Saltmarsh Angiosperm Assessment Tool for Ireland (SMAATIE)

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Executive Summary

The European Union (EU) Water Framework Directive (WFD; 2000/60/EC) aims to protect and enhance the quality of rivers, lakes, groundwater, estuaries and coastal waters. EU Member States (MS), such as Ireland, must aim to achieve Good status in all waters by 2015 and ensure that status does not decline. As part of this commitment, MS must assess and classify the quality of transitional and coastal waters. One of the Biological Quality Elements (BQEs) to be assessed is “angiosperms” and saltmarshes are included within this BQE. Hitherto, a suitable WFD status assessment tool for saltmarshes has not been fully developed in an Irish context.

During 2013-2014, BEC Consultants conducted an eight month desk study into developing the Saltmarsh Angiosperm Assessment Tool for Ireland (SMAATIE). The following main project objectives were identified:

- collate available and historical records on Irish saltmarshes including environmental pressures
- assess similar tools used by other MS in the Northeast Atlantic Geographical Intercalibration Group (NEA-GIG)
- investigate potential metrics for inclusion in the tool addressing the required aspects of angiosperm abundance, composition and disturbance-sensitive taxa
- apply the finalised tool to a representative sample of Irish water bodies containing saltmarsh habitat
- calculate Ecological Quality Ratio (EQR) values for selected Irish water bodies with regard to saltmarsh

Chapter 1 introduces the main concepts and terminology concerning the WFD assessment of the ecological status of saltmarshes in transitional and coastal water bodies. Chapter 2 presents background information on Irish saltmarshes including the topics of distribution, types, communities, pressures, uses and management, conservation value and designations.

To assist in development of the tool, available datasets of quantitative vegetation plots were collated and analysed with multivariate statistics (Chapter 3). Twenty-two saltmarsh communities were classified grouped into six vegetation classes. The six classes represent pioneer vegetation, lower saltmarsh, middle saltmarsh, upper saltmarsh, upper saltmarsh transition and brackish swamps.

A number of existing datasets were used to determine the most frequently occurring pressures acting on either saltmarshes or water bodies which support saltmarshes (Chapter 4). Seventy individual pressures were identified and categorised under five main pressure categories: pollution, morphology, water regime, biology or other. The most frequent pressures recorded in water bodies containing saltmarsh were pollution from point sources (49%), grazing (47%), and transportation and service corridors, including paths, tracks and pipelines (39%).

The assessment tools used by other MS were examined in detail (Chapter 5). This examination of potential metrics led to the development of SMAATIE, comprising metrics for angiosperm abundance (habitat

extent), taxonomic composition (zonation) and disturbance sensitive taxa (halophyte diversity) (Chapter 6). All necessary equations, normalisation values and weightings, as well as a worked example, are provided.

SMAATIE metrics were applied to a selection of forty coastal and transitional water bodies (Chapter 7). Four had a resulting WFD ecological status of High, fifteen were Good, eighteen were Moderate and three had a Poor ecological status. The main causes for Moderate or Poor ecological status of water bodies were small areas of extant saltmarsh, large areas of *Spartina* swards and an imbalance in the dominance of zones within the saltmarsh systems. Significant relationships with EQRs were not found when analysing EPA trophic status, EPA risk assessment status or previous overall biological status. However, there was strong correlation between EQR values generated by SMAATIE and pressures related to water regime modification.

Chapter 8 provides guidance on data collection, particularly in the field, with suggestions on how to incorporate both the requirements of the WFD and Habitats Directive (HD) while recording data. This chapter is further expanded upon in the Practitioner's Manual, one of the outputs from the project, which can be downloaded from the EPA SAFER website (http://erc.epa.ie/safer/).

Chapter 9 discusses limitations encountered during development of the tool. These primarily concern deficiences in available data, including the lack of required Geographical Information Systems (GIS) data for some sections of the coast, the lack of historical information on saltmarsh extent and species distributions, the nature of data on human pressures on the habitat, and the categories hitherto used to map saltmarsh.

Chapter 9 also presents the project recommendations. Amongst these are calls for research programmes into the functioning and ecosystem services of saltmarshes, and the relationships between pressures (e.g. eutrophication, grazing) and ecological indicators. A field-test of the developed tool is needed followed by a review procedure and application to all relevant Irish water bodies. Appropriate GIS data should be obtained or specifically recorded for areas where it is missing. The vegetation classification system developed by this project should be adopted and implemented during field work for future WFD monitoring.

1. Introduction

1.1 Water Framework Directive

The European Union (EU) Water Framework Directive (WFD; 2000/60/EC) is an important piece of environmental legislation which aims to protect and enhance the quality of rivers, lakes, groundwater, estuaries and coastal waters. EU Member States (MS), such as Ireland, must aim to achieve at least Good status in all waters by December 2015 and ensure that status does not decline. All waters are divided by the WFD into two groups, surface waters and groundwater, for which there are different objectives and characterisation requirements (EC, 2003a). These two groups can be further subdivided into water bodies, which are the geographical units used for reporting and assessing compliance with the Directive's environmental objectives (EC, 2003a).

Each surface water body can be defined as a "discrete and significant element" of surface water (e.g. a lake, river, estuary or stretch of coastal water) (EC, 2003a). Only two types, Coastal Water Bodies (CWBs) and Transitional Water Bodies (TWBs) are relevant to this report. The Directive defines transitional waters as "bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows" (WFD, Article 2(6)). Coastal water is defined as "surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters" (WFD, Article 2(7)).

1.2 Ecological status classification

The Directive defines surface water status as "the general expression of the status of a body of surface water, determined by the poorer of its ecological status and its chemical status" (WFD, Article 2(17)) (Figure 1.1). Chemical status refers only to those priority substances for which Environmental Quality Standards (EQSs) are set at the European level; it is only divided into two classes: Pass and Fail (EC, 2003b). Ecological status is defined as an "overall expression of the structure and function of its biological community, taking into account geographical and climatic factors, together with physical and chemical conditions, including those resulting from anthropogenic influences" (Cusack *et al.*, 2008). It is based upon biological, hydromorphological and physico-chemical quality elements, and levels of specific pollutants (WFD Annex V, Section 1.1), with the biological elements especially important (Borja *et al.*, 2006).

There are five Biological Quality Elements (BQEs): phytoplankton, macro-algae, angiosperms, benthic invertebrate fauna and fish fauna. These BQEs are required for the classification of the ecological status of transitional and coastal (TraC) water bodies (Figure 1.1; Best *et al.*, 2007). Ecological status is divided into five classes: High, Good, Moderate, Poor and Bad. The WFD provides normative definitions for the first three classes (High, Good and Moderate). MS are expected to further define these definitions, as well as provide definitions for the other two classes (Poor and Bad) (Best *et al.*, 2007). Classification tools must be consistent with WFD normative definitions (Best *et al.*, 2007) and must also be comparable between MS in order to ensure a harmonised approach in defining Good ecological status (EC, 2003c).

Reference conditions represent undisturbed (or nearly so) conditions, where human pressures are allowed providing there are no or only very minor ecological effects. They are a description of the BQEs at high status (EC, 2003b). The Ecological Quality Ratio (EQR) is derived by comparing monitoring results with the reference conditions. It is expressed as a numerical value which lies between 0 and 1. For the purposes of intercalibration with other MS, the EQR values for High, Good and Moderate status classes must represent the relevant normative definitions. Intercalibration ensures that class boundaries represent a comparable level of anthropogenic alteration to the BQE across the MS involved (EC, 2011). Furthermore, it is required that EQR values derived from a classification tool show some relationship with independently measured pressure gradients.

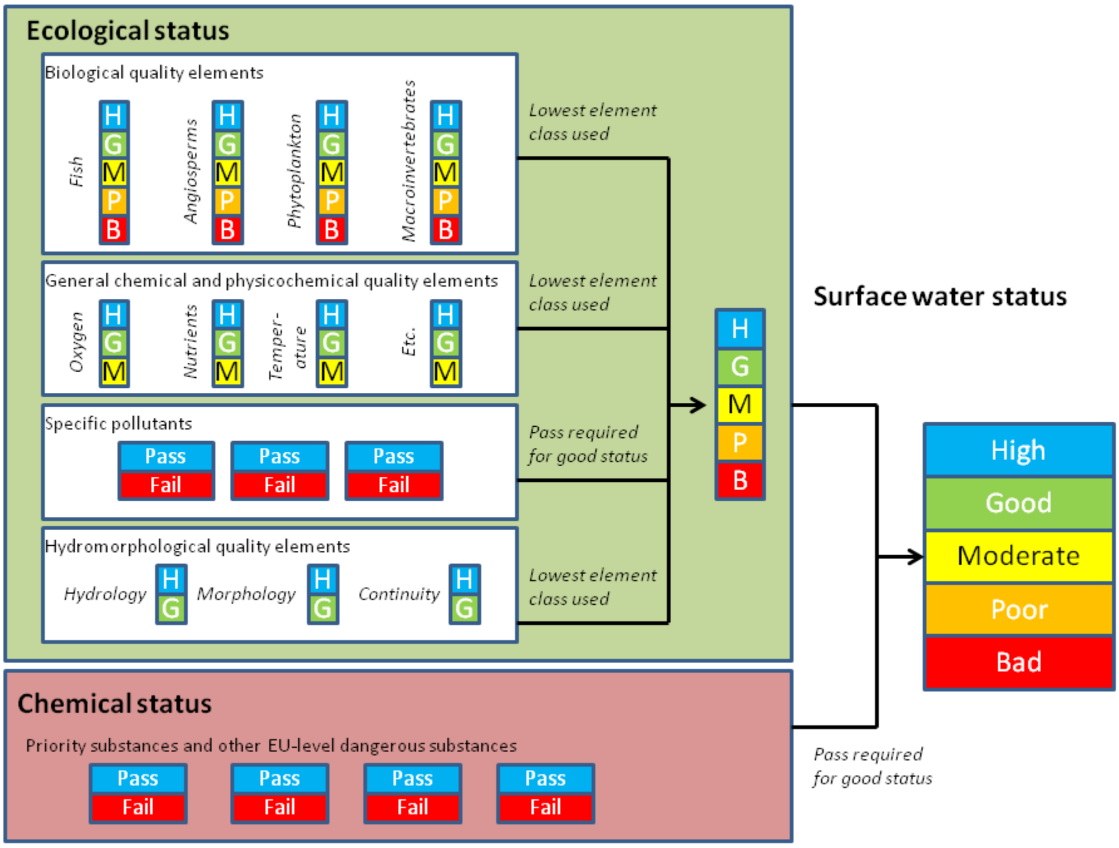


Figure 1.1. Overview of the elements that are combined to classify surface water status, where the lowest status of each ecological quality element (biological, physico-chemical, specific pollutants, hydromorphology) is carried forward to classify the water body being assessed. (Based on diagrams from the Environmental Protection Agency and the Scottish Environment Protection Agency).

1.3 Saltmarshes and the WFD

Saltmarshes are wetlands which tend to exhibit zonation in response to salinity and periodicity of tidal inundation (Curtis, 2003), and can be found in both transitional and coastal waters. Initially, only intertidal and sub-tidal seagrasses comprised the angiosperm BQE, however guidance that the upper limit of TraC water bodies be defined by Highest Astronomical Tide (HAT) (EC, 2003b) resulted in the inclusion of saltmarsh within the angiosperm BQE. The normative definitions of ecological status classifications for angiosperms in TraC water bodies are presented in Table 1.1.

Table 1.1. Normative definitions of ecological status classifications for angiosperms in transitional and coastal water bodies. Text is taken directly from Annex V, sections 1.2.3 and 1.2.4, of the WFD.

	Transitional	**Coastal**
High Status	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in angiosperm abundance due to anthropogenic activities.	All disturbance-sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are present. The levels of macroalgal cover and angiosperm abundance are consistent with undisturbed conditions.
Good Status	There are slight changes in the composition of angiosperm taxa compared to the type-specific communities. Angiosperm abundance shows slight signs of disturbance.	Most disturbance-sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are present. The level of macroalgal cover and angiosperm abundance show slight signs of disturbance.
Moderate Status	The composition of the angiosperm taxa differs moderately from the type-specific communities and is significantly more distorted than at good quality. There are moderate distortions in the abundance of angiosperm taxa.	A moderate number of the disturbance-sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are absent. Macroalgal cover and angiosperm abundance is moderately disturbed and may be such as to result in an undesirable disturbance to the balance of organisms present in the water body.

1.4 Project overview and objectives

The Saltmarsh Angiosperm Assessment Tool for Ireland (SMAATIE) project was an eight month desk study commissioned through the research programme of Environmental Protection Agency (EPA). The overall project aim was to develop and apply a tool for the ecological status assessment of the saltmarsh component of the angiosperm BQE in coastal and transitional waters for the WFD. The SMAATIE project will facilitate Ireland’s involvement in the last round of intercalibration with other MS.

The specific objectives of the project, which will be addressed in the following chapters, were to:

- collate available and historical records on Irish saltmarshes
- collate associated information on possible environmental pressures acting on the saltmarsh communities
- assess similar tools used by other MS in the Northeast Atlantic Geographical Intercalibration Group (NEA-GIG)
- investigate potential metrics for inclusion in the tool addressing the required aspects of angiosperm abundance, composition and disturbance-sensitive taxa
- test draft versions of the tool in the context of available data on environmental pressures
- apply the finalised tool to a representative sample of Irish water bodies containing saltmarsh habitat
- calculate EQR values for selected Irish water bodies with regard to saltmarsh
- provide guidance and recommendations on the timing and methodology of data collection for ongoing monitoring purposes

2. Irish Saltmarshes

2.1 General characteristics of saltmarsh

Saltmarshes are wetlands associated with TraC water bodies which are subjected to periodic inundation by the sea. They develop on a range of substrata, such as mud, sand and coastal peat deposits (Fossitt, 2000), and form when fine, predominantly muddy sediments accumulate and are colonised by halophytic vegetation (Foster *et al.*, 2013). Saltmarsh vegetation can only develop if these sediments are not re-suspended, therefore they are found in sheltered coastal areas with low energy conditions where tidal current and wave action are limited (Adnitt *et al.,* 2007; Foster *et al.,* 2013). They are generally "restricted to the area between mid neap tide level and high water spring tide level" (JNCC, 2004; McCorry, 2007) and occur in marine and brackish water conditions (Fossitt, 2000). Common features, particularly of larger saltmarshes, include tidal creeks, channels and pools known as pans (Fossitt, 2000).

2.2 Saltmarsh habitats, types and distribution in Ireland

Saltmarshes in Ireland can be broadly divided into two habitats – Lower saltmarsh (CM1) and Upper saltmarsh (CM2) as outlined in Fossitt (2000). Curtis (2003) also identifies these habitats, referring to lower saltmarsh as "submergence marsh" and upper as "emergence marsh". Lower saltmarsh can be defined as areas which undergo more than 360 submergences a year and typically occur within the range of area from mean high water neap tide level to mean high water (Curtis, 2003). Upper saltmarsh can be defined as areas that undergo less than 360 submergences a year and tend to occur in the range of area from mean high water to mean high spring tide level (Curtis, 2003). Due to differences in duration of submergence and level of water and substrate salinity, the suite of plant species which colonise lower and upper saltmarsh differ too. The development of different plant communities due to the different environmental conditions across a saltmarsh can form distinctive zonation patterns (Curtis, 2003; McCorry and Ryle, 2009a). This zonation can be very complex and although discrete bands of communities do occur, they frequently overlap with each other and do not necessarily correlate with increasing distance from the sea (Curtis, 2003).

Saltmarshes can also be assigned to one of five basic types (Curtis and Sheehy Skeffington, 1998; Curtis, 2003): estuary, bay, sandflats, lagoon and fringe. The estuary type occurs at the mouths of medium to large rivers, while the bay type forms in sheltered bays where freshwater input is minimal and saltmarshes can occur in extensive patches here. Both types primarily have substrates of silts and clays. The sandflat type typically forms in association with dune systems and can develop as extensive seaward extensions of machair in the west of Ireland. The lagoon type, the rarest of the saltmarsh types, forms behind shingle or sand barriers and more rarely on peat. Those forming on peat are inundated by natural channels (or channels modified by peat cutting) creating mosaics of saltmarsh and blanket bog habitats (McCorry and Ryle, 2009a). The fringe type, also referred to as ombrogenic Atlantic saltmarsh (Cott *et al.,* 2013), overlies peat substrates and is found fringing sheltered rocky bays or develops as a narrow band between the sea and bog or heath dominated hinterland. Fringe saltmarshes formed in a much different manner to the other saltmarsh types, in that the peat substrates were formed under freshwater conditions and subsequently developed saltmarsh vegetation after a marine transgression (Cott *et al.*, 2012). All five saltmarsh types overlap to some degree.

The distribution of saltmarshes is determined by the shelter afforded by large scale coastal morphology and also by more local factors such as tidal dynamics, sediment transport pathways, locally generated waves and the presence or absence of vegetation (Adnitt *et al.,* 2007). Curtis and Sheehy Skeffington (1998) identified a total of 238 saltmarshes along the coastline of the Republic of Ireland, with a further 12 in Northern Ireland (Figure 2.1). Additional saltmarsh areas were identified by McCorry and Ryle (2009a) from a survey of aerial photos and from information from other sources such as Wymer (1984), Nairn (1986), the Coastal Monitoring Project (Ryle *et. al.*, 2009), the National Parks and Wildlife Service (NPWS) Habitat Assignment Project database and other NPWS data sources. These additional areas of saltmarshes were identified at many sites around the coast, particularly along the western shoreline (McCorry and Ryle, 2009a). In the study of Curtis and Sheehy Skeffington (1998), the estuary type was the most commonly recorded saltmarsh type, followed by fringe, bay, sandflat and lagoon. The estuary type tends to occur in the larger estuaries in Cork, Donegal, Dublin, Limerick, Waterford and Wexford. The fringe type occurs widely along the west coast of Ireland, restricted as it is by its occurrence on mainly *Sphagnum* peat. The bay type also has a high occurrence on the west coast and is particularly common in Clew Bay, Mayo, Galway Bay, Galway, and around Donegal's coastline. The sandflat type, as mentioned above, is largely associated with major sand dune systems. It too occurs widely on the west coast, but is also found in Dublin, Waterford and Wexford. The lagoon type, though rare, is found around the coast of Ireland, with examples in Mayo, Galway, Cork, Waterford, Wexford and Wicklow.

2.3 Saltmarsh zonation and plant communities

The distribution of plants across a saltmarsh is determined by a number of factors, such as salinity, period of inundation, soil structure and nutrient status; 'classic saltmarsh zonation' is therefore not always the norm (Curtis, 2003). Fringe saltmarshes may lack zonation entirely, with only a narrow fringe of *Juncus maritimus* present to identify it. The intensity and pattern of grazing may also impact on the vegetation of the saltmarshes and thus complicate the recognition of zones (Sheehy Skeffington and Wymer, 1991; Curtis, 2003). There are differences between vegetation communities found on the east coast of Ireland compared with the west coast, due to climatic differences, substrate origin, grazing intensity and geographical ranges of plant species (Sheehy Skeffington and Wymer, 1991; Curtis, 2003). Chapter 3 discusses saltmarsh plant communities in detail.

2.4 Study of saltmarsh habitats and communities in Ireland

There have been a number of studies carried out on Irish saltmarshes or saltmarsh species. Many are site specific, for example O'Reilly and Pantin (1957) who focused on saltmarsh formations in Dublin estuaries, Ní Lamhna (1982) who focused on the vegetation of saltmarshes at Malahide Island, and O'Connor (1992) who investigated the land use and ecology of saltmarshes on Tawin Island. A number of studies on saltmarshes in Galway were carried out by NUIG students, with their projects listed on the Ramsar National Inventory of Wetland Resources (IRWC, 2012a). These include Murphy (1987), Springer (1999), Delaney (2005) and Kelly (2010). Other studies investigated saltmarsh species, such as Furphy (1970), Boyle (1972; 1976; 1977), Wallace (1995), Andrews (1997), Hammond (2001), McCorry (2002), Hammond and Cooper (2002) and McCorry *et al.* (2003).

Saltmarsh habitats and species in Ireland have also been investigated as part of coastal management plans and environmental impact statements (Otte, 1994; ESB International, 1996; Murray, 2003; McCorry and Ryle, 2009b). There have also been a number of studies on the overall ecology and vegetation of Irish saltmarshes at a regional and / or national level. These include Wymer (1984), Nairn (1986), Adam (1987), Sheehy Skeffington and Wymer (1991), Cooper *et. al.* (1992), Curtis and Sheehy Skeffington (1998), Curtis (2003), DOENI (2005), McCorry (2007), McCorry and Ryle (2009a) and Cott *et al.* (2012; 2013). Finally, saltmarsh vegetation communities have also been studied in the wider context of lagoonal research. These include Hatch (1996), Healy *et al.* (1997) and Roden (1998).

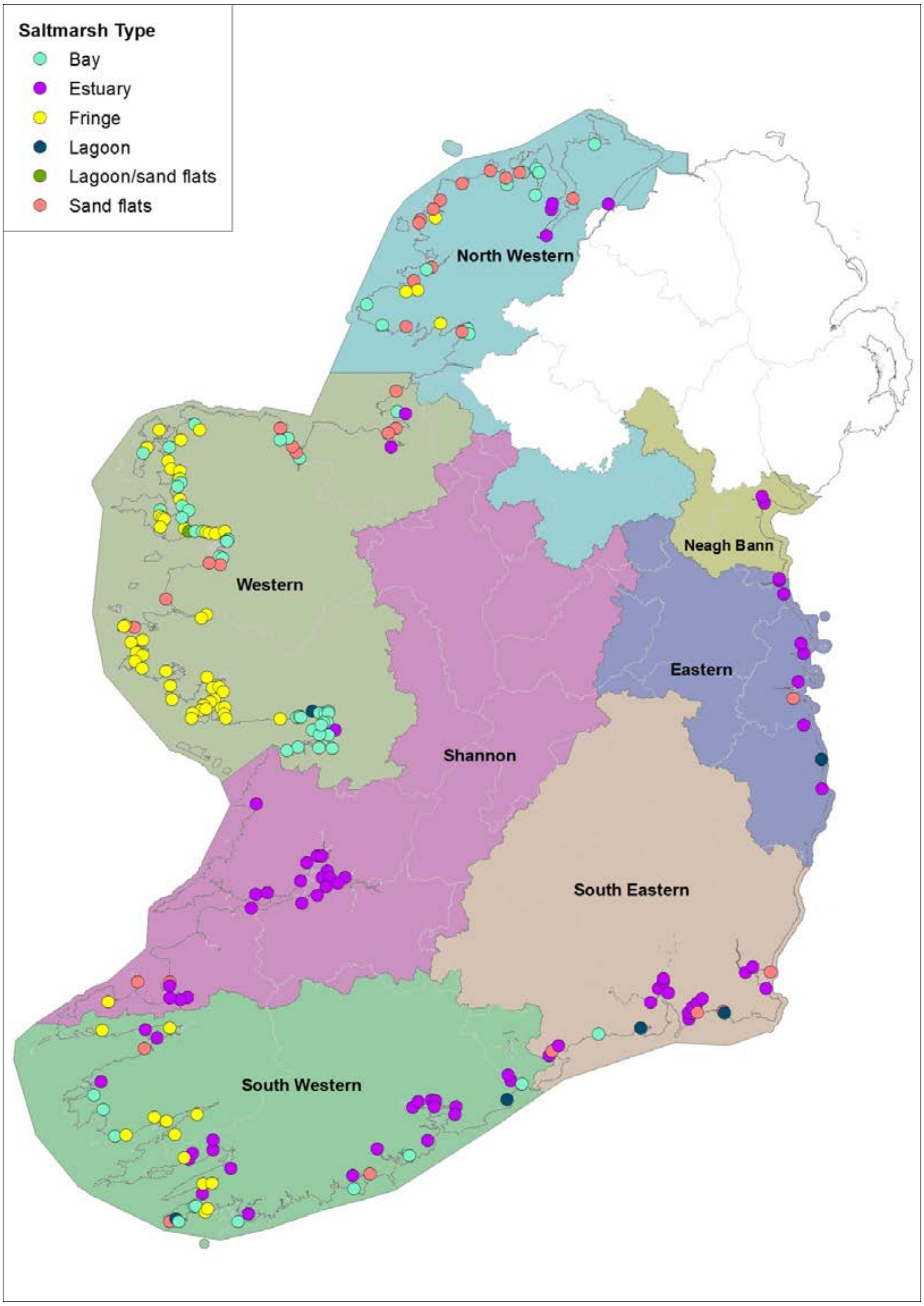


Figure 2.1. The distribution of saltmarsh types as identified by Curtis and Sheehy Skeffington (1998), and the seven River Basin Districts (RBDs) of the Republic of Ireland.

2.5 Current and historical uses and management of saltmarshes

In the past, saltmarshes in Ireland were widely used for cultivation leading to widespread reclamation attempts in the middle part of the nineteenth century (Curtis, 2003). Land reclamation was also popular for building developments, with many saltmarshes, particularly of the estuary type, used as sites for port, urban and industrial developments. The fringe type of saltmarsh was previously cut for fuel due to its peat substrates, and some saltmarsh sites were used as sources for brick making (Curtis, 2003).

Currently, saltmarshes in Ireland are mainly used for grazing, particularly saltmarshes along the west coast of Ireland. Grazers include domestic animals (mainly cattle and sheep) and also geese, hares and rabbits. They are popular with birdwatchers due to the large amounts of waterfowl that use saltmarshes and they are also used as areas for amenity and recreation (Curtis, 2003).

2.6 Value of saltmarsh habitats

Saltmarshes provide a number of valuable and essential services. They are particularly important for overwintering and migratory birds which use saltmarshes for food, nesting and roosting (Boorman, 2003; Foster *et al.*, 2013), with Irish saltmarshes of exceptional importance due to Ireland's geographical location. They provide spawning sites, nursery grounds and feeding opportunities for a range of fish species (Boorman, 2003; Foster *et al.*, 2013) and habitat for a number of noteworthy and rare plant species (McCorry and Ryle, 2009a). They can also provide an alternative feeding ground for invertebrates (Boorman, 2003). Saltmarshes play a critical role in protecting land from coastal flooding as they act as a natural buffer which can decrease wave height and energy (Foster *et al.*, 2013). This ecological service could become even more significant in the future with predicted climate change patterns (e.g. increased storm frequency, rising sea levels). Saltmarshes also play a vital role in purifying water by acting as filters and accumulating a wide variety of pollutants (Boorman, 2003).

2.7 Pressures acting on saltmarshes

The Saltmarsh Monitoring Project (SMP; McCorry, 2007; McCorry and Ryle, 2009a) is the most comprehensive survey of Irish saltmarshes. The main negative anthropogenic activities acting on saltmarsh habitats recorded during this project included inappropriate grazing, roads, paths and tracks, landfill and land reclamation. Chapter 4 discusses the main pressures acting on saltmarshes in detail.

2.8 Conservation of saltmarsh habitats

The importance of saltmarshes is reflected in national and international policies and designations. These policies and designations vary in the level of protection they provide to the species and habitats found within them. The Wildlife Act, 1976 and the subsequent Wildlife (Amendment) Act, 2000, form the principal legal framework for the protection of wildlife in Ireland. The basic designation for wildlife is intended to be the Natural Heritage Area (NHA). As not all NHAs have yet been officially designated, the term proposed NHA (pNHA) is used to denote sites which are non-designated but whose conservation value has been recognised. These sites are of significance for wildlife and habitats, and currently saltmarsh is listed as being present in 88 pNHAs (Wymer, 2008). Designation of these pNHAs will proceed on a phased basis over the coming years (NPWS, 2012). The current list of plant species protected by Section 21 of the Wildlife Act, 1976 is set out in the Flora (Protection) Order, 1999. The saltmarsh species *Carex divisa*, *Hordeum secalinum, Puccinellia fasciculata* and *Sarcocornia perennis* are listed on this order. The Flora (Protection) Order, 1999, affords protection to these plant species, and the protection extends to their habitats (i.e. saltmarsh).

Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) are designated as a result of the EU Habitats Directive (HD; 92/43/EEC) and the Birds Directive (79/409/EEC) respectively. They are referred to collectively as Natura 2000 sites and are prime wildlife conservation areas in Ireland. These areas are considered to be important on both an Irish and European level. The HD has contributed to the conservation of saltmarshes in Ireland by listing and defining a number of Annex I saltmarsh habitats of conservation importance, four of which are present in Ireland: 1310 *Salicornia* and other annuals colonising mud and sand, 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae), 1410 Mediterranean salt meadows (Juncetalia maritima) and 1420 Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi). Refer to McCorry and Ryle (2009a) and NPWS (2013) for a detailed description of each of these Annex I saltmarsh habitats. The Annex I habitat *Spartina* swards (Spartinion maritimae) (1320) was previously recognised in Ireland, however it has now been decided by NPWS that stands of *Spartina* are not worthy of designation as *Spartina anglica* is not considered to be native in Ireland (McCorry and Ryle, 2009a). Under the HD, Ireland has a responsibility to designate SACs to protect these habitats and to maintain them at a favourable conservation status. SPAs, as part of the Natura 2000 network, are similarly protected.

Ireland is a contracting party to the Convention on Wetlands (Ramsar Convention) and in 2010 the Irish Ramsar Wetlands Committee (IRWC) was set up. The primary objective of the IRWC is to promote the wise use and protection of all wetlands in Ireland through national land-use planning, appropriate policies and legislation, management actions and public education. A number of Irish saltmarsh sites have been designated as wetlands of international importance (known as Ramsar sites) (IRWC, 2012b).

Saltmarshes are also afforded some protection by the Foreshore Acts, 1933 to 2011, and European Union (Environmental Impact Assessment) (Foreshore) Regulations, 2012 (S.I. No. 433/2012). The Foreshore Acts require that “a lease or licence must be obtained from the Minister for the Environment, Heritage and Local Government for the carrying out of works or placing structures or materials on, or for the occupation or removal of material from, State-owned foreshore which represents the greater part of the foreshore. Developments on privately owned foreshore also require the prior permission of the Minister under the Foreshore Acts” (Environ, 2014). The foreshore is defined as “the seabed and shore below the line of high water of ordinary or medium tides and extends outwards to the limit of twelve nautical miles” (Environ, 2014), thus encompassing saltmarsh systems. Finally, saltmarshes are protected in an indirect manner under the WFD and the Nitrates Directive (91/676/EEC). The Nitrates Directive has the objective of reducing water pollution caused or induced by nitrates from agricultural sources.

3. Vegetation Communities of Irish Saltmarshes

3.1 Introduction

Coastal saltmarshes are classic examples of how plant species abundances vary individually in response to environmental conditions as there is typically a single major environmental gradient at the local scale, with change in elevation influencing the duration and regularity of tidal inundation (Jefferies, 1977; Gray, 1992; Sánchez *et al.,* 1996). Nevertheless, in common with other habitats, artificial partitioning of this vegetation continuum into recognisable and, usually, discrete zones or communities is widely needed for practical purposes, such as habitat inventory, ecosystem monitoring, and management (Peet and Roberts, 2013). In Europe, such purposes include the identification of communities that link with habitats of Annex I of the HD. Saltmarsh zonation has also has been considered by several countries within the assessment of this habitat for the WFD where it is included as part of the angiosperm BQE for TraC water bodies (Dijkema *et al.,* 2005; Best *et al.,* 2007; Wanner *et al.,* 2007). The inclusion of saltmarshes within the scope of these directives reflects the key ecosystem services that they provide, for example, nutrient cycling (Sousa *et al.*, 2010), carbon sequestration (Chmura, 2009), water purification (Boorman, 2003) and wave dissipation / sea defence (Möller *et al.*, 1999). They are also important as fish nurseries (Laffaille *et al.*, 2000), and as habitats for birds (Brindley *et al.*, 1998) and macroinvertebrates (Irmler *et al.,* 2002).

Ireland has approximately 38 km^2 of HD Annex I saltmarsh (McCorry and Ryle, 2009a) and a further undefined area of non-Annex I habitat. This occurs in a variety of locations (e.g. estuaries, bays, sandflats and lagoons) and on a range of different substrates (e.g. mud, sand, peat, or, more rarely, gravel) (Curtis and Sheehy Skeffington, 1998). At locations in the west of Ireland where there is a peat substrate, saltmarsh formation has not followed the classical model of gradual accretion of fine sediment and succession (Chapman, 1964) but has occurred where sea level increases have resulted in submergence of Atlantic blanket bog (Sheehy Skeffington and Wymer, 1991). These relatively narrow bands of fringing habitat have been termed 'ombrogenic Atlantic saltmarsh' (Cott *et al.* 2012; 2013).

Ireland lacks a coherent national-scale, community-level vegetation classification system with most contemporary mapping and sampling utilising the broad habitat categories of Fossitt (2000). However, due primarily to the enduring influence of Braun-Blanquet and Tüxen (1952), Ireland has had a strong history in recording vegetation data in the style of Central European Phytosociology (CEP; *sensu* Ewald, 2003) as evinced by the overview of White and Doyle (1982). The majority of the considerable amount of relevé data generated has recently been gathered to form the National Vegetation Database (NVD; Weekes and FitzPatrick, 2010) which includes saltmarsh datasets gathered at local scale (e.g. Ní Lamhna, 1982) and national scale (e.g. Wymer, 1984).

When partitioning vegetation datasets, fuzzy set theory (Zadeh, 1965) is an attractive concept to apply as it recognises that real world classes of objects may not have precise membership criteria. In 'hard' or 'crisp' partitioning algorithms based on classical set theory, objects have binary membership, that is they either belong (1) or do not belong (0) to a class. In 'fuzzy' classifications each object has a probability (or goodness of fit) from 0 to 1 of belonging to each class, the sum of these probabilities being 1. Hence, this approach facilitates the reality that vegetation samples will often be transitional in nature between perceived vegetation types (De Cáceres *et al.*, 2010). Fuzzy set theory can be employed when assigning samples or defining types, processes termed 'determination' and 'entitation' by Peet and Roberts (2013). In determination, a crisped result can be achieved by assigning samples to the type for which they have maximal membership. In entitation, the exclusion of transitional plots (plots with a maximal membership less than a threshold α) has been suggested as a means of increasing the distinctiveness and cohesiveness of the defined vegetation types (De Cáceres *et al.*, 2010). For a general introduction to fuzzy classification see Höppner (1999).

In this study, we aimed to utilise a collation of quantitative vegetation data from the full range of Irish saltmarsh types to produce a statistically robust tiered classification of Irish saltmarshes with broad classes divided into a number of communities at a level of resolution roughly akin to the vegetation communities or sub-communities of the British National Vegetation Classification (NVC; Rodwell, 1995; 2000) and the association level of CEP. A tiered classification was sought to facilitate ease of use in the field and to produce a structure paralleling similar endeavours for other habitats by Cross *et al.* (2010) and O'Neill *et al.* (2013). We sought to demonstrate the technique of fuzzy analysis with exclusion of transitional samples and to validate the classification using a range of multivariate analyses and through cross-referencing the communities with existing schemes. In a more applied sense, our article considers how saltmarsh communities should be recorded for the purposes of monitoring under the HD and WFD.

3.2 Methods

3.2.1 Data sources and preparation

An overview of the data flow during the analysis is provided in Figure 3.1. Quantitative vegetation plot[1] data were obtained from two main sources, the NVD and the SMP (McCorry 2007; McCorry and Ryle, 2009a), the latter being a national survey conducted primarily for the purposes of monitoring HD Annex I saltmarsh habitats. All plot datasets used are listed in Appendix 1. Plots from sand dunes, shingle banks, sea cliffs and rocks, coastal heath, grassland and bog found in these datasets were excluded. Aquatic lagoon vegetation was also excluded but marginal lagoon vegetation was retained. *Zostera* beds were not considered here. Data for algal species were omitted due to the likelihood of recording inconsistencies between datasets. Data of non-algal species recorded only to genus level were omitted, with the exceptions of the genera of *Cochlearia, Ruppia*, *Salicornia, Spartina*, *Spergularia* and *Taraxacum* for which all records were pooled at the genus level due to taxonomic or identification issues. When non-algal taxa data were omitted from a plot and comprised ≥ 5% cover, that plot was excluded. Taxa present in less than three plots were omitted to reduce noise. Cover data recorded on an ordinal scale were converted to percentage cover as shown in Table 3.1. This assessment procedure yielded a collated matrix containing 3,467 plots and 149 species which was square-root transformed to down-weight the influence of abundant species. The final dataset had good coverage at the national scale (Figure 3.2).

[1] The general term 'plot' is used as not all data were from relevés *sensu stricto.*

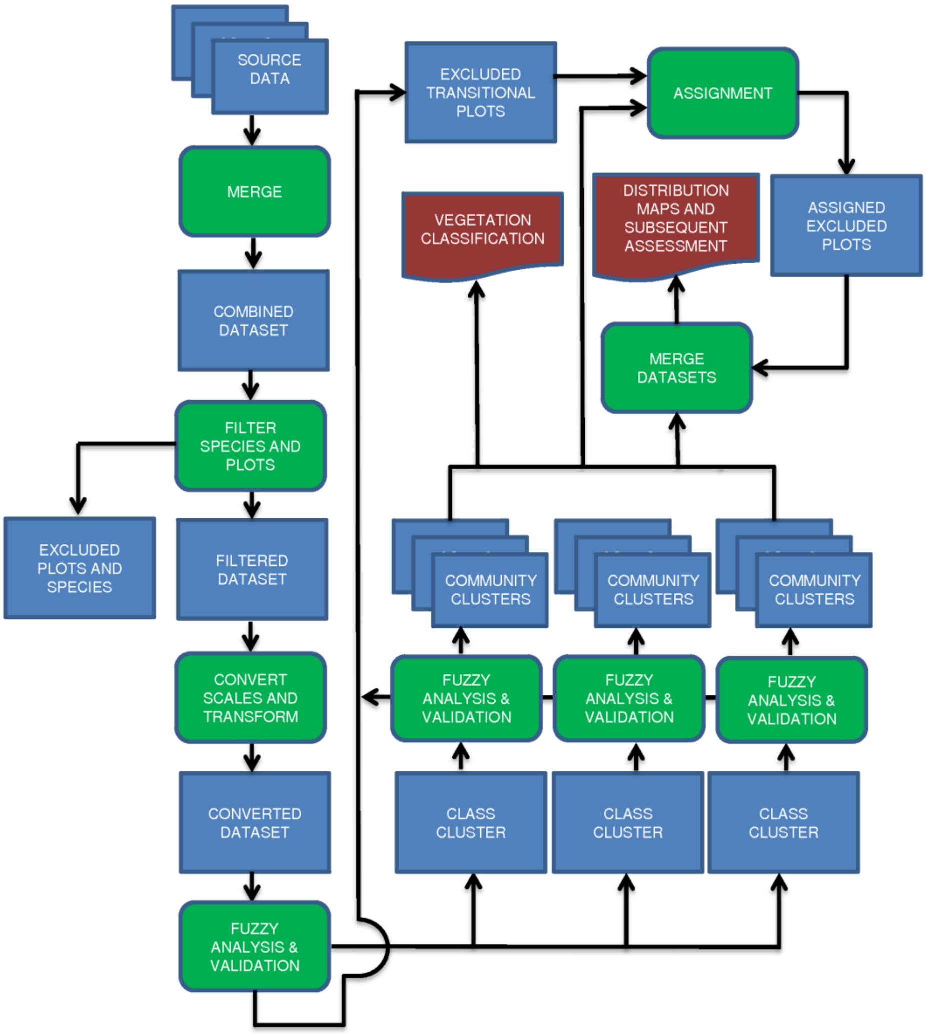


Figure 3.1. Flow chart of data analysis procedure. Blue boxes indicate datasets, green boxes indicate processes, red boxes indicate outputs.

