Practitioners Guide to the Opportunistic Macroalgal Blooming Tool
Water Framework Directive: Transitional and Coastal Waters

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

Note: this document does not describe all aspects of the opportunistic macroalgal blooming 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 has as such has a meaning defined by the directive.

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

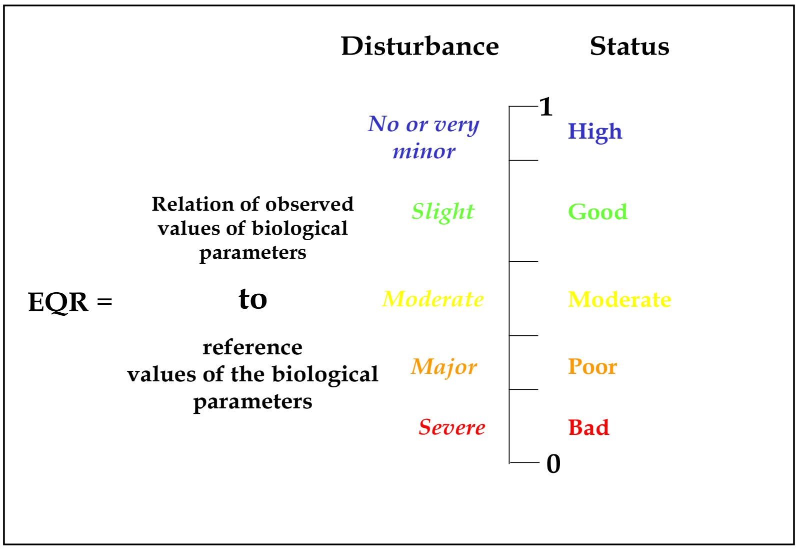

Fig. 1: Illustration of the Ecological Quality Ratio and how it relates to level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance

1. Key Facts

1.1 Tool Overview: Opportunistic Macroalgal Blooming Tool

The OMBT enables an assessment of the condition of the quality element, "Macroalgae ", as listed in Tables 1.2.3 and 1.2.4 of Annex V to the WFD (2000/60/EC). The WFD requires that the assessment of the macroalgal quality element considers composition, macroalgal cover, abundance and disturbance-sensitive taxa.

The OMBT is a multimetric index composed of five metrics:

(i) percentage cover of the available intertidal habitat (AIH)
(ii) total extent of area covered by algal mats (affected area (AA)) **or** affected area as a percentage of the AIH (AA/AIH, %)
(iii) biomass of AIH (g m^2)
(iv) biomass of AA (g m^2)
(v) presence of entrained algae (percentage of quadrats)

The metrics are equally weighted and combined within the multimetric, in order to best describe the changes in the nature and degree of opportunist macroalgae growth on sedimentary shores due to nutrient pressure.

An assessment of opportunistic macroalgae was reported for the first River Basin Management Plans (2009) however, the option to use either the total extent of area covered by algal mats (affected area (AA)) **or** affected area as a percentage of the AIH (AA/AIH, %) is a new modification of the tool.

The OMBT operates over a 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 OMBT, the percentage cover, biomass and presence of entrained opportunistic algae within a known area of sedimentary shore are required. Samples have to be defined by sampling (e.g. area of patch) and processing (e.g. wet weight) methodologies.

Where several surveys are carried out within a reporting period, the EQR is averaged.

1.2 Applicability

Where: The OMBT is suitable for use in UK transitional and coastal waters which have intertidal areas of soft sedimentary substratum (i.e. areas of AIH for opportunistic macroalgal growth). The tool is not currently used for assessing saline lagoons due to the particular challenges in setting suitable reference conditions for these water bodies.

When: The OMBT has been developed to classify data over the maximum growing season so sampling should target the maximum potential growth of the algal bloom. The peak bloom is generally monitored in summer (June to September), although peaks in opportunistic algal growth can occur during the spring and rarely “secondary” peaks may be seen in the late summer or early autumn. Peak timing may vary among water bodies, so local knowledge is required to identify the maximum growth period. Sampling is not recommended outside the summer period due to seasonal variations that could affect the outcome of the tool and possibly lead to misclassification; blooms may become disrupted by stormy autumn weather and often die back in winter. Sampling should be carried out during spring low tides in order to access the maximum area of the intertidal.

Response to Pressure: The OMBT has been designed to identify the impact on macroalgae from nutrients and organic enrichment and should detect signs of eutrophication.

