**Practitioners 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 has as such has a meaning defined by the directive.

To carry out a WFD biological assessment, each biological quality element (BQE) (defined in the WFD) is required to give a statistically robust definition of the 'health' of that element in the sampled water body. The 'health' of a BQE is assessed by comparing the measured conditions (observed value) against that described for reference conditions (minimally disturbed). This is reported as an Ecological Quality Ratio (EQR). An EQR with a value of one represents reference conditions and a value of zero represents a severe impact. The EQR is divided into five ecological status classes (High, Good, Moderate, Poor and Bad) that are defined by the changes in the biological community in response to disturbance (Fig. 1). Once the EQR score and ecological status class have been calculated an assessment must be made to consider the certainty of the classification (i.e. confidence in the assigned class).
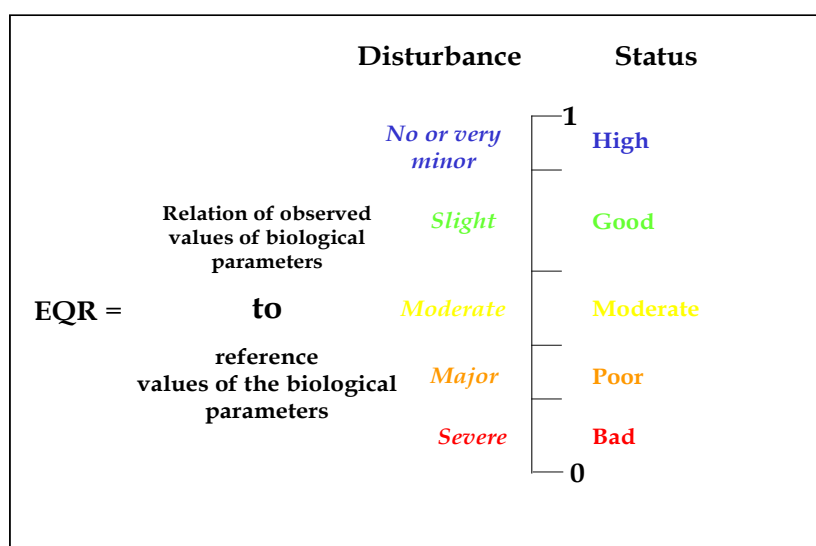
Fig. 1: Illustration of the Ecological Quality Ratio and how it relates to level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance.

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)
- 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

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

The saltmarsh tool operates over a range from zero (a severe impact) to one (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 six saltmarsh zones and
- 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 saltmarsh occurs.

When: The saltmarsh is expected to be assessed at least once in every six year WFD reporting cycle. 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 (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.

Response to pressure: The saltmarsh tool has been developed to reflect the impact of morphological pressures.

1.3. Key Documents

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

Best M., Massey A., Prior A. (2007). Developing a saltmarsh classification tool for the Europeanwater framework directive. Marine Pollution Bulletin 55 (2007) 205–214. - This is the first published paper on the initial ideas for the saltmarsh tool.

Hambidge C, Jago L., Potter T. (2012), PM_1180: Historic WFD Surveillance Saltmarsh Zonation project. Environment Agency Geomatics report. This describes how saltmarsh zones were determined and mapped from aerial imagery.

Phelan N. (2010). Document to provide background on a proposal to develop an agreed habitat mapping system for WFD, compatible with RCMP and conservation agency mapping requirements. This documents explains the saltmarsh zones used for image interpretation.

Phelan N., Shaw A., Baylis A., (2011). The extent of saltmarsh in England and Wales: 2006–2009. Environment Agency Report SCHO0811BUBC-E-E. This report and datasets maps the extent of all salmarsh in England and Wales in a consistent manner and provides information on comparisons of aerial imagery.

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

*SaltMarsh Error Evaluation (SMEE) – Excel workbook to estimate the precision of the assessment.

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 will 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 are being delivered, the tool has undergone modifications and is being further tested and refined as required.

Saltmarsh classification focuses on:
(i)   habitat extent,
(ii)   zonation and
(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 beds) 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 Belgium, 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"
    • **SMAw** Saltmarsh extent as proportion of the intertidal
    • ΔSMA Change in saltmarsh extent over two or more time periods	

Saltmarsh zones   Current number, and dominance of, the 5 main saltmarsh zones (Zn):
 	
    • **Zn/5**   fraction of zones present
    • **Znmax** proportion of areal cover by the dominant zone	

Saltmarsh taxa diversity   Current taxa number (T) as proportion of the historical reference:
 	
    • T_h Proportion of historical reference value
OR
    • T_{15} Proportion of taxa relevant to 15 taxa	

Final score is a weighted average	

2.4 Reference conditions

**Extent**: The extent of the saltmarsh is determined by 3 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 maps of saltmarsh and grazing marsh extent
- 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 (ii) 75% of the estimate of whichever is the greatest estimate. Current data suggest that the 75% figure is the more robust and is currently being used as the best reference figure. (It should be noted that the methodology of calculating saltmarsh loss due to land claim is being reviewed).

