Practitioners Guide to the Intertidal Seagrass Tool
Water Framework Directive: Transitional and Coastal Waters

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

Note*:* this document does not fully describe all aspects of the intertidal seagrass tool development and application; for this please refer to the full technical report (Foden *et al.*, 2010). A summary of key documents and references is also 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).

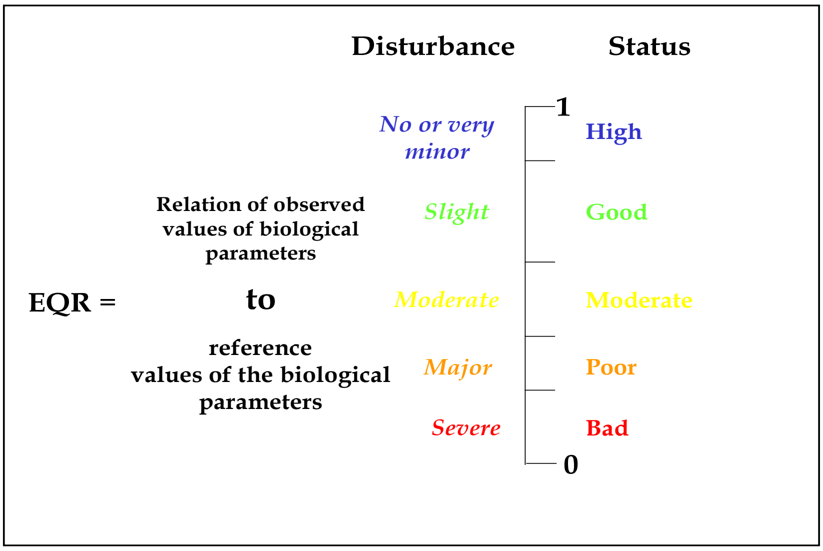


Fig. 1: Illustration of the Ecological Quality Ratio and how it relates to level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance.

1. Key Facts

1.1 Index overview

The intertidal seagrass tool enables an assessment of the condition of the quality element, "angiosperm", as listed in Tables 1.2.3 and 1.2.4 of Annex V to the Water Framework Directive (2000/60/EC). The WFD requires that the assessment of the angiosperm quality element considers taxonomic composition, abundance and disturbance-sensitive taxa. Note: Although seagrasses are the only true marine angiosperms, saltmarsh is also considered as part of this biological element under the WFD. The assessment of saltmarsh is considered in a separate guide.

The seagrass tool is a multimetric index composed of three individual components referred to as metrics, these are:

(i) taxonomic composition
(ii) shoot density (as a percentage cover loss or gain in a single year) or shoot density (as a rolling mean of percentage loss or gain)
(iii) bed extent (percentage area loss or gain)

The individual metrics are considered separately and have equal weighting in the final multimetric calculation. Note: It is not possible for a single metric to be used in isolation to derive a robust WFD classification for a water body; all metrics must be used to assess ecological status.

An assessment of seagrass was not reported for the first River Basin Management Plans (2009) due to insufficient available data at that time.

The seagrass tool operates over an Ecological Quality Ratio (EQR) range from zero (major disturbance) to one (reference/minimally disturbed). The four class boundaries are:

- High/Good = 0.8
- Good/Moderate = 0.6
- Moderate/Poor = 0.4
- Poor/Bad = 0.2

To calculate the tool, the percentage cover change in shoot density and bed extent, along with changes in taxonomic composition, are required. Taxonomic composition is based upon the stability of species richness and limited to a maximum of five species (three *Zostera* species and two *Ruppia species*). The percentage shoot density metric has been developed to classify data using both a single sampling event and a rolling 5 year mean (should extended data be available).

1.2 Applicability

Where: The intertidal seagrass tool can be applied to all UK transitional and coastal waters where a suitable habitat type for seagrass exists, notably a sandy to muddy substratum. However, the tool is not currently used for assessing saline lagoons due to the particular challenges in setting reference conditions for these water bodies. Note: This tool is currently only applied to ***intertidal*** seagrass beds and not to ***subtidal*** beds.

When: Sampling should be completed from June through to September. Monitoring is not recommended outside of this period due to seasonal variations that could affect the classification outcome and possibly lead to misclassification. Sampling should be carried out during spring low tides in order to expose the maximum area of intertidal and full bed extent.

Response to Pressure: The seagrass tool is designed to detect the impact on intertidal seagrass communities of increased nutrient concentrations (eutrophication), and general disturbance including hydromorphological change, excess deposition and habitat loss.

1.3 Key Documents

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

*Davey, A (2011). Confidence of class for the WFD seagrass classification tool. WRC project note to the Environment Agency. 7pp

Foden, J. & D.J. de Jong, 2006. Assessment metrics for littoral seagrass under the European Water Framework Directive; outcomes of UK intercalibration with the Netherlands. Hydrobiologia.

Foden, J. & D.P. Brazier, 2007. Angiosperms (seagrass) within the EU Water Framework Directive; a UK perspective. Marine Pollution Bulletin, **55**, 181-195.

*Foden, J., Brazier, D.P. & Wells, E., 2010. Water Framework Directive development of classification tools for ecological assessment: Intertidal seagrass. *UK TAG Report for Marine Plants Task Team*, January 2010, Publ. UK TAG

*Seagrass Assessment Incorporating Likelihood of Risk (SAILOR) – Excel workbook to estimate the precision of the assessment.