1.3 Key documents

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

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

*Foden, J, Wells, E, Scanlan, C, Best M. A. 2010. Water Framework Directive development of classification tools for ecological assessment: Opportunistic Macroalgae Blooming. *UK TAG Report for Marine Plants Task Team*, January 2010, Publ. UK TAG

Scanlan, C. M., Foden, J., Wells, E. & Best, M.A. 2007. The monitoring of opportunistic macroalgal blooms for the water framework directive. *Marine Pollution Bulletin*, **55**, 162-171.

*Confidence And Precision Tool Aids aNalysis v12.4 (CAPTAIN) – *Excel workbook to estimate the precision of the assessment*.

2. Background

2.1 Ecological principles: An opportunistic algal species is considered able to take advantage of conditions in which other species often struggle to survive or compete. Due to characteristically high rates of mineral nutrient uptake and enhanced reproductive capability, they can prevent or stunt growth of perennial algae by excessive abundance and competition for space (Wallentinus, 1984; Hoffmann & Ugarte, 1985; Kruk-Dowgiallo, 1991). Blooms form principally of species of *Ulva* (this includes taxa formerly known as *Enteromorpha), Chaetomorpha* or *Cladophora*, although other green, red (e.g. *Ceramium, Porphyra*) and brown algae (e.g. *Ectocarpus, Pilayella*) may also reach nuisance proportions (Fletcher, 1996a, 1996b).

All potential bloom-forming species are a natural component of intertidal ecosystems (Abbott & Hollenberg, 1976), however, the formation of opportunistic macroalgal blooms is considered indicative of anthropogenically elevated nutrient levels when they grow to nuisance proportions. Blooms of rapidly growing macroalgae can have deleterious effects on intertidal communities and an undesirable imbalance with effects such as:

- blanketing of the surface causing a hostile physico-chemical environment in the underlying sediment,
- sulphide poisoning of infaunal species,
- anoxic gradient at the water sediment interface,
- effects on birds including changes in the feeding behaviour of waders,
- smothering of seagrass beds,

- interference with water use activities by rafts of floating, detached weed,
- aesthetic effects such as odour nuisance and deposition on sites such as bathing waters.

In some situations it is possible for the algae to grow within the underlying sediment or to continue growth after cover by sedimentary deposits. Entrained algae can promote new algal growth by causing nutrient enrichment within the sediment through decomposing plant material and provide over-wintering material for new growth in spring.

2.2 Normative definitions: In Annex V (1.2.3 and 1.2.4) of the WFD, normative definitions describe the aspects of the macroalgal community that must be included in the ecological status assessment; these are:

- taxonomic composition
- abundance
- disturbance sensitive taxa

To facilitate the development of a suitable assessment method the WFD normative definitions were further interpreted into expanded normative definitions (Table 1).

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

Reference Conditions High	*All disturbance-sensitive macroalgal associated with undisturbed conditions are present. The levels of macroalgal cover are consistent with undisturbed conditions.*	Algal cover <5% and low density. Area and % cover is representative of or close to reference conditions with cover at its minimum accounting for seasonal fluctuations and variations in growth. Macroalgae shows no persistence including lack of entrained algae. The taxonomic composition corresponds totally or nearly totally with undisturbed conditions and disturbance sensitive taxa are present.
Good	*Most disturbance-sensitive macroalgae associated with undisturbed conditions are present. The level of macroalgal cover shows slight signs of disturbance.*	Limited cover (<15%) and low biomass (<500gm^{-2}) of opportunistic macroalgal blooms and with no growth of algae in the underlying sediment. Macroalgae cover shows slights signs of disturbance with slight deviation from reference conditions. Macroalgae shows no persistence with little entrained algae. Most disturbance-sensitive macroalgae associated with undisturbed conditions are present.
Moderate	*A moderate number of disturbance-sensitive macroalgal associated with undisturbed conditions are absent. Macroalgal cover is moderately disturbed and may be such as to result in an undesirable disturbance in the balance of organisms present in the water body.*	Increased cover (>15%) and/or biomass (>500gm^{2}) of opportunistic macroalgal blooms; may have algae growing in the underlying sediment (boundary condition). Macroalgae growth shows moderate deviation from reference conditions and is slightly detrimental to the surrounding environment with some signs of persistence. A number of disturbance-sensitive macroalgal taxa associated with undisturbed conditions are absent.

2.3 Development of the tool

The OMBT combines measures of opportunistic macroalgae cover, biomass and entrainment into a multimetric index. The individual metrics (expressed on an EQR scale) are averaged to create the final OMBT assessment. Historical and current knowledge of the causes and effects of opportunistic macroalgal blooms were used to design a suitably responsive index.

