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Common Standards Monitoring Guidance

for

Estuaries

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Common Standards Monitoring guidance for estuaries

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 guidance when setting attributes for estuaries.

1 Definition of an estuary

Estuaries are complex ecosystems linking the terrestrial and aquatic environments and are composed of an interdependent mosaic of subtidal, intertidal and surrounding terrestrial habitats. There is a gradient of salinity from freshwater at the head to increasingly marine conditions towards the open sea. Input of sediment from the river, shelter from wave action and often, low current flows lead to the presence of extensive sediment flats. Similar large geomorphological systems where seawater is not significantly diluted by freshwater are classified within the Annex I habitat *Large shallow inlets and bays***.** The intertidal and subtidal sediments of estuaries support biological communities that vary according to geographic location, the type of sediment, tidal currents and salinity gradients within the estuary. The parts of estuaries furthest away from the open sea are usually characterised by soft sediments and are generally more strongly influenced by fresh water.

Many habitats found within estuaries, such as intertidal mudflats and sandflats, sandbanks, saltmarshes and rocky reefs, are identified as notified features in their own right and are covered in separate guidance. Estuaries may also support populations of important species. The physiographical character of estuaries is similar to that of a large shallow inlet and bay but is influenced to a greater extent by freshwater. Thus the term 'Estuaries' here covers only the following habitat types:

Box 1. Habitats included in 'Estuaries'

Habitats Directive	BAP Broad habitat type[1]	BAP Priority habitat/Action Plan[1]	OSPAR Threatened Habitats[2]
Estuaries	Inshore sublittoral sediment Inshore sublittoral rock Littoral sediment Littoral rock	May include a wide range of priority habitats	Intertidal mudflats[3]

2 Attributes, targets and condition assessment

A condition assessment of Estuaries should be based on the attributes[4] and their associated targets derived from the generic attributes table (Table 1, Section 7) that are considered most likely to

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[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 –** and form the reporting categories used within the Site Condition Monitoring Programme.

[2] These are derived from a provisional list agreed by the OSPAR Biodiversity Committee at their Leiden Workshop, 5-9 November 2001, and therefore may change when the final list is agreed.

[3] The habitat originally proposed was 'estuarine intertidal mudflats' and was subsequently amended to 'intertidal mudflats', hence its inclusion in this guidance.

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 adequately the conservation interest of the feature, fully reflecting any local distinctiveness (see Section 3).

Selecting the attributes to define the condition of an estuary is often complicated by the fact that it may contain habitats and species that are notified features in their own right. It must be emphasised however, that the condition of these individual features does not automatically relate to the condition of the broader complex feature in which they are located. Furthermore, there may be other habitats and species integral to the condition of the complex feature that are not notified features, which should nevertheless contribute to the condition assessment. It is important to establish the relationship between the condition of these 'simple' features and the 'complex' feature prior to selecting the attributes to assess that complex feature's condition. Establishing this relationship requires a clear understanding of the key conservation interest of the complex feature. Staff should refer to the '*generic introduction for marine features*' for further guidance on selecting attributes to assess the condition of an estuary feature.

Estuaries often form part of very dynamic systems. They interact with other adjacent features such as salt marshes and sand dunes. The shape and functioning of the estuary system is therefore determined both by the coastal processes acting upon it and the influence of these adjacent habitats. The overarching objective for all of these features is to allow for 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. 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.

It is thought that many estuarine systems are subject to medium term (decades to centuries) cyclical changes in sedimentary regime, alternating between a system typified by net deposition to one typified by net erosion. This has a direct effect on mudflat topography, which in turn may influence sediment characteristics such as the drainage rate of interstitial water and hence influence the distribution of infaunal organisms. Changes in erosion rates may also influence the ratio of saltmarsh to mudflat area in the estuarine system. The possibility that these cyclical changes could be occurring should be considered when assessing the condition of the site, and known cyclical changes should be accommodated in target setting wherever possible.

3 Background, targets and monitoring techniques for individual attributes

Table 1 (Section 7) lists five attributes, four of which (*Extent, Distribution/spatial pattern of sub-features/biotopes, Salinity and Nutrient status*) are mandatory for all sites. The last is 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.

3.1 Extent

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

3.1.1 Background to the attribute

Some changes may be considered acceptable or 'natural' and may be attributable to the following:

[4] 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.*

- *Saltmarsh encroachment*

This is the colonisation of the littoral sediment part of the estuary feature by saltmarsh plants. The importance of this issue is dependent on whether the 'boundary' for the estuary feature includes the saltmarsh within it or whether it is outside. 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 cord-grass *Spartina anglica*, considered to be an invasive species that may impact on intertidal mud flats, pioneer and low-mid marsh communities. If this occurs a monitoring programme could be triggered and there may be a need for management action. An indicative target for *Spartina* has been set at less than 10 % expansion to pioneer saltmarsh in the last 10 years (see CSM saltmarsh guidance), 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 due to a natural process. Specialist advice is required when dealing with this issue. English Nature is currently producing a guidance note with regard to saltmarsh.

- *Erosion following winter storms or floods*

Wave energy or high tides/river levels during storm events may cause erosion of the littoral sediment part of the estuary feature, 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 the 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 (see Section 3.5. *Morphological equilibrium*). Where changes in extent are attributable to the estuary adjusting to equilibrium, then the condition of the feature should be considered favourable. Where this process is constrained by hard sea defences, then this would be considered as coastal squeeze (see below).

Where the field assessment judges the extent to be unfavourable, and subsequent investigation reveals that 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 if attributable to *coastal squeeze*, which is the term applied to the effect of hard defences (including beaches fixed in position by control structures) when they interrupt the natural response of the shoreline to sea level rise. A rise in sea level acts as part of the estuarine squeeze, attempting to move the intertidal zone upwards and inland. Under natural conditions estuarine ecosystems are capable of responding to such changes. This inland movement is, however, now generally prevented by sea defences such as sea walls or other embankments, which are often too steep to allow natural encroachment, restricting the natural landward retreat and resulting in the intertidal zone being 'squeezed'. This causes reduction in the extent of intertidal habitat as a result of the higher levels of energy occurring in the intertidal zone. Land-claim is part of a more general estuarine squeeze that is pushing the high water mark seawards (through land-claim, sea defences, barrages and rising sea levels) and low water mark landwards (through effects of dredging, barrages and rising sea-level).

