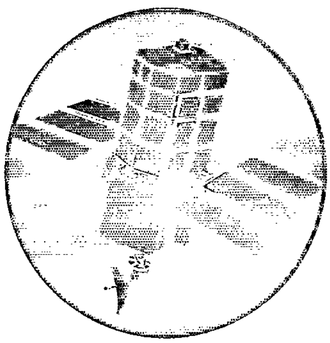
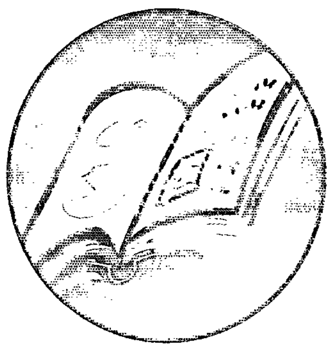
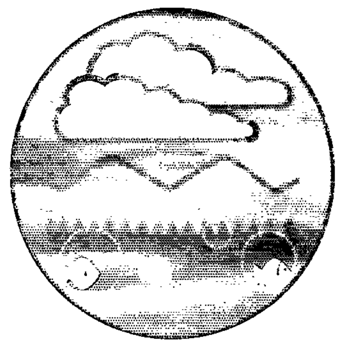
Definition of the Extent and Vertical Range of Saltmarsh

Research and Development
Technical Report
W153

ENVIRONMENT AGENCY

Definition of the Extent and Vertical Range of Saltmarsh

Technical Report W153

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This R&D Technical Report provides a definition of the vertical range of saltmarsh. It is intended to assist coastal managers in determining the upper and lower limits of saltmarsh relevant to realignment schemes in flood defence.

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EXECUTIVE SUMMARY

The aim of this project is to provide a concise and widely applicable definition of the vertical range of saltmarsh and to identify links between saltmarsh, coastal fauna and coastal processes. The need for such a definition has arisen during recent flood defence realignments including the set-back of defences and the creation of new areas of saltmarsh. Saltmarsh usually supports a range of plant communities, the species and communities present changing with increasing elevation of the marsh and so decreasing frequency of tidal inundation. The ecological importance of saltmarshes is recognised by their inclusion in many sites of nature conservation importance and by lower saltmarsh zones (with cord-grass *Spartina* and glasswort *Salicornia*) being considered as important in the European Community Habitats Directive.

Vegetation on saltmarshes also serves to affect sediment dynamics by increasing the frictional roughness of the intertidal profile, thereby causing the deposition of suspended sediment. The sediment transported onto saltmarshes may be derived from a number of potential sources, both within the immediate intertidal profile and from more remote areas.

Saltmarshes provide habitats for marine and freshwater invertebrates and provide one element of the overall habitat requirements of a number of bird species. The upper saltmarsh/terrestrial transition zone has been identified as an important, and often uncommon, habitat in terms of its vegetation communities and terrestrial invertebrate species.

Prior to determining the vertical range of saltmarsh, it is necessary to derive a clear definition of 'saltmarsh'. A widely accepted definition of the lower limit of saltmarsh was taken as the lower limit of terrestrial vegetation. The species recorded at the lowest levels of the tidal profile is cord-grass *Spartina*. A formula for calculating the lower limit (LL) of Spartina colonisation has been adopted after Gray et al (1989):

$LL(OD_N) = -0.815 + 0.451$ (Mean Spring Tidal Range in metres).

The upper limit of saltmarsh is marked by a transition to non-saline habitats. Previous definitions of the upper limit of saltmarsh focus on tidal submergence and the salinity of the soil, the consensus being in the region of Highest Astronomical Tide (HAT). Consequently a conservative assessment was made of actual tidal levels at Holland on Sea in relation to predicted HAT at the nearby Standard Port of Walton on the Naze. On the basis of this data, multiplication of HAT by a factor of 1.23 would provide an estimate of the upper extent of seawater influence. This would allow the development of a full transition zone providing a 'natural' environment within which to accommodate surge tide events and, accordingly, provide important habitat for species and communities of flora and fauna.

Key Words

Saltmarsh, Vegetation Communities, Sediment Dynamics, Fauna, Definition, Upper Limit, Lower Limit.