Macroalgal blooms in littoral soft sediment environments have been a cause of concern under Directives that pre-date the WFD, principally the Urban Waste Water Treatment (UWWTD, 1991), Nitrates (Nitrates Directive, 1991) and Habitats (Habitats Directive, 1992) Directives, and also to OSPAR (Oslo and Paris Commission, 2003) all of which consider the assessment of eutrophication. As the need to normalise definitions of eutrophication, and monitoring schemes, to produce a robust assessment satisfying all relevant criteria is recognised, attention has been paid to align methods between directives.

Understanding the individual Metrics within the OMBT:

(WFD criteria compliance – taxonomic composition, disturbance sensitive taxa) The majority of algal mats encountered in UK locations are composed principally of *Ulva*, although other green species of algae such as *Cladophora* and *Chaetomorpha* have been reported, along with the brown algae *Ectocarpus* and *Pilayella* and the red algae *Porphyra* which may also reach nuisance proportions. The taxonomic composition of macroalgal blooms is generally limited to one or more of a number of fast-growing, opportunistic species.

Taxonomic composition *per se* is not considered to be appropriate as a metric, due to the small number of taxa typically found in blooms or estuaries. Additionally these taxa may be considered as a representative group, as defined in Annex 5 section 1.4.1(i) of the WFD, for the quality element in soft sediment areas.

Spatial Extent **(WFD criteria compliance – abundance).** Spatial coverage is considered as both (i) a percentage of the AIH and (ii) total area cover (affected area in hectares) of the water body. It is important to define the AIH suitable for macroalgal growth. Some areas, e.g. channels and channel edges subject to constant scouring, may never be suitable for algal blooms and need to be excluded from area assessment. Suitable areas are considered to consist of mud, muddy sand, sandy mud, sand, stony mud and mussel beds.

In large water bodies with '*relatively*' small patches of macroalgal coverage, there was concern that despite the total percentage cover of the AIH remaining below the threshold, the total area covered could actually be quite substantial and could still affect the surrounding and underlying communities. Therefore an additional metric was established to help compensate for this; Affected Area as a percentage of the AIH (AA/AIH, %). In the final assessment ***either*** the AA ***or*** percentage AA/AIH is used, whichever reflects the worse case scenario.

Biomass **(WFD criteria compliance – abundance).** Assessment of the spatial extent of the algal bed alone will not indicate the level of risk to a water body. A very thin (low biomass) layer covering over 75% of a shore might have little impact on underlying sediments and fauna. The influence of biomass is therefore incorporated.

Biomass is calculated as a mean for (i) the whole of the AIH **and** (ii) for the affected areas. The potential use of maximum biomass was rejected, as it could falsely classify a water body by giving undue weighting to a small, localised blooming problem.

Entrained Algae: The persistence of algae within sediments provides both a means for over-wintering of algal spores and a source of nutrients within the sediments. Build-up of weed within sediments therefore implies that blooms can become self-regenerating given the right conditions (Raffaelli *et al.*, 1989). Absence of weed within the sediments lessens the likelihood of bloom persistence, while its presence gives greater opportunity for nutrient exchange with sediments. Consequently, the presence of opportunistic macroalgae growing within the surface sediment was included in the tool.

2.4 Reference conditions

Published and unpublished literature, along with expert opinion, was used to derive critical threshold values suitable for defining quality status classes.

A Department of the Environment, Transport and the Regions (DETR) expert workshop suggested reference levels of < 5% cover of AIH of climax and opportunistic species for high quality sites (DETR, 2001). In line with this approach, the WFD adopted < 5% cover of opportunistic macroalgae in the AIH as equivalent to High status. From the WFD North East Atlantic intercalibration phase 1 results, German research into large sized water bodies revealed that areas over 50 ha may often show signs of adverse effects, however if the overall area was less than $1/5^{th}$ of this adverse effects were not seen, so the High/Good boundary was set at 10 ha. In all cases a reference of 0% cover for truly un-impacted areas was assumed. *Note:* opportunistic algae may occur even in pristine water bodies as part of the natural community functioning.

The proposal of reference conditions for levels of biomass took a similar approach, considering existing guidelines and suggestions from DETR (2001), with a tentative reference level of <100g m^{-2} wet weight. This reference level was used for both the average biomass over the affected area and the average biomass over the AIH. As with area measurements a reference of zero was assumed.

An ideal of no entrainment (i.e. no quadrats revealing entrained macroalgae) was assumed to be reference for un-impacted waters. After some empirical testing in a number of UK water bodies a High / Good boundary of 1% of quadrats was set.

2.5 Class boundaries

The overall class boundaries for the OMBT are shown in table 2.