Table 3.1. Conversion of cover data on ordinal scales to percentage cover using mid-range values.

Braun-Blanquet (original)	Braun-Blanquet (extended)	Cover range (%)	Converted cover (%)	Domin	Cover range (%)	Converted Cover (%)
5	5	76-100	88	10	91-100	96
4	4	51-75	63	9	76-90	83
3	3	26-50	38	8	51-75	63
2	.	5-25	15	7	34-50	42
.	2b	12.6-25	19	6	26-33	30
.	2a	5-12.5	9	5	11-25	18
.	2m	<5	4	4	5-10	8
1	1	1-5	3	3	1-4	3
+	+	<1	0.5	2	<1	0.5
r	r	<1	0.1	1	<1	0.3
				+	<1	0.1

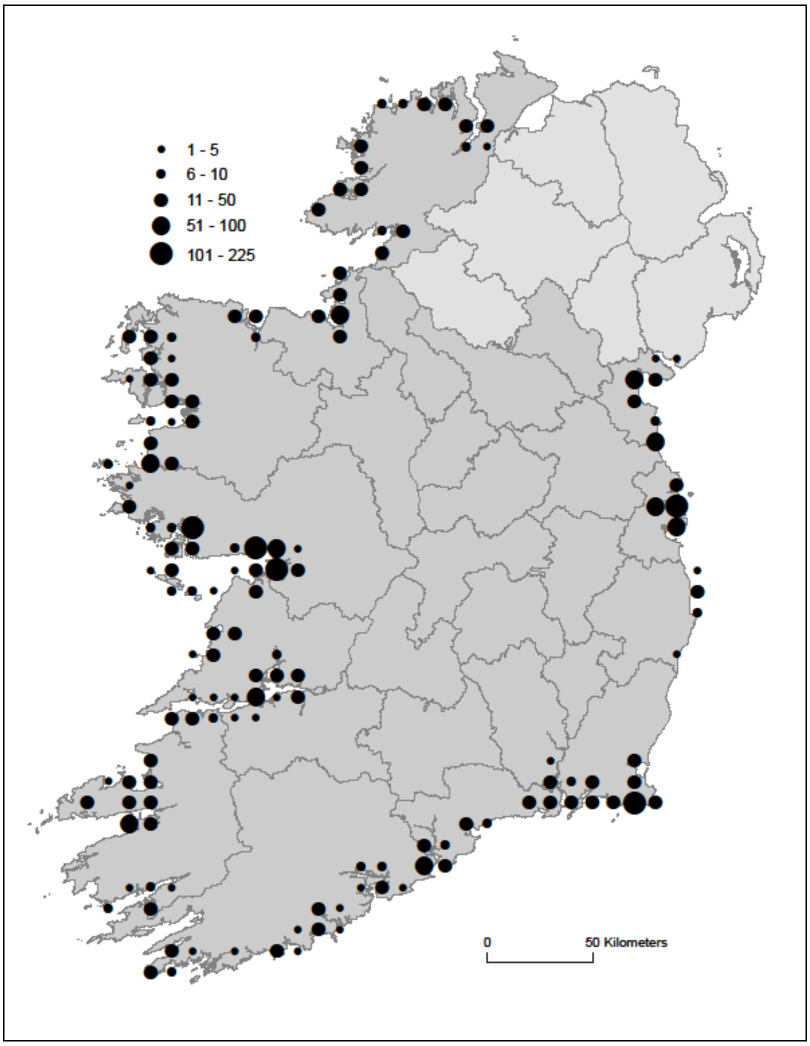


Figure 3.2. Distribution of saltmarsh plots from Ireland used in the analysis. The size of symbol indicates the number of plots in each hectad.

3.2.2 Dissimilarity measure and clustering algorithm

Unless otherwise stated, analyses were performed within the R statistical environment (version 2.15.2; R Core Team, 2012). The data matrix of n plots × p species was used to calculate an $n \times n$ distance matrix defining the dissimilarity between each pair of plots. Quantitative Sørensen (Bray-Curtis) dissimilarity was selected as this measure has been shown to be one of the most effective for ecological community analysis, being less prone to exaggerating the influence of outliers and retaining greater sensitivity with heterogeneous datasets (McCune and Grace, 2002). Fuzzy analysis, a non-hierarchical method based on Kaufman and Rousseeuw (1990), was then implemented using function *fanny()* in package *cluster* (Maechler *et al.,* 2013), with membership exponent (r) = 1.1 and maximum iterations = 10,000. Tests with a range of cluster validation measures on a similar size vegetation dataset have shown that this function performs favourably in comparison with other potential algorithms (P.M.P., unpublished data).

3.2.3 Cluster validation

Fuzzy analysis was conducted for k = {2, 3, 4, …, 10} to find an appropriate partition of the data into vegetation classes. At each cluster level, plots judged transitional by the fuzzy classification (α = 0.75) were excluded and the remaining subset of the data was reanalysed to produce a crisp classification. Partitions were assessed against the criteria: i) clusters should be relatively homogeneous and distinct from one another; ii) clusters should have ecologically interpretable patterns of species distribution (Peet and Roberts, 2013). The first criterion was assessed using silhouette analysis and partition analysis. Silhouette analysis (Rousseeuw, 1987) is conducted automatically by function *fanny()* and calculates the silhouette width of a sample (plot) from the average dissimilarity of that sample to all samples in the same cluster and from the average dissimilarity of that sample to all samples in the next most similar cluster (Maechler *et al.,* 2013). Positive values indicate a good fit and negative values indicate that a sample would fit better elsewhere. The Average Silhouette Width (ASW) for a cluster indicates the quality of that cluster, and the overall ASW of all samples indicates the quality of the classification (Peet and Roberts, 2013). Partition analysis was conducted by function *partana()* in package *optpart*. This is a progression of the silhouette analysis concept and defines a global statistic, the PARTANA ratio, which is the mean similarity of samples within a cluster to the mean similarity of samples among all clusters (Peet and Roberts, 2013). The second criterion was assessed by expert judgement examination of constancy (species frequency) tables for ecologically meaningful clusters. Ancillary guidance was derived from the variation in community composition (beta-diversity), calculated using function *clustvar()* in package *vegclust* (De Cáceres *et al.,* 2010). To visually assess the relationship between classes a Non-metric Multidimensional Scaling (NMS) ordination was conducted using the function *metaMDS()* in package *vegan*. A two-dimensional solution was sought using Quantitative Sørensen as the distance measure and a maximum of 20 random starts.

Once the optimal number of vegetation classes was identified, the subsets of data for each class were then reanalysed separately, with further exclusion of transitional plots, to define clusters at the community level. The validity of these community clusters was similarly assessed. Vegetation classifications are inherently artificial constructs that seek to provide interpretation of complex ecological patterns. Cluster validation is therefore an important step in the classification procedure as it is necessary to demonstrate confidence in the integrity of the clusters produced.

3.2.4 Cluster characterization

To identify species that differentiated between classes, Indicator Species Analysis (ISA) developed by Dufrêne and Legendre (1997) was used. ISA produces percentage Indicator Values (IndVals) for species and works on the concept that, for a predetermined grouping of samples, an ideal indicator species will be found exclusively within one group and will be found in all of the samples in that group. IndVals are thus a simple combination of measures of relative abundance between groups and relative frequency within groups. Species are assigned to the group for which their IndVal is maximal and a permutation test is used to check the significance of the relationship. For this analysis, an extension of this approach (De Cáceres and Legendre, 2009) implemented by function *multipatt()* in package *indicspecies* was used, which looks for indicator species not only of individual sample groups but also of combinations of sample groups. The analysis was limited to examination of singletons, doublets and triplets of sample groups (classes), as higher order combinations were deemed unhelpful.

For each community, Ellenberg proxy environmental scores for light, wetness, reaction, fertility and salinity, weighted by mean cover, were calculated using the British and Irish calibrations for vascular plants (Hill *et al.,* 2004). The Modular Analysis of Vegetation Information System software (MAVIS; Centre for Ecology and Hydrology, Lancaster, UK) was used to identify the closest match with the British NVC by comparing the constancy tables produced by the current analysis with the published synoptic tables of Rodwell (1995, 2000) through application of the Czekanowski coefficient. To downweight the effect of rare species, only species with frequency ≥ 12% in at least one community and ≥ 5% in a given community were used. Correspondence with HD Annex I habitats was analysed by examining the partition between communities of plots assigned to Annex I habitat categories by McCorry (2007) and McCorry and Ryle (2009a). Affinities with the habitats of Fossitt (2000) and CEP were subjectively determined. For the latter we used the standardised lists of Mucina (1997) for classes and Rodwell *et al.* (2002) for orders and alliances. Comparison with CEP literature was used to draw out where potential sub-communities could be defined, although it is beyond the scope of this paper to statistically define these.

3.2.5 Transitional plot assignment

For the purposes of examining the geographical distribution of vegetation types, all plots judged to be transitional at either the class or community entitation stages were assigned statistically to communities on the basis of best fit (maximum membership probability). The fuzzy c-medoids algorithm described by Krishnapuram *et al.* (1999) was used through the assignment function *vegclass()* in package *vegclust* (De Cáceres *et al.,* 2010) with a fuzziness exponent (*m*) of 1.1. The underlying algorithm is similar in principle to that used by function *fanny()* but is heuristic rather than exhaustive.

3.3 Results

3.3.1 Cluster validation

Exclusion of transitional plots improved the overall ASW and PARTANA ratio by means of 34.1% and 18.1% respectively for k = {2, 3, 4, …, 10} (Figure 3.3) and it is these results which are referred to here. The highest PARTANA ratio of 3.7 occurred at the three-cluster level but the highest overall ASW of 0.27 occurred at the eight-cluster level. At the four-cluster level, three clusters were formed with a high degree of ecological interpretability, representing recognisable assemblages of lower marsh (beta-diversity = 0.15), middle marsh (beta-diversity = 0.17) and upper marsh (beta-diversity = 0.11). The fourth cluster exhibited markedly higher variation (beta-diversity = 0.41). By subjecting this fourth cluster only to another phase of fuzzy analysis (k = 3, without exclusion of transitional plots) to define further three clusters representing assemblages of lower marsh / mudflat transition (beta-diversity = 0.23), upper marsh / freshwater transition (beta-diversity = 0.25) and brackish swamps (beta-diversity = 0.37), a six-cluster solution (comprising 2,856 plots) was reached. This was deemed on balance to be most appropriate for defining classes. The overall ASW of 0.26 was high and there were only a small proportion (1.5%) of potentially misclassified plots (Figure 3.4), these occurring in the rather variable brackish swamp cluster. The PARTANA ratio of 3.6 compares well with the majority of the solutions in Figure 3.3 and the pale ascending diagonal line of the Mondrian plot (Figure 3.5) demonstrates cluster distinctiveness.

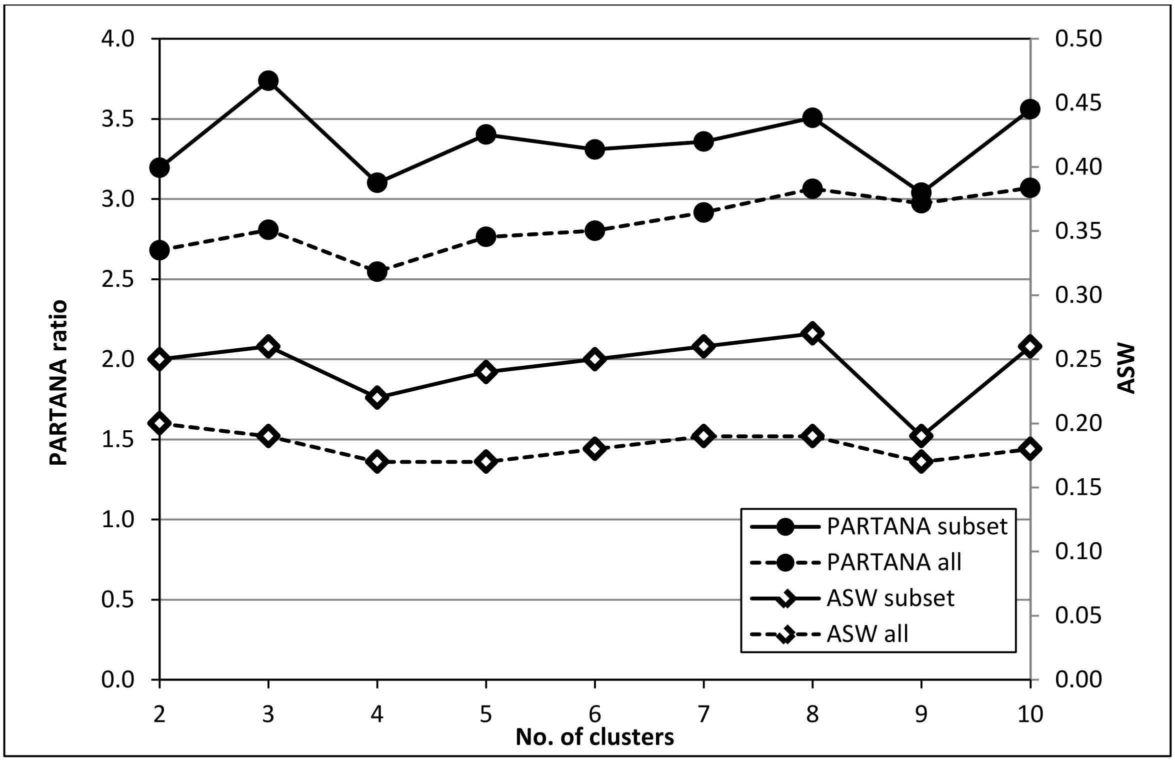


Figure 3.3. Average Silhouette Width (ASW) and Partition Analysis (PARTANA) ratio for saltmarsh vegetation partitioned with k = {2, 3, 4, …, 10} by fuzzy analysis. 'All' denotes all plots were used in analysis (n = 3,467). 'Subset' denotes analysis following exclusion of transitional plots.

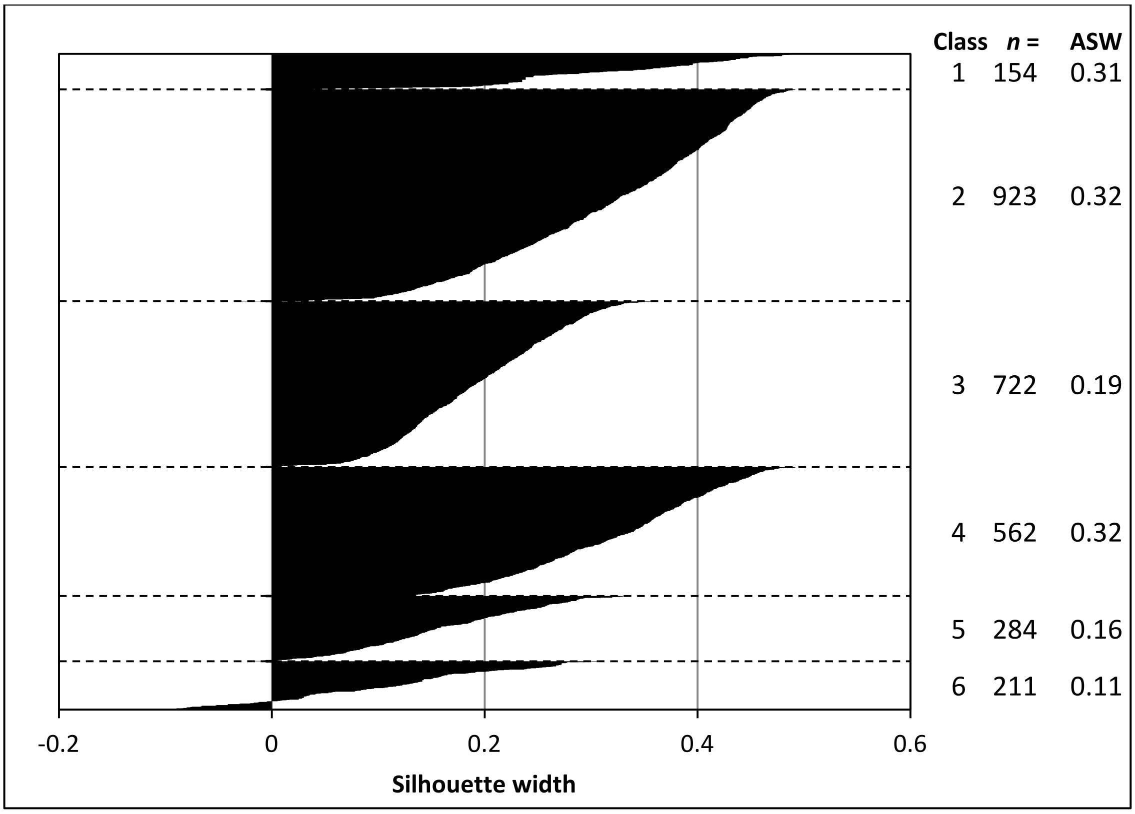
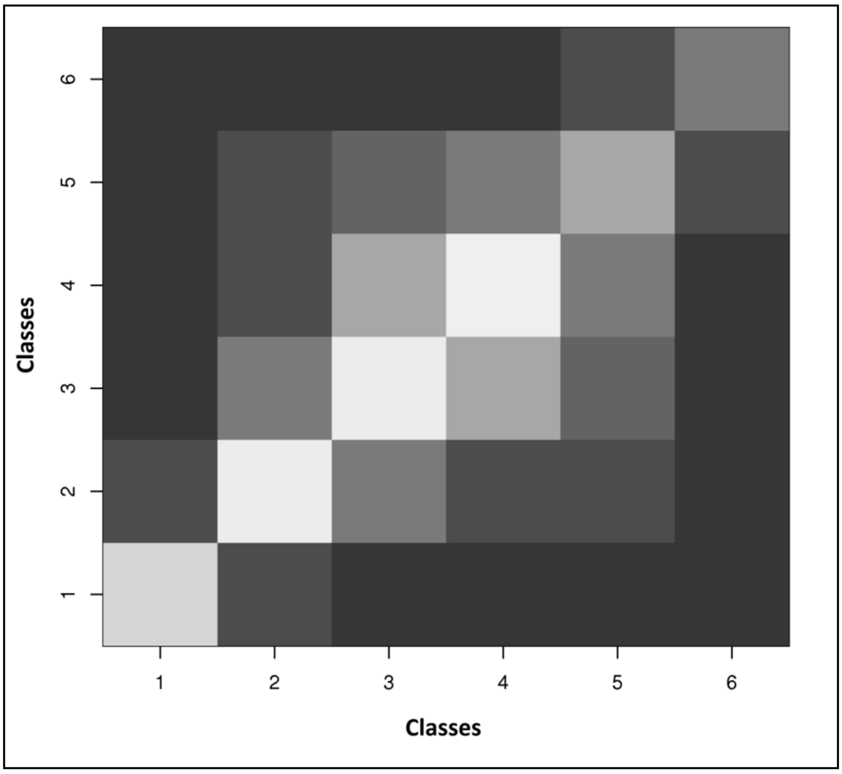


Figure 3.4. Silhouette widths for the six classes of saltmarsh vegetation defined by fuzzy analysis. ASW = average silhouette width. Overall ASW = 0.26. Total n = 2,856.

(a)



(b)

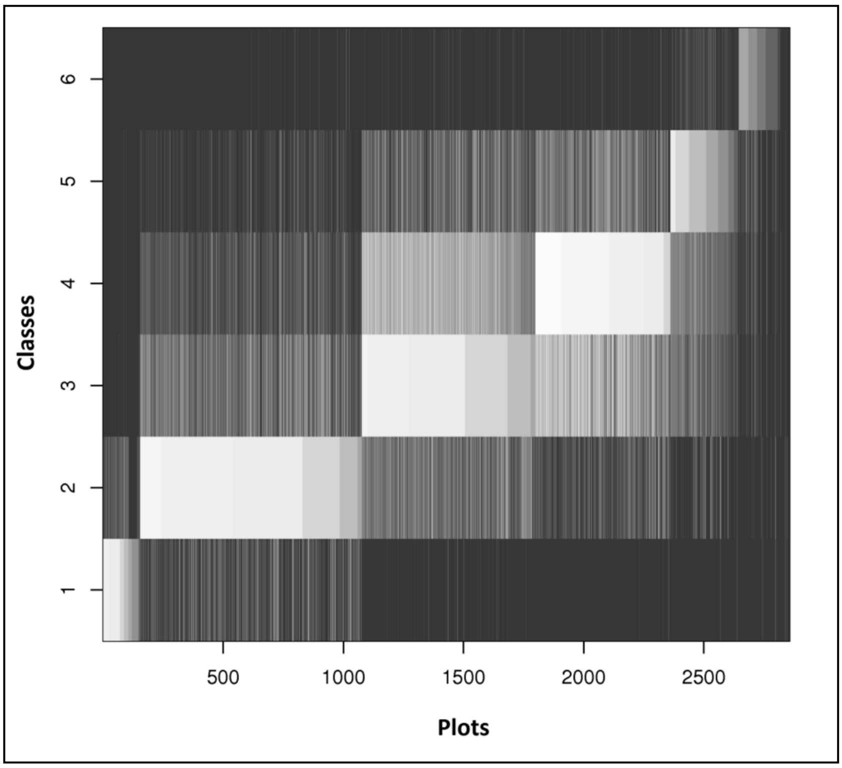


Figure 3.5. Mondrian plots of the results of partition analysis for plots (n = 2,856) in six classes of saltmarsh vegetation defined by fuzzy analysis. Lighter shades represent higher ratios of within–cluster similarity to between-cluster similarity (a) class-to-class similarity. (b) plot-to-class similarity. Overall PARTANA ratio = 3.6.

These six classes were subsequently divided by similar analysis (Appendix 2) into a total of 22 vegetation communities which, following exclusion of intermediates, comprised 2,265 plots or 65.3% of the plots in the original matrix.

3.3.2 Class and community descriptions

Summary data accompanies the following descriptions in a sequence of tables. Percentage frequency species data and IndVals are presented in Table 3.2 with cover abundance data presented in Appendix 3 in the style of Stevens *et al.* (2010). Affinities with other classification systems are presented in Tables 3.3, 3.4 and 3.5a, mean cover-weighted Ellenberg scores in Table 3.5b and community variance in Table 3.5c. We use the CEP term 'constant' in referring to species with > 60% frequency.

Class 1: Lower marsh / mudflat transition

This class comprises two communities of pioneer vegetation of the mudflat interface which is typically inundated daily for long periods, and subject to high-salinity conditions. *Spartina* spp. and *Salicornia* spp. are good class-specific indicators.

- 1a *Spartina* community. The vegetation here is strongly dominated by *Spartina* spp. These are species-poor swards with exceptionally low variability in which other species are occasional at best. *Salicornia* agg., *Aster tripolium* and *Atriplex prostrata* are the most likely associates. No plots were assigned to this community from the west coast north of the Shannon Estuary (Figure 3.6a), although there are known to be isolated records from this coastline (e.g. Clew Bay, Donegal Bay) (Preston *et al*., 2002). The distribution is strongly effected by the historical planting of *Spartina* in harbours from which locations it has naturally colonised.

  Within the dataset, *Spartina* records were always *Spartina anglica* except potentially in some plots from North Bull Island, Dublin Bay where *S.* × *townsendii* has previously been recorded (Boyle, 1977). *S.* × *townsendii* has also been recorded in the past on Lough Foyle (Hackney, 1980) and recently in Co. Wexford by P.Greene. *Spartina maritima*, of dubious native status, has previously been recorded in Co. Dublin (Boyle, 1976, 1977).

- 1b *Salicornia* community. These are stands in which annual *Salicornia* species are typically the main plants, with the vast majority of records being *S. europaea*. Invading *Spartina* spp. are frequently present but never abundant as in community 1a. *Suaeda maritima* is only occasional but sometimes abundant. Other species, such as *Limonium humile* and *Puccinellia maritima* are rare or occasional. This community has strong affinity with the HD Annex I habitat 1310.

Class 2: Lower marsh

This class comprises five communities of vegetation of the lower marsh often covered by spring tides. All the communities have affinity with HD Annex I habitat 1330 and fall within with the Puccinellion maritimae. *Puccinellia maritima* and *Spergularia* spp. are class-specific indicators; the vast majority of *Spergularia* records are *Spergularia media*. *Puccinellia maritima* is almost always present and typically abundant or dominant. Species generally frequent include *Cochlearia* spp., *Limonium humile*, *Suaeda maritima* and *Triglochin maritima.*

Table 3.2. Percentage frequency of taxa in Irish saltmarsh communities defined by fuzzy analysis. Only species with frequency ≥ 12% in at least one community are shown. IndVal indicates the percentage indicator value of each species. Greyed figures indicate the vegetation class or classes (1-6) for which species are indicators. Frequencies less than 0.5 are rounded to 1. Dotted lines group species which are indicators or the same class of classes.

	Community																						
	1a	**1b**	**2a**	**2b**	**2c**	**2d**	**2e**	**3a**	**3b**	**3c**	**3d**	**4a**	**4b**	**5a**	**5b**	**5c**	**5d**	**5e**	**6a**	**6b**	**6c**	**6d**	**IndVal**
Salicornia spp.	9	100	100	49	36	44	37	6	4	.	.	2	.	.	.	.	2	.	.	3	.	2	77
Spartina spp.	100	43	34	54	20	5	8	5	2	2	1	2	1	.	4	.	2	.	.	.	.	4	66
Limonium humile	3	17	79	73	14	15	47	15	14	5	1	8	1	.	.	.	.	.	.	.	.	2	55
Suaeda maritima	.	30	55	38	15	22	17	12	3	1	.	1	.	.	.	.	.	.	.	.	.	4	50
Atriplex portulacoides	3	5	24	100	5	.	13	12	7	2	1	4	3	.	.	.	.	.	.	.	.	11	37
Puccinellia maritima	3	25	100	100	100	100	99	17	17	12	3	15	2	.	24	.	2	.	.	3	.	4	94
Spergularia spp.	.	8	69	63	37	68	40	21	19	5	4	4	1	22	4	.	6	2	.	3	2	6	59
Plantago maritima	.	2	21	43	36	79	100	81	99	94	63	75	49	13	7	28	3	.	.	1	.	2	83
Armeria maritima	.	.	23	29	18	94	92	36	96	61	31	46	12	4	4	.	6	.	.	.	.	.	69
Aster tripolium	6	8	60	76	72	93	86	58	65	52	23	54	17	9	28	.	38	5	6	14	.	.	69
Triglochin maritima	3	2	19	27	33	47	48	42	48	67	49	39	32	48	20	28	12	2	3	14	7	9	58
Cochlearia spp.	.	1	3	14	27	46	18	47	30	29	32	43	32	4	15	.	9	.	.	7	.	2	52
Limonium binervosum agg.	.	1	.	14	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	2	11
Festuca rubra	.	.	.	5	5	8	5	100	85	86	100	36	100	.	7	.	5	2	.	4	.	8	90
Glaux maritima	.	3	6	2	36	62	53	59	78	90	62	64	60	83	24	11	66	47	.	16	10	8	71
Juncus gerardii	.	1	1	.	5	13	6	11	26	100	57	52	33	17	22	11	100	71	.	7	5	6	68
Trifolium repens	.	.	.	.	.	.	.	6	1	7	26	4	26	9	9	.	6	29	.	.	.	2	35
Carex extensa	.	.	.	.	1	.	1	5	10	20	9	20	5	4	4	.	3	2	.	.	2	.	32
Plantago coronopus	.	.	1	.	1	3	3	6	12	15	29	2	2	13	6	6	5	9	.	.	.	4	35
Atriplex prostrata	6	2	5	1	16	1	1	24	1	1	18	5	14	9	41	.	11	15	.	14	.	11	29
Juncus maritimus	.	.	2	1	2	6	4	10	5	10	7	100	100	.	4	.	2	.	.	3	.	.	98
Agrostis stolonifera	.	.	.	.	19	5	1	19	8	41	100	66	87	87	100	100	92	84	12	47	19	23	80
Scorzoneroides autumnalis	.	.	.	.	2	.	.	10	1	20	36	25	41	30	7	28	18	49	.	3	.	2	50
Oenanthe lachenalii	.	.	.	.	.	.	.	.	.	2	3	4	21	.	2	6	3	2	.	1	5	.	30
Samolus valerandi	.	.	.	.	.	.	.	.	.	1	.	10	4	43	2	28	8	4	3	6	21	6	69
Potentilla anserina	.	1	.	.	.	.	.	1	.	1	3	1	6	13	4	6	66	100	3	1	.	4	33
Calliergonella cuspidata	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	.	.	.	2	28
Sagina nodosa	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	.	.	.	2	27
Centaurium pulchellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	20	.	.	.	.	25
Isolepis cernua	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	11	.	7	.	.	2	4	24
Carex nigra	.	.	.	.	.	.	.	.	.	.	.	.	.	17	2	11	2	4	.	.	2	2	23
Odontites vernus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	3	18	.	.	.	.	21
Juncus bufonius	.	.	.	.	1	.	.	.	.	1	1	.	.	48	4	6	11	18	.	.	2	11	20
Lotus corniculatus	.	.	.	.	.	.	.	1	1	.	2	1	3	.	.	.	3	29	.	.	.	.	13
Trifolium fragiferum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	16	.	.	.	.	12
Juncus articulatus	.	.	.	.	.	.	.	.	.	.	3	1	2	39	7	33	2	.	.	.	7	13	27
Triglochin palustris	.	.	.	.	.	.	.	.	1	1	.	.	1	48	2	22	2	4	.	1	10	13	27
Eleocharis uniglumis	.	.	.	.	.	.	.	.	.	.	1	1	.	.	2	72	2	5	.	.	7	6	24
Eleocharis palustris	.	.	.	.	.	.	.	.	.	.	.	1	.	4	2	33	.	2	.	4	7	2	20
Hydrocotyle vulgaris	.	.	.	.	.	.	.	.	.	.	.	1	1	13	.	6	.	7	6	.	5	2	20
Mentha aquatica	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	6	2	.	24	.	2	.	19
Galium palustre	.	.	.	.	.	.	.	.	.	.	.	.	1	9	2	.	2	2	18	.	.	4	18
Ranunculus flammula	.	.	.	.	.	.	.	.	.	.	.	.	.	13	.	6	2	.	.	.	7	4	16
Apium nodiflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	22	.	.	.	.	6	1	2	.	15
Lythrum salicaria	.	.	.	.	.	.	.	.	.	.	.	1	1	.	2	6	.	2	15	.	.	.	14
Phragmites australis	.	1	1	.	1	.	.	.	.	2	3	9	3	.	9	6	.	2	100	16	17	8	49
Bolboschoenus maritimus	.	1	.	.	6	2	.	1	.	2	3	3	1	17	13	11	8	7	18	100	14	21	66
Schoenoplectus tabernaemontani	.	.	.	.	.	.	.	.	.	.	1	2	1	17	4	17	2	4	21	11	100	23	58
Ruppia spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	10	21	29
Elytrigia repens	.	.	1	.	.	1	1	3	.	1	4	.	5	.	4	.	.	5	.	9	.	21	24
Potamogeton pectinatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	17	4	23
Equisetum fluviatile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	.	13
Lemna minor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	3	2	2	19
***n* =**	**35**	**118**	**86**	**84**	**176**	**120**	**154**	**144**	**144**	**162**	**118**	**240**	**270**	**23**	**54**	**18**	**65**	**55**	**34**	**70**	**42**	**53**	

- 2a *Puccinellia maritima-Salicornia* community. This assemblage represents a succession from community 1b as *Salicornia* spp. are very frequent and sometimes abundant. These stands, however, are more diverse and *Salicornia* is accompanied by a range of species characteristic of the Puccinellietum maritimae.

- 2b *Puccinellia maritima-Atriplex portulacoides* community. The shrub *Atriplex portulacoides* is very frequent here and often plentiful lending this vegetation a distinct physiognomy. *Spartina* spp. are frequent invasives and *Limonium binervosum* agg. is occasional. This community is predominantly found along the south and east coasts (Figure 3.6b).

- 2c *Puccinellia maritima*-dominated community. *Puccinellia maritima* is strongly dominant here and typically lawn-forming with *Aster tripolium* the only other constant. Other species typically contribute little cover.

- 2d *Puccinellia maritima-Aster tripolium* community. This category essentially represents the 'typicum' community for this class. *Armeria maritima*, *Glaux maritima, Plantago maritima* and *Spergularia media* are constants.

- 2e *Puccinellia maritima-Plantago maritima* community. *Plantago maritima* and *Armeria maritima* are very frequent here and typically abundant, with *Puccinellia maritima* contributing less cover than elsewhere in this class.

Class 3: Middle marsh

This class comprises four communities of the middle marsh occasionally covered by spring tides. There are no class-specific indicators although the presence of *Festuca rubra* is a strong characteristic. As with class 2, all the communities correspond with HD Annex I habitat 1330, but these assemblages have affinities to the Armerion maritimae.

- 3a *Festuca rubra*-dominated community. This community comprises dense swards of *Festuca rubra*. *Plantago maritima* is the only other constant, although *Glaux maritima*, *Aster tripolium* and *Cochearia* spp. are also frequent.

- 3b *Festuca rubra-Armeria maritima* community. *Plantago maritima* and *Armeria martima* are almost always present and typically abundant here. *Glaux maritima* and *Aster tripolium* are also constants.

- 3c *Festuca rubra-Juncus gerardii* community. These are *Juncus gerardi* stands of the middle-marsh. *Plantago maritima* and *Glaux maritima* are very frequent and *Festuca rubra* is still typically the main grass species, although *Agrostis stolonifera* also commonly occurs.

- 3d *Festuca rubra-Agrostis stolonifera* community. These are grassy stands in which *Festuca rubra* dominates but *Agrostis stolonifera* is also significant. *Plantago maritima* and *Glaux maritima* are again constants, while *Juncus gerardi* is still frequent. *Trifolium repens* is occasional.

Class 4: Upper marsh

This class comprises two communities of the upper marsh rarely covered by spring tides, which are very frequent in the dataset. *Juncus maritimus* is the class-specific indicator and indeed these are typically rushy stands that correspond with HD Annex I habitat 1410.

- 4a *Juncus maritimus*-dominated community. In these very rushy stands, *Festuca rubra* is not so frequent and typically provides little cover. *Plantago martima*, *Glaux maritima* and *Agrostis stolonifera* are constants. It is particularly frequent on the west coast (Figure 3.6c).

- 4b *Juncus maritimus-Festuca rubra* community. *Juncus maritimus* and *Festuca rubra* tend to be co-dominant in these stands. Middle marsh indicators such as *Plantago maritima*, *Armeria maritima* and *Aster tripolium* are less frequent than in community 4a but *Glaux maritima* and *Agrostis stolonifera* are still constants. *Oenanthe lachenalii* and *Trifolium repens* are occasional.

Class 5: Upper marsh / freshwater transition

This class comprises five communities of the upper marsh where there is an increased freshwater influence. There are a number of class-specific indicators, (e.g. *Carex nigra*, *Juncus bufonius*) but most are fairly weak, with the best being *Potentilla anserina*. The presence of *Agrostis stolonifera* is characteristic.

- 5a *Agrostis stolonifera-Glaux maritima* community. This is a variable grouping with a small sample size characterised by the constancy of *Agrostis stolonifera* and *Glaux maritima* which are accompanied by a variety of species typical of freshwater, or at least low-salinity, marshes including *Isolepis cernua*, *Juncus articulatus*, *Juncus bufonius*, *Samolus valerandi* and *Triglochin palustris.* It does not seem to fit comfortably into any described CEP association.

- 5b *Agrostis stolonifera*-dominated community. This is a species-poor grassy sward with no constants apart from *Agrostis*. *Atriplex prostrata* is the most frequent halophyte, with *Aster tripolium*, *Glaux maritima*, *Juncus gerardii*, *Puccinellia maritima* and *Triglochin maritima* being only occasional.

- 5c *Agrositis stolonifera-Eleocharis uniglumis* community. The eponymous species are the constants of this assemblage and *Eleocharis uniglumis* can be abundant. Cover of halophytic species is rather low. *Juncus articulatus*, *Eleocharis palustris*, *Samolus valerandi* and *Triglochin palustris* are occasional.

- 5d *Agrostis stolonifera-Juncus gerardii* community. Like community 3c, this grouping represents *Juncus gerardi* stands, but here *Festuca rubra* is rare and the understorey is formed of *Agrostis stolonifera* and, to a lesser extent, *Potentilla anserina* and *Glaux maritima*.

- 5e *Agrostis stolonifera-Potentilla anserina* community. This community, which was frequently recorded near lagoons, is a progression of 5d. The abundance and ubiquity of *Potentilla anserina* are the diagnostic features. *Agrostis stolonifera* and *Juncus gerardii* are constants but whilst the former typically dominates, the latter is much less prolific. *Glaux maritima* is the other main halophyte. The frequency of *Odontites vernus* and *Trifolium repens* indicates that some trampled and enriched habitats are included here. Examples with *Centaurium pulchellum*, a rare and protected species in

Ireland, are all from the southeast of the country. *Scorzoneroides autumnalis* is at its most frequent in this community.

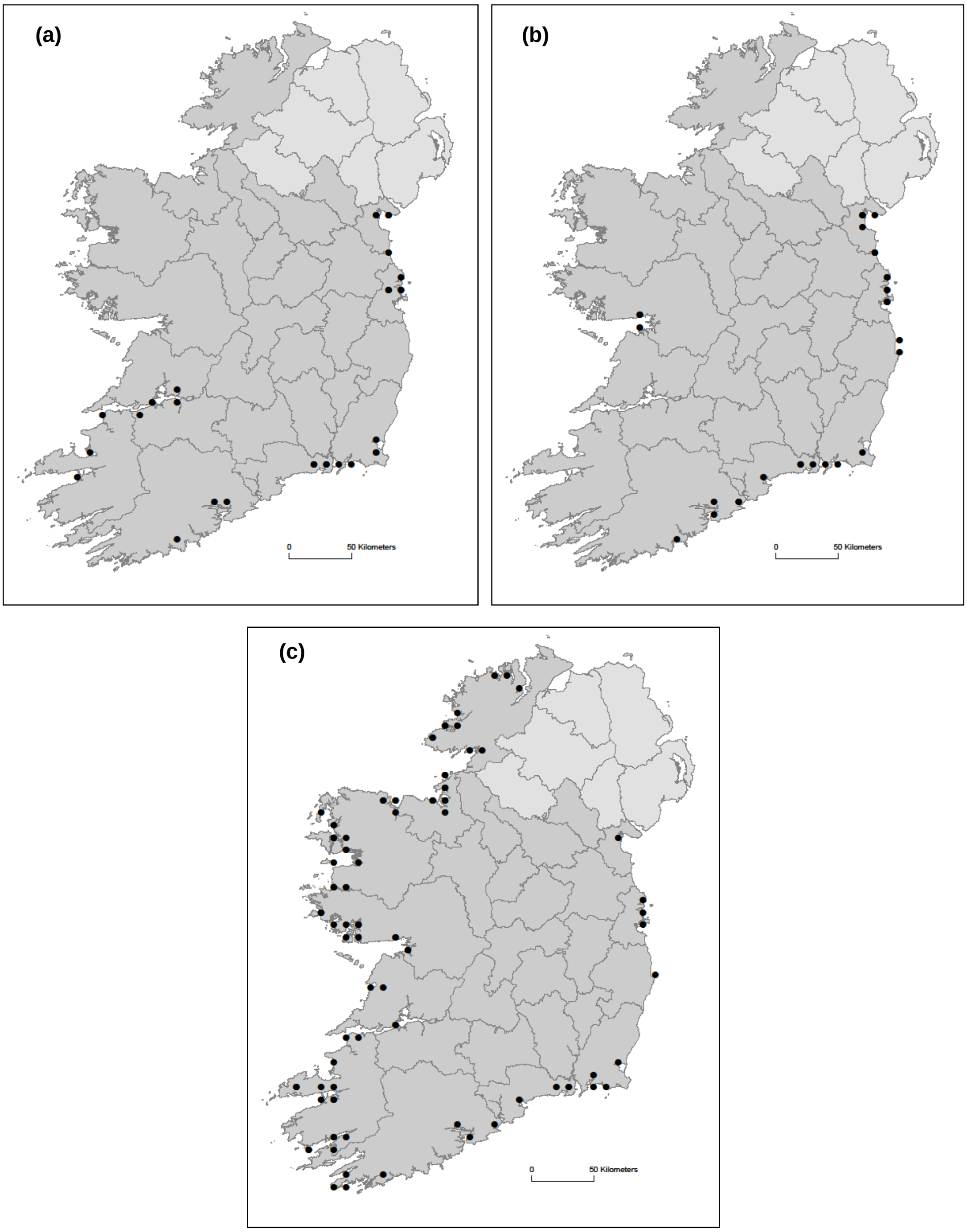


Figure 3.6. Hectad distribution maps for selected communities based on classified plots including transitional plots assigned to communities by function *vegclass()*: (a) 1a *Spartina* community; (b) 2b *Puccinellia maritima-Atriplex portulacoides* community; (c) 4a *Juncus maritimus*-dominated community.

