Cyfoeth Naturiol Cymru
Natural Resources Wales

Guidance note

Benthic habitat assessment guidance for marine developments and activities

A guide to characterising and monitoring saltmarsh habitat

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1. Introduction and summary

This guidance document is one of a series of Benthic Habitat Assessment Chapters developed by Natural Resources Wales (NRW) for key habitats of conservation importance around Wales. It has been prepared by NRW with the initial document prepared under contract by APEM Ltd.

The guidance aims to assist developers in designing and undertaking robust benthic habitat characterisation surveys and monitoring of these habitats in the context of Ecological Impact Assessment, thereby helping streamline the regulatory review and consultation process.

This habitat chapter (GN030a) is not intended to be used alone and should always be used in conjunction with the NRW Guidance Note GN030 and the Introductory chapter (GN030-intro).

1.1. What are saltmarshes and where are they found in Wales?

Saltmarshes are intertidal areas of fine sediment that have been stabilised by a characteristic form of vegetation. They are widespread around the coast of Wales (see section 2 for more details) where they are found in all major estuaries and inlets as well as in other sheltered locations such as in the lee of spits or in the shelter of islands. The total area of saltmarsh habitat in Wales is estimated to be around 7-8,000 ha, representing some 17% of the total area in England and Wales as a whole.

1.2. The conservation importance of saltmarsh

Saltmarshes are extremely important coastal habitats. They support specialist plant communities with very high primary productivity and provide a habitat for a wide variety of animals including birds (breeding and feeding), fish (feeding and nursey areas), small mammals, terrestrial and marine invertebrates.

The value of saltmarsh is recognised under a number of different pieces of national and international legislation, including:

- Habitats Directive
- Birds Directive
- Ramsar Convention
- Water Framework Directive
- OSPAR Convention
- Environment (Wales) At 2016
- Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way (CROW) Act 2000)
- Marine and Coastal Access Act 2009

More information is provided in section 2.4.

1.3. What kind of developments and activities might affect saltmarshes?

Developments and activities that could affect this habitat during construction and/or operational phases include those involving actions that could result in:

- Changes to salinity regime and temperature
- Changes to water flow and tidal inundation regime
- Changes to water quality (nutrient and organic enrichment; suspended solids)
- Land claim and coastal squeeze
- Removal, disturbance and compaction of sediment;
- Changes to sediment transport dynamics, erosion/accretion regime and geomorphology
- Introduction of invasive species
- Change to grazing regime
- Pollution and other chemical changes

Further detail relating to potential pressures from developments and activities on saltmarshes is provided in section 2.5.

1.4. Existing data and guidance for surveying and monitoring saltmarsh

A brief summary of available guidance and data for surveying and monitoring requirements is provided in section 3. Key sources of existing data and guidance for surveying and monitoring saltmarsh are:

- Joint Nature Conservation Committee (JNCC): recent JNCC guidance for the monitoring of marine benthic habitats (Noble-James *et al*, 2017)
- Common Standards Monitoring: developed for site monitoring and assessment of protected sites (JNCC, 2004)
- Water Framework Directive (WFD) Monitoring: monitoring approaches for saltmarsh to assess the ecological health of the biological quality element 'angiosperms' for the WFD (WFD-UKTAG, 2014).
- National Vegetation Classification: Survey methodology for floristic classification and spatial distribution of vegetation communities (Rodwell, 2006)
- Aerial survey: Mapping European Seabed Habitats (MESH) recommended operating guidelines for aerial photography (Piel & Populus, 2007) and the Royal Institute for Chartered Surveyors guidelines for aerial survey
- National Biodiversity Network Gateway: species distribution data that can be searched for by site or by species.
- NRW Guidance GN006 (Natural Resources Wales, 2019) Marine ecology datasets for marine developments and activities, provides information on the marine ecology data that we hold and routinely use and how you can access them.

1.5. Survey and monitoring design

The requirements for survey and monitoring design are covered in section 4. The following provides a brief summary of key points.

- A comprehensive desk-based review of all available existing data should be conducted prior to designing any habitat characterisation or monitoring programmes. This will help determine the scope of survey that may be required
- If there is little or no existing data or it is out of date or of poor quality, a bespoke aerial survey may be required to determine the overall extent of the saltmarsh and target the field survey
- NRW advises that field and aerial surveys should ideally be carried out between 1st June and 30th September

- Relevant ecological parameters need to be selected. The key parameters (section 4.2) to be assessed for saltmarshes in relation to the impact assessment process are:
  - extent and zonation of vegetation
  - plant species diversity and abundance and,
  - presence of any pressures on the habitat not associated with the proposed development or activity
- Where recent NVC maps are unavailable NRW recommends that a NVC survey (see section 3.3) is conducted to determine the distribution and extent of the vegetation communities. From this, any protected site features such as Annex I habitats which characterise the site can be determined. The zonation of the saltmarsh communities can also be extrapolated from the NVC data.
- The aims of the habitat characterisation survey and monitoring need to be clearly stated and the survey programmes tailored to deliver these requirements. This includes defining hypotheses and trigger levels for monitoring.
- Sampling designs can involve grid-based (i.e. systematic) random sampling or stratified random sampling. Before-After-Control-Impact may need to be an integral part of the programme design. The design will depend on the characteristics of the habitat, availability of existing data for the survey area and the aims of the survey.
- Sampling effort should represent each of the major saltmarsh zones: pioneer saltmarsh, lower and mid marsh, and upper marsh.
- Other parameters of the wider environment that influences saltmarsh may need to be characterised and monitored; this will depend on the nature and location of a proposed development or activity and the associated pressures arising from this. This could include aspects of the physical structure such as creeks and pans, geomorphological processes and water quality.

1.6. Survey and monitoring methods and analysis

There are numerous methods available to survey saltmarshes (section 5). Each provides information on different aspects of the habitat. Method selection depends on the specific parameters being assessed. Options include:

- Remote sensing: using technology, including aerial imagery, to infer vegetation patterns on the ground
  - This is the only realistic means of monitoring change in saltmarsh extent over wide spatial scales.
  - Satellite or existing aerial photography can be used, but there are benefits from using a bespoke aerial survey.
  - Combining aerial photographs with detailed elevation maps (e.g. from LIDAR) can help improve estimates of habitat extent and classification of vegetation types. However, some ground truthing of the remote sensing data is always likely to be required.
  - Specialist image processing software should be used for image correction and to quality control image data.
- Transects (e.g. field-based habitat/zonation mapping)
  - The WFD/Habitats Directive transect approach is recommended for recording broad-scale changes in plant community composition across a large site.
  - Additional sampling within specific areas may be required depending on the aims of the survey.

- Quadrats: sited within observed vegetation types across the site and providing very localised quantitative information
  - Applicable for quantitative sampling.
  - Relevant to assess abundance and number of taxa present within saltmarsh habitats.
- Other permanent monitoring sites: for assessing change at fixed points

Mapping vegetation using ground-truthed aerial imagery together with a relatively basic method of classification, is a more practical approach for monitoring than repeating a detailed vegetation survey on a regular basis. Once changes have stabilised, however, it is recommended that a NVC survey is carried out to enable full assessment on vegetation community extent, composition and quality.

Quality control measures for the field methods including species identification need to be clearly defined and implemented by field staff undertaking the survey work.
Not all methods will be required for a particular development or activity and proposed methods need to be defined on a project-specific basis. The JNCC Marine Monitoring Method Finder, a web-based information hub, has been developed to provide a single point of access to the numerous guidance documents and tools generated both within and outside the UK. It can be used in conjunction with this document to ensure a consistent approach to data collection and analysis.

2. Habitat introduction

2.1. Overview

Saltmarshes are intertidal areas of fine sediment that have been stabilised by vegetation (Boorman 2003). The UK Biodiversity Action Plan (UKBAP 2006) defined saltmarsh as 'the upper, vegetated portions of intertidal mudflats, lying approximately between mean high water neap tides and mean high water spring tides'. The lower limit is that delimited by pioneer saltmarsh plants, excluding seagrass *Zostera* beds (UKBAP 2008). However, saltmarsh often extends beyond the level of mean high water spring tides to the level of highest astronomical tide where it may support upper or 'high' marsh communities, inundation grassland and other brackish communities such as reedbeds. It can be difficult to define the vegetation communities of this habitat as community boundaries are often diffuse. Furthermore, there can be a gradient along the transition to more terrestrial habitats; a number of plants can occur in both freshwater marsh, terrestrial grassland and saltmarsh.