*UKTAG Biological Status Methods: Coastal and Transitional Waters Intertidal Seagrasses – high level non-technical summary.

2. Background

2.1 Ecological principles

Seagrasses are the only truly marine angiosperms and can be used as monitoring objects because they are sensitive to human disturbance (Short & Wyllie-Echeverria, 1996). As seagrasses are disturbance sensitive their presence, health and abundance are likely to indicate a water body's quality status; they can be considered at good or high status if there is no evidence of degradation or loss of species from localities where they were previously found in the water body. Importantly, despite much recent research effort, the ideal environmental parameters for supporting seagrass are not entirely understood, so that absence of seagrass from areas apparently suited to its growth are not always explicable (Krause-Jensen *et al.*, 2003). Absence therefore, does not necessarily suggest a catastrophic loss of species, unless a historic bed was previously recorded and is no longer present.

Loss of seagrass abundance occurs in many coastal environments (Short & Wyllie-Echeverria, 1996), often from natural causes such as high energy storms. Anthropogenic hydrodynamic stress from dredging and other activities can effect seagrass beds due to increased suspended sediment in the water column (blocking light) or excess sedimentation (causing smothering). Seagrasses can also be sensitive to nutrient enrichment and in some temperate estuaries areas of seagrass habitat decrease logarithmically and percentage loss of habitat increases logarithmically as nitrogen loading rates increase (Hauxwell *et al.*, 2003). However, seagrass can recover if conditions improve. Nutrient enrichment may also lead to excessive growth of opportunistic epiphytic algal species, or blooming species such as *Enteromorpha*, *Ulva*, *Chaetomorpha* and *Ectocarpus* on seagrass beds potentially compromising the health and viability of seagrass by overlying and smothering.

2.2 Normative Definitions

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

- taxonomic composition
- abundance
- disturbance sensitive taxa

The intertidal seagrass tool describes the composition of seagrass taxa and percentage loss or gain of bed extent and shoot density. To assist with the development of a suitable assessment the WFD definitions were further interpreted into expanded normative definitions (Table 1).

Table 1: Description of the characteristics of seagrass at each WFD status class in accordance with the normative definitions (WFD Annex V) and expanded normative definitions (detailed national interpretation).

Interpretation of structural & functional relevance	There are only 5 UK seagrass species; *Zostera marina*, *Z. angustifolia* (known as littoral *Z. marina* in continental Europe) and *Z. noltii and 2 species of* Ruppia. *Z. noltii* (littoral) and *Z. marina* (sublittoral) occur commonly as mono-specific stands in UK waters. Where present, beds should be healthy, with no loss of bed extent or density (percentage cover). This defines the Good/Moderate boundary. Note: natural variability may be up to 30% (Krause-Jensen *et al*., 2003). Where data sets allow, a 5-year rolling mean for density should be used to reduce noise and identify longer term trends. A 30% reduction in density when using a 5-year rolling mean will mask underlying trends. Therefore 15% is considered as tolerable evidence of natural variation and decreases in extent of > 15% should be viewed suspiciously.	
High	*The angiosperm taxonomic composition corresponds totally with undisturbed conditions. There are no detectable changes in angiosperm abundance due to anthropogenic activities*	No loss of seagrass species. Abundance as bed extent: no loss in area of seagrass bed – at maximum potential and stable (within natural variability). Abundance as density: no loss of density – bed expanding or at highest previously recorded (within natural variability).
Good	*There are slight changes in the composition of angiosperm taxa compared with the type-specific communities. Angiosperm abundance shows slight signs of disturbance*	No loss of seagrass species. Abundance as bed extent: < 30% deviation from highest recorded; i.e. within natural variability, but bed at less than maximum potential extent for local physical regime or compared with bed's historic extent. Abundance as density: no loss of density – < 30% (or <15% if using 5-year mean) deviation from highest previously recorded; i.e. within natural variability. Changes that occur at this stage are gradual and reversible in the short term.
Moderate	*The composition of angiosperm taxa differs moderately from type-specific conditions and is significantly more distorted than at good quality. There are moderate distortions in the abundance of angiosperm taxa*	Loss of 1 *seagrass* species, but 1 species still remaining in the water body. Abundance as bed extent: >30% deviation from highest recorded; i.e. greater than natural variability. Disturbance evident as moderate loss of area covered compared with previous highest recorded extent. Abundance as density: >30% (or >15% if using 5-year mean) deviation from highest previously recorded; i.e. beyond natural variability.

		The changes that occur at this stage are still gradual and reversible in the medium-term; e.g. within a reporting cycle (5 year rolling mean).

2.3 Development of the Seagrass tool

The initial development of the tool focused on which metrics were the most appropriate to meet the normative definitions and could be assessed practically in UK waters. The three main factors that needed to be considered were:

(i) the five species of seagrass that occur in the UK (three *Zostera* species and two *Ruppia species*) occur mainly in single species or two-species stands,
(ii) all five UK seagrass species are disturbance sensitive,
(iii) the use of an assessment of total biomass as a measure of abundance requires destructive sampling.