Table 3.3. Primary affinities of Irish saltmarsh communities with i) the Irish Heritage Council system (Fossitt, 2000), ii) the British NVC (Rodwell, 1995; 2000) with the percentage match as calculated by MAVIS. Three sub-communities are subjectively defined for community 6d.

Community		Irish Heritage Council	British National Vegetation Classification	MAVIS
1a		CM1 Lower salt marsh	SM6 *Spartina anglica* salt-marsh community	22.5
1b		CM1 Lower salt marsh	SM8 Annual *Salicornia* salt-marsh community	66.5
2a		CM1 Lower salt marsh	SM13a *Puccinellia maritima* salt-marsh community sub-community with *Puccinellia maritima* dominant	72.7
2b		CM1 Lower salt marsh	SM14c *Halimione portulacoides* salt-marsh community *Puccinellia maritima* sub-community	67.0
2c		CM1 Lower salt marsh	SM13a *Puccinellia maritima* salt-marsh community sub-community with *Puccinellia maritima* dominant	74.0
2d		CM1 Lower salt marsh	SM13b *Puccinellia maritima* salt-marsh community sub-community *Glaux maritima* sub-community	71.5
2e		CM1 Lower salt marsh	SM13d *Puccinellia maritima* salt-marsh community *Plantago maritima-Armeria maritima* sub-community	72.9
3a		CM2 Upper salt marsh	SM16c *Festuca rubra* salt-marsh community *Festuca rubra-Glaux maritima* sub-community	68.1
3b		CM2 Upper salt marsh	SM16c *Festuca rubra* salt-marsh community *Festuca rubra-Glaux maritima* sub-community	75.7
3c		CM2 Upper salt marsh	SM16c *Festuca rubra* salt-marsh community *Festuca rubra-Glaux maritima* sub-community	88.6
3d		CM2 Upper salt marsh	SM18a *Juncus maritimus* salt-marsh community *Plantago maritima* sub-community	81.0
4a		CM2 Upper salt marsh	SM18a *Juncus maritimus* salt-marsh community *Plantago maritima* sub-community	77.2
4b		CM2 Upper salt marsh	SM18a *Juncus maritimus* salt-marsh community *Plantago maritima* sub-community	82.0
5a		CM2 Upper salt marsh	SM20 *Eleocharis uniglumis* salt-marsh community	56.0
5b		CM2 Upper salt marsh	S4d *Phragmites australis* swamp and reed-beds *Atriplex prostrata* sub-community	69.4
5c		CM2 Upper salt marsh	SM20 *Eleocharis uniglumis* salt-marsh community	63.9
5d		CM2 Upper salt marsh	SM20 *Eleocharis uniglumis* salt-marsh community	67.5
5e		CM2 Upper salt marsh	SM20 *Eleocharis uniglumis* salt-marsh community	59.4
6a		FS1 Reed and large sedge swamp	S4a *Phragmites australis* swamp and reed-beds *Phragmites australis* sub-community	56.9
6b		FS1 Reed and large sedge swamp	S21c *Scirpus maritimus* swamp sub-community *Agrostis stolonifera* sub-community	67.3
6c		FS1 Reed and large sedge swamp	S20a *Scirpus lacustris* ssp. *tabernaemontani* swamp *Scirpus lacustris tabernaemontani* sub-community	59.0
	i	CM2 Upper salt marsh	SM28 *Elymus repens* salt-marsh community	48.9[a]
6d	ii	FS1 Reed and large sedge swamp	S12a *Typha latifolia* swamp *Typha latifolia* sub-community	76.0
	iii	CM1 Lower salt marsh	SM2 *Ruppia maritima* salt-marsh community	-[b]

a, Best match actually with community S21 (56.3%); b, No data presented by NVC.

Table 3.4. Primary affinities of Irish saltmarsh communities with Central European phytosociology. Classes, orders and alliances are from the standardised lists of Mucina (1997) and Rodwell *et al.* (2002). Three sub-communities are subjectively defined for community 6d.

Community		Class	Order	Alliance	Association
1a		Spartinetea maritimae	Spartinetalia maritimae	Spartinion maritimae	Spartinetum anglicae Corillon 1953corr. Géhu et Gehu-Franck 1984
1b		Thero-Salicornietea	Thero-Salicornietalia	Thero-Salicornion	Salicornetum europaea Warming 1906
2a		Juncetea maritimi	Glauco-Puccinellietalia	Puccinellion maritimae	Puccinellietum maritimae (Warming 1906) Christiansen 1927
2b		Juncetea maritimi	Glauco-Puccinellietalia	Puccinellion maritimae	Halimionetum portulcoides (Kuhnholtz-Lordat 1927) Des Abbayes et Corillon 1949
2c		Juncetea maritimi	Glauco-Puccinellietalia	Puccinellion maritimae	Puccinellietum maritimae (Warming 1906) Christiansen 1927
2d		Juncetea maritimi	Glauco-Puccinellietalia	Puccinellion maritimae	Puccinellietum maritimae (Warming 1906) Christiansen 1927
2e		Juncetea maritimi	Glauco-Puccinellietalia	Puccinellion maritimae	Puccinellietum maritimae (Warming 1906) Christiansen 1927
3a		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Armerio-Festucetum Hohenester 1960
3b		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Armerietum Yapp & John 1917 / Plantaginetum Chapman 1934
3c		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Juncetum gerardi Warming 1906
3d		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Juncetum gerardi Warming 1906
4a		Juncetea maritimi	Glauco-Puccinellietalia	Glauco maritimae-Juncion maritimi	Juncetum maritimi auct. angl.
4b		Juncetea maritimi	Glauco-Puccinellietalia	Glauco maritimae-Juncion maritimi	Juncetum maritimi auct. angl.
5a		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	*Agrostis stolonifera-Glaux maritima* nodum
5b		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Juncetum gerardi Warming 1906
5c		Juncetea maritimi	Glauco-Puccinellietalia	Eleocharition uniglumis	Eleocharitetum uniglumis Nordhagen 1923
5d		Juncetea maritimi	Glauco-Puccinellietalia	Armerion maritimae	Juncetum gerardi Warming 1906
5e		Molinio-Arrhenatheretea	Potentillo-Polygonetalia	Potentillion anserinae	Trifolio fragiferi-Agrostietum stoloniferae Lj.Mark 1973
6a		Phragmito-Magnocaricetea	Phragmitetalia	Phragmition communis	Phragmititetum australis (Gams 1927) Schmale 1939
6b		Phragmito-Magnocaricetea	Scirpetalia maritimi	Scirpion maritimi	Scirpetum maritimi (Br.-Bl. 1931) R. Tx. 1937
6c		Phragmito-Magnocaricetea	Scirpetalia maritimi	Scirpion maritimi	Scirpetum tabernaemontani Passarge 1964
	i	Honckenyo-Elymetea arenarii	Honckenyo-Elymetalia	Agropyro-Rumicion crispi	Elymetum repentis maritimum Nordhagen 1940
6d	ii	Phragmito-Magnocaricetea	Phragmitetalia	Phragmition communis	Typhetum latifoliae Soó 1927
	iii	Ruppietea maritimae	Ruppietalia maritimae	Ruppion maritimae	Ruppietum maritimae Hocquette 1927

Table 3.5. (a) Affinities with HD Annex I habitats with figures indicating the partitioning of plots recorded by McCorry (2007) and McCorry and Ryle (2009a) between communities as percentages. (b) Ellenberg proxy environmental scores for each community weighted by the mean cover of each vascular species. (c) Variance in community composition as calculated by function *clustvar()*.

	Community																					
	1a	1b	2a	2b	2c	2d	2e	3a	3b	3c	3d	4a	4b	5a	5b	5c	5d	5e	6a	6b	6c	6d
(a) HD Annex I habitats																						
1310 (*n* = 95)	2.1	95.8	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.1
1330 (*n* = 727)	.	0.4	4.5	8.0	15.4	4.1	11.7	14.2	12.2	15.1	10.3	.	0.6	0.3	1.2	.	1.0	.	.	0.4	.	0.6
1410 (*n* = 397)	.	0.3	.	.	0.3	0.5	0.5	0.5	0.3	0.8	.	38.5	57.9	.	.	.	0.3	.	.	0.3	.	.
1420 (*n* = 2)	.	.	.	50.0	.	.	50.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
(b) Ellenberg scores																						
Light	7.5	6.5	6.7	7.2	6.8	6.8	6.7	6.0	5.8	5.7	5.6	5.4	5.4	3.2	4.6	3.7	4.5	4.3	4.1	4.3	4.3	3.5
Wetness	7.5	5.3	5.9	6.4	6.1	6.1	5.9	4.1	4.8	4.8	4.1	5.1	4.5	3.1	4.1	3.8	4.0	3.8	5.6	5.2	4.8	3.3
Reaction	6.7	5.7	5.5	6.1	5.4	5.4	5.1	4.6	4.4	4.8	4.6	5.1	4.9	2.9	4.4	3.4	4.1	4.0	4.0	4.3	3.9	3.2
Nitrogen	5.1	4.4	4.5	4.8	4.6	4.5	4.0	3.8	3.4	3.9	3.8	3.5	3.6	2.2	3.8	2.4	3.5	3.4	3.5	3.8	3.4	2.9
Salinity	5.8	5.6	4.5	4.6	3.9	3.6	3.2	1.9	2.3	2.3	1.6	3.0	2.3	1.3	1.2	1.4	1.7	1.3	1.4	2.3	1.7	1.7
(c) Variance in community composition																						
Beta-diversity	0.02	0.14	0.08	0.09	0.06	0.08	0.07	0.07	0.09	0.09	0.08	0.11	0.07	0.27	0.12	0.17	0.09	0.14	0.06	0.08	0.11	0.44

Class 6: Brackish swamps and residue

This class comprises four communities chiefly of species-poor swamp vegetation associated with saltmarshes. *Bolboschoenus maritimus*, *Schoenoplectus tabernaemontanii* and *Phragmites australis* are class-specific indicators. Admixtures of these species are not uncommon. Halophytes characteristic of saltmarsh communities proper are only occasional at best. Many of the records are of lagoonal margins (Hatch, 1996; Roden, 1998), but brackish swamp vegetation also occurs on open coast saltmarshes alongside creeks and in pans or other depressions, usually in the upper marsh (Wymer, 1984).

- 6a *Phragmites australis* community. This is the most freshwater of the swamps, with the dominant *Phragmites* often accompanied by more glycophytic (salt-intolerant) species such as *Galium palustre*, *Lythrum salicaria* and *Mentha aquatica*. It may occur as a late-successional stand on the upper marsh and in the upper parts of estuaries. For the purposes of the WFD, reedbeds along freshwater tidal reaches of rivers could also be accommodated here.

- 6b *Bolboschoenus maritimus* community. *Bolboschoenus* is fairly frequently accompanied by an understory of *Agrostis stolonifera. Aster tripolium, Triglochin maritimum, Glaux maritima* and *Atriplex prostrata* may occur but are rare or occasional.

- 6c *Schoenoplectus tabernaemontani* community. Stands of *Schoenoplectus* are accompanied infrequently by *Agrostis stolonifera, Glaux maritima, Samolus valerandi* and *Potamogeton pectinatus*.

- 6d Residue ‘community’. This is a *de facto* residue of plots which could not be adequately assigned elsewhere and it has relatively high variability. From this cluster three fairly consistent ‘sub-communities’ with small sample sizes can be subjectively extracted: i) *Elytrigia repens* swards (*n* = 11) of the upper marsh terminus; ii) *Typha latifolia* swamp (*n* = 2) of low salinity lagoons; iii) mudflats or salt pans with *Ruppia* spp. (usually *Ruppia maritima*) (*n* = 8). The remaining residue plots often have sparse overall cover.

3.3.3 Ordination

Stress on the ordination solution (Figure 3.7) was 16.6%, which is reasonably good given the large dataset size (*n* = 2,654) (McCune and Grace, 2002). Classes 2, 3 and 4 form tight point clusters, whereas classes 1 and 5 display greater point dispersion and hence variability. Class 6 (brackish swamps) was excluded for the sake of clarity; preliminary analyses resulted in these points being highly dispersed along upper axis one. This axis represents the main gradient in the data with progression for lower shore / high salinity communities to upper shore / low salinity communities (Table 3.5b). Overall the ordination provides good support for the class partitioning.

3.4 Discussion

3.4.1 Methodological considerations

Removal of transitional plots could be argued to artificially increase the fidelity of diagnostics species (represented in the present study by IndVals) and to reinforce the characterisation of preconceived vegetation types (Ewald, 2003). Indeed, one of the guiding principles of the NVC (Rodwell, 1995; 2000) was to not exclude troublesome samples that might ‘confuse an otherwise crisply-defined result’. Justification of methodology is, however, dependent on the aims. Our objective was not to classify and describe the entire dataset, but to extract from the vegetation continuum the key noda (high sample density areas in multivariate space) that could, ultimately, be more readily identified in the field. Between these noda transitional plots can and do occur. These can be identified as such by fuzzy analysis and, if required, assigned to the best matching noda.

Selecting the optimal number of clusters for a dataset is a perennial problem for vegetation scientists. A number of validation statistics have been suggested to objectively achieve this (e.g. Dufrêne and Legendre, 1997; Aho *et al.,* 2009; Tichý *et al.,* 2010). Often, however, cluster validation measures do not vary in a clear unimodal fashion with increasing number of clusters (e.g. Perrin *et al.,* 2006), or the measures do not find a consensus, in which case selection of the validation measures becomes itself a subjective step in the procedure. In this study we decided to be guided by validation criteria towards an appropriate number of clusters supported by ecological interpretation rather than be restricted by a mathematical optimum.

Integrating multiple datasets yields its own set of problems, including taxonomic inconsistencies and differences in plot size, cover scale and the recognition of vertical strata (Peet and Roberts, 2013) but it is likely to be a common scenario when tackling national-scale classifications. We dealt with taxonomic and cover scale concerns as detailed above and strata were not an issue for this habitat. Plot size may be more problematic as it varied between data sources and sometimes within them, especially those of earlier recorders (e.g. Beckers *et al.,* 1976; Brock *et al.,* 1978). Larger plots are typically used in vegetation of taller stature (Kent, 2012) or where there is a perceived paucity in species richness, hence some variation in plot size is not unexpected in an integrated dataset that contains tall swamps, low-stature saltmarsh and *Spartina* swards. However, the uncertain influence of this variation on similarity calculations and indicator species (Peet and Roberts, 2013) is not likely to be significant as the majority of plots areas (87.7%) were within the relatively narrow range of 1.0 – 4.0 m^2.

Another issue was inconsistent recording between data sources of supporting environmental data which meant we were unable to use these to aid in the interpretation of the vegetation types. This is a highly probable scenario when integrating datasets as collection of these data are often dependent on the aims (and budgetary resources) of the original surveys. In such situations Ellenberg proxy environmental scores are of value.

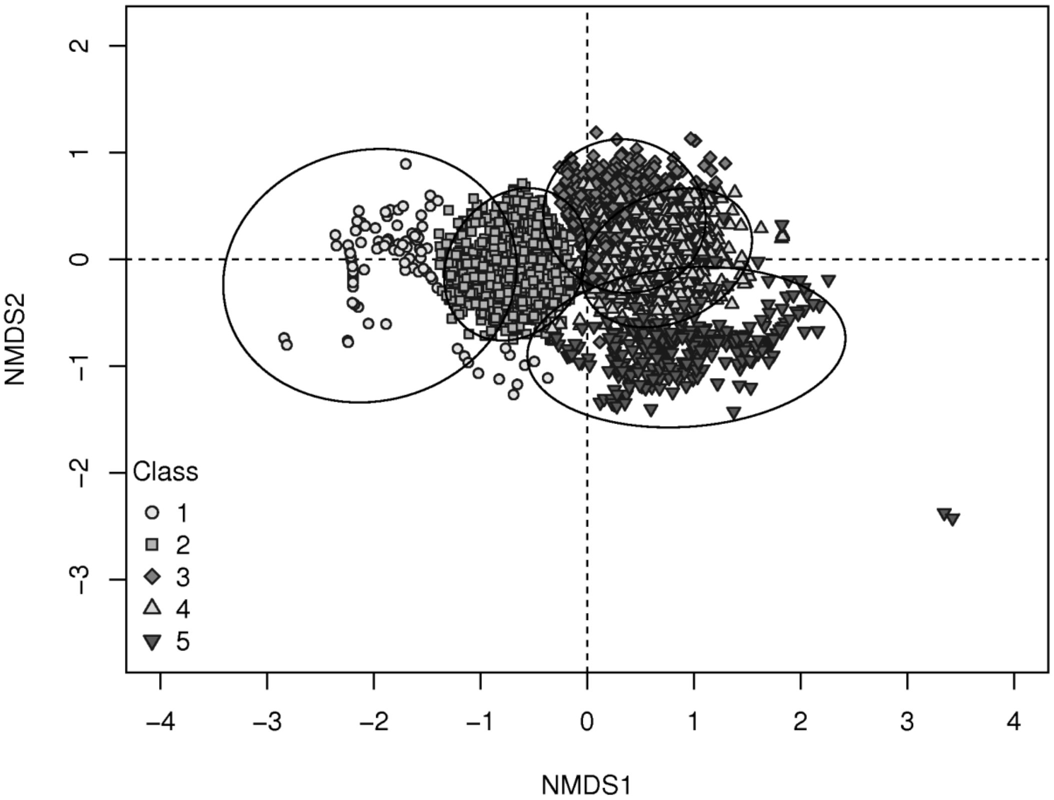
A more conceptual problem related to inconsistency in sampling effort may be the occurrence in integrated datasets of a type of pseudoreplication *sensu* Hurlbert (1984). Some data sources may have multiple samples from the same habitat at the same location (e.g. replication of monitoring plots, transects), resulting in a sequence of plots with very high similarity. Whilst the inclusion of pseudoreplicates does not invalidate an analysis it can manifest by increasing the consistency of communities.

Finally, the classification is inevitably limited by the available data. Whilst the dataset used was relatively large and covers the major range of saltmarsh vegetation diversity, further recording could elucidate the communities with small sample sizes.

3.4.2 Comparisons with other classifications

The majority of Irish communities correlated strongly with categories of the NVC, particularly those in classes 2-4. NVC communities SM8, SM13, SM14, SM16 and SM18, all widespread in Britain (Rodwell, 2000), have clear Irish parallels. Transitional vegetation characterised by *Agrostis stolonifera* with freshwater influence (class 5) and brackish swamps generally did not match so well with the NVC. Some NVC saltmarsh communities that MAVIS did not evaluate as a top match for any community relate to specialised CEP syntaxa whose occurrence in Ireland is discussed below (e.g. SM9 *Suaeda maritima* salt-marsh community). Other communities do not occur in Ireland because the impoverishment of the Irish flora (Webb, 1983) means that the diagnostic species are absent (e.g. *Eleocharis parvula*, *Frankenia laevis*, *Limonium vulgaris, Spartina maritima* and *Suaeda vera*). *Aster tripolium* var. *discoideus* which dominates in NVC community SM11 (Asteretum tripolii) has been recorded only from the southeast of Ireland (National Biodiversity Data Centre, unpublished data) but we have no data on a correlating assemblage. Whilst formulated with British data, the NVC is employed as the basis of saltmarsh mapping in Northern Ireland (Northern Ireland Environment Agency, 2005).

Figure 3.7 (next page). Non-metric multidimensional scaling ordination of Irish saltmarsh plots (*n* =2,654) from classes 1-5. (a) Plots. Symbols represent different vegetation classes. Ellipses represent 95% confidence limits. (b) Species. For clarity, only species with IndVal ≥ 50% for classes 1-5 are shown. Agrostol = *Agrostis stolonifera*, Armemari = *Armeria maritima*, Astetrip = *Aster tripolium*, Cochspp = *Cochlearia* spp., Festrubr = *Festuca rubra*, Glaumari = *Glaux maritima*, Juncgera = *Juncus gerardii*, Juncmari = *Juncus maritimus*, Limohumi = *Limonium humile*, Planmari = *Plantago maritima*, Poteanse = *Potentilla anserina*, Puccmari = *Puccinellia maritima*, Salispp = *Salicornia* spp., Scorautu = Scorzoneroides autumnalis, Sperspp = *Spergularia* spp., Suaemari = *Suaeda maritima*, Trigmari = *Triglochin maritima*.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NMDS1
Class
1
2
3
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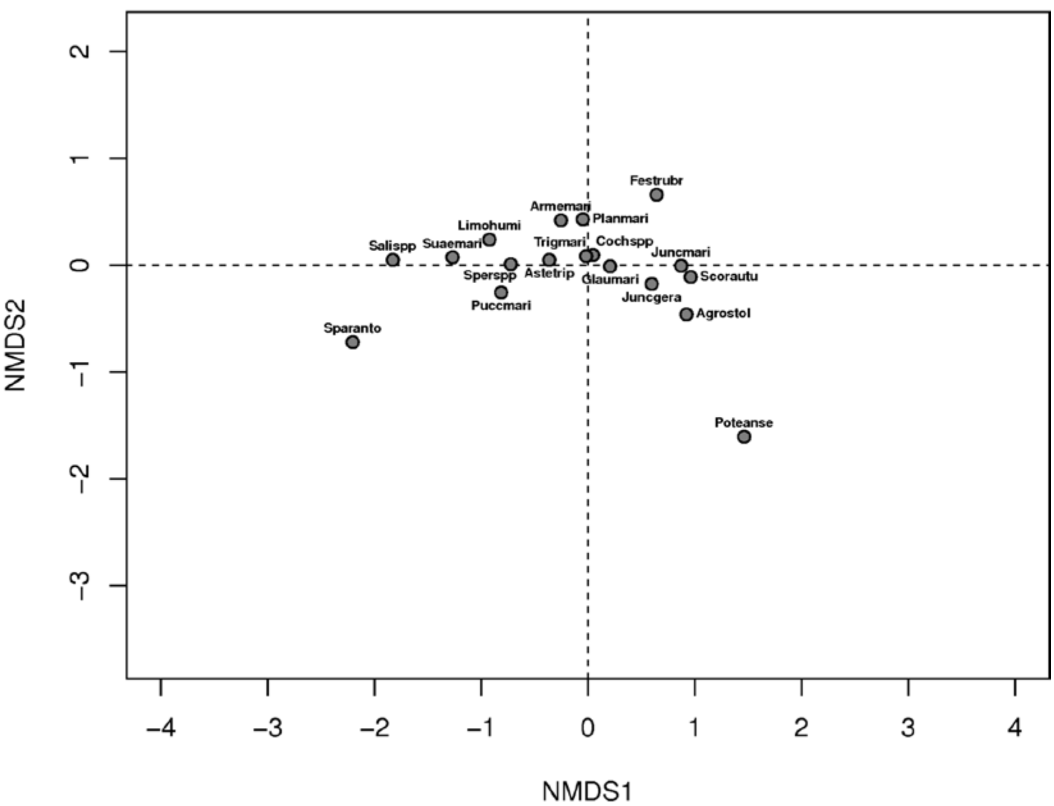
5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Astetrip
Glaumari
Scorautu
Juncgera
Puccmari
Agrostol
Sparanto
Poteanse

Difficulties arise in deducing the affinities of Irish communities with CEP syntaxon due to the lack of a comprehensive syntaxonomic conspectus for Ireland, such as exists for many other European countries (e.g. Rivas-Martínez *et al.,* 2001; Chytrý, 2007, 2009, 2011; Šilc and Čarni, 2012). The 'catalogue raisonné' of White and Doyle (1982) is patchy in its coverage and occasionally speculative. It has also been outdated by subsequent revisions at the class (Mucina, 1997) and alliance (Rodwell *et al.,* 2002) levels. Nevertheless, the main saltmarsh alliances of northwest Europe (Spartinion maritimae, Thero-Salicornion, Puccinellion maritimae, Armerion maritimae and Glauco maritimae-Juncion maritimi) are partitioned relatively neatly between the classes of the scheme presented here.

There is broad correlation of the communities with the classification of Wymer (1984). However, at the association level, some syntaxa described for Ireland by Wymer (1984) and other previous workers (Ní Lamhna, 1982; White and Doyle, 1982) do not constitute the primary affinity for any community in the current scheme as they are represented by a low number of samples relative to the size of the dataset and / or lack statistical distinctiveness. Low sample numbers may reflect under-recording or genuine rarity of vegetation types. Lack of distinctiveness may reflect low relative cover of some diagnostic species and the absence of others. The potential relationships of these syntaxa to the current scheme are discussed here.

The Suaedetum maritimae (Conrad 1935) Pignatti 1953 is an assemblage in which the annual *Suaeda maritima* is the dominant species and is regarded as a sub-type of HD Annex I habitat 1310 in Ireland (McCorry and Ryle, 2009a). In Ireland, this association, which rarely covers extensive areas, has been noted developing on nitrogen-rich tidal deposits (Wymer, 1984) but it also occurs on bare sandy substrate in the transition to sand dunes (Ní Lamhna, 1982). Adam (1981) reports that in Britain this association may occur as dense stands on drift litter, but also accompanied by annual *Salicornia* spp. on creeksides and in pioneer habitats. Vegetation relating to this association could be accommodated within the present classification as a subjectively defined sub-community in community 1b.

The Sagino maritimae-Cochlearietum danicae (R. Tx. 1937) R. Tx et Gillner 1957 is also regarded as a sub-type of HD Annex I habitat 1310 (McCorry and Ryle, 2009a). It is an assemblage of ephemeral vegetation on disturbed substrates which commonly occurs as a narrow ecotone (0.5 m - 5.0 m) between saltmarsh and sand dune vegetation and is characterised by annuals (e.g. *Sagina maritima*, *Cochlearia danica*, *Parapholis strigosa* and *Juncus bufonius*) or short-lived perennials (e.g. *Sagina nodosa* and *Plantago coronopus*) (Wymer, 1984). It is probably not a frequent vegetation type in Ireland; the SMP (McCorry, 2007; McCorry and Ryle, 2009a) recorded *Sagina maritima* from only three saltmarsh sites. In the Netherlands, grazing has been linked with an expansion of Saginion maritimae vegetation types (Bakker and Ruyter, 1981), although this does not seem to hold true in Ireland where grazing is common. Further investigation of old turf-cuttings may locate more examples as this association is characteristic of this habitat in Britain (Rodwell, 2000). There are insufficient data to position this association in the current scheme.

Ní Lamhna (1982) described two new associations for the saltmarsh – sand dune ecotone from Malahide, Co. Dublin. In the Limonietum binervosi, *Limonium binervosum* is the character species but *Atriplex portulacoides* is often abundant and it may best be regarded as a sub-community of community 2b. The Sagino nodosae-Tortelletum flavovirentis is a described as vicariant of the Sagino maritimae-Tortelletum flavovirentis Beeftink, Tx. et Westhoff 1963 but *Limonium binervosum* is plentiful in most of these plots reducing its distinctiveness from the Limonietum binervosi. Proper assessment of these syntaxa, however, would require a joint analysis of saltmarsh and sand dune datasets.

White and Doyle (1982) opined that the Junco-Caricetum extensae Br.-Bl. et De Leeuw 1936 was poorly differentiated from the Juncetum gerardi in Ireland, noting that *Carex extensa* is regarded as a character species of this latter association by Braun-Blanquet and Tüxen (1952). Similarly, Adam (1977a) concluded that most of the British vegetation described as the Junco-Caricetum could be incorporated into the Juncetum gerardi. Relevés with *Carex extensa* were afforded only variant status within the Juncetum gerardi by Wymer (1984) although Ivimey-Cook and Proctor (1966) deemed it to be a character species of *Juncus gerardii* stands near the Burren. The present scheme finds little support for this association in Ireland as *Carex extensa* shows no great fidelity for *Juncus gerardii* stands and is seldom plentiful. It could only cautiously be regarded as a sub-community of community 3c.

White and Doyle (1982) effectively placed all stands characterised by *Juncus maritimus* in Ireland within the Junco maritimi-Oenanthetum lachenalii R. Tx. 1937. However, Wymer (1984) argues that plots lacking *Oenanthe lachenalii* be excluded from the association as they are floristically distinct and our data reveal that this species is present in only a small proportion of these stands (13% of plots in class 4). We have therefore followed Rodwell (2000) in chiefly associating our *Juncus maritimus* communities under the broad banner of the Juncetum maritimi with the Junco maritimi-Oenanthetum lachenalii being best regarded as a sub-community within community 4b. Adam (1977a) suggested that in Britain, *Juncus maritimus* is an important constituent of a wider range of vegetation than elsewhere in northwest Europe; further study is needed to see how Irish vegetation of this nature compares. On the west coast of Ireland, for example, *Juncus maritimus* is present in vegetation with *Schoenus nigricans* and *Molinia caerulea* that is transitional from fringe saltmarsh to blanket bog.

The Atriplici-Agropyretum pungentis Beeftink et Westhoff 1962 recorded by Wymer (1984) is an upper marsh community of driftlines and levees, characterised by the abundance of *Elytrigia atherica* (= *Agropyron pungens*). Like the Elymetum repentis maritimum (community 6d(i)), it has been rarely sampled thus far in Ireland, falling between the remits of Annex I habitat surveys focussed on saltmarsh (McCorry, 2007; McCorry and Ryle, 2009a) and semi-natural grassland (O'Neill *et al.,* 2013). *Elytrigia atherica* is somewhat infrequently distributed, mainly along the south and east coasts and swards of this species were noted at only about 6% of sites by the SMP (McCorry, 2007; McCorry and Ryle, 2009a). In comparison, swards of *Elytrigia repens* (= *Elymus repens*), a far more common and widespread species, were noted at approximately 57% of SMP sites being a common vegetation type of levees. Adam (1981) regarded the Elymetum repentis maritimum as a northern and western vicariant of the Atriplici-Agropyretum pungentis in Britain. Further recording is required to characterise and quantify these communities in Ireland.

The Blysmetum rufi (G.E. et G. Du Rietz 1925) Gillner 1960 first recorded in Ireland by Wymer (1984) is characterised by the perennial herb *Blysmus rufus*, which is found most frequently on the coast of Donegal, and occurs as small isolated stands or in mosaic with other communities. In plots from our main dataset where *Blymus rufus* was fairly abundant (> 20% cover, n = 12), *Glaux maritima*, *Agrostis stolonifera*, *Juncus gerardi* and *Armeria maritima* were its constant associates, with *Plantago maritima*, *Festuca rubra* and *Triglochin maritima* also frequent, matching the description for this association in Britain (Rodwell, 2000). These species appear to link the association with the Armerion maritimae and it could tentatively form a sub-community of communities 3c or 3d.

The Artemiesetum maritimae (Hocquette 1927) Br.-Bl. et De Leeuw 1936 is a localised variant of the upper marsh boundary characterised by *Seriphidium maritimum* (= *Artemisia maritima*) and has been recorded from the Shannon Estuary and Galway Bay (Wymer, 1984; McCorry and Ryle, 2009a). Again, we examined plots from our main dataset where the character species was fairly abundant (>15% cover, n = 17). *Festuca rubra* and *Agrostis stolonifera* occurred in the majority of plots, but *Seriphidium* also occurred in *Puccinellia maritima* swards. Wymer (1984) placed these latter plots in the Puccinellietum maritimae. This assemblage therefore has rather questionable distinctiveness in Ireland.

The Puccinellietum distantis Feekes (1934) 1945 is another ephemeral association of trampled ground, probably occurring along the east and south coasts, and is characterised by the presence of the titular species and *Spergularia marina* (White and Doyle, 1982; Wymer, 1984). It is uncommon, but due to its association with grazed and disturbed sites is likely to be under-recorded. In the 24 plots in the current dataset in which *Puccinellia distans* was recorded, there were no other constants, although *Cochlearia* spp., *Agrostis stolonifera*, *Atriplex prostrata* and *Aster tripolium* were frequent. This association could be regarded as a sub-community of community 5b. The Puccinellietum fasciculatae Beeftink 1965, speculated to occur in Ireland by White and Doyle (1982), cannot be substantiated using the present data, however, with *Puccinellia fasciculata,* a rare and protected species in Ireland being significant in only a single plot. It occurs in the southeast and east of the country but at low densities.

A variant or nodum within the Puccinellietum maritimae supporting ‘turf fucoids’ has been described in Ireland by Wymer (1984). These are dwarf forms of species including *Ascophyllum nodosum* (L.) Le Jolis, *Fucus vesiculosus* L. and *Pelvetia canialiculata* (L.) Decne. & Thur. A similar feature has been recorded from the west of Scotland (Adam, 1977b; 1981). Inspection of the current dataset, however, suggests vascular vegetation associated with these algal assemblages is not that consistent. More data are required to ascertain if the vascular vegetation is superimposed (Rodwell, 2000).

Finally in regard to CEP associations, vegetation previously ascribed to the Halo-Scirpetum maritimi (Van Langendonck 1931) Dahl et Hadac 1941 by White and Doyle (1982) and Wymer (1984) is now accommodated within the Scirpetum maritimi (community 6b) due to the demise of the Halo-Scirpion in Rodwell *et al.* (2002).

Compositionally, most if not all of the plots in community 1a would link with the HD Annex I habitat 1320 *Spartina* swards (*Spartinion maritimae*). However, as *Spartina anglica* is considered an alien invasive taxa in Ireland (McCorry and Otte, 2000; McCorry *et al.,* 2003) these communities are not now afforded Annex I status. If present, stands of other forms of *Spartina* (*S. maritima*, *S.* × *townsendii*) could be considered of conservation value.

Stands of *Juncus maritimus* in Ireland are deemed to represent HD Annex I habitat Mediterranean salt meadows (Juncetalia maritimi) (1410), this species being listed as an indicator for one of the sub-types. However, due to the biogeographic location of the country we have classified these stands (class 4) within the Glauco-Puccinelletalia as Glauco maritimae-Juncion maritimi, an alliance that Rodwell *et al.* (2002) define as ‘Atlantic oligo-haline salt-marsh communities’. *Juncus acutus* is also an indicator for this HD Annex I sub-type on saltmarsh but it is an uncommon species in Ireland. In the UK, habitat 1410 was considered not to occur following scrutiny of phytosociological literature and discussion with European specialists (McLeod *et al.,* 2005) and these stands are instead included within HD Annex I habitat 1330 Atlantic salt meadows (Glauco-Puccinellietalia). McCorry and Ryle (2009a) thus recommended that the occurrence of this HD Annex I habitat in Ireland should be re-evaluated.

HD Annex I habitat 1420 Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi) is defined in the Ireland by the presence of a single species, *Sarcocornia perennis*, a rare plant found only in four hectads in Co. Wexford in the southeast of the country (Preston *et al.,* 2002). McCorry and Ryle (2009a) found that it did not occur within a single distinctive vegetation community, being found mainly amongst Spartinion swards and stands of the Puccinellion maritimae, with cover values <5%. The presence of the Sarcocornetea fruticosi in Ireland is therefore questionable, and it is doubtful whether plots with *Sarcocornia perennis* are worthy of a sub-community.

3.4.3 Factors influencing communities

Grazing can have significant impacts on saltmarsh vegetation, and has been well studied in northwest continental Europe (e.g. Jensen, 1985; Andresen *et al.,* 1990; Kiehl *et al.,* 1996; Bos *et al.,* 2002; Kleyer *et al.,* 2003; Tessier *et al.,* 2003); higher levels of grazing can negatively affect some species (e.g. *Aster tripolium*, *Atriplex portulacoides*, *Elytrigia atherica* and *Seriphidium maritimum*) whilst promoting others (e.g. *Puccinellia maritima, Salicornia europaea*). Grazing by sheep and cattle is almost ubiquitous on the saltmarshes of western Ireland, but much less frequent in the east (Curtis and Sheehy Skeffington, 1998). This is likely to be a significant factor explaining the scarcity of *Atriplex portulcoides* and the lower marsh community 2b in the west, although climatic limitation may be an influence in the north of the island (Sheehy Skeffington and Curtis, 2000). It may be speculated that the absence of *Elytrigia atherica* from most of the west coast (Preston *et al.,* 2002) is also partly attributable to high grazing pressure. This late-successional native species has spread vigorously on the upper zones of continental European saltmarshes which have been abandoned by grazers (Bakker *et al.,* 2003), replacing communities such as *Festuca rubra* swards (Bos *et al.,* 2002). *Festuca rubra* can itself replace the grazing-tolerant *Puccinellia maritima* at intermediate grazing levels (Kleyer *et al.,* 2003). In the Netherlands, *Phragmites* beds are regarded as a potential climax vegetation type for saltmarshes in the absence of grazing (Dijkema *et al.,* 2005). An indirect impact of long-term cattle grazing is nutrient enrichment, of which the reasonable frequency of *Trifolium repens* in some of the Irish communities may be indicative (McCorry and Ryle, 2009a). It is important to therefore note that whilst variance in inundation regime is a fundamental influence on saltmarsh vegetation, grazing pressure is also an important factor that may explain differences between the communities presented here. Agriculture may also influence vegetation composition through the eutrophicating effect of run-off from adjacent fields. It may be hypothesized that this could manifest as an increase in some species, such as *Agrostis stolonifera*, in the upper transitional zone of saltmarshes. Targeted research is, however, needed to test this theory.

Tidal amplitude effects community-level diversity in saltmarshes. Coastal lagoons typically have limited tidal range; in recent Irish surveys, lagoons were characterised as having no more than ~20% of the range of the open coast (Healy, 2003). Thus, while marginal lagoon vegetation has distinct similarities with open coast saltmarshes, there is truncation of the zonation. Salinity ranges, which can vary considerably between lagoons, will also influence the occurrence of saltmarsh species on lagoon margins; Irish lagoons vary from oligohaline (0.5-5 g^{l-1}) through to euhaline (30-40 g^{l-1}) (Healy, 2003). Roden (1998) noted several important differences in lagoonal saltmarshes when compared with open coast sites: i) the *Salicornia* pioneer zone (community 1b) is absent; ii) *Puccinellia maritima* swards (communities 2a, 2c-2e) have a very limited distribution at the water's edge and are confined to the most saline lagoons; iii) *Juncus maritimus* stands (class 4) occur right down to water's edge; iv) *Juncus gerardii* stands often support fewer halophytes and more glycophytes, for example a variant with *Potentilla anserina* (communities 5d, 5e) occurs at the water's edge in low salinity lagoons. Reduced zonation is also seen in non-tidal situations such as the Baltic and Mediterranean Seas (Wanner *et al.,* 2007).