3.1.2 Setting a target

In principle the target should be set at no loss of area of the whole Estuary feature during the monitoring cycle, but accommodating any known geomorphological trajectory. It may be necessary to set a target that declines in steps over each monitoring cycle, but this will depend on there being sufficient data available to predict (via a model) a downward trend in extent due to geomorphological trajectory[5]. Departure from this predictive target would then be a trigger for investigation and the condition of 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 associated with this feature (see above).

When measuring extent, the following issues should be considered:

- Check that all aerial photographs and broad-scale 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'

Targets	Comments
No change in extent of estuary feature set at 43,687 hectares	Condition would be judged unfavourable if change in extent due to factors other than cyclical natural processes or geomorphological trajectory is considered to have had an adverse effect on site integrity.

3.1.3 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 based on the absence of any known pressures or impacts. 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.

The extent of an estuary is unlikely to change significantly over time where pressures and impacts are low or absent, but nevertheless it needs to be measured periodically to inform target values.

Measuring the extent of an estuary requires the careful definition of boundary in relation to the seaward limit, the landward transition to the river, and the high water limit.

For those estuaries bounded by rocky shores or solid anthropogenic boundaries such as harbour walls or seawalls, measuring the extent may be a straightforward cartographic exercise using the most up-to-date maps of the area.

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

Estuaries with ‘soft’ boundaries such as saltmarsh may require a more sophisticated mapping exercise such as remote sensing, particularly in dynamic estuaries where tidal currents result in erosion and/or accretion of these ‘soft’ habitats. The position of the main estuary channel, and more likely the smaller creeks, may move considerably during a monitoring cycle, although the impact of such a change on the overall extent of the estuary may be negligible.

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).

3.2 Distribution/spatial pattern of habitats[6]

Distribution/spatial pattern of habitats is an essential component of the feature, representing the structure and particularly the function of an estuary and therefore **must be assessed for all sites.**

3.2.1 Background to the attribute

This attribute is concerned with the position of the target habitats and their spatial relationship to one another. This attribute ensures that the distribution of the features of conservation interest is maintained throughout the feature. Distribution refers to the geographic location of habitats throughout the feature, for example the “presence of muddy creeks in the upper third of the estuary”. Spatial pattern refers to the local zonation or juxtaposition of habitats at specified locations.

This attribute may highlight important structural and functional components of the feature, depending on the habitats chosen. If the ‘habitats’ of interest are biotopes, it is important to understand cyclical succession of biotopes. These cycles are normally an acceptable part of the interest of the feature and must be considered when phrasing target values. Biotopes are often defined by differing abundance of species; certain biotopes will cycle about each other, and may disappear and reappear over time. Their distribution may vary on a seasonal basis and this should be considered when setting targets and planning survey timing. A suite of the biotopes expected at the site should be listed with their “cyclical partners”.

Transitional (brackish water) communities are a defining component of estuarine ecosystems and their distribution in the estuary is an essential structural component of the feature.

The distribution/spatial pattern attribute may address all or only a subset of the habitats identified in the feature. A subset should be selected for the following reasons:

- The habitat is a qualifying feature (e.g. subtidal sandbank).

- The habitat has been highlighted in the site citation as being important and needing to be taken into account in the overall assessment of the estuary feature, but is a non-qualifying feature.

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[6] The term habitat is used generically to include the feature (whole Annex 1) or sub-features (biotopes incl. NVC types)

Assessing the distribution of habitats throughout the entire feature should highlight any progressive loss or change in the integrity of the feature. A change in this distribution may signal an important shift in the local environmental regime as a result of an anthropogenic activity: for example a shift in the intertidal sediment habitat could be due to extending coastal defences onto the intertidal mudflats and sandflats, causing a change in tidal flow and sediment deposition elsewhere within the feature.

This attribute complements an assessment of the 'Extent of sub-feature or representative/notable biotope' attribute identified for habitat types in Annex I of the Habitats Directive, assessed in their own right and covered in the separate guidance on littoral sediment, littoral rock and inshore sublittoral rock and sublittoral sediments. This attribute ensures that the distribution of the conservation interest is maintained throughout the feature.

Expected changes should be reflected in the target. However, where the field assessment judges the changes in distribution to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to cyclical natural processes or expected shifts in distribution (e.g. due to a movement of a drainage channel) then 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.

3.2.2 Setting a target

In principle the target should be set at no change in distribution/spatial pattern of habitats during the monitoring cycle. The target must consider any expected shift(s) in distribution and spatial pattern due to cyclical changes or an expected trajectory. It is possible to use an absolute measure or an index approach to measuring habitat distribution.

Normally a subset of the habitats present should be identified where the feature supports a diverse range of habitats. Alternatively, where appropriate, the overall sub-feature composition could be determined and specified. SSSI citations, SAC Regulation 33 packages, habitat maps, or more detailed survey records should help to determine the sub-features/biotopes of nature conservation importance within a site, which in turn will determine the target list of habitats. Due consideration should also be given to activities occurring within sites.

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

- Specify which habitats are to be addressed (all or a subset selected on the basis of the conservation interest of the feature.)
- Habitat distribution may change in response to extreme low frequency events such as increased storm occurrence.
- Is it logistically feasible to establish the distribution pattern over the whole site or should it be done within limited/indicative areas?
- Is the habitat transitional or likely to alter position in the dynamic estuarine environment? (e.g. gradual migration of intertidal sandbanks in response to tidal currents or sudden topographical changes in response to winter storms)

An example of how a target for this attribute might be expressed is shown in Box 3

Box 3 A site-specific target for the attribute ' Distribution/spatial pattern of habitats'

Target	Comments
Maintain the known distribution of the mussel beds such that they occur in the hard ground of the outer estuary.	Condition of the attribute should be designated as favourable if distributional changes are due to natural factors. These might include hydrological changes resulting in burial by sediment or fluctuations in predator populations and recruitment altering the extent of the bed. If distributional changes are due to anthropogenic pressures such as dredging or over-exploitation of the shellfish resource, condition should be designated as unfavourable

3.2.3 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. In such cases emphasis should be placed on assessing the continued distribution of those habitats of greatest conservation value. Within some sites these habitats may be clumped disproportionately within a small section of a larger site, and here it would be important also to include habitats and sampling locations representative of the remainder of the site. More detailed sampling effort should focus on those habitats of highest conservation value, and habitats considered to be most threatened by adverse anthropogenic activities.

Ideally, a mapping or inventory study of all habitats would be undertaken to provide baseline information to identify the conservation objective for the site-specific attribute. Such a study would also guide more detailed targeted studies to assess biological quality. DGPS should be used for recording position on extensive intertidal or subtidal habitats. Photographs and/or diagrams of characteristic topographical features should supplement maps.