On the whole, saltmarsh soils are waterlogged, creating anoxic saline conditions and containing substances normally toxic to plant growth. Consequently, saltmarsh plants are characterised by adaptations to anoxia, such as air-filled spaces in the roots and rhizomes, and are tolerant of salt and phytotoxins (e.g. ferric ions and sulphides) to a varying degree. Within the saltmarsh plant community there is a halophyte element (species more or less confined to this particular kind of saline environment) and a glycophyte element (species which are widespread in inland, non-saline habitats). Their habitat tolerances largely determine which zone or zones they occur in.

2.2. Sub-habitats

The Introductory Chapter of this guidance (GN030-intro, section 3.2.4) provides information on the Joint Nature Conservation Committee (JNCC) and European Nature Information System (EUNIS) classification systems for marine habitats and biotopes. We recommend the JNCC website as a reference point to determine the latest guidance documentation for habitat and biotope assignment. The information provided below is based on the latest available guidance at the time of writing.

In the strict sense of saltmarsh there are approximately 40 species of higher plants found in the habitat (Boorman 1966 & 2003), with any individual saltmarsh containing between 10 and 20 species, although in a broader sense there are a larger number of plant species found at the upper and transitional zones.

The National Vegetation Classification (NVC) system recognises 28 communities of saltmarsh vegetation (Rodwell 2000). Three of these communities relate to seagrass *Zostera* spp. and tasselweed *Ruppia* spp. in tidal flats and ditches. However, these are covered by the separate Seagrass beds chapter in this guidance (GNO30f) and are not considered further here. The remaining 25 communities are subdivided into lower saltmarsh (12 communities), middle saltmarsh (eight communities), and upper saltmarsh (five communities) (Table 1).

The saltmarsh NVC communities include the following:

- pioneer species (i.e. early colonisers, beginning a chain of ecological succession) such as *Spartina anglica* (often present as a result of deliberate introduction historically) and *Salicornia* spp.;
- lower and middle marsh species such as *Puccinellia maritima*, *Atriplex portulacoides* and *Limonium vulgare*
- low-mid marsh species such as *Festuca rubra*
- upper marsh species such as *Juncus maritimus* or *Elytrigia altherica*

Additional plant communities which can also be present on saltmarsh are also covered by the NVC system, these include certain inundation grassland types, brackish reedbeds and swamp communities and mires (Rodwell 1991, 1992 & 1995).

Table 1. NVC communities for saltmarsh vegetation (Rodwell, 2000)

Community	Taxonomic identity	Characteristic zone of saltmarsh	Distribution in Wales
SM1	*Zostera* communities	Sublittoral (see Seagrass beds GN030f)	
SM2	*Ruppia maritima* saltmarsh	Sublittoral (see Seagrass beds GN030f)	
SM3	*Eleocharis parvula* saltmarsh community	Sublittoral: in pans and on bare mud & often where there is fresh water input	Rare. *Eleocharis parvula* has only been recorded within the Dwyryd/Glaslyn and Mawddach Estuaries in recent years
SM4	*Spartina maritima* saltmarsh community	Low	Absent from Wales
SM5	*Spartina alterniflora* saltmarsh community	Low	Absent from Wales
SM6	*Spartina anglica* saltmarsh community	Low	Widespread and extensive around the coast
SM7	*Arthrocnemum perenne* stands	Low	Rare. SM7 occurs locally within the Artro and Mawddach estuaries
SM8	Annual *Salicornia* saltmarsh community	Low	Widespread around the coast
SM9	*Suaeda maritima* saltmarsh community	Low	Locally present around the coast
SM10	Transitional low-marsh vegetation with *Puccinellia maritima,* annual *Salicornia* species and *Suaeda maritima*	Low	Around the coast

Community	Taxonomic identity	Characteristic zone of saltmarsh	Distribution in Wales
SM11	*Aster tripolium* var. *discoideus* saltmarsh community	Low	No mapped stands in Wales but *Aster tripolium* var. *discoideus* is present
SM12	Rayed *Aster tripolium* on saltmarshes	Low	Widely distributed around the coast in small quantities.
SM13	*Puccinellia maritima* saltmarsh community	Low	Widespread and extensively distributed around the coast
SM14	*Halimione portulacoides* saltmarsh community	Low	Widely distributed around the coast
SM15	*Juncus maritimus - Triglochin maritima* saltmarsh community	Low	Widely distributed around the coast
SM16	*Festuca rubra* saltmarsh community	Mid	Widely and extensively distributed around the coast
SM17	*Artemisia maritima* saltmarsh community	Mid	Restricted to the south-west
SM18	*Juncus maritimus* saltmarsh community	Mid	Widespread and extensively distributed around the coast
SM19	*Blysmus rufus* saltmarsh community	Mid	No mapped stands in Wales but *Blysmus rufus* is present.
SM20	*Eleocharis uniglumis* saltmarsh community	Mid	Restricted to north-west
SM21	*Suaeda vera - Limonium binervosum* saltmarsh community	Mid	Absent from Wales
SM22	*Halimione portulacoides - Frankenia laevis* saltmarsh community	Mid	Absent from Wales
SM23	*Spergularia marina - Puccinellia distans* saltmarsh community	Mid	Restricted to the Severn Estuary
SM24	*Elymus pycnanthus* saltmarsh community	Upper	Distributed around the coast
SM25	*Suaeda vera* drift-line community	Upper	Absent from Wales
SM26	*Inula crithmoides* on saltmarshes	Upper	No mapped stands in Wales but *Inula crithmoides* is present in Wales but generally not on saltmarsh.

Community	Taxonomic identity	Characteristic zone of saltmarsh	Distribution in Wales
SM27	Ephemeral saltmarsh vegetation with *Sagina maritima*	Upper	Rare, recorded within the Dee Estuary.
SM28	*Elymus repens* saltmarsh community	Upper	Distributed around the coast.

Within the EUNIS classification, the habitat code for 'Coastal saltmarshes and saline reed beds' is A2.5. There are five saltmarsh biotope complexes (Level 4) and 66 biotopes (Level 5) (Table 2).

Table 2. The overall EUNIS habitat/biotope hierarchy for saltmarsh, using '*Salicornia* spp. Pioneer saltmarshes' as an example

Level	EUNIS code	Habitat	Example
Level 1	A	Marine Habitats	
Level 2	A2	Broad Habitat	Littoral sediment
Level 3	A2.5	Main Habitat	Coastal saltmarshes and saline reed beds
Level 4	e.g. A2.55	Biotope complex	Pioneer saltmarshes
Level 5	e.g. A2.551	Biotope	*Salicornia*, *Suaeda* and *Salsola* pioneer saltmarshes
Level 6	e.g. A2.5513	Sub-biotope	*Salicornia* spp. Pioneer saltmarshes

Of the 66 biotopes and 55 sub-biotopes (Table 3), 45 biotopes and five sub-biotopes are found in the UK. Information about the relationship between NVC vegetation types and EUNIS biotopes/sub-biotopes is available on the JNCC website.

Table 3. EUNIS saltmarsh habitats/biotopes

EUNIS biotope complex	Description	Number of biotopes	Number of sub-biotopes
A2.51	Saltmarsh drift lines	12	0
A2.52	Upper saltmarshes	12	15
A2.53	Mid-upper saltmarshes and saline and brackish reed, rush and sedge beds	20	22
A2.54	Low-mid saltmarshes	11	9
A2.55	Pioneer saltmarshes	11	9

2.3. Extent/distribution in Wales

Saltmarshes are found in all major estuaries and inlets around the Welsh coast (Figure 1). They are also found in other sheltered locations such as in the lee of spits at Abermenai Point, Anglesey or in the shelter of islands such as Holy Island.