1. INTRODUCTION

1.1 Background and project objectives

Recently, realignment of flood defences has involved set-back of defences to allow for development of saltmarsh - with both flood control and habitat creation benefits. During the course of these realignments, however, it has become clear that there is no agreed definition of what constitutes a saltmarsh, particularly in terms of its vertical range within the intertidal profile.

The aim of the present project is to produce a concise and widely applicable definition of the vertical range of saltmarsh, and to identify links between saltmarsh and both coastal processes and coastal fauna.

1.2 Overall approach

Realignment will increase the width of the intertidal zone, allowing for the extension of existing saltmarsh or, in appropriate areas, the development of new saltmarsh. It is therefore necessary to identify the extent of the area within which saltmarsh could develop after exposure to unrestricted tidal influence. The area of saltmarsh will be determined by the frequency of tidal inundation, and so by the local tidal levels. The need to produce a definition based on these levels is further reinforced by regional and seasonal variations in soils, climate and vegetation.

The approach adopted here is firstly to describe the vegetation communities associated with saltmarshes, the links between saltmarshes and coastal processes and the use of saltmarshes by fauna. The second objective is to produce a sufficiently rigorous definition of a saltmarsh to allow determination of the tidal levels on the shore (such as Mean High Water Neap Tide) which mark the upper and lower saltmarsh extent. The definitions produced are intended to be applicable throughout England and Wales, many Scottish saltmarshes are known to have different characteristics and so would require further investigation prior to their inclusion within any definitions produced.

2. VEGETATION COMMUNITIES OF SALTMARSH

The vegetated saltmarsh usually supports a range of communities which generally form parallel zones, the species and communities present changing with increasing elevation of the marsh and so the frequency of tidal inundation (Gray, 1992; Gray and Scott, 1987). Zonation of vegetation, and the extent of different vegetation types also varies according to geographical location, management and substrate (Adam, 1981).

CORINE biotopes (European Commission, 1991) are used to classify vegetation communities on a European level. Table 1 provides a correspondence between the saltmarsh habitats defined according to CORINE and the National Vegetation Classification (NVC), which has been developed to classify vegetation in Britain. The main species of each community are identified, together with the main saltmarsh zone in which each community occurs. This table is a modified and expanded version of that presented in Toft and Maddrell (1995).

Table 1

Saltmarsh Zone	**NVC Communities**	**CORINE**	**Main species**
Pioneer	SM4, SM5, SM6	C15.21	*Spartina* (Cord-grass)
	SM7	C15.622	*Salicornia perennis* (Perennial glasswort)
	SM8, SM9	C15.111	*Salicornia, Suaeda maritima* (Glasswort, Sea-blite)
	SM11, SM12	C15.322	*Aster/Puccinellia* (Saltmarsh-grass)
Lower	SM10	C15.323	*Puccinellia*
	SM13	C15.31	*Puccinellia*
	SM14	C15.621, C15.321	*Puccinellia/Atriplex portulacoides* (Sea-purslane)
Upper	SM13c	C15.31	*Puccinellia/Limonium/Armeria* (Sea-lavender, Thrift)
	SM13, SM16, SM17	C15.31,C15.331, C15.33B	*Puccinellia/Festuca/Juncus gerardii/Artemesia maritima* (Fescue, Saltmarsh Rush, Sea wormwood)
	SM15, SM18	C15.33A,C15.51	*Juncus maritimus* (Sea-rush)
	SM19	C15.338	*Blysmus rufus* (Saltmarsh Flat-sedge)
	SM20	C15.339	*Eleocharis uniglumis* (Slender Spike-rush)
Upper/Transition	SM24, SM28	C15.35	*Elytrigia* (Couch-grass)
	SM25	C15.623	*Suaeda* (Sea-blite)
	S4	C53.11	*Phragmites* (Common reed)
	S19	C15.339	*Eleocharis* (Spike-rush)
	S20, S21	C53.17	*Scirpus* (Club-rush)
	SM21, SM22	C15.337, C15.33D	*Suaeda/Limonium/. Frankenia* (Sea-heath)
	MG11, MG12	C37.242	*Festuca/Agrostis* (Bent)

NVC saltmarsh communities not included in the above table are those dominated by *Zostera* (SM1 and SM2) and some communities found in atypical brackish environments (SM3, SM23, SM26 and SM27).

