Mudflats and sandflats not covered by seawater at low tide

Definition

Sands and muds of the coasts of the oceans, their connected seas and associated lagoons, not covered by sea water at low tide, devoid of vascular plants, usually coated by blue algae and diatoms. They are of particular importance as feeding grounds for wildfowl and waders. The diverse intertidal communities of invertebrates and algae that occupy them can be used to define subdivisions of 11.27, eelgrass communities that may be exposed for a few hours in the course of every tide have been listed under 11.3, brackish water vegetation of permanent pools by use of those of 11.4.[1]

Introduction to the feature's interest

This is a widespread habitat type on the coasts of Atlantic Europe and occurs widely throughout the UK. Sites were selected to encompass the range of geographical and ecological variation of this habitat type in the UK. Sites with large areas of intertidal flats as well as a range of shelter, mobility and diversity of sub-types were favoured.

Intertidal mudflats and sandflats are submerged at high tide and exposed at low tide. They form a major component of estuaries and embayments in the UK but also occur on the open coast. The physical structure of the intertidal flats can range from the mobile, coarse-sand beaches of wave-exposed coasts to the stable, fine-sediment mudflats of estuaries and embayments. This habitat type can be divided into three broad categories: clean sands, muddy sands and muds, although in practice there is a continuous gradient between them. Within this range, the plant and animal communities present vary according to the type of sediment, its stability and the salinity of the over-lying water.

Clean sands. These communities occur on clean, sandy beaches on the open coast and in bays around the UK, where wave action or strong tidal streams prevent the deposition of finer silt. Clean sands also occur in estuaries where the supply of silt in suspension is low. In such conditions, there is a high proportion of the heavier grains of sediment. Owing to the mobility of the sand and consequent abrasion, species that inhabit clean sands tend to be mobile and robust and include amphipod crustaceans, such as sandhoppers *Bathyporeia* spp., some polychaete worms and bivalve molluscs.

Muddy sands. These occur in a particular combination of conditions. Shelter from wave action is sufficient to allow the deposition of fine sediments, but some water movement or the lack of supply of silt leads to a sandier substratum. Such conditions may occur at the mouths of estuaries or behind barrier islands, where sediment conditions are more stable. A wide range of species, such as lugworms *Arenicola marina* and bivalve molluscs, can colonise these sediments. Substantial beds of mussels *Mytilus edulis* may develop on the lower shore. Beds of intertidal dwarf eelgrass *Zostera noltii* or narrow-leafed eelgrass *Zostera angustifolia* and eelgrass *Zostera marina* may also occur on the lower shore. In estuaries, reduced salinity may cause a variation in these communities.

Mudflats. These form in the most sheltered areas of the coast, usually where large quantities of silt derived from rivers are deposited in estuaries. The sediment is stable and communities are dominated by polychaete and oligochaete worms, and bivalve molluscs. Soft mudflats often support very high densities of some infaunal species, where the high biomass of intertidal species provides an important food source for waders and wildfowl.

The complex nature of the Annex I feature *mudflats and sandflats* means that many sites will contain a mixture of the types described above.

Typical attributes to define the feature's condition

Generic attributes

Table 3.5-1 lists the generic attributes for mudflat features and presents examples of the measures proposed for some of the candidate SACs in the UK. This list is not exhaustive and will be further developed as our knowledge improves of the factors that determine the condition of intertidal sediment ecosystems.

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1 These numbers are the habitat codes in the Palaearctic classification (originally the CORINE classification). For further information refer to *The Interpretation Manual of European Habitats – EUR 15* (version 2, October 1999) published by the European Commission (see: **http://europa.eu.int/comm/environment/nature/docum.htm**)

Table 3.5-1 Summary of attributes that may define favourable condition of intertidal mudflats and sandflats