The total area of saltmarsh habitat in Wales is estimated to be around 7-8,000 ha, representing some 17% of the total area in England and Wales as a whole (Phelan *et al.*,

2011). Differences between estimates are thought to be influenced by variation in vegetation survey and mapping methods.

The presence and distribution of NVC saltmarsh communities occurring in Wales is as follows (summarised in Table 1):

- *Lower saltmarsh communities*: Nine of the 12 NVC lower saltmarsh communities are found in Wales (SM6–10, SM12–15) (Table 2). These communities are distributed around the Welsh coast, with the exception of SM7 which has been reported locally on the Artro estuary.
- *Middle saltmarsh communities*: Five of the eight NVC middle saltmarsh communities are found in Wales. *Juncus gerardii* (SM16) and *Juncus maritimus* (SM18) are widely distributed around the Welsh coast; *Eleocharis uniglumis* (SM20) is restricted to the northwest; and *Seriphidium maritimum* (SM17) is limited to the southwest.
- *Upper saltmarsh communities*: Four of the five NVC upper saltmarsh communities are found in Wales, namely *Elymus pycnanthus* (SM24), *Sagina maritima* (SM27) and *Elymus repens* (SM28).

There is a general consensus that saltmarsh extent has been decreasing on a UK-wide scale in the last three decades (Pye & French 1993, UKBAP 2006, Environment Agency 2008). A level of stability has been observed in some areas of Wales (Bristow & Pile 2002), and some vertical accretion has been observed in the Dyfi estuary in mid-west Wales (Shi 1993), and in the Dee Estuary. However, losses of intertidal habitat, including saltmarsh, due to coastal squeeze, where habitats are caught between rising sea-levels and fixed defences, are predicted by the Shoreline Management Plans (Atkins, 2010, Halcrow, 2012(a), Halcrow 2012(b), Royal Haskoning, 2012). On the Welsh border of the Severn estuary, however, saltmarshes have been shown to be generally decreasing (Allen 1990, Otto 1996). The most recent JNCC assessment summary available for the UK reports that 58% of the assessed saltmarsh features are in favorable condition.

2.4. Conservation importance

Saltmarsh is an important coastal habitat supporting specialist plant communities with very high primary productivity and supporting a wide range of organisms. Although generally species poor, pioneer and low marsh support halophytic plant species found only within saltmarsh. The plant diversity and structural complexity of saltmarshes, and the transition between freshwater and brackish conditions, provides a habitat that supports important populations of invertebrates (Ford *et al*. 2013) which are also a food resource for birds. The plant diversity increases higher up the marsh as more generalist species are able to colonise. Natural transitions to terrestrial and freshwater habitats are often the most diverse communities but are absent from many marshes due to flood defences. A range of threatened and declining plant species are supported by saltmarsh in Wales which include:

- *Alopecurus bulbosus*
- *Althaea officinalis*
- *Bupleurum tenuissimum*
- *Carex punctata*
- *Juncus acutus*
- *Lepidium latifolium*

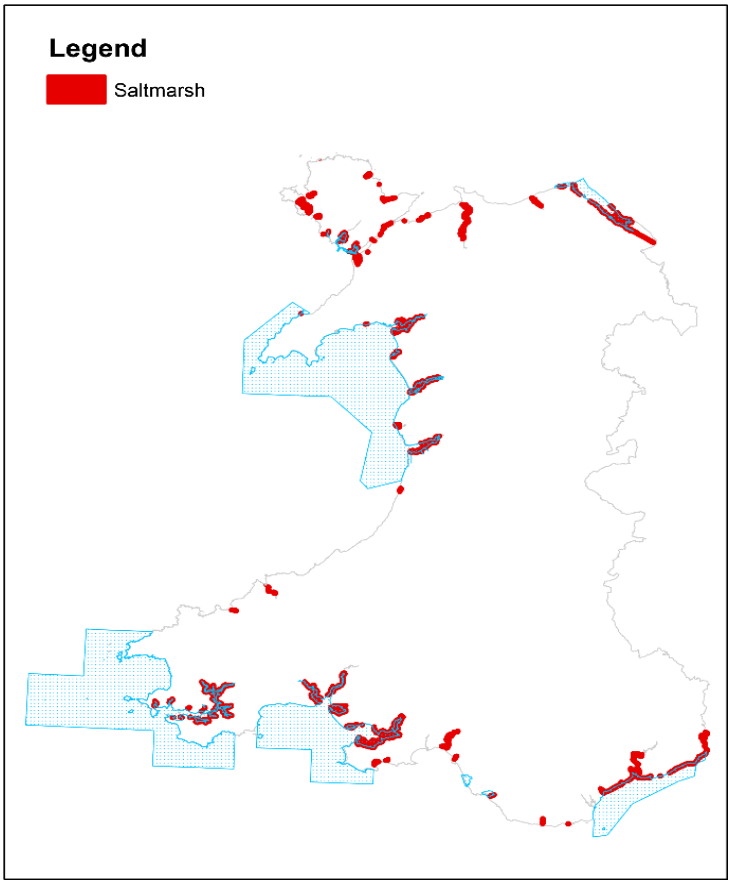

Figure 1. Saltmarsh in Wales (SACs with saltmarsh features are shown in blue), from Lough *et al.*, 2007)

Saltmarsh supports breeding populations of wading birds, gulls, terns and a limited range of passerines, and provide a high tide roost for feeding waders from adjacent mudflats and feeding grounds for overwintering birds and passage migrants (Maddock 2008). In addition, saltmarsh habitats support a range of invertebrates and small mammal species, and fish may use saltmarshes as feeding and nursery areas.

Saltmarshes can act as natural flood defences, providing protection against coastal erosion and flooding, and they have been shown to decrease the height of waves under storm surge conditions (Moller *et al.* 2014). Saltmarshes are also involved in the cycling and retention of nitrogen and phosphorous (Sousa *et al* 2010). They can capture carbon at a rapid rate and store it for long periods, providing a sustained sink for atmospheric carbon dioxide (Burden *et al*., 2013, Beaumont *et al*., 2014).

The Introductory Chapter GN030-intro of this guidance (section 3.2.2) provides summary information on conservation policies and legislation, but key aspects relevant to saltmarsh are highlighted below.

2.4.1. Habitats Directive

The Habitats Directive lists habitats and species of interest in Annex I and Annex II respectively. The following coastal saltmarsh habitats are designated Annex I habitats which are present in Wales:

- *Salicornia* and other annuals colonising mud and sand (code[1] 1310)
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (code 1330)
- Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*) (code 1420)

Special Areas of Conservation (SACs) are protected sites designated under the Habitats Directive, and saltmarsh habitats are features of seven SACs in Wales (Lough *et al.* 2007). These are illustrated in figure 1 and listed in table 4.

Most of the saltmarsh in Wales is made up of Atlantic salt meadow habitat. The *Salicornia* habitat is less extensive but widespread. The habitat type 'Mediterranean and thermo-Atlantic halophilous scrubs' is only present in very small quantities within the Pen Llŷn a'r Sarnau SAC. Saltmarsh is also a component of the broader 'Estuaries' (code 1130) and 'Large shallow inlets and bays' (code 1160) Annex I habitats. Saltmarsh provides an important feeding habitat and dispersal corridor for otter *Lutra lutra*, while the upper saltmarsh/transition zone can provide a key habitat for the narrow-mouthed whorl snail *Vertigo angustior* (both of which are Habitats Directive Annex II species).

Table 4. Special Areas of Conservation in Wales where saltmarsh is a designated feature

Special Area of Conservation	Annex I saltmarsh habitats
Dee Estuary SAC / Aber Dyfyrdwy ACA	Atlantic salt meadows; Salicornia and other annuals
Glannau Môn Cors Heli SAC / Anglesey Coast: Saltmarsh	Atlantic salt meadows; Salicornia and other annuals
Pen Llŷn a'r Sarnau SAC / Lleyn Peninsula and the Sarnau	Atlantic salt meadows; Salicornia and other annuals
Pembrokeshire Marine SAC / Sir Benfro Morol	Atlantic salt meadows
Carmarthen Bay and Estuaries SAC / Bae Caerfyrddin ac Aberoedd	Atlantic salt meadows; Salicornia and other annuals
Kenfig SAC / Cynffig	Atlantic salt meadows
Severn Estuary SAC / Môr Hafren	Atlantic salt meadows

2.4.2. Birds Directive

This Directive aims to protect all European wild birds and the habitats of listed species, in particular through the designation of Special Protection Areas (SPAs), including all the most suitable territories for these species. Saltmarsh provides habitat for important populations of overwintering wildfowl, a high-tide refuge for birds feeding on adjacent mudflats, breeding sites for waders, a source of food for passerines and raptors.

