UKTAG Transitional & Coastal Water Assessment Method

Angiosperm

Intertidal Seagrass Tool

by

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

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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 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 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 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 (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).

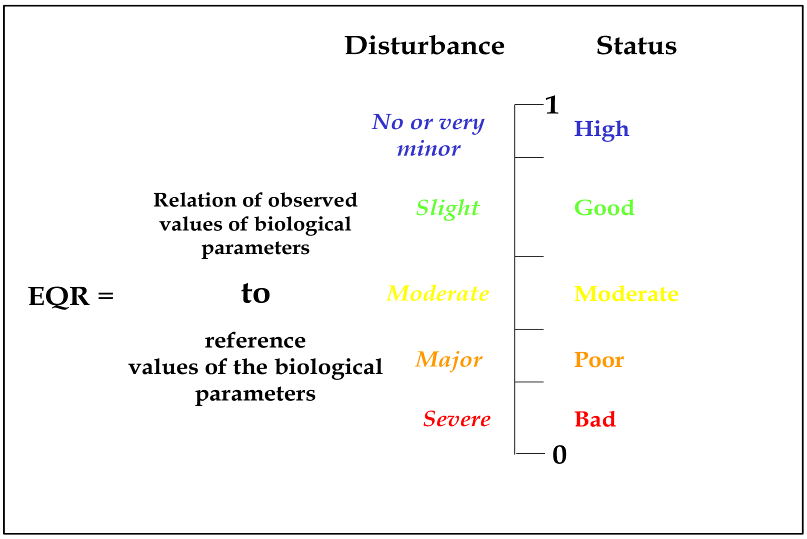


Figure 1: Illustration of the Ecological Quality Ratio and how it relates to the level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance (WFD CIS Guidance Document No. 5, 2003).

1. Key Facts

1.1 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 cover loss or gain)*
(iii) bed extent (percentage area loss or gain).

**Note:* shoot density per se is considered impractical in intertidal seagrass beds, and percentage cover of substratum is used instead.

The individual metrics are considered separately and have equal weighting in the final multimetric calculation. 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 = 0.80
- Good/Moderate = 0.60
- Moderate/Poor = 0.40
- Poor/Bad = 0.20.

To calculate the tool, the change in percentage cover 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 four taxa (three *Zostera* species and *Ruppia sp.).*

Note: Ruppia is difficult to identify to species level, so is aggregated to genus level only.

The percentage cover metric has been developed to classify data using both a single sampling event and a rolling 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 between June and September (inclusive). 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 the intertidal and full seagrass bed extent.

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

1.3 Key Documents

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

*Davey, A. (2014). Confidence of class for the WFD seagrass classification tool. WRC project note to the Environment Agency. 7pp

*Foden, J., Brazier, D. P., Best, M., Scanlan, C. & 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 v.2.3) – *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 is 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 affect 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. In subtidal situations, nutrient enrichment may also lead to excessive growth of opportunistic epiphytic algal species, or blooming species such as, *Ulva*, *Chaetomorpha* and *Ectocarpus* on seagrass beds, potentially compromising the health and viability of seagrass by overlying and smothering them.

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 (= percentage cover). 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[1]; *Zostera marina*, *Z. angustifolia* (known as littoral *Z. marina* in continental Europe) and *Z. noltei and 2 species of Ruppia*. *Z. noltei* (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 shoot density[2] 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 density increasing 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 at least 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).

Note 1: For WFD purposes *Z.angustifolia* is considered as a separate taxon. *Ruppia* is only considered at genus level, owing to the practical difficulties of species level identification.

Note 2: Shoot density is applicable in subtidal beds; density is measured as “percentage cover” in intertidal beds.

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 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 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 of area).

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 (Figure 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).

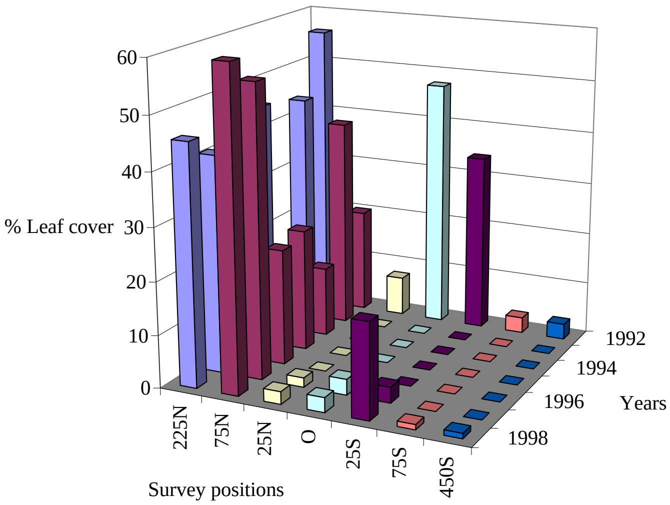


Figure 2: Mean percentage cover of *Zostera* at 7 sites along a transect; Westfield, North Morecambe.

