UKTAG Transitional and Coastal Water Assessment Method

Angiosperms

Saltmarsh Tool

by

Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG)

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Health and safety statement

WARNING. Working in or around water is inherently dangerous; persons using this standard should be familiar with normal laboratory and field practice. This published monitoring system does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate health and safety practices and to ensure compliance with any national regulatory guidelines.

It is also the responsibility of the user if seeking to practise the method outlined here, to gain appropriate permissions for access to water courses and their biological sampling.

UKTAG Guide to the Saltmarsh Tool
Water Framework Directive: Transitional and Coastal Waters

Purpose of document: To provide an overview of the saltmarsh tool to inform Practitioners of how to monitor, assess and classify suitable saltmarsh data according to Water Framework Directive (WFD) requirements in transitional and coastal waters.

Note: this document does not describe all aspects of the saltmarsh tool development and its application; for this please refer to the key documents and references provided within this document.

Introduction to WFD Terminology and Assessment: This guide describes a system for classifying in accordance with the requirements of Article 8; Section 1.3 of Annex II and Annex V of the WFD (2000/60/EC). Practitioners should recognise that the terminology used in this document is specific to the WFD and as such has a defined meaning.

To carry out a WFD biological assessment, each WFD defined biological quality element (BQE, defined in the WFD) is required to give a statistically robust definition of the 'health' of that element in the defined water body. The 'health' of a BQE is assessed by comparing the measured conditions (observed value) against that described for reference (minimally impacted) conditions. This is reported as an Ecological Quality Ratio (EQR). An EQR of one represents reference conditions and zero represents severe impact. The EQR is divided into five ecological status classes (High, Good, Moderate, Poor, Bad) that are defined by the changes in the biological community in response to disturbance (Figure 1).

Alongside the EQR score and class status, any assessment must consider the certainty of the assessment (i.e. confidence in the assigned class).

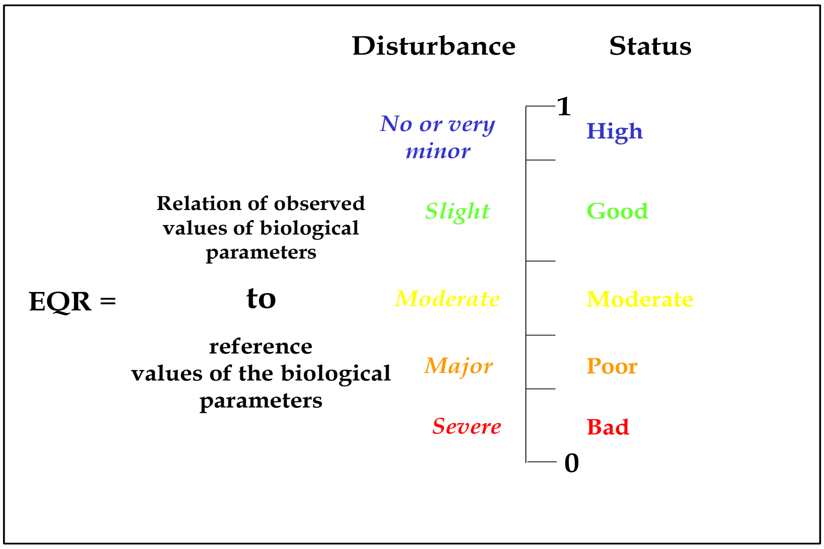

Figure 1: Illustration of the Ecological Quality Ratio and how it relates to the level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance (WFD CIS Guidance Document No. 5, 2003).

1. Key Facts

1.1 Tool Overview: Saltmarsh

The saltmarsh tool enables an assessment of the ecological health of the biological quality element, "angiosperms" as listed in Tables 1.2.3 and 1.2.4 of Annex V to the WFD (2000/60/EC). Seagrasses are the only true marine angiosperms (and are considered in a separate guide), however, within the WFD, saltmarsh is also considered as part of this biological element. The WFD requires that the assessment of the angiosperm quality element considers composition, abundance and disturbance sensitive taxa.

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

- saltmarsh extent as proportion of "historic saltmarsh"
- saltmarsh extent as proportion of the intertidal
- change in saltmarsh extent over two or more time periods
- proportion of saltmarsh zones present (out of five zones for England and Wales)
- proportion of saltmarsh area covered by the dominant saltmarsh zone
- proportion of observed taxa to historical reference value **or** proportion of observed taxa to 15 taxa.

Note: these metrics are currently only established for England and Wales.

The individual metrics have been weighted and averaged within the tool in order to best describe the changes in the saltmarsh in response to anthropogenic pressures. The saltmarsh tool was not reported in the first River Basin Cycle.

The saltmarsh tool operates over a range from 0 (a severe impact) to 1 (reference/minimally disturbed). The four class boundaries are:

- High/Good = 0.80
- Good/Moderate = 0.60
- Moderate/Poor = 0.40
- Poor/Bad = 0.20.

To calculate the saltmarsh tool the following information is required:

- areal extent of the saltmarsh (usually obtained from aerial imagery with groundtruthing)
- the area of each of the five saltmarsh zones
- a taxa list for the marsh.