2.4.3. Ramsar Convention on Wetlands

The adoption of the Ramsar Convention on Wetlands of International Importance in 1971 committed the UK to conserve and sustainably use intertidal mudflats and saltmarshes.

[1] The code assigned to the Annex I features is the Natura 2000 code which is a four digit code given in the Natura 2000 standard data-entry form. Natura 2000 is a network of nature protection sites in the territory of the European Union. It is made up of Special Areas of Conservation and Special Protection Areas.

Saltmarsh can form supporting habitat for birds within Ramsar sites. Welsh Ramsar sites include Burry Inlet, Cors Fochno and Dyfi.

2.4.4. Water Framework Directive

Saltmarsh is a sub-element (along with seagrass) which makes up the Water Framework Directive (WFD) Angiosperm Biological Quality Element (BQE) which is used to assess the status of Transitional and Coastal (TraC) waterbodies for the WFD (WFD-UKTAG 2014). Where a development or activity has the potential to impact upon saltmarsh, a WFD compliance assessment must be carried out as part of the environmental assessment process. The purpose of the WFD assessment is to show whether the development or activity will contribute to deterioration of waterbody status and/or jeopardise the water body achieving good status.

2.4.5. OSPAR list of threatened and/or declining species and habitats

Whilst saltmarsh is not included on the OSPAR list of threatened and/or declining habitats it is a habitat that can be protected within Marine Protected Areas (MPA) designated under OSPAR. Examples in Wales include Glannau Môn/Anglesey Coast SAC and Pen Llŷn a'r Sarnau/Lleyn Peninsula and the Sarnau SAC.

2.4.6 International Union for the Conservation of Nature (IUCN) Red Data List of threatened species

This IUCN Red Data List provides an information source on the conservation status of flora and fauna using internationally approved IUCN criteria and categories. There are several saltmarsh vascular plant species on the Red Data list, for example:

- *Atriplex longipes*
- *Polygonum maritmum*
- *Eleocharis parvula*
- *Limosella australis*
- *Bryum marratii (a bryophyte)*

2.4.7 Environment (Wales) Act 2016 Section 7 list of habitats/species of principal importance (previously NERC S42 lists)

Section 7 of the Environment (Wales) Act 2016 lists coastal saltmarsh as a priority habitat in the Marine habitat list under the Littoral sediment section.

2.4.8 The Wildlife and Countryside Act 1981 (amended by the Countryside and Rights of Way (CROW) Act 2000)

The Act provides for the designation of Sites of Special Scientific Interest (SSSIs). There are more than 1,000 SSSIs in Wales, covering about 12% of the country, and over 40 of these have saltmarsh as a designated feature e.g. Aber Taf, Beddmanarch–Cymyran, and Crymlyn Burrows SSSIs. In SACs, SPAs and Ramsar sites, SSSI designations also underpin the terrestrial components of these sites.

2.4.9 Marine and Coastal Access Act 2009

The Act enables Marine Conservation Zones (MCZs) to be designated to conserve 'nationally important' features including coastal saltmarshes and saline reed beds, marine flora, fauna, habitats and geological or geomorphological structures. At present, the only MCZ currently designated in Wales is the Skomer MCZ.

2.4.10 Welsh Marine Protected Area Network

Coastal saltmarshes and saline reedbeds are one of the Broadscale Habitats on the Welsh MPA Network feature list (2016).

2.5 Key potential pressures

The potential pressures of marine developments/activities on saltmarsh habitats vary in relation to factors such as the nature of the development/activity, construction methods, mode of operation and scale of the project. These factors are all considered at the EcIA stage, along with the conservation value and sensitivity of the habitat/species of interest and the magnitude of effect, to assess the significance of the effect of a given pressure on a specific receptor (CIEEM, 2018).

Table 5. Key potential pressures of marine developments and activities on saltmarsh habitat (adapted from Tillin & Tyler-Walters, 2014)

Pressure	Examples
Salinity changes	Cooling water discharges, freshwater inputs or abstraction.
Temperature changes	Cooling water discharges.
Water flow (tidal current) changes; Wave exposure changes; Change in tidal inundation regime and/or water levels	Construction of coastal structures (ports, pilings, jetties, coastal defences, tidal lagoons etc.); Coastal defences (e.g. managed realignment).
Nutrient and organic enrichment; Presence of pollutants	Sewage effluent; Agricultural run-off; Marinas; Aquaculture; Spillage of contaminants during development construction/operation.
Changes to suspended solid levels (water clarity); Changes to siltation rates (smothering)	Dredging; Discharges to marine environment; Spoil disposal; Agricultural run-off.
Land claim and coastal squeeze	Agriculture; Construction and operation of coastal structures/developments (incl. access roads), transport infrastructure; Coastal defences (e.g. managed realignment).
Changes to, removal and disturbance of substrate surface and subsurface	Dredging; Anchoring/mooring; Vehicle use; Construction and operation of coastal structures/ developments; Coastal defences (e.g. managed realignment); Extraction industry; Grazing; Recreation.
Changes to sediment transport and erosion/accretion regime; Changes to saltmarsh structure/geomorphology	Dredging; Construction and operation of coastal structures/developments; Coastal defences (e.g. managed realignment); Extraction industry; Grazing.
Introduction or spread of invasive non-native species (INNS)	Vessel activity; Discharges to marine environment; Marinas; Aquaculture; Spoil disposal; Construction and operation of coastal structures/developments.

Pressure	Examples
Biological pressures	Other anthropogenic influences e.g. Waste tipping; Barrage construction; Recreational pressures.

2.6. Sensitivity (resistance and resilience to pressures)

For any species or habitat in the Zone of Influence (ZoI) of a development or activity, it is important to understand their sensitivity to each of the specific associated pressures arising from the development/activity. The presence of saltmarshes is related to the supply of sediment for the accretion of the marsh surface, and saltmarsh buffers are naturally self-repairing and maintenance-free. Rates of recovery and recolonisation depend on the level of damage or disturbance and will likely be protracted where the sediment has been disturbed (Beeftink 1979). Saltmarsh stability may be a function of biological, chemical and physical factors.

MarLIN provides sensitivity reviews for pioneer saltmarsh and *Puccinellia maritima* saltmarsh. It is important for you to read the further information and considerations related to MarLIN assessments in the introductory chapter (GN030 – intro).

The MarLIN sensitivity reviews indicate that pioneer and *P. maritima* saltmarsh has intermediate to high intolerance to a number of physical pressures related to changes in sediment and water regime. Recoverability for both ranges is from moderate to very high, however, resulting in a low to moderate sensitivity to physical pressures, while sensitivity to biological pressures is very low or low for both habitat types. Pioneer saltmarsh is indicated to be most sensitive to the chemical pressure of hydrocarbon contamination, including oil spills (high sensitivity and low recoverability), while the sensitivity and recoverability of *P. maritima* saltmarsh to this pressure is indicated to be moderate.

Figure 2. Common cord-grass *Spartina anglica* in the pioneer SM6 community, Traeth Cefni, Anglesey (left) © John Ratcliffe; Surveying *Puccinellia* saltmarsh (right) © John Ratcliffe

3. Existing guidance and data

The JNCC has recently produced specific guidance for the monitoring of marine benthic habitats (Noble-James *et al.* 2017). A brief summary of available guidance for monitoring requirements and approaches for saltmarshes is provided below, with key references indicated.

3.1 Common Standards Monitoring

Common standards monitoring (CSM) was developed in the context of SSSIs and SACs to set and assess conservation objectives to help staff who are undertaking site monitoring and assessment (JNCC 2004). A key use of this monitoring data is to satisfy the requirement to report on the status of international site networks under Article 17 of the Habitats Directive (see Section 2.4.1).

Saltmarsh Habitats Directive monitoring is required to assess the condition and extent of the Annex I habitats (Section 2.4.1), which feeds into Article 17 (Habitats Directive) reporting for each of the features across Wales and the UK. CSM uses a classification proposed by the Council of Europe (Dijkema 1984). The CSM assessment is applied to the reporting unit and is based on monitoring the following set of mandatory attributes, with the objective of assessing whether the feature is in a favourable condition:

- habitat extent
- physical structure: creeks and pans
- vegetation structure: zonation, sward structure
- vegetation composition: characteristic species, indicator of negative trend (*Spartina anglica*)
- other negative indicators (e.g. artificial drains, pollution, trampling)

High level information for monitoring these attributes is provided in the CSM *Guidance for Saltmarsh Habitats* (JNCC 2004). The CSM documents provide broad guidance for feature-specific monitoring, indicating the background, targets and monitoring techniques for feature attributes. The saltmarsh attributes indicated above, and associated monitoring, are also relevant to SSSIs designated under the Wildlife and Countryside Act 1981 (as amended).

The saltmarsh monitoring for Article 17 Habitats Directive reporting that NRW has undertaken to date has been based on the framework of attributes and targets that the CSM guidelines provide. For Habitats Directive reporting in Wales the CSM targets are normally refined to make them site-specific.

3.2 Water Framework Directive Monitoring

The WFD UK Technical Advisory Group (UKTAG) document on saltmarshes (WFD-UKTAG 2014) provides an overview of the saltmarsh tool and how to monitor, assess and classify suitable saltmarsh data in transitional and coastal waters according to WFD requirements. In line with the WFD normative definitions, ‘abundance’ is considered to relate to the extent of the saltmarsh (i.e. the area of the stands) and ‘composition’ is considered to relate to both taxonomic diversity and the number and proportion of zones of the saltmarsh.

The saltmarsh tool is a multimetric index that is composed of six individual components known as metrics:

- saltmarsh extent as a proportion of ‘historic saltmarsh’
- saltmarsh extent as a proportion of the intertidal zone
- change in saltmarsh extent over two or more time periods
- proportion of saltmarsh zones present (out of five)
- proportion of saltmarsh area covered by the dominant saltmarsh zone
- proportion of observed taxa to historical reference value, or to 15 taxa

The individual metrics have been weighted and averaged within the tool to describe the changes in the saltmarsh as a response to anthropogenic pressures. Normalisation and rescaling is conducted to convert each metric to the index score between 0 (Poor) and 1 (Good). The Ecological Quality Ratio (EQR) value is then calculated, from which the ecological status class, and confidence of class, are determined.

3.3 National Vegetation Classification

The saltmarsh communities of the NVC were described in Volume 5 of *British Plant Communities* (Rodwell 2000). Additional plant communities which can also be present on saltmarsh are described in other volumes: for example, S21 *Scirpus maritimus* (Sea club-rush) swamp is described in Volume 4: ‘Aquatic Plant Communities, swamps and tall-herb fens’. The survey methodology is available in Rodwell (2006).

NVC surveys provide data on the floristic classification and spatial distribution of vegetation communities, allowing areas of high ecological value and those related to Annex I habitats to be identified. The NVC is also relevant to SSSI designation, because this is the classification system used to identify and describe vegetation communities of importance or of restricted distribution in the SSSI Designation Guidelines.

3.4 Aerial survey guidance

The Mapping European Seabed Habitats (MESH) project conducted between 2004 and 2008 was a consortium of twelve partners from five European countries, led by the UK’s JNCC. Part of the project involved the production of a number of ‘Recommended operating guidelines’ (ROGs). The aerial photography ROG is relevant to intertidal survey (Piel & Populus 2007), hosted on the EMODnet website (EMODnet 2017). In addition, aerial imagery should be captured according to Royal Institute for Chartered Surveyors (RICS) guidelines for aerial survey.

Saltmarsh aerial photos are gathered under the NRW WFD monitoring programme to determine extent and zonation and may be available from NRW for specific areas. The validity of the outputs from photographic interpretation depends upon a wide variety of factors, including quality of the imagery (to include tidal cycle images at low tide), time of year, and the time of day that the photos were taken.

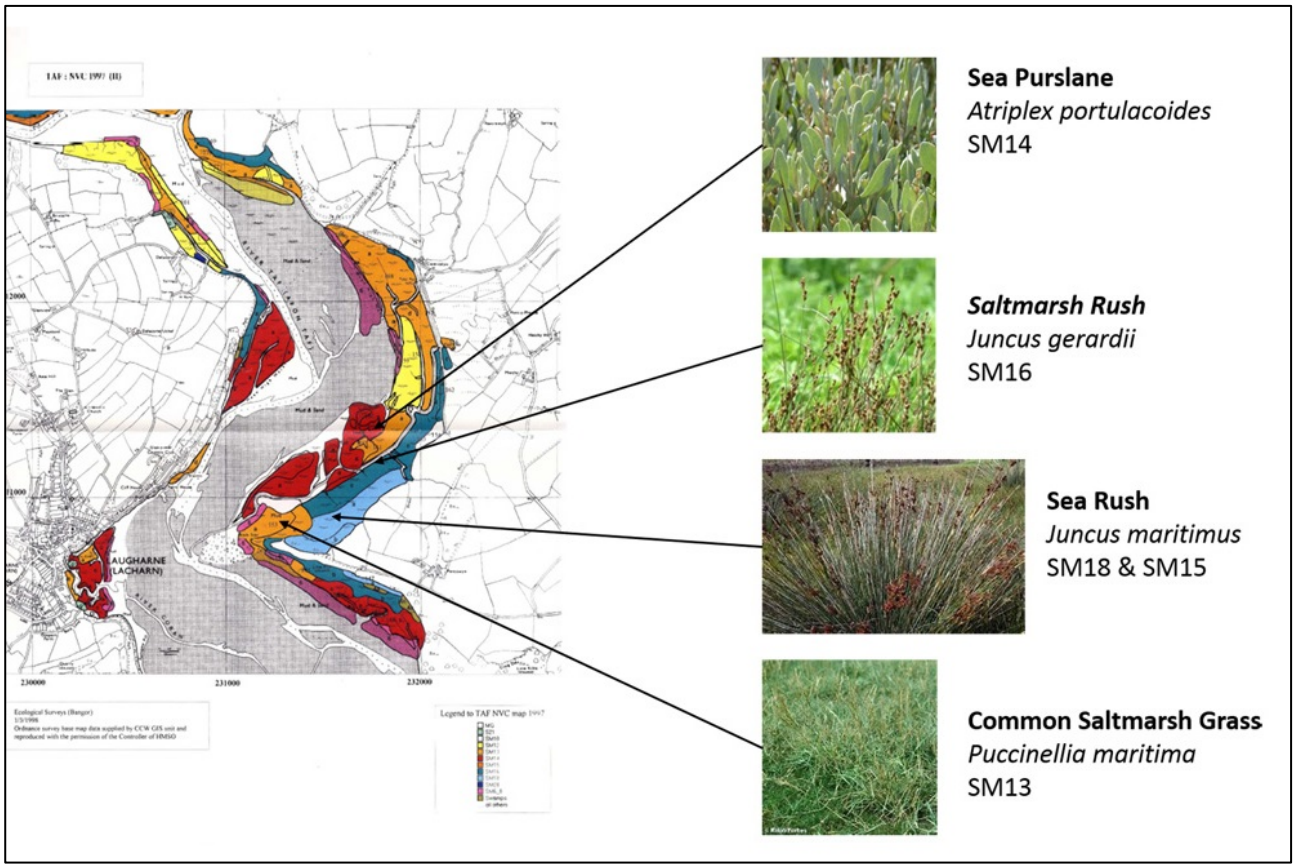

Figure 3. An example of the distribution of four key saltmarsh NVC community types and their NVC code, in the Black Scar saltmarsh in south-west Wales
(Universities of St Andrews and Bangor, CBESS project; based on an NVC survey map of the Taf, Tywi and Gwendraeth Estuaries (Prosser & Wallace, 1998)).