Substrate can be a factor in determining the presence and distinctiveness of communities. Cott *et al.* (2013) found that ombrogenic Altantic saltmarshes exhibited less variation between plant communities of the lower, mid and upper shore than saltmarshes on non-peat substrates. In her study from the southwest of Ireland, stands of *Spartina anglica* (community 1a) and *Atriplex portulacoides* (community 2b) and swards of *Puccinellia maritima* (communities 2a, 2c-2e) were absent from peat sites, and the typically upper marsh species *Juncus maritimus* occurred throughout the profile. Cott *et al.* (2013) concluded that greater homogeneity of peat saltmarshes may be due to the lack of distinct gradient. *Juncus maritimus* has been noted previously as occurring low down on the marsh in the west of the country (Doyle, 1982; Sheehy Skeffington and Wymer, 1991) and western Scotland (Adam, 1977b).

Realised niche width (Hutchinson, 1957) underpins saltmarsh zonation which is generated by overlaps in the vertical range of individual species (Gray, 1992). Broader niches mean larger overlaps and fuzzier distinction of zones. Even after excluding transitional plots, our analysis still yielded a scheme with relatively few class-specific indicator species. Many of the most characteristic species of Irish saltmarshes are indicators for three classes (e.g. *Armeria maritima*, *Aster tripolium*, *Glaux maritima*, *Juncus gerardii*, *Plantago maritima* and *Triglochin maritima*). Class 3, which represents a part of the Armerion maritimae, is distinctive but lacks class-specific indicators. Adam (1981) concluded that that the Armerion was not easily defined by faithful taxa in Britain, in part because *Armeria maritima* has a wider ecological tolerance in the British Isles than in continental Europe, and this may also be true for other species (e.g. *Glaux maritima*; Wymer, 1984). Mean niche overlap can be significantly smaller on saltmarshes with more diverse vegetation due to increased competition (Pianka, 1974; Russell *et al.,* 1985), although this was not found by Cott *et al.* (2013) whose most species-rich sites (on peat substrate) were also the most homogeneous. Does lower diversity in Irish saltmarshes compared with continental Europe result in broader realised niche width?

3.4.4 Zonation in respect of European directives

Mapping and plot monitoring of saltmarsh in Ireland is currently conducted for the purposes of HD Article 17 reporting (McCorry, 2007; McCorry and Ryle, 2009a), recorded using Fossitt (2000) and HD Annex I habitats. Monitoring plots have been recorded in a quasi-stratified manner, such that lower, middle and upper saltmarsh diversity is recorded. For practical purposes, it is desirable that future surveys, especially field surveys, be designed to simultaneously provide, as far as possible, the requisite information for both the HD and the WFD. The intentionally broad categories of Fossitt (2000) clearly do not adequately distinguish the variation in saltmarsh zonation. Nor do Annex I habitat categories, as habitat 1330 exhibits considerable variation and links to multiple communities across several classes. Furthermore, saltmarsh habitats which are not considered to correspond with HD Annex I habitats, such as brackish swamps, upper marsh transitional communities and swards of *Elytrigia atherica* or *Elytrigia repens*, but which may be considered as relevant for the assessment of zonation for the WFD fall outside the current monitoring protocol. Coarse-scale category recording could result in the oversight of important changes in vegetation composition and zonation such as those resulting from succession (Olff *et al.,* 1997), alterations in grazing regime (Bakker *et al.,* 2003) and the loss of upper marsh communities due to coastal squeeze (Doody, 2013).

We recommend that future monitoring of saltmarshes in Ireland for the purposes of European directives is conducted at the community-scale and includes the full range of vegetation types detailed in this paper. From these data, the presence and area of each of a list of zones within WFD water bodies can be calculated (Table 3.6).

Table 3.6. Proposed vegetation zones for WFD assessment of saltmarsh indicating typical occurrence in different types of water bodies.

			Water body type		
Zones		**Communities**	**Open coast**	**Estuaries**	**Lagoons**
Spartina beds	1a	*Spartina* community	•	•	
Pioneer	1b	*Salicornia* community	•	•	
Lower marsh	2a	*Puccinellia maritima-Salicornia* community	•	•	
	2b	*Puccinellia maritima-Atriplex portulacoides* community	•	•	
	2c	*Puccinellia maritima*-dominated community	•	•	
	2d	*Puccinellia maritima-Aster tripolium* community	•	•	
	2e	*Puccinellia maritima-Plantago maritima* community	•	•	
Middle marsh	3a	*Festuca rubra*-dominated community	•	•	•
	3b	*Festuca rubra-Armeria maritima* community	•	•	•
	3c	*Festuca rubra-Juncus gerardii* community	•	•	•
	3d	*Festuca rubra-Agrostis stolonifera* community	•	•	•
Upper marsh	4a	*Juncus maritimus*-dominated community	•	•	•
	4b	*Juncus maritimus-Festuca rubra* community	•	•	•
Upper transitional	5a	*Agrostis stolonifera-Glaux maritima* community			•
	5b	*Agrostis stolonifera*-dominated community			•
	5c	*Agrostis stolonifera-Eleocharis uniglumis* community			•
	5d	*Agrostis stolonifera-Juncus gerardii* community			•
	5e	*Agrostis stolonifera-Potentilla anserina* community			•
Phragmites / Typha swamps	6a	*Phragmites australis* community		•	•
	6d(ii)	*Typha latifolia* community		•	•
Bolboschoenus / Schoenoplectus swamps	6b	*Bolboschoenus maritimus* community	•	•	•
	6c	*Schoenoplectus tabernaemontani* community	•	•	•
Elytrigia atherica / E. repens* swards	6d(i)	*Elytrigia repens* community	•	•	•

*Not statistically defined by the present classification.

In both the UK and Germany, brackish swamps occurring in isolation from other saltmarsh vegetation, are also included in WFD assessments (Wanner *et al.,* 2007; Adolph and Arens, 2011; UKTAG, 2013) and the inclusion of these in Ireland's assessments should be considered. We suggest that *Phragmites* beds are treated as a separate zone to *Bolboschoenus* and *Schoenoplectus* stands as the former can occur at higher levels on the saltmarsh profile (e.g. Deegan and Harrington, 2004). Where small areas of *Ruppia* spp. (community 6d(iii)) occur in salt pans within saltmarsh, they can be regarded as part of the zone they occur within, but occurrences on mudflats outside a saltmarsh context should not be considered. Adjustments to the reference list of zones would need to be made on a water body-specific basis to account for natural variation. *Phragmites* beds may not occur in some coastal water bodies where freshwater runoff is minimal or absent (UKTAG, 2013). Due to truncation of zonation a more limited number of zones should be expected in lagoonal water bodies. Fewer zones may also occur under optimal conditions at sites on ombrogenic substrate and specific targets may need to be set for water bodies where a high proportion of the saltmarsh resource occurs at these sites. Rather than scoring zones on a simple binary presence / absence basis, we propose that each zone should comprise a certain range of proportion of the saltmarsh resource (e.g. 5-35% but possibly lower for *Elytrigia* swards and swamps; Dijkema *et al.,* 2005). *Spartina* swards (community 1a) are a special case, since, as reviewed by McCorry *et al.* (2003), there is considerable debate over the positive and negative impacts of these non-native stands. Positive effects include the promotion of saltmarsh development through rapid sediment accretion and the protection of seaward zones from erosion, but *Spartina* also invades communities of *Zostera* spp. and *Salicornia* spp. Even if desirable, eradication of *Spartina* has proven difficult in the extreme. We suggest that whilst low levels of *Spartina* should be regarded neutrally by assessments, large expanses should be regarded as undesirable.

4. Pressures Acting on Saltmarsh Communities

4.1 Rationale

The purpose of this chapter is to identify and discuss the main pressures acting on Irish saltmarshes in the context of the WFD. Pressures resulting from human activities that could affect the status of aquatic ecosystems must be considered when assessing the risk of failure in achieving the WFD environmental objectives (EC, 2003d). The coverage of pressure data collated here will be used to help select forty Irish water bodies to be assessed using SMAATIE. The pressure data will also be analysed with the calculated EQR scores for these forty water bodies to assess the applicability of the tool (refer to Chapter 7). Metrics that will be examined by SMAATIE include potential and current extent of saltmarshes in Ireland, community zonation and angiosperm taxa diversity (refer to Chapter 6). Pressures detailed in this chapter may impact on these metrics.

In dealing with pressures, the guidance provided in EC (2003d) has been largely adhered to. Terminology will follow that laid out in the Driver, Pressure, State, Impact, Response (DPSIR) analytical framework, where a pressure is taken to be the direct effect of the driver (an anthropogenic activity) and an impact is the environmental effect of the pressure. A significant pressure is any pressure that on its own, or in combination with other pressures, may lead to a failure to achieve the specified objective(s) of the WFD. The guidance note proposes the use of three broad pressure categories: point and diffuse sources of pollution, effects of modifying the flow regime through abstraction or regulation, and morphological alterations. Any other pressures which do not fall within one of these categories should also be identified. Other pressures related to biology were treated as a separate category resulting in five categories in total.

4.2 Datasets and information

A number of datasets were used to determine the most frequently occurring pressures acting on either saltmarshes or TraC water bodies which support saltmarsh communities: the SMP (McCorry, 2007; McCorry and Ryle, 2009a), various data provided by the EPA and Site Inspection Reports (SIRs) of Natura 2000 sites as recorded by NPWS rangers.

4.2.1 Saltmarsh Monitoring Project

The SMP (McCorry, 2007; McCorry and Ryle, 2009a) is the most significant piece of recent research on saltmarshes in Ireland. Anthropogenic activities were recorded at a site level for the SMP using a standard list of codes and included the following data: intensity of activity on a three point scale, area of the habitat affected, source of the activity (inside or outside the site) and whether the impact of the pressure was negative (irreparable or reparable), neutral or positive (natural or managed). It should be noted that SMP used the period 1995 to 2007-2008 as their monitoring period. Anthropogenic activities which occurred outside this time were not considered. Therefore, port development and land reclamation for example, which occurred prior to 1995, would not have been recorded as pressures (McCorry and Ryle, 2009a). There were several sources for the SMP data: the report for the pilot survey (McCorry, 2007), the report for the main survey (McCorry and Ryle, 2009a), four volumes containing individual site reports for all SMP sites surveyed, an Access database (Coastal_Habitats_Database_2011.mdb) and a Geographical Information Systems (GIS) polygon shapefile (smp_national_sm_resource_revised_GIS_2011.shp) which contained habitats mapped as part of the SMP and additional polygons of potential saltmarsh mapped as part of a separate desktop survey. All sources of data were provided by NPWS.

To assign each habitat polygon within the SMP polygon shapefile to an individual water body, it was intersected with two water body shapefiles downloaded from the EPA Geoportal website [2] (WFD_CoastalWaterBodies.shp, WFD_TransitionalWaterBodies.shp). Polygons which did not intersect were assigned to a water body manually, while polygons which spanned more than one water body were either wholly assigned to one water body or divided between the water bodies by cutting at a logical place. All polygon assignments were reviewed to ensure that they made sense in terms of current flow and direction, and potential physical barriers. Pressure data were then extracted from the Coastal_Habitats_Database_2011 Access database. Each incidence of a pressure was linked to a water body using the polygons assignments made above resulting in a comprehensive list of pressures at a water body level. Where inconsistencies were found between or within the Access database, polygons shapefile and the reports, the data and supporting text presented in the individual site reports were given precedence. The individual site reports were also referred to in cases where SMP sites spanned more than one water body; this ensured that pressures recorded at these sites were assigned to the correct water bodies.

Only anthropogenic activities recorded as having a negative impact on saltmarsh were included in this analysis. Saltmarshes tend to undergo natural cycles of erosion and accretion, and succession to other natural habitats can occur. Therefore where such processes were recorded as a negative impact each case was examined individually and only those related to anthropogenic activities were brought forward in this analysis. Of the 193 water bodies containing saltmarsh as mapped by the SMP or desktop survey, 89 had negative pressures recorded.

4.2.2 EPA datasets

Under the requirements of Article 5 of the WFD, the EPA and the coordinating authorities of the River Basin Districts (RBDs; Fig. 2.1) carried out an initial characterisation and analysis of RBDs (EPA, 2005). Part of this process involved an analysis of the pressures and impacts that human activities exert on Irish waters, which was based on collaboration between the EPA, local authorities and other state agencies. Risks were assessed for each water body under four risk categories: point sources (relating to pollution), morphological risk, marine direct impacts (MDIs) assessment, and abstraction (TWBs only). Risks were classed in terms of their influence on the likelihood that a water body will not achieve good ecological or chemical status by 2015, either "1a: At risk", "1b: Probably at risk", "2a: Probably not at risk" or "2b: Not at risk". The raw data were made available for this project. Only the 93 water bodies containing risks classified as either 1a or 1b were used for the purposes of this chapter as these were interpreted as having negative impacts. Of these water bodies, 47 coincide with the SMP water body pressure data.

The trophic status of individual TraC water bodies was assessed by O'Boyle *et al.* (2010) using the EPA's Trophic Status Assessment Scheme (TSAS). The raw data from this assessment were provided by the

[2] These shapefiles were the original shapefiles available at the start of the project, with the website accessed 14 November 2013. New shapefiles of Irish TraC water bodies were issued after commencement of the project. The merging of three pairs of original water bodies (Ballysadare Bay with Ballysadare Estuary, Castlemaine Harbour with Cromane, and Garavogue Estuary with Sligo Harbour) was taken into account, but no other changes were made to the GIS or GIS-derived data already processed.

EPA. Trophic status was assessed as eutrophic, potentially eutrophic, intermediate or unpolluted depending on specific criteria under three categories: nutrient enrichment, accelerated plant growth and disturbance to the level of dissolved oxygen normally present. Of the 89 water bodies measured for trophic status, 67 supported saltmarsh communities, with 8 of these assessed as eutrophic.

4.2.3 Site Inspection Reports

SIRs are compiled by NPWS rangers and contain information on impacting activities that were observed on Natura 2000 sites (SACs, NHAs, SPAs) at the time of the ranger's visit(s). Four time periods are available: end of period 2001, 2003, 2006 and 2009. Only negative pressures were used in this analysis. Not all of the data from this resource could be utilised due to a high level of uncertainty concerning the water bodies impacted upon as there was a lack of specific location data (e.g. grid references). In fact, only 20 water bodies contained sufficient location data to assign the negative pressures to their corresponding water bodies.

4.3 Summary statistics

The pressure data from the various sources discussed in Section 4.2 were merged resulting in one set of pressures for each water body. A total of 138 water bodies that contained saltmarsh had pressure data after the merging of the various datasets (Table 4.1). The EPA risk assessment data had the largest number of water bodies with pressure data, with the SMP data having a slightly lower number. By utilising the SIR data, three more water bodies were included in the pressures analysis, which would not have been included otherwise. Only the EPA trophic status data did not add any new water bodies to the analysis.

Table 4.1. List of datasets and corresponding number of water bodies used in the collation of pressure data. SMP: Saltmarsh Monitoring Project; EPA: raw data from EPA (2005) and O'Boyle *et al.* (2010); SIR: Site Inspection Reports.

	No. of water bodies		
Dataset	**No overlap with other datasets**	**Overlap with other datasets**	**Total**
SMP	34	55	89
EPA_risk assessments	42	51	93
EPA_trophic status analysis	0	8	8
SIR	3	17	20
Total no. of water bodies	**79**	**59 (overlaps not counted)**	**138**

Following the collation of the pressure data, each individual pressure recorded for each water body was grouped with other similar pressures under a pressure sub-category heading; for example, the separate pressures of roads and port areas were grouped under the sub-category "transportation and service corridors". These sub-categories were, in turn, grouped under the five main pressure categories mentioned in Section 4.1, referred to hereafter as pollution, morphology, water regime, biology and other. Table 4.2 lists each of the five main categories with their associated sub-category pressures and the frequency of each sub-category pressure within each RBD. Refer to Appendix 4 for how the seventy individual pressures were assigned to the sub-categories.

Of water bodies containing saltmarsh within the Eastern RBD, 91.7% had point pollution recorded as impacting on them (Table 4.2). In the same RBD, 75% of water bodies also had dykes, embankments or artificial beaches recorded whilst this pressure was also noted in 62.5% of water bodies within Neagh Bann

RBD. Grazing was most frequent within the North Western and Western RBDs at 64.7% and 66.7% respectively, while invasive (non-native) species was the most frequent pressure recorded for water bodies within the South Eastern RBD (66.7%). Within water bodies in the Shannon RBD, the pressures of point pollution and modifications to hydrological functioning were equally frequent (both 57.1%), while the South Western RBD had point pollution as the most frequently recorded pressure (53.3%). Two RBDs (Western and North Western) had less than 20.0% of their water bodies impacted upon by eutrophication whilst South Eastern RBD had 40.0% of its water bodies impacted upon by this pressure. On a national level, point pollution (48.6%), grazing (47.1%) and transportation and service corridors (39.1%) were the most frequently recorded negative pressures within water bodies containing saltmarsh.

Table 4.2. Percentage frequency of occurrence of sub-category pressures in water bodies within each River Basin District (RBD). Data presented are from the merged SMP, EPA and SIR datasets.

Category	*River Basin District (RBDs)							
Sub-category	EA	NB	NW	SE	SH	SW	WE	Total
	(*n*=12)	(*n*=8)	(*n*=17)	(*n*=15)	(*n*=14)	(*n*=30)	(*n*=42)	(*n*=138)
Pollution								
Eutrophication	25.0	25.0	17.6	40.0	28.6	30.0	2.4	20.3
Other pollution	16.7	12.5	5.9	20.0	7.1	13.3	9.5	11.6
Point pollution	91.7	25.0	41.2	53.3	57.1	53.3	35.7	48.6
Morphology								
Erosion (anthropogenic)	8.3	0.0	5.9	33.3	0.0	10.0	21.4	13.8
Landfill, land reclamation and drying out	25.0	12.5	29.4	46.7	35.7	26.7	21.4	27.5
Other natural system modifications	41.7	37.5	0.0	26.7	28.6	23.3	14.3	21.0
Other urbanisation, industrial & similar activities	25.0	12.5	5.9	13.3	21.4	20.0	11.9	15.2
Transportation and service corridors	66.7	0.0	29.4	60.0	28.6	16.7	54.8	39.1
Water regime								
Dykes, embankments, artificial beaches	75.0	62.5	11.8	26.7	42.9	20.0	14.3	27.5
Modifications to hydrological functioning	16.7	37.5	35.3	33.3	57.1	20.0	14.3	26.1
Biology								
Biological resource use other than agriculture	0.0	0.0	0.0	26.7	0.0	0.0	0.0	2.9
Grazing	16.7	0.0	64.7	53.3	42.9	33.3	66.7	47.1
Invasive (non-native) species	58.3	37.5	17.6	66.7	28.6	13.3	0.0	22.5
Other								
Land management	0.0	0.0	5.9	6.7	7.1	0.0	9.5	5.1
Other agricultural activities	0.0	0.0	5.9	6.7	0.0	3.3	2.4	2.9
Other human intrusions	8.3	0.0	0.0	0.0	0.0	0.0	2.4	1.4
Outdoor sports, recreational activities & structures	50.0	0.0	29.4	13.3	0.0	3.3	7.1	12.3

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

While frequency gives a good indication of the more typical pressures which impact on saltmarshes, it does not inform us about the severity of the impact. As mentioned above, the SMP data included the intensity and area of the habitat affected. Using this available data, each recorded pressure within each water body was ranked in severity on a three point scale (High, Medium, Low). Pressures were ranked as “High” when there was either high or medium impact intensity over a proportionally large area. Pressures were ranked as “Low” when there was either medium or low impact intensity over a proportionally small area, while any other combinations were ranked as “Medium” (Tables 4.3-4.6). For example, disposal of industrial waste recorded as high intensity but at a localised scale (1% of total saltmarsh area) would get an overall severity of “Medium”. However, if the area impacted upon was greater, such as, 15% of the total saltmarsh area, this would get a severity rating of "High". Any pressures which rank as "High" severity are pressures which by themselves, or in combination with others, may lead to a failure to achieve the specified objectives of the WFD due to a combination of the area impacted upon by the pressure with its intensity.

Table 4.3. Percentage frequency of occurrence of sub-category pressures in water bodies within each River Basin District (RBD). Data presented are from the SMP dataset only.

Category	*River Basin District (RBDs)							
Sub-category	EA (*n*=9)	NB (*n*=3)	NW (*n*=11)	SE (*n*=12)	SH (*n*=7)	SW (*n*=15)	WE (*n*=32)	Total (*n*=89)
Pollution								
Point pollution	11.1	0.0	45.5	33.3	28.6	13.3	21.9	23.6
Other pollution	11.1	0.0	9.1	16.7	0.0	6.7	9.4	9.0
Morphology								
Erosion (anthropogenic)	11.1	0.0	9.1	33.3	0.0	20.0	28.1	20.2
Landfill, land reclamation and drying out	11.1	33.3	45.5	33.3	42.9	40.0	28.1	32.6
Other natural system modifications	0.0	0.0	0.0	0.0	42.9	6.7	0.0	4.5
Other urbanisation, industrial & similar activities	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.1
Transportation and service corridors	88.9	0.0	45.5	75.0	57.1	40.0	75.0	62.9
Water regime								
Dykes, embankments, artificial beaches	0.0	0.0	9.1	8.3	0.0	6.7	21.9	11.2
Modifications to hydrological functioning	11.1	0.0	18.2	25.0	57.1	0.0	6.3	13.5
Biology								
Biological resource use other than agriculture	0.0	0.0	0.0	33.3	0.0	0.0	0.0	4.5
Grazing	22.2	0.0	90.9	66.7	85.7	66.7	87.5	71.9
Invasive (non-native) species	77.8	100.0	27.3	83.3	57.1	33.3	0.0	36.0
Other								
Land management	0.0	0.0	9.1	8.3	0.0	0.0	3.1	3.4
Other agricultural activities	0.0	0.0	9.1	8.3	0.0	6.7	3.1	4.5
Outdoor sports, recreational activities & structures	55.6	0.0	45.5	8.3	0.0	13.3	9.4	18.0

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

Transportation and service corridors (62.9%), and grazing (71.9%), were the most frequently recorded pressures from the SMP dataset (Table 4.3). By examining severity, it can be seen that grazing is a significant pressure, with it ranked as "High" for 30.3% of water bodies (Table 4.4). Contrary to this, only 1.1% of water bodies were assessed as having transportation and service corridors as a pressure with a severity ranking of "High". This highlights the fact, that although a pressure may be very frequent, the actual impact of the pressure may not be significant for the majority of cases where it occurs.

Of the pressures assessed as having a "High" severity impact (Table 4.4), the water bodies within the Western RBD had the highest frequency of grazing (56.3%), those within the Eastern RBD had the highest frequency of invasive (non-native) species (22.2%) and water bodies within the South Western RBD had the highest frequency of landfill, land reclamation and drying out (13.3%). The North Western RBD water bodies also had a high incidence of grazing with "High" severity (36.4%). The South Eastern RBD water bodies were the only ones which had other pollution, erosion (anthropogenic) and other agricultural activities with "High" severity impacts (all at 8.3%), while water bodies within the Shannon RBD had the highest frequency of point pollution (14.3%). Only the Neagh Bann RBD had no pressures with "High" severity impacts. Of the five main pressure categories, all had sub-category pressures which scored within the "High" severity ranking.

Table 4.4. Percentage frequency of occurrence of “High” severity sub-category pressures in water bodies within each River Basin District (RBD). Data presented are from the SMP dataset only.

Category / Sub-category	*River Basin District (RBDs)							
	EA (*n*=9)	NB (*n*=3)	NW (*n*=11)	SE (*n*=12)	SH (*n*=7)	SW (*n*=15)	WE (*n*=32)	Total (*n*=89)
Pollution								
Point pollution	0.0	0.0	0.0	8.3	14.3	0.0	0.0	2.2
Other pollution	0.0	0.0	0.0	8.3	0.0	0.0	0.0	1.1
Morphology								
Erosion (anthropogenic)	0.0	0.0	0.0	8.3	0.0	0.0	0.0	1.1
Landfill, land reclamation and drying out	0.0	0.0	0.0	8.3	0.0	13.3	3.1	4.5
Transportation and service corridors	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.1
Water regime								
Modifications to hydrological functioning	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.1
Biology								
Grazing	11.1	0.0	36.4	0.0	14.3	20.0	56.3	30.3
Invasive (non-native) species	22.2	0.0	9.1	8.3	0.0	0.0	0.0	4.5
Other								
Other agricultural activities	0.0	0.0	0.0	8.3	0.0	0.0	0.0	1.1

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

Table 4.5. Percentage frequency of occurrence of “Medium” severity sub-category pressures in water bodies within each River Basin District (RBD). Data presented are from the SMP dataset only.

Category / Sub-category	*River Basin District (RBDs)							
	EA (*n*=9)	NB (*n*=3)	NW (*n*=11)	SE (*n*=12)	SH (*n*=7)	SW (*n*=15)	WE (*n*=32)	Total (*n*=89)
Pollution								
Point pollution	0.0	0.0	0.0	16.7	0.0	0.0	9.4	5.6
Other pollution	0.0	0.0	0.0	8.3	0.0	0.0	3.1	2.2
Morphology								
Erosion (anthropogenic)	0.0	0.0	0.0	0.0	0.0	6.7	3.1	2.2
Landfill, land reclamation and drying out	11.1	33.3	45.5	25.0	14.3	20.0	12.5	20.2
Other natural system modifications	0.0	0.0	0.0	0.0	28.6	0.0	0.0	2.2
Other urbanisation, industrial & similar activities	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.1
Transportation and service corridors	11.1	0.0	0.0	16.7	0.0	0.0	3.1	4.5
Water regime								
Dykes, embankments, artificial beaches	0.0	0.0	0.0	0.0	0.0	6.7	9.4	4.5
Modifications to hydrological functioning	11.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Biology								
Biological resource use other than agriculture	0.0	0.0	0.0	16.7	0.0	0.0	0.0	2.2
Grazing	11.1	0.0	27.3	41.7	57.1	6.7	12.5	20.2
Invasive (non-native) species	22.2	100.0	0.0	41.7	14.3	20.0	0.0	15.7
Other								
Land management	0.0	0.0	0.0	8.3	0.0	0.0	3.1	2.2
Outdoor sports, recreational activities & structures	0.0	0.0	0.0	8.3	0.0	6.7	0.0	2.2

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

Landfill, land reclamation and drying out (20.2%), grazing (20.2%) and invasive (non-native) species (15.7%) were the most frequently recorded pressures assessed with “Medium” severity (Table 4.5). All RBDs were impacted upon by landfill, land reclamation and drying out at this severity, with the highest frequency within water bodies of the North Western RBD (45.5%). Of water bodies assessed with “Medium” severity grazing, those within the Shannon and South Eastern RBDs had the highest frequencies (57.1 and

41.7% respectively). The Neagh Bann water bodies had the highest frequency of invasive (non-native) species (100%).

Many of the pressures recorded in the SMP have been recorded at all three severity rankings (Tables 4.4-4.6), but of all the negative pressures recorded (Table 4.3), grazing was the only one which was most frequently recorded at "High" severity ranking (Table 4.4). Landfill, land reclamation and drying out was the only pressure which was most frequently recorded at "Medium" severity ranking (Table 4.5). All other pressures were most frequently recorded at "Low" severity ranking (Table 4.6), or had equal frequency within the "Low" and "Medium" severity rankings.

Table 4.6. Percentage frequency of occurrence of "Low" severity sub-category pressures in water bodies within each River Basin District (RBD). Data presented are from the SMP dataset only.

Category Sub-category	*River Basin District (RBDs) EA (*n*=9)	NB (*n*=3)	NW (*n*=11)	SE (*n*=12)	SH (*n*=7)	SW (*n*=15)	WE (*n*=32)	Total (*n*=89)
Pollution								
Point pollution	11.1	0.0	36.4	8.3	14.3	13.3	12.5	14.6
Other pollution	11.1	0.0	9.1	0.0	0.0	6.7	6.3	5.6
Morphology								
Erosion (anthropogenic)	11.1	0.0	9.1	25.0	0.0	13.3	25.0	16.9
Landfill, land reclamation and drying out	0.0	0.0	0.0	0.0	28.6	6.7	12.5	7.9
Other natural system modifications	0.0	0.0	0.0	0.0	14.3	6.7	0.0	2.2
Transportation and service corridors	77.8	0.0	45.5	58.3	57.1	40.0	68.8	57.3
Water regime								
Dykes, embankments, artificial beaches	0.0	0.0	9.1	8.3	0.0	0.0	12.5	6.7
Modifications to hydrological functioning	0.0	0.0	18.2	25.0	57.1	0.0	3.1	11.2
Biology								
Biological resource use other than agriculture	0.0	0.0	0.0	16.7	0.0	0.0	0.0	2.2
Grazing	0.0	0.0	27.3	25.0	14.3	40.0	18.8	21.3
Invasive (non-native) species	33.3	0.0	18.2	33.3	42.9	13.3	0.0	15.7
Other								
Land management	0.0	0.0	9.1	0.0	0.0	0.0	0.0	1.1
Other agricultural activities	0.0	0.0	9.1	0.0	0.0	6.7	3.1	3.4
Outdoor sports, recreational activities & structures	55.6	0.0	45.5	0.0	0.0	6.7	9.4	15.7

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

The majority of records for negative pressures depend on visual identification of the pressure (or the impact) in any given area on any given day. The presence of the pressure, and the area and intensity of the impact could therefore be overestimated or underestimated. While keeping these limitations in mind, significant pressures impacting on saltmarshes can still be identified by focusing on those pressures with a "High" severity either within a RBD or over all the RBDs (Table 4.4), and to a lesser extent, those pressures with a "Medium" severity (Table 4.5). These include: grazing, invasive (non-native) species, pollution (point and other), landfill, land reclamation and drying out, erosion (anthropogenic), modifications to hydrological functioning, transportation and service corridors and other agricultural activities.

Pressures listed in the EPA risk assessments (EPA, 2005) as either "1a: At risk" or "1b: Probably at risk" represent three of the five main pressure categories: pollution, morphology and water regime (Table 4.7). Similar to the analysis of SMP data, pollution, landfill, land reclamation and drying out, and modifications to hydrological functioning are identified as significant pressures. In addition to these pressures, other natural system modifications, other urbanisation, industrial and similar activities, and dykes, embankments and artificial beaches were also identified as issues.

Table 4.7. Percentage frequency of occurrence of sub-category pressures in water bodies within each River Basin District (RBD). Pressures were assessed as either "1a: At risk" or "1b: Probably at risk". Data presented are from EPA risk assessments only.

Category	*River Basin District (RBDs)															
	EA		NB		NW		SE		SH		SW		WE		Total	
Sub-category	1a	1b	1a	1b	1a	1b	1a	1b	1a	1b	1a	1b	1a	1b	1a	1b
	(*n* = 12)		(*n* = 8)		(*n* = 8)		(*n* = 12)		(*n* = 11)		(*n* = 23)		(*n* = 19)		(*n* = 93)	
Pollution																
Eutrophication	8	17	13	0	13	25	25	8	18	18	35	0	0	5	17	9
Other pollution	0	8	0	13	0	0	0	17	0	9	4	9	0	5	1	9
Point pollution	42	50	0	25	0	25	17	25	27	45	9	57	5	42	14	42
Morphology																
Landfill, land reclamation and drying out	8	0	0	0	0	0	0	8	9	0	0	4	0	0	2	2
Other natural system modifications	17	25	25	13	0	0	8	25	0	9	4	22	5	26	8	19
Other urbanisation, industrial & similar activities	25	0	13	0	13	0	17	0	27	0	17	9	16	5	18	3
Water regime																
Dykes, embankments, artificial beaches	25	42	0	50	0	13	0	25	27	27	0	26	0	0	6	24
Modifications to hydrological functioning	0	0	25	13	0	63	0	33	0	36	17	4	11	0	9	16

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

4.4 Descriptions of pressures acting on saltmarshes

4.4.1 Pollution

Pollution was split into three sub-category pressures: eutrophication, point pollution and other pollution. Occurrences of eutrophication comprise those water bodies recorded as eutrophic based on the data of O'Boyle *et al.* (2010) and also those water bodies which had either OSPAR Comprehensive Procedures or UWWT Regulation Designations as described under the MDI assessment in EPA (2005). Point pollution relates to discharges (disposal of various types of waste, urban, household or industrial), Waste Water Treatment Plants (WWTP), Water Treatment Plants (WTP), sewer and treatment plant overflows, Integrated Pollution Prevention and Control (IPPC) industries and Section 4s (Local Authority licenced discharges), while other pollution includes less defined sources of pollution as recorded in the SMP and also hazardous substances as recorded in EPA (2005). It is important to note that many of the point pollution pressures could also be sources of nutrient loads, resulting in eutrophication, however, as they were separated in the data provided (EPA, 2005), they were kept separate in this report too. The majority of records for pollution (particularly discharges) depend on visual identification of the impact in any given area on any given day.

Eutrophication (nutrient and organic enrichment) from diffuse agricultural sources and municipal sewage systems is a major concern in the tidal waters environment (O'Boyle *et al.,* 2010). Eutrophication of TraC water bodies can result in the rapid growth of green algae (Boorman, 2003; Adnitt *et al.,* 2007), which can smother the germination and growth of pioneer saltmarsh species (Boorman, 2003), thereby reducing diversity within the saltmarsh (Adnitt *et al.*, 2007). Additionally, agricultural run-off is likely to impact on the upper saltmarsh zones, with decreasing effects as it moves down through the saltmarsh. A dominance of *Agrostis stolonifera* has been hypothesized as a good indicator of eutrophication (Cilian Roden, pers. comm.).

Pollutants from agricultural and industrial chemicals, as well as those from oil spills should also be considered. Agricultural chemicals tend to occur at low levels and impacts are therefore hard to assess, however industrial chemicals (e.g. tributyltin (TBT) and Irgarol) have been shown to impact negatively on the growth of some saltmarsh species (Boorman, 2003; Adnitt *et al.,* 2007). Small oil spills, particularly in estuaries, occur on a regular basis, with impacts on saltmarsh species varying greatly depending on the species sensitivity to the effects of oil. An indirect impact from oil spills, particularly those of a larger scale, involves damage to the saltmarsh through cleaning operations (Boorman, 2003).

As pollution can negatively impact on angiosperm abundance and taxa diversity, pollution must be considered a significant pressure on saltmarshes. Based on current data it is noted that not all types of pollution are wide scale or frequent events. Currently, sampling for eutrophication is at a water body level, rather than at a saltmarsh level. The impacts of pollution may not have obvious implications for saltmarsh viability for a number of years until after a pollution event. As saltmarshes are thought to act as significant sinks for pollutants, erosion and resulting re-circulation of sediments and re-suspension of toxic substances is a cause for long-term concern for water quality (Adnitt *et al.*, 2007).

4.4.2 Morphology and water regime

Under the main pressure category morphology are grouped: landfill, land reclamation and drying out; transportation and service corridors; other urbanisation, industrial and similar activities; other natural system modifications and erosion when caused by anthropogenic activities. Dykes, embankments and artificial beaches, and modifications to hydrological functioning are grouped under the main pressure category water regime. Many pressures linked to water regime could also be grouped under morphology, and *vice versa,* due to both being inherently linked therefore they are dealt with together here. Morphological alterations usually result in a loss of saltmarsh extent, often permanently, and they often impact on the natural flooding dynamics of saltmarshes too.

In the past, coastal defences, such as sea walls, were built to exclude the sea from saltmarshes in order to utilise the land for agricultural or development purposes, in other words, for land reclamation. Where this was successful, it caused loss of extent of saltmarsh habitat. Now, the role of sea walls is one of coastal defence and the sea walls tend to be much larger and higher (Boorman, 2003). The presence of these walls and other ‘hard’ engineering, coastal defences can lead to coastal squeeze of saltmarshes, an issue which is likely to be more serious when combined with the predicted increases in sea level and storm activity caused by climate change (Farrell, 2009; Fealy and Murphy, 2009). Coastal squeeze would lead to a further decrease in saltmarsh extent. An additional impact caused by the presence of coastal defences is the damage they cause to the saltmarsh during construction and also during maintenance works (Adnitt *et al.*, 2007).

Transportation and service corridor pressures include the impacts from pipe and electricity lines, roads, bridges or viaducts, paths and tracks, and ports. Paths and tracks were recorded frequently during the SMP, but these tended to be of low intensity with very small areas of saltmarsh impacted upon. Electricity lines and roads were also of low intensity and neither was frequently recorded as having a negative impact on saltmarshes during the SMP. Roads, as hard barriers, may become more of a significant pressure in the future, as their presence prevents natural landward retreat of saltmarshes (McCorry and Ryle, 2009a), which could lead to coastal squeeze. There is one instance of a port recorded during the SMP with negative impacts at a medium intensity, similarly there are only a few instances of pipe lines and bridges or viaducts with associated negative impacts and intensities of medium or high (McCorry and Ryle, 2009a). The construction of ports, bridges or viaducts and the installation of pipe lines can cause damage to the surface of the saltmarsh, as well as disturbance to sediment dynamics, both of which can impact on the extent of the saltmarsh. Coastal construction works are therefore considered a significant pressure on Irish saltmarshes, however it is expected that occurrence of this pressure will be infrequent and localised based on available data. Most construction works occurred prior to 1995, which was the lower cut-off date for recording pressures by the SMP (McCorry and Ryle, 2009a).

Dredging (included under other natural system modifications) and channel alterations (included under modification to hydrological functioning) can cause a net movement of sediment from the intertidal area into the dredged areas due to slumping and increased wave erosion over the steepened edges of the channel (Adnitt *et al.,* 2007). Dredging can also lead to a reduction or permanent loss of sediment from the system if the dredged material is disposed at sea (Adnitt *et al.*, 2007). Alternatively, dredged material is sometimes dumped within the saltmarsh habitat, causing localised infilling (included under other natural system modifications). The SMP deemed that where this occurred, areas were unlikely to recover (i.e. redevelop saltmarsh vegetation) due to an increase in elevation (McCorry and Ryle, 2009a). Another impact caused by dredging is the potential for introduction of pollutants through sediment re-circulation.

Erosion of saltmarshes is another pressure which impacts on habitat extent. Saltmarshes naturally go through cycles of erosion and accretion, and in such cases erosion should not be classified as a pressure. It is only when erosion is caused by anthropogenic activities that it is classified as a pressure here. Erosion of the saltmarsh leads to a loss of extent, some of which is irreparable if there is no capacity for landward retreat (due to the presence of coastal defences or other hard barriers) (McCorry and Ryle, 2009a). The most common anthropogenic activities which can cause erosion of the saltmarsh include intensive grazing, and recreation and amenity use (see below).

