant anthropogenic threats.

4 Recommended visiting period and frequency of visits

4.1 Seasonal effects

Marine communities show seasonal patterns. Many marine organisms have seasonal reproductive patterns that can significantly alter the number of individuals present at different times of the year. Some polychaete worms have semelparous or 'boom and bust' life history strategies where the mature adults spawn synchronously and then die. Clearly, the number of adults present in the sediment will depend on the stage in their life cycle. Larval settlement and recruitment of juveniles to the population can result in a massive increase in the population size at certain times of the year. This phenomenon is often visible on mussel *Mytilus edulis* beds, where the entire surface may be covered with tiny mussels.

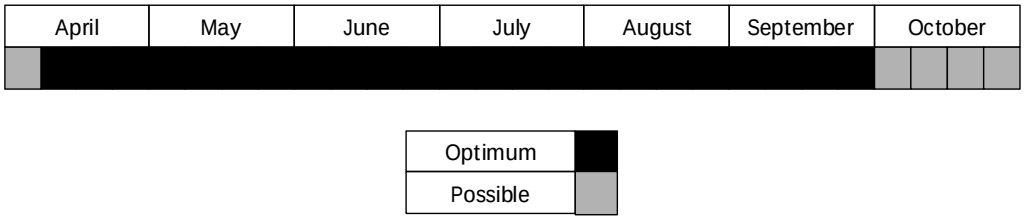
Algal communities show the most obvious seasonal trends and littoral sediment may support dense green algal mats during the summer months. Rapid growth of microscopic algae, and diatoms in particular, can change the appearance (colour) of littoral sediment (Patterson *et al.,* 1998). Similar changes may be caused by nutrient enrichment and therefore it is important to exercise a degree of caution when interpreting the results of a monitoring study.

Seasonal effects are also prevalent in eelgrass *Zostera* spp. communities. The blade density of the eelgrass itself will increase during the summer and then the decrease during the autumn and winter – a process known as dieback (Short *et al*., 1988). Eelgrass blades may support dense assemblages of epiphytic algae during the summer months.

4.2 Time of assessment

It is important to consider seasonal patterns when planning timing of a condition assessment. Sampling should be undertaken at the same time of year if seasonal variation is likely to affect an attribute. It may be necessary to specify the duration of a sampling window, for example to precede post-reproductive death in polychaete communities.

Recommended timing for survey (months - weeks)



4.3 Meteorological changes

Organisms living in littoral sediment are adapted to the incident environmental conditions, particularly salinity, sediment structure, wave exposure, tidal stream strength, temperature and tidal ranges. Extreme events affecting any of these factors can have major effect on the community composition of littoral sediment.

Meteorological changes that may result in gross visual changes to littoral sediment include:

- winter storms or river flood events may cause erosion that will affect the extent of the littoral sediment habitats
- storms or flood events may lead to the movement of river channels or drainage creeks that will change the topography (Wyn & Kay, 2000).
- a change in the rainfall pattern may lead to a change in sediment depositional patterns, changes in run-off and/or river flow rates.

Marine organisms are tolerant of fluxes in temperatures, however extremes of temperatures can devastate species populations in the intertidal and shallow subtidal. Extremely cold temperatures can freeze organisms and excessively hot temperatures can cause desiccation of organisms and bleaching of marine algae on the surface of sediment. Both stresses can cause mass mortality in marine organisms.

The UK sits on a biogeographic boundary between warm waters to the south and west and cold, arctic influenced waters to the north and east. This is reflected in the distribution of some littoral sediment species that reach their northern/southern limit around the UK coastline. Seawater temperatures are changing in response to climate change, which will affect the relative abundance and range of species present, allowing warm water species to advance north, and out-competing the colder water species (Hawkins *et al.*, 2001).

5 Additional information

5.1 Planning a sampling programme

The whole feature must be considered when planning a sampling programme. Clearly, this poses considerable logistical problems when dealing with very extensive sites (such as the Wash and Morecambe Bay). A monitoring strategy will need to encompass techniques to consider broad-scale, whole feature attributes and some detailed sampling to assess the biological quality (Wyn & Kay, 2000). Broad-scale maps can provide both data for the whole feature (extent, biotope distribution) and the necessary information to apply a stratified sampling programme to select locations to monitor sediment structure and the composition of biotopes *via* direct sampling.