Table 2: Overall ecological status boundaries for the OMBT

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

Published and unpublished literature were used to derive the critical threshold values suitable for defining class boundaries. Some metric thresholds, e.g. affected area were derived using a combination of expert opinion and existing data. For the affected area metric this was achieved through a UK process using known sites of opportunistic blooms of varying intertidal habitat and environmental factors.

The Comprehensive Studies Task Team (DETR, 2001) that was set up to derive standards and criteria for the Urban waste Water Treatment Directive (UWWTD), stated that a symptom of the potential start eutrophication is when:

(i) 25% of the available intertidal habitat has green macroalgae

and

(ii) at least 25% of the sediment (i.e. 25% in a quadrat) is covered.

This implies that an overall cover of the AIH of 6.25% (25*25 %) represents the start of a potential problem. For the High/Good boundary 5% is used as slight deviation from reference.

However, in reality, it was suggested that greater than 25% cover should be considered an indicator of harm. Wither (2003) stated that, in reality, true problem areas often have a >60% cover within the affected area of 25% of the water body. This would equate to 15% overall cover of the AIH (i.e. 25% of the water body covered with algal mats at a density of 60%). Wither (2003) suggested that the 15% value could therefore be used for % cover at the next critical level (Good / Moderate boundary). The Environment Agency has considered >75% cover as seriously affecting an area, and this formed a threshold for Bad status. The final % cover thresholds for the levels of ecological quality status are provided in Table 3.

Class boundaries for biomass values were derived from DETR (2001) recommendations that <500 g/m^2 wet weight was an acceptable level above the reference level of <100 g/m^2 wet weight. In Good status only slight deviation from High status is permitted so 500 g/m^2 represents the Good/Moderate boundary. Moderate quality status requires moderate signs of distortion and significantly greater deviation from High status to be observed. The presence of >500 g m^2 but less than 1,000 g m^2 would lead to a classification of Moderate quality status at best, but would depend on the percentage of the AIH covered.

DETR (2001) and others (Lowthion *et al.*,1985; Hull, 1987, Wither, 2003) have identified 1kg m^{-2} wet weight as a level of biomass at, or above, which significant harmful effects on biota have been observed. *Note*: some local studies have not shown harmful impacts at or above 1kg m^{-2} (e.g. Rees-Jones, 2006) due to local conditions, but UK experts generally agreed that there is reasonable evidence to support the DETR expert committee's view that this level of biomass is unacceptable.

For the presence of entrained algae, empirical studies testing a number of scales were undertaken on a number of impacted waters. It was clear from these that seriously impacted waters have a very high percentage (>75%) of the beds showing entrainment (Poor / Bad boundary). Entrainment was felt to be an early warning sign of potential eutrophication problems so a tight High /Good standard of 1% was selected (this allows for the odd change quadrat or error to be made), Consequently the Good / Moderate boundary was set at 5% where (assuming sufficient quadrats were taken) it would be clear that entrainment and potential over wintering had started.

Table 3 shows the metric ranges and boundary values.

Table 3: Face value and metric EQR ranges used in the OMBT

Quality Status	**High**	**Good**	**Moderate**	**Poor**	**Bad**
EQR	**≥0.8 - 1.0**	**≥0.6 - < 0.8**	**≥0.4 - < 0.6**	**≥0.2 - < 0.4**	**0.0 - < 0.2**
% cover of AIH	0 - 5	5 - 15	15 -25	25 - 75	75 - 100
Average biomass (g m^2) of AIH	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000 (- 6,000)
Average biomass (g m^2) of AA	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000 (- 6,000)
*AA (hectares)**	*≥0 - 10*	*≥10 - 50*	*≥50 - 100*	*≥100 - 250*	*≥250 (- 6,000)*
*AA/AIH (%)**	*≥0 - 5*	*≥5 - 15*	*≥15 - 50*	*≥50 - 75*	*≥75 - 100*
% entrained algae	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