Another morphological alteration which modifies hydrological functioning is the creation of drainage ditches. In the past drains were cut through saltmarshes in order to link ditches from adjacent agricultural land to the intertidal zone (McCorry and Ryle, 2009a), thus changing the physical structure of saltmarshes. Recent drainage work usually focuses on the maintenance of existing ditches, which in itself can lead to further pressures acting on the saltmarsh, such as sediment re-circulation, erosion at the edges of the ditches and disposal of dredged materials. Modification of hydrological functioning of the saltmarsh can occur through abstraction of water, or through the prevention of, or reduction in, access to saltmarsh by the sea, all of which can modify natural flows and cause changes in residence time. Changes in residence time will have knock-on implications for the vegetation of the saltmarshes.

As morphological alterations and modifications to the hydrological functioning of saltmarshes can impact negatively on habitat extent, angiosperm abundance and taxa diversity, both pressures are deemed to be significant.

4.4.3 Biology

Three sub-category pressures were grouped under this main category: grazing, invasive (non-native) species and biological resource use other than agriculture. Both grazing and invasive (non-native) species were deemed to be significant pressures and are discussed below.

Grazing can exclude or reduce the numbers of certain saltmarsh species, however other species can exploit the conditions created by grazing, such as shorter vegetation and small areas of bare soil (Boorman, 2003). Grazing impacts negatively on a saltmarsh when the intensity is either too high (overgrazed) or too low (undergrazed or abandoned). Overgrazing leads to a decrease in plant structural diversity, which can impact negatively on invertebrate and bird diversity. It also causes poaching which damages the surface of the saltmarsh, increasing the potential for erosion (McCorry, 2007). Grazing sensitive species, such as *Atriplex portulacoides,* are eliminated and the growth of tillering grasses favoured (Adnitt *et al.,* 2007). Ungrazed or lightly grazed saltmarshes, on the other hand, can create conditions where vegetation is too dense to support high nest densities of birds (Adnitt *et al.*, 2007), as species such as *Elytrigia repens* tend to dominate these areas (McCorry, 2007). As grazing can have negative impacts on saltmarshes in terms of a reduction in angiosperm taxa diversity, and in severe cases, due to a reduction in extent (through erosion), grazing is considered a significant pressure for Irish saltmarshes.

The most common invasive (non-native) species referred to in relation to saltmarshes is *Spartina anglica*. *Spartina anglica* is mainly found on mudflats seaward of saltmarsh vegetation, but it can also be found in isolated clumps within lower saltmarsh communities. It has the potential to keep spreading at sites where it is found and form dense swards which can exclude or significantly lower the density of *Salicornia* species (McCorry, 2007). Its survival and persistence in middle and upper saltmarsh communities is generally limited (Boorman, 2003) with some *Spartina* swards in the lower marsh successfully invaded and out-competed by *Puccinellia maritima* in Britain and Holland (McCorry *et al.,* 2003). Originally this plant was perceived to have quite a detrimental effect on the conservation value of saltmarshes. More recently, views on this species have begun to change (McCorry *et al.,* 2003). There have been several cases of newly developing saltmarsh appearing where none were previously mapped and it is thought that the saltmarsh probably developed after invasion by *Spartina anglica* on the mudflats (McCorry and Ryle, 2009a). Therefore the presence of *Spartina anglica* can have indirect positive effects, indeed McCorry and Ryle (2009a) suggested that *Spartina* swards should be considered as a pioneer saltmarsh community. Accurate assessment of the impacts of *Spartina anglica* on Irish saltmarshes is not possible due to a lack of information on historical extents of both saltmarsh communities and *Spartina anglica*. About two thirds of the records of *Spartina anglica* during the SMP were deemed to have a negative effect on the saltmarsh communities, and of those over half were recorded as being of medium or high intensity. As *Spartina anglica* can reduce plant biodiversity where it is found, it is considered a pressure on Irish saltmarshes for the purposes of this report. Small areas as a proportion of the total area of saltmarsh in a water body are tolerated however due to its positive effects on saltmarsh development.

4.4.4 Other

Land management, other agricultural activities, other human intrusions, and outdoor sports, recreational activities and structures were grouped under this main pressure category. Other agricultural activities had one instance where it was ranked as a “High” severity pressure, while land management and outdoor sports, recreational activities and structures had two instances each where they ranked as “Medium” severity pressures.

Amenity use of saltmarshes includes walking, horse-riding, the use of all-terrain vehicles and scramblers, and camping (McCorry and Ryle, 2009a). The most significant impact from recreation and amenity use is the development of tracks, which can affect sward height and cause localised erosion through trampling or repeated wear and tear of the saltmarsh surface. Tracks tend not to cover large areas of saltmarsh however. The majority of amenity uses recorded during the SMP were ranked as low intensity activities impacting negatively on small areas of the saltmarsh. For this reason, the pressure of recreation and amenity use is not deemed to be a significant pressure on saltmarshes using current available data. It is important to review impacts from this pressure on a site by site basis however, as were the intensity to increase it could become a significant pressure in the future.

Land management and other agricultural activities relates to pressures such as burning, forestry and cultivation. In the majority of cases this would require land reclamation of the saltmarsh first. However, there have been recorded cases of forestry impacting on the health of adjacent saltmarsh through shading effects (McCorry and Ryle, 2009a), whilst fire could lead to additional inputs of nutrients and damage to saltmarsh vegetation which could lead to loss of sediment. This can lead to a loss of habitat extent and decrease in species diversity and therefore, where these pressures occur on a large scale, they must be deemed as significant pressures. Like coastal construction works discussed above, it is expected that occurrence of these pressures will be infrequent and localised based on available data.

5. Review of Saltmarsh Assessment Tools of Other European Union Member States

5.1 Rationale

A key action identified by the WFD is the intercalibration procedure which ensures that for each BQE in each water body type, good ecological status represents the same level of quality in each MS. Intercalibration occurs between MS in Geographical Intercalibration Groups (GIGs). For TraC waters, Ireland is in the NEA-GIG. Whilst, technically, the purpose of intercalibration is not to harmonise assessment tools themselves, just the results, in practice the need for intercalibration has driven methods development. Therefore tools used by other MS are a practical starting point in tool development.

In this chapter, saltmarsh assessment procedures in use by other members of the NEA-GIG are reviewed. Through an internet search and using contacts supplied by the EPA, documentation on the WFD assessment of saltmarshes in Belgium, Germany, Netherlands, Portugal, Spain and United Kingdom were collated. Documentation on saltmarsh assessments from Denmark, France, Sweden and Norway (which is not a MS, but is participating on a voluntary basis) were not located; it appears that these countries have made a conscious decision not to include saltmarshes within their angiosperm BQE assessments.

5.2 Belgium

The Flemish government have responsibility for the assessment of the transitional water bodies of the Scheldt basin in northern Belgium and a tool was developed by Brys *et al.* (2005). Whilst the authors looked at a number of potential metrics including isolation (habitat patch fragmentation), topographical heterogeneity, creek intertwining and temporal changes in zonation, the final assessment was based on habitat area, shape index and vegetation quality.

Habitat area was assessed by comparing current area with reference values for Maximum Ecological Potential (MEP) and Good Ecological Potential (GEP). These areal values were calculated through a combination of two approaches. The hydromorphological approach calculated the minimum width of habitat needed to achieve an optimal gradient between the bottom of the channel and the mean high water line. The functional approach calculated the area of saltmarsh needed to prevent silicon limitation and adverse shifts in the proportion of diatoms in the phytoplankton community. The details of these calculations are beyond the scope of this report. Area was assessed at the levels of the ecosystem (the whole basin), water body and site. Current extent of saltmarsh and brackish swamp vegetation in the Scheldt basin has subsequently been mapped by remote sensing (Bertels *et al.*, 2011).

A shape index (*VI* from *vormindex*) was calculated following Forman and Godron (1981) for each site from the current area (*A*) and perimeter (*P*) measurements (Equation 5.1).

$$VI = \frac{P}{2(A\pi)^{1/2}} \qquad (5.1)$$

Narrow, elongated sites that occur between rivers and dikes tended to have short, steep gradients. Broader sites have greater morphological diversity which should be reflected in plant species richness.

Vegetation quality was a weighted combination at the site level of species richness, vegetation diversity and a Floristic Quality Index (*FQI*). Vegetation diversity was calculated using the Shannon Diversity index (*H'*) which is shown in Equation 5.2, where *N* is the number of vegetation types (e.g. pioneer, herb, reed, rush, grassland, thicket, forest) present and p_i is the proportion of vegetation belonging to the *i*th vegetation type.

$$H' = -\sum_{i=1}^{N} p_i \ln p_i \tag{5.2}$$

The *FQI* was calculated using site species lists and Equation 5.3 where *CC* is the coefficient of conservatism of species *i* and *N* is the total number of species.

$$FQI = \frac{\sum_{i=1}^{N} CC_i}{\sqrt{N}} \tag{5.3}$$

CC is a subjectively predetermined measure of rarity and ecological tolerance that varies from 0 (very general, opportunistic) to 10 (very specific, high habitat fidelity). Higher *FQI* scores represent more intact, less disturbed habitats.

After transforming raw metric scores to Ecological Quality Ratios (EQRs) the EQR for individual sites was calculated using Equations 5.4 and 5.5 where *α* is species richness.

$$EQR_{site} = \frac{(2 \times EQR_{VI}) + EQR_{veg}}{3} \tag{5.4}$$

$$EQR_{veg} = \frac{(2 \times EQR_{H'}) + EQR_{\alpha} + EQR_{FQI}}{4} \tag{5.5}$$

At the water body level, the overall EQR was determined from two parameters, the EQR for habitat area and the mean EQR_{site} for all sites within that water body. If both parameters were ranked in the same class (High, Good, Moderate, Poor or Bad) the average of the two was calculated, otherwise the lower parameter score was used.

5.3 Germany – North Sea

Adolph and Arens (2011) report on the current methods used to assess saltmarshes, brackish marshes and reed beds in the transitional and coastal waters of Lower Saxony, with additional details given in Arens (2009). The transitional water bodies of the Ems and the Weser were subdivided into estuarine areas and riverine areas. For coastal waters and the estuarine areas of transitional waters two metrics were employed: saltmarsh and brackish marshes area, and vegetation zonation.

Saltmarsh and brackish marshes area was assessed by comparing current habitat extent (excluding the pioneer zone) with a reference value relating to the historical situation of 1860 as derived from maps. This date was chosen as most diking (embankment construction) had occurred by this time and the authors did not believe the previous situation could ever be restored. Equation 5.6 shows how this reference value was calculated, where *HFL* is the historical foreland, *HWB* is the historical water body and *CuWB* is the current water body. Foreland refers to flooded area in front of any dikes.

$$Area_{REF} = \frac{Area_{HFL}}{Area_{HWB}} \times Area_{CuWB} \quad (5.6)$$

Balanced vegetation zonation was regarded as indicative of an undisturbed cycle of sedimentation and erosion. It was assessed by scoring the percentage area of four zones (pioneer zone, low saltmarsh, high saltmarsh and brackish marsh) in relation to the foreland area. Two points were scored for each zone whose percentage area was within a range regarded as near-natural and one point was scored where there were minor deviations. The ranges were determined by expert judgement due to the lack of historical information. Brackish marsh was given reduced weighting in coastal waters.

For the riverine areas of the transitional water bodies, four metrics were used: foreland area, area of near-natural biotope types, width of reeds, and species and structure of reeds.

The assessment of foreland area was calculated in a similar way to that for coastal waters and estuarine areas (Equation 5.6). For the Ems, historical information from 1897 was used, but as the current area of foreland (in 2007-2008) exceeded $Area_{REF}$, $Area_{REF}$ was changed to the current area.

The area of near-natural biotope types was assessed by calculating the proportion of the area of foreland composed of the following five habitat types: natural vegetation of the shores (reeds, pioneer vegetation of the shores), species-rich extensive grassland of moderately humid to moderately dry habitats, species-rich moist and wet grasslands, species-rich sward, and saltwort mudflats and saltmarsh. The reference value was set as 100%.

Reed beds are important to fauna, purify water, stabilize shorelines and take in nutrients and pollutants. Broader reed beds are of higher ecological status. Five width classes were defined by experts, relating to High, Good, Moderate, Poor and Bad status. The definition of these width classes was river-specific. An index of width of reeds (here denoted *RW*) was calculated as shown in Equation 5.7, where $Shore_i$ is the total length of shore assigned to width class *i*, $Shore_t$ is the total length of shore and W_i is the weighting given to width class *i,* with weighting varying from 5 for High to 1 for Bad.

$$RW = \sum_{i=1}^{5} \frac{Shore_i}{Shore_t} \times W_i \quad (5.7)$$

The species and structure of reeds metric used a tool called the “Standorttypeindex-Makrophyten” (STI_M) developed by Stiller (2005a; 2005b; 2007; 2008) (Equation 5.8) who has applied it on the Elbe. The factor Bs_{ges} is a measure of population structure of the intertidal and sub-tidal, the factor *Bs* is a measure of the population structure of the intertidal, K_{DA} is the assessment value of an ecological category and *nK* is the number of ecological categories.

$$STI_M = Bs_{ges} \times Bs \times \frac{\sum_{i=1}^{nK} K_{DA_i}}{nK} \quad (5.8)$$

The factor *Bs* represents a four point nominal scale (0.25, 0.50, 0.75 and 1.00) and is composed of three components (extent, vegetation zonation, vitality) each of which is scored subjectively from 1 to 3. Extent is a measure of the width of the reedbeds or reedbeds and *Salicornia* zone. Vegetation zonation compares the completeness of zonation and the occurrence of species indicative of each zone to a reference condition; reference conditions for High and Good ecological status were derived from the historical situation before 1900/1920 and during 1948-1951 respectively. Vitality assesses the health of vegetation, the occurrence of gaps and the uniformity of the transition to open water. The factor Bs_{ges} takes the value of 1.00 when there are submergent and emergent macrophytes and a value of 0.75 when submergent plants are absent.

To derive K_{DA}, the relative total cover of plants species assigned to different ecological categories was first calculated using Equation 5.9 for all i = 1, 2, 3, 4, where RC_i is the relative total cover of the ith category, N_i is the number of species in the ith category, cov_{ij} is the cover of jth species in the ith category and cov_t is the total cover of species.

$$RC_i = \frac{\sum_{j=1}^{N_i} cov_{ij}}{cov_t} \qquad (5.9)$$

The value of K_{DA} for each category was then obtained from Table 5.1. Categories 1 to 4 represent a progression from wide to narrow habitat specificity (i.e. eurytopic to stenotopic).

Table 5.1. Matrix to determine K_{DA} values for ecological categories from relative cover

	Ecological category			
RC_i	**1**	**2**	**3**	**4**
≤5%	5	6	11	16
>5 ≤10%	4	7	12	17
>10 ≤25%	3	8	13	18
>25 ≤50%	2	9	14	19
>50%	1	10	15	20

Lengths of shoreline were assigned to status classes (High, Good, Moderate, Poor and Bad) based on local STI_M values. An overall score for a water body (or subdivision) can be calculated using a similar weighting procedure to that in Equation 5.7.

To obtain an overall EQR value, Adolph and Arens (2011) combined all relevant metrics without weighting.

5.4 Germany – Baltic Sea

Some German water bodies fall within the remit of the Baltic Sea GIG rather than the NEA-GIG. Nevertheless, it was felt a review of the methods used for these areas as reported by Wanner *et al.* (2007) would also be informative. Four metrics were considered by these authors: hydromorphology, coastal marsh area, zonation and plant species composition.

The authors deviated from the strict requirements of the WFD by including an assessment of the coastal marsh hydromorphology at the site level. Officially, hydromorphology is a separate quality element that only supports the BQEs. The hydromorphology metric was assessed using three criteria: flooding dynamics (density of creeks and pans), intensity of drainage (density of ditches) and restriction of flooding (occurrence of dikes).

The coastal marsh area metric was calculated by comparing the present coastal marsh area (including saltmarsh and brackish reed beds) with the potential coastal salt marsh area. It was assessed at the water body level. The reference area was defined as the area that could be covered by coastal marshes if all anthropogenic alterations of flooding dynamics were removed (e.g. dikes and other coastal defence structures). Use of a historical reference was considered but dismissed due to lack of data for times with no anthropogenic alteration and the perforce arbitrary selection of a reference time. Also the historical approach ignores the dynamic nature of these systems over time. The limit of the potential flooding area was defined as 1 m above sea level. The area was generated using digital terrain models.

Only two vegetation zones were distinguished for the purposes of assessing zonation, a pioneer zone and a lower and upper coastal marsh zone. This is because the concepts of cyclic sedimentation and erosion processes that govern zonation on, for example, Dutch saltmarshes cannot be transferred to the non-tidal Baltic Sea coast. Rather than calculating a numerical EQR, each ecological class was defined by a description of the development of the zones and the transition to terrestrial habitats. These ranged from no zones for Bad through to two completely developed zones with gradual transition for High. A second descriptive criterion examined the occurrence of freshwater species in the pioneer zone. The lower of the two criteria was taken. Zonation was assessed at the site level.

In assessing plant species composition, one list for the whole of the German Baltic coast was selected, rather than site-specific lists as that approach was viewed too static. A separate sub-list was made for the pioneer zone and the lower and upper coastal marsh zone. Some species were characteristic of only low salinity systems and some had restricted geographic distribution.

The frequency of species was to be assessed in the field during structured walks using the DAFOR scale. Ecological status classes were essentially defined descriptively rather than by a numerical EQR. These definitions specified minimum frequency and abundance requirements for the two zones. For example, High status required “at least one species abundant, two other frequent, one other rare” in the pioneer zone and “at least two species abundant, three other frequent, two other occasional” in the main zone. A second criterion based on total percentage species cover was tentatively proposed. Species composition was assessed at the site level.

Water bodies were only considered for assessment if coastal marsh comprised at least 250 ha or at least 10% of the combined area of water and potential coastal marsh area. The potential impact of marshes on the ecological quality of other water bodies was not deemed relevant. Site results were combined by weighting by percentage of area. Hydromorphology, area and vegetation quality (zonation and species composition combined) were given equal weighting in combining the results at the water body level.

5.5 Netherlands

The Dutch assessment procedure is presented in Dijkema *et al.* (2005). It comprises just two metrics: condition acreage (area) and condition quality (zonation). As saltmarshes support a limited number of species and these species define the zones, species were not assessed separately.

In assessing condition area, the authors defined Potential Reference Condition (P-REF) and Potential Good Ecological Status (P-GES) on a case by case basis for each water body. These values formed the lower threshold for the High and Good ecological classes. The term 'potential' is used as restoration of the unquantifiable natural reference conditions (i.e. before any embankments) is deemed unobtainable. A series of historical maps was used to assist in defining P-REF. P-GES was based on P-REF but with a minimum area of 500 ha. For some water bodies, the thresholds comprised numbers of locations rather than area. Class boundaries for Moderate, Poor and Bad were simply defined as percentages of P-GES. Current extent within each water body was assessed against these thresholds.

In assessing condition quality, five zones were considered: pioneer, low, middle, high and brackish. The brackish zone was not required for some water bodies. Each zone scored a point if it fell between the range of 5-35% of the area within the water body (or 5-40% for water bodies not requiring the brackish zone). In addition, for all water bodies, the area of *Elymus* (presumedly *E. atherica*) was assessed and a point was scored if the *Elymus*-dominated area was at maximum the same area as the high zone. At one water body a point was scored if the area of reed beds did not exceed the area of the brackish zone. Hence, the P-REF was set at between five and seven points for each water body. Classes were defined simply by the number of points scored, rather than as a proportion of the P-REF (i.e. no EQR was scored).

5.6 Portugal

Caçador *et al.* (2013) developed an Angiosperm Quality Assessment Index (AQuA-Index) for Portuguese saltmarshes in transitional waters (estuaries and coastal lagoons). A number of possible metrics were tested. These included several ecological diversity indices: Shannon Diversity (*H'*), Maximum Shannon Diversity (H'_{max}), Simpson Diversity (*D*), Species Richness (*S*), Pielou Evenness (*J*), Margalef Diversity and Menhinick. Also tested as possible metrics were the relative percentage cover of primary pioneer species (*Spartina maritima*, *Scirpus maritimus* and *Juncus maritimus*) and secondary pioneer species (*Aster tripolium*, *Salicornia nitens* and *Puccinellia maritima*). The impact of exotic species was evaluated through the relative coverage of *Phragmites australis*, *Juncus holoschoenus* and *Cistanche phelypaea*.

Data were collected by recording species abundance along several transects within each saltmarsh. Aerial photograph interpretation then appears to have been used to extrapolate the total area covered by each species.

Potential variables were assessed by performing a Principal Component Analysis (PCA) and selecting the five variables with the highest weighting factors for the axis with the highest percentage of explained variance. Thus the PCA-based index (representing the EQR) was defined as shown in Equation 5.10, where n is the number of variables (here n = 5), W_i is the PCA weighting factor of the ith variable and E_i is the respective score of that ith variable.

$$AquA - Tool = \sum_{i=1}^{n} W_i E_i \tag{5.10}$$

Scores (E_i) were normalised using a sigmoidal equation limited from 1 to 0 (Equation 5.11), where a is the maximum score of the variable, x is the value of the variable, x_O is the average value of the variable and b is the value of the slope of the equation (here b = -2.5 was used).

$$E = \frac{a}{1 + (x/x_O)^b} \tag{5.11}$$

The five variables selected for integration were Species Richness, Shannon Diversity (Equation 5.2), Maximum Shannon Diversity (Equation 5.12, where *S* is total number of species), Pielou Evenness (Equation 5.13) and Margalef Diversity (Equation 5.14, where *S* is again the total number of species and *N* is the number of individuals). The application of this last index to the vegetation data is unclear.

$$H'_{max} = \log S \tag{5.12}$$

$$J' = \frac{H'}{H'_{max}} \tag{5.13}$$

$$D_{MG} = \frac{S - 1}{\ln N} \tag{5.14}$$

5.7 Spain

García *et al.* (2009) developed an Angiosperm Quality Index (*AQI*) for evaluating the status of the transitional waters of the Cantabrian estuaries. This is an integrated assessment for both the WFD and the HD and thus is broader in its scope than just saltmarshes. The AQI for a water body was based on three parameters: diversity of estuarine habitats; relative deviations from optimal coverage; variations in the surface area of natural tidal habitats. Coverage in this context means the proportion of area actually covered by angiosperms (i.e. vegetation density).

Diversity of estuarine habitats was quantified using the Gini-Simpson index (I_G) as shown in Equation 5.15. The quantity *k* is the number of habitats and p_i is the proportion of all habitat patches belonging to the *i*th habitat.

$$I_G = 1 - \sum_{i=1}^{k} {p_i}^2 \tag{5.15}$$

For the relative deviation from the optimal coverage the mean coverage of each habitat was first calculated as shown in Equation 5.16 (a minor correction has been made to the equation presented by the authors) for all *i* = 1, …, *k*. The quantities $area_i$ and N_i are the area and number of patches of the *i*th habitat respectively. The quantities $area_{ij}$ and cov_{ij} are respectively the area and coverage of the *j*th patch of the *i*th habitat.

$$\overline{cov_i} = \frac{\sum_{j=1}^{N_i} area_{ij} \times cov_{ij}}{area_i} \tag{5.16}$$

The relative deviation in coverage of each habitat is then calculated using Equation 5.17 for all *i* = 1, …, *k*. The quantity Opt_i is the predetermined value for optimal coverage of the *i*th habitat in pristine conditions. Where $Icov_i$ exceeded 1 it was truncated to 1.

$$Icov_i = \frac{\overline{cov_i}}{Opt_i} \tag{5.17}$$

The final coverage index is computed by averaging the relative deviances over all habitats as shown in Equation 5.18.

$$I_C = \frac{\sum_{i=1}^{k} Icov_i}{k} \tag{5.18}$$

Variation in the surface area of natural tidal habitats (e.g. mudflats, saltmarshes, dunes, beaches, woodland) was calculated as shown in Equation 5.19, where S_A is the area currently occupied by all the natural habitats together and S_T is the total area of the estuary (i.e. transitional water body).

$$I_V = \frac{S_A}{S_T} \tag{5.19}$$

These three metrics were combined by computing the geometric mean (Equation 5.20) rather than the arithmetic mean as they are multiplicative rather than additive (i.e. they are interrelated).

$$AQI = ((1 + I_G)(1 + I_C)(1 + I_V))^{1/3} - 1 \tag{5.20}$$

5.8 United Kingdom

The most recent UK assessment tool (UKTAG 2013) is a multimetric index with six components. Early development of the tool is described by Best *et al.* (2007). The six components are:

- saltmarsh extent as a proportion of "historic saltmarsh"
- saltmarsh extent as a proportion of the intertidal
- recent change in saltmarsh area (measured over six year periods)
- number of saltmarsh zones present
- proportion of saltmarsh area covered by the dominant saltmarsh zone
- proportion of observed taxa to historical reference value or proportion of observed taxa to standard checklist

The reference conditions for historic saltmarsh area (SMAh) are based on interpretation of historical maps (1843-1893) and an estimate of land claim using the HAT and LiDaR (Light Detection and Ranging) data. To allow for natural variation and cyclical processes the lower boundary for High status is set at 80% of the reference condition.

UKTAG (2013) states the proportion of current saltmarsh relative to the intertidal (SMAi) is based on suggestions that the habitat should cover 25-50% of the suitable intertidal. These figures have been interpreted as the minimum area that should be covered rather than an optimal range as the High / Good Boundary has been set as 50% with the reference condition as 100%.

The metric concerning recent change in saltmarsh area (ΔSMA) compares current extent with reference conditions defined by reliable previous measurements. Whilst it is stated that there is 20% natural variability in saltmarsh extent the High / Good boundary has been set at 10% loss.

Five zones are defined for purposes of the zonation metrics:

- pioneer (with *Salicornia* etc.)
- *Spartina*-dominated marsh
- mid-low (with *Atriplex* [*portulacoides*] and *Puccinellia* [*maritima*])
- high (with *Festuca rubra*, *Elytrigia* [*atherica* or *repens*], *Bolboschoenus* and *Juncus* [*maritimus*])
- brackish reed beds (*Phragmites*)

The reference value for the number of zones present metric (Zn/N) is five for England and Wales but fewer distinct zones may be expected in Scotland and Northern Ireland where saltmarshes tend to be smaller, for example, the average size of site in Northern Ireland is only 15.9 ha (Boorman 2003). The reference value for the proportion of the area covered by the dominant zone metric (ZnMax) is 20% for England and Wales (i.e. all five zones equally represented), with a High / Good boundary of 40%.

The final component, diversity of saltmarsh taxa, uses one of two reference values. A historical reference list based on data from 1971 to 2009 is used where reliable data for a water body exist (metric T_h). Otherwise, a reference value of 15 saltmarsh species is used (metric T_{15}), this figure being about half the number of taxa on a standard checklist.

In combining the metrics, greater weighting (x1.5) was applied to ΔSMA and lesser weighting (x0.5) was applied to SMAi and ZnMax.

5.9 Discussion

Evidently, there is considerable variation in the tools developed by the different MS (summarised in Table 5.2). Many of the methods have a broader scope than just saltmarshes *sensu stricto* and in particular brackish reed beds are a common inclusion. We partition the various metrics used here in terms of the concepts of abundance (habitat extent), composition (zonation) and disturbance sensitive taxa (species diversity) and discuss their applicability in an Irish context.

Area was assessed by six of the seven assessment procedures but there was variation in determining the reference values. Strictly, WFD area reference values should represent undisturbed conditions (i.e. saltmarsh on coastlines with no embankments). GIS modelling of potentially flooded areas behind embankments can be used to approximately define this unmodified coastline. Restoration of such conditions has been rejected as impractical by several MS, but in light of predicted sea levels rises large-scale remodelling of coastlines to improve or create sustainable sea defences may be an increasingly viable option.

Historical maps can be used to estimate habitat extent in the past, but as these typically post-date periods of major embankment it is questionable how much relevance the figures derived from these maps have to good ecological status of the water body. Historical Ordnance Survey (OS) maps exist for Ireland from the 1830s onwards and do delimit areas covered by spring tides or liable to flooding. Areas of reclaimed land can also be identified by the presences of sluices and grid-like field systems.

Table 5.2. Summary of metrics in saltmarsh assessment tools developed by different Member States

Member State		Abundance (habitat extent)	Composition (zonation)	Disturbance sensitive taxa (taxa diversity)
Belgium		i) Extent compared with reference values derived from hydromorphological and functional modelling ii) Site shape index	Diversity of vegetation types using Shannon Diversity index.	i) Species richness ii) Floristic Quality Index
Germany (North Sea)	Coastal & estuarine	Extent as % of water body compared with historical reference value	Number of 4 zones present comprising appropriate % of extent	No metric
	Riverine	i) Extent as % of water body compared with historical reference value ii) Width of reed beds (assessed twice) iii) Area of near natural habitats	i) Vegetation zonation and vitality ii) Presence of submerged plants	Proportion of stenotopic and eurytopic species
Germany (Baltic Sea)		Extent as % of potential saltmarsh area	i) Presence and distinctiveness of 2 zones (pioneer and main saltmarsh) ii) Occurrence of freshwater indicators in pioneer zone	i) Zone specific checklist with DAFOR criteria ii) Cover of checklist species
Netherlands		Extent as % of potential reference condition informed by historical extent	i) Proportion of each of 4 or 5 zones is 5-40% or 5-35% ii) Cover of *Phragmites* and *Elytrigia* areas relative to other zones	No metric
Spain (TWBs only)		i) % of estuary occupied by all natural habitats ii) Density of vegetation as % of optimal coverage	Diversity of estuarine habitats using Gini-Simpson index and patch frequency	No metric
Portugal (TWBs only)		No metric	No metric	Weighted combination of diversity and evenness indices applied to extrapolated extent of halophytes from checklist
United Kingdom		i) Extent as % of historical/modelled extent ii) Extent as % of intertidal iii) Change in extent over time	i) Number of 5 zones present ii) Proportion of dominant zone	i) Proportion of historical site checklist ii) Proportion of halophyte checklist (15 species required)

Ideally, reference values would be based on the modelling of functional data (as demonstrated by Brys *et al.*, 2005); what minimum extent of saltmarsh do we need for it to provide the required ecosystem services? However, this is likely to be a complex approach, and, currently, collecting the required monitoring data on regular basis may not be practical.

A novel approach of the UK is the use of the area of the intertidal as a “surrogate for the area available for saltmarsh growth” (UKTAG, 2013). However, there may be issues with this approach. Firstly, this metric appears to refer to the mean intertidal rather than the astronomical intertidal. In Ireland at least, the majority of the saltmarsh habitat (62.3% as mapped by the SMP and the subsequent desktop survey) occurs above the mean high water line. Indeed, it was guidance that the upper limit of WFD water bodies be defined by

HAT (EC, 2003b) that resulted in the inclusion of saltmarsh within the WFD assessment. However, to map the HAT, high resolution digital terrain maps such as produced from LiDaR data are required and current LiDaR coverage of the Irish coastline is patchy. Secondly, regardless of which intertidal (mean or astronomical) is used, a substantial proportion will naturally be mudflat rather than saltmarsh, so a reference value of 100% would appear to be unobtainable. The UK tool also looks at recent change in saltmarsh extent. As the SMP represents a baseline map of the habitat in Ireland, data are not available for this approach currently. Mapping data collected during the next round of monitoring will permit comparisons with the SMP baseline mapping enabling recent change in saltmarsh extent to become a tool metric at that stage.

Zonation was also assessed by six of the seven assessment procedures. Of these, two used a diversity index and three considered the relative proportions of each zone within the saltmarsh. The use of diversity indices offers a simple and accepted approach, but does not allow for zone-specific caveats. Maximum proportion thresholds ensure that no one zone dominates within the saltmarsh. Incorporating minimum proportion thresholds also appears logical to prevent zones from scoring when they represent only insignificant areas. As discussed in chapters 3 and 6, fringing marsh, *Spartina* swards, *Elytrigia* swards and swamps may need special rulings.

Only five of the seven assessment procedures used metrics relating to taxa diversity. Assessment of disturbance sensitive taxa has been tackled by both Belgium and Germany by using a measure of stenotopism of the total vegetation based on a pre-determined categorisation of species. No categorisation of plant species in this regard exists for Ireland. However, in the context of saltmarshes, all halophytes could be regarded as stenotopic and therefore disturbance sensitive. Thus a metric based on a checklist of Irish halophytes similar to that of the UK would be appropriate. However, due to the lack of historical data, the large number of Irish water bodies and the dynamic nature of saltmarshes, site- or water body-specific lists are probably impractical so a single national checklist would be needed. Furthermore, following the German approach for the Baltic Sea, some minimum degree of frequency within typical zones should be used to ensure that species are only scored when they are significantly represented.

The Portuguese approach combines a number of diversity measures including the Shannon Diversity index, the continued use of which Magurran (2004) questions. A single, justified measure may provide a metric that is more intuitively meaningful.

6. Development of the Irish Saltmarsh Assessment Tool

6.1 Rationale

The normative definitions for ecological status classifications for angiosperms in TraC water bodies (Annex V, sections 1.2.3 and 1.2.4 of the WFD respectively) are outlined in Table 1.1. From this it can be seen that three key elements are used to classify the ecological status of the angiosperm BQE for TraC waters: taxonomic composition, angiosperm abundance and disturbance sensitive taxa. In the context of assessing saltmarsh[3] within the angiosperm BQE, we have taken these three key elements to roughly translate as saltmarsh zonation (taxonomic composition), saltmarsh extent (angiosperm abundance) and presence of halophytes (disturbance-sensitive taxa), which is similar to the UK's approach (UKTAG, 2013).

SMAATIE is composed of the following five metrics, designed to measure and assess these key elements:

i. Saltmarsh extent as a proportion of the reference area ($Area_{ref}$) (angiosperm abundance)
ii. Proportion of saltmarsh zones present (taxonomic composition)
iii. Proportion of saltmarsh area covered by the dominant saltmarsh zone (taxonomic composition)
iv. Proportion of saltmarsh composed of *Spartina* (taxonomic composition)
v. Proportion of observed taxa to 15 taxa (disturbance-sensitive taxa)

These metrics have been designed to utilise currently available data, mainly those collected by the SMP. Consideration will be given later to how these metrics could be modified in light of recommendations for the collection of monitoring data in the future.

6.2 Angiosperm abundance

Angiosperm abundance (i.e. abundance of saltmarsh vegetation) is essentially a measure of the extent of saltmarsh habitat. After assessment of metrics of other MS for this element, we decided to follow the method proposed by Wanner *et al.* (2007).

Metric (i): Saltmarsh extent as a proportion of the reference area ($Area_{ref}$)

The reference value for this metric is set at the total area that would be expected to be covered by saltmarsh if anthropogenic activities and alterations which impact on flooding dynamics (e.g. embankments) were removed ($Area_{ref}$). $Area_{ref}$ (Equation 6.1) comprises current extent ($Area_{current}$) and "Potential Saltmarsh Area" ($Area_{PSA}$).

$$Area_{ref} = (Area_{current} \times 1.0) + (Area_{PSA} \times 0.75) \quad (6.1)$$

$Area_{PSA}$ includes areas suitable for saltmarsh development based on interpretation of historical maps (third edition[4] Ordnance Survey six inch maps) as follows:

[3] Brackish and tidal-freshwater swamps also fall within the remit of the tool. Hereafter the inclusion of these habitats should be implicit when the term 'saltmarsh' is used, unless otherwise stated.
[4] The set of digital OS maps referred to here as the third edition is in fact an amalgam of sheets from the second and third editions and sheets from later revisions. No complete set of maps exists for any edition except the first. Sheets within this amalgam could date from as early as 1848 to as late as 1957 depending upon the county. There is no metadata with the digital maps which are clipped of the margins in which the year of production would have been marked (R. Ovington, pers. comm.). It would be necessary to access the original paper maps to obtain the date for each digital sheet.

- areas marked with "Covered by spring tides"
- areas marked with "Saltmarsh" or "Saltings"
- areas marked with "Liable to Floods" when closely adjacent to coastal or transitional water bodies
- areas marked with marsh or swamp symbology when closely adjacent to coastal or transitional water bodies
- areas marked with "Intake"
- areas where representations of features relating to reclamation works, including embankments, artificial arterial drainage channels and sluices, and large uniform fields are obvious

Areas marked as creeks on the third edition six inch maps with a width of 5 m or greater were not included within $Area_{PSA}$, nor were any areas that clearly looked to be on higher ground than surrounding saltmarsh. The Ordnance Survey Discovery Series maps were referred to in order to help determine these higher areas, as was the Street View function on GoogleMaps™ where available. Dense settlements or urbanised areas were not included within $Area_{PSA}$ even if their locations would be expected to flood if coastal defences were removed as it would be extremely difficult for saltmarsh to develop on an artificial (concrete) surface. Particular consideration was given to polygons representing non-saltmarsh habitats within the SMP habitat shapefile. Where LiDaR data were available, $Area_{PSA}$ was reviewed and modified where necessary by modelling the HAT line. Refer to Section 8.3 for details of LiDaR sources and modelling methodology.

A weighting of 0.75 is applied to $Area_{PSA}$ to allow for the presence of smaller creeks and non-saltmarsh habitats, such as sandflats and mudflats, and also to allow for a certain degree of error or uncertainty in the map-derived data. This is the same downweighting adopted by the UK for their reference condition for historical saltmarsh, citing uncertainty in their datasets (UKTAG, 2013).

$Area_{current}$ comprises all saltmarsh polygons mapped within the smp_national_sm_resource_revised_GIS_ 2011 shapefile, which contains all of the saltmarsh mapped during the desktop survey for Conservation Status Assessment plus the polygons mapped and ground-truthed during the SMP fieldwork and from other projects (McCorry and Ryle, 2009a).

The index value for the angiosperm abundance metric (Ind_{Area}) is calculated by expressing current extent as a proportion of $Area_{ref}$ (Equation 6.2).

$$Ind_{Area} = \frac{Area_{current}}{Area_{ref}} \times 100 \qquad (6.2)$$

6.3 Taxonomic composition

Saltmarsh zonation, both in terms of the number and proportion of saltmarsh zones within each water body is taken to be a measure of taxonomic composition. The presence of *Spartina* within water bodies is also assessed, but as a separate metric, due to its non-native status in Ireland.

Metric (ii): Proportion of saltmarsh zones present

The reference condition for this metric is the presence of the expected number of saltmarsh zones which should occur naturally within the water body for a fully functioning saltmarsh. These zones should essentially represent the full successional sequence of a saltmarsh in "dynamic equilibrium" (Wanner *et al.*, 2007) and presence of these zones within a saltmarsh reflects the "successfulness of its ecological functioning" (UKTAG, 2013). Note that for this metric, it is the number of zones present which is important, rather than a requirement to have specific zones.

The estuary type of saltmarsh would be expected to have five zones (this is the reference value) as this type tends to have a high diversity of surfaces at different elevations due to the presence of creeks, channels and eroding surfaces; this results in a range of different vegetation types (Curtis, 2003). The five expected zones are the pioneer zone, lower marsh (Puccinellion maritimae), middle marsh (Armerion maritimae), upper marsh and other saltmarsh habitats comprising swamps and *Elytrigia* swards.

The bay and sandflat types of saltmarsh would be expected to have at least four zones. *Phragmites* swamps can be absent from these coastal types if there is no freshwater runoff or no creek system (UKTAG, 2013). If all swamp types and *Elytrigia* swards are absent from these types then the required number of zones would thus necessitate the presence of the pioneer zone, lower marsh, middle marsh and upper marsh zone.

Zonation for the lagoonal type is dependent on the nature of the shore and the tidal range within the lagoon (Healy, 2003). Reeds, sedges and rushes are usually present, but overall saltmarsh vegetation is species-poor (Healy, 2003); the reference value for this type of saltmarsh is therefore set at two of the aforementioned zones.