Therefore three metrics were developed that apply to littoral seagrass beds, in both transitional and coastal waters, and allow for non-destructive monitoring:

- taxonomic composition (presence of disturbance sensitive taxa)
- abundance, determined by seagrass shoot density (expressed as loss/gain in percentage cover)
- abundance, measured by seagrass bed spatial extent (expressed as percentage loss/gain)

Each of these metrics was then investigated for their response to anthropogenic and natural change and their applicability in assessing ecological quality status (Foden & Brazier, 2007; Foden *et al.*, 2010). Due to lack of historical and long time-series data there are limited data representing the response of seagrass across the whole pressure range (high to bad status) and types of pressures (nutrients and hydromorphology). Some hydromorphic pressures can be acute, spasmodic and irregular (e.g. storms, bait digging, anchor chains) making it difficult to show the biological response across the pressure gradient. However there is an example of a clear response to disturbance pressure by the deliberate and thorough clearing of a seagrass bed and its subsequent recovery (Tittley *et al.*, 1998).

A site for which angiosperm beds were cleared due to construction in 1992 provides a visual illustration of base-line abundance (seagrass density) across 7 transects in 1992, depletion between 1993 and 1996/1997, and indication of recovery in 1998 (Fig 2). Anthropogenic impact was high because clearance was deliberate, and recovery at naturally variable rates is evident in all transects. (See Tittley *et al.*, 1998 for further details).

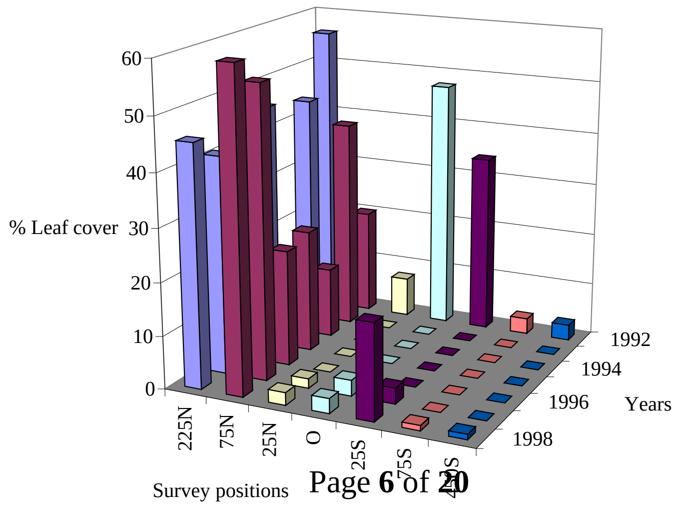


Fig. 2: Mean percentage cover of *Zostera* at 7 sites along a transect; Westfield, North Morecambe

Note: It is not possible for a single metric to be used in isolation to derive a robust WFD classification for a water body; all metrics must be used to assess ecological status.

2.3.1 Understanding the individual metrics

2.3.1.1Taxonomic composition: (WFD criteria compliance – taxonomic composition, disturbance sensitive taxa)

This metric reflects the loss of seagrass species as compared to the reference species list for the specified water body (or gain where a bed is recovering).

Only five species of seagrass occur in the UK. Seagrasses in the northern temperate oceans tend to form broad single species stands (Davison & Hughes, 1998), often patchy in nature, and typified by meadows of *Zostera* spp. in the Atlantic coastal regions (Short *et al.*, 2001). The three species of *Zostera* found in the UK are *Z. noltii*, *Z. marina* and *Z. angustifolia* (Davison & Hughes, 1998). *Zostera angustifolia* is frequently regarded as a littoral ecotypic or phenotypic form of *Z. marina*, however, in most UK literature the two species are considered to be separate and are treated as such with the WFD assessment. In UK waters *Z. marina* is predominantly a sublittoral species found in shallow, fully marine conditions on relatively coarse sediment (Davison & Hughes, 1998). *Zostera angustifolia* and *Z. noltii* are found in the intertidal zone. *Zostera angustifolia* generally occurs between the mid- and low-tide mark, preferring poorly-draining muddy sediments, particularly pools and creeks that are unlikely to entirely dry out during low tide. *Zostera noltii* occurs higher on the shore to the high-tide mark, on mud and sand and, being more tolerant of desiccation, will inhabit exposed areas that entirely dry out at low tide (Davison & Hughes, 1998).
Although *Ruppia* species are not strictly considered as part of the traditional seagrass arrangement (Kuo & den Hartog, 2001) workers often group *Ruppia* species with *Zostera* species, considering them all seagrasses. For the purposes of WFD assessment both genera are monitored. However, while *Zostera* spp are identified to species level, *Ruppia* are identified to genus only, due to the difficulty of species identification, as recommended by Foden & Brazier (2007): this means that four taxa are the maximum found in any UK water body.

As the actual number of seagrass species is low, total richness is inappropriate as an assessment method. Therefore the final metric is based around the number of species present, as detailed from historical records, remaining consistent. Any loss of species is considered to be as a consequence of changing environmental conditions and would reflect a deviation from reference conditions. Conversely, beds recovering from pollution or disturbance might show an increase in the number of taxa present.

2.3.1.2 Shoot density*:* (WFD criteria compliance – abundance)

The *shoot density* metric reflects the change (loss or gain) of density compared with reference conditions, expressed as percentage cover. The objective is for a seagrass bed's abundance to increase or remain at the maximum potential for the site, with the expectation that the bed will decrease in density if there is ecological deterioration in the water body. Where several years of annual data exist for a seagrass bed, the objective will be the previously recorded maximum density of the bed, or, if shoot density appears to show a high level of natural fluctuation, the mean of several years' data.

2.3.1.3 Total bed extent: (WFD criteria compliance – abundance)

The *spatial extent* of a seagrass bed should aim to reach, and be in equilibrium at, its maximum potential physical extent, given the local climate, substratum and hydrodynamic regime.

Currently, WFD compliant data are being assessed to provide further understanding of the variability seen within water bodies. It should be noted that to determine changes to the metrics, brought about by anthropogenic disturbance, with any level of certainty may take 5 –10 years (Duarte & Kirkman, 2001), unless disturbance is catastrophic such as habitat removal for coastal redevelopment. Consequently, where enough data exist, interpretation of the metrics should take account of data trends. There may be a high degree of inter-annual variability, so calculation of a rolling mean considerably reduces noise, and underlying trends should become more apparent. The shoot density metric can be calculated as a rolling mean (the rolling-mean value for each year is an average of that year and the previous five years' mean densities) for incorporation in to the EQR but trends for the other metrics are used to aid interpretation only.

2.4 Reference Conditions

Reference conditions are set as the seagrass bed's taxonomic composition and abundance remaining stable at the maximum potential for the site, or the first set of data where no historical data exist. For all metrics it is not possible to compare data across geographic regions, even within WFD defined water body types, as naturally occurring local physical parameters may cause significant natural change (e.g. Krause-Jensen *et al.*, 2003).

Expert opinion and published and unpublished literature were used to set an approach for setting reference conditions (see Foden & Brazier, 2007; *Foden et al*., 2010 for further details). Since water body type reference conditions cannot be quantified across all seagrass beds, due to a variety of factors, reference conditions are based on historical site-specific data.

To help form reference conditions, records of seagrass occurrence were obtained from the National Biodiversity network (NBN). Historic seagrass data are rare as there has not been a national seagrass monitoring programme in the UK. However, these scarce historic data have been a vital component in the process of developing not only the assessment tool, as they provide detailed information on the locations of beds, but they also provide some much needed time series data and natural levels of seagrass that have been used as a reference from which class boundaries were established.

2.5 Class Boundaries

Seagrass distribution, abundance and ecological condition are highly variable and sensitive, and there can be multiple causes of deviation from proposed reference conditions. Class boundaries for each of the metrics have been defined using a combination of published data and expert opinion (Foden & Brazier, 2007). These were tested on UK data (Foden & Brazier, 2007; Foden et al., 2010). Historical data of appropriate quality were used where possible.

The overall class boundaries are shown in Table 2 and the metric class boundaries are shown in Table 3.

Table 2: Overall ecological status boundaries for the intertidal seagrass tool

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

Table 3: Metric ecological status boundaries for the intertidal seagrass tool

	EQR range		Taxonomic composition	Spatial Extent of bed (% loss)		Annual Shoot density (% cover loss)		5 Year Rolling Mean Shoot density (% loss)	
QualityStatus	low	high		low	high	low	high	low	high
High	≥0.8	1	All reference species present	≤10	0	≤10	0	≤5	0
Good	≥0.6	<0.8	Loss of 25% to 33% of ref. spp	≤30	>10	≤30	>10	≤15	>5
Moderate	≥0.4	<0.6	Loss of 33% to 66% of ref. spp	≤50	>30	≤50	>30	≤25	>15
Poor	≥0.2	<0.4	Loss of 66% to 75% of ref. spp.	≤70	>50	≤70	>50	≤35	>25
Bad	0	<0.2	Loss of 75% to 100% of ref. spp	100	>70	100	>70	100	>35

N.B. Where there is no loss but a measured gain, this is equivalent to a 0% loss and High status class for that metric.

2.5.1 Taxonomic composition: This metric has assigned scores, representing the midpoint of the class range, associated with the loss of species from reference conditions (Table 3, EQR value, column 2).

Where no seagrass taxa remain the water body would be scored as 0.1 for this metric. The implication is that total loss of a mono-specific stand could downgrade a water body from a score of 0.9 to 0.1 in one step. In such cases the metric is insensitive to intermediate classes (0.3–0.7).

Note: if a seagrass bed scores 0.1 for taxonomic composition then it is likely all seagrass species have been entirely lost, negating the necessity of monitoring abundance by measuring density and bed extent as it is to be expected that these must be zero..

2.5.2 Shoot density (annual): The proposed scoring system for shoot density is based on percentage losses from reference conditions, measured as percentage cover.

Based on expert judgement and historical data it was concluded that the High/Good class boundary should be set at ≤10% loss of density. If a bed is expanding or becoming more dense than its reference condition it will record 0% loss and will naturally be in ‘High’ status.

Krause-Jensen *et al.* (2003) analysed the importance of light, wave exposure and salinity on the biomass, cover and shoot density of a large dataset crossing different geographic regions, at different depth intervals. Variability was highest in shallow waters, where populations were disturbed by physical parameters. The modelled factors explained only up to 40% of the overall variation in the data., Therefore local, physical parameters may cause significant natural change. The remaining 60% may result from a combination of natural cause (e.g. grazing, bioturbation, sediment conditions, epiphytes, extreme climatic or tidal events) and anthropogenic influences leading to undesirable disturbance. Based on this model, the Good/Moderate boundary value was set at ≤30% loss of density from reference conditions. This limit allows for natural variability but is sensitive enough to highlight variability caused by anthropogenic activity. A loss of 70% of bed density could possibly result in a change in hydrodynamics or altered sediment regime leaving the remaining bed vulnerable. ≤70% was considered an appropriate Poor/Bad boundary. The remaining Moderate/Poor class boundary was chosen mathematically as the mid-point between 30% and 70%, i.e. at ≤50% (Table 3).