If access by foot is restricted or impossible, it is possible to sample littoral sediment by boat at high water where there is sufficient tidal range. Small versions of ship-borne sampling devices are available, such as hand-operated grabs or corers, and a suction sampler (Mulder & Arkle, 1980). Note that sampling at high water does not allow any visual appraisal of the broad-scale character of littoral sediment.

DGPS should be used for recording position on extensive littoral sediment[12]. Whilst landmarks may often be extremely valuable when relocating stations, it is important not to rely on the location of features within sediment flats (creeks, scars, old tyres) as they are liable to change.

5.2 Health and safety

All fieldwork must follow approved codes of practice to ensure the health and safety of all staff. Risks specific to working on littoral sediment are detailed in the Marine Monitoring Handbook (Davies *et al.* 2001), the NMMP's Green Book[11] and references therein.

[12] See the Marine Monitoring Handbook Procedural guideline N^{o} 6-1.

6 Generic attributes table

The following table lists the generic attributes that should be used to define the condition of littoral sediment features.

For details of assessment techniques see Section 2 and Davies *et al*., 2001.

Table 1. UK GUIDANCE ON CONSERVATION OBJECTIVES FOR MONITORING DESIGNATED SITES

Interest feature: Littoral sediment

Equivalent Phase 1 category: H1 Intertidal mud/sand, shingle/cobbles, boulders/rocks.
Includes the following NVC types: SM1 *Zostera* communities (part) and SM2 *Ruppia maritima* salt-marsh community (part).

Includes the Habitats Directive Annex I habitat types: H1140 **Mudflats and sandflats not covered by seawater at low tide**, H1130 **Estuaries** (in part) and H1160 **Large shallow inlets and bays** (in part).

Reporting category: Littoral sediment

NOTES: The attributes apply to all sites with littoral sediment features except those with asterisks which may not be applicable to all sites, and should be selected only where they reflect the conservation interest of the individual site.

It is essential that the section in the marine introductory text entitled *Setting objectives and judging favourable condition* is read in conjunction with this table when selecting the attributes to judge the condition of the feature.

Attribute	Target	Method of assessment	Comments
Extent	No decrease in extent of littoral sediment.	Extent should be assessed periodically against a baseline map showing the distribution of littoral sediment, or through the review of any known activities that may have caused an alteration in extent. Possible sources of	Where changes in extent are known to occur due to cyclical natural processes, then the target value should accommodate this variability. If required a declining value may be established where sufficient information is available to predict a trend. Where the field assessment judges extent to be unfavourable, and subsequent investigation reveals the cause is clearly

Attribute	Target	Method of assessment	Comments
		baseline data are archive remote sensing, aerial photographs and intertidal resource mapping (see Davies *et al.*, 2001).	attributable to cyclical natural processes, the final assessment will require expert judgement to determine the reported condition of the feature. The feature's condition could be declared favourable where the officer is certain that the conservation interest of the feature is not compromised by the failure of this attribute to meet its target condition. Where there is a change outside the expected variation or a loss of the conservation interest of the site, (e.g. due to anthropogenic activities or unrecoverable natural losses) then condition should be considered unfavourable. Changes in extent would be considered unfavourable if attributable to activities which interrupt natural coastal processes e.g. hard sea defences.
Biotope composition of littoral sediment	Maintain the variety of biotopes identified for the site, allowing for natural succession/ known cyclical change.	Repeated assessment of overall biotope composition or a subset of biotopes identified for the site. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Where changes in biotope composition are known to be attributable to natural processes (e.g. winter storm/flood events, changes in supporting processes or mass recruitment or dieback of characterising species) then the target value should accommodate this variability. Where there is a change in biotope composition outside the expected variation or a loss of the conservation interest of the site, then condition should be considered unfavourable.
Sediment character: sediment type	No change in composition of sediment type across the feature, allowing for natural succession/known cyclical change.	Distribution of sediment types should be assessed across the whole feature and compared to baseline conditions. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Where changes in sediment type are are known to be clearly attributable to natural processes (e.g. winter storm/flood events, changes in supporting processes) then the target value should accommodate this variability. Where extreme events cause a change in sediment type, then this may have caused a change in the structure of the feature, which may lead to the condition of the feature being considered as unfavourable.