The fringe saltmarsh type does not follow the classic dynamic model and it is by definition comprised of narrow areas of saltmarsh. Extent of this saltmarsh type is determined by its seaward gradient (Curtis and Sheehy Skeffington, 1998). The reference value for this type is also set at two of the aforementioned zones.

Many water bodies will contain more than one type of saltmarsh. Where this occurs, we recommend that the reference value is set to the type which would be expected to contain the largest number of zones. In hierarchical terms this would be: estuary (five zones) > bay and sandflats (four zones) > lagoon and fringe (two zones). It is strongly recommended that classification of saltmarsh sites according the scheme of Curtis and Sheehy Skeffington (1998) be reviewed.

It should be stressed that the reference conditions set here are guidelines only. Surveyors in the field should ultimately decide what the reference value should be on a water body by water body basis. The pioneer zone, for example, may be missing altogether if a saltmarsh is naturally undergoing erosion and the reference value should reflect this natural state. For example, the expected number of zones for an eroding sandflat saltmarsh would be lowered from four zones to three. Similarly, some fringe saltmarsh sites may naturally have only one zone due to the seaward gradient, therefore the reference condition for these saltmarshes should be reduced from two zones to one. Note that, water bodies supporting only fringe saltmarsh comprising one zone may not contain sufficient habitat to warrant assessment under the WFD.

To apply this metric, the number of zones present within Irish TraC water bodies was calculated from the SMP datasets. Three of the five aforementioned zones were scored on the basis of areas mapped by the

SMP, with a zone only counted if it comprised a minimum percentage of the total saltmarsh area excluding any area of *Spartina* swards:

- ≥1% for 1310 *Salicornia* and other annuals colonising mud and sand (pioneer zone)
- ≥5% for 1410 Mediterranean salt meadows (Juncetalia maritima) (upper marsh)
- ≥5% for “Other saltmarsh” (brackish swamps and *Elytrigia* swards)

The HD Annex I habitat 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae) is essentially divided into two zones, representing the Puccinellion maritimae and the Armerion maritimae (lower and middle marsh). As these zones were not mapped separately during the SMP, they were scored on presence of any plots classified in Chapter 3 as classes 2 and 3 respectively.

The index value for this metric ($Ind_{\#Zones}$) is expressed as the number of zones present within the water body as a proportion of the reference value (expected number of zones) (Equation 6.3).

$$Ind_{\#Zones} = \frac{\#\ zones\ present}{Expected\ number\ of\ zones} \times 100 \qquad (6.3)$$

Metric (iii): Proportion of saltmarsh area covered by the dominant saltmarsh zone

The reference condition for this metric is that no one zone within the saltmarsh should dominate. Working from the maximum number of zones (five), with no one zone dominant over the others, the reference value for this metric is set to 20%. Dominance of any one zone suggests that the natural cycles of erosion and deposition, which are intrinsically linked to saltmarsh succession, are being impacted upon. For example, saltmarsh within Castletown Estuary is dominated by the lower marsh zone (Puccinellion maritimae). This saltmarsh has developed in front of berms which were put in place for land reclamation (McCorry and Ryle, 2009c). A proportionally inferior area of upper saltmarsh and *Elytrigia* swards can suggest coastal squeeze is occurring due to the presence of hard barriers backing the saltmarsh (Mossman *et al.,* 2013), and this also appears to be the case for saltmarsh within the Castletown Estuary. The UK’s tool has the same reference value of 20%, which they have linked to sampling noise, with the Danes also using a similar figure (Mike Best, pers. comm.).

Although the reference value is set at 20%, the lower threshold of High status is set to 50% for the largest zone. This is to allow for some natural variation between the zones, for example, as an acknowledgement that the saltmarsh may have been undergoing an erosion or deposition event at the time of survey. As discussed above, both the lagoon and fringe type of saltmarsh can exhibit poor zonation naturally. It would be unfair to assess the ecological status of water bodies containing only these saltmarsh types as less than Good in relation to the dominant saltmarsh zone. For this reason, it is recommended not to apply this metric when assessing these two saltmarsh types.

In applying this metric, the area of each zone was calculated using the saltmarsh polygons mapped within the smp_national_sm_resource_revised_GIS_2011 shapefile. As mentioned above, the lower and middle marsh zones (Puccinellion maritimae and Armerion maritimae) were mapped together as HD Annex I habitat 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae) polygons. An approximation of the area of each of these zones was calculated based on the proportion of plots within this Annex I habitat classified in Chapter 3 as classes 2 and 3 respectively. The remaining three zones were mapped separately within the smp_national_sm_resource_revised_GIS_2011 shapefile.

The index value for this metric (Ind_{ZnMax}) is expressed as the area of the largest zone as a proportion of the total saltmarsh area, excluding areas of *Spartina* swards (Equation 6.4).

$$Ind_{ZnMax} = \frac{Area\ of\ largest\ zone}{Area_{current(excl.\ Spartina)}} \times 100 \tag{6.4}$$

Metric (iv): Proportion of saltmarsh composed of *Spartina*

The reference condition for this metric is the absence of *Spartina* swards. *Spartina* is a non-native genus in Ireland which was first planted in Cork Harbour in 1925 (McCorry *et al.,* 2003). Although non-native, the presence of *Spartina* can, however, have some positive effects on saltmarsh. These include the promotion of saltmarsh development through rapid sediment accretion and the protection of seaward zones from erosion. The lower threshold for High class status is therefore set at 5% to acknowledge the potential for net positive effects of *Spartina* swards at lower abundances. The EPA's stance on invasive species is that while ideally no invasive species should be present at the reference condition, a small amount can be present with the water body still attaining high status, providing no impact on the BQEs can be observed (Robert Wilkes, EPA, pers. comm.).

The index value for this metric ($Ind_{Spartina}$) is expressed as the area of *Spartina* swards as a proportion of the total saltmarsh area (Equation 6.5). The area of *Spartina* swards comprises all *Spartina* polygons mapped within the smp_national_sm_resource_revised_GIS_2011 shapefile.

$$Ind_{Spartina} = \frac{Area\ of\ Spartina\ swards}{Area_{current}} \times 100\% \tag{6.5}$$

6.4 Disturbance sensitive taxa

The halophytic vegetation of saltmarshes is specially adapted to deal with the natural stressors of duration and frequency of inundation by the sea, therefore these species can be classified as disturbance sensitive taxa. Significant anthropogenic effects on these stressors can lead to shifts in species composition, or even loss of plant communities (Adolph and Arens, 2011).

Metric (v): Proportion of observed taxa to 15 taxa

The reference condition for this metric is the presence within saltmarsh habitat of at least 15 halophytes from Table 6.1. Relatively common halophytes are only counted if they have a frequency of at least 15% in terms of the number of plots they are present in within their characteristic vegetation classes (or communities) as defined in Chapter 3. Locally distinctive plants, on the other hand, are counted solely on their presence within the water body. The reference value of 15 taxa is approximately half the number of Irish halophyte taxa, but is otherwise arbitrarily selected.

The index value for this metric (Ind_{Taxa}) is expressed as the number of halophytes present as a proportion of the minimum requirement of 15 taxa (Equation 6.6). If Ind_{Taxa} >100 it is truncated to 100.

$$Ind_{Taxa} = \frac{No.of\ common\ taxa + No.of\ rare\ taxa}{15} \times 100 \quad (6.6)$$

Table 6.1. List of halophytes with their characteristic classes / communities. Under category, C indicates a common halophyte requiring 15% frequency to score, R indicates a rare halophyte requiring presence only to score.

Species	Characteristic class/community	Category	Species	Characteristic class/community	Category
Armeria maritima	2, 3, 4	C	*Limonium binervosum* agg.	2	C
Aster tripolium	2, 3, 4	C	*Limonium humile*	1, 2	C
Atriplex portulacoides	1, 2	C	*Oenanthe lachenalli*	4, 5	C
Atriplex prostrata	3, 5, 6	C	*Phragmites australis*	6a, 6b, 6c	C
Blysmus rufus	3	R	*Plantago coronopus*	3, 5	C
Bolboschoenus maritimus	6a, 6b, 6c	C	*Plantago maritima*	2, 3, 4	C
			Puccinellia maritima	2	C
Carex extensa	3, 4, 5	C	*Salicornia* spp.	1	C
Centaurium pulchellum	5	R	*Samolus valerandi*	4, 5, 6	C
Cochlearia spp.	2, 3, 4	C	*Sarcocornia perennis*	1, 2	R
Eleocharis uniglumis	5, 6	C	*Schoenoplectus tabernaemontani*	6a, 6b, 6c	C
Elytrigia atherica	6d	R			
Elytrigia repens	6d	C	*Seriphidium maritimum*	2, 3, 4	R
Glaux maritima	3, 4, 5	C	*Spergularia* spp.	2	C
Juncus acutus	4	R	*Suaeda maritima*	1, 2	C
Juncus gerardii	3, 4, 5	C	*Trifolium fragiferum*	5	R
Juncus maritimus	4	C	*Triglochin maritima*	2, 3, 4	C

6.5 Normalisation of index values

To allow for the combination of all indices, each index value needs to be normalised to the EQR scale (0.0-1.0, with five equidistant class divisions). The same approach used in UKTAG (2013) is applied here as shown in Equation 6.7, where Ind indicates index values, EQR indicates normalised values, Upper is the relevant upper class boundary, Lower is the relevant lower class boundary, and x is one of the five metrics (Area, #Zones, ZnMax, Spartina or Taxa).

$$EQR_x = EQR_{Upper} - \left(\left(Ind_x - Ind_{Upper} \right) \times \left(\frac{0.2}{Ind_{\ Lower} - Ind_{Upper}} \right) \right) \quad (6.7)$$

All of the values to be used in Equation 6.7 are taken from Table 6.2 with the exception of Ind_x, which is calculated for each metric using Equations 6.2 – 6.6 above. If an index or EQR corresponds exactly with a class boundary, the upper class division is taken. A worked example is given at the end of this chapter.

6.6 Overall EQR and weightings

The overall EQR value for each water body containing saltmarsh ($EQR_{Overall}$) can be calculated using Equation 6.8 once individual EQRs for the above metrics have been normalised.

$$EQR_{Overall} = \quad (6.8)$$

$$\frac{(3 \times EQR_{Area}) + (1 \times EQR_{\#Zones}) + (0.5 \times EQR_{ZnMax}) + (0.5 \times EQR_{Spartina}) + (1 \times EQR_{Taxa})}{6}$$

Some metrics are deemed to be more important than others and have higher weightings. The metric for angiosperm abundance (EQR_{Area}) is deemed to be of primary importance; even if the metrics for taxonomic composition and disturbance sensitive taxa score highly, a low EQR_{Area} score will prevent a water body from scoring highly overall.

Table 6.2. Values for the normalisation of index values to EQR values for the five metrics.

	Class division	Lower index class boundary	Upper index class boundary	Index class range	Lower EQR class boundary	Upper EQR class boundary	EQR class range
Ind_{Area}	High	80	100	20	0.8	1.0	0.2
	Good	60	80	20	0.6	0.8	0.2
	Moderate	40	60	20	0.4	0.6	0.2
	Poor	20	40	20	0.2	0.4	0.2
	Bad	0	20	20	0	0.2	0.2
$Ind_{\#Zones}$	High	80	100	20	0.8	1.0	0.2
	Good	60	80	20	0.6	0.8	0.2
	Moderate	40	60	20	0.4	0.6	0.2
	Poor	20	40	20	0.2	0.4	0.2
	Bad	0	20	20	0	0.2	0.2
Ind_{ZnMax}	High	50	20	30	0.8	1.0	0.2
	Good	60	50	10	0.6	0.8	0.2
	Moderate	70	60	10	0.4	0.6	0.2
	Poor	80	70	10	0.2	0.4	0.2
	Bad	100	80	20	0	0.2	0.2
$Ind_{Spartina}$	High	5	0	5	0.8	1.0	0.2
	Good	15	5	10	0.6	0.8	0.2
	Moderate	30	15	15	0.4	0.6	0.2
	Poor	50	30	20	0.2	0.4	0.2
	Bad	100	50	50	0	0.2	0.2
Ind_{Taxa}	High	80	100	20	0.8	1.0	0.2
	Good	60	80	20	0.6	0.8	0.2
	Moderate	40	60	20	0.4	0.6	0.2
	Poor	20	40	20	0.2	0.4	0.2
	Bad	0	20	20	0	0.2	0.2

Three different metrics are used to assess taxonomic composition compared to one metric for each of the other two key elements. Two of the metrics for taxonomic composition, EQR_{ZnMax} and $EQR_{Spartina}$, are downweighted for this reason. Another reason for downweighting $EQR_{Spartina}$ is because of the level of uncertainty in where the threshold between net positive and negative effects of *Spartina* swards actually lies in terms of relative *Spartina* abundance.

The final element, disturbance sensitive taxa, is assessed using EQR_{Taxa}. There is some overlap between this metric and those of taxonomic composition, as species composition is linked to the number of zones present. For this reason, disturbance sensitive taxa has the lowest overall weighting of the three key elements.

6.7 Potential metrics

6.7.1 Angiosperm abundance

Angiosperm abundance is currently assessed only by metric (i), saltmarsh extent as a proportion of the reference area ($Area_{ref}$). It is envisioned that in future rounds of reporting a new metric for area can be implemented – recent change in area. As the SMP was essentially a baseline survey of saltmarshes, this metric could not be developed for this first draft of SMAATIE. With subsequent monitoring of saltmarsh (required by both the HD and WFD), recent changes in area (from one reporting period to the next) will be measured and this metric will then have the necessary data to be included in the tool.

During the development of the tool, a site shape index such as that outlined in Brys *et al.* (2005) was discussed. It was felt that this metric would be unfairly biased against fringe saltmarsh due to their natural form of being long and narrow therefore this potential metric was not developed further.

6.7.2 Taxonomic composition

The reference condition for metric (ii), proportion of saltmarsh zones present, is set at the number of expected zones the saltmarsh should support in its natural state. Depending on the type(s) of saltmarsh within the water body, a reference value of between two to five zones is suggested. As outlined in chapter 3 however, eight native vegetation zones relevant to the assessment of saltmarshes as part of the WFD were identified from analysis of quantitative plot data (Table 3.6). The development and testing of the tool was based on current available data therefore the reference value for this metric was set at the presence of up to five zones due to a lack of habitat mapping at a plant community level. It is our recommendation that future monitoring maps to community level and that *Phragmites / Typha* swamps, *Bolboschoenus / Schoenoplectus* swamps and *Elytrigia* swards be treated as separate zones rather than combined as "Other saltmarsh". Mapping to this level would also permit the HD Annex I habitat 1330 Atlantic salt meadows be mapped according to vegetation alliance (Puccinellion maritimae or Armerion maritimae). Using eight zones rather than five would require that reference values for this metric are reassessed.

Use of the *Spartina* metric can also be developed with future monitoring by looking at increases or decreases in $EQR_{Spartina}$ over time. In particular, a spread of *Spartina* into any water body where it was not recorded previously, even if the proportion of extent is <5%, needs to be instantly flagged so this can be monitored and control measurements put in place as soon as possible to prevent further spread.

6.7.3 Disturbance sensitive taxa

Metric (v), proportion of observed taxa to 15 taxa is the only metric in place for the disturbance sensitive taxa element. The project team considered another metric for this – a species diversity index. After a review of the data however, it was decided that this additional metric was not necessary.

A potential metric would be a measure of the presence or abundance of specific indicator species for disturbance. Abundant *Agrostis stolonifera* may be a good indicator of eutrophication and similarly an absence of *Atriplex portulacoides* could indicate overgrazing. There is currently, however, not enough research in this area to develop this metric for the tool.

6.8 Worked example

This worked example is based on data from the Kilmakilloge Harbour water body (SW_190_0200). Refer to Chapter 7 for methods on how the 40 water bodies for assessment were chosen.

Required data for Kilmakilloge Harbour:

$Area_{current}$	11.76 ha
$Area_{PSA}$	4.04 ha

$Area_{ref}$	14.79 ha	(calculated using Equation 6.1)
Ind_{Area}	**79.5%**	(calculated using Equation 6.2)
# zones present	3	
Saltmarsh type	Fringe	
Expected # zones	2	
$Ind_{\#zones}$	**100%**	(calculated using Equation 6.3)
Area of largest zone	9.02 ha	
Ind_{ZnMax}	**76.7%**	(calculated using Equation 6.4)
Area of Spartina	0.00 ha	
$Ind_{Spartina}$	**0%**	(calculated using Equation 6.5)
No. of common taxa	11	
No. of rare taxa	0	
Ind_{Taxa}	**73.3%**	(calculated using Equation 6.6)

Using the values from Table 6.2, Equation 6.7 is populated as follows for each of the five metrics:

$$EQR_{Area} = 0.8 - \left((\mathbf{79.5} - 80) \times \left(\frac{0.2}{-20}\right)\right) = 0.80\ (High)$$

$$EQR_{\#zones} = 1.0 - \left((\mathbf{100} - 100) \times \left(\frac{0.2}{-20}\right)\right) = 1.00\ (High)$$

$$EQR_{ZnMax} = Not\ applicable$$

$$EQR_{Spartina} = 1.0 - \left((\mathbf{0.0} - 0) \times \left(\frac{0.2}{5}\right)\right) = 1.00\ (High)$$

$$EQR_{Taxa} = 0.8 - \left((\mathbf{73.3} - 80) \times \left(\frac{0.2}{-20}\right)\right) = 0.73\ (Good)$$

Using these EQR values, the overall EQR value (and overall status) can be calculated by populating Equation 6.8.

$$EQR_{Overall} = \frac{(3 \times 0.80) + (1 \times 1.00) + (0.5 \times \text{Not applicable}) + (0.5 \times 1.00) + (1 \times 0.73)}{6 - 0.5\ (\text{ZnMax: Not applicable})} = 0.84\ (High)$$

7. Application of the Irish Saltmarsh Assessment Tool to Irish Water Bodies

7.1 Methodology used in the selection of water bodies

The selection of forty water bodies for assessment and testing of SMAATIE was a step by step process which is summarised in Table 7.1. Only water bodies which contained mapped saltmarsh areas were used as the starting point (193 water bodies out of 306 TraC water bodies in Ireland). This number of water bodies was based on the assignment of saltmarsh habitat polygons from the smp_national_sm_resource_revised_GIS_2011 shapefile to water bodies as described in Section 4.2.1. The next step excluded any water bodies which only had saltmarsh polygons mapped as part of the desktop study, reducing the number of water bodies to 111. This was an important step as data required to calculate metrics for taxonomic composition (Section 6.3) and disturbance sensitive taxa (Section 6.4) were lacking for these water bodies.

Table 7.1. The step-by-step process used in the selection of 40 water bodies for assessment and use in the testing of SMAATIE

Steps:		No. of water bodies removed	No. of water bodies remaining
	EPA TraC water bodies	-	306
1.	Water bodies must contain mapped areas of saltmarsh	113	193
2.	Mapped areas of saltmarsh in each water body must contain at least some areas mapped from the SMP fieldwork (i.e. ground-truthed)	82	111
3.	Water bodies must have data relating to Overall status according to the EPA WFD Status Access database	55	56
4.	Water bodies must have vegetation data associated with them	3	53
5.	Total saltmarsh area in each water body must be at least 10 ha	11	42
6.	Each water body must have at least five SMP vegetation plots	4	38

One of the required amendments to the initial project proposal was that the overall status of each water body as recorded within the EPA WFD Status Access database should be considered as an additional selection criterion. Of the remaining 111 water bodies, only 56 had an overall status recorded. The next step involved the removal of three more water bodies due to a lack of vegetation (plot) data. Vegetation data are necessary in order to fulfil the requirements of the metric for disturbance sensitive taxa (as outlined in Section 6.4). The penultimate step involved applying a minimum saltmarsh area threshold of 10 ha, reducing the number of remaining water bodies from 53 to 42. This threshold was used as it was felt that any water bodies containing saltmarsh below this area would not contain sufficient habitat to warrant assessment under the WFD. This value was not based on any scientific measurement however and was arbitrarily chosen. In comparison, the average area of saltmarsh for monitoring in the UK is approximately 8.25 ha (Mike Best, pers. comm.). The final step in selecting the forty water bodies was ensuring that the remaining water bodies had at least five SMP vegetation plots. Again, this is important in order to calculate the metrics for taxonomic composition (Section 6.3) and also the metric for disturbance sensitive taxa (Section 6.4).

After all the steps outlined in Table 7.1 were carried out, 38 water bodies remained. An additional two water bodies were selected from those already eliminated in order to reach the target of forty water bodies to assess and test against SMAATIE. The two additional water bodies met all criteria except the minimum threshold area; however, as this threshold was arbitrarily chosen, this was deemed acceptable.

Another required amendment to the initial project proposal was that in selecting the forty test water bodies, pressures should be considered as a criterion. While the pressure data collated in Chapter 4 were not used explicitly in the steps listed in Table 7.1, it was inherent that by only using water bodies that contained saltmarsh as mapped by the SMP (step 2) and plots recorded by the SMP (step 6), these water bodies would have associated SMP pressure data.

7.2 Summary statistics of the selected water bodies

Details of the forty selected water bodies are given in Table 7.2, while the distribution of these water bodies selected are shown in Figure 7.1.

Table 7.2. (a) The EU and MS codes, RBD, name and type for each of the 14 coastal water bodies (CWBs) selected

EU Code	MS Code	RBD	Name	Type
IE_EA_060_0000	EA_060_0000	EA	Malahide Bay	CW8
IE_NB_040_0000	NB_040_0000	NB	Outer Dundalk Bay	CW5
IE_NW_100_0000	NW_100_0000	NW	Northwestern Atlantic Seaboard (HAs 37;38)	CW2
IE_NW_200_0000	NW_200_0000	NW	Mulroy Bay Broadwater	CW8
IE_SE_040_0000	SE_040_0000	SE	Wexford Harbour	CW8
IE_SE_120_0000	SE_120_0000	SE	Tramore Back Strand	CW8
IE_SH_060_0000	SH_060_0000	SH	Mouth of the Shannon (HAs 23;27)	CW2
IE_SW_140_0000	SW_140_0000	SW	Roaring Water Bay	CW2
IE_SW_190_0000	SW_190_0000	SW	Outer Kenmare River	CW2
IE_WE_170_0000	WE_170_0000	WE	Inner Galway Bay North	CW5
IE_WE_200_0000	WE_200_0000	WE	Kilkieran Bay	CW5
IE_WE_340_0000	WE_340_0000	WE	Clew Bay	CW2
IE_WE_350_0000	WE_350_0000	WE	Inner Clew Bay	CW5
IE_WE_420_0000	WE_420_0000	WE	Killala Bay	CW5

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

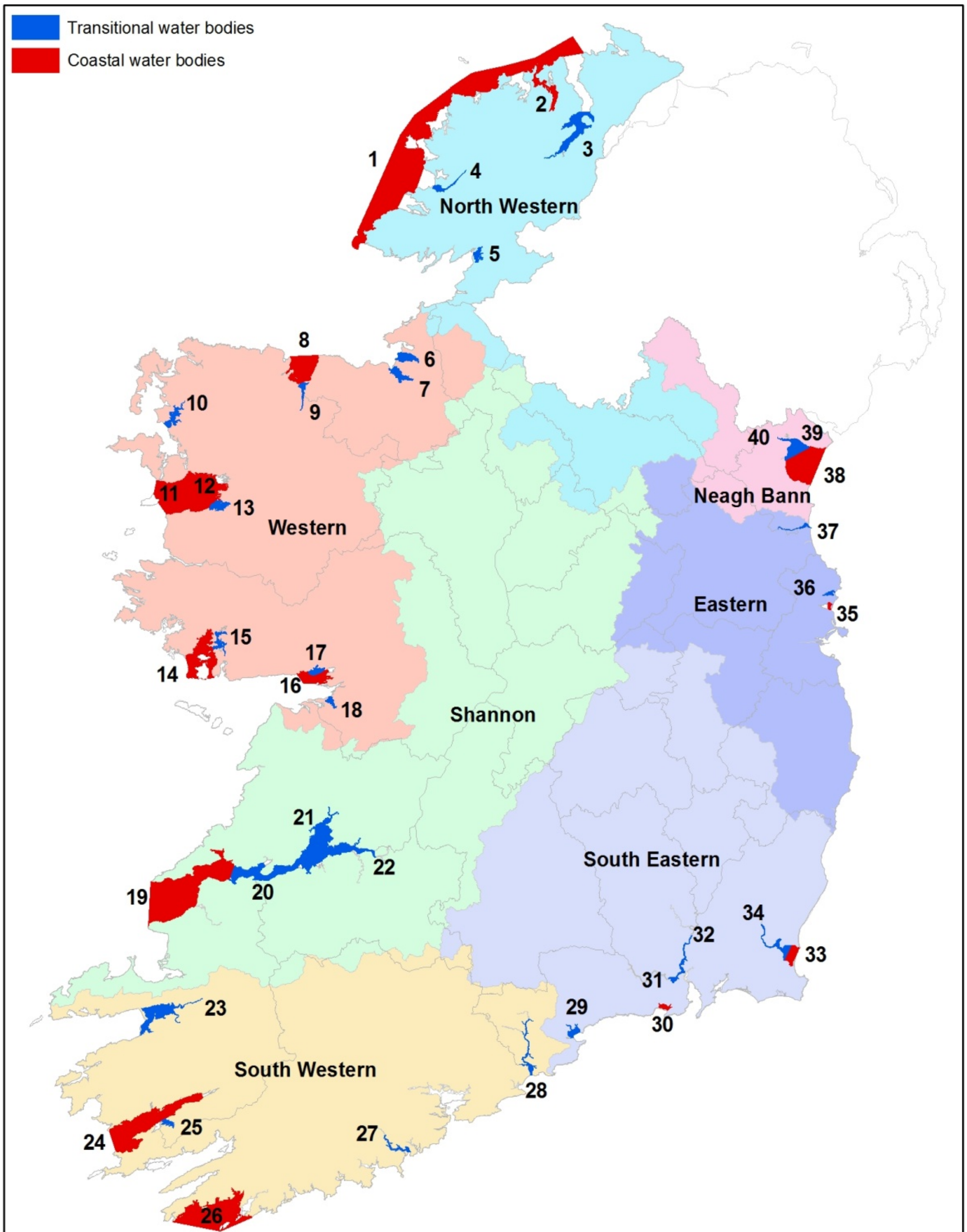
The selected water bodies have a good distribution around the coast of Ireland, with good representation in the majority of Ireland's major estuaries and bays. All seven RBDs partially or wholly within the state have at least three water bodies selected, and all water body types also have representatives with the exception of the lagoonal types (CW10 and TW6). This was not deemed problematic, however, as it had been recommended by the Steering Committee that for the sake of simplicity the selection of water bodies did not focus on lagoons. Of the water bodies selected, 65% were transitional water bodies. This is an approximate representation of the overall ratio of CWBs to TWBs for the Republic of Ireland (110:196). The western coast, comprising the North Western, Western, Shannon and South Western RBDs, has a much higher proportion of selected water bodies compared to the southern and eastern coasts (Neagh Bann, Eastern and South Eastern RBDs) (Figure 7.1). This can partially be explained by the sampling density of saltmarshes during the SMP on which project a lot of the selection criteria were based and also due to the fact that although the east coast supports large saltmarsh systems, the distribution of saltmarsh habitat is not as widespread as those on the western coast due to large areas of coastline being unsuitable to saltmarsh development.

Table 7.2. (b) The EU and MS codes, RBD, name and type for each of the 26 transitional water bodies (TWBs) selected

EU Code	MS Code	RBD	Name	Type
IE_EA_010_0100	EA_010_0100	EA	Boyne Estuary	TW2
IE_EA_050_0100	EA_050_0100	EA	Rogerstown Estuary	TW2
IE_NB_040_0100	NB_040_0100	NB	Inner Dundalk Bay	TW2
IE_NB_040_0200	NB_040_0200	NB	Castletown Estuary	TW2
IE_NW_050_0100	NW_050_0100	NW	Inner Donegal Bay	TW2
IE_NW_120_0100	NW_120_0100	NW	Gweebarra Estuary	TW2
IE_NW_220_0100	NW_220_0100	NW	Swilly Estuary	TW2
IE_SE_040_0200	SE_040_0200	SE	Lower Slaney Estuary	TW2
IE_SE_100_0200	SE_100_0200	SE	New Ross Port	TW2
IE_SE_100_0500	SE_100_0500	SE	Lower Suir Estuary (Little Island - Cheekpoint)	TW2
IE_SE_140_0100	SE_140_0100	SE	Colligan Estuary	TW2
IE_SH_060_0300	SH_060_0300	SH	Lower Shannon Estuary	TW2
IE_SH_060_0800	SH_060_0800	SH	Upper Shannon Estuary	TW2
IE_SH_060_1100	SH_060_1100	SH	Fergus Estuary	TW2
IE_SW_020_0100	SW_020_0100	SW	Lower Blackwater M Estuary / Youghal Harbour	TW2
IE_SW_080_0100	SW_080_0100	SW	Lower Bandon Estuary	TW2
IE_SW_190_0200	SW_190_0200	SW	Kilmakilloge Harbour	TW2
IE_SW_230_0200	SW_230_0200	SW	Castlemaine Harbour	TW2
IE_WE_160_0100	WE_160_0100	WE	Kinvarra Bay	TW2
IE_WE_170_0700	WE_170_0700	WE	Corrib Estuary	TW2
IE_WE_200_0200	WE_200_0200	WE	Camus Bay	TW2
IE_WE_350_0100	WE_350_0100	WE	Westport Bay	TW2
IE_WE_390_0100	WE_390_0100	WE	Tullaghan Bay	TW2
IE_WE_420_0300	WE_420_0300	WE	Moy Estuary	TW2
IE_WE_460_0300	WE_460_0300	WE	Ballysadare Estuary	TW2
IE_WE_470_0100	WE_470_0100	WE	Garavoge Estuary	TW2

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

Two of the criteria used to select the forty water bodies were saltmarsh area mapped in the field and number of vegetation plots in each water body in order to be able to satisfy the requirements for calculating the metrics for angiosperm abundance, taxonomic composition and disturbance sensitive taxa. Table 7.3 summarises these details for the forty selected water bodies. All RBDs have a good representation of saltmarsh mapped in the field, and although the Shannon RBD only has over 25% of saltmarsh field mapped this still represents over 350 ha. In terms of the area of saltmarsh mapped expressed as a proportion of the area of associated water bodies, figures are low. The Eastern RBD has the highest proportion (16.1%), but the North Western and South Western have less than 1% each. As can be seen from Figure 7.1 both of these RBDs contain large water bodies, particularly compared to the Eastern and South Eastern RBDs. Fringe saltmarsh, common on the west coast, is by its nature long and narrow, while saltmarsh on the east coast, though less widespread, tends to develop much larger systems.



1 = Northwestern Atlantic Seaboard (HAs 37;38); 2 = Mulroy Bay Broadwater; 3 = Swilly Estuary; 4 = Gweebarra Estuary; 5 = Inner Donegal Bay; 6 = Garavoge Estuary; 7 = Ballysadare Estuary; 8 = Killala Bay; 9 = Moy Estuary; 10 = Tullaghan Bay; 11 = Clew Bay; 12 = Inner Clew Bay; 13 = Westport Bay; 14 = Kilkieran Bay; 15 = Camus Bay; 16 = Inner Galway Bay North; 17 = Corrib Estuary; 18 = Kinvarra Bay; 19 = Mouth of the Shannon (HAs 23;27); 20 = Lower Shannon Estuary; 21 = Fergus Estuary; 22 = Upper Shannon Estuary; 23 = Castlemaine Harbour; 24 = Outer Kenmare River; 25 = Kilmakilloge Harbour; 26 = Roaring Water Bay; 27 = Lower Bandon Estuary; 28 = Lower Blackwater M Estuary / Youghal Harbour; 29 = Colligan Estuary; 30 = Tramore Back Strand; 31 = Lower Suir Estuary (Little Island - Cheekpoint); 32 = New Ross Port; 33 = Wexford Harbour; 34 = Lower Slaney Estuary; 35 = Malahide Bay; 36 = Rogerstown Estuary; 37 = Boyne Estuary; 38 = Outer Dundalk Bay; 39 = Inner Dundalk Bay; 40 = Castletown Estuary

Figure 7.1. The distribution of the forty water bodies selected for assessment using SMAATIE.

Table 7.3. Area of mapped saltmarsh habitat and number of plots recorded for the forty selected water bodies. Data are presented at a RBD level.

RBD*	Mapped saltmarsh (ha)	Field mapped saltmarsh only (ha)	% of saltmarsh field mapped	Mapped saltmarsh as % of WB area	No. plots
EA	138	138	100.0	16.1	223
NB	540	539	99.7	5.5	114
NW	213	157	73.5	0.3	114
SE	323	204	63.2	5.0	196
SH	1436	367	25.6	2.6	196
SW	405	221	54.6	0.9	251
WE	551	436	79.2	1.0	465

* RBDs abbreviations: EA = Eastern; NB = Neagh Bann; NW = North Western; SE = South Eastern; SH = Shannon; SW = South Western; WE = Western

For the selected water bodies, a summary of the SMP severity pressure data is presented in Table 7.4 (see Section 4.3 for definitions). The Western RBD contains the largest overall number of pressures and also the highest number of "High" severity pressures. Conversely, the Eastern and Neagh Bann RBDs have no "High" severity pressures, and in fact, the Neagh Bann RBD has the lowest number of pressures overall. The South Eastern RBD has the next highest overall number of pressures, with three assessed as "High" severity pressures. The North Western RBD also has three "High" severity pressures, however the overall number of pressures is much lower at 19. The Shannon and South Western RBDs have a similar number of overall pressures, but the majority of these are of either "Medium" or "Low" severity.

Table 7.4. Summary of the SMP severity pressure data for the forty selected water bodies. Multiple pressures can be associated with any one water body. Data presented are the number of pressures recorded at a RBD level.

	Severity			
RBD	High	Medium	Low	Total
EA	0	2	11	13
NB	0	4	0	4
NW	3	3	13	19
SE	3	14	15	32
SH	1	8	9	18
SW	2	7	9	18
WE	9	8	29	46
Total	**18**	**46**	**86**	**150**

Summary EPA risk assessment data for the selected water bodies are presented in Table 7.5. The Western, Shannon and South Eastern RBDs contain three water bodies apiece deemed to be "1a: At risk". The water bodies within the Eastern, Neagh Bann and South Eastern RBDs are all either "1a: At risk" or "1b: Probably at risk", and of the remainder, all but the water bodies within the North Western RBD, have over 50% of their water bodies either "1a: At risk" or "1b: Probably at risk".

Table 7.5. Summary of the EPA risk assessment data for the forty water bodies selected for assessment. Risk refers to the risk that a water body will not achieve good ecological or good chemical status/potential at least by 2015. Data presented are at a RBD level.

RBD	Risk category				Total
	1a: At risk	1b: Probably at risk	2a: Probably not at risk	2b¨Not at risk	
EA	2	1			3
NB	2	1			3
NW		2	1	2	5
SE	3	3			6
SH	3		1		4
SW	2	2	1	1	6
WE	3	4	6		13
Total	**15**	**13**	**9**	**3**	**40**

Based on the data presented in Table 7.5, it would be predicted that only 30% of the water bodies assessed will have EQR values of 0.6 or higher (Good or High ecological status); that is, only twelve water bodies out of the forty selected have been assessed as either "Probably not at risk" or "Not at risk".

7.3 Ecological status of selected water bodies

By applying SMAATIE to the forty water bodies selected, EQR values for each metric were calculated, as well as an overall EQR value for each water body. Using the overall EQR value, the ecological status for each water body could be determined (refer to Chapter 6 for the equations and calculations used). The results of this application of the tool are presented in Table 7.6.

Of the forty water bodies assessed, four had an ecological status of High, fifteen Good, eighteen were Moderate and three were of Poor ecological status. Overall, nearly 50% of the water bodies assessed had EQR values of 0.6 or higher (Good or High ecological status). This is higher than the percentage predicted based on the EPA risk assessment data (Table 7.5).

As the objective of the WFD is for water bodies to achieve a minimum of Good ecological status, we examine here the scores for the eighteen water bodies attaining only Moderate status. The main cause was a low EQR value for Area: three had EQR_{Area} values equivalent to Moderate status (0.4-0.6), eleven had EQR_{Area} values equivalent to Poor status (0.2-0.4) and four had EQR_{Area} values equivalent to Bad (0.0-0.2). All $EQR_{\#zones}$ values were equivalent to either High or Good, but EQR_{ZnMax} had a large range of values with equivalents from Poor to High ecological status. Over half of these water bodies had $EQR_{Spartina}$ values equivalent to High, however seven had EQR values equivalent to Moderate or worse. The final metric had three water bodies with EQR_{Taxa} equivalent to Moderate, with the remainder equivalent to either High or Good. The main cause for water bodies attaining a Poor ecological status was low EQR_{Area} values (all equivalent to Bad), and also due to poor scores for the ZnMax and *Spartina* metrics.

The results suggest that for water bodies with either Moderate or Poor ecological status, large areas with the potential of supporting saltmarsh currently do not as they have been modified or developed upon. This is also somewhat reflected in the lower EQR_{ZnMax} values for these water bodies, where one main zone is dominating the marsh; this could be a sign that the saltmarsh is suffering from external pressures which is preventing the full range of zones typical of undisturbed saltmarsh systems to develop.

Table 7.6. EQR values and overall ecological status for the forty water bodies selected for assessment.