The ecological importance of saltmarshes is recognised by their inclusion within many sites of nature conservation importance designated under national legislation and international directives and conventions. In particular the Habitats Directive identifies several saltmarsh habitats in Britain (using the CORINE classification) as being of European Community importance, these are:

C15.1 *Salicornia* and other annuals colonising mud and sand
C15.2 *Spartina* swards
C15.3 Atlantic salt meadows
C15.5 Mediterranean salt meadows
C15.6 Mediterranean and Thermo-Atlantic scrubs

The majority of saltmarsh vegetation types in Britain fall into the category C15.3.

The Habitats Directive also requires EU member states to endeavour to encourage the management of features of the landscape which are of major importance for wild flora and fauna. In addition, the provisions of the Ramsar convention require contracting parties (including the UK Government) to promote wetland generally. Both of these requirements could be applied to saltmarshes.

3. SEDIMENT DYNAMICS OF SALTMARSHES

Vegetation on saltmarshes causes frictional roughness, and a change in the passage of water by extracting momentum from the fluid by hydraulic drag and by generating turbulence *via* disruption. The effect of this is to dampen and dissipate wave energy and promote tidal sedimentation (Frey and Bason, 1978; Long and Mason, 1983; Toft and Maddrell, 1995; Shi *et al.* 1995; Pethick and Burd, 1995; Spencer *et al.* 1995). In this way saltmarsh influences the sediment dynamics operating in the intertidal profile.

A balance exists between 'saltmarsh' and 'mudflat' where the movement of sediment between the two varies depending on the prevailing conditions (Pethick and Burd, 1995). During storm conditions, the intertidal profile widens and flattens with erosion of both the upper surface and the seaward margin of the saltmarsh. Sediment is then transported from the saltmarsh to the mudflat. During calm conditions sediment is re-entrained from the mudflat and deposited on the saltmarsh (Pethick, 1992; Pethick and Burd, 1995).

However, the sediments deposited on saltmarshes, especially silts and clays, are also transported in suspension in tidal waters and, therefore, may travel considerable distances from their original source (Allen and Pye, 1992). Indeed, it has been suggested that saltmarsh sediment is mostly redistributed from, or below low water (Dalby, 1970).

Morphological features that may be present on some saltmarshes are sinuous ridges comprised predominantly of shells, sands and gravels (the coarser sediments present on a saltmarsh) these are colloquially referred to as chenier ridges (Otvos, 1979). These ridges are formed during high energy, storm, conditions when the finer sediments are held in suspension, whereas, the coarser sediments are deposited, often forming long sinuous ridges, which may provide a measure of protection to adjacent saltmarsh.

The sediment that makes up the saltmarsh is, therefore, derived from a combination of potential sources, both the immediate intertidal profile and also more remote sources. This is illustrated by the development of saltmarsh on sandy sediments with the subsequent trapping of silts and clays within the developing saltmarsh, as in the Ribble Estuary and Morecambe Bay (Gray and Scott, 1987; pers. obs.)

4. FAUNAL USE OF SALTMARSHES

4.1 Marine invertebrates

The distribution of many intertidal marine species extends well above MHWN, accordingly invertebrates burrowing within the sediment in saltmarshes have been found to represent a continuum with the fauna of the adjacent mudflats (Long and Mason, 1983; Heath and Mason, 1989). Creeks and lower level saltmarsh with sparser vegetation would be particularly suitable for colonisation by marine species. Numbers of species has been found to be lower amongst *Spartina* than on open mudflats, while biomass is greater amongst *Spartina* than on mudflats, a phenomenon ascribed to heavier predation pressures on open mud (Long and Mason, 1983). Some species are also associated with saltmarsh pools which are not commonly found on adjacent mudflats, such as the isopod crustaceans *Paragnathia formica* and *Lekanesphaera rugicauda*, these species, however, rely on regular tidal inundation for dispersion within estuaries (Hough and Naylor, 1991). Other specialist species such as the sandhopper (amphipod crustacean) *Orchestia gammarella* occupy upper tidal levels, around or above MHWS.