Attribute	*Measure*	*Comments*
Extent		
Extent of the feature	Area of the intertidal flats	Extent of the feature is a reporting requirement of the Habitats Directive. For dynamic coastlines, fluctuations in extent may be great, but are attributable to natural coastal processes.
Extent of a sub-feature or characteristic biotope	Area of seagrass measured during peak growth period (*likely between May–August*)	Where present, the extent of seagrass is an important structural component of sediment flats, and provides a long-term integrated measure of environmental conditions across the feature.
	Area of mussel beds	The extent of mussel beds is an important structural component of sediment flats and, depending on the size and distribution of the beds, they may play an important functional role within the feature, e.g. by stabilising sediment. It should be recognised that mussel beds are a dynamic habitat, although in many cases beds tend to remain in the same place in the long term whilst patchiness within them is much more dynamic.
Physical structure		
Sediment character	Particle size distribution of the sediment used to characterise sediment type. The analysis should include the parameters: % sand/silt/gravel, mean and median grain size, and sorting coefficient	Sediment character defined by particle size analysis is key to the structure of the feature, and reflects all of the physical processes acting on it. Particle size composition varies across the feature and can be used to indicate spatial distribution of sediment types (*and some or all sub-features*), thus reflecting the stability of the feature and the processes supporting it.
	Sediment penetrability by the degree of sinking	Penetrability is an indicator of sediment stability, degree of compaction indicates the shear strength of the sediment and thus the susceptibility of that sediment type to erosion. Compaction of the sediment influences the biological community within the sediment.
	Proportion of organic carbon from sediment sample	Organic content critically influences the infaunal community and can cause deoxygenation of the feature, which can be detrimental to the biota.
	Oxidation/reduction potential by the depth of any black layer, or by an in situ measurement (Eh of redox potential)	Degree of oxidation/reduction, reflecting oxygen availability within the sediment, critically influences the infaunal community and the mobility of chemical compounds. It is an indicator of the structure of the feature.
Topography	Tidal elevation and shore profile	Topography reflects the prevailing energy conditions and the stability of the sediment, which is key to the overall structure of the feature. Height on the shore has a major influence on the distribution of communities throughout the feature. Measuring topography may also indicate the position of channels through the feature, which is another important indicator of the processes influencing the site.
Water density: temperature and salinity	Regular measurement of water temperature and salinity	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), including those at the edge of their geographic ranges.
Nutrient status of overlying water mass	Abundance of macroalgae on the feature	Nutrient status is a key functional factor that influences biota associated with sediments including infauna as well as plants/algae at the surface. *Indicator macroalgae* indicate elevated nutrient levels that reduce the quality of the sediments and their communities, primarily through smothering and deoxygenation. Opportunistic macroalage compete with important species such as seagrass and affect the associated species assemblage. An increase in filamentous green algae may be a related natural phenomenon or may indicate eutrophication
Notable species - macroalgae	Extent (ha) across whole or parts of site, measured during peak growth period (*likely between May–August*) every three years (*more frequently depending on site*) during reporting cycle.	Nutrient status is a key functional factor that influences the sub-feature as opportunistic macroalgae compete with important biotopes (sub-features) such as seagrass, and affect associated species. Note that an increase in filamentous green algae may be a related natural phenomenon or may indicate eutrophication.

Attribute	*Measure*	*Comments*
Biotic composition		
Biotope composition	Number and occurrence/frequency of a range of specified biotopes	The number and occurrence/frequency of biotopes is an important structural aspect of the feature.
Species composition of a specific biotope	Measure the frequency and occurrence/diversity index of composite species (total or sub-set)	Species composition is an important contributor to the structure of a biotope. A determination of species diversity gives an indication of the quality of the biotope, and a change in diversity may indicate cyclic change/trend in sediment communities.
Population status of a characteristic species	Estimate the population size using a measure of *abundance/occurrence/ frequency/biomass* Measure relevant population parameters, e.g. age structure	The species selected may be of interest in its own right, and/or may be indicative of the structure of a characteristic or notable biotope. A change in the population status of the species may indicate a cyclic change/trend in the host biotope, and/or the sediment communities in the feature as a whole.
Notable species	Occurrence and frequency of characteristic species	Notable species: are of nature conservation importance due to e.g. rare/scarce, regionally important; contribute to sediment structure; and/or can be used as an indicator of environmental stress e.g. molluscan sensitivity to TBT.
Zostera marina and/or *Zostera noltii* density	Average density of a sea-grass species, measured during peak growth period (*likely between May–August*)	An early indicator of seagrass under stress is a reduction in biomass, normally represented through the number and length of leaves. Density is preferred as a surrogate for biomass, being less destructive, based on baseline survey to establish the relationship between density and biomass at a site.
Biological structure		
Spatial distribution of all biotopes, or a range of specified biotopes	Relative distribution of biotopes throughout the (sub) feature	The relative distribution of biotopes is an important structural aspect of the feature. Changes in extent and distribution may indicate long-term changes in the physical conditions at the site.
Spatial distribution of a specific biotope	The distribution/presence or absence/frequency of a specified typical or notable biotope	The spatial distribution/occurrence of a biotope is a key structural component of the sediments, and is particularly important if: it is notable for nature conservation due to its rarity/scarcity or regional value; it has high species richness; it is an extensive example; it is sensitive to anthropogenic activity; and/or an indicator of changes in the supporting processes of the feature.
Spatial patterns in populations of characteristic species	For mussel *Mytilus edulis* beds, measure the extent, abundance and/or size/age profile, or spatfall[2]	If present, mussels are an important structuring species of the (sub) feature and therefore a key influence on the associated community. An indication of the population dynamics of the species and whether it is sustaining itself within the bed is necessary in addition to extent of all mussels beds in the feature.