MS Code	Name	EQR values						Status
		Area	#Zones	ZnMax	Spartina	Taxa	Overall	
NW_050_0100	Inner Donegal Bay	0.94	1.00	0.84	1.00	0.80	0.93	**High**
WE_390_0100	Tullaghan Bay	0.90	0.75	0.80	1.00	0.73	0.85	**High**
SW_190_0200	Kilmakilloge Harbour	0.80	1.00	N.A.	1.00	0.73	0.84	**High**
WE_160_0100	Kinvarra Bay	0.89	0.50	0.75	1.00	0.80	0.81	**High**
WE_200_0200	Camus Bay	0.68	1.00	N.A.	1.00	0.73	0.78	**Good**
SE_140_0100	Colligan Estuary	0.56	1.00	0.92	0.89	1.00	0.76	**Good**
WE_420_0000	Killala Bay	0.55	1.00	0.71	1.00	1.00	0.75	**Good**
SW_080_0100	Lower Bandon Estuary	0.83	0.60	0.87	1.00	0.47	0.75	**Good**
WE_200_0000	Kilkieran Bay	0.59	1.00	N.A.	1.00	0.80	0.74	**Good**
EA_050_0100	Rogerstown Estuary	0.72	0.60	0.81	0.41	1.00	0.73	**Good**
WE_170_0000	Inner Galway Bay North	0.62	0.50	0.81	1.00	1.00	0.71	**Good**
WE_470_0100	Garavoge Estuary	0.37	1.00	0.85	1.00	1.00	0.67	**Good**
WE_420_0300	Moy Estuary	0.58	0.75	0.82	1.00	0.60	0.67	**Good**
NB_040_0000	Outer Dundalk Bay	0.65	0.60	0.73	0.58	0.80	0.67	**Good**
SW_140_0000	Roaring Water Bay	0.53	0.75	0.78	1.00	0.80	0.67	**Good**
WE_170_0700	Corrib Estuary	0.57	0.75	0.87	1.00	0.53	0.66	**Good**
NB_040_0100	Inner Dundalk Bay	0.71	0.60	0.42	0.42	0.80	0.66	**Good**
SH_060_0000	Mouth of the Shannon (HAs 23;27)	0.58	0.80	0.86	0.12	0.80	0.64	**Good**
EA_010_0100	Boyne Estuary	0.55	0.80	0.47	0.35	0.73	0.60	**Good**
EA_060_0000	Malahide Bay	0.53	0.60	0.61	0.39	0.87	0.59	**Moderate**
NW_120_0100	Gweebarra Estuary	0.43	0.75	0.73	1.00	0.60	0.58	**Moderate**
SW_190_0000	Outer Kenmare River	0.39	1.00	N.A.	1.00	0.53	0.58	**Moderate**
SH_060_0300	Lower Shannon Estuary	0.39	0.80	0.86	0.14	0.93	0.57	**Moderate**
SE_100_0500	Lower Suir Estuary (Little Island - Cheekpoint)	0.56	0.60	0.83	0.43	0.47	0.56	**Moderate**
WE_460_0300	Ballysadare Estuary	0.29	0.80	0.88	1.00	0.67	0.55	**Moderate**
SE_120_0000	Tramore Back Strand	0.31	1.00	N.A.	0.25	0.87	0.53	**Moderate**
WE_340_0000	Clew Bay	0.36	0.75	0.26	1.00	0.67	0.52	**Moderate**
NW_100_0000	Northwestern Atlantic Seaboard (HAs 37;38)	0.22	1.00	0.61	1.00	0.67	0.52	**Moderate**
WE_350_0100	Westport Bay	0.21	0.75	0.82	0.94	0.87	0.52	**Moderate**
SW_230_0200	Castlemaine Harbour	0.20	0.80	0.80	0.57	0.93	0.50	**Moderate**
NW_200_0000	Mulroy Bay Broadwater	0.19	0.75	0.77	1.00	0.80	0.50	**Moderate**
SW_020_0100	Lower Blackwater M Estuary / Youghal Harbour	0.14	1.00	0.46	0.96	0.73	0.48	**Moderate**
SE_100_0200	New Ross Port	0.21	0.60	0.62	0.82	0.80	0.46	**Moderate**
SH_060_1100	Fergus Estuary	0.27	0.80	0.79	0.19	0.60	0.45	**Moderate**
NB_040_0200	Castletown Estuary	0.38	0.60	0.31	0.13	0.67	0.44	**Moderate**
WE_350_0000	Inner Clew Bay	0.11	0.75	0.58	1.00	0.60	0.41	**Moderate**
SE_040_0200	Lower Slaney Estuary	0.17	0.60	0.82	0.83	0.47	0.40	**Moderate**
SH_060_0800	Upper Shannon Estuary	0.14	0.60	0.28	0.65	0.80	0.38	**Poor**
NW_220_0100	Swilly Estuary	0.09	0.60	0.79	0.25	0.60	0.33	**Poor**
SE_040_0000	Wexford Harbour	0.02	0.80	0.56	0.26	0.73	0.33	**Poor**

The occurrence of *Spartina* is particularly high within the Shannon Estuary as demonstrated by EQR values equivalent to Bad for The Mouth of the Shannon (HAs 23;27), Lower Shannon Estuary and Fergus Estuary. The majority of *Spartina* swards in Ireland have established on bare mudflats but saltmarsh can be invaded. The pioneer zone is the most vulnerable to displacement, althought the SMP found some evidence of the lower saltmarsh also being affected (Mark McCorry, pers. comm.).

The #Zones and Taxa metrics tended to have EQR values equivalent to either High or Good status. This suggests that, in general, all expected zones are present, with a good diversity of taxa, within the water bodies. This in turn suggests that there is good potential for improvement of saltmarsh condition within the Irish water bodies assessed.

It is important to note that there is an assumption within the Area metric that the saltmarsh polygons within the smp_national_sm_resource_revised_GIS_2011 shapefile comprises all current areas of saltmarsh, including brackish swamps, in each water body. It is possible that some areas of saltmarsh, particularly the swamps and *Elytrigia* swards, were missed during the desktop element in the creation of this shapefile. While these areas of extant saltmarsh may have been overlooked in the desktop survey, they may have been picked up by the analysis of LiDaR data and six inch maps, thereby increasing $Area_{PSA}$ rather than $Area_{current}$. If this has occurred, the EQR_{Area} values would be lower than they really should be for those water bodies. It will be very important to ground-truth the areas mapped as PSA to determine whether or not there is in fact existing saltmarsh there.

7.4 Testing of the Irish Saltmarsh Assessment Tool’s performance

In this section overall EQR values were analysed in conjuction with pressure and status data. This is an important part of the intercalibration process. If the metrics developed for SMAATIE show no relationship with the pressures recorded within the water bodies, the boundary setting process for these metrics cannot proceed (EC, 2011).

Analysis of variance was used to test for differences in overall EQR values between water bodies with different categorical status. No statistically significant differences were found related to EPA risk assessment status (Fig. 7.2, $F = 2.048$, $p = 0.124$), although there is some suggestion of higher EQR values in risk group 2a, water bodies deemed to be “Probably not at risk”. No statistically significant differences were found related to EPA trophic status (Fig. 7.3, $F = 0.899$, $p = 0.453$) or current overall biological status (Fig. 7.4, $F = 1.727$, $p = 0.192$).

Pearson’s product moment correlation was used to test for a relationship between overall EQR values and an area-weighted pressure index calculated using the Future Prospects data of Annex I habitats from the SMP, combined within water bodies (Equation 7.1). Higher index values indicate higher perceived pressures.

$$Pressure\ index = \frac{Area_{Unfavourable\ Inadequate} + (2 \times \ Area_{Unfavourable\ Bad})}{2 \times Area_{Annex\ I\ habitat}} \qquad (7.1)$$

No statistically significant relationship was found ($r^2 = 0.071$, $p = 0.095$) but linear regression does suggest a trend of decreasing EQR values with increased pressure index values (Fig. 7.5). A statistically significant correlation was, however, found between overall EQR values and the number of pressures recorded for each water body as reviewed in Chapter 4 (r^2 = 0.146, p = 0.015), with EQR values decreasing with increasing number of pressures (Fig. 7.6). To investigate this further, a multiple regression was used with the number of pressures in each of the five pressure categories entered as a separate variable (Table 7.7). This indicates that the number of water regime pressures, such as dykes, embankments and modifications to hydrological functioning, was the significant element in predicting overall EQR values.

Table 7.7. Results of multiple regression analysis of pressure variables predicting overall EQR values. * indicates *p* <0.05

Variable	Estimate	Standard Error	*p* value
(intercept)	0.707	0.058	-
Biology	-0.020	0.028	0.469
Morphology	-0.006	0.019	0.741
Water regime	-0.099	0.031	0.003*
Pollution	0.007	0.014	0.611
Other	0.005	0.025	0.851

r^2 = 0.3229, F = 3.243, p = 0.017

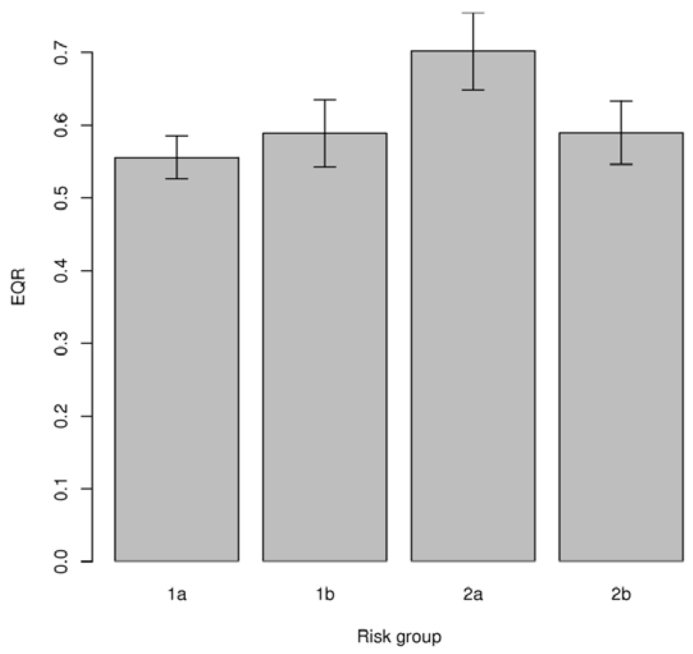


Figure 7.2. Mean overall EQR values in water bodies with different EPA risk assessment status. Vertical lines indicate standard errors.

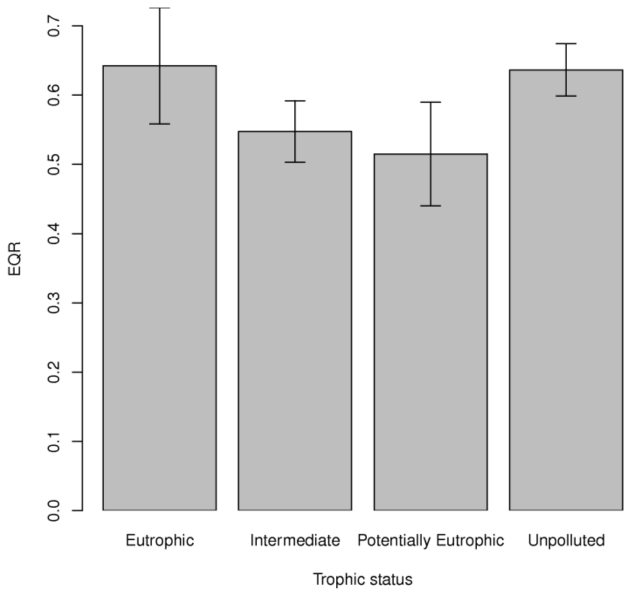


Figure 7.3. Mean overall EQR values in water bodies with different trophic status. Vertical lines indicate standard errors.

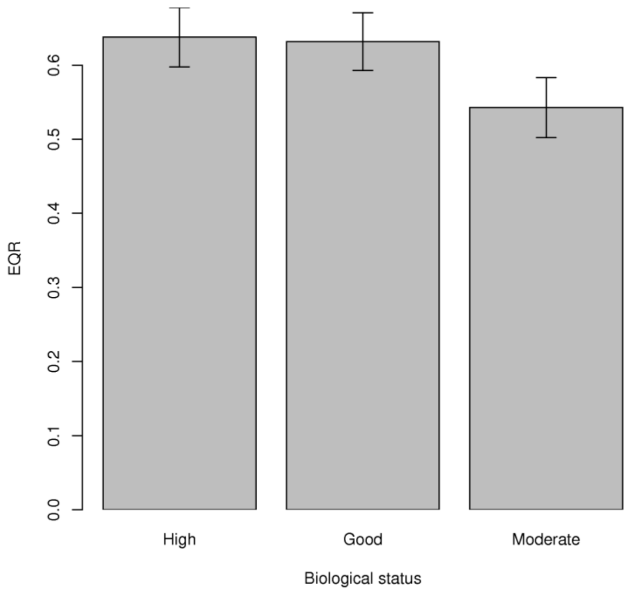


Figure 7.4. Mean overall EQR values in water bodies with different overall biological status. Vertical lines indicate standard errors.

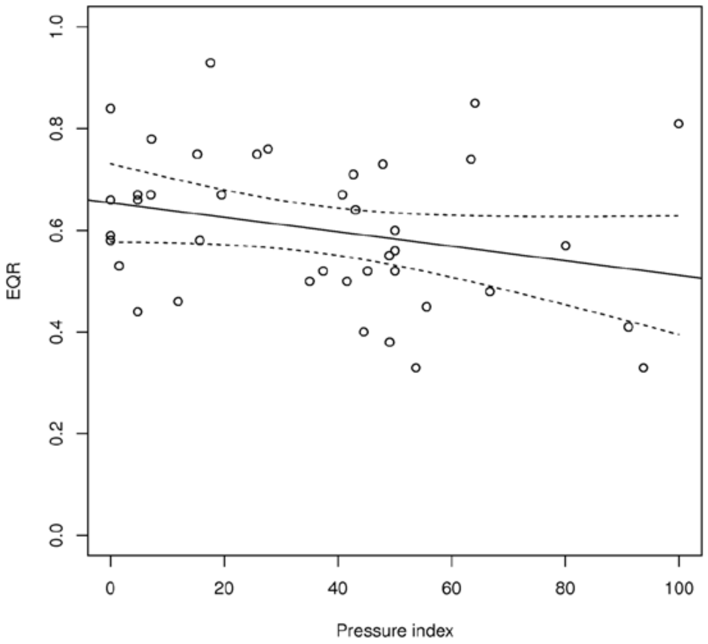


Figure 7.5. Linear regression of overall EQR values and the SMP pressure index. Dotted lines indicate 95% confidence intervals. EQR = -0.001 x Pressure index + 0.654.

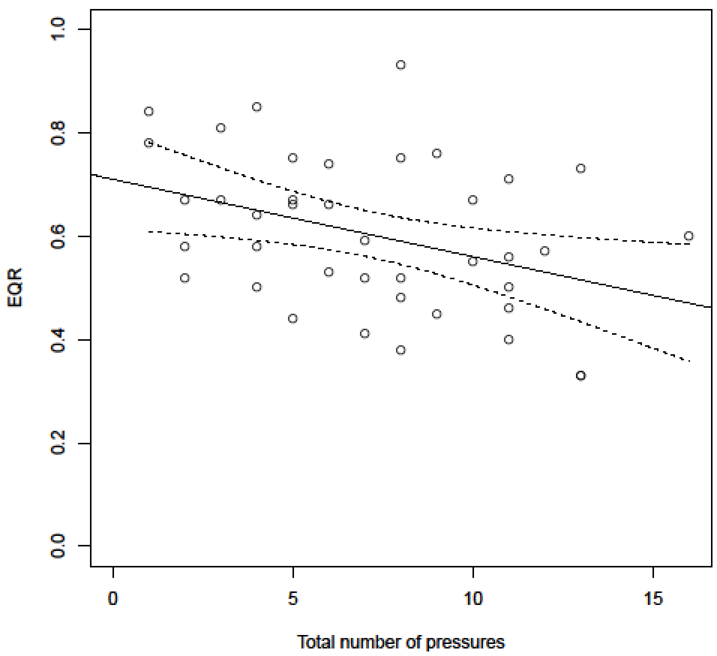


Figure 7.6. Linear regression of overall EQR values and total number of pressures. Dotted lines indicate 95% confidence intervals. EQR = -0.015 x number of pressures + 0.710.

These analyses demonstrate some relationships between the results of the tool and available pressure/status data, but the relationship is not strong. This can be interpreted in two ways. Firstly, there may be deficiencies in the pressure/status data, for example they may not encompass all of the impacts which the tool is designed to measure. The SMP data, for instance, has been collected at the level of individual Annex I habitats and not at an ecosystem level where the number and relative proportion of zones is of importance. Furthermore, if an anthropogenic activity, such as land reclamation or port development, occurred prior to 1995, it was not recorded by the SMP as this was not part of the remit of the survey (McCorry and Ryle, 2009a). As land reclamation has such an important impact on the results of the tool, the lack of strong correlations is therefore perhaps not unexpected. In addition, the EPA risk assessment data were based on expert judgement (Robert Wilkes, pers. comm.). Secondly, the tool may not be sensitive enough to adequately detect some of the impacts of the pressures. Certainly, there is a lack of information in areas such as the effects of pollution and eutrophication on saltmarshes in Ireland and further research in these areas may produce data which can be used to improve the tool. It should also be noted that it is extremely difficult to link biological indicators with pressure gradients (stress-response relationships), with many biological indicators related to multiple stressors and scales (Niemi *et al.*, 2004; Kent, 2012).

8. Guidance on Data Collection

8.1 Data requirements

In order to apply SMAATIE to TraC water bodies there are a number of necessary data requirements for the metrics. For metric (i), saltmarsh extent as a proportion of the reference area, access to six inch historical maps, the coastal and transitional water body shapefiles and current habitat maps of saltmarsh within the water bodies being assessed are needed. Where there is suitable coverage, access to LiDaR data and the ability to process these is also highly preferable as it will greatly improve accuracy. Relevé data are required for the final metric (v), proportion of observed taxa to 15 taxa. These should be representative of the vegetation classes and communities present. The type of saltmarsh (estuary, bay, sandflats, lagoon or fringe) within each water body will also be required. A final data requirement for SMAATIE is a current list of pressures acting on saltmarshes within each water body being assessed. Ideally, an estimate of area impacted upon and the intensity of the pressure should be given, and a standardised list of pressures used.

8.2 Field methodology

In practical terms, the assessment of saltmarshes for the WFD is likely to have a high degree of overlap with the assessment of Annex I habitats for the HD. It would be pragmatic and cost effective if the data for both assessments could be gathered within the same field exercise. As outlined above, data requirements for SMAATIE include habitat maps (at community or zone level), relevé data and a list of current pressures, all of which are requirements for the individual components of the HD conservation status assessment: habitat extent, structure and functions and future prospects (McCorry and Ryle, 2009a; NPWS, 2013). For this reason, we recommend following the methodology as described in McCorry and Ryle (2009a), with some minor adjustments.

8.2.1 Scale and timing of the work

SMAATIE is to be applied at a water body scale, where often there are several distinct saltmarsh systems present (sites), particularly within larger water bodies. Data from these saltmarsh sites as assessed for the HD should be scaled up to a water body level for the WFD assessment.

The reporting cycles for the HD and WFD are every six years, with a difference of three years between them (e.g. the last reporting round for the HD was 2007-2012, while 2015 is the end of the first management cycle for the WFD). Data collected for HD assessments should be used in the subsequent WFD assessment. The best time for carrying out habitat surveys in general is during the growing season for most plants (April to September) (Smith *et al.*, 2011), with the optimal survey period for saltmarsh surveying June to September (UKTAG, 2013). The study of tide tables is essential prior to fieldwork to identify periods of low tide when lower saltmarsh zones can be mapped and assessed safely (McCorry and Ryle, 2009a).

Timing of fieldwork should allow for a training day prior to commencement of the field survey. This is for quality control purposes and ensures that all members of the survey team are consistent in their recording of field data, and are familiar with and competent in the use of the equipment.

8.2.2 Equipment

Each surveyor should be equipped with a ruggedised handheld mapper with an integrated Global Positioning System (GPS) receiver. The handheld mappers should be installed with GIS mapping software with the relevant GIS layers imported. These include aerial photographs, Ordnance Survey Discovery Series maps, site and water body boundaries, and a preliminary habitat map for each site. The mappers should be used to record waypoints for delineating or redefining habitat boundaries and for the recording of additional waypoints for relevés or monitoring stops, negative impacts and other points of interest. Spreadsheet software, such as Microsoft Mobile Excel, should also be installed on the mappers allowing all assessment data and site notes to be entered in the field for maximum efficiency. Standardised recording forms should be prepared in advance of the field survey.

In addition, fieldworkers should be supplied with a site pack. Each pack should include a cover sheet that details general site information, e.g. site area, saltmarsh type, habitats recorded at the site by previous surveys (such as the SMP) and the Discovery Series map number. A hard copy map of the survey area should also be supplied displaying the site boundary over aerial photographs at a scale appropriate for mapping. Hard copies of the recording sheets on waterproof paper should also be supplied in the event of technical failure.

8.2.3 Habitat mapping

GIS mapping should be consistent with the guidelines of Smith *et al.* (2011). A minimum mappable polygon size of 400 m^2 and minimum mappable polyline length of 20 m should be employed, with smaller features, relevés or monitoring stop positions, and the occurrence of notable fauna and flora recorded as point features. The smp_national_sm_resource_revised_GIS_2011 shapefile (available from NPWS) should form the basis of the preliminary habitat map. Habitat maps should be mapped to community level or at the least to the level of the zones indicated in Table 3.6. This is necessary in fulfilling the requirements for metrics (ii), proportion of saltmarsh zones present; (iii), proportion of saltmarsh area covered by the dominant saltmarsh zone and (iv), proportion of saltmarsh composed of *Spartina*. Correspondence of zones or communities with HD Annex I habitats should be noted on a polygon by polygon basis.

In cases where areas of saltmarsh contain an intimate mosaic of saltmarsh communities or zones which cannot be practically separated, each community or zone present in each polygon should be recorded with the approximate percentage area of the polygon they cover. As the total area of each polygon will be known from digitisation, data on the approximate extent of each community or zone can be readily calculated using this method. Attempting to map smaller polygons representing single communities or zones in these areas would greatly increase the amount of time spent mapping and the number of polygons mapped, and would not ultimately eliminate the need for recording mosaics at smaller scales.

8.2.4 Taxonomic composition – structure and functions

It is necessary to assess the structure and functions of the various Annex I saltmarsh habitats for the HD, and methods should follow those laid out in McCorry and Ryle (2009a). In terms of the WFD, only the vegetation composition attribute of the structure and functions assessment is of import. This attribute assesses the species diversity of each Annex I saltmarsh habitat, with the target for each habitat set at maintaining the presence of typical species (McCorry and Ryle, 2009a). Within each monitoring stop (10 m x 10 m), a 2 m x 2 m quadrat was surveyed and the percentage cover of each species present was recorded. It is recommended that additional 2 m x 2 m quadrats should be recorded in non-Annex saltmarsh habitat (brackish and freshwater swamps, *Elytrigia* swards and other transitional habitats) to get a full complement of vegetation data for the entire saltmarsh system within each water body.

8.2.5 Pressures analysis – future prospects

The future prospects component of the conservation status assessment is based on the occurrence and intensity of various pressures and threats recorded as impacting on the Annex I saltmarsh habitats. In a change since the SMP was carried out, all impacts and activities should follow the standard list of Ssymank (2010). In terms of the WFD, any pressures which may impact on the saltmarsh zones and/or the water body should be listed using the EPA's system of recording risks. The current list will have to be expanded however to include risks such as grazing, soil eutrophication and land reclamation. Ideally, an estimate of area impacted upon and the intensity of the pressure should also be given.

8.3 LiDaR data

8.3.1 LiDaR sources

During this study, LiDaR data were obtained from two sources, the INFOMAR project (www.infomar.ie) and the Office of Public Works (OPW) (Table 8.2). The INFOMAR project (Integrated Mapping for the Sustainable Development of Ireland's Marine Resource) is conducted jointly by the Geological Survey of Ireland and the Marine Institute. Data were available from the project website for a number of bays along the west coast. The OPW have a collation of coastal LiDaR datasets recorded primarily for the purposes of coastal flood defence planning. Data were available for the entirety of the east and southeast coasts and selected coastal settlements in the southwest.

8.3.2 Modelling methodology

LiDaR data were used to model the HAT line which provides a good estimation for the upper limits of the development of potential saltmarsh vegetation.

Available INFOMAR data had 5 m spacing between points and used Lowest Astronomical Tide (LAT) as the vertical datum. To convert from LAT to HAT, the VORF 2.0 (Vertical Offshore Reference Frame) application (University College London/United Kingdom Hydrographic Office) was used. Each point in the LiDaR data within the coverage of the VORF model was independently converted.

Available OPW data typically had 2-3 m spacing between points and used Malin Head (MH) as the vertical datum. To convert from MH to HAT, MH data were first converted to the ETRF (European Terrestrial Reference Frame) datum. For each water body, this conversion was based on the difference between these two reference systems as calculated by the Grid Inquest 7.0.0 application (Ordnance Survey) at a single, subjectively chosen point associated with that water body. The VORF model was then used to convert each point independently from ETRF to HAT. For Wexford Harbour, there were significant areas of the North and South Slobs which lay outside the limits of the VORF model. Each of these areas were converted from ETRF to HAT using the difference between these two reference systems as calculated by VORF 2.0 at single, subjectively chosen points on the boundary of the model envelope (North Slobs = 56.97 m, South Slobs = 57.10 m).

The GRASS tools plugin for QGIS 2.0.1 was used to convert the resulting HAT point shapefiles to rasters with 5 m x 5 m cells and to produce HAT contours from these rasters.

8.4 Other considerations

First and foremost, it is important to highlight that this project was desk-based, with the development and testing of SMAATIE carried out using available data. The project team recommends that a feasibility test by nature of a field trial should be carried out before the tool is applied to other Irish TraC water bodies containing saltmarsh. EQR values obtained from this tool must be taken to have a low confidence level as this is the first edition of this tool and the data used were not directly applicable. The most up-to-date data available were taken from the SMP project in which data were recorded between 2006 (McCorry, 2007) and 2007-2008 (McCorry and Ryle, 2009a). It is highly recommended that another round of saltmarsh surveying and assessment be carried out, particularly after the winter storms of 2013-2014, following the adapted methodology as outlined in this chapter before applying SMAATIE. As the data currently available for SMAATIE is between five and seven years old, it may not reflect the current saltmarsh condition within the water bodies and therefore any EQR values calculated from this may be misleading. Also, as already discussed, some of this data were not recorded at a fine enough level to fully apply the metrics developed.

Hydromorphological elements were beyond the remit of this project but they should be examined in conjunction with the biological elements. Often pressures on saltmarshes (and therefore water quality) are more readily seen by morphological elements than by angiosperms, as there is often a time lag between an activity and the visible effect on vegetation. Wanner *et al.* (2007) took this approach in their assessment tool, where they looked at flooding dynamics (number of creeks and salt pans), intensity of drainage and restriction of flooding (dikes). One of the HD assessment attributes for the structure and functions of Annex I saltmarsh habitats is “Physical structure – creeks and pans”, which assesses the condition of these structures (McCorry and Ryle, 2009a). Due to the recommendation that the assessments of saltmarshes for the HD and WFD be combined in the one field survey, this hydromorphological element will be covered. The presence of drainage ditches and dikes should also be recorded in the future prospects (HD) / pressure analysis (WFD) for saltmarsh habitats.

The presence of *Spartina* is difficult to assess in terms of the WFD and HD as its presence has both positive and negative implications for saltmarshes. McCorry and Ryle (2009a) suggest that any available resources should be used to prevent the spread of this non-native genus to new sites and to remove new populations, but that eradication where it is well established is not a viable action. They also suggest however that *Spartina* swards should perhaps be treated as a pioneer saltmarsh community. Due to the level of uncertainty in where the threshold between net positive and negative effects of *Spartina* swards actually lies in terms of relative *Spartina* abundance, we took a cautionary approach to the presence of this genus. This should be revisited in light of any ensuing conservation measures or management plans that may develop in the future in regards to the status and possible control of this species.

Table 8.2. Availability and coverage of LiDaR data for the forty selected water bodies. For the OPW datasets, the single point correction from Malin Head to ETRF vertical datum is shown.

MS Code	Name	Data source	Coverage	MH-ETRF correction
WE_200_0000	Kilkieran Bay	INFOMAR	High	-
NW_050_0100	Inner Donegal Bay	INFOMAR	High	-
WE_170_0000	Inner Galway Bay North	INFOMAR	High	-
WE_200_0200	Camus Bay	INFOMAR	High	-
WE_470_0100	Garavoge Estuary	INFOMAR	High	-
WE_420_0000	Killala Bay	INFOMAR	Medium	-
WE_460_0300	Ballysadare Estuary	INFOMAR	High	-
NW_200_0000	Mulroy Bay Broadwater	INFOMAR	High	-
WE_420_0300	Moy Estuary	INFOMAR	Medium	-
NW_100_0000	Northwestern Atlantic Seaboard (HAs 37;38)	INFOMAR	Very low	-
WE_350_0100	Westport Bay	INFOMAR	High	-
WE_170_0700	Corrib Estuary	INFOMAR	High	-
WE_340_0000	Clew Bay	INFOMAR	Medium	-
WE_350_0000	Inner Clew Bay	INFOMAR	High	-
NW_220_0100	Swilly Estuary	INFOMAR	High	-
SW_080_0100	Lower Bandon Estuary	OPW	Low	57.22
SE_140_0100	Colligan Estuary	OPW	High	56.28
NB_040_0000	Outer Dundalk Bay	OPW	High	56.81 (N) 56.63 (S)
SE_100_0500	Lower Suir Estuary (Little Island - Cheekpoint)	OPW	Medium	56.27
NB_040_0100	Inner Dundalk Bay	OPW	High	56.81
EA_010_0100	Boyne Estuary	OPW	High	56.30
SW_020_0100	Lower Blackwater M Estuary / Youghal Harbour	OPW	Medium	56.22 (N) 56.55 (S)
SE_100_0200	New Ross Port	OPW	Medium	56.27
EA_050_0100	Rogerstown Estuary	OPW	High	56.07
SE_040_0200	Lower Slaney Estuary	OPW	Medium	56.23
EA_060_0000	Malahide Bay	OPW	High	56.07
SE_120_0000	Tramore Back Strand	OPW	High	56.27 (N) 56.28 (W)
SE_040_0000	Wexford Harbour	OPW	High	56.23
NB_040_0200	Castletown Estuary	OPW	High	56.81
WE_390_0100	Tullaghan Bay	-	None	-
WE_160_0100	Kinvarra Bay	-	None	-
SW_190_0200	Kilmakilloge Harbour	-	None	-
SW_140_0000	Roaring Water Bay	-	None	-
SH_060_0000	Mouth of the Shannon (HAs 23;27)	-	None	-
NW_120_0100	Gweebarra Estuary	-	None	-
SW_230_0200	Castlemaine Harbour	-	None	-
SH_060_1100	Fergus Estuary	-	None	-
SH_060_0300	Lower Shannon Estuary	-	None	-
SH_060_0800	Upper Shannon Estuary	-	None	-
SW_190_0000	Outer Kenmare River	-	None	-

There are arguments for and against the use of either historical saltmarsh extent or potential saltmarsh area as a metric or part thereof, for angiosperm abundance. The UK tool (UKTAG, 2013) looked at both saltmarsh extent as a proportion of historic saltmarsh and also recent change in saltmarsh extent, with a higher importance attached to recent changes. Adolph and Arens (2011) based their reference condition on the historic saltmarsh area in 1860, after the majority of diking activities had been completed. They felt that basing the reference condition prior to this situation “could neither be quantified nor be restored” (Adolph and Arens, 2011). Wanner *et al.* (2007), on the other hand, decided not to use a historical reference due to a lack of adequate data and maps for the time prior to land reclamation. Instead they went with the potential coastal marsh area, similar to the $Area_{PSA}$ in SMAATIE. While both historical and potential saltmarsh area are theoretically quite different, the outcome is essentially the area of saltmarsh that would (or should) be present if anthropogenic alterations to flooding dynamics were removed (or never existed). Land reclamation is a large scale morphological pressure that cannot be ignored. In many cases it is unrealistic and financially unviable to re-flood productive reclaimed land, however the possibility of managed retreat should not be totally disregarded. McCorry and Ryle (2009a) mentioned that there are a number of sites around the coast of Ireland where managed retreat would be a practical management option, particularly in abandoned, unproductive areas. They further discuss the possibility of including managed retreat within any future agri-environment schemes in Ireland.

Following on from this, the proportion of saltmarsh area to area of the water body should not be ignored. As seen in Table 7.3, this proportion for the representative forty water bodies was quite low (presented at a RBD level). While this may be partially due to the large size of some of the water bodies within the RBDs, it is also due to land reclamation in some areas, reducing the size of saltmarsh extent (as evident by low EQR values for Area in Table 7.6). Wanner *et al.* (2007), in assessing the coastal marshes of the German Baltic Sea, only considered water bodies for assessment if the potential coastal marsh area comprised at least 250 ha or at least 10% of the combined area of water and potential coastal marsh area. The potential impact of marshes on the ecological quality of other water bodies was not deemed relevant due to a lack of sufficient area in proportion to the water bodies. There is therefore an argument against applying SMAATIE to all TraC water bodies in Ireland as, in some cases, due to the low proportional size of saltmarsh habitat relative to water body area, the presence of saltmarsh may have no significant bearing on the overall ecological status for that water body.

When deciding if water bodies meet with any given threshold values and are worthy of assessment, $Area_{PSA}$ should ideally be taken into account. Otherwise the selection of future water bodies for assessment will be biased against water bodies currently containing really degraded examples of saltmarsh, or indeed, water bodies where all previously existing saltmarsh has been lost. This would give a false positive on the ecological quality of some of our water bodies. However, it was beyond the remit of this project to calculate $Area_{PSA}$ for every TraC water body (beyond the forty assessed in Chapter 7), but this will be a necessary step in the future in terms of selecting appropriate water bodies.

By using current saltmarsh area ($Area_{current}$) as a substitute for $Area_{PSA}$ in the interim, a suggested list of twenty water bodies additional to the original forty selected by this project can be compiled using a cut-off threshold of 10% proportion of saltmarsh to combined water body and saltmarsh area (Table 8.3). Note that lagoons have not been included in this list at the behest of the Steering Committee.

Table 8.3. Tentative list of additional water bodies for monitoring and assessment using SMAATIE in future monitoring phases.

MS_Code	Name	Type	Proportion saltmarsh to water body & saltmarsh area (%)	Current saltmarsh area (ha)
SH_100_0100	Inagh Estuary	TW2	66.11	114.35
EA_130_0100	Broad Lough	TW2	44.05	58.64
SE_090_0100	Corock Estuary	TW2	38.12	22.69
NB_040_0300	Ballymascanlan Estuary	TW2	36.62	43.38
EA_030_0100	Nanny Estuary	TW2	32.10	10.15
SW_030_0100	Womanagh Estuary	TW2	29.51	47.74
EA_080_0100	Mayne Estuary	TW2	28.36	54.34
SW_080_0300	Upper Bandon Estuary	TW2	26.55	12.45
NW_060_0100	Eany Water Estuary	TW2	24.80	2.47
SH_060_0600	Deel Estuary	TW2	21.47	73.84
SE_140_0200	Brickey Estuary	TW2	18.89	14.38
SH_050_0100	Lee K Estuary	TW2	16.83	60.17
SE_130_0100	Mahon Estuary	TW2	16.80	1.85
SE_080_0100	Bridgetown Estuary	TW2	15.35	33.37
SH_060_0700	Maigue Estuary	TW2	13.58	46.87
SW_060_0300	North Channel Great Island	TW2	12.67	101.95
SW_090_0200	Argideen Estuary	TW2	11.92	59.62
SH_060_1200	Clonderalaw Bay	TW2	11.13	44.34
SH_050_0000	Inner Tralee Bay	CW8	10.76	174.11
EA_090_0200	Tolka Estuary	TW2	10.49	41.90

Table 8.4. List of water bodies already assessed by SMAATIE to be retained for future monitoring and assessment for the saltmarsh element of the angiosperm BQE.

MS_Code	Name	Type	Proportion *saltmarsh to water body + *saltmarsh area (%)	Current *saltmarsh (ha)
NB_040_0200	Castletown Estuary	TW2	60.4	196.2
SW_020_0100	Lower Blackwater M Estuary / Youghal Harbour	TW2	47.5	1051.6
SE_040_0000	Wexford Harbour	CW8	43.5	1513.6
SE_100_0200	New Ross Port	TW2	43.4	492.2
SH_060_0800	Upper Shannon Estuary	TW2	39.6	2391.8
SH_060_1100	Fergus Estuary	TW2	35.5	3774.7
SE_120_0000	Tramore Back Strand	CW8	33.2	235.7
EA_010_0100	Boyne Estuary	TW2	27.2	104.4
EA_060_0000	Malahide Bay	CW8	26.0	75.2
SE_040_0200	Lower Slaney Estuary	TW2	25.3	612.8
EA_050_0100	Rogerstown Estuary	TW2	22.5	81.3
SW_230_0200	Castlemaine Harbour	TW2	22.2	1602.4
WE_460_0300	Ballysadare Estuary	TW2	18.9	390.4
NB_040_0100	Inner Dundalk Bay	TW2	15.7	559.3
NW_220_0100	Swilly Estuary	TW2	15.5	1079.2
SE_100_0500	Lower Suir Estuary (Little Island - Cheekpoint)	TW2	15.2	98.5
SH_060_0300	Lower Shannon Estuary	TW2	3.5	456.1
SH_060_0000	Mouth of the Shannon (HAs 23;27)	CW2	1.3	422.8

*Saltmarsh = current saltmarsh area + PSA

By applying the proposed 10% proportion cut-off threshold to the forty water bodies assessed by this project, but using both $Area_{current}$ and $Area_{PSA}$, only sixteen water bodies would remain selected (Table 8.4). An additional two water bodies could be retained as both have in excess of 400 ha of current or potential saltmarsh. Four of these eighteen water bodies have an EQR value equivalent to Good, eleven to Moderate and three equivalent to Poor (Table 7.6).

9. Conclusions and Recommendations

9.1 Conclusions

This research project was undertaken to develop and apply a tool for the ecological status assessment of the saltmarsh component of the angiosperm BQE (Biological Quality Element) in coastal and transitional waters for the WFD (Water Framework Directive). Tools generated by other countries for this purpose in the Northeast Atlantic Geographical Intercalibration Group (NEA-GIG) were reviewed and assessed for suitability. The developed tool, Saltmarsh Angiosperm Assessment Tool for Ireland - SMAATIE, comprises metrics examining saltmarsh extent, the number of vegetation zones present, the relative proportion of these zones, the abundance of the non-native invasive plant *Spartina anglica* and the frequency of salt-tolerant native species. To assist in development, a vegetation classification for Irish saltmarshes was produced through fuzzy analysis of over 3,400 existing quantitative vegetation samples. Six classes of vegetation were defined describing the pioneer zone, lower marsh, middle marsh, upper marsh, upper transitional zone, and brackish swamps. To assist in mapping areas where saltmarsh habitat could potentially develop, modelling based on LiDaR (Light Distance and Ranging) data and historical map interpretation were used. The tool was tested using available data for a selection of forty water bodies. Of these, four (10.0%) had an ecological status of High, fifteen (37.5%) were Good, eighteen (45.0%) were Moderate and three (7.5%) were Poor. The main reason for water bodies failing to make Good status was scoring poorly under the area metric due to widespread land reclamation. An overview of the application of the tool is presented in Fig. 9.1

The outputs from the project, which can be downloaded from the EPA SAFER website (http://erc.epa.ie/safer/), consist of:

- This main report
- A Practitioner's Manual for application of SMAATIE
- An EQR calculator in Microsoft Excel© format
- Parameter and EQR data for the forty selected water bodies in Microsoft Excel© format
- Pressure data for all water bodies containing saltmarsh in Microsoft Excel© format
- GIS data in ESRI shapefile format:
    - Assignment of saltmarsh areas to water bodies
    - Potential Saltmarsh Area for the forty selected water bodies
    - Saltmarsh quantitative vegetation plots used in the vegetation analysis

There were a number limitations encountered during the project and consequently a number of recommendations; these are summarised in the following sections.