All quantitative sampling must be effort-limited to ensure comparability between monitoring events. The sampling strategy will depend on the local topography: transects are more suited to steeply inclined habitats; a grid sampling strategy is appropriate to extensive level habitats.

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/spatial pattern of sub-features/biotopes are:

- 1-1 Intertidal resource mapping using aerial photographs;
- 1-2 Fixed viewpoint photography;
- 1-3 Seabed mapping using acoustic ground discrimination interpreted with ground truthing (AGDS);
- 3-1 *In situ* intertidal biotope recording (Grid sampling using effort-limited biotope id techniques);
- 3-3 *In situ* survey of subtidal (epibiota) biotopes and species using diving techniques (Transect survey using effort-limited biotope id techniques);
- 3-5 Identifying biotopes using video recordings (Point sample mapping using drop-down video data)
- 3-9 Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs (Point sample mapping from Grab sampling);
- 3-14 *In situ* survey of sublittoral epibiota using towed sledge video and still photography

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

- mosaicing side scan sonar images to map seabed features

- aerial photography and photogrammetry (air photo interpretation)
- satellite and airborne multi-spectral remote sensing (remote imaging)
- descriptive and quantitative surveys using remote operated vehicles (point sample mapping using ROV).

Note: Remote sensing techniques (AGDS/sidescan sonar) have a limited capability to discriminate between detailed biotopes and are more suited to broad habitat patterns.

Note: A transect-based sampling strategy is most appropriate to identify zonation patterns. Transects should be located throughout the feature using a stratified sampling strategy.

3.3 Salinity

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

3.3.1 Background to the attribute

Because one end of an estuary grades into fresh water and the other is open to the sea it follows that a salinity gradient of some form will exist along the estuary. One of the major characteristics of an estuary is the reduction in numbers of species with distance from the sea. This reduction has classically been attributed to a salinity effect. In most estuaries salinity changes are accompanied by changes in the suspended sediment (turbidity) and temperature, current speed, wave action and substrate type also change radically. The extent of stratification in an estuary is also an important parameter. The distribution of some species is likely to be affected by all these factors. Any changes in salinity, however, may affect the presence and distribution of species (along with recruitment processes and spawning behaviour).

Where the field assessment judges the salinity change to be unfavourable, and subsequent investigation reveals the cause is clearly attributable to 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 changes in salinity occur through adverse impacts (e.g. industrial discharges or water abstraction) a loss or shift in community structure may result, such that the conservation interest is adversely affected. Condition should then be judged as unfavourable. Staff should refer to the flow diagrams in the introductory text to the marine features for more information on these issues.

3.3.2 Setting a target

Patterns of salinity changes within estuarine systems are typically complex and dynamic. The salinity levels at any given location in an estuary will be influenced by tidal state (which itself may vary due to meteorological conditions) and by changes in the discharge rate of the river. As well as gradients along the main axis of the estuary, there may be gradients across the estuary due to the influence on local water flow patterns of topographical features such as sandbanks, bridge pilings etc. In calm, non-turbulent conditions vertical gradients in salinity may occur as a result of the density difference between marine and freshwater.

In order to establish a realistic target range of salinities for a specific sample station it will be necessary to refer to baseline salinity data taken at a range of tidal states and different weather conditions. Many estuaries have been intensively studied in the past and in these cases a suitable baseline dataset may be available. Where suitable data are unavailable it may be worth considering deploying a self recording salinity meter to record salinity fluctuations over the tidal cycle.

The targets should be selected to represent the limits of the range of the species/biotopes on the salinity gradient of the estuary; targets should confirm the presence of named species/ biotopes at selected locations along the length of the estuary. The species/ biotopes will be representative of a range of estuarine environments from fully marine to freshwater.

An example of how a target for this attribute might be expressed is shown in Box4.

Box 4 A site-specific target for the attribute 'Salinity'

Target	Comments
Readings should not deviate from the salinity range predicted for the site by the baseline data. Targets should confirm the presence of named species/ biotopes at selected locations along the length of the estuary	Notes should be made of local weather conditions, particularly wind strength and direction because of the potential that the predicted tidal cycle may be modified by high winds. Where readings are other than predicted, recent meteorological records and tidal gauges should be consulted to establish if high rainfall or pressure changes are responsible.

3.3.3 Suggested techniques

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

Suggested methods for measuring salinity, not detailed in the handbook are:

- CTD / salinity probe.
- Samples could be collected and subsequently analysed using a hand held refractometer.
- Routine monitoring of water chemistry parameters using *in situ* data loggers
- Sampling species/biotopes to ascertain whether they are representative of a range of estuarine environments from fully marine to freshwater.

3.4 Water quality

Water quality is an essential functional component of the feature and therefore **must be assessed for all sites.**

It is essential that a site-specific representation of this attribute is developed in relation to the actual conservation interest of the estuary feature, particularly taking into account any known or anticipated anthropogenic threats to the feature’s status. Furthermore, it may be necessary to include multiple water quality attributes to maintain the status of an extensive and/or complex feature.

3.4.1 Background to the attribute

Water quality is used as generic term to represent the physico-chemical composition of the fluid medium in recognition of its key functional role in determining the biological composition of the estuary ecosystem. Many estuaries are subjected to a suite of anthropogenic pressures and historically have received discharges of fluid waste directly from point source discharges or indirectly from diffuse run-off. The parameters known to influence the status of estuaries and/or their associated communities include both non-toxic (nutrient status, organic enrichment, suspended solids) and toxic contamination. This is not an exhaustive list and additional parameters may be appropriate depending upon the conservation interest of the estuary feature.

The causal relationship between water quality parameters and observed biological changes in marine communities is often unclear or unknown. Acute effects in response to a known impact are often straightforward where there is mass mortality, but chronic effects from continued low exposure to a compound that lead to more modest physiological changes are difficult to detect. This attribute should therefore be considered as a precautionary or 'early warning' measure of ecosystem state, particularly when biological attributes appear favourable yet water quality is clearly unfavourable.

3.4.1.1 Nutrient status/Organic Carbon Budget

Nutrient status is important in estuaries because it drives primary production both in the water column and in the benthos. This, in turn, manifests itself in the production of organic carbon that deposits in estuarine sediments in combination with other anthropogenic sources of carbon input. However, the expression of this primary production is dependent on limiting factors such as the residence time of the water, the turbidity of the estuary and levels of nutrients such as nitrogen, phosphorus and silica. Changes in the nutrient status of a system may involve biological change even if the system does not become eutrophic. More information on the impacts of nutrients on marine water quality is detailed in a water quality overview document produced under the UK marine SACs project (Hailey, N. *et al.* 2003) plus the guidance documents being prepared for the Water Framework Directive and the OSPAR assessments[7].