**N.B. Only the lower EQR of the 2 metrics, AA or AA/AIH should be used in the final EQR calculation*

3 Undertaking an assessment

3.1 Summary of the process

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

Work Area	*Considerations*
Monitoring Design	• Is opportuntistic macroalgae an appropriate assessment tool? (Define suitable AIH) • Establish peak growth period for monitoring • Consider aerial imagery for bed extent measurements
↓ Sample collection	• Does preliminary survey show <5% cover in water body? If yes, full survey not required • If full survey required, use standardised methods • Measure bed extent by aerial imagery or ground assessment using handheld GPS • Measure % cover in quadrats (no. defined by algal coverage) • Collect macroalgae for biomass measurement from quadrats • Record entrainment (growth > 3cm in sediment) • Record taxa and supporting observations
↓ Sample analysis	• Quality assurance procedures for % cover • Wet weight (biomass) of algae • Calculate AIH (refine with local knowledge)
↓ Calculation: Face value	• Total affected Area • Total % cover of Available Intertidal Habitat (AIH) • Average Biomass of Available Intertidal Habitat (AIH) • Average Biomass of affected area • Presence of entrained algae (% of quadrats)
↓ EQR calculation	• Normalise and rescale values to equidistant 0-1 range *Final Equidistant index score = Upper Equidistant Class range value – ((Face Value - Upper Face value range) * (Equidistant class range / Face Value Class Range))*
↓ Water body classification	• Derive WB EQR • Assign Class Status (use defined class boundaries) • Calculate Confidence of Class and Risk of Misclassification

Fig. 2: Flow chart summarising the main stages involved in undertaking an OMBT assessment.

3.2 Data requirements

The calculation of the OMBT requires monitoring of total bed extent (ha) in the water body, and macroalgal cover (%), macroalgal biomass (wet weight g m^{-2}) and presence of entrained algae (%) in the measured quadrats. The algal taxa present need to be recorded but to genus level only.

Additional information such as depth of the algal mat and anoxic layer, the presence of e.g. *Corophium*, cockles within the quadrat, etc should be recorded in the field. Although this information is not used within the tool, it can provide useful supporting evidence.

3.3 Sampling strategy

For a full survey to take place there must be evidence of > 5 % opportunistic macroalgal cover of the AIH in the water body. Sampling should take place during the peak growth season, generally June through September. The exact sampling strategy used varies depending on the extent of the algal bed and what areas can be accessed safely.

AIH is defined as the water body area composed of mud, muddy sand, sandy mud, sand, stony mud and mussel beds from mean high water springs to mean low water springs, excluding hard substrate such as piers and jetties and channels. The AIH for each water body is calculated from Ordinance Survey maps or using aerial or remotely sensed images and refined using local, expert knowledge.

A preliminary site visit should be made to establish, semi-quantitatively, if the percentage macroalgal cover is < 5 %. If the area of cover is < 5% of the AIH of the water body, the water body status is reported as High. No further samples are required. If the area of cover is > 5 %, a full survey is carried out. *Note*: Some very large water bodies may have patches comprising under 5% of the total water body area. However these patches may still be having a significant local impact so should be assessed.

Bed extent can be distinguished by aerial or remotely sensed images, or ground surveys with hand held GPS. Overall density and percentage cover are determined by measurements using quadrats within the beds.

3.4 Sampling methodology

The WFD competent monitoring authorities (EA, NIEA, SEPA) have their own operating procedures and instructions (please refer to the relevant Agency for further details).

Aerial or remotely sensed images, or ground surveys with hand held GPS, are used to identify the opportunistic macroalgal bed boundaries. Perimeters of algal beds are measured at >15%. A second boundary may be established surrounding this limit at <15% but >5% (see Figs 3 and 4). Examples of the sampling strategy where a single defined macroalgae bloom exists in the water body (Fig. 3) or where several patches exist (Fig. 4). These demonstrate the mapping of algal beds and use of quadrats for estimating average cover and biomass.

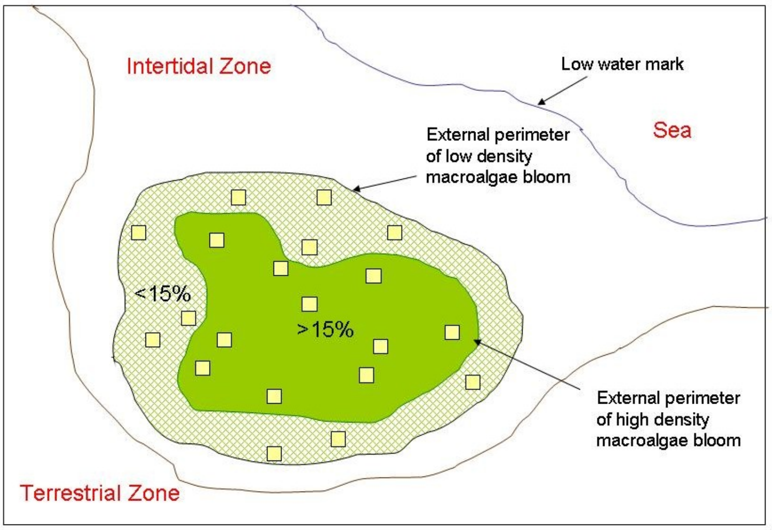

Figure 3: Example 1 of sampling methods within a single defined patch of algal growth.