1.2 Applicability

The saltmarsh tool is applied at the water body scale.

Where: The tool can be applied to all UK coastal and transitional waters where suitable saltmarsh occurs. However, it is not used for assessing saline lagoons due to the particular challenges in setting suitable type-specific reference conditions for these water bodies.

When: The saltmarsh is expected to be assessed at least once in every six year WFD reporting cycle, unless greater intervals can be justified on the basis of technical knowledge and expert judgement. As such the tool is able to classify data from a single sampling event.

Aerial flights and ground truthing generally takes place in the summer season (May/June to September), when saltmarsh growth is at its maximum and plants are easiest to identify. Similarly the summer should give the most cloud free days for the collection of aerial imagery. The ground truthing and flights do not have to be co-incident but should be at the same time of year and within +/- one year.

Response to pressure: The saltmarsh tool has been developed primarily to reflect the impact of hydromorphological pressures (and secondarily to other impacts such as nutrients).

1.3 Key Documents

The documents marked * will be hosted on the UK technical advisory group (UKTAG) website www.wfduk.org.

*Davey, A. (2013). Confidence of Class for Saltmarsh and Fucoid Extent WFD Classifcation Tools. WRc report for the Environment Agency No. UC9363.03

*Saltmarsh Key Indicators Processed Precisely and Estimated Robustly (SKIPPER v1.0) – *Excel workbook to estimate the precision of the assessment*.

*UKTAG Biological Status Methods: Coastal and Transitional Waters Saltmarsh – *High level non-technical summary.*

2. Background

2.1 Ecological principles

Saltmarsh vegetation consists of a limited number of halophytic (salt tolerant) species adapted to regular immersion by the tides. A natural saltmarsh system shows a clear zonation according to the frequency of inundation. At the lowest level the pioneer glassworts *Salicornia spp*. can withstand twice daily immersion (over 700 tides per year) while transitional species of the upper marsh can only withstand occasional inundation. Saltmarshes are naturally species poor, with approx. 40 species of higher plants found in British saltmarshes (Boorman *et al*., 1996). Species are highly adapted to survive extreme conditions including: submersion by tide; high soil salinity; and smothering by deposition of sediment (Boorman, 2003).

Saltmarshes are naturally dynamic systems; many show cycles of erosion and accretion within a given period that may span decades or centuries.

Boorman (2003) reviewed the sensitivity of saltmarsh to the factors affecting their development and these were divided into hydraulic and anthropogenic factors. Hydraulic factors include: wave climate (height, direction and frequency), currents (strength and direction), sediment water level, wind speed and direction, sediment supply and transport, relative sea level change, cyclical and secular changes in tidal range, the shape/gradient of tidal curve, storm frequency and the migration of main channel positions. The anthropogenic factors include: enclosure, ‘‘coastal squeeze’’, construction and development on marshes, grazing, ship and boat movements (e.g. return currents/waves/ water level draw down), dredging activities, localised mud digging, pollution, eutrophication, refuse disposal, and trampling (Boorman, 2003). The saltmarsh index was developed to respond to these pressures.

2.2 Normative definitions

In Annex V (1.2) of the WFD, normative definitions (Table 1) describe the aspects of the angiosperms that must be included in the ecological status assessment of a water body; these are:

- composition
- abundance
- disturbance sensitive taxa.

Table 1: The normative definitions (WFD Annex V) for angiosperms. (*Note*: in coastal waters, the assessment of angiosperms at a Quality Element level is combined with macroalgae).

	High	Good	Moderate
Transitional Angiosperms	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in angiosperm abundance due to anthropogenic activities.	There are slight changes in the composition of angiosperm taxa compared to the type-specific communities. Angiosperm abundance shows slight signs of disturbance.	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.
Coastal Macroalgae & Angiosperms	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.	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.	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.

2.3 Development of the Index

To establish a WFD compliant classification tool that is an indicator of disturbance, suitable metrics (a metric is a measure of the biota that changes in some predictable way with increased human influence) relating to the structure and functioning of the saltmarsh were combined to establish a single index.

An outline tool was initially developed (see Best *et al.*, 2007) based on the current theory and previously published results. As fully WFD compliant data have been delivered, the tool has undergone modifications and has been further tested and refined as required.

Saltmarsh classification focuses on:

(i) habitat extent
(ii) zonation
(iii) taxa diversity.

In line with the WFD normative definitions, abundance was considered to be extent of the saltmarsh (i.e. the area of the marsh) and composition was considered as both taxa diversity and, more importantly, the number and proportion of zones of the saltmarsh which reflect the successfulness of its ecological functioning.

Initial ideas were obtained from English Nature's (now Natural England) 2004 Common Standards Monitoring Guidance for Saltmarsh Habitats, which although not fully WFD compliant, contained useful principles. Further information was obtained from a joint Belgian/ Dutch/ UK working group which met in 2005. Initially the tool was primarily concerned with the extent of saltmarsh and saltmarsh zones compared with the maximum predicted by models (Best *et al.,* 2007). This was then further developed with both static and dynamic metrics with a qualitative discrete points system.