4.2 Terrestrial invertebrates

Many of the species of terrestrial invertebrate recorded from saltmarshes are generalists which occur in the vicinity of the upper marsh and also in terrestrial grassland and marsh habitats inland. However, specialist species, restricted to saltmarshes, also occur. The richest saltmarsh fauna occurs in areas where there is periodic flooding by spring tides (Muddiman, 1988; Fry and Lonsdale, 1991). Several nationally scarce invertebrates are restricted to saltmarsh habitats, including the bug *Macrosteles sordidipennis* and the ground beetles *Dyschirus impunctipennis* and *Dyschirus nitidus*. The Red Data Book bug *Orthotylus rubidus* is associated with saline soils which are not regularly inundated. The retention of upper transitional zones in a saltmarsh is, therefore, a priority for the conservation of such species.

4.3 Birds

No British avifauna are exclusively associated with saltmarshes, rather, intertidal marshes comprise one element, amongst several, of the overall habitat requirements of a number of species. Species which may breed on saltmarshes include redshank, snipe, oystercatcher, skylark, meadow pipit and reed bunting. Nesting generally takes place on high level marshes where the risk of tidal inundation is reduced.

In winter, saltmarsh habitats represent a range of resources for birds. They are particularly significant for roosting waders, which favour grazed marshes where low vegetation height allows vigilance against predators. *Spartina* marshes typically feature taller vegetation and are therefore considered to be less attractive to waders (Prater, 1981).

Waders such as redshank, curlew and snipe frequently feed within saltmarshes during the winter, especially on bare mud areas around creeks or pools. Wildfowl such as geese and widgeon feed on saltmarsh vegetation and use saltmarshes as secure nocturnal roosts. Passerine species, particularly finches, frequently gather on saltmarshes during winter, to feed on seeds.

Within estuarine ecosystems, saltmarshes are important in ornithological terms. However, no species are exclusively restricted to saltmarshes instead, due to their mobility, there is a high degree of overlap in the use of adjacent habitats.

5. DEFINITION OF THE EXTENT OF SALTMARSH

5.1 Previous definitions

In order to determine the vertical range of saltmarsh it is first necessary to determine a sufficiently accurate definition of what constitutes 'saltmarsh'. The Oxford English Dictionary defines a saltmarsh as "marshland overwashed by the sea". More accurate definitions are:-

- areas of alluvial or peat deposits, colonised by herbaceous and small shrubby plants, almost permanently wet and frequently inundated with saline waters (Long and Mason, 1983).
- vegetated mudflats (Pethick, 1984).
- saltmarsh is part of the intertidal profile rather than a self contained landform with a sharp dividing line between open mudflat and vegetated marsh (Pethick, 1992).
- Phanerogam communities (*i.e.* flowering plants) subject to tidal flooding (Kidson and Heyworth, 1979).
- an area in which the vegetation is predominantly phanerogamic (but excluding *Zostera* spp) and which is subject to direct tidal influence (Adam, 1981).
- natural or semi-natural halophytic grassland and dwarf brush wood on the alluvial sediments bordering saline water bodies (Beeftink, 1977).
- Randerson (1979) saltmarsh is distinguished from mudflat by vegetation cover.
- an area of land between mean high water springs (MHWS) and mean low water springs (MLWS) including the vegetated surface and the fronting mudflats (Dixon and Weight, undated).
- limited to between mid neap tide level and MHWS (Allen and Pye, 1992).
- vegetation (normally dominated by flowering plants) which develops on muddy shores between mean sea level (MSL) and MHWS (Dalby, 1970).

Many definitions are based on the lower and upper limits. The lower limit of saltmarsh is suggested to be:-

- the lower limit of vegetation is... typically MHWN (Toft and Maddrell, 1995).
- (even in particularly sheltered sites) the lower limit of saltmarsh is MHWN to Mean High Water (MHW), saltmarsh is very rare below MHWN (Long and Mason, 1983).
- determined by the ability of colonists.....to establish themselves (Kidson and Heyworth, 1979).
- the lower limit of sustainable saltmarsh is MLWS (Pethick and Burd, 1995).
- Mean Low Water (MLW) (Leggett and Dixon, 1994).