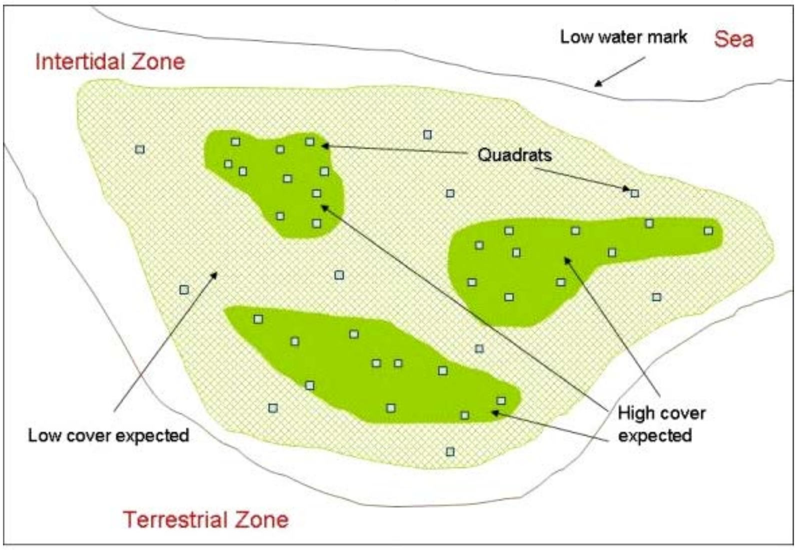

Figure 4: Example 2 of sampling methods within three discrete patches of algal growth.

The algal taxa present are recorded to genus level. Additional information such as depth of the algal mat and anoxic layer, the presence of e.g. *Corophium*, cockles within the quadrat, etc are recorded in the field.

Percentage cover: The percentage cover estimation is achieved through stratified random sampling within the areas of >15% cover (high density area) and <15% cover (low density area). These areas are considered separately to ensure accurate percentage cover is achieved for the high density areas and so as not to underestimate the cover of the bloom. Within the high density areas, a minimum of 3 quadrats for each discrete patch of algal bloom should be recorded. This should be repeated for the less dense areas of <15%. Within each quadrat the total percentage cover should be estimated as accurately as possible to 5%. The actual number of quadrats should be proportional to the variability of algal density and the irregularity of patches, i.e. one large, consistently dense patch may require fewer quadrats than scattered, patches within which cover is variable. Quadrat size is generally 0.25m^2.

Biomass: Macroalgae on the surface of the sediment (not that buried within the sediment) are collected to determine the average biomass of opportunistic macroalgae per monitored patch.

Entrained Algae: This is measured in conjunction with biomass, as removal of algae for weighing will indicate its level of entrainment. Algae are considered as entrained in muddy sediment when they are found growing >3cm deep within sediments.

These values may be considerably lower in sandy substrate.

3.5 Sample analysis and quality

Identification of opportunistic algae to genus level is done using an appropriate identification guide.

Collected algae for biomass assessment are thoroughly rinsed to remove all sediment and invertebrate fauna (e.g. cockles, *Hydrobia*), hand squeezed until water stops running and the wet weight of algae recorded.

For quality assurance of the percentage of cover, two independent readings should be within +/- 5%. A photograph should be taken of every quadrat for intercalibration and cross-checking of percent cover determination. Measures of biomass should be calculated to 1 decimal place of wet weight of sample. For both procedures the accuracy should be demonstrated with the use of quality assurance checks and procedures.

3.6 Data treatment

No specific data treatment is required prior to the calculations.

3.7 EQR calculation

Each metric in the OMBT 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 values is then used to establish the final water body level EQR and classification status.

The Ecological Quality Ratio (EQR) determining the final water body classification ranges between a value of zero to one. The process is illustrated in the conceptual diagram (Figure 5)

Calculate Results from Raw data:

Total affected area
Total % cover
Average Biomass of AIH
Average Biomass of affected area
Entrained algae

Combine values within the metric system

Quality Status	High			Good			Moderate			Poor			Bad		
EQR	≥0.8	-	1.0	≥0.6	-	<0.8	≥0.4	-	<0.6	≥0.2	-	<0.4	0	-	<0.2
% Cover of Avaiable Intertidal Habitat (AIH)	≤5	-	0	≤15	-	>5	≤25	-	>15	≤75	-	>25	100	-	>75
Average biomass of AIH (g m^{-2})	≤100	-	0	≤ 500	-	>100	≤1000	-	>500	≤ 3000	-	>1000	≤ 6000	-	>3000
Average biomass of Affected Area (AA) (g m-2)	≤100	-	0	≤ 500	-	>100	≤1000	-	>500	≤ 3000	-	>1000	≤ 6000	-	>3000
Affected Area (Ha)	≤10	-	0	≤50	-	>10	≤100	-	>50	≤250	-	>100	≤ 6000	-	>250
AA/AIH [%]	≤5	-	0	≤15	-	>5	≤50	-	>15	≤75	-	>50	100	-	>75
% Entrained Algae	≤1	-	0	≤5	-	>1	≤20	-	>5	≤50	-	>20	100	-	>50