3.5 Data sources

Distribution data for saltmarsh species in the UK are available on the National Biodiversity Network's (NBN) Gateway, a database holding more than 127 million species records. More than 160 partners provide this data, and searches can be conducted based on species distribution data by either site or species.

Our guidance Note (GN006 Marine ecology datasets for marine developments and activities (Natural Resources Wales, 2019)) provides information on the marine ecology data that we hold and routinely use and how you can access them. It also includes details of available benthic habitat mapping outputs held by ourselves and others and explains where you can view and download information about marine protected areas and protected habitats and species. Data includes outputs from NVC surveys that cover most of the saltmarsh in Wales from the later 1990's to early 2000s and other relevant saltmarsh maps.

4. Survey and monitoring design

The Guidance Note GN030 and Introductory Chapter GN030-intro explain when and why habitat characterisation and monitoring may be required in relation to development proposals and activities and over-arching principles for both of these[2]. It is important to understand the differences between characterisation surveys and monitoring when designing project-specific survey programmes.

4.1 Existing data

Where possible, and where timeframes allow, a comprehensive desk-based review of all available data relevant to saltmarsh habitats within the area of interest should be conducted prior to designing any habitat characterisation surveys or monitoring programmes. Further information relating to sourcing and using data is provided in the Introductory Chapter GN030-intro and Noble-James *et al*. (2017).

4.2 Selecting ecological parameters

The Introductory Chapter GN030-intro (sections 3.2.7 and 4.2.1) summarises the importance of selecting suitable ecological parameters for survey (known as 'indicators' for monitoring programmes) and the process to determine the effectiveness, appropriateness and validity of parameters.

The main ecological parameters that can be measured for saltmarsh habitats include:

- extent and distribution of saltmarsh
- extent and distribution of NVC communities present
- physical structure of saltmarsh including distribution of creeks and pans
- saltmarsh zonation information
- number of plant taxa and plant species diversity
- plant abundance (usually on an ordinal scale e.g. Domin, and/or frequency in quadrats)
- distribution and abundance of any species of conservation importance or non-native species
- saltmarsh condition and identification of pressures which may be affecting the saltmarsh

4.3. Benthic habitat characterisation

4.3.1. Aims of benthic characterisation surveys for saltmarsh

The aim of the habitat characterisation survey is to collate data to describe the saltmarsh within the survey area and provide an up-to-date ecological appraisal to inform EcIA (see the Guidance note GN030 and Introductory Chapter GN030-intro for more details on the role of habitat characterisation surveys).

[2] Note that the Guidance Note and Introductory Chapter apply to all of the specific habitat chapters of this guidance; consequently, some parts may not be directly relevant to a specific marine habitat, and information should be evaluated as appropriate.

4.3.2. Design of benthic habitat characterisation surveys for saltmarsh

Development- and activity-specific information should inform the design of habitat characterisation surveys, which will also be influenced by the scale of the development or activity (see Introductory Chapter GN030-intro)[3].

If recent mapping outputs are not available, are out of date, or are of poor quality, a bespoke aerial survey may be required to determine the extent of the overall marsh and to target field survey work. However, this may also depend on the scale of the area to be mapped. Even where aerial surveys are conducted, ground-truthing is generally necessary to ascertain landward transitions and the boundaries of zones and certain vegetation communities.

The range of available survey methods for habitat characterisation is indicated in Section 5.1 and should be decided on a project-by-project basis prior to survey.

4.3.2.1. Survey design options

Where recent NVC maps are unavailable NRW recommends that a NVC survey (see section 3.3) is conducted to determine the distribution and extent of the vegetation communities. From this, any protected site features such as Annex I habitats which characterise the site can be determined. The zonation of the saltmarsh communities can also be extrapolated from the NVC data.

4.3.2.2. Timing

Both field and aerial surveys should ideally be carried out between 1st June and 30th September, when saltmarsh growth is at its maximum and plants are easiest to identify (WFD-UKTAG 2014). Summer should give the most cloud-free days for the collection of aerial imagery, and the ground survey should be undertaken at a similar time of year, though in exceptional circumstances it may be one year after or before (WFD-UKTAG 2014). The characteristic plant species of saltmarshes are mostly perennial, which allows them to be assessed over a period of several months.

4.4. Monitoring

4.4.1. Aims of monitoring programmes for saltmarsh

The aims of the monitoring need to be clearly defined and will depend on the potential impacts as identified through the EcIA process and relevant assessments as required (e.g. Habitats Regulations Assessment, Water Framework Directive assessment) and conditions set by the regulator.

Monitoring requires repeat sampling to detect change over time in one or more indicators (i.e. selected ecological parameters). In relation to regulatory development control, monitoring usually consists of pre-construction monitoring (this is known as the baseline), during construction, and post-construction operational monitoring (see Introductory Chapter GN030-intro section 4.1).

Traditional ground-based surveys are generally best practice for sampling saltmarshes to assess changes in saltmarsh habitats. A more sophisticated mapping exercise such as use of remote sensing methodologies may be required, however, particularly in dynamic

[3] The NRW marine license webpage contains details of which activities and projects require different levels of ecological assessment according to the various pieces of legislation (including activities that are exempt).

estuaries where tidal currents result in considerable erosion and/or accretion of the habitat. The monitoring methodology including experimental design needs to fulfil the monitoring requirements for the development or activity, providing sufficient information to the regulator to satisfy the relevant environment assessment processes and any conditions set by the regulator. As noted in the Introductory Chapter (section 4.2) it can be beneficial to make any development-related monitoring compatible with data from existing, ongoing monitoring programmes undertaken by NRW.

Additional community or species-specific monitoring may also be required depending on the potential impacts identified, for example where a plant community of particular value is at risk or rare, or scarce species are present in the ZoI of a proposed development/activity.


Figure 4. Saltmarsh with *Aster, Limonium and Atriplex portilacoides*, Traeth Cefni, Anglesey (left) © John Ratcliffe; Using quadrats for saltmarsh vegetation survey (right) © NRW / Heather Lewis

4.4.2. Defining hypotheses and trigger levels

Hypotheses to inform ecological monitoring are generally framed to detect change in a selected indicator over time, and to determine if any change observed is outside normal expectations. In the context of regulatory development control and EcIA, key thresholds known as 'trigger levels' are generally set to help assess whether impacts are evident on a given indicator over the course of a monitoring programme, together with management action(s) to be implemented if trigger levels are exceeded. The Introductory chapter provides further detail relating to hypotheses testing and considerations associated with the potential use of trigger levels.

As part of the EcIA process, measures may also be proposed to enhance existing or created habitats to mitigate impacts or to offset predicted biodiversity loss (Cook & Clay 2013; Defra & Natural England 2012).

4.4.3. Design of monitoring programmes for saltmarsh

Sampling designs can involve grid-based (i.e. systematic) sampling, random sampling, or stratified random sampling, depending on the characteristics of the habitat to be sampled, available data for the survey area, the aims of the survey and the type and level of impact. In addition, a Before-After-Control-Impact (BACI) design can be applied which involves identifying suitable control stations (see Introductory Chapter GN030-intro, section 4.2.5.).

4.4.3.1. Monitoring programme design options

The WFD/Habitats Directive transect approach (WFD methodology adapted to incorporate Habitats Directive requirements) is recommended for recording broad-scale changes in plant community composition across a large site. This methodology is described in a NRW note (NRW 2017, draft note currently under review; see section 5.1).

More detailed sampling may be required in certain circumstances. Where a monitoring programme needs to specifically consider areas with vegetation communities of high value, records of scarce or rare species, or where impacts are likely to be the greatest, then the monitoring design is likely to require additional sampling within these areas. In addition, sampling may need to be put in place where there are changes to saltmarsh management arising from the development or activity, such as loss of grazing on a previously grazed marsh. More detailed sampling is also recommended at critical locations, such as: areas on the edge of the ZoI where change may be minimal and difficult to detect, areas of greatest change, or areas where change would affect habitats or species of particular conservation value.