The upper limit of saltmarsh is described:-

- a driftline / transitional marsh at Highest Astronomical Tide HAT (Toft and Maddrell, 1995).
- subject to inundation only a few times per year (Ranwell, 1972).
- where halophytes become a minority, normally MHWS to HAT (Beeftink, 1977).
- upper limit is where saltmarsh is replaced by non-saline habitats of facultative halophytes only capable of withstanding brief and infrequent periods of inundation (Long and Mason, 1983).

- is at HAT, where a transitional zone may be recorded with species such as *Elytrigia atherica*, *Beta maritima* and *Phragmites australis* are present (Toft and Maddrell, 1995).
- At 1m above the highest recorded surge level (Pethick and Burd, 1995).
- the point somewhere between MHWS and the upper limit of marine activity, *i.e.* storm conditions during high water of equinoctial spring tides (Kidson and Heyworth, 1979).

(Nb. HAT is the highest predicted tide over a nodal period - 18.6 years. Following consultation with the Proudman Oceanographic Laboratory, we understand the term Extreme High Water Springs (EHWS) to be a term used outside the UK and to be synonymous with HAT.)

However, none of the above definitions provides a sufficiently rigorous description of 'saltmarsh' to allow upper and lower limits to be accurately distinguished. A more thorough description of saltmarsh is therefore required prior to defining its extent and vertical range.

5.2 Factors influencing the definition of saltmarsh extent

There is debate as to whether 'saltmarsh' includes fronting mudflats, together with their associated aquatic plants (eelgrass and algae). Most authorities, however, define a saltmarsh on the basis of vegetation cover or the vertical range within which halophytic vegetation develops. The upper extent of saltmarsh is generally recorded as the limit of saline influence, around HAT. Factors which may influence (extend or reduce) a definition of the extent of saltmarsh are considered below.

5.2.1 Lower limit of saltmarsh

Sediment movements between mudflat and saltmarsh

Given the various sources of sediment supply to saltmarshes (described in Section 3) it is not considered possible to clearly identify a lower limit to saltmarsh on the basis of sediment supply or source.

Inclusion of Eelgrass (*Zostera*) spp. and macroalgae

A consensus of opinion is that eelgrass (*Zostera spp.*) is excluded from saltmarsh vegetation (Ratcliffe, 1977; Adam, 1981; Long and Mason, 1983; Toft and Maddrell, 1995; Beeftink, 1977) on the basis that eelgrass is an aquatic rather than a terrestrial saltmarsh plant (Beeftink, *op. cit*). In addition, the presence of eelgrass over the lower intertidal zone and into the subtidal zone (to a depth of 3-4m below MLW; Giesen *et al.* 1990) suggest a distinct difference in habitat requirements between *Zostera* and 'terrestrial' saltmarsh plant species.

Exceptions to the exclusion of eelgrass from a definition of saltmarsh are provided by Pethick and Burd (1995) and Randerson (1979) who suggest that a definition of saltmarsh should include all vegetation in the intertidal zone including eelgrass and algae. However, as the subtidal extent of *Zostera* and macroalgae is largely determined by the light penetration of the water, the inclusion of these species would cause a blurring of the lower limit of saltmarsh at a point some depth below MLWS. Consequently, eelgrass is not considered here as part of the saltmarsh.

Mudflat microflora

Microflora (especially epipelic diatoms) are motile and secrete mucus. This acts to trap and bind the sediments of the mudflats and accelerate their deposition (Long and Mason, 1983). Therefore, microflora could act as precursors to saltmarsh development on mudflats (Coles, 1979; Toft and Maddrell, 1995).

Although diatom zonation may be related to communities of flowering plants (Kidson and Heyworth, 1979) no specific zone of microflora, related to saltmarsh development, has been identified. Therefore, the presence or absence of microflora cannot be used to determine the lower limit of saltmarsh but may be an important component of the intertidal profile with respect to saltmarsh development.

Coastal Processes

The intertidal zone fronting a saltmarsh acts to dissipate wave energy and stabilise the shoreline (Toft and Maddrell, 1995). However, the most acceptable definition of saltmarsh is the lower limit of halophytic terrestrial vegetation (Section 5.1). Although fronting mudflats and sandflats serve a role in modifying coastal processes, these are, therefore, not considered as part of a saltmarsh.