Index calculation
- Non-equidistant score normalised at the metric level
- Results rescaled into equidistant score (0-1)

Waterbody Classification
- EQR Calculated from the average of the two index scores
- Compare to status boundaries H≥0.8, G≥0.6, M≥0.4, P≥0.2, B≥0

Fig 5: Conceptual diagram illustrating how the Opportunistic Macroalgal Blooming Tool 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, so that the metrics can be combined. A stepwise process is followed:

(i) calculation of the face value (e.g. percentage cover of AIH) for each metric

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

(iii) calculation of OMBT(average of equidistant metric scores).

To calculate the individual metric face values:

- **Percentage cover of AIH (%)** = (Total % Cover / AIH} x 100

Where Total % cover = Sum of {(patch size) / 100} x average % cover for patch

- **Affected Area, AA (ha)** = Sum of all patch sizes

- **Biomass of AIH (g m^{-2})** = Total biomass / AIH

Where Total biomass = Sum of (patch size x average biomass for the patch)

- **Biomass of Affected Area (g m^{-2})** = Total biomass / AA

Where Total biomass = Sum of (patch size x average biomass for the patch)

- **Presence of Entrained Algae** = (No. quadrats with entrained algae / total no. of quadrats) x 100

- **Size of AA in relation to AIH (%)** = (AA/AIH) x 100

Normalisation and rescaling of face values to metric range.

The face values are converted to an equidistant EQR scale to allow combination of the metrics. Initially this was carried out in a two step process by 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 give the critical values at each class range required for the above equation. The first three numeric columns contain the face values (FV) for the range of the index in question, the last three numeric columns contain the values of the equidistant 0 - 1 scale and are the same for each index. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range.

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
% Cover of Avaiable Intertidal Habitat (AIH)	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	≤75	>25	49.999	≥0.2	<0.4	0.2
	Bad	100	>75	24.999	0	<0.2	0.2
Average biomass of AIH ($g\ m^{-2}$)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Average biomass of Affected Area (AA) (g m-2)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Affected Area (Ha)	High	≤10	0	10	≥0.8	1	0.2
	Good	≤50	>10	39.999	≥0.6	<0.8	0.2
	Moderate	≤100	>50	49.999	≥0.4	<0.6	0.2
	Poor	≤250	>100	149.99	≥0.2	<0.4	0.2
	Bad	≤6000	>250	5749.999	0	<0.2	0.2
AA/AIH [%]	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤50	>15	34.999	≥0.4	<0.6	0.2
	Poor	≤75	>50	24.999	≥0.2	<0.4	0.2
	Bad	100	>75	27.999	0	<0.2	0.2
% Entrained Algae	High	≤1	0	1	≥0.0	1	0.2
	Good	≤5	>1	3.999	≥0.2	<0.0	0.2
	Moderate	≤20	>5	14.999	≥0.4	<0.2	0.2
	Poor	≤50	>20	29.999	≥0.6	<0.4	0.2
	Bad	100	>50	49.999	1	<0.6	0.2

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

3.8 Water body level classification

Opportunistic macroalgae are monitored, and the OMBT applied, at water body level. For any one year's survey the EQR is the average of the metrics. The final water body EQR at the end of the reporting period is the average of all survey year's EQR.

3.9 Understanding the certainty of the assessment

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

A methodology for calculating a measure of the confidence of class (CofC) for the Opportunistic Macroalgal Blooming tool, 'Confidence And Precision Tool AIds aNalysis' (CAPTAIN), was developed by WRc (Davey, 2009).

CAPTAIN calculates confidence of class (CofC) at three levels: metric, survey (single sampling event) and water body over the reporting period (potentially several surveys):

- The CofC for each metric in each survey is based on the metric EQR and takes account of sampling error plus any error in the measurement. This aspect describes how each metric score is derived, and its corresponding standard error is calculated to give a metric CofC.
- The CofC for each survey is based on the Survey EQR and takes account of combined uncertainty in the five metrics. This part of the system considers how the metric scores are combined to yield an EQR and CofC for each survey.
- The CofC for the water body is based on the Final EQR and takes account of the temporal variation among the EQR results from replicate surveys. This part of the CofC assessment is performed for the water body as a whole.