As a result of the combined factors of tidal oscillations and riverine input, estuaries tend to retain organic matter. As a consequence, estuaries tend to have high overall productivity and are rich in nutrients. In most cases the main source of nutrients entering an estuary are from fresh water inputs (rivers), direct discharges (e.g. sewage treatment works) and coastal water exchange. Other potential nutrient sources may include groundwater seepage, and atmospheric deposition. A significant proportion of the nutrient load arising from river inputs can often be attributed to diffuse agricultural inputs, and hence nutrient levels in estuarine waters could be largely determined by the rate of freshwater input and the nature of the river catchment area. If the river catchment area is fertile, intensively farmed land then higher quantities of nutrients would be expected to enter the estuary than if the catchment is mountainous and sparsely populated. However, other factors may influence estuarine nutrient levels, including tidal flushing rate of the estuary (which determines the retention time of nutrients within the system), seasonality (which influences the rate of nutrient uptake by actively growing organisms) and climatic factors (such as temperature and rainfall).

There are many indicators that could be chosen to assess the impact of nutrients and work is currently being undertaken to inform the Environment Agency's review of consents, in addition to the development of attributes and indicators to implement the Water Framework Directive.

An example indicator of nutrient pollution is the presence blanketing mats of algae (*Enteromorpha* sp., *Vaucheria* sp. and *Ulva* sp.). On eelgrass beds, such mats can cause shading of the eelgrass, inhibiting its photosynthesis. Nutrient enrichment may also break down the eelgrass immune system, making it more susceptible to disease (Den Hartog, 1988). Where algal mats lie on sediment habitats, the covering of algae over the sediment surface can reduce the dissolved oxygen exchange between the sediment and the water column, leading to the establishment of anoxic conditions in the sediment, thus increasing BOD and the release of ammonia and hydrogen sulphide which can be toxic to aquatic life. Some benthic invertebrate species are tolerant of the effects of eutrophication, with the result that they thrive at the expense of the more sensitive species and so alter community composition. Other indicators are increased frequency or duration of phytoplankton blooms and an increase in the chlorophyll-a concentration in the water column.

[7] For example the CEFAS report *Establishing practical measures for the assessment of eutrophication risks and impacts in Estuaries* [CEFAS Contract Report C1706].

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). When a system is nutrient-rich the nitrogen content of the algae is high and consequently extensive algal mats flourish (Schramm & Nienhuis, 1996). However, extent or presence/absence of algal mats alone will not necessarily indicate nutrient enrichment, and algal growth *per se* cannot be expressed in terms of nitrogen inputs (Khan, 1998). It is often a change in the location or extent of green algal mats that indicates a change in the nutrient loading to the estuary and thus often used as an indicator of eutrophication. The extent of mats may be used *in conjunction* with the nutrient content of the mats (for example, a simple C:N ratio of the algal material) to define the eutrophication status (Janet Khan SNH, *pers comm*.). The growth of algal mats tends to be governed by distinct temperature and light intensity ranges (Khan, 1998). Algae bloom in response to light and temperature, but in optimum environmental conditions if there is a high input to the system then this is reflected in an extensive growth of green algal mats. Conversely, low or no inputs to the system generally results in no, or restricted growth of green algal mats (Schramm & Nienhuis, 1996). 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). Given the complexities of using algal mats as indicators of nutrient pollution, other early warning indicators include increased frequency or duration of phytoplankton blooms and an increase in the chlorophyll-a concentration in the water column. The assessment of nutrient status should include consideration of all primary and secondary ecological impacts.

There may be other indicators that are more appropriate to an estuary, particularly where the necessary data are collected by other monitoring or surveillance programmes. For instance, fish assemblages/migratory fish/invertebrate populations may be indicators of nutrient status. Research by Dr Peter Henderson on the observed changes in fish and invertebrate populations retained on cooling water intake screens for power stations in the Severn Estuary indicated that such changes are linked to changes in nutrient inputs to the river (Gabrielle Wyn CCW, pers. comm.).

Where the field assessment judges nutrient status to be unfavourable, further investigation will be necessary to identify the cause and then expert judgement will be required to determine the reported condition of the feature. Where there is a change outside the expected variation or a loss of the conservation interest of the site, (e.g. nutrient levels increase due to anthropogenic factors such as changing agricultural practices or increased effluent discharge) then condition should be considered unfavourable. It should be noted that the source of undesirable inputs may be in the river catchment area a considerable distance from the estuarine site itself. Staff should refer to the flow diagrams in the introductory text to the marine features for more information on these issues.

3.4.1.2 Water clarity

Turbidity levels are usually much higher in estuaries than those in adjacent coastal waters thus reducing water clarity. The main source of turbidity is likely to derive from re-suspended sediments and fluvial loads although plankton blooms may be a contributory factor in spring and autumn. Hard coastal defences such as sea walls and groynes deflect wave energy further along the coast, which can lead to scour of saltmarsh and littoral sediments, causing a re-suspension of sediment. Sediment can be transported into the estuary from land drainage and sewage outfalls, and the discharges themselves may scour the saltmarshes and sediments, forcing sediment into suspension. Turbidity caused by re-suspension of sediments results in associated effects of increased oxygen demand, release of nutrients and potentially toxic substances. 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. Most estuarine communities are used to turbid conditions and increases from man-induced sources are likely to be tolerated. However, increases in turbidity levels brought about by activities such as dredging and disposal may, under certain conditions, have adverse effects on filter-feeding organisms, clogging feeding or respiratory structures. Increases in turbidity may also reduce light penetration through the water. This may reduce the growth rate of organisms dependent on sunlight for photosynthesis.

3.4.1.3 Toxic contamination

Many estuarine species and communities are highly sensitive to toxic contamination through the introduction of metals or synthetic compounds such as pesticides, PCBs and biocides such as TBT. Metals such as copper, lead and aluminium can be particularly toxic to invertebrates and fish under acid conditions either from naturally acid riverine inputs or from atmospheric pollution. Many synthetic compounds such as PCBs are known to have toxic effects, even in low concentrations, and high levels of bioaccumulation can occur. Many benthic organisms such as molluscs are poor at regulating their uptake of contaminants. The potential effects of toxic pollutants vary according to the state and availability of the compound and the characteristics of the receiving environment. Where the effects are lethal and result in the removal of individual species, key grazers or predators may be lost and a dominance of pollution-tolerant organisms may result. In sheltered, low energy environments such as estuaries, muddy sediments can act as a contaminant sink. Hydrophobic contaminants bind to fine sediments and may then be remobilised if the sediment is disturbed (e.g. by dredging) making them available once more as potential pollutants. Toxic contamination can reach the feature from point and diffuse sources, such as land-based discharges, run-off from roads, water-based discharges (e.g. from ships or anti-fouling paints) and atmospheric deposition.