4.4.3.2. Number of stations (sampling effort)

The most distinct patterns within saltmarsh habitats are usually formed by the distribution of different major zones of saltmarsh such as pioneer marsh and lower, mid and upper marsh, and the sampling effort should represent each of these zones. There may also be recognisable subdivisions within these major zones, however, and sampling error can be considerably reduced by following the transect-stratified sampling of the WFD/Habitats Directive monitoring method (NRW 2017).

The strength in using such subdivisions within a zone, which are identified and then sampled separately, is that it ensures more equal effort and avoids under-sampling, particularly of smaller but ecologically important elements.

The statistical power, or sensitivity, of the sampling effort is related to factors both in the surveyor's control (e.g. the number, size and positioning of quadrats and transects) and inherent to the habitat type (e.g. distribution pattern, plant size and abundance of species in the habitat) see Introductory Chapter GN030-intro, section 4.2.4.).

4.4.4 Sampling timing, frequency and duration

4.4.4.1. Timing

Both field and aerial surveys should ideally be carried out between 1st June and 30th September, when saltmarsh growth is at its maximum and plants are easiest to identify (WFD-UKTAG 2014). Summer should give the most cloud-free days for the collection of aerial imagery, and the ground survey should be undertaken at a similar time of year, though in exceptional circumstances it may be one year after or before (WFD-UKTAG 2014). The characteristic plant species of saltmarshes are mostly perennial, which allows them to be assessed over a period of several months.

4.4.4.2. Frequency and duration

There is no set guidance on the frequency of sampling of saltmarsh for monitoring purposes. However, more information on relevant considerations when determining potential frequency and duration of monitoring is provided in the Introductory Chapter GN030-intro, section 4.3).

4.4.5. Supporting environment

As part of a saltmarsh monitoring programme, it is important to consider other parameters of the wider environment that may influence saltmarsh and that may also require monitoring depending on the nature, scale and location of a proposed development or activity and associated environmental pressures. This will enable an assessment of the potential influence of wider environmental parameters on saltmarsh over time, for example, water quality, tidal inundation regime and geomorphological processes within the wider system that may influence the presence and development of saltmarsh over time. These requirements are outside the scope of this guidance document but are identified here as they may need to be incorporated into a monitoring programme.

5. Survey and monitoring methods and analysis

5.1 Field methods

A range of survey methods could be appropriate for saltmarsh depending on the specific parameters being assessed. The main options include:

- Remote sensing (e.g. LiDAR, aerial imagery)
- Field-based habitat/zonation mapping
- Quantitative sampling (e.g. quadrats, transects)

These methods are discussed in further detail below with respect to the parameters that can be surveyed using these approaches. The types of methods that are appropriate will vary in relation to both the scale and nature of the proposed development/activity.

The main survey methods appropriate for saltmarsh surveys are detailed in the respective protocols for NVC (Rodwell 2000), CSM (JNCC 2004), and WFD (WFD-UKTAG 2014). NRW has prepared a draft note describing WFD saltmarsh monitoring methodology that has been adapted to incorporate Habitats Directive requirements (NRW 2017). We are currently reviewing our internal guidance for saltmarsh monitoring with the aim of producing a method that will satisfy both WFD and HD requirements.

5.1.1. Saltmarsh ecological parameters

5.1.1.1. Extent & zonation of habitat

Remote sensing

Remote sensing is considered the only realistic means of monitoring change in saltmarsh extent over wide spatial scales, allowing the production of accurate digital maps for inter-annual comparison. Ground-based methods, whilst highly accurate in small areas, require interpolation to cover the full extent of the coastal zone, which can introduce inaccuracies if applied in isolation. Ground cover types can be identified from remote sensing imagery using a technique known as digital image classification. It is increasingly possible to obtain hyperspectral imagery, which helps delineate the vegetated areas and even classify the different types of flora.

Satellite imagery can provide low and medium resolution data which can be used to determine long-term change in coastal habitats, although it is traditionally less useful for measuring more rapid or small-scale change due to the periodicity of image capture at a specific location. There have been recent improvements in periodicity of satellite imagery and the resolution of images has increased (in some cases to about 0.3 m ground resolution).

There are, however, considerable benefits from using a bespoke aerial survey to obtain imagery instead of using satellite imagery. For example, cloud cover is often a problem for satellite imagery from the UK, whereas aerial surveys are only undertaken when cloud cover is at an acceptable level. In addition, it is often not clear at which stage of the tide satellite imagery has been captured, while aerial surveys can be specifically flown at low water on a spring tide to ensure optimum exposure of the saltmarsh habitat.

Aerial imagery is therefore more commonly used to obtain data for intertidal areas, and this can be done with high resolution imagery, LiDAR, or a combination of both. Note that

use of aerial imagery interpreted using ground truthing data is a part of the WFD monitoring protocol for saltmarsh (Environment Agency 2013, WFD-UKTAG 2014).

Such datasets can now be combined with detailed elevation maps, obtained using techniques such as aerial photogrammetry or LiDAR, to further improve the estimation of habitat extent and confidence in the vegetation classification. Even so, some ground-truthing is usually required to help train the classification software and provide a quality check from one survey to the next.

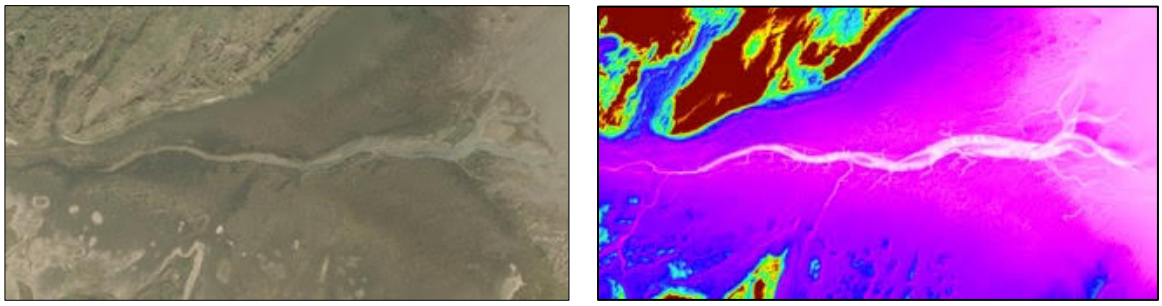

Figure 5. Saltmarsh remote sensing images for part of Traeth Melynog, Anglesey: Aerial photograph (left) © Getmapping plc and Bluesky International Limited 2009, and colour enhanced 1m DTM LiDAR (right) © Natural Resources Wales and Database Right. All rights Reserved.

Field-based transects

As indicated above, aerial surveys will also usually require aspects of ground-truthing using field-based survey methods. This is necessary to determine the landward transitions of vegetation communities. Where zonation is the key consideration, the emphasis of a ground survey would be on the distribution, extent and number of vegetation zones, in addition to the diversity and composition of vegetation within them.

The WFD/Habitats Directive transect methodology is recommended to assess broad scale changes in zonation. This methodology is described in a NRW draft note (NRW 2017). Where changes to zonation have been identified as a potential impact of a development/activity, it is recommended that this approach is reinforced with additional sampling, for example by establishing additional transects with regular, closely spaced sample points where quadrats will be deployed to provide quantitative data for vegetation intersecting the transect (see Section 5.1.1.2). This could be conducted at regular intervals or could involve selecting locations within homogenous stands of vegetation intersecting the transect.

A suitable GPS is required for locating pre-selected routes and points (ideally a differential GPS with <2 m accuracy) or marking quadrat locations. Permanent markers may be suitable in some instances.