2 Settlement of juvenile mussels onto the seabed.

Suggested techniques for monitoring attributes of mudflats and sandflats

For each of the attributes likely to be selected to monitor the condition of a feature, there are many techniques available to measure its value. To help implement the UK's Common Standards for Monitoring programme, it is necessary to recommend a small number of techniques that are likely to provide comparable measures (Table 3.5-2). The UK Marine SACs project evaluated the inter-comparability of some of these techniques (recording biotope richness, species counts), but further work is required on other techniques (such as measuring extent with remote sensing techniques). The advice presented below will be updated when new information becomes available.

Table 3.5-2 Suggested techniques for measuring attributes of mudflats and sandflats. The terms under *Technique* appear under the heading *Summary title* in the procedural guidelines provided in Section 6. Guidance will be developed for the techniques in italics.

Generic attribute	*Feature attribute*	*Technique*
Extent		*Air photo interpretation; Remote imaging;* Intertidal resource mapping;
	Biotope extent	Intertidal resource mapping; Intertidal biotope ID; *Air photo interpretation; Remote imaging*
Physical properties	Substratum: sediment character	Particle size analysis; *Sediment chemical analyses*
	Topography	*LIDAR; Shore profiling*
	Water chemistry (including salinity, temperature)	Measuring water quality; *Water chemistry data loggers*
	Nutrient status	Measuring water quality; *Water chemistry data loggers;* (Biotope extent techniques for algal mats)
Biotic composition	Biotope richness	Intertidal resource mapping; Intertidal biotope ID; Intertidal core sampling
	Species composition/richness	Intertidal core sampling; Intertidal ACE
	Characteristic species	Intertidal core sampling; Intertidal ACE; Intertidal biotope ID; Mollusc shell ageing
Biological structure	Spatial pattern of biotopes	Intertidal resource mapping; Intertidal biotope ID; *Air photo interpretation; Remote imaging; Transect survey*

Specific issues affecting the monitoring of mudflats

Each attribute will have its own inherent source of variability that must be addressed during data collection and subsequent interpretation of the results. However, some generic issues should be considered when planning the whole monitoring study.

Seasonal effects

Marine communities show seasonal patterns that could significantly affect a monitoring programme. Algal communities show the most obvious seasonal trends and sediment flats often support dense green algal mats during the summer months. Rapid growth of microscopic algae, and diatoms in particular, can change the appearance (colour) of intertidal flats.[b] 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. It would be prudent to avoid sampling during the spring and summer months where such seasonal changes are known to occur at a site and are not linked to the attribute under investigation.

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 lifecycle. 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.

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 die-back.[c] Eelgrass blades may support dense assemblages of epiphytic algae during the summer months.

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

Meteorological changes

Meteorological changes that may affect intertidal flats include:

- erosion following winter storms or river flood events will affect the extent of the flats;
- accretion of saltmarsh will reduce the intertidal area;
- movement of river channels[d] or drainage creeks will change the topography:
- different rainfall patterns may lead to a change in sediment depositional patterns through to changes in run-off and/or a river flow rates.

Access

Intertidal sediment flats may cover a vast area and therefore present significant logistical problems for sampling. Sampling must coincide with low water during the spring tide part of the tidal cycle to gain access to the entire feature. There are important health and safety issues to consider in relation to access (see Health and Safety), especially in relation to tidal inundation and the stability of the sediment. Sites may have local restrictions on bait collection and therefore it will be necessary to advise the local organisation responsible for enforcement of any sampling activity. It may be tactful to ensure local fishermen and bait collectors are fully informed that sampling activities (perhaps undertaken by 'outsiders') are for monitoring the SAC.

It may be necessary to use a boat to gain access to the lowest shore areas, and any 'island' areas created by tidal creeks. Motorised transport such as small All Terrain Vehicles (ATVs), tractors (wheels can get stuck in soft sediment) or hovercraft (very noisy) can maximise the time available for sampling within the tidal cycle, and to carry any samples collected.

Sediment flats often support large populations of birds and, in some cases, seals. Sampling activities are likely to disturb these animals and therefore field visits should not coincide with important periods in the life-cycle (breeding, rearing of offspring).

Sampling in soft sediment poses additional problems, particularly through the instability of the substratum. Plastic sledges are useful for carrying sampling equipment and providing support in soft sediment areas. 'Mud shoes' help spread an individual's body weight over a larger area to reduce the risk of sinking, and thus improve their ease of movement. Subtidal sampling techniques may be used to sample extensive areas of soft mud at high water if access from land is particularly difficult or dangerous.

Any areas of quicksand should be identified; gathering knowledge from local inhabitants is often vital in this respect. Mussel beds, whilst appearing to give a solid surface, are often unstable and the sediment underneath may be very soft.

Sampling issues

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 such as extent, and detailed sampling to assess the biotic composition. A broad-scale mapping exercise would both provide data on the extent of the whole feature and show any spatial patterns in the habitat/biotopes present within the feature. Broad-scale maps provide the necessary information to apply a stratified sampling programme to select locations to monitor sediment structure and the composition of biotopes via direct sampling.

Monitoring trials supported by the UK Marine SACS Project investigated three approaches to direct sampling: a transect-sampling approach in the Wash & North Norfolk Coast cSAC[e] and the Mawddach Estuary, Pen Llyn a'r Sarnau cSAC[f] and an *in situ* biotope recording and Phase 2 sampling with a grid strategy in the Mawddach Estuary.[g] All sampling techniques collected core samples, for sediment analysis and the enumeration of infaunal species assemblages, at pre-determined points along a transect or at a grid node. These strategies will also identify any spatial patterns in the biotic composition of the feature, such as zonation from the top to the bottom of the shore.

If access by foot is restricted or impossible, it is possible to sample intertidal flats 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.[h] Note that sampling at high water does not allow any visual appraisal of the broad-scale character of intertidal flats.

It is important to select the most appropriate mesh size for an infaunal sampling campaign on sediment flats. A general recommendation is that a 1mm mesh is sufficient for most sediment types from mud to sand, unless previous investigations indicate a finer mesh is necessary to sample the target biotic assemblage adequately. The studies in the Wash and the Mawddach used a 0.5mm mesh when sampling predominantly sandy sediments. Where a finer mesh is necessary, the sample should be sub-divided to provide a 1mm mesh fraction. It is important to consider any other established sampling and monitoring studies in an SAC prior to finalising the mesh size. If the data from such studies can contribute to an SAC monitoring programme, it will be necessary to harmonise the mesh size between all monitoring studies to ensure data are comparable.

Site marking and relocation

Intertidal flats are dynamic environments that present considerable problems for site marking. Markers can be buried or washed away if the flats change their profile. When using a transect approach, it will be necessary to fix the end of the transect with a marker pole taking care to record its position accurately either by dGPS or via photographs/drawing of any conspicuous landmarks. The position of samples along a transect can be recorded by dGPS and/or marked with a permanent marker. Long canes (1.5m) pressed down into the sediment to leave approximately 30cm exposed lasted at least 3 years in the Wash.[f]

DGPS should be used for recording position on extensive intertidal flats.[3] 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.

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 intertidal flats are:

- *Stranding due to the rising tide*. Due to the 'flat' nature of this environment, a rising tide can inundate the shore faster than a person can run. Creeks can fill rapidly creating 'islands' on the flats.
- *Stuck in the sediment*, particularly in soft mud, on quick sands and mussel beds.
- *Illness and disease from contaminated sediment*. Sediments bind contaminants such as heavy metals (and radioactive isotopes) at high concentrations, which are subsequently released upon disturbance. It is possible to contract serious diseases such as hepatitis from sewage effluent, or Weils disease (from water contaminated with rat urine). In such circumstances, protective gloves should be used to avoid skin contact with the sediment.

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