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.

Understanding the individual metrics

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

This metric reflects the loss of seagrass taxa as compared to the number of reference taxa 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* (true seagrass) found in the UK are *Z. noltei*, *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 within 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. noltei* are found in the intertidal zone. *Zostera angustifolia* generally occurs between the mid- and low-tide mark, preferring poorly-draining muddy sediments, particularly pools, creeks and wet sand ripples that are unlikely to entirely dry out during low tide. *Zostera noltei* 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 (widgeon grass) 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* is identified to species level, *Ruppia* is 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 taxa present, as detailed from historical records, remaining constant. 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.

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. The expectation is that the bed will decrease in size in response to pressures.

Annual variability of bed extent can be naturally high, so assessment would ideally be based on trend data. However this requires frequent annual data to assess this variability.

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 certainty may take 5 – 10 years (Duarte & Kirkman, 2001), unless disturbance is catastrophic such as habitat removal for coastal redevelopment.

The current extent of the bed would be compared to the maximum extent recorded (see section 2.4, reference conditions).

If data exist to enable trend lines to be plotted, these may help interpretation of classification data. Ideally the trendlines would be neutral if the bed is in equilibrium at its predicted maximum potential, or positive if the bed's abundance is lower than its predicted potential, but is in a recovery phase. A negative trend is a signal of deterioration and more detailed investigation may be necessary to halt further decline.

Shoot density (percentage cover) (WFD criteria compliance – abundance)

In intertidal seagrass beds, shoot density is assessed as percentage cover (% cover). This metric reflects the change (% loss or gain) of seagrass cover compared with reference conditions. The objective is for a seagrass bed's density to increase or remain at the maximum potential for the site, with the expectation that the average number of plants per unit area (represented intertidally by % cover) will decrease if there is ecological deterioration in the water body.

The current percentage cover would be compared with the maximum cover recorded (see section 2.4, reference conditions).

Alternatively, when sequential yearly data exist, calculation of a 5 year rolling mean considerably reduces noise in this metric, and underlying trends should become more apparent. The % cover metric rolling mean is an average of that year and the previous four years' measurements.

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* where no historical data exist, the first set of reliable data. 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. In practice all the reference conditions below are associated with the greatest total bed extent recorded.

Taxonomic Composition
Ideally the reference condition would be the historically greatest number of taxa recorded. However as mentioned in section 2.1, the ideal environmental parameters for supporting seagrass are not entirely understood, so that absence of seagrass from areas apparently suited to its growth is not always explicable and absence therefore, does not necessarily indicate an anthropogenic impact.

Historic seagrass data are rare as there has not been a national seagrass monitoring programme in the UK. To help inform reference conditions, records of seagrass occurrence were obtained from the National Biodiversity network (NBN) where possible.

For practical purposes the number of taxa associated with the total bed extent reference condition is used (i.e. the maximum bed extent, see below).

Total bed extent
Ideally the reference condition would be the greatest historical extent achieved by the seagrass in that waterbody. However, historic seagrass data are rare, as there has not been a national seagrass monitoring programme in the UK.

For practical purposes the reference extent is the greatest extent recorded in the first WFD cycle. In practice this may not be the first year's data as extra beds are often found in the following year(s). Expert judgement may be needed to determine the baseline data.

Shoot density (% cover)
As mentioned earlier the ideal reference would be for the seagrass % cover to be at the maximum potential for the site. This information is unlikely to be available historically. The reference % cover is the greatest density found recorded in the first WFD cycle. This is normally associated with the greatest bed extent, but where this is not the case then the density associated with the greatest bed extent reference condition should be used.

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 Tables 3 and 4. Tables 3 and 4 define the range of potential observed, or face values for each metric per class.