2.5.3 Shoot density (Rolling mean): Rolling means from longer term datasets even out natural, inter-annual variation, so data are less “noisy”. This means that High/Good and Good/Moderate boundaries can be more stringent than for annual data. Rolling mean metric boundaries were set at 50% of the boundary values for the annual mean metric (Foden *et al*., 2010)

2.5.4 Spatial extent: The class boundaries have been set as described for annual shoot density (see 2.5.2).

Annual natural variability in extent may be high, so interpretation of the final assessment should consider longer terms trends in bed extent where data exist.

3. Undertaking an assessment

3.1 Summary of the process

The process for undertaking an assessment using the seagrass tool is summarised below (Fig 2).

Work Area	*Considerations*
Monitoring Design	• Is there suitable habitat for intertidal seagrass beds? • Are seagrass beds present in the water body/have they historically been present? • Are there historical records for setting reference conditions • Can trends be assessed?
Sample collection	• Use of standardised methods • Identify seagrass taxa (*Zostera* species and *Ruppia*) present in water body • Identify bed extent (all beds in water body at at 5% cover of seagrass, optional for <5% boundary) • Identify percentage cover through quadrats representing all beds, take photos of at least 10% of quadrats. • Record any negative impacts/signs of disturbance.
Sample analysis / Data treatment	• Quality assurance–of percentage cover in photographed quadrats • QA and orthorectification of any remote imagery used in mapping of beds and density • Calculation of individual bed extents (ha) • Calculate change in bed extent • Identify taxa and calculate taxa change • From quadrats identify change in shoot density
EQR calculation	Calculate EQR *Final Equidistant index score = Upper Equidistant Class range value – ((Face Value - Upper Face value range) * (Equidistant class range / Face Value Range))*
Water body classification	• Derive WB average EQR • Assign Class Status (use defined boundaries) • Calculate Confidence of Class and Risk of Misclassification

Fig 2: Flow chart summarising the main stages involved in undertaking an assessment using the intertidal seagrass tool.

3.2 Data Requirements

Calculation of the index requires the identification and enumeration of the seagrass taxa (*Zostera* and *Ruppia*) present in the water body; the percentage cover (shoot density) from quadrats; and the spatial extent of the seagrass bed (defined by the ≥5% cover boundary).

Historic data relating to the above metrics, where it exists for the water body, are required to help set reference conditions.

3.3 Sampling strategy

All known intertidal seagrass beds should be assessed within a water body i.e. all intertidal seagrass (*Zostera* and *Ruppia)* beds lying between mean high and low water springs. Monitoring of seagrass beds should take place at low water springs, at peak growth between June and the end of September. Ideally seagrass beds should be monitored annually to obtain sufficient data to obtain a rolling mean for assessment of shoot density and general trend in taxonomic composition and bed extent, which helps account for natural inter-annual variation. The time for the survey should remain relatively constant year-on-year, unless there is reason to believe the peak growth period has altered.

Whilst small simple beds may be assessed from the ground alone, larger beds and those with mixed macroalgal cover or restricted access may require the use of aerial imagery to collect the extent data. Any survey planning should build in the need for aerial images and time the ground surveys to be close to that period (ideally no more than 2 weeks apart).

Where new images are not collected, older images can still be used to inform the planning of the field survey.

3.4 Sampling methodology

Further guidance may be found in the operational instructions and standard operating procedures from the WFD monitoring Agencies.

3.4.1 Taxonomic composition*:* The number and composition of taxa of seagrass should be recorded to species level in the case of *Zostera* sp. and to genus level for the *Ruppia* sp. (maximum taxa is four). The taxa recorded should be that observed in the water body as a whole (even if they are not present in any quadrat). The relative proportions are recorded as % of taxa present within each quadrat (See 3.4.3).

Note: if a seagrass bed scores 0.1 for taxonomic composition then all seagrass species have been entirely lost, negating the necessity of monitoring abundance by measuring density and bed extent.

3.4.2 Mapping Bed Extent: Bed extent (bed boundaries) may be identified using

- aerial/remotely sensed images with ground-truthing extent at representative locations around the beds. This will confirm boundaries are accurate and the beds observed in the images are seagrass.

or

- mapped in full on the ground by fieldworkers using a handheld differential Global Positioning System datalogger/unit.

Where mixed beds of green macroalgae and seagrass are found or the beds are less distinct or irregular in form, more intensive groundtruthing of extent is required. Groundtruthing must take place at a similar time to the aerial imagery. The boundary of the beds is set at where the beds are of a density ≥5%. Where the precise edge of a bed is indistinct a subjective decision needs to be made as to the bed boundary, which should be supported by descriptive notes and photographs.

Many littoral seagrass beds have extensive areas of very low cover (shoot density < 5%) around the periphery of the denser, continuous bed (> 5% cover) (Fig. 3). Where possible UK WFD monitoring authorities map the boundary of this peripheral low shoot density area as well to aid data interpretation, although seagrass density is not measured in this very low cover area and the area is not included in the seabed extent metric calculation.