At reference it would be 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 to the intertidal (SMAi) is calculated on for each water body. 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 previous extent. The reference condition is no loss (0%) or growth of saltmarsh. As there may be 20% natural variability in saltmarsh, the High /Good boundary has been set at a precautionary 10% loss.

Saltmarsh zonation: 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).
- Reedbeds (*Phragmites*)

Consequently the reference value for England and Wales is 5 zones (1.0) with the High / Good boundary set at 4 (0.8).

North of the 'Solway line' there tend to be fewer distinct zones, while the increased rainfall tends to allow typically upper shore species to occur lower down. 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 5 zones, the reference would be 20% (i.e. all zones are an equal size). The High / Good boundary would be 40%.

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

Note: some zones may not be present in water bodies due to natural local morphological conditions. In these cases an adjustment will be necessary.

Taxa Diversity: 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. This is based on the simple field studies guide list.)

- T_{15} Proportion of taxa relevant to 15 taxa

T_h (using a historical reference condition)

The National Biodiversity Network (NBN) 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. In these cases 15 taxa are used.

As the metric compares the number of taxa actually found with the 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 of 15)

There are some water bodies that do not have NBN data. For these a "standard list" of saltmarsh taxa may be used (e.g. produced by Field studies council). The reference condition is half the taxa in each zone of these lists. This gives a total taxa of 15.

As the metric divides the total number taxa found by the reference of 15, 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 relevant 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.
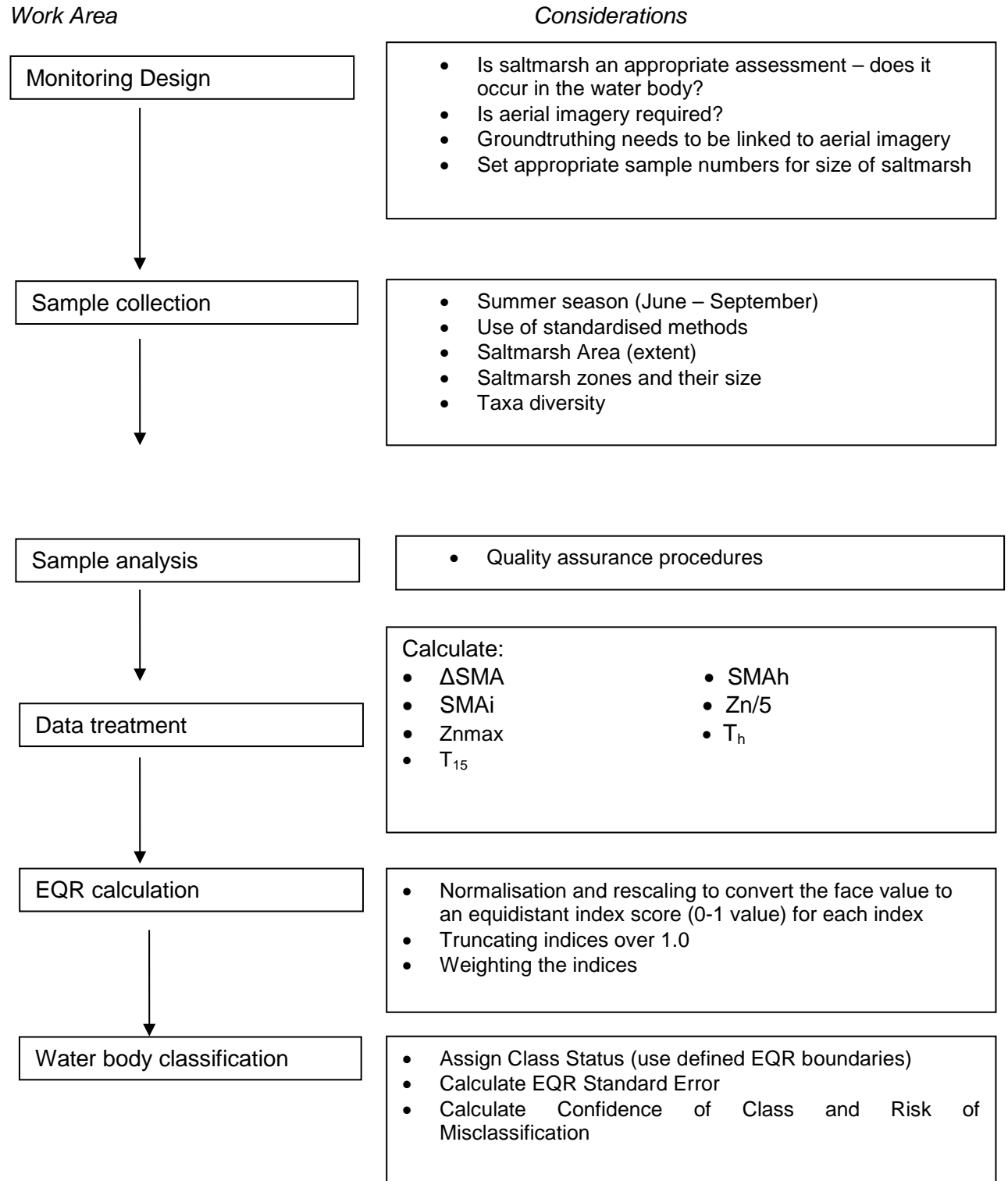
Sub-metric	Saltmarsh areal extent						Saltmarsh zones				Saltmarsh taxa diversity			
	SMAh - proportion of historic Saltmarsh		SMAi - proportion of intertidal		ΔSMA - change in extent (loss)		Zn/5 - proportion of maximum zones present		Znmax - size of the largest zone as % of total		Th - Taxa count 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	≤0	1.00	5	1	20%	1	≥ 1.0	1.00	15	1.00
High/Good	80%	0.80	50%	0.80	10%	0.80	4	0.8	40%	0.8	0.8	0.80	12	0.80
Good / Moderate	60%	0.60	25%	0.60	25%	0.60	3	0.6	60%	0.6	0.6	0.60	9	0.60
Moderate / Poor	40%	0.40	10%	0.40	50%	0.40	2	0.4	80%	0.4	0.4	0.40	6	0.40
Poor /Bad	20%	0.20	5%	0.20	75%	0.20	1	0.2	100%	0.2	0.2	0.20	3	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 (Fig. 5).

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 for size of saltmarsh

Sample collection

- Summer season (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}
- SMAh
- Zn/5
- T_h

EQR calculation

- Normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index
- Truncating indices over 1.0
- Weighting the indices

Water body classification

- Assign Class Status (use defined EQR boundaries)
- Calculate EQR Standard Error
- Calculate Confidence of Class and Risk of Misclassification

Fig. 5: Flow chart summarising the main stages involved in undertaking an assessment using the saltmarsh tool.

3.2 Data requirements

Calculation of the saltmarsh requires areal extent of the saltmarsh (usually obtained from aerial imagery with groundtruthing), the area of each of the six saltmarsh zones and a taxa list for the marsh. Reference saltmarsh area and taxa list 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 (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 may be 1 year before or 1 year after, in exceptional circumstances.

3.4 Sampling methodology

The WFD competent monitoring authorities (EA, NIEA, SEPA) 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 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 will be 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 were determined and mapped from aerial imagery.

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

3.6.1 Historic saltmarsh extent

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

3.6.2 Saltmarsh extent as proportion of intertidal area

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

3.6.3 Change in saltmarsh extent

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

3.6.4 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

3.6.5 The proportion of the maximum zone

ZnMax = area of largest zone / total saltmarsh area

3.6.6 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. The process is outlined in Fig. 5, section 3.1.

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 6 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: the table 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·.