Depending on the predicted impacts of the development, saltmarsh quality measures should be recorded such as, sward height or species diversity as well as indicators of damage such as compacted or disturbed ground

Mapping vegetation using ground-truthed aerial imagery together with a relatively basic method of classification, is a more practical approach for monitoring than repeating a

detailed vegetation survey on a regular basis. Once changes associated with the impacts of the development or activity have stabilised however, it is recommended that a NVC survey is carried out, to provide a complete audit of the impacts of the development or activity on vegetation community extent, composition and quality (using the methods outlined below). This will allow the extent of any changes to NVC communities and sub-communities to be assessed

5.1.1.2. Biological community composition and extent

Quantitative sampling (quadrats)

Taxon abundance and the number of taxa present within saltmarsh habitats are quantified using quadrats deployed along transects. Rodwell (2000) recommends a quadrat size of 2 x 2m or 4 x 4m for NVC saltmarsh surveys, depending on the terrain and scale of the vegetation. For example, where vegetation is sparse, such as in some areas of lower marsh, a larger quadrat size can be more appropriate. Nested quadrats can often be very effective for monitoring but, for some surveys where the standard quadrat sizes for monitoring are not essential, it may also be worth considering the use of different sizes of quadrats. Suitable quadrat sizes should be decided on a project-by-project basis.

Taxon abundance is a challenging measure to assess in a completely objective and repeatable way. It is usually assessed by field surveyors with an ordinal scale, such as the Domin scale used by NVC as a measure of percent cover (Rodwell 2006) (see Section 4.2).

The number of plant taxa present is an especially useful parameter, giving a measure of the distribution of taxa throughout the saltmarsh. The WFD protocol (WFD-UKTAG 2014), for instance, records the total number of present taxa compared to the total number of historically recorded taxa. Care should be taken with such taxonomic diversity data to distinguish richness and evenness (for which several indices can be used) and the sampling curve (traditionally regarded as a diminishing gain relationship between area sampled and number of species recorded).

There are practical considerations associated with using permanent quadrats for a survey or sampling regularly. Generally, the statistical objections to repeat monitoring of permanent quadrats rather than assessing a different set of random quadrats for each assessment are outweighed by the practical advantages of the approach, but the sensitivity of saltmarshes to damage by trampling also needs to be considered – even annual visits to fixed sample points can cause visible changes to the vegetation. In addition, the dynamic nature of saltmarshes can make it difficult to relocate quadrat markers, although this can be facilitated by using metal detectors and accurate GPS positioning systems to locate hidden markers.

Field survey is used to achieve the highest resolution of ecological data collection and impact assessment, providing ground-truthing and quantitative data to complement remote sensing outputs. Although saltmarshes are relatively species-poor, expert botanical identification is required for the fieldwork, which includes some challenging halophyte taxa including grasses, sedges and hybrids (e.g. *Limonium* spp.). If plants cannot be identified confidently in the field, fertile specimens should be brought back for examination by microscope and preserved to maintain the audit trail. Identifying small rosettes of non-flowering plants can be particularly challenging.

Fixed point photography
Fixed photography provides a time series which may reveal change in the landscape not obvious from ground survey fieldwork. It can be used in combination with the *in situ* recording of the parameters outlined for quadrat survey above.

5.1.1.3. Physical structure
Fixed photography, aerial photographs and appropriate analysis software can be used to obtain sedimentation rates and vector datasets of attributes such as the marsh edge, and morphological features such as pans (localised depressions in the saltmarsh surface) and creeks which can be important considerations when assessing changes in saltmarsh habitat.

5.1.2. Fieldwork Quality Control
All fieldwork should be carried out by experienced field scientists, with appropriate taxonomic identification skills and necessary health and safety provisions. There should be full sample tracking documentation and field notes for the sampling procedures. Sample collection and handling during surveys, if required, must conform to the requirements of subsequent analytical analyses.

Across all methods it is important to obtain accurate detailed records and to retain records/data for quality control/assurance procedures. If multiple teams are conducting a survey it may be useful to conduct a pre-survey sampling session with all of the surveyors together, or to sample the first station together to ensure consistency.

All field data, images, preserved material etc. should be retained for future reference or Analytical Quality Control (AQC).

5.2. Analytical methods
5.2.1. Aerial imagery
Specialist image processing software should be used to perform the following functions:

- Geometric image correction
- Radiometric image correction
- Quality control image data before, during and after download

The pre-processing functions above are used to create colour-balanced, distortion-free aerial imagery. The processed imagery and associated flight log data are imported into specialist proprietary photogrammetric software, to be mosaiced and orthorectified to generate seamless high resolution georeferenced orthomosaics.

The imagery should be aligned using pixel-matching algorithms which identify common features between each image pair. The post-processed GPS data from the aircraft is then used to triangulate the block, creating a continuous model of the site. Once the initial triangulation is complete, any Ground Control Point (GCP) data captured in the field can be imported into the block to enhance the accuracy of the model. A final seamless, accurately georeferenced image mosaic should then be produced.

5.2.2. Specimen identification

Following the use of hand-lenses in the field, compound and dissecting microscopes can be used in the laboratory to view the definitive morphological features of plant specimens. This may be required for some species to identify them with a high level of confidence. For most purposes it is recommended that the UK authoritative text for plant identification is used (Stace 2010), rather than other more simplified and less comprehensive field guides.

5.3. Data analysis and interpretation

The Introductory Chapter GN030-intro outlines a number of approaches which are available for data analysis. The most suitable approach for each habitat should consider a variety of factors such as whether data are being analysed for a habitat characterisation or monitoring survey, and the survey design. Further detail is provided in a wide range of published and grey literature such as Noble-James *et al*. (2017).

5.3.1. Habitat Characterisation and Monitoring

Key outputs of the habitat characterisation surveys will include the production of a GIS layer indicating saltmarsh communities (based on a selected vegetation classification method e.g. NVC), with accompanying quadrat data and quadrat photographs. Univariate and multivariate analyses can be applied to the data to distinguish spatial trends in vegetation communities. The main purpose of habitat characterisation for saltmarsh in the context of proposed developments and activities is to provide the data outputs necessary for the EcIA process and to provide evidence in support of any associated assessments including HRA and WFD assessment as required (see the Guidance Note GN 0303 and Introductory Chapter GN 030-intro).

Monitoring data should be subject to in-depth statistical analysis and interpretation to test the hypotheses set out at the design stage. A wide range of suitable univariate and multivariate analysis and mapping techniques are available to achieve this and as a result those chosen are likely to vary markedly between projects. A full account of the proposed statistical tests to be used to monitor change should be set out in the information about the proposed monitoring programme.

5.3.1.1. WFD classification

The design of saltmarsh surveys will probably need to be WFD compliant. WFD compliance assessments (provided with applications to regulators for permission for activities) must consider potential impacts to saltmarsh. WFD assessments must show if the activity will cause or contribute to deterioration of waterbody status and/or jeopardise the water body achieving good status. However, whether it will be necessary to calculate the Ecological Quality Ratio (EQR) index as part of the survey deliverables is something that must be discussed on a project-by-project basis. It is more likely that these calculations will be required for monitoring requirements than for habitat characterisation.

Saltmarsh is a sub-element (along with seagrass) which makes up the Water Framework Directive (WFD) Angiosperm Biological Quality Element (BQE) which is used to assess the status of Transitional and Coastal (TraC) waterbodies for the WFD (WFD-UKTAG 2014). Where a development or activity has the potential to impact upon saltmarsh, a WFD compliance assessment must be carried out as part of the environmental assessment process. The purpose of the WFD assessment is to show whether the development or activity will contribute to deterioration of waterbody status and/or jeopardise the water body achieving good status.

5.3.1.2. Statistical modelling

Modelling of sediment transport or water quality changes can be a useful option for predicting the likelihood of significant effects of a development or activity on saltmarsh (and/or ascertaining whether there could be adverse effects on the integrity of a protected site for which saltmarsh is a feature). Statistical analyses can be applied to these data to assess potential relationships between biotic data and environmental data (see Introductory Chapter GN030-intro).

A range of methods (e.g. Phelan *et al.* 2011) have been used to predict future change in saltmarsh extent. These methods include the use of linear extrapolation of historic trends, regime methods, mudpack modelling, and expert geomorphological assessment.

5.3.1.3. Habitat mapping

Saltmarsh survey data may be presented as detailed survey maps, typically using spatial mapping software packages, with the most common software typically being ESRI ArcGIS. Further information relating to the types of classification systems that can be used to map benthic habitats and the inclusion of point sampling data within the mapping outputs is provided in the Introductory Chapter GN030-intro (section 3.2.4).

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