For the CofC of each of the five metric scores and metric EQRs the level of standard error can be calculated incorporating all variables including measurement error. This can be converted to a confidence of class using a normal distribution approach. The confidence of class for the survey EQR is calculated using the average of the five metric EQRs. As the standard errors of the five metrics cannot be assumed to be independent because they are based on data from the same quadrats, they will share any errors in the measurement of patch area and AIH. Therefore the system calculates a further standard error of the whole survey EQR which is also converted to a confidence of class following the same normal distribution approach.

The standard error is calculated as an approximation due to the normalised EQR scale. This is achieved by estimating the 95% confidence interval around each metric score and normalising the upper and lower confidence limits,

Finally the standard error of the final EQR measures the uncertainty in the final status assessment. However, where only one survey is undertaken with a single EQR result, the variability cannot be measured directly; it has to be estimated indirectly using data from other water bodies. Therefore, the standard deviation is instead estimated from the mean EQR using an approach developed by Ellis & Adriaenssens (2006) to estimate the likely spatio-temporal variability in Survey EQR as a function of the mean Survey EQR in a water body. Variability is expected to be greatest in water bodies of moderate status (EQR ≈ 0.5), and to get progressively smaller as the mean EQR tends towards 0 or 1e.g. to have a mean EQR of exactly 0 (or 1), all surveys must yield EQR values of 0 (or 1) – i.e. there must be no variation among surveys. The Final EQR and its standard error are then converted to a confidence of class following the t-distribution approach

4. Worked example

A water body with an available intertidal habitat of 1481.8 ha has four discrete patches. Quadrat results were obtained for percentage cover and biomass from each patch. No entrainment of macroalgae was determined. The results are given in the tables below for each of the algal patches (Tables 8, 9).

Table 8: Face value biomass and percentage cover data for four discrete patches in the water body

Patch	Patch area (Ha)	Average % cover in quadrats	Average biomass in quadrats (g m-2)	Actual cover (patch area * % cover)	Actual Weight (Patch Area * biomass)
1	92.7	11	56.8	10.20	5265.36
2	97.3	63.33	376	61.62	36584.8
3	153.7	70.5	302.152	108.36	46440.7624
4	104.2	92	1278.947	95.86	133266.2774
Totals	**447.9**			**276.04**	**221557.2**

Table 9: Water body face value results for the analysis of opportunistic macroalgae cover and biomass.

Totals	
Cover of algae (ha)	276.04
Biomass of algae (gm^2)	221557.2
Affected intertidal area (ha)	447.9
Available intertidal habitat (ha)	1481.8

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))*

Percentage cover of AIH (%) = (Total % Cover / AIH) x 100
= (276.04 / 1481.8) * 100 = 18.629
This value is in the Moderate band of table 4, substituting into the Equation above gives:
Final Equidistant index score = 0.599 – ((18.629 – 15.001) * (0.2 / 9.999))
= 0.526

Biomass of AIH (g m^2) = Total biomass / AIH
= 221557.2 / 1481.8
= 149.52
This value is in the Good band of table 4, substituting into the Equation above gives:
Final Equidistant index score = 0.799 – ((149.52 – 100.001) * (0.2 / 399.99))
= 0.774

Biomass of Affected Area (g m2) = Total biomass / AA
= 221557.2 / 447.9
= 494.658
This value is in the Good band of table 4, substituting into the Equation above gives:
Final Equidistant index score = 0.799 – ((494.658 – 100.001) * (0.2 / 399.99))
= 0.602

Affected Area, AA (ha) = Sum of all patch sizes
= 447.9
This value is in the Bad band of table 4, substituting into the Equation above gives:
Final Equidistant index score = 0.199 – ((447.9 – 250.001) * (0.2 / 5749.999))
= 0.192

Size of AA in relation to AIH (%) = (AA/AIH) x 100
= (447.9 / 1481.8) * 100
= 30.23%
This value is in the Moderate band of table 4, substituting into the Equation above gives:
Final Equidistant index score = 0.599 – ((30.23 – 15.001) – (0.2 / 34.999)
= 0.512
[Note in this example this value will not be used as the final calculation uses the lower value of AA or AA / AIH]

Presence of Entrained Algae = {No. quadrats with entrained algae / total no. of quadrats} x 100.

As there are no quadrats with entrainment this is 0.00% which is in the High band and will give an EQR value of 1.0.

The overall EQR for this survey is:

= (0.526 + 0.774 + 0.602 + 0.192 + 1.0) / 5

= 0.619 (Good)

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