During the mapping of the bed extent (and density), notes are also made on any factors visibly affecting the seagrass patch such as:

- the general health and condition of the shoots (e.g. evidence of wasting disease)
- any opportunistic macroalgal cover
- any obvious blow-outs (bare areas caused by natural physical disturbance)
- anthropogenic influences such as bait digging holes, anchor-chain scour, litter, other physical removal or vehicle tracks.

3.4.3 Seagrass density: Seagrass density is measured through stratified random quadrat sampling recording the percentage of seagrass cover. The percentage of other plant species, and the percentage of bare ground is also recorded to aid further interpretation.

Once the area(s) of >5% density are identified (i.e. the bed extent mapped), the density of seagrass is determined through the use of quadrats. Quadrats should ensure they are representative of the range of percentage cover across the bed (Fig. 3). With limited or no prior information, the default requirement is that

- Within a discrete patch, a minimum of three replicate quadrats are taken at random. The number of quadrats is reduced if a patch is particularly small.
- Within a bed, a minimum of around 30 quadrats are taken for a homogenous seagrass bed for statistical viability; more may be required for heterogenous seagrass beds.

When suitable recent past data exists the appropriate number of quadrats may be statistically estimated to take account of the recorded variability.

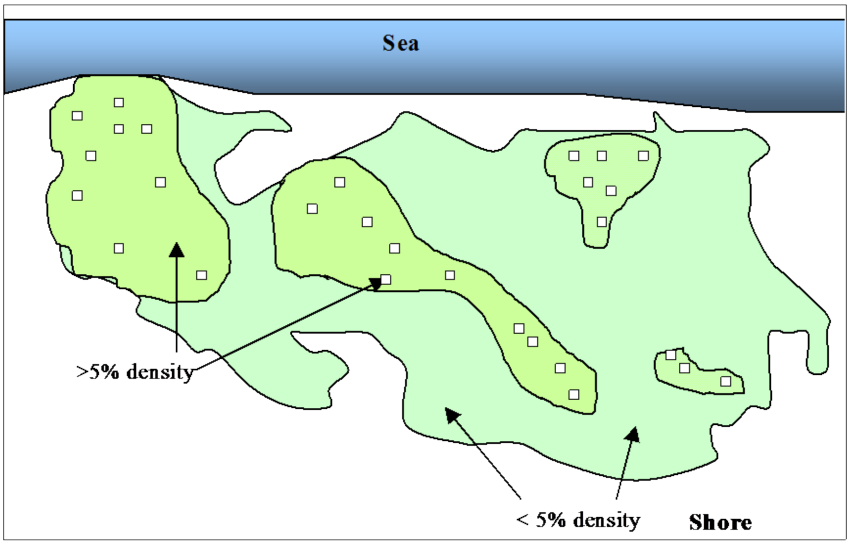


Fig 3: Diagram to illustrate quadrat sampling of seagrass patches within an intertidal seagrass bed.

UK WFD-competent authorities use 0.25 m^2 or ≥ 1 m^2 quadrats (these may be subdivided into four or more squares) to estimate percentage cover of seagrass for patchy or mixed species beds. ≤1m^2 quadrats can be used for continuous uniform beds; this may also be appropriate if a random stratified approach is used for patches which have distinct areas of differing seagrass densities within them.

UK WFD-competent authorities photograph at least 10% of the quadrants for quality assurance intercalibration and cross-checking of percent cover estimates.

3.5 Sample analysis

Identification of angiosperms should be achieved by an experienced taxonomist to the level of species for *Zostera* sp. and to genus for *Ruppia* spp.

Shoot density (measured as percentage cover) should be established at a 5% confidence level by two field workers using guidance photographs to calibrate and minimise variation. Where agreement cannot be reached quadrat photo analysis may be required to confirm accurate levels of percentage cover.

Aerial imagery must be orthorectified and image (colour) balancing completed. Images must be rejected if cloud cover is too high and obscures the study area.

3.6 Data treatment

Raw data require minor treatment prior to calculation of the metric EQR.

3.6.1 Bed extent

Total increase/decrease = ((recent area - past area)/past area)*100

3.6.2 Shoot density /cover

Total increase/decrease = ((recent % cover - past % cover) / past % cover)*100

Shoot density/cover is calculated as the arithmetic mean of percentage change over all quadrat values.