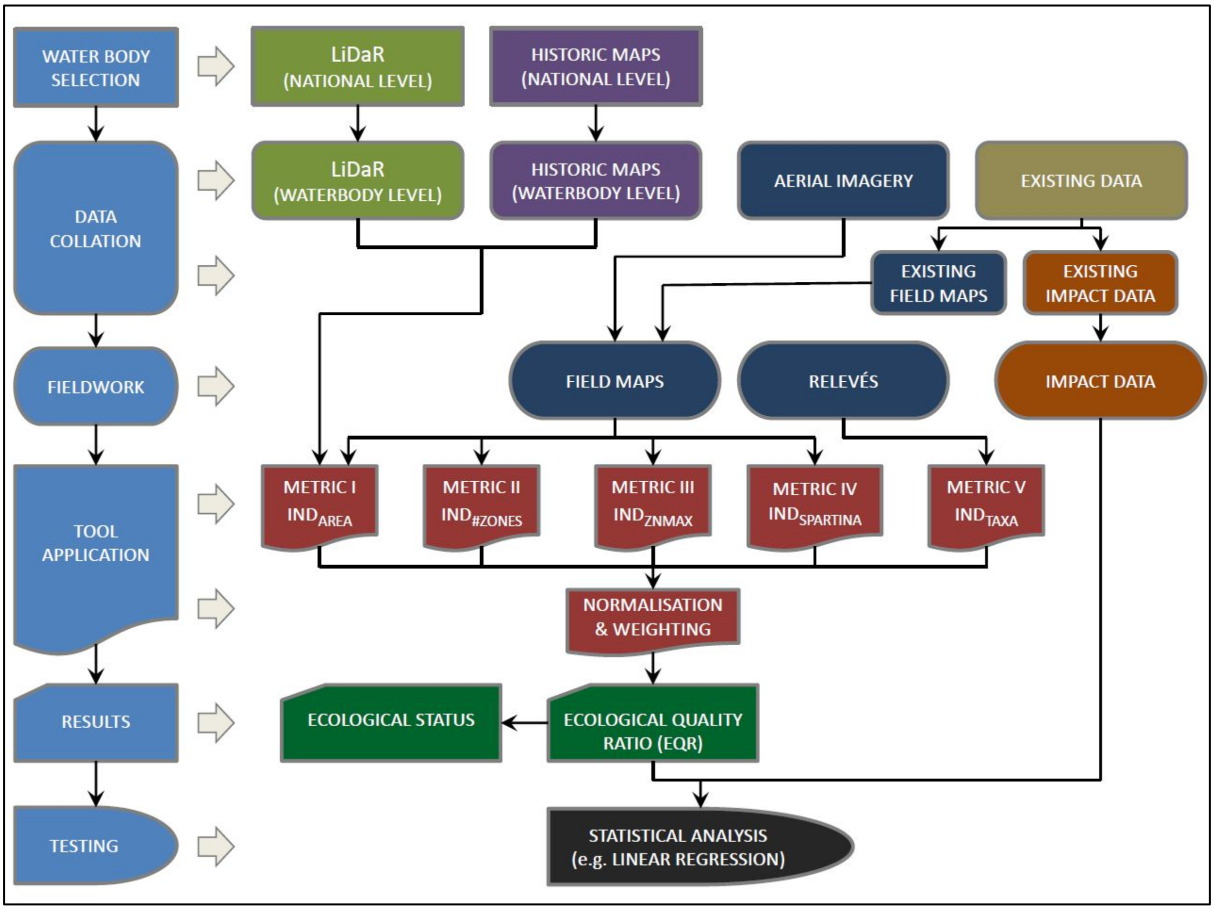


Figure 9.1. Flow diagram identifying the main steps involved in the application of SMAATIE to Irish TraC waters

9.2 Limitations

SMAATIE has been developed using available data and ecological knowledge. When assessing the tool, the following limitations should be recognised:

1. Production of Highest Astronomical Tide (HAT) lines was limited by the availability of LiDaR data. This was obtained for only 29 of the 40 selected water bodies and with varying degrees of coverage. Calculation of HAT lines was also limited by the scope of the Vertical Offshore Reference Frame (VORF) model which did not extend far enough inland for some water bodies (e.g. Wexford Harbour). HAT data substantially increased the accuracy of the Potential Saltmarsh Area (PSA) estimates.
2. The definition of reference conditions/values for saltmarsh area was also limited by lack of information on past and historical extent of saltmarsh. The Saltmarsh Monitoring Project (SMP) was a baseline survey and therefore changes in saltmarsh extent in the recent past could not be calculated. The Ordnance Survey six inch maps are spatially accurate in general terms but not explicit in defining areas of saltmarsh. The definition of reference conditions/values for area in terms of the minimum area required for functional ecosystem services is desirable but was beyond the scope of this project.

3. Development of the zones metrics was limited by the habitat categories recorded by the SMP. The categories used were Habitats Directive (HD) Annex I habitat categories and an ‘Other saltmarsh’ category. The HD Annex I habitat 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae) essentially includes two zones, the Puccinellion maritimae and the Armerion maritimae (lower and middle marsh). The ‘Other saltmarsh’ category combines *Elytrigia* swards and brackish swamp of reed or sedges. This lack of distinction within the dataset was problematic.
4. Calculation of the area and zone metrics was limited as not all areas of mapped saltmarsh had been field surveyed. Areas mapped during a previous desktop study are unverified; they may not be genuine saltmarsh habitat, or if they are, the habitat categories assigned to them may not be correct. This introduced a degree of uncertainity to the relevant EQR values.
5. Development of the taxa metric was limited by lack of knowledge about tipping points in species diversity and how this relates to ecosystem functioning. Therefore the target of 15 species was developed based on expert judgement and does not represent any data-derived threshold.
6. Development of the taxa metric was also limited by the lack of reliable historical species lists. This meant that species checklists specific to each water body could not be used as they have been, for example, in the UK. Use of a generic national list of halophytes was, however, improved by including rare species which would give some saltmarsh sites local distinctiveness.
7. The selection of water bodies for testing of the tool was limited by the availability of pressure / status data and by the coverage of the SMP. Pressure / status data were required to test the performance of the tool. Some areas of saltmarsh in the SMP dataset have not been ground-truthed and lack vegetation plot data; habitat and plot data are necessary for implementation of the tool.
8. Comparisons with pressure / status data were limited by the scope, nature and accuracy of the pressures recorded and the method of defining status. The SMP recorded pressure data only for Annex I habitats and for each of these habitats individually, not at an ecosystem level. Furthermore, the SMP did not record land reclamation that had occurred prior to 1995; these habitat losses have a major impact on the results produced by the tool. Pressure categories recorded by the EPA did not cover some topics pertinent to saltmarshes, such as grazing pressure, soil eutrophication, erosion and land reclamation. Moreover, there are intrinsic (and possibly extreme) difficulties in linking ecological measurements to specific human pressures.
9. Irish TraC (transitional and coastal) water bodies as currently delineated by EPA shapefiles are bounded on the landward side by the MHW (Mean High Water) mark rather than the recommended HAT line. As a result the majority of saltmarsh actually currently occurs outside the officially delineated areas for these water bodies. This had consequences when assigning areas of saltmarsh to TraC water bodies. It is also unclear, if as result of this divergence, if pressures unique within a given water body to saltmarsh would have been included in the EPA pressure assessment procedure. Also in relation to delineation of water bodies, the upper limit of transitional waters is intended to be the upper limit of tidal influence, thus bringing tidal freshwater sections of rivers and estuaries into these water bodies and tidal freshwater swamp into the remit of this tool. There is some inconsistency in the application of this delineation (e.g. the River Bride and Finisk River sections of the Lower Blackwater Estuary / Youghal Harbour water body).
10. The production of the classification system was limited by the availability of plot data. Whilst the dataset used was relatively large (nearly 3,500 plots) and covers the major range of saltmarsh

vegetation diversity, further recording could elucidate the communities with small sample sizes (e.g. *Elytrigia* swards). Not all plants in the dataset had been recorded to species level and consequently some data had to be combined at the genus level. Data on algal species had been inconsistently recorded.

11. It was beyond the remit of this project to calculate PSA for every TraC water body; therefore the list of water bodies provided for future saltmarsh monitoring is limited being based only on current extent of saltmarsh. Feasibily, water bodies with a high potential for saltmarsh but a low current extent have been overlooked.
12. This project was solely desk-based, therefore there was no scope within the project for field-testing the methodology. Field-testing would have facilitated insight into practical aspects of applying the tool.

9.3 Recommendations

9.3.1 Tool-specific recommendations

Following on from these limitations, the following specific recommendations are made for improving and applying the tool in the future:

1. LiDaR data should be obtained or specifically recorded for areas where they are currently lacking to enable more accurate definition of areas where saltmarsh may potentially develop. Consultation should be made with the developers of the VORF model to investigate amending its landward limits.
2. Future rounds of monitoring should map saltmarsh habitats using the zones and communities defined by this project. Where intimate mosaics of saltmarsh zones or communities occur, the percentages of the different elements should be recorded as proportions within polygons.
3. Field surveyors should record *Salicornia* spp., *Spergularia* spp. and *Cochlearia* spp. at a species level rather than genus level where possible when recording plots; it is acknowledged that *Salicornia* in particular can be quite difficult to identify to species level at certain times of the year. Recording of algal species (e.g. turf fucoids) is also recommended.
4. Potential Saltmarsh Area should be calculated for all TraC water bodies before the list of water bodies selected for future saltmarsh monitoring is finalised. Although lagoons were not assessed by this first version of the tool at the behest of the Steering Committee, lagoonal water bodies can and should be assessed in the future using later versions of the tool.
5. The classification of individual saltmarshes using the types of Curtis and Sheehy Skeffington (1998) (bay, estuary, fringe, lagoon and sandflat) should be reviewed.
6. The tool should be field-tested as soon as possible and thresholds (e.g. the *Spartina* metric class boundaries) should be reviewed once the field test has occurred. Once the tool has been field-tested and revised it should be applied to all relevant water bodies.

9.3.2 General recommendations

The following general recommendations are also relevant to application of the tool:

1. A research programme into the functioning of Irish saltmarsh ecosystems should be conducted. This should include definition of ecosystem services and modelling of ecosystem functions. This research would assist in quantitatively and objectively defining minimum requirements for saltmarsh extent.

2. A research programme should be conducted to investigate and define the relationships between human pressures (e.g. eutrophication, grazing pressure, *Spartina* extent) and ecological measurements from Irish saltmarshes. As part of this research programme, pressure data specific to saltmarshes as identified by this report should be collected.
3. Based on the findings of the proposed pressures research programme, potential additional metrics should be considered, such as the use of disturbance indicator species (e.g. the absence of *Atriplex portulacoides* could indicate overgrazing, while a dominance of *Agrostis stolonifera* may indicate eutrophication) and trends in *Spartina* extent.
4. Future rounds of saltmarsh monitoring should continue to examine the relationship between pressure gradients (based on the best available current data) and the tool's metrics (updated as necessary). This step is vital for the intercalibration process and to the ultimate acceptance of the tool by the EU.
5. Recent change in saltmarsh area should be considered as an additional metric for the angiosperm abundance element. This metric would compare current extent with the extent recorded in the previous rounds of monitoring.
6. Species checklists specific to each water body should be considered in an additional metric for the disturbance sensitive taxa element. This metric would compare current species lists with those from previous rounds of monitoring.
7. The EPA should redefine TraC water bodies so that the landward boundary is delineated by HAT. The upper riverine limits of transitional water bodies should be reviewed so that the extent of tidal freshwater is consistently identified. Assignment of saltmarsh areas to water bodies can then be made on a more objective basis.
8. More quantitative vegetation data (from relevés or monitoring plots) is required for poorly studied saltmarsh communities. This should be collected as part of the aforementioned research programmes or as part of the HD/WFD monitoring programme.
9. For practical purposes, collection of field data for WFD saltmarsh assessment should be a combined operation with collection of field data for HD Article 17 saltmarsh assessment. Data will need to be recorded in a format or formats compatible with the requirements of both Directives. Liaison between the EPA and NPWS is required in this regard.

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Acronyms

AQI	Angiosperm Quality Index
AQUA-Index	Angiosperm Quality Assessment Index
ASW	Average Silhouette Width
BQE	Biological Quality Element
CEP	Central European Phytosociology
CuWB	Current Water Body
CWBs	Coastal Water Bodies
DPSIR	Driver, Pressure, State, Impact, Response
EPA	Environmental Protection Agency
EQR	Ecological Quality Ratio
EQSs	Environmental Quality Standards
ETRF	European Terrestrial Reference Frame
EU	European Union
FQI	Floristic Quality Index
GEP	Good Ecological Potential
GIGs	Geographical Intercalibration Groups
GIS	Geographical Information Systems
GPS	Global Positioning System
HAT	Highest Astronomical Tide
HD	Habitats Directive
HFL	Historical Foreland
HWB	Historical Water Body
IndVals	Indicator Values
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
IPPC	Integrated Pollution Prevention and Control
IRWC	Irish Ramsar Wetlands Committee
ISA	Indicator Species Analysis
LAT	Lowest Astronomical Tide
LiDaR	Light Detection and Ranging
MAVIS	Modular Analysis of Vegetation Information System
MDIs	Marine Direct Impacts
MEP	Maximum Ecological Potential
MH	Malin Head
MHW	Mean High Water
MS	Member States
NEA-GIG	Northeast Atlantic Geographical Intercalibration Group
NHAs	Natural Heritage Areas
NMS	Non-metric Multidimensional Scaling
NPWS	National Parks and Wildlife Service
NVC	National Vegetation Classification
NVD	National Vegetation Database
OPW	Office of Public Works
OS	Ordnance Survey

OSPAR	Oslo-Paris Convention (for the protection of the marine environment of the North-East Atlantic)
PARTANA	Partition Analysis
PCA	Principal Component Analysis
P-GES	Potential Good Ecological Status
pNHAs	Proposed Natural Heritage Areas
P-REF	Potential Reference Condition
PSA	Potential Saltmarsh Area
RBDs	River Basin Districts
SACs	Special Areas of Conservation
SIRs	Sites Inspection Reports
SMAATIE	Saltmarsh Angiosperm Assessment Tool for Ireland
SMP	Saltmarsh Monitoring Project
SPAs	Special Protection Areas
STI_M	Standorttypeindex-Makrophyten
TBT	Tributyltin
TraC	Transitional and Coastal
TSAS	Trophic Status Assessment Scheme
TWBs	Transitional Water Bodies
UWWT plants	Urban Wastewater Treatment Plants
VI	Vormindex (shape index)
VORF	Vertical Offshore Reference Frame
WFD	Water Framework Directive
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant

Appendix 1

Table A1.1 Vegetation plot datasets collated for the analysis of Irish saltmarsh vegetation, indicating cover scale and number of plots used. A indicates plots from non-remit habitats, B indicates plots with removed genus level records >5%, C indicates recording errors, D indicates plots without data after other amendments.

Source	No. plots	Excluded plots				No. plots used	Cover scale	Geographic area
		A	B	C	D			
Beckers *et al.* (1976)	336	303	1	0	0	32	Braun-Blanquet (extended)	Co. Mayo
Bleasdale & Conaghan (1999)	31	23	0	0	0	8	Domin	Co. Cork
Boorman (1967)	89	0	0	0	0	89	Domin	National
Braun-Blanquet & Tüxen (1952)	20	0	0	10	0	10	Braun-Blanquet (original)	National
Brock *et al.* (1978)	365	340	3	0	0	22	Braun-Blanquet (extended)	Co. Mayo
Delaney (2002)	83	0	0	0	0	83	Braun-Blanquet (original)	Co. Galway
Hatch (1996)	282	105	0	0	0	177	Percentage	National
Irvine (2004)	50	0	0	0	0	50	Braun-Blanquet (original)	Co. Dublin
Ivimey-Cook & Proctor (1966)	29	0	0	0	0	29	Domin	Co. Clare
Kelly (2010)	62	0	0	0	0	62	Braun-Blanquet (original)	Co. Galway
McCorry (2007)	361	0	1	0	8	352	Modified Domin	National
McCorry & Ryle (2009a)	1,432	0	2	0	4	1,426	Modified Domin	National
Murphy (1987)	44	0	0	0	0	44	Braun-Blanquet (original)	Co. Galway
Murray (2003)	51	0	0	0	0	51	Percentage	Co. Dublin
Ní Lamhna (1982)	147	75	0	0	0	72	Braun-Blanquet (original)	Co. Dublin
O'Connor (1992)	54	0	0	0	0	54	Braun-Blanquet (original)	Co. Galway
Roden (1998)	226	92	0	0	0	134	Braun-Blanquet (original)	National
Roden (2002)	115	0	4	0	0	111	Braun-Blanquet (original)	Co. Wexford
Springer (1999)	71	3	0	0	0	68	Braun-Blanquet (original)	Co. Galway
Wymer (1984)	191	34	14	0	0	143	Braun-Blanquet (original)	National
J.R. Martin (unpubl.)	3	0	0	0	0	3	Domin	Co. Limerick
O. Ní Annrachain (unpubl.)	206	145	0	0	0	61	Braun-Blanquet (original)	Co. Dublin
Members of Department of Botany University College Dublin (unpubl.)	416	7	20	1	2	386	Braun-Blanquet (original)	National
Total	**4,664**	**1127**	**45**	**11**	**14**	**3,467**		

Appendix 2

Table A2.1 Average silhouette widths (ASW) and PARTANA ratios for k = {2, 3, 4, …, 6} from fuzzy analysis of data subsets representing the six saltmarsh classes. Data are presented for the full data subsets (fuzzy) and for these subsets after exclusion of transitional plots (crisped). Greyed lines indicate the number of communities (k) chosen for each class.

		Fuzzy			Crisped		
	k =	*n* =	ASW	PARTANA	*n* =	ASW	PARTANA
Class 1	2	154	0.52	4.7	153	0.53	4.8
	3	154	0.40	2.6	150	0.42	2.7
	4	154	0.37	2.4	146	0.37	2.3
	5	154	0.37	2.4	142	0.42	2.5
	6	154	0.36	2.4	150	0.38	2.5
Class 2	2	923	0.20	1.3	803	0.25	1.4
	3	923	0.18	1.3	713	0.25	1.5
	4	923	0.14	1.3	625	0.22	1.5
	5	923	0.14	1.4	620	0.23	1.5
	6	923	0.13	1.4	614	0.22	1.5
Class 3	2	722	0.21	1.4	646	0.26	1.5
	3	722	0.21	1.4	622	0.26	1.5
	4	722	0.17	1.4	568	0.23	1.5
	5	722	0.15	1.4	545	0.22	1.5
	6	722	0.13	1.4	508	0.20	1.5
Class 4	2	562	0.20	1.2	510	0.23	1.3
	3	562	0.15	1.2	458	0.20	1.3
	4	562	0.16	1.3	437	0.22	1.3
	5	562	0.13	1.3	421	0.18	1.3
	6	562	0.13	1.3	410	0.19	1.4
Class 5	2	284	0.16	1.5	240	0.21	1.6
	3	284	0.16	1.6	238	0.20	1.8
	4	284	0.16	1.7	213	0.24	1.9
	5	284	0.14	1.7	215	0.23	1.9
	6	284	0.14	1.8	205	0.22	2.0
Class 6	2	211	0.26	4.2	201	0.28	5.2
	3	211	0.33	5.1	199	0.36	6.4
	4	211	0.38	6.4	199	0.42	8.4
	5	211	0.33	5.4	186	0.39	7.1
	6	211	0.33	5.7	193	0.39	6.3

Notes: For classes 1 and 6, the choice of number of communities was simplified as one value of *k* produces markedly higher scores for both ASW and PARTANA. For classes 2-5, there is typically less differentiation between values of *k* and contrary trends of increasing PARTANA scores and decreasing ASW scores. For these classes, greater emphasis was placed on ecological interpretation.

Appendix 3

Table A3.1 Minimum, median and maximum Domin scores for taxa in Irish saltmarsh communities defined by fuzzy analysis. Only species with frequency ≥ 12% for at least one community are shown. IndVal indicates the percentage indicator value of each species. Greyed figures indicate the vegetation class or classes (1-6) for which species are indicators. Dotted lines group species which are indicators or the same class of classes. Columns continue on a second panel.

	Community											
	1a	1b	2a	2b	2c	2d	2e	3a	3b	3c	3d	IndVal
Salicornia spp.	2-(3)-6	2-(5)-9	2-(5)-9	2-(3)-6	2-(3)-5	1-(3)-5	2-(3)-6	2-(3)-4	2-(3)-3	.	.	77
Spartina spp.	7-(8)-10	2-(3)-5	2-(3)-7	2-(4)-8	2-(3)-5	2-(3)-4	2-(3)-7	3-(3)-3	2-(3)-3	3-(3)-3	3-(3)-3	66
Limonium humile	3-(3)-3	2-(3)-5	2-(3)-8	2-(3)-7	2-(3)-6	2-(3)-5	2-(3)-7	2-(3)-5	2-(3)-5	2-(3)-4	2-(2)-2	55
Suaeda maritima	.	2-(3)-9	2-(3)-8	2-(3)-5	2-(3)-5	2-(3)-7	1-(3)-5	2-(3)-3	1-(3)-3	2-(3)-3	.	50
Atriplex portulacoides	2-(2)-2	2-(3)-4	2-(2)-5	3-(7)-9	3-(3)-4	.	2-(3)-7	2-(3)-7	2-(3)-5	3-(3)-4	3-(3)-3	37
Puccinellia maritima	2-(2)-2	2-(3)-3	3-(7)-9	3-(6)-9	7-(9)-10	5-(7)-9	2-(5)-7	2-(3)-5	2-(3)-5	2-(3)-7	3-(4)-5	94
Spergularia spp.	.	2-(3)-3	2-(3)-5	2-(3)-5	2-(3)-7	2-(3)-5	2-(3)-5	2-(3)-3	2-(3)-7	2-(3)-3	2-(3)-3	59
Plantago maritima	.	3-(3)-3	2-(2)-5	2-(3)-6	1-(3)-4	2-(3)-6	2-(7)-9	2-(3)-7	3-(7)-9	2-(4)-8	2-(3)-7	83
Armeria maritima	.	.	1-(3)-5	2-(3)-7	2-(3)-3	2-(4)-8	2-(5)-9	2-(3)-5	2-(5)-8	2-(3)-6	2-(3)-7	69
Aster tripolium	2-(4)-4	2-(3)-3	2-(3)-7	2-(3)-7	1-(3)-7	2-(3)-7	+-(3)-7	1-(3)-6	1-(3)-7	2-(3)-5	2-(3)-5	69
Triglochin maritima	2-(2)-2	3-(3)-3	1-(3)-3	2-(3)-4	+-(3)-6	2-(3)-7	2-(3)-7	2-(3)-5	1-(3)-7	2-(3)-7	2-(3)-5	58
Cochlearia spp.	.	2-(2)-2	2-(2)-5	2-(3)-4	2-(3)-5	2-(3)-7	1-(3)-4	2-(3)-5	1-(3)-7	2-(3)-5	2-(3)-3	52
Limonium binervosum agg.	.	2-(2)-2	.	2-(5)-7	.	3-(3)-3	.	3-(3)-3	3-(3)-3	.	.	11
Festuca rubra	.	.	.	3-(4)-5	2-(3)-5	2-(3)-7	3-(4)-5	7-(9)-9	2-(5)-9	2-(5)-8	5-(8)-9	90
Glaux maritima	.	2-(3)-3	2-(3)-5	2-(3)-3	1-(3)-5	1-(3)-8	2-(3)-7	1-(3)-6	2-(3)-7	2-(3)-8	2-(3)-7	71
Juncus gerardii	.	3-(3)-3	3-(3)-3	.	2-(3)-4	2-(3)-7	2-(3)-4	2-(3)-5	2-(3)-5	5-(7)-9	2-(5)-7	68
Trifolium repens	.	.	.	.	.	.	.	3-(4)-4	3-(3)-3	2-(3)-5	2-(3)-7	35
Carex extensa	.	.	.	.	2-(2)-2	.	2-(2)-2	1-(3)-3	2-(3)-6	2-(3)-6	2-(3)-6	32
Plantago coronopus	.	.	3-(3)-3	.	3-(3)-3	3-(3)-5	2-(2)-3	2-(4)-7	2-(3)-5	2-(3)-8	2-(3)-7	35
Atriplex prostrata	2-(5)-5	2-(3)-4	2-(2)-3	3-(3)-3	2-(3)-5	2-(2)-2	2-(3)-3	2-(3)-5	3-(3)-3	2-(3)-3	2-(3)-4	29
Juncus maritimus	.	.	2-(3)-3	3-(3)-3	3-(3)-3	3-(5)-7	2-(3)-6	2-(3)-5	2-(3)-5	2-(3)-5	2-(3)-3	98
Agrostis stolonifera	.	.	.	.	2-(3)-5	2-(3)-3	2-(2)-2	2-(3)-3	1-(3)-7	2-(3)-7	3-(5)-8	80
Scorzoneroides autumnalis	.	.	.	.	3-(3)-3	.	.	3-(3)-3	3-(3)-3	2-(3)-4	2-(3)-5	50
Oenanthe lachenalii	.	.	.	.	.	.	.	.	.	2-(2)-3	3-(3)-3	30
Samolus valerandi	.	.	.	.	.	.	.	.	.	2-(2)-2	.	69
Potentilla anserina	.	2-(2)-2	.	.	.	.	.	3-(4)-5	.	2-(3)-3	2-(3)-4	33
Calliergonella cuspidata	.	.	.	.	.	.	.	.	.	.	.	28
Sagina nodosa	.	.	.	.	.	.	.	.	.	.	.	27
Centaurium pulchellum	.	.	.	.	.	.	.	.	.	.	.	25
Isolepis cernua	.	.	.	.	.	.	.	.	.	.	.	24
Carex nigra	.	.	.	.	.	.	.	.	.	.	.	23
Odontites vernus	.	.	.	.	.	.	.	.	.	.	.	21
Juncus bufonius	.	.	.	.	3-(3)-3	.	.	.	.	2-(2)-2	2-(2)-2	20
Lotus corniculatus	.	.	.	.	.	.	.	5-(5)-5	3-(3)-3	.	3-(3)-3	13
Trifolium fragiferum	.	.	.	.	.	.	.	.	.	.	.	12
Juncus articulatus	.	.	.	.	.	.	.	.	.	.	3-(3)-3	27
Triglochin palustris	.	.	.	.	.	.	.	.	2-(2)-2	2-(2)-2	.	27
Eleocharis uniglumis	.	.	.	.	.	.	.	.	.	.	3-(3)-3	24
Eleocharis palustris	.	.	.	.	.	.	.	.	.	.	.	20
Hydrocotyle vulgaris	.	.	.	.	.	.	.	.	.	.	.	20
Mentha aquatica	.	.	.	.	.	.	.	.	.	.	.	19
Galium palustre	.	.	.	.	.	.	.	.	.	.	.	18
Ranunculus flammula	.	.	.	.	.	.	.	.	.	.	.	16
Apium nodiflorum	.	.	.	.	.	.	.	.	.	.	.	15
Lythrum salicaria	.	.	.	.	.	.	.	.	.	.	.	14
Phragmites australis	.	3-(3)-3	3-(3)-3	.	3-(3)-3	.	.	.	.	2-(3)-3	3-(3)-3	49
Bolboschoenus maritimus	.	3-(3)-3	.	.	2-(3)-5	3-(3)-3	.	2-(2)-2	.	3-(3)-3	3-(3)-5	66
Schoenoplectus tabernaemontani	.	.	.	.	.	.	.	.	.	.	3-(3)-3	58
Ruppia spp.	.	.	.	.	.	.	.	.	.	.	.	29
Elytrigia repens	.	.	2-(2)-2	.	.	2-(2)-2	2-(2)-2	3-(3)-3	.	4-(4)-4	3-(3)-7	24
Potamogeton pectinatus	.	.	.	.	.	.	.	.	.	.	.	23
Equisetum fluviatile	.	.	.	.	.	.	.	.	.	.	.	13
Lemna minor	.	.	.	.	.	.	.	.	.	.	.	19
n =	**35**	**118**	**86**	**84**	**176**	**120**	**154**	**144**	**144**	**162**	**118**	

Table A3.1 continued

	Community											
	4a	**4b**	**5a**	**5b**	**5c**	**5d**	**5e**	**6a**	**6b**	**6c**	**6d**	**IndVal**
Salicornia spp.	2-(3)-3	.	.	.	.	3-(3)-3	.	.	3-(3)-3	.	3-(3)-3	77
Spartina spp.	2-(3)-3	3-(3)-3	.	3-(5)-6	.	3-(3)-3	.	.	.	.	4-(6)-7	66
Limonium humile	2-(3)-7	2-(3)-3	.	.	.	.	.	.	.	.	8-(8)-8	55
Suaeda maritima	2-(3)-3	.	.	.	.	.	.	.	.	.	5-(7)-8	50
Atriplex portulacoides	2-(3)-8	2-(3)-5	.	.	.	.	.	.	.	.	2-(8)-9	37
Puccinellia maritima	2-(2)-6	2-(3)-5	.	3-(5)-5	.	2-(2)-2	.	.	2-(3)-3	.	2-(4)-5	94
Spergularia spp.	2-(3)-8	2-(3)-3	2-(2)-3	2-(3)-3	.	2-(3)-3	2-(2)-2	.	4-(4)-5	2-(2)-2	2-(3)-4	59
Plantago maritima	1-(3)-8	2-(3)-6	2-(2)-3	3-(3)-3	3-(3)-3	2-(3)-3	.	.	2-(2)-2	.	2-(2)-2	83
Armeria maritima	2-(3)-7	2-(3)-4	2-(2)-2	5-(5)-5	.	3-(3)-3	.	.	.	.	.	69
Aster tripolium	2-(3)-5	2-(3)-4	3-(3)-3	3-(4)-5	.	2-(3)-7	2-(3)-5	3-(3)-3	2-(3)-7	.	.	69
Triglochin maritima	2-(3)-5	2-(3)-5	2-(2)-7	3-(3)-7	3-(3)-4	2-(3)-3	2-(2)-2	3-(3)-3	2-(3)-5	3-(3)-4	2-(3)-3	58
Cochlearia spp.	1-(3)-5	2-(3)-5	2-(2)-2	3-(3)-5	.	3-(3)-3	.	.	2-(2)-4	.	3-(3)-3	52
Limonium binervosum agg.	.	.	.	.	.	.	.	.	.	.	8-(8)-8	11
Festuca rubra	2-(3)-5	3-(7)-9	.	3-(3)-3	.	2-(2)-3	4-(4)-4	.	3-(3)-5	.	2-(3)-3	90
Glaux maritima	1-(3)-7	2-(3)-5	2-(3)-9	2-(3)-5	3-(5)-5	2-(3)-7	2-(3)-8	.	2-(3)-8	1-(3)-3	2-(3)-4	71
Juncus gerardii	2-(4)-9	2-(4)-7	2-(2)-2	2-(3)-5	3-(4)-4	5-(7)-9	2-(3)-7	.	2-(3)-7	2-(3)-3	2-(2)-3	68
Trifolium repens	2-(3)-3	2-(3)-7	2-(4)-4	2-(3)-5	.	2-(4)-5	2-(3)-3	.	.	.	3-(3)-3	35
Carex extensa	2-(3)-6	2-(3)-5	3-(3)-3	3-(3)-3	.	2-(3)-3	3-(3)-3	.	.	1-(1)-1	.	32
Plantago coronopus	2-(3)-5	2-(3)-7	2-(2)-2	2-(5)-5	2-(2)-2	2-(4)-7	2-(3)-3	.	.	.	2-(3)-3	35
Atriplex prostrata	2-(2)-4	2-(3)-5	3-(3)-3	3-(4)-9	.	2-(3)-5	2-(2)-3	.	2-(3)-5	.	3-(5)-9	29
Juncus maritimus	5-(8)-9	4-(7)-9	.	2-(3)-3	.	3-(3)-3	.	.	2-(3)-3	.	.	98
Agrostis stolonifera	1-(3)-8	2-(4)-8	2-(4)-7	6-(8)-10	3-(5)-7	2-(5)-8	2-(7)-9	3-(3)-5	2-(3)-7	2-(4)-9	2-(3)-5	80
Scorzoneroides autumnalis	2-(3)-5	2-(3)-5	2-(3)-3	2-(3)-3	3-(3)-3	1-(3)-4	2-(3)-5	.	2-(3)-3	.	3-(3)-3	50
Oenanthe lachenalii	1-(3)-3	2-(3)-5	.	3-(3)-3	3-(3)-3	2-(3)-3	3-(3)-3	.	2-(2)-2	1-(3)-3	.	30
Samolus valerandi	1-(3)-3	2-(3)-3	2-(4)-8	7-(7)-7	3-(3)-4	2-(2)-5	3-(4)-5	3-(3)-3	3-(4)-5	1-(3)-5	3-(3)-5	69
Potentilla anserina	3-(3)-3	2-(3)-5	3-(3)-3	3-(3)-3	2-(2)-2	2-(4)-7	2-(5)-9	3-(3)-3	2-(2)-2	.	2-(2)-2	33
Calliergonella cuspidata	.	.	3-(4)-4	.	.	.	.	.	.	.	3-(3)-3	28
Sagina nodosa	.	.	2-(3)-3	.	.	.	.	.	.	.	2-(2)-2	27
Centaurium pulchellum	.	.	.	.	.	2-(2)-2	2-(2)-2	.	.	.	.	25
Isolepis cernua	.	.	2-(3)-4	.	3-(3)-3	.	2-(3)-3	.	.	3-(3)-3	2-(2)-2	24
Carex nigra	.	.	2-(3)-3	2-(2)-2	3-(3)-3	2-(2)-2	2-(4)-5	.	.	3-(3)-3	5-(5)-5	23
Odontites vernus	.	.	.	2-(2)-2	.	3-(3)-3	2-(3)-3	.	.	.	.	21
Juncus bufonius	.	.	2-(3)-3	3-(3)-3	2-(2)-2	2-(3)-3	2-(3)-5	.	.	4-(4)-4	2-(3)-5	20
Lotus corniculatus	3-(3)-3	2-(3)-3	.	.	.	2-(3)-3	2-(3)-5	.	.	.	.	13
Trifolium fragiferum	.	.	.	.	.	2-(2)-2	2-(3)-5	.	.	.	.	12
Juncus articulatus	3-(3)-3	2-(3)-3	2-(3)-3	2-(2)-3	3-(3)-5	2-(2)-2	.	.	.	3-(3)-3	2-(3)-5	27
Triglochin palustris	.	3-(3)-3	2-(3)-5	3-(3)-3	2-(3)-3	2-(2)-2	3-(3)-3	.	3-(3)-3	2-(3)-3	2-(3)-4	27
Eleocharis uniglumis	3-(3)-3	.	.	3-(3)-3	3-(7)-8	6-(6)-6	3-(3)-5	.	.	4-(5)-8	2-(7)-8	24
Eleocharis palustris	5-(5)-5	.	4-(4)-4	7-(7)-7	3-(3)-7	.	3-(3)-3	.	2-(3)-4	3-(3)-4	6-(6)-6	20
Hydrocotyle vulgaris	3-(3)-3	3-(3)-3	3-(4)-4	.	3-(3)-3	.	3-(4)-5	3-(3)-3	.	4-(4)-4	3-(3)-3	20
Mentha aquatica	.	.	2-(2)-2	.	2-(2)-2	1-(1)-1	.	3-(3)-4	.	4-(4)-4	.	19
Galium palustre	.	3-(3)-3	2-(3)-3	3-(3)-3	.	2-(2)-2	2-(2)-2	3-(3)-3	.	.	2-(3)-3	18
Ranunculus flammula	.	.	2-(3)-3	.	2-(2)-2	2-(2)-2	.	.	.	3-(3)-3	2-(4)-5	16
Apium nodiflorum	.	.	3-(3)-4	.	.	.	.	3-(3)-4	3-(3)-3	4-(4)-4	.	15
Lythrum salicaria	3-(3)-3	3-(3)-3	.	4-(4)-4	2-(2)-2	.	2-(2)-2	3-(3)-5	.	.	.	14
Phragmites australis	1-(3)-5	3-(3)-3	.	3-(4)-10	2-(2)-2	.	2-(2)-2	5-(9)-10	2-(3)-7	3-(4)-4	2-(3)-4	49
Bolboschoenus maritimus	2-(3)-3	3-(3)-3	2-(3)-3	3-(4)-5	2-(3)-3	2-(4)-7	3-(4)-5	3-(3)-7	5-(8)-10	1-(4)-5	2-(3)-4	66
Schoenoplectus tabernaemontani	3-(3)-5	3-(3)-3	2-(2)-2	3-(4)-5	3-(3)-5	3-(3)-3	5-(5)-5	3-(4)-5	2-(4)-5	4-(7)-10	2-(3)-4	58
Ruppia spp.	.	.	.	.	.	.	.	4-(4)-4	3-(7)-8	3-(3)-3	3-(5)-9	29
Elytrigia repens	.	2-(3)-5	.	3-(4)-5	.	.	3-(3)-7	.	2-(2)-3	.	5-(10)-10	24
Potamogeton pectinatus	.	.	.	.	.	.	.	.	3-(3)-4	3-(4)-6	3-(7)-9	23
Equisetum fluviatile	.	.	.	.	.	.	.	3-(4)-8	.	.	.	13
Lemna minor	.	.	.	.	.	.	.	3-(5)-6	2-(3)-3	3-(3)-3	3-(3)-3	19
***n* =**	**240**	**270**	**23**	**54**	**18**	**65**	**55**	**34**	**70**	**42**	**53**	

Appendix 4

Table A4.1 Assignment of pressures recorded in the 138 water bodies (CWB and TWB) containing saltmarsh to pressure categories and sub-categories.

Pressure Category	Pressure Sub-Category	Pressure
Biology	Biological resource use other than agriculture	Fish and shellfish aquaculture Leisure fishing Professional fishing
	Grazing	Grazing Grazing: overgrazing by cattle Grazing: overgrazing by hares, rabbits, small mammals Grazing: overgrazing by sheep Grazing: undergrazing
	Invasive (non-native) species	Biocoenotic evolution: invasion by a species
Morphology	Erosion (anthropogenic)	Erosion
	Landfill, land reclamation and drying out	Impoundments Landfill, land reclamation and drying out, general Landfill, land reclamation and drying out, general: infilling of ditches, dykes, pools, marshes or pits Landfill, land reclamation and drying out, general: polderisation Landfill, land reclamation and drying out, general: reclamation of land from the sea, estuary or marsh
	Other natural system modifications	Deposition Dredging Dumping, depositing of dredged deposits Intensive landuse (lagoons) Removal of sediments (e.g. mud) Sand and gravel extraction: removal of beach materials
	Other urbanisation, industrial and similar activities	Built structures – port tonnage Built structures – power / industrial intakes Built structures – urban / industrial shoreline Other urbanisation, industrial and similar activites Urbanised areas, human habitation: discontinuous urbanisation
	Transportation and service corridors	Communication networks: bridge, viaduct Communication networks: paths, tracks, cycling tracks Communication networks: port areas Communication networks: routes, autoroutes Energy transport: electricity lines Energy transport: pipe lines
Other	Land management	Other agriculture and forestry activities Burning General forestry management Hunting Improved access to site
	Other agricultural activities	Cultivation: agricultural improvement Cultivation: mowing / cutting
	Other human intrusions	Trampling, overuse
	Outdoor sports, recreational activities and structures	Outdoor sports and leisure activities: motorised vehicles Outdoor sports and leisure activities: walking, horseriding and non-motorised vehicles Sport and leisure structures: camping & caravans Sport and leisure structures: golf course
Pollution	Eutrophication	Eutrophication OSPAR Comprehensive Procedure UWWT Regs Designations
	Other pollution	Fertilisation Hazardous substances Other pollution or human impacts / activities Pollution Pollution: water pollution
	Point	Combined sewer overflows and treatment plant overflows Discharges Discharges: disposal of household waste Discharges: disposal of industrial waste Discharges: disposal of inert materials Discharges: other discharges IPPC Section 4 (Local Authority licensed discharges) Waste Water Treatment Plants (WWTP) Water Treatment Plants (WTP)
Water regime	Dykes, embankments, artificial beaches	Coastal defences Dykes, embankments, artificial beaches, general Dykes, embankments, artificial beaches, general: sea defence or coastal protection works
	Modifications to hydrological functioning	Abstraction – water balance Channelisation Drainage Modification of hydrographic functioning, general Other human induced changes in hydraulic conditions