	Metric "Class"	Lower Face Value range value (the measurements towards the "bad" end of this class range)	Upper FV range value (the measurements towards the "High" end of this class range)	FV 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	≥0.8	1	0.2
	Good	≥60	<80	-19.999	≥0.6	<0.8	0.2
	Moderate	≥40	<60	-19.999	≥0.4	<0.6	0.2
	Poor	≥20	<40	-19.999	≥0.2	<0.4	0.2
	Bad	0	<20	-19.999	0	<0.2	0.2
SMAi - proportion of intertidal (%)	High	≥50	100	-50	≥0.8	1	0.2
	Good	≥25	<50	-24.99	≥0.6	<0.8	0.2
	Moderate	≥10	<25	-14.99	≥0.4	<0.6	0.2
	Poor	≥5	<10	-4.99	≥0.2	<0.4	0.2
	Bad	0	<5	-4.99	0	<0.2	0.2
ΔSMA - change in extent as proportion of previous extent	High	≥0.90	1.00	-0.1	≥0.8	1	0.2
	Good	≥0.75	<0.90	-0.149	≥0.6	<0.8	0.2
	Moderate	≥0.5	<0.75	-0.249	≥0.4	<0.6	0.2
	Poor	≥0.25	<0.5	-0.249	≥0.2	<0.4	0.2
	Bad	0	<0.25	-0.249	0	<0.2	0.2
Zn/5 - proportion of maximum zones present	High	≥0.8	1	-0.2	≥0.8	1	0.2
	Good	≥0.6	<0.8	-0.199	≥0.6	<0.8	0.2
	Moderate	≥0.4	<0.6	-0.199	≥0.4	<0.6	0.2
	Poor	≥0.2	<0.4	-0.199	≥0.2	<0.4	0.2
	Bad	0	<0.2	0.199	0	<0.2	0.2
Znmax - size of the largest zone as % of total	High	≤30	20	10	≥0.8	1	0.2
	Good	≤40	>30	9.99	≥0.6	<0.8	0.2
	Moderate	≤60	>40	19.99	≥0.4	<0.6	0.2
	Poor	≤80	>60	19.99	≥0.2	<0.4	0.2
	Bad	100	>80	19.99	0	<0.2	0.2
Th - Taxa count as proportion of historic reference	High	≥0.8	1	-0.2	≥0.8	1	0.2
	Good	≥0.6	<0.8	-0.199	≥0.6	<0.8	0.2
	Moderate	≥0.4	<0.6	-0.199	≥0.4	<0.6	0.2
	Poor	≥0.2	<0.4	-0.199	≥0.2	<0.4	0.2
	Bad	0	<0.2	-0.199	0	<0.2	0.2
T15 - Taxa count as proportion of 15 taxa	High	≥12	15	-3	≥0.8	1	0.2
	Good	≥9	<12	-2.99	≥0.6	<0.8	0.2
	Moderate	≥6	<9	-2.99	≥0.4	<0.6	0.2
	Poor	≥3	<6	-2.99	≥0.2	<0.4	0.2
	Bad	0	<3	-2.99	0	<0.2	0.2

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

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 and so a weighting has been developed for the metric scores.

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 been weighted lower.

Saltmarsh taxa

In practice only one of these two submetrics should be used, if that is the case then it is unweighted. It is felt that the T15 is likely to be the weaker sub-metric as it uses a fixed reference number for all water bodies.

The situation is summarised below

- 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
- T_{15} x 0.5 (if used with T_h, else x 1.0)

The final calculation

Once the values have been calculate for each metric the final EQR for saltmarshes can be calculated using the equation below:

EQR =

((ΔSMA * 1.5) + (SMAh) + (SMAi * 0.5) + (Zn5) + (Znmax * 0.5) + **EITHER** (Th) **OR** (T15)) / 6

Note: either the historic tax should be used or where there is no historic taxa 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** (Th) **OR** (T15)) / 6

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 Error Evaluation (SMEE), 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.

SMEE 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 zero and one. 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).

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4. Worked Example

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
- Historical reference taxa   28 taxa
- Number of recently counted taxa 26 taxa
-

The calculated face value for each metric is:

- SMA_h = 244 / 882 = 0.27664 = 27.66 % (note the most recent Saltmarsh extent is used). This would have a face value metric class of "Poor"
- SMA_i = 244 / 1499 =   0.1627 = 16.27 %   (note 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"
- Zn_{max} = 242 / 281 = 0.8612 = 86.12%. 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 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))*

<u>For SMAh</u>

The face value of 27.66% is in the Poor band:

= 0.399 – ((27.66 – 39.99) * (0.2 / -19.999))

= 0.276

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 0.276 **("Poor")**

<u>For SMAi</u>

The face value of 16.27% is in the Moderate band:

= 0.599 – ((16.27 – 24.99) * (0.2 / -14.99))

= 0.483

<u>For ΔSMA</u>

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 86.12% is in the Bad band:

= 0.199 – ((86.12 – 80.001) * (0.2 / 19.99))

= 0.138

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   = 0.276 ("Poor")
- SMAi   = 0.483 ("Moderate")
- ΔSMA   = 0.808 ("High")
- Zn/5   = 1.000 ("High")
- Znmax   = 0.138 ("Bad")
- T_h = 0.929 ("High")
- T_{15} = 1.000 ("High")

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

= (0.267 + 0.483 +0.808 + 1.000 + 0.138 + 0.929) / 6

= 0.604

this would be just into the Good class.

However as mentioned above the metrics are weighted differently.

The weighted average gives a multimetric EQE of::

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

= ((0.276) + (0.483*0.5) + (0.808*1.5) + (1.0) + (0.138*0.5) + (0.929) / 6

= **0.621**

this would be classified as "**Good**".

Interpreting the results

An EQR of just over 0.6 suggest that the current class is close to the Good/Moderate border. The high variability of values suggests there would be a low "Confidence of Class" . Assuming we have checked that the reference figure are appropriate for this water body then inspection of the final results for each metric suggests that:

- lots 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 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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