On reviewing the data in 2010 the saltmarsh tool underwent a substantial revision using a continuous scoring system for each of the metrics and applying a weighting to the metrics. The six metrics, and how they relate to habitat extent, zonation and taxa diversity, are shown in Table 2.

Table 2: The individual metrics included in the saltmarsh tool.

Saltmarsh areal extent	Current extent of saltmarsh area (SMA) compared to three measures: • **SMAh** Saltmarsh extent as proportion of "historic saltmarsh" • **SMAi** Saltmarsh extent as proportion of the intertidal • **∆SMA** Change in saltmarsh extent over two or more time periods
Saltmarsh zones	Current number, and dominance of, the main saltmarsh zones (Zn): • **Zn/5** fraction of zones present (A denominator 5 for England and Wales) • **Znmax** proportion of areal cover by the dominant zone
Saltmarsh taxa diversity	Current taxa number (T) as proportion of the historical reference: • $\mathbf{T_h}$ Proportion of historical reference value **OR** • $\mathbf{T_{15}}$ Proportion of taxa relative to 15 taxa (England and Wales)
Final score is a weighted average	

When considering the metrics and their expression of the biological community, it is important to understand that there are three numerical scales of data to consider:

(i) the "face value" i.e. the initial measurement value such as area of saltmarsh
(ii) the normalised non-equidistant value ('normalisation' is used here to describe the compression/expansion of one scale (face value range) to operate over another scale (0 to 1 EQR scale)
(iii) the rescaled equidistant value (rescaling changes non-equidistant boundaries to equidistant boundaries e.g. adjusting chlorophyll metric boundaries to 0.2, 0.4, 0.6 and 0.8 on the 0 to 1 EQR scale).

During early stages of development, calculations were presented in these three separate steps. For practical purposes, steps (ii) and (iii) are now combined mathematically (see Section 3.7).

2.4 Reference conditions

Extent: The extent of the saltmarsh is determined by three metrics**:**

- SMAh Saltmarsh extent as a proportion of "historic saltmarsh"
- SMAi Saltmarsh extent as a proportion of the intertidal area
- ΔSMA Change in saltmarsh extent

SMAh: The reference condition for historic saltmarsh (SMAh) is derived for each water body from an estimate based on:

- the "first epoch" (1843 - 1893) - Ordinance Survey (OS) maps of "saltmarsh" and "grazing marsh" extent (later epoch OS maps may be used if a waterbody was unmapped in the earlier period)
- an estimate of land claim within a 3 km boundary inland of the highest astronomical tide (HAT). This is based on LiDaR (Light Detection and Ranging) which is a powerful technique for delivering highly accurate height data and indicates the amount of land that would be submerged if there were no flood defence or reclamation barriers.

Due to the uncertainty in these datasets (e. g. some of the older maps have missed some marsh or included freshwater marsh as saltmarsh, while LiDaR land claim is a theoretical loss), two reference values have been developed; (i) the average of the two estimates and (ii) 75% of the estimate of whichever is the greatest estimate. Current data suggest that there is little difference between the two figures. The average is currently being used as the best reference figure. (The methodology of calculating saltmarsh loss due to land claim will be reviewed as further data becomes available.)

At reference it is expected that the current saltmarsh would be the same size or greater than the historic area. This figure has to allow for the natural variation and cyclical nature of saltmarsh growth and decline (about 20%). Consequently High status is felt to be anything greater than 80% (0.80).

SMAi: The proportion of the current saltmarsh relative to the intertidal (SMAi) is calculated for each water body. The intertidal is a surrogate for the available area suitable for saltmarsh growth. The area of the intertidal is calculated from the OS landline series with appropriate corrections.

For a fully functioning saltmarsh, it has been suggested that between 25 - 50% of the *suitable* intertidal should be covered by saltmarsh (De Jong, 2004; Dijkema *et al.,* 2004). In some water bodies the natural hydrodynamics may mean that they are eroding systems and proportionally less intertidal is available for saltmarsh. The High/Good boundary is consequently set at 50% (0.5 as a proportion) of the intertidal, with a potential of reference condition of 100% (1.0 as a proportion).

ΔSMA: Unlike the historic change metric, ΔSMA looks at recent changes in saltmarsh extent. This metric compares the current extent with the first reliable year of extent measurements. The reference condition is no loss (0%) or growth of saltmarsh. As there may be 20% natural variability in saltmarsh (e.g. Allen, 2000; van der Wal *et al.*, 2008; Huang *et al.*, 2008), the High/Good boundary has been set at a precautionary 10% loss.

<u>Saltmarsh zonation</u>: There are two metrics used to determine saltmarsh zonation:

- Zn/N the fraction of zones present
- ZnMax the proportion of areal cover by the dominant zone.

Zn/N: This metric assumes that a fully functioning saltmarsh will have all its major zones. The number of zones varies depending on the bio-geographical region.
In England and Wales there are five functional zones:

- Pioneer: *Salicornia* and pioneer species
- *Spartina* dominant marsh
- Mid-Low marsh mix (*Atriplex, Puccinellia*)
- High marsh (*Festuca rubra, Elytrygia* dominant marsh, *Bulboshoenus, Juncus* dominant marsh)
- Brackish water reedbeds (*Phragmites*).