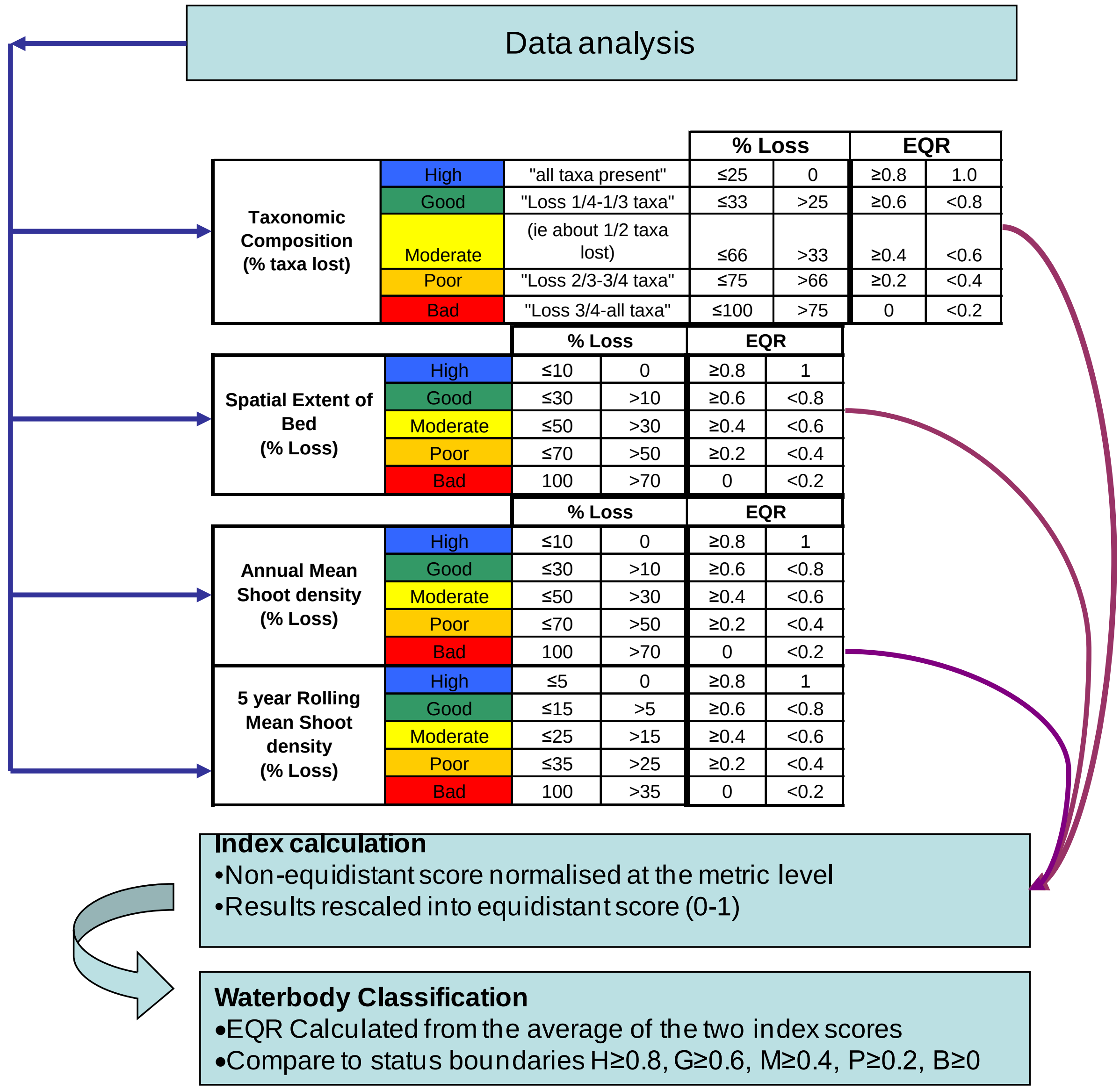
3.6.3 Taxonomic composition

The percentage of taxa lost compared with the reference condition, must be calculated.

% loss = (Observed no. of taxa / Reference no. of taxa) * 100

3.7 EQR calculation

Each metric in the seagrass tool has equal weighting and is combined to produce the ecological quality ratio score (EQR). The face value metrics work on a sliding scale to enable an accurate metric EQR value to be calculated. An average of these EQRs is then used to establish the final water body level EQR and classification status. The process is illustrated in the conceptual diagram (Fig. 4)



Taxonomic Composition (% taxa lost)		% Loss		EQR	
High	"all taxa present"	≤25	0	≥0.8	1.0
Good	"Loss 1/4-1/3 taxa"	≤33	>25	≥0.6	<0.8
Moderate	(ie about 1/2 taxa lost)	≤66	>33	≥0.4	<0.6
Poor	"Loss 2/3-3/4 taxa"	≤75	>66	≥0.2	<0.4
Bad	"Loss 3/4-all taxa"	≤100	>75	0	<0.2

Spatial Extent of Bed (% Loss)	% Loss		EQR	
High	≤10	0	≥0.8	1
Good	≤30	>10	≥0.6	<0.8
Moderate	≤50	>30	≥0.4	<0.6
Poor	≤70	>50	≥0.2	<0.4
Bad	100	>70	0	<0.2

Annual Mean Shoot density (% Loss)	% Loss		EQR	
High	≤10	0	≥0.8	1
Good	≤30	>10	≥0.6	<0.8
Moderate	≤50	>30	≥0.4	<0.6
Poor	≤70	>50	≥0.2	<0.4
Bad	100	>70	0	<0.2

5 year Rolling Mean Shoot density (% Loss)				
High	≤5	0	≥0.8	1
Good	≤15	>5	≥0.6	<0.8
Moderate	≤25	>15	≥0.4	<0.6
Poor	≤35	>25	≥0.2	<0.4
Bad	100	>35	0	<0.2

Fig 4: Conceptual diagram illustrating how the Seagrass indices are combined to calculate a water body classification

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 3 metrics can be combined. A stepwise process is followed:

(i) calculation of the face value for each metric

(ii) normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each metric.

(iii) calculation of the seagrass tool (average of equidistant metric scores).