Where toxic contamination through adverse impacts causes a loss or shift in community structure such that the nature conservation interests of the site are affected, then condition should be judged as unfavourable. The review of consents process by the Environment Agency is taking steps to address these issues in SACs. Environmental Quality Standards (EQS) have been established for some toxic compounds although their use in assessing ecosystem health is subject to some debate. The Review of Consent process would assume that a failure in EQS amounts to an ‘adverse effect on site integrity’. It will be necessary to seek expert judgement to assess whether available EQS are relevant to the conservation interest of the feature and therefore whether an EQS failure will influence the assessment of condition.

3.4.2 Setting a target

The specific representation of this attribute will depend on the perceived threat to the conservation interest of the feature. For many marine communities, the precise water quality requirements are unknown and therefore the actual attribute selected, and its target condition will require specialist input and should be subject to regular review. Staff in the environmental protection agencies[8] have significant expertise on this topic and should be consulted wherever possible. 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. Furthermore, targets must be set within the wider context of the status of the whole estuary rather than simply considering any local ‘problem areas’. Whether the long-term trend in water quality is improving, static or deteriorating will need to be ascertained and taken into account.

Water quality is an integral part of the Environment Agency’s Review of Consents under the Habitats Regulations, in addition to other European Directives (Water Framework Directive, Urban Waste Water Treatment Directive) and International Conventions (OSPAR Convention). These legislative drivers are deriving international and/or nationally agreed standards in relation to eutrophication and hazardous substances. Comprehensive research programmes are or being established to fill gaps in our

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[8] Environment Agency, Scottish Environmental Protection Agency, Environment and Heritage Service, Northern Ireland, CEFAS, Fisheries Research Services and Department for Agriculture and Rural Development (Northern Ireland) have considerable expertise in the effect of chemical inputs and the disposal of spoil waste to marine systems.

knowledge of the effects of these compounds on marine systems. It is vital that common standards monitoring of protected sites links with, and uses the outputs from, these initiatives.

It will often be impossible to set a target value representing the baseline condition for water quality attributes because their status at the point of designation may not be known. Under such circumstances, the target condition should where appropriate default to the international or national standards described above until sufficient local data are available to set site-specific targets. Common standards monitoring will then take the form of measurements to assess compliance with the standard, rather than a comparison with a baseline.

The following text provides guidance on setting site-specific targets where sufficient local data are available. It focuses on nutrient status in recognition of its perceived importance in assessing status of estuaries, although similar principles will apply to other water quality measures.

Nutrient concentrations could be measured directly in water or in appropriate biota (for example green algae), or assessed indirectly using one or more of the indicators mentioned in the previous section (for example phytoplankton populations, chlorophyll-a concentrations, or the presence/thickness of green algal mats). Selecting an appropriate measure will require some knowledge of the likely effect of changing nutrient concentrations on the conservation interest of the feature. For example, benthic communities in littoral sediment will be adversely affected from smothering by dense green algal mats; seagrass beds or algal communities would be affected by reduced turbidity caused by phytoplankton blooms.

Setting a target for phytoplankton abundance and/or species composition will require access to a long term dataset and an understanding of how this links to the conservation interests of the feature. Where such datasets are available it is often possible to identify regular patterns which are site or region specific. If suitable baseline data are unavailable it is unlikely that meaningful abundance targets can be established for phytoplankton, however targets derived for species composition or biomass may still be of use. A surrogate for phytoplankton abundance could be chlorophyll levels as setting targets for phytoplankton abundance may only be appropriate if the residence time of water and other factors such as light levels allows primary productivity to respond to the nutrient status within the estuary. CEFAS and the Environment Agency are establishing phytoplankton baseline levels as part of the implementation of the Water Framework Directive.

Setting a target for changes in extent of algal mats will rely on baseline data derived from mapping surveys and/or aerial photography, plus data on the concentration of nutrients in algae. In most cases the conservation agencies will have no baseline data and may rely on targets derived from other organisations. If baseline data represent only a single time point it will be difficult to establish a target range for extent that encompasses seasonal and inter-annual variability. It is probable that the target will require revision as further data are accumulated during the monitoring process. If an increase in extent is identified this should trigger a more intensive investigation to assess whether the increased coverage is really indicative of eutrophication. The C:N ratio of the algal mat should be assessed at the beginning of the next growing season (April/May), but in the first instance the algal mat biomass should be assessed and levels above 100g per m^2 would be regarded as evidence of eutrophication. Studies being undertaken through the Environment Agency's Review of Consents are developing targets and thresholds for assessing risk and impact of eutrophication in estuaries. It may also be necessary to set a minimum extent for algal mats to represent an adverse reduction in the available nutrients within the estuary system. Such targets would require a detailed understanding of the nutrient budget for the estuary, and a clear understanding of the link between nutrient concentrations and algal biomass.

An example of how a target for water quality in the form of nutrient status might be expressed is shown in Box 5.

Box 5 A site-specific target for the attribute' Nutrient status/Organic Carbon budget'

Target	Comments
Extent of algal mats should not deviate significantly from baseline levels recorded in 2000.	Significant changes in algal mat extent should trigger a more intensive investigation. This could involve assessing algal mat biomass (>100g per m^2 would give cause for concern) or direct measurements of phytoplankton biomass or nutrients, to compare to an established baseline. Algal mat C:N ratio could be assessed at the beginning of the next growth season to establish if nutrients are internally cycled or derived from external sources. Eutrophication due to effluent discharge or agricultural run-off will result in the attribute being designated as unfavourable. Significant changes from baseline will trigger site visit to ascertain algal mat biomass. Reference to aerial photographs and baseline data from Bunker, Moore & Perrins (2001).

3.4.3 Suggested techniques

Water quality monitoring is an integral part of both existing and emerging statutory monitoring programmes undertaken by the environmental protection agencies**Error! Bookmark not defined.**. For example, nutrients and hazardous substances are measured annually by the National Marine Monitoring Programme (NMMP) at coastal and estuarine stations to provide data for the UK to comply with the OSPAR requirements. .Information on the sampling and analytical procedures is available in the Green Book, which is available from the NMMP web site.[9] Similarly, the Water Framework Directive classification of status will require measures of nutrient status, hydromorphological parameters, macroalgae, phytoplankton and hazardous substances.