Consequently the reference value for England and Wales is five zones (1.0) with the High/Good boundary set at four (0.8). North of the 'Solway line' there tend to be fewer distinct zones. These marshes are often small, associated with rocky shores and the heads of lochs. A similar situation is found in Northern Ireland.

ZnMax: Although the saltmarsh extent and the zones sizes are dynamic and change with time, the ZnMax metric assumes that no one zone will strongly dominate the others. So for England and Wales with five zones, the reference is 20% (i.e. all zones are an equal size). The High/Good boundary is 30%.

For different bio-geographical areas with different numbers of zones these values will be different.

Note: some zones may not be present in a waterbody due to natural local morphological conditions (e.g. some coastal waters may have no freshwater run-off and no creek system, so a brackish *Phragmites* zone is unlikely). In these cases, an adjustment will be necessary.

<u>Taxa Diversity:</u> There are two possible metrics that compare the current taxa count with an expected taxa count for the water body. Only one of the two metrics is used:

- T_h Proportion of historical reference value
  (Where there is no historic reference value for the water body 15 taxa are used in England and Wales. This is based on proportions from the simple field studies guide list.)

or

- T_{15} Proportion of taxa in relation to 15 taxa.

T_h (using a historical reference condition): The National Biodiversity Network (NBN, www.nbn.org.uk) provides historic data potentially back to 1600, but data from 1971 to 2009 were used to set the historic reference. The average number of taxa found in any single year and the total number of taxa found in the water body over that time period (cumulative) were calculated, with the average of these two numbers forming the reference condition.

There are some water bodies where the NBN holds no saltmarsh data. If there is no other reliable historical source of taxonomic information, then 15 taxa are used as the reference condition (for England and Wales, see below).

As the metric compares the number of taxa actually found with the historic reference number of taxa, the reference condition is a proportion of 1.0 or greater (where new taxa are found). The High/Good boundary is 0.8.

or

T_{15} (using a reference taxa number of 15): There are some water bodies that do not have NBN data or where the data is not considered reliable enough. For these a “standard list” of saltmarsh taxa may be used (e.g. produced by Field Studies Council). The reference condition is half the number of taxa in each zone of these lists. This gives a total taxa number of 15.

As the metric divides the total number of taxa found by the reference of 15 (for England and Wales), at reference the proportion is 1.0 (or greater if additional taxa are found). The High/Good boundary is 0.8 (12 taxa).

2.5 Class boundaries

The saltmarsh tool class boundaries (Table 3) are applicable to both transitional and coastal waters.

Table 3: Ecological status boundaries for the saltmarsh tool.

Status	EQR
High/Good	0.80
Good/Moderate	0.60
Moderate/Poor	0.40
Poor/Bad	0.20

The metric face value and the EQR score for metric (normalised and rescaled to the EQR 0 - 1 scale) are shown in Table 4.

Table 4: Class boundaries for the saltmarsh metrics, shown as face values and normalised EQR metric values.

	Saltmarsh areal extent						Saltmarsh zones				Saltmarsh taxa diversity			
Sub-metric	**SMAh - proportion of historic Saltmarsh**		**SMAi - proportion of intertidal**		**ΔSMA - as proportion of previous**		**Zn/5 - proportion of maximum zones present**		**Znmax - size of the largest zone as % of total**		**Th - Taxa count as proportion of historic reference**		**T15 - Taxa count as proportion of 15 taxa**	
Boundary	**Face value**	**sub metric score**	**Face value**	**sub metric score**	**Face value**	**sub metric score**	**Face value**	**sub metric score**	**Face value**	**sub metric score**	**Face value**	**sub metric score**	**Face value**	**sub metric score**
Ref	≥100%	1.00	100%	1.00	100%	1.00	1	1	20%	1	≥ 1.0	1.00	1	1.00
High/Good	80%	0.80	50%	0.80	90%	0.80	0.8	0.8	30%	0.8	0.8	0.80	0.8	0.80
Good / Moderate	60%	0.60	25%	0.60	75%	0.60	0.6	0.6	40%	0.6	0.6	0.60	0.6	0.60
Moderate / Poor	40%	0.40	10%	0.40	50%	0.40	0.4	0.4	60%	0.4	0.4	0.40	0.4	0.40
Poor /Bad	20%	0.20	5%	0.20	25%	0.20	0.2	0.2	80%	0.2	0.2	0.20	0.2	0.20

3. Undertaking an assessment

3.1 Summary of the process

The process for undertaking a water body assessment for the saltmarsh tool is summarised below (Figure 2).