To calculate the individual metric face values:

See section 3.6

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 metrics. 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 4 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 metric. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range.

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 4.999’.

		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
Taxonomic Composition (% taxa lost)	High	≤25	0	25	≥0.8	1	0.2
	Good	≤33	>25	7.999	≥0.6	<0.8	0.2
	Moderate	≤66	>33	32.999	≥0.4	<0.6	0.2
	Poor	≤75	>66	8.999	≥0.2	<0.4	0.2
	Bad	≤100	>75	24.999	0	<0.2	0.2
Spatial Extent of Bed (% Loss)	High	≤10	0	10	≥0.8	1	0.2
	Good	≤30	>10	19.999	≥0.6	<0.8	0.2
	Moderate	≤50	>30	19.999	≥0.4	<0.6	0.2
	Poor	≤70	>50	19.999	≥0.2	<0.4	0.2
	Bad	100	>70	29.999	0	<0.2	0.2
Annual Mean Shoot density (% Loss)	High	≤10	0	10	≥0.8	1	0.2
	Good	≤30	>10	19.999	≥0.6	<0.8	0.2
	Moderate	≤50	>30	19.999	≥0.4	<0.6	0.2
	Poor	≤70	>50	19.999	≥0.2	<0.4	0.2
	Bad	100	>70	29.999	0	<0.2	0.2
5 year Rolling Mean Shoot density (% Loss)	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤35	>25	9.999	≥0.2	<0.4	0.2
	Bad	100	>35	64.999	0	<0.2	0.2

Table 4. Values for the normalisation and rescaling of face values to EQR metric ranges.

3.8 Water body level classification

The metrics are applied at a water body level, averaging metrics across the entire water body. If there are several seagrass beds within the same water body, the data may be averaged across them to arrive at a water body level classification (Foden & Brazier, 2007; Foden *et al.*, 2010).

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.

Like other biological quality elements, it is not always possible to survey seagrass communities across a whole water body continuously throughout the whole reporting period. Additionally there will always be some sampling error, which will lead to some 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 and to estimate the risk of mis-classification.

An approach to assessing the precision of the results, Seagrass Assessment Incorporating Likelihood of Risk (SAILOR), was developed by WRC (Davey, 2011).

SAILOR works in a similar way to the other CoC tools, however special consideration has to be given to taxonomic composition. Uncertainty in the EQR for this metric could arise from error in assessing which species are present; a species may either go undetected (a false negative) or mis-identification may lead to the mistaken belief that a species is present when it is not (a false positive). It is thought that for seagrass the taxonomic composition metric is more likely to be under-estimated than over-estimated.

For a water body in which the reference condition is three species, if the probability of a false positive is assumed to be 0% for each species and the probability of a false negative is assumed 10% for each species then:

if the sampling identifies two species, then there is 90% confidence that status is Good (i.e. 33% species loss) and 10% confidence that the third species was accidentally missed and therefore that status is High.

if the sampling identifies only one species, then there is 81% confidence that status is Poor (i.e. 66% species loss), 18% confidence that one species was accidentally missed and therefore that status is Good, and 1% confidence that two species were missed and that status is High.

It is assumed that the reference condition is known without error.

There is no way to reliably estimate a standard error for the metric EQR as it can take just one of five possible EQR values. An approximate standard error can be estimated, however, by calculating a weighted mean and standard deviation using the confidence of class results. Continuing the above example, if the confidence of class assessment gives 81% confidence of Poor (EQR = 0.3), 18% confidence of Good (EQR = 0.7) and 1% confidence of High (EQR = 0.9), then the weighted EQR result is:

Metric EQR = (0.81 * 0.3) + (0.18 * 0.7) + (0.01 * 0.9) = 0.459

and the associated standard error is:

$SE = SQRT\ (0.81 * (0.3 - 0.459)^2 + 0.18 * (0.7 - 0.459)^2 + 0.01 * (0.9 - 0.459)^2\ ) = 0.224$

4. Worked Example

A water body which has only had short term monitoring (i.e. less than 5 years) has the results given in table 5.

Patch	Number of taxa	Bed Extent (ha)	Shoot density (%)
Historic	1	58.2	39
Current	1	56.95	22.73
Change	**0**	**-2.15**	**-41.72**

Table 5. Water body values and initial change calculations

Calculation of the metric EQR values

The critical values to calculate the EQRs are taken from Table 4 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>Taxonomic Composition</u>

There is no change in the number of taxa so we would expect the EQR to be 1.0.

<u>Bed Extent</u>

The value of -2.15 (i.e. a *loss* of 2.15) is in the High Band of Table 4. Substituting into the above equation gives

= 1.0 – ((2.15 – 0) * (0.2 /10))

= 1.0 – ((2.15) * (0.02))

= 1.0 – 0.043

= 0.957

<u>Shoot Density</u>

The value of – 41.72 (a *loss* of 41.72) is in the Moderate band of table 4 (note if this value were a five year rolling mean it would be in the Bad band):

= 0.599 – ((41.72 – 30.001) * (0.2/19.999)

= 0.599 – ((11.719) * (0.01)

= 0.599 – 0.117

= 0.482

Overall Ecological Status; Combining the Metrics

To assign a water body's overall ecological status for seagrass the mean of all three metrics is calculated:
= (0.9 + 0.957 + 0.482) / 3

= 0.78
=**Good status** for the water body

5. References

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