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: taxonomic composition

QualityStatus	Change in taxonomic composition from reference condition	Metric score
High	All reference species present	0.9
Good	Loss of 25% to 33% of reference species	0.7
Moderate	Loss of 33% to 66% of reference species	0.5
Poor	Loss of 66% to 75% of reference species	0.3
Bad	Loss of all reference species	0.1

Table 4: Metric ecological status boundaries for the other metrics of the intertidal seagrass tool

	EQR range		Spatial Extent of bed (% loss)		Annual Shoot density (% cover loss)		5 Year Rolling Mean Shoot density (% loss)	
QualityStatus	lower	upper	lower	upper	lower	upper	lower	upper
High	≥0.8	1	≤10	0	≤10	0	≤5	0
Good	≥0.6	<0.8	≤30	>10	≤30	>10	≤15	>5
Moderate	≥0.4	<0.6	≤50	>30	≤50	>30	≤25	>15
Poor	≥0.2	<0.4	≤70	>50	≤70	>50	≤35	>25
Bad	0	<0.2	100	>70	100	>70	100	>35

Note: where there is no loss but a measured gain in spatial extent or percentage cover, this is equivalent to a 0% loss and High status class for that metric.

Taxonomic composition: This metric has assigned scores, as the small number of possibilities is limiting. Where no taxa are lost compared with the reference condition, a score of 0.9 is assigned. Where some species are lost compared with reference (i.e. for the Good, Moderate and Poor classes), an EQR representing the midpoint of the class range is assigned depending on the percentage of species lost (Table 3). Where no seagrass taxa remain, the water body would be scored as 0.1 for this metric. For statistical reasons, it is not possible to have absolute certainty that either all or no species have been detected, and so scores of 0.1 for Bad and 0.9 for High are used, rather than 0.0 and 1.0 respectively. This is explained in more detail in Davey (2014) and Section 3.9.

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.

Note: if a seagrass bed scores 0.1 (equivalent to a face value of 0) for taxonomic composition then all seagrass species have been entirely lost, negating the necessity of monitoring for abundance by measuring density and bed extent, as it is to be expected that these must be also 0.

Percentage cover (shoot density, *annual*): The proposed scoring system 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 cover. 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 causes (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 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 4).

Percentage cover (shoot density, *rolling mean*): Rolling means from multiple 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), as shown in Table 4.

***Spatial extent*:** The class boundaries have been set as described for annual percentage cover. Annual natural variability in extent may be high, so interpretation of the final assessment should consider longer term 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 (Figure 3).

Work Area	*Considerations*
Monitoring design	• Are seagrass beds present in the water body/have they been present historically? • 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 > 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. • Collate historic information
Sample analysis / data treatment	• Quality assurance of percentage cover in photographed quadrats • QA and ortho-rectification 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 metric 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 & Risk of Misclassification

Figure 3: 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* spp and *Ruppia* sp) 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 they exist 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 and ground-truthing 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 two 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 competent monitoring Agencies.

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

Note: if a seagrass bed scores 0 (EQR 0.1, see 2.5) for taxonomic composition then all seagrass species have been entirely lost, negating the necessity of monitoring abundance by measuring density and bed extent.

***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 Global Positioning System datalogger/unit of appropriate accuracy level.

Where mixed beds of green macroalgae and seagrass are found or the beds are less distinct or irregular in form, more intensive ground-truthing of extent is required. Ground-truthing must take place at a similar time to the aerial imagery (see 3.3). The boundary of beds is set at where 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) (Figure 4). 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.

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

Once the area(s) of > 5% density are identified (i.e. the bed extent mapped), the % cover of seagrass is determined through the use of quadrats. Quadrats should ensure they are representative of the range of percentage cover across the bed (Figure 4). 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, or increased if particularly large.
- Within a bed, a minimum of around 30 quadrats are taken for a homogeneous seagrass bed for statistical viability; more may be required for heterogeneous seagrass beds.

When suitable recent past data exist, the appropriate number of quadrats may be estimated statistically to take account of the recorded variability. Ranked % cover photographs (spanning the whole % cover range) may be used to help assess % cover in the field.