Work Area	*Considerations*
Monitoring design ↓	• Is saltmarsh an appropriate assessment – does it occur in the water body? • Is aerial imagery required? • Groundtruthing needs to be linked to aerial imagery • Set appropriate sample numbers (transects) for the size of the saltmarsh
Sample collection ↓	• Summer season (May/June – September) • Use of standardised methods • Saltmarsh Area (extent) • Saltmarsh zones and their size • Taxa diversity
Sample analysis ↓	• Quality assurance procedures
Data treatment ↓	Calculate: • ΔSMA • SMAi • Znmax • T_{15} or T_h • SMAh • Zn/5
EQR calculation ↓	• Normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index • Truncate indices over 1.0 • Weight the indices
Water body classification	• Assign Class Status (use defined EQR boundaries) • Calculate EQR Standard Error • Calculate Confidence of Class and Risk of Misclassification

Figure 2: Flow chart summarising the main stages involved in undertaking an assessment using the saltmarsh tool.

3.2 Data requirements

Calculation of the saltmarsh index requires areal extent of the saltmarsh (usually obtained from aerial imagery with groundtruthing), the area of each of the five saltmarsh zones and a taxa list for the marsh. Reference saltmarsh areas and taxa lists from historic data are also required.

3.3 Sampling strategy

Aerial Survey
For all but the smallest saltmarshes, an aerial survey is likely to be required to determine the extent of the overall marsh and its major communities. Imagery needs to be taken in daylight, at low water, preferably on a spring tide, in order to capture the full extent of the saltmarsh and reveal the creek system.

Field Survey
The field survey method is designed primarily to provide the information necessary for diversity assessment of the marsh and secondarily to assist in the photo interpretation of the marsh. The field survey data informs photo-interpreters on the zones within a saltmarsh (through the plant communities identified) and the diversity of the saltmarsh (through the species found).

Field surveying is planned for the summer months (May/June to September) when the saltmarsh is most developed. The closer the ground survey is to the aerial survey the easier it is for the photo interpreters to identify the saltmarsh features. The ground survey should be at a similar time of year to the aerial survey but in exceptional circumstances may be one year before or one year after. Notice should be taken of any severe weather events, which may have significantly changed the marsh between aerial survey and the ground survey.

3.4 Sampling methodology

The WFD competent monitoring authorities have their own operating procedures and instructions; please refer to the relevant Agency for further details.

Field Survey
Field surveys are carried out along transects. The species and their percentage abundance is generally recorded in two $4m^2$ quadrats (2m x 2m), at stations along the transect ($1m^2$ quadrats could also be used in smaller saltmarsh systems). The percentage cover of species indicates the plant community. The field visit is also used to confirm the saltmarsh boundary.

Each transect covers the seaward and landward extents of the saltmarsh. They must also cross over areas of the marsh which encompass the most communities possible; usually by covering the elevational gradient. In most cases, this will be perpendicular to the coastline. Transect spacing is usually between 500 - 1000m apart depending on the size and accessibility of the saltmarsh. Transects are not required where the marsh consists solely of *Phragmites* (usually found in the upper reaches of water bodies), as this will not enhance the species diversity part of the tool; these are sampled by simple point survey.

There are four categories of information that are recorded along each transect; all which require average GPS position fixing and target notes:

- the most landward and seaward saltmarsh extent points
- major community transition points
- quadrat sample sites in major communities (quadrat data, target notes, bearings to features, photos, and optionally sward height which gives additional information to interpret the condition of saltmarsh)

- additional species diversity information.

It is recommended that a minimum of four stations are sampled along every transect; however if there are more communities or the saltmarsh is very small the actual number of stations will vary.

Samples are the percentage cover of species within the quadrat, rounded to the nearest 5%. Where a species present is less than 5% cover, it is rounded down to 1% cover.

As well as the taxa recorded in each quadrat, additional species noted along the transect, or between, should be recorded. The total list of saltmarsh species found on the marsh while walking the transects are used in the species diversity assessment.

Aerial Survey

The minimum specification for aerial survey data to be collected includes:

- resolution of at least 10 - 25cm
- red green blue (RGB)
- near Infrared (NIR) if available
- stable lighting conditions throughout the period of photography, meaning there should be little or no cloud shadow.

The validity of the outputs from photographic interpretation depends upon a wide variety of factors, including quality of the imagery, time of growing season imagery was acquired and time of day imagery was acquired.

3.5 Sample Analysis

Hambidge *et al.* (2012) describes how saltmarsh zones are determined and mapped from aerial imagery.

3.6 Data treatment

The raw data do not require transformation or treatment before the EQR can be calculated, however the face values must be calculated from the raw data.

Historic saltmarsh extent

SMAh = (Current extent of saltmarsh / “historic reference”) * 100

Saltmarsh extent as proportion of intertidal area

SMAi = (Current extent of saltmarsh / intertidal area)) * 100

Change in saltmarsh extent

ΔSMA = (most recent saltmarsh extent / previous saltmarsh extent)

The proportion of saltmarsh zones present

Zn/N = number of zones / Total number of potential zones

In England and Wales the total potential number of zones is 5, so for England and Wales:

Zn/N = number of zones / 5

The proportion of the maximum zone

ZnMax = area of largest zone / total saltmarsh area

Historical taxa diversity

T_h = Number of “saltmarsh taxa” found in water body / “historical reference” for water body

or, where there is no historic reference a value of 15 is used:

T_{15} = Number of “saltmarsh taxa” found in water body / 15

3.7 EQR calculation

Each of the saltmarsh metrics has different units and scales. In order to calculate a final score, all the metric values are converted to a common EQR scale of 0-1, with an equal distance for each class unit.