Wherever possible, common standards monitoring of protected sites should use the data and assessments of water quality undertaken by these other statutory programmes. Any deviation from the reference conditions/standards within these programmes could provide a trigger for more intensive biological monitoring under the Common Standards Programme.

Biomarkers are emerging and potentially important tools to assess sub-lethal effects from toxic contaminants. They are currently mostly used as a "weight of evidence" tool, for instance where there is a contaminant "hot spot", biomarkers could validate biological effects and act as an early warning indicator of harm - potentially at the population level. They have been deployed by organisations such as Plymouth Marine Laboratory and CEFAS to look at the effects of specific chemical exposure and general health. To date biomarkers have had little use in the "regulatory" sense as there are no robust stand-alone tools yet available. Consequently their use in condition assessment at the present time should be non-prescriptive. Information on biomarkers could be used as supporting evidence depending on interest features and hazards etc. English Nature have recently undertaken a project and held a workshop on the use of biomarkers, and they are considering their potential use in the Fal estuary SAC (Michael Coyle, English Nature, pers. comm).

If existing programmes cannot deliver appropriate monitoring data, conservation agency staff will require specialist advice before embarking on a new monitoring programme. The conservation

[9] See **http://www.marlab.ac.uk/NMPR/NMP.htm** for information on the NMMP and **http://www.marlab.ac.uk/greenbook/GREEN.htm** for the Green Book.

agencies should establish close links with other agencies to participate in any review of the coverage and location of existing monitoring stations and to encourage new or re-located stations to be positioned within marine SAC.

3.5 Morphological equilibrium

Examination of estuaries around the world has shown that there is a relationship between cross sectional areas of the estuary mouth and the size of the tidal prism (The change in the volume of water covering an area between a low tide and the subsequent high tide.)

Anthropogenic activity has significantly altered the tidal prism for some estuaries (e.g. by land claim) and this has caused a deviation from this relationship. Where there are large deviations from the relationship, the estuary will try to restore this relationship through sedimentation or erosion. This process may take hundreds of years to reach equilibrium.

Morphological equilibrium 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.

3.5.1 Background to the attribute

Estuary morphology – the relationship between its physical form and function – was considered an appropriate attribute to encapsulate the ecological status of an estuary (Coastal Geomorphology Partnership, 1999). In simple terms, estuary morphology is the form taken by the bed and banks of the estuarine channel. These views are based on *regime theory,* which includes the hypothesis proposed by O'Brien. Initial sampling should establish the bathymetry of the estuary and from this the tidal prism/cross section (TP/CS) ratio can be calculated. Depending on the ratio that emerges it should be possible to establish where the site sits in relation to the predicted ratio – the level of deviation and subsequent deviations tells us whether the site is moving towards or away from morphological equilibrium. Also, the TP/CS ratio can be calculated at any point along the estuary and can be used to predict its desired morphology, assuming no anthropogenic modification.

The TP/CS ratio should be assessed once to establish if the site deviates from the expected equilibrium level because of historical or geological factors. From then on measures could be taken on a routine basis, if this is deemed necessary to predict ongoing changes in estuary dynamics or if there is reason to believe it is being artificially altered.

- *Changes in estuary morphology*

Estuaries have a natural tendency to accumulate sediment (Roger Morris 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. The characteristic morphology provides the diversity of water depths, current velocities and substrate types necessary to fulfil the migratory requirements of estuarine species.

Where changes, principally in tide and wave forces, are attributable to the estuary adjusting towards morphological equilibrium, then the condition of the feature should be determined favourable and the target should accommodate this geomorphological trajectory.

Regime theory provides a simple and effective method of predicting equilibrium morphology in estuaries. The approach may be used both to assess differences between estuaries and within given estuaries. Not all estuaries have reached morphological equilibrium, and in the case of those that have not, the factors may be natural rather than anthropogenic. Dis-equilibrium is not necessarily brought about by human interference in the system. In some estuaries natural changes are proceeding, that will eventually lead to the attainment of equilibrium. Either the lack of naturally occurring sediment is a factor behind the absence of significant areas of mudflat and saltmarsh in many south western estuaries; or the size of the initial estuary basin is such that this process has not been accomplished.

3.5.2 Setting a target

The TP/CS ratio should be assessed to establish a target from which deviations from the expected equilibrium can be measured.

Specialist guidance is required to set appropriate targets and the results will need to be provided to conservation officers before the feature can be assessed.

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

Box 1 A site-specific target for the attribute 'Morphological equilibrium'

Target	Comments
Intra- and inter-estuarine TP/CS ratio should not deviate significantly from an established baseline, subject to natural change.	Where changes are attributable to natural processes, then the condition of the attribute should be judged as favourable. Changes would be considered unfavourable if attributable to novel anthropogenic developments resulting in changes to estuarine sediment dynamics. The continuation of established practices such as the maintenance dredging of navigational channels will only be regarded as unfavourable if it can be demonstrated that the practice is likely to cause a net deterioration of the site. See **www.hrwallingford.co.uk/projects/ERP/doclist** for a practical example of the application of O'Briens rule.

3.5.3 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 for measuring morphological equilibrium, not as yet detailed in the handbook are:

- LIDAR
- measuring bathymetry using standard hydrographic techniques (bathymetric mapping)
- using current meters
- using tide tables.

4 Other environmental and physical parameters

Although condition assessment will look at the attributes specified 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. Such attributes are considered site-specific, to highlight local distinctiveness when assessing the overall conservation value of a site, and should only be included 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 that a reliable method of measurement is available, since a failure to meet the target condition will render condition unfavourable.

Parameters known to influence the status of estuaries and/or their associated communities include tidal regime, hydromorphological changes including man-made structures and sediment supply. 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. Appropriate site-specific attributes should be derived to reflect the potential influence of the environmental parameter on the conservation interest of the feature.

5 Recommended visiting period and frequency of visits

5.1 Seasonal effects

Estuarine communities show seasonal patterns. Many of these are regularly cyclic and variations in river flow, tidal motion, daylight and wind stress are the principal agents. Marine organisms have seasonal reproductive patterns that can significantly alter the number of individuals present at different times of the year. Further information on seasonal effects is covered in the separate guidance on littoral sediment, littoral rock and inshore sublittoral rock and sublittoral sediments.

Algal communities show some of the most obvious seasonal trends. Banks of loose stones and gravel are often sufficiently seasonally stable to support dense assemblages of ephemeral algae. Littoral sediments 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 sediments (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. Mud veneers and layers of leaf litter from river flood events can also influence the surface appearance of the sediment.