Attribute	Target	Method of assessment	Comments
Distribution of biotopes	Maintain the distribution of biotopes, allowing for natural succession/ known cyclical change.	Assessment of the distribution of biotope(s) identified for the site. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Where changes in distribution are known to be clearly attributable to cyclical succession or expected shifts in distribution (for example due to a movement of a drainage channel) then the target value should accommodate this variability. Where there is a change in biotope distribution outside the expected variation, or a loss of the conservation interest of the site, then condition should be considered unfavourable.
* Extent of sub-feature or represent-ative/ notable biotopes	No change in extent of the littoral sediment biotope(s) identified for the site allowing for natural succession/known cyclical change.	Assessment of the extent of biotope(s) identified for the site because of their nature conservation importance. For details of assessment techniques see Section 2 and Davies *et al*., 2001..	Where there clearly established natural variation in extent or in cyclical succession between biotopes, then the target value should accommodate this variability. Where there is a change in extent outside the expected variation or a change in the structure of the biotope leading to a loss of the conservation interest of the site, then condition should be considered unfavourable.
* Species composition of representa-tive or notable biotopes	No decline in biotope quality due to changes in species composition or loss of notable species, allowing for natural succession/known cyclical change.	Assessment of biotope quality through assessing species composition, where the biotope is representative of the site or contains a number of species of conservation importance. Assessing this attribute will require specialist taxonomic expertise. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Where a change in species composition is known to be clearly attributable to natural succession, known cyclical change or mass recruitment or dieback of characterising species, then the target value should accommodate this variability. Where there is a change in biotope quality outside the expected variation or a loss of the conservation interest of the site, then condition should be considered unfavourable.

Attribute	Target	Method of assessment	Comments
*****Species population measures -Population structure of a species	Maintain age/size class structure of a (named) species.	Population structure should be assessed in terms of viability of the named species identified for the feature. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Where there is a sizeable shift in the age/size class structure (i.e. loss of mature adults or recruitment failure) or if disturbance causes a species of nature conservation importance to be lost, or if there is a significant reduction in abundance, then condition would be considered unfavourable.
-Presence or abundance of specified species	Maintain presence or abundance of named positive indicator species. No increase in presence or abundance of named negative indicator species.	Assessment of the presence or abundance of positive/negative indicator species identified for the feature. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Increased abundance of negative indicator species i.e. those indicative of stressed habitats which would be detrimental to the feature as a whole, would also cause condition to be considered unfavourable.
*Topography	No change in topography of the littoral sediment, allowing for natural responses to hydrodynamic regime.	Tidal elevation and shore slope to be assessed periodically. For details of assessment techniques see Section 2 and Davies *et al*., 2001.	Obvious changes in topography in terms of an overall lowering (shallowing) of the shore slope may act as a trigger for further investigation. Scouring adjacent to sea defences, which lowers the shore slope, should be considered unfavourable. A suitable period over which to ascertain trends resulting in a net lowering of shore profiles is 5 years.
* Sediment character: Organic carbon content	Organic carbon content should not increase in relation to an established baseline.	Organic carbon content assessed in specified area. For details of assessment techniques see Section 2.	An increase in organic carbon due to natural events such as floods or storms is a normal change to the feature and may be considered favourable if it does not compromise the conservation interest of the feature. An increase in organic content due to sewage effluent or nutrient enrichment, causing a change in the infaunal community of the sediment and thus the functioning of the littoral sediment, will be considered unfavourable. Organic carbon content is likely to be assessed by specialists.

Attribute	Target	Method of assessment	Comments
* Sediment character: Oxidation-reduction profile (Redox layer)	Average depth to the top of the black layer should not increase in relation to baseline.	For details of assessment techniques see Section 2.	An increase in anoxic conditions due to natural events such as mass deposition of organic material following floods or storms is a normal change to the feature and condition may be considered favourable if it does not compromise the conservation interest of the feature. An increase in anoxic conditions due to sewage effluent or nutrient enrichment, causing a change in the infaunal community of the sediment and thus the functioning of the littoral sediment, should be considered unfavourable. Degree of oxidation/reduction reflects the oxygen availability within the sediment that critically influences the infaunal community and the mobility of chemical compounds.

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