To calculate the overall water body classification it is necessary to convert the face value measurement to an equidistant EQR scale, in order that the six metrics can be combined. A stepwise process is followed:

(i) calculation of the face value (e.g. historic saltmarsh loss or proportion of saltmarsh zones) for each metric (outlined in section 3.6)
(ii) normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index
(iii) truncation of indices over 1.0
(iv) weighting of the indices
(v) calculation of saltmarsh tool (weighted average of equidistant metric scores).

Normalisation and rescaling of face values to metric range

The face values need to be converted to an equidistant EQR scale to allow combination of the indices. Initially this was carried out in a two step process, normalisation of face values to an EQR (0-1) scale (non-equidistant class boundaries) and then rescaling to an equidistant class EQR scale. These steps have now been mathematically combined in the following equation:

*Final Equidistant index score = Upper Equidistant Class range value – ((Face Value - Upper Face value range) * (Equidistant class range / Face Value Class Range))*

Table 5 gives the critical values at each class range required for the above equation. The first three numeric columns contain the face values (FV) for the range of the index in question, the last three numeric columns contain the values of the equidistant 0 -1 scale and are the same for each index. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range, hence the negative values for all metrics except ZnMax.

Note: Table 5 is “simplified” with rounded numbers for display purposes. The face values in each class band may have greater than (>) or less than (<) symbols associated with them, for calculation a value of <5 is actually a value of 4.9999.

Table 5: Values for the normalisation and rescaling of face values to EQR metric ranges.

	Metric "Class"	Lower Face Value range value (the measurements towards the "bottom" end of this class range)	Upper FV range value (the measurements towards the "Top" end of this class range)	Face Value class range	Lower 0-1 equidistant range value	Upper 0-1 equidistant range value	Equidistant class range
SMAh - proportion of historic Saltmarsh (%)	High	≥80	100	-20	≥0.80	1	0.20
	Good	≥60	<80	-19.9999	≥0.60	<0.80	0.20
	Moderate	≥40	<60	-19.9999	≥0.40	<0.60	0.20
	Poor	≥20	<40	-19.9999	≥0.20	<0.40	0.20
	Bad	0	<20	-19.9999	0	<0.2	0.20
SMAi - proportion of intertidal (%)	High	≥50	100	-50	≥0.80	1	0.20
	Good	≥25	<50	-24.9999	≥0.60	<0.80	0.20
	Moderate	≥10	<25	-14.9999	≥0.40	<0.60	0.20
	Poor	≥5	<10	-4.9999	≥0.20	<0.40	0.20
	Bad	0	<5	-4.9999	0	<0.20	0.20
ΔSMA - change in extent as proportion of previous extent	High	≥0.90	1.00	-0.1	≥0.80	1	0.20
	Good	≥0.75	<0.90	-0.1499	≥0.60	<0.80	0.20
	Moderate	≥0.50	<0.75	-0.2499	≥0.40	<0.60	0.20
	Poor	≥0.25	<0.50	-0.2499	≥0.20	<0.40	0.20
	Bad	0	<0.25	-0.2499	0	<0.20	0.20
Zn/5 - proportion of maximum zones present	High	≥0.80	1	-0.2	≥0.80	1	0.20
	Good	≥0.60	<0.80	-0.1999	≥0.60	<0.80	0.20
	Moderate	≥0.40	<0.60	-0.1999	≥0.40	<0.60	0.20
	Poor	≥0.20	<0.40	-0.1999	≥0.20	<0.40	0.20
	Bad	0	<0.20	0.1999	0	<0.20	0.20
Znmax - size of the largest zone as % of total	High	≤30	20	10	≥0.80	1	0.20
	Good	≤40	>30	9.9999	≥0.60	<0.80	0.20
	Moderate	≤60	>40	19.9999	≥0.40	<0.60	0.20
	Poor	≤80	>60	19.9999	≥0.20	<0.40	0.20
	Bad	100	>80	19.9999	0	<0.20	0.20
Th - Taxa count as proportion of historic reference	High	≥0.80	1	-0.2	≥0.80	1	0.20
	Good	≥0.60	<0.80	-0.1999	≥0.60	<0.80	0.20
	Moderate	≥0.40	<0.60	-0.1999	≥0.40	<0.60	0.20
	Poor	≥0.20	<0.40	-0.1999	≥0.20	<0.40	0.20
	Bad	0	<0.20	-0.1999	0	<0.20	0.20
T15 - Taxa count as proportion of 15 taxa	High	≥12	15	-3	≥0.80	1	0.20
	Good	≥9	<12	-2.9999	≥0.60	<0.80	0.20
	Moderate	≥6	<9	-2.9999	≥0.40	<0.60	0.20
	Poor	≥3	<6	-2.9999	≥0.20	<0.40	0.20
	Bad	0	<3	-2.9999	0	<0.20	0.20

Truncating the metrics

The metric EQR is the observed value divided by the metric reference. However, there are circumstances where the observed value may be better than the reference conditions and so a final EQR may be greater than 1.0 (*Note*: this is rare in UK waters if the reference conditions are well understood). However the normalising and rescaling process requires an "upper value" to calculate the 0-1 non-equidistant metric. In some case this will be the reference condition (e.g. 5 zones or 20% maximum of zone) and it cannot change. In other cases (e.g. the proportion of saltmarsh against a historical value) the reference may be the historical value but it is impossible to know what the maximum upper value would be. If the upper value is set too big it may skew the final class boundaries (usually the High or Bad), so only a reasonable estimate can be made. Pragmatically if any value is above 1.0 it should be limited to 1.0 at this stage.

Weighting the metrics
Some metrics are judged as more important than others when assessing status and so a weighting has been developed for the metric scores. These weightings apply to data from England and Wales.

Areal Extent

It is considered that recent (accurately measured) changes in saltmarsh area are more important than the historic measures which are more important than the proportion of the intertidal (as we do not know the exact requirements for saltmarsh habitat).

Saltmarsh Zones

It is felt that the maximum extent of a zone, while a good measure of dominance, does not reflect the dynamic variability within a marsh and so has a lower weighting.

Saltmarsh taxa

Only one of these two metrics is used, and both carry a weighting of one.

The metric weighting are summarised as:

- ΔSMA x 1.5
- SMAh x 1.0
- SMAi x 0.5
- Zn/5 x 1.0
- Znmax x 0.5
- T_h x 1.0 **or** T_{15} x 1.0

Note: when data are limited, application of these weightings may be inappropriate. For example if the recent change in saltmarsh is only separated by 1 or 2 years, the change may only reflect natural variation and the weighting should be reduced from 1.5 to 1.0. Any change in weightings must be justified on the basis of technical knowledge and clearly reported.

The final calculation

Once the values have been calculate for each metric the final EQR for the saltmarsh is calculated using the equation below:

EQR =

((ΔSMA * 1.5) + (SMAh) + (SMAi * 0.5) + (Zn5) + (Znmax * 0.5) + **EITHER** (T_h) **OR** (T_{15})) / 5.5

Note: either the historic taxa should be used or, where there is no historic taxa information, the taxa set against a reference of 15 should be used.

3.8 Water body level classification

The saltmarsh index is a water body level tool. The water body EQR is as described above:

EQR =

((ΔSMA * 1.5) + (SMAh) + (SMAi * 0.5) + (Zn5) + (Znmax * 0.5) + **EITHER** (T_h) **OR** (T15)) / 5.5

However, if multiple saltmarshes in a water body have been monitored and described separately, EQRs may have been calculated separately. The water body classification is the arithmetic mean of all the saltmarsh EQRs.

3.9 Understanding the certainty of the assessment

Providing an estimate of the statistical uncertainty of water body assessments is a statutory requirement of the WFD (Annex V, 1.3). In an ideal world of comprehensive monitoring data containing no errors, water bodies would always be assigned to their true class with 100% confidence. However, estimates of the truth based on monitoring are subject to error because monitoring is not done everywhere and all the time, and because monitoring systems, equipment and people are less than perfect. Understanding and managing the risk of misclassification as a result of uncertainties in the results of monitoring is important on two counts; first, because of the potential to fail to act in cases where a water body has been wrongly classified as being of better status than it is, and secondly because of the risk of wasting resources on water bodies that have been wrongly classified as worse than they are.

A methodology for calculating a measure of the confidence of class (CofC) for the some of the marine plant tools tool was developed by WRc (Davey, 2009).

For classification purposes, the estimated EQR is translated directly into a face value class (i.e. High - Bad). However, because it is not possible to survey the biological community across a whole water body continuously throughout whole reporting period, there will always be some sampling error, which will lead to uncertainty in the estimate of the EQR. This uncertainty can be quantified as the expected difference between the observed EQR and the true underlying EQR, which can then be used to calculate the probability of the water body being in each of the five status classes. From this it is possible to determine the most probable class (the one with the highest probability) and state what level of confidence we have that the true status is good or better, and moderate or worse.

The confidence of class tool assumes that saltmarsh surveys are conducted in such as way as to give a representative and unbiased measure of biological conditions across the whole water body throughout the whole reporting period. Statistical manipulation of the resulting data cannot compensate for poorly planned and executed field sampling; there is no substitute for a sampling scheme that measures directly the spatial and temporal variation in the target population.

An excel workbook, Saltmarsh Key Indicators Processed Precisely and Estimated Robustly (SKIPPER), calculates the confidence of class for the saltmarsh index. It performs calculations for multiple water bodies simultaneously. As each metric integrates spatial and temporal variability in the saltmarsh community, the uncertainty in the Final EQR is estimated by combining estimates of the uncertainty within each metric EQR.

SKIPPER adopts a bottom-up approach whereby each metric score and its corresponding standard error are first used to compute the confidence of class for each metric. Next, the six metric scores are normalised to produce metric EQRs between 0 and 1. Finally, the metric EQRs are combined to give a final index EQR, and their standard errors are also combined to produce an overall confidence of class for the Final EQR result (for full details see Davey, 2009, 2013).

4. Worked Example

In this hypothetical example for a fictitious water body, the measured parameters are:

- Area of water body 4864 ha
- Area of intertidal 1499 ha
- Historic Saltmarsh ref area 882 ha
- Saltmarsh exent in period 1 281 ha
- Saltmarsh extent in period 2 254 ha
- Extent of biggest zone 242 ha (estimated in period 1)
- Number of Zones 5
- Proportion of biggest zone 0.88 (214 ha)
- Historical reference taxa 28 taxa
- Number of recently counted taxa 26 taxa

The calculated face value for each metric is:

- SMAh = 254 / 882 = 0.2879= 28.79 % (the most recent Saltmarsh extent is used). This would have a face value metric class of "Poor"
- SMAi = 254 / 1499 = 0.1694 = 16.94 % (the most recent Saltmarsh extent is used). This would have a face value metric class of "Moderate"
- ΔSMA = 254 / 281 = 0.904. This would have a face value metric class of "High"
- Zn/5 = 5/5 = 1.0. This would have a face value metric class of "High"
- Znmax = 214 / 242 = 0.8842 = 88.42%. This would have a face value metric class of "Bad"
- T_h = 26 /28 = 0.9286 = 92.86 %. This would have a face value of "High"
- T_{15} = 26 /15 = 1.73. This would have a face value metric class of "High"

Calculation of the metric EQR values

The critical values to calculate the EQRs are taken from table 5 using the equation:

*Final Equidistant index score = Upper Equidistant Class range value – ((Face Value - Upper Face value range) * (Equidistant class range / Face Value Range))*

For SMAh

The face value of 28.79% is in the Poor band:

= 0.399 – ((28.79 – 39.99) * (0.2 / -19.999))

= 0.288

Note: The SMAh metric is already on an equidistant scale (20%) ranging from 0-100% which is equivalent to 0.0-1.0 (with 0.2 units) so the transformation equations will not affect this value which becomes 0.288 ("Poor").

For SMAi

The face value of 16.94% is in the Moderate band:

= 0.599 – ((16.94 – 24.99) * (0.2 / -14.99))

= 0.492

For ΔSMA

The face value of 0.904 is in the High band:

= 1.0 – ((0.904 – 1.0) * (0.2 / -0.1)

= 0.808

For Zn/5

The face value of 1 is in the High band. As the face value scale is identical to the EQR scale *there is **no** need to apply the equation* but is given for completeness:

= 1.0 – ((1.0 – 1.0) * (0.2 / -0.2))

= 1.0

For Znmax

The face value of 88.42% is in the Bad band:

= 0.199 – ((88.42 – 80.001) * (0.2 / 19.99))

= 0.115

For T_h

The face value of 0.9286 is in the High band. As the face value scale is identical to the EQR scale *there is **no** need to apply the equation* but is given for completeness:

= 1.0 – ((0.9286 – 1.0) * (0.2 / -0.2))

= 0.929

For T_{15}

When using proportions the face value of 1.73 is in the High band. As the face value scale is identical to the EQR scale *there is **no** need to apply the equation.*

As 1.73 is above 1.0 truncation is applied giving a final value of 1.0.

The final normalised equidistant scores for each of the metrics are:

- SMAh = 0.288 ("Poor")
- SMAi = 0.492 ("Moderate")
- ΔSMA = 0.808 ("High")
- Zn/5 = 1.000 ("High")
- Znmax = 0.115 ("Bad")
- T_h = 0.929 ("High")
- T_{15} = 1.000 ("High")

The multimetric EQR is the weighted average of the first 6 scores (T_{15} is not required in this example). A simple non-weighted mean would give an EQR of:

= (0.288 + 0.492 +0.808 + 1.000 + 0.115 + 0.929) / 6

= 0.605 which would be just into the Good class.

However, as mentioned above the metrics are weighted differently.

The weighted average gives a multimetric EQR of:

= ((SMAh) + (SMAi * 0.5) +(ΔSMA * 1.5) + (Zn5) + (Znmax * 0.5) + (Th))

= ((0.288) + (0.492*0.5) + (0.808*1.5) + (1.0) + (0.115*0.5) + (0.929)) / 5.5

= **0.679**

= **Good** status

Interpreting the results

An EQR of over 0.6 suggests that the current class is Good. The high variability of values suggests there would be a low “Confidence of Class”. Assuming we have checked that the reference figures are appropriate for this water body then inspection of the final results for each metric suggests that:

- A lot of saltmarsh was lost in the past
- But the rate of loss in recent years does not appear to be large. This may mean that the loss has stabilised, more results would be required to confirm this
- With only 16% of the saltmarsh occupying its potential intertidal habitat suggests that the saltmarsh has not yet colonised all it could
- This is also reflected by the poor score for zones, one main zone is dominating the marsh
- However all zones are present if small and there is a good diversity of taxa, so there is good potential for further improvement
- It may be that this marsh is located in a highly modified habitat with flood defences and dredging that have constrained it to its greatest potential.

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