UKTAG Transitional Water Assessment Method

Macroalgae

Fucoid Extent Tool

by

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

Publisher: **Water Framework Directive – United Kingdom Advisory Group (WFD-UKTAG)**
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April 2014

ISBN: 978-1-906934-38-5

Health and safety statement

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

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

UKTAG Guide to the Fucoid Extent Tool
Water Framework Directive: Transitional Waters

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

Note: this document does not fully describe the development of all aspects of the fucoid extent tool; for this please refer to the additional literature (e.g. Wilkinson *et al.,* 2007). 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 defined meaning.

To carry out a WFD biological assessment, each WFD defined biological quality element (BQE, defined in the WFD) is required to give a statistically robust definition of the 'health' of that element in the defined water body. The 'health' of a BQE is assessed by comparing the measured conditions (observed value) against that described for reference (minimally impacted) conditions. This is reported as an Ecological Quality Ratio (EQR). An EQR of 1 represents reference conditions and 0 represents severe impact. The EQR is divided into five ecological status classes (High, Good, Moderate, Poor, Bad) that are defined by the changes in the biological community in response to disturbance (Figure 1).

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

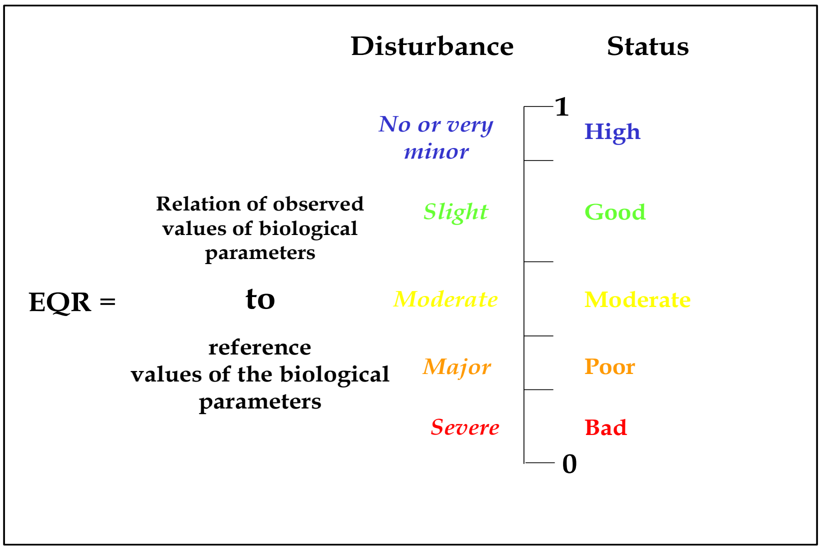


Figure 1: Illustration of the Ecological Quality Ratio and how it relates to the level of disturbance and ecological status. The class band widths relate to biological changes as a result of disturbance. (WFD CIS Guidance Document No. 5, 2003).

1. Key Facts

1.1 Tool Overview: Fucoid Extent

The fucoid extent tool contributes to the assessment of the condition of the quality element, "macroalgae", as listed in Table 1.2.3 of Annex V to the WFD (2000/60/EC). The WFD requires that the assessment of the macroalgal quality element considers composition, macroalgal cover and abundance.

The fucoid extent tool uses the position of fucoids in relation to the median salinity at the freshwater end of the fucoid range in a transitional water to evaluate the status of the water body.

The fucoid extent tool operates over an Ecological Quality Ratio (EQR) range from 0 (major disturbance) to 1 (reference/minimally disturbed). The four class boundaries are:

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

An assessment using the fucoid extent tool was not reported for the first 2009 River Basin Management Plans due to insufficient available data at that time.

To calculate the tool, the identification of the upper fucoid limit point within the transitional water and the measurement of the median salinity at that point are required. Where no fucoids are present, the presence of other macroalgal species in the water body needs to be considered.

1.2 Applicability

Where: The fucoid extent tool is suitable for use in linear-type (riverine form) UK transitional waters where there is suitable substratum for macroalgae to grow. It is **not** suitable for the assessment of:

- saline lagoons identified as transitional waters under WFD
- embayed transitional waters.