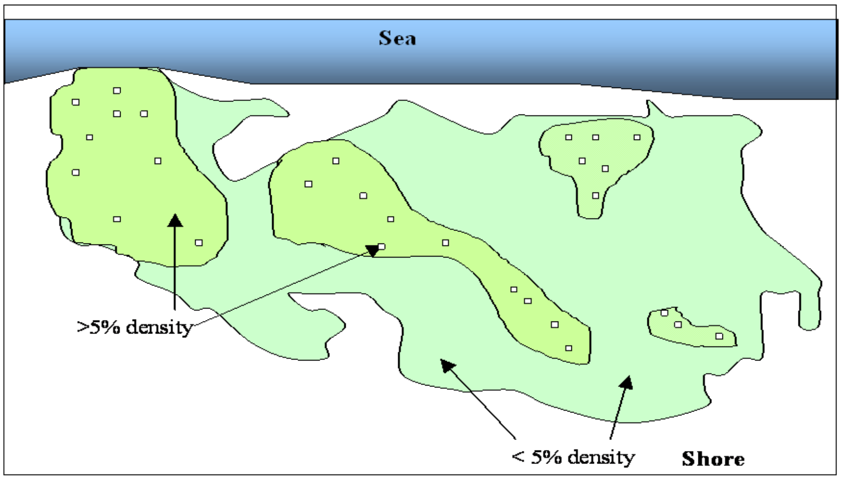


Figure 4: Diagram to illustrate quadrat sampling of seagrass patches within an intertidal seagrass bed.

UK WFD competent monitoring 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.

It is recommended that at least 10% of the quadrats are photographed for quality assurance intercalibration and cross-checking of percent cover estimates.

3.5 Sample analysis

Identification of angiosperms should be by an experienced surveyor to the level of species for *Zostera* spp. 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.

Bed extent

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

Percentage cover (shoot density)

Total increase/decrease = ((recent % cover – past[(a)] % cover) / past[(a)] % cover)*100

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

[a] *Note*: “past“ may mean baseline in some cases.