Seasonal effects are also prevalent in seagrass communities. The blade density of the seagrass itself will increase during the summer and then decrease during the autumn and winter – a process known as die-back (Short *et al*., 1988). Seagrass blades may support dense assemblages of epiphytic algae during the summer months, which then decline during the winter.

5.2 Time of assessment

It is important to consider seasonal patterns when planning timing of a condition assessment. Sampling should always be undertaken at the same time of year if seasonal variation is likely to affect an attribute. Seasonal changes in seagrass have important consequences for the timing of remote sensing campaigns because the spectral signature of the seagrass will change between summer and winter. (Pooley & Bamber, 2000).

It is important to synchronise timings with previous data collected at the site, taking into account the aforementioned seasonal effects. See also guidance on littoral sediment, littoral rock and inshore sublittoral rock, inshore sublittoral sediment and saltmarsh for timings of assessment.

5.3 Meteorological changes

Tidal range is an important factor in understanding estuarine processes and their distribution. This determines the velocity of tidal currents and residual current velocities and therefore the rates and amounts of sediment movement. Both monthly and annual tidal cycles will affect estuarine habitats and therefore any monitoring programme must be carefully planned and implemented to take account of tidal effects.

Variations in salinity are a key factor determining the character and spatial patterns of the biotic assemblages within an estuary. The volume of freshwater entering the estuary (normally a reflection of rainfall patterns) and the tidal cycle determine ambient salinity at any point within an estuary. Both factors are subject to seasonal variation and therefore ambient salinity will show a strong seasonal pattern (Figure 1).

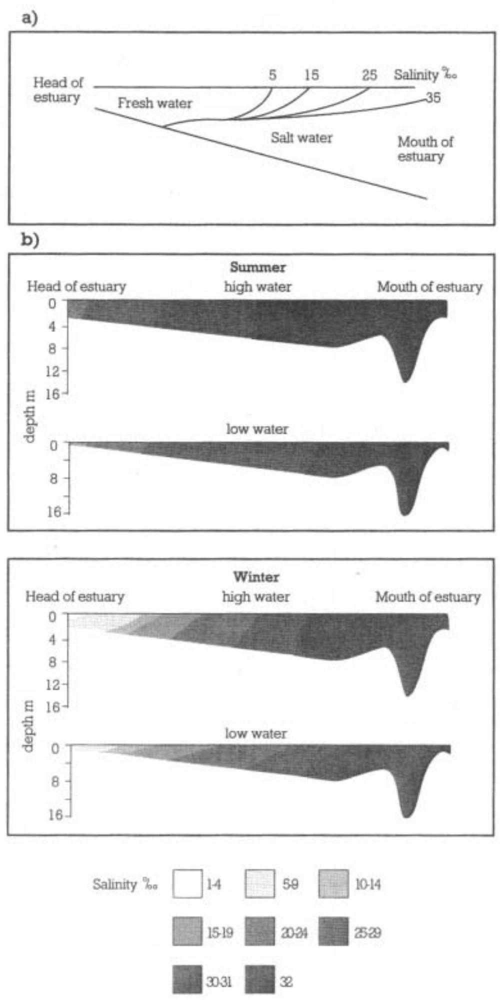

Figure 1 Seasonal changes in salinity in an estuary (from Davidson *et al.*, 1991)

Periods of reduced water flow can lead to marked improvements in water clarity. This must be taken into account if monitoring water clarity as an attribute, and will affect the timing of any remote sensing or SCUBA diving campaigns.

Organisms living in littoral sediments 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 sediments.

Storm events can have a massive effect on marine communities through the removal of species either by direct abrasion, or through damage from wave-borne debris (e.g. logs, rocks, sand). This episodic removal of species allows for a succession of marine communities from the ephemeral, fast growing to the eventual re-establishment of a stable community, the composition of which will be influenced by the supply of available larvae at that time. Storm events will have a profound effect on intertidal and shallow subtidal communities, but have a lesser effect on the deeper circalittoral benthic communities. Storm events can also mobilise sediment, thereby reducing water clarity and reducing the light available for algal growth.

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).

6 Additional information

6.1 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 for applying a stratified sampling programme to select locations to monitor sub-features. Further information on this can be found in Sanderson *et al.* (2001), *Section 1.3: Providing a background for planning monitoring trials.*

An estuary may contain other marine Annex I features (e.g. mudflats and sandflats, subtidal sandbanks, and reefs). Advice on the monitoring of saltmarsh habitats is provided by Scottish Natural Heritage (Ecoscope, 2000). Each estuarine attribute will have its own inherent source of variability that must be addressed during data collection and subsequent interpretation of the results. A monitoring programme must consider the whole estuary, even where it may contain other Annex 1 features since these notified features will have their own dedicated monitoring programme. An estuary's monitoring programme may therefore be an aggregation of both the sampling programmes for a range of Annex 1 features in their own right and a dedicated sampling programme for additional features of the whole estuary.

Land surrounding estuaries is often under private ownership and therefore it will be necessary to seek the landowner's permission to gain access to the shore, unless access is possible by boat. Gaining access to estuarine intertidal and subtidal habitats is subject to the issues described under the Guidance on *littoral rock and inshore sublittoral rock, littoral sediments* and *inshore sublittoral sediments*, and are therefore not repeated here.

DGPS should be used for recording position, particularly on extensive intertidal flats or open sea areas at the mouth. Where dGPS is used for site location, it is vital that the necessary variables (often settings of the machine itself) influencing the position resolution are accurately recorded. These records will be vital for accurate future location of the site. Permanent marking of sampling stations is very difficult in dynamic environments where the substrata are mobile. Garden canes (1.5m long) have been used successfully to mark stations in the Wash over a period of three years (Yates *et al*., 2000). For less dynamic habitats, sites may be marked with acoustic transponders (Sanderson *et al*., 2000) or curly whirlies[10] or ‘nylon whips’ attached to sub-surface blocks.

6.2 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 estuaries are similar to those on littoral sediments and are detailed in the Marine Monitoring Handbook (Davies *et al*,. 2001), the NMMP’s Green Book**Error! Bookmark not defined.** and references therein.

Some sampling in estuaries will involve SCUBA diving techniques. All diving operations are subject to the procedures described in the Diving at Work Regulations 1997[11] (see: **http://www.hse.gov.uk/spd/spddivex.htm**) and must follow the Scientific and Archaeological Approved Code of Practice[12] (**http://www.hse.gov.uk/spd/spdacop.htm - a**).

[10] Plastic corkscrews that are screwed down into the sediment: see Fowler, S L (1992) *Marine monitoring in the Isles of Scilly 1991*. English Nature Research Report No. 9. English Nature, Peterborough.

[11] The Diving at Work Regulations 1997 SI 1997/2776. The Stationery Office 1997, ISBN 0 11 0651707.

[12] Scientific and Archaeological diving projects: The Diving at Work Regulations 1997. Approved Code of Practice and Guidance – L107. HSE Books 1998, ISBN 0 7176 1498 0.

7 Generic attributes table

The following table lists the generic attributes that should be used in conjunction with those attributes highlighted from sub-feature guidance to define the condition of the entire Estuary Feature.

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: Estuary

Equivalent Phase 1 category: H1 intertidal, and H2 saltmarsh, K Marine

Includes the following NVC types: various SM, MG and S types

Includes the Habitats Directive Annex I habitat types: Estuaries

Reporting category: Littoral sediment

NOTE: The attributes apply to all sites with Estuary features <u>except</u> the one with an asterisk, which may <u>not</u> be applicable to all sites, and should be selected <u>only</u> where it reflects 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.

Attributes	**Target**	**Method of assessment**	**Comments**
Extent	No change in extent of estuary feature	Assessment of extent should be measured periodically against a baseline map/aerial image or through the review of any known activities that may have caused an alteration in extent. Possible sources of baseline data are archive remote sensing, aerial photographs and intertidal resource	Where changes in extent are known to occur due to cyclical natural processes, then the target value should accommodate this variability. If appropriate, a declining value may be established where sufficient information is available to predict a trend. Where changes in extent are clearly

Attributes	Target	Method of assessment	Comments
		mapping. For details of assessment techniques see Section 3 and 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, land reclamation)
Distribution/spatial pattern of habitats	Maintain the pattern of distribution of predominant habitats throughout the feature.	Assessment of the distribution of habitats identified for the site. Confirm the presence of named habitats at selected locations along the length of the estuary. The habitats will be representative of a range of estuarine environments from fully marine to freshwater. The sites will be selected to represent the limits of the range of the habitats along the salinity gradient of the estuary	Where changes in distribution/spatial pattern are clearly attributable to cyclical succession or expected shifts in distribution, or they occur as a consequence of natural geomorphological changes in the estuary (e.g. change in the position of the low water channel) then the target value should accommodate this variability. Where there is a change in distribution/ spatial pattern outside the expected

Attributes	Target	Method of assessment	Comments
		For details of assessment techniques see Section 3 and Davies *et al*., 2001.	variation or a loss of the conservation interest of the site, possibly as a consequence of anthropogenic developments, then condition should be considered as unfavourable.
Salinity	Salinity gradient throughout the estuary should not deviate significantly from an established baseline, subject to natural change and taking into account natural change in the area of transition from fully marine to freshwater environments.	Assessment of salinity at key locations in the estuary, measured periodically throughout the reporting cycle Confirm the presence of named species/ biotopes at selected locations along the length of the estuary. The species/ biotopes will be representative of a range of estuarine environments from fully marine to freshwater. The sites will be selected to represent the limits of the range of the species/biotopes on the salinity gradient of the estuary. For details of assessment techniques see Section 3 and Davies *et al*., 2001.	Where changes in salinity are due to natural processes, such as high rainfall, then this will be considered to be a normal change to the feature and condition may be considered favourable if it does not compromise the conservation interest of the feature. Where changes in salinity through adverse impacts (e.g. industrial discharges, water abstraction) cause a loss or shift in community structure, such that the conservation interest is adversely affected, then condition should be judged as unfavourable.
Water quality *The specific representation of this attribute will depend on the local conservation interest of the feature and take into account any perceived threat to the system.*	Target values should default to appropriate national or international standards where appropriate. If sufficient local data are available to establish the baseline condition, site-specific targets can be set.	Water quality parameters could be assessed directly using in water measurements or in appropriate biota, or using one or more indicators (for example, indicators of nutrient status are phytoplankton levels, chlorophyll-a concentrations or through the presence/thickness of green algal mats) For details of assessment techniques see Section 3.	Water quality standards are currently being established by the environmental protection agencies**Error! Bookmark not defined.** for European Directives (Water Framework Directive, Urban Waste Water Treatment Directive) and the OSPAR Convention. Monitoring data are or will be available from these agencies to support feature assessment under common standards

Attributes	**Target**	**Method of assessment**	**Comments**
			monitoring. In all cases, local measurements should be compared with regional or national assessments to establish whether any local changes are part of a wider trend. Eutrophication due to effluent discharge or agricultural run-off will result in the condition of the attribute being designated as unfavourable.
Water quality *The specific representation of this attribute will depend on the local conservation interest of the feature and take into account any perceived threat to the system.*	Target values should default to appropriate national or international standards where appropriate. If sufficient local data are available to establish the baseline condition, site-specific targets can be set.	Water quality parameters could be assessed directly using in water measurements or in appropriate biota, or using one or more indicators (for example, indicators of nutrient status are phytoplankton levels, chlorophyll-a concentrations or through the presence/thickness of green algal mats) For details of assessment techniques see Section 3.	Water quality standards are currently being established by the environmental protection agencies**Error! Bookmark not defined.** for European Directives (Water Framework Directive, Urban Waste Water Treatment Directive) and the OSPAR Convention. Monitoring data are or will be available from these agencies to support feature assessment under common standards monitoring. In all cases, local measurements should be compared with regional or national assessments to establish whether any local changes are part of a wider trend. Eutrophication due to effluent discharge or agricultural run-off will result in the condition of the attribute being designated

Attributes	**Target**	**Method of assessment**	**Comments**
			as unfavourable.
*Morphological equilibrium	Maintain the characteristic physical form and flow of the estuary. Maintain the planimetric form (width as defined by its mudflats and, if present, its salt marshes).	The TP/CS ratio of selected sites along the estuary should periodically be assessed. The horizontal boundary of mudflats/saltmarsh interface and the distribution of sandbanks and drainage channels should be measured periodically against an aerial image. For details of assessment techniques see Section 3 and Davies *et al*., 2001.	Intra- and inter- estuarine TP/CS ratio/relationship should not deviate significantly from an established site-specific baseline The horizontal boundary of mudflats/saltmarsh interface and the topography of sedimentary features, including the distribution of sandbanks and drainage channels, should not deviate significantly from a baseline. Where changes are 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.

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The most up-to-date version of this text may be downloaded from the JNCC web site:
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