5.2.2 Upper extent of saltmarsh

Effect of saline influence

The overriding influence determining the presence of saltmarsh vegetation is tidal submergence and the ionic level of the soil (Long and Mason, 1983). In the Netherlands the change from saline to non-saline vegetation occurs where mean salinity of the soil solution drops below $5gl^{-1}$ (Beeftink, 1977). Zonation can, therefore, be related to tide level (Toft and Maddrell, 1995), although soak up and sea spray may extend the region of saline influence further inland.

However, a simple picture of vegetation zonation relating to tidal inundation is difficult to attain, due to local differences in soils, species competition, grazing and truncation by banks (Randerson, 1979).

Extent of Saltmarsh Vegetation

Some communities found at the transition of saltmarshes are associated with brackish conditions such as the spear-leaved Orache *Atriplex prostrata* sub-community of MG11 ***Festuca rubra-Agrostis stolonifera-Potentilla anserina*** grassland and the *A. prostrata* sub-community of S4 ***Phragmites australis*** swamp. There is, however, no uniformly characteristic transitional vegetation type or types which characterise the upper saltmarsh limit.

Vegetation at the upper extremes of saltmarsh can often be floristically diverse, and can support specialised, and consequently scarce, species, particularly in the south and east. Such species include annual beard grass *Polypogon mospeliensis*, stiff saltmarsh grass *Puccinellia rupestris,* matted sea lavender *Limonium bellidifolium*, rock sea lavender *L. binervosum* and sea heath *Frankenia laevis* (Toft and Maddrell, 1995).

Coastal Processes

The area landward of saltmarsh may be affected by extreme surge tide conditions. The slope and vegetation communities present may serve to dissipate wave and tidal energy, in a similar manner to saltmarshes, under such conditions.

6. DEFINITION OF THE VERTICAL RANGE OF SALTMARSH

Definition of the vertical range of saltmarsh, *specific to a flood defence realignment site*, may be related to actual spring tidal range measured at that site and compared with simultaneous records at the nearest Standard Port. Comparison of records from the site and standard port, gathered over as many tidal cycles as possible (a minimum would be one months recording) would allow calculation of mean spring tidal range, and HAT, for the realignment site. These calculations would then form the basis of the determination of upper and lower limits as detailed below.

6.1 Lower Limit Of Saltmarsh

The lowest terrestrial species recorded on the tidal profile is *Spartina* (Goodman *et al.* 1969; Proctor 1980; Robinson and Pringle, 1987; Mullins, 1985; Gray *et al.* 1989). The lower limit of *Spartina* may, therefore, be taken as the lower limit of saltmarsh.

A calculated mean spring tidal range for the realignment site could be used in the following linear regression model of Gray *et al*, 1989 to calculate the lower limit (LL) of *Spartina* colonisation.

LL (OD_N)= -0.815 + 0.451 (Mean Spring Tidal Range, in metres)

Further information on the model, including standard errors and refinements to allow increased accuracy of prediction may be obtained from Gray *et al*, 1989.

6.2 Upper Limit Of Saltmarsh

The upper limit of saltmarsh is marked by a transition to non-saline habitats. This transition serves to support uncommon floral communities (Section 5.2.2) faunal communities (Section 4.2) and acts in modifying coastal processes under extreme tidal conditions (Section 5.2.2)

To determine the relationship between predicted and actual highest tidal levels, comparisons were made between predicted HAT at a number of Standard Ports (Immingham, Avonmouth, Walton-on-the-Naze and Liverpool) and actual mean highest water levels recorded at the nearest Environment Agency tide gauge (means were of the highest recorded tide each year over a period of at least five years).

The most appropriate data was considered to be that from the Holland on Sea tide gauge and Standard Port of Walton on the Naze; these two locations were in close proximity, provided the most conservative data and are in an area of considerable saltmarsh extent.

At Holland on Sea, the mean highest water level was 0.56m above HAT at Walton on the Naze, or 23% higher. Therefore, the mean highest water level approximates to 123% of HAT at Walton on the Naze. Consequently, multiplication of HAT by a factor of 1.23 therefore provides a conservative estimation of the upper extent of seawater influence at this location and can be used as a predictive mechanism for the upper limit of saltmarsh. This upper limit would allow the development of a full brackish transition zone, providing a 'natural' environment within which to accommodate surge tide events and providing important habitat for species and communities of flora and fauna.

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