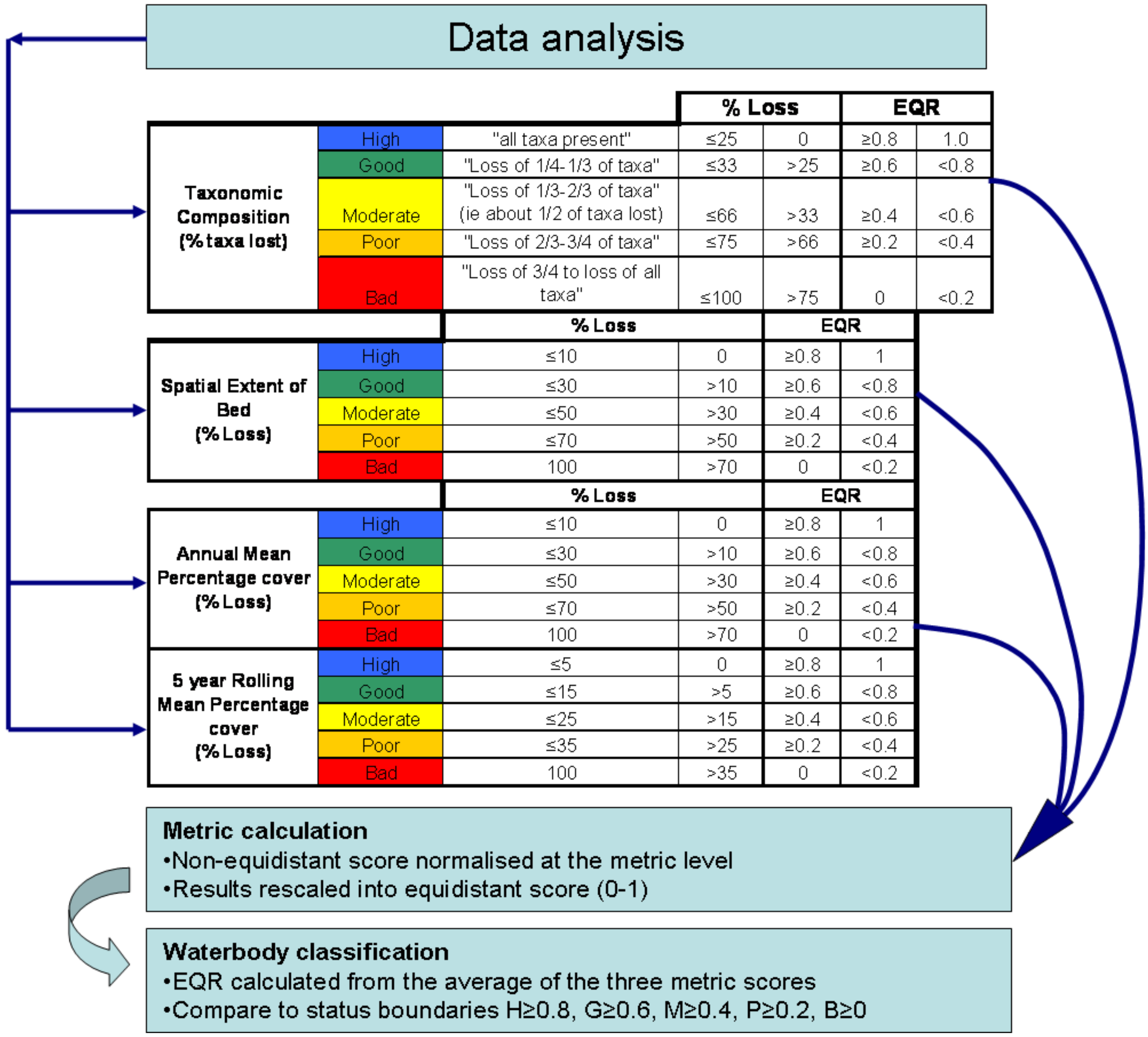
Taxonomic composition

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 (EQR). The face value metrics work on a sliding scale to enable an accurate metric EQR value to be calculated. An average of these metric EQRs is then used to establish the final water body level EQR and classification status. The process is illustrated in the conceptual diagram (Figure 5)



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

Metric	Status	% Loss		EQR	
Spatial Extent of Bed (% Loss)	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

Metric	Status	% Loss		EQR	
Annual Mean Percentage cover (% Loss)	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 Percentage cover (% 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

Figure 5: Conceptual diagram illustrating how the seagrass metrics are combined to calculate a water body classification. *Note*: either the annual mean or rolling mean metric is used.

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 three 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 metric 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 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 4.9999’.

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

		Lower Face Value range value (the measurements towards the lower end of this class range)	Upper FV range value (the measurements towards the upper 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	7.9999	≥0.6	<0.8	0.2
	Moderate	≤66	>33	32.9999	≥0.4	<0.6	0.2
	Poor	≤75	>66	8.9999	≥0.2	<0.4	0.2
	Bad	≤100	>75	24.9999	0	<0.2	0.2
Spatial Extent of Bed (% Loss)	High	≤10	0	10	≥0.8	1	0.2
	Good	≤30	>10	19.9999	≥0.6	<0.8	0.2
	Moderate	≤50	>30	19.9999	≥0.4	<0.6	0.2
	Poor	≤70	>50	19.9999	≥0.2	<0.4	0.2
	Bad	100	>70	29.9999	0	<0.2	0.2
Annual Mean Percentage cover (% Loss)	High	≤10	0	10	≥0.8	1	0.2
	Good	≤30	>10	19.9999	≥0.6	<0.8	0.2
	Moderate	≤50	>30	19.9999	≥0.4	<0.6	0.2
	Poor	≤70	>50	19.9999	≥0.2	<0.4	0.2
	Bad	100	>70	29.9999	0	<0.2	0.2
5 year Rolling Mean Percentage cover (% Loss)	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.9999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.9999	≥0.4	<0.6	0.2
	Poor	≤35	>25	9.9999	≥0.2	<0.4	0.2
	Bad	100	>35	64.9999	0	<0.2	0.2

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).

The final water body EQR for a reporting cycle is an average of the relevant survey years' EQRs.

It is important to note that the WFD treats Coastal Water Angiosperms and Macroalgae as one biological element and in Transitional waters, they are treated as separate elements.

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, 2014).

SAILOR works in a similar way to the other Confidence of Class (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 taxa, 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) = 0.378

and the associated standard error is:

$SE = SQRT\ ((0.81 * (0.3 - 0.378)^2) + (0.18 * (0.7 - 0.378)^2) + (0.01 * (0.9 - 0.378)^2\ )) = 0.1622$

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 6.

Table 6. Water body values and initial change calculations

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**

Calculation of the metric EQR values

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

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

Taxonomic Composition

There is no change in the number of taxa so we would expect the EQR to be 0.9.

Bed Extent

The value of -2.15% (i.e. a *loss* of 2.15%) is in the High Band of Table 5. 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

Percentage cover (Shoot Density)

The value of – 41.72% (a *loss* of 41.72%) is in the Moderate band of Table 5 (*Note:* if this value were a five year rolling mean it would be in the Bad band):

= 0.5999 – ((41.72 – 30.0001) * (0.2/19.999))

= 0.5999 – ((11.719) * (0.01))

= 0.5999 – 0.117

= 0.4829

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 + 0.4829) / 3

= 0.78

= **Good** status

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