Note: factors such as barriers influencing the upstream fucoid penetration must be considered when interpreting the tool output.
Very high natural turbidity and/or a very high level of natural suspended solid settlement can prevent fucoid colonisation. Where turbidity is known to be particularly high and upstream fucoid penetration is restricted, it should be considered that this tool may be unsuitable.

Fucoids need suitable substrata to attach to, i.e. rocks or other hard structures. It may be necessary to search thoroughly to find suitable upstream substrata. Where there is definitely an absence of suitable substrata in the upper reach of an estuary then the water body should be considered unsuitable for this tool.

When: The fucoid extent tool has been developed to classify data using a single sampling event for the identification of the upper fucoid limit point. This identification can be done at any time throughout the year. Multiple sampling is required to identify the relevant median salinity for the location. It is recommended that data across the Spring – Neap tidal cycle and from periods of high freshwater flow and low freshwater flow are considered.

Response to pressure: The tool is designed to detect the collective impact of a broad range of toxic substances related to heavy industry and sewage discharges, including heavy metals and pesticides, on the distribution of the fucoid macroalgal species.

1.3 Key Documents

The documents marked * will be hosted on the UK Technical Advisory Group (UKTAG) website www.wfduk.org.

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

*Environment Agency (2012). Median Salinity use for Fucoid Extent tool. Internal Environment Agency Note.

*TRansitional Ecological Assessment: Salinity Uncertainty Robustly Evaluated (TrEASURE v1.1) - *Excel workbook to produce classification and CoC assessment.*

*UKTAG Biological Status Methods (2009). Transitional Water Assessment Methods Macroalgae (Fucoid Extent). – *High level non-technical summary*

* Wilkinson, M. & Brown, H. (2009). Macroalgae in Estuaries v2. Marine Plants Task Team (MPTT) paper. 70 pages

Wilkinson, M., Wood, P., Wells, E., & Scanlan, C. (2007). Using attached macroalgae to assess ecological status of British estuaries for the European Water Framework Directive. Marine Pollution Bulletin, 55, (1-6), 136-150.

2. Background

2.1 Ecological Principles

The fucoid extent tool is designed to detect the impact of toxic substances on the ecological status of an estuary. It is based on the assumption that the higher the upper fucoid limit is within an estuary, the better the water quality is. With little toxic stress, fucoids can penetrate almost to the freshwater inflows. However anthropogenic pressure can limit the upstream colonisation of estuarine habitats by these species.
The tool takes into account variations of fucoid penetration of the estuary owing to natural changes in salinity.

The tool is based on a common concept of the distribution of macroflora in estuaries (Figure 2, Wilkinson *et al*., 1995, Wilkinson *et al.,* 2007, Wilkinson & Brown, 2009).

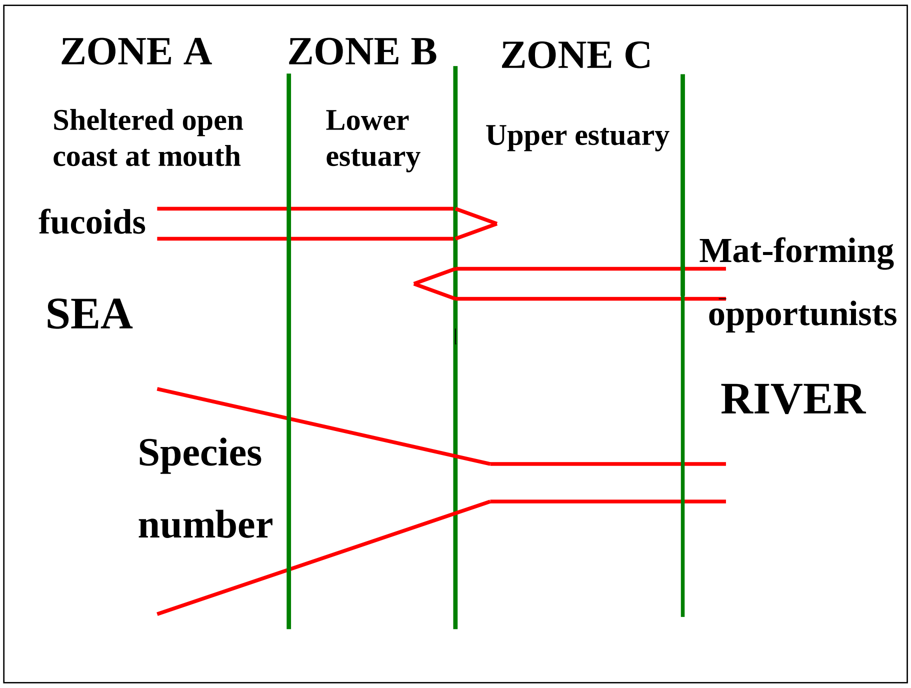


Figure 2: Conceptual illustration of the distribution of macroalgae in estuaries (Wilkinson *et al*., 1995)

The boundary between zone B and zone C marks the upper fucoid limit within the estuary. There are many examples across the UK where abatement of pollution can be linked to the upstream movement of the upper fucoid limit and examples of severely polluted estuaries where the presence of fucoids is completely absent above the estuary mouth (Wilkinson *et al*., 2007, Wilkinson & Brown, 2009). The presence and location of the upper fucoid limit can therefore be used as a suitable marker reflective of the ecological impact of toxic pollutants.

Of the relevant UK fucoid species, *Fucus ceranoides*, *F. spiralis* and *F.vesiculosus* is the most likely to penetrate furthest upstream in the majority of estuaries (Wilkinson *et al*., 2007). Salinity tolerance is a factor in the ability of these species to extend upstream and so the tool assesses the salinity at the upper fucoid limit.

Where there is a complete absence of fucoids or where the salinity at the upper point of the fucoid distribution is high, the water quality is inferred to be poor unless other factors are influencing the fucoid distribution.

Other influences on the upper fucoid limit are:

- the presence of physical barriers
- the absence of suitable substrate for attachment
- the level of turbidity in the water.

The tool requires that these factors are considered in the classification process as they can limit the penetration of fucoids in the upper estuary (regardless of the water quality).

2.2 Normative definitions

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

(i) composition
(ii) abundance
(iii) macroalgal cover.

The fucoid extent tool relates to the investigation of the composition of algal taxa (Table 1).

Table 1: Normative definitions for macroalgae for High, Good and Moderate ecological status in transitional waters (WFD, Annex V, 1.2.3)

High Status	Good Status	Moderate Status
The **composition** of macroalgal taxa is consistent with undisturbed conditions. There are no detectable changes in macroalgal cover due to anthropogenic activities.	There are slight changes in the **composition** and abundance of macroalgal taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of phytobenthos or higher forms of plant life resulting in undesirable disturbance to the balance of organisms present in the water body or to the physico-chemical quality of the water.	The **composition** of macroalgal taxa differs moderately from type-specific conditions and is significantly more distorted than at good quality. Moderate changes in the average macroalgal abundance are evident and may be such as to result in an undesirable disturbance to the balance of organisms present in the water body.

2.3 Development of the tool

Development of the tool has been based around an observed common pattern found in estuaries, which once suffered severe pollution and have since undergone significant pollution abatement. After pollution abatement, a gradual recovery of fucoids followed, along with an upstream advance of the fucoid upper extent. All estuaries found to still lack fucoid colonisation were considered to be highly polluted (Wilkinson *et al.,* 2007) (see Table 2).

Table 2: Estuaries in which fucoids are presently absent, or were formerly so, or have moved substantially upstream in the last 30 years (Wilkinson *et al*., 2007). (Examples are from personal observations of M. Wilkinson with Thames observations from Tittley, 2001; Tittley & John, 1998.)

Estuary	**Type of Change**	**Possible Cause**
Afan (South Wales)	Colonisation by *Fucus vesiculosus* between 1978 and 2000. In 1978 this estuary lacked fucoids and much of it was dominated by floating mats of cyanobacteria over strongly anoxic mud. In 2000 there was a very well developed fucoid zone going much of the way up the estuary.	Abatement of severe sewage and mine drainage water pollution

Estuary	Type of Change	Possible Cause
Thames	Movement of *Fucus vesiculosus* upstream from Belvedere to Woolwich between 1976 and 1993.	Abatement of pollution but also possible salinity change from c.1.9ppt to c.6.7ppt
Mersey	Movement upstream of *Fucus vesiculosus* between1978 and 2005 by about 3km.	Abatement of pollution
Tyne	Movement upstream of *Fucus vesiculosus* from Hebburn in 1972 to Blaydon in 2004 by about 17km.	Abatement of pollution
Tees	Colonisation by *Fucus spiralis* at the lowermost end and its recorded sustained spread upstream to the furthest possible limit at the physical barrier of the Tees Barrage between 1990 and 2002.	Abatement of very severe industrial pollution
Carron (Forth)	Colonisation by *Fucus spiralis* between 1978 and 2000.	Abatement of very severe industrial pollution
Humber	Colonisation by fucoids between 1982 and 1996 of a stretch of the lower estuary about 4km long, surrounded on both sides by Zone B flora, but in which Zone B flora was absent in 1982, being replaced by Zone C flora (Wilkinson & Telfer, 2000).	Abatement of very severe industrial pollution
Billingham Beck	No fucoid colonisation despite salinities up to c.20ppt in lower estuary	Severe industrial pollution
Avoca (RoI)	No fucoid colonisation despite surface salinities over 20 ppt in lower estuary. Believed to be similar severe effects on benthic fauna (Wilson, 1980, 2003 pers. comm.)	Severe heavy metal pollution
Avon (Forth)	No fucoid colonisation despite salinities over 20 ppt.	Severe pollution
Don	Colonisation by *Fucus ceranoides* between 1976 and 2003.	Abatement of severe paper mill pollution
Garnock	Colonisation and upstream movement to tidal freshwater by *Fucus ceranoides* between 1980 and 1986. (Wilkinson *et al.*, 1980 & 1986)	Abatement of very severe industrial pollution
Almond (Forth)	Upstream movement of *Fucus ceranoides*. between 1978 and 1994. This is only a very small completely flushed estuary less than 1 km long.	Abatement of nutrient pollution

The findings from these studies of fucoid penetration in estuaries form the basis of the fucoid extent tool. The tool accepts the premis that the higher the upper fucoid limit is within an estuary, the better the water quality, except where high turbidity, a lack of suitable substrata or presence of physical barriers are an issue. Where fucoids are absent, then water quality (as affected by toxic substances) is assumed to be unsatisfactory. Where fucoids are present, the median salinity at the upper fucoid limit is considered a suitable metric for assessment with reference conditions.

Note: the tool originally used an annual mean salinity for classification. An annual **median** salinity is now considered more appropriate where environmental data is skewed, e.g. particularly for estuaries with asymmetric tides or estuaries which switch rapidly between high and low salinities. In such cases, the annual median salinity provides a better reflection of the salinity experienced by the fucoids within the estuary (see Environment Agency, 2012).

2.4 Reference Conditions

Reference conditions have been derived using a combination of expert opinion and best available sites. For reference (minimally disturbed) conditions, one of the fucoid species is expected to be present in upstream parts of transitional waters with salinities in the range 0 - < 6.

2.5 Class Boundaries

The overall class boundaries for the Fucoid Extent tool are shown in Table 4. These are only applicable to transitional waters.

Table 3: Overall ecological status boundaries for the Fucoid Extent Tool.

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

The WFD class boundaries have been defined on the presence of a fucoid zone (Table 4, Figure 2). The distinction between the moderate, good and high status classes relates to the median annual salinity limits at the location of the highest penetrating fucoid. Proposed salinity boundaries are based on the limited data available and other subjective estimates of salinity at upper fucoid limits. The poor and bad class distinctions relate to the presence/absence of other macroalgal species.

Table 4: Description of WFD classes in terms of the algal zones described in Figure 2.

High	Good	Moderate	Poor	Bad
Zone B (fucoid zone extends upstream to a point where the median salinity is below 6 and possibly to tidal freshwater.	Zone B (fucoid dominated zone) extends upstream to a point where the median salinity is between 6 and 12.	Zone B (fucoid dominated zone) is present in the lower estuary but not above 12 median annual salinity.	No zone B (fucoid dominated zone) present in the estuary – only zone C species present even in lower estuary.	No macroscopic algal community visible in estuary.

The boundaries have been derived by expert judgement considering the penetration of fucoids to or above the salinities in most of the estuaries of reasonable quality, for which good salinity data are available, and on the subjective visual estimate in other estuaries of being close to the limit of salt penetration.

The descriptions (Table 4) have then been converted in to WFD EQR classes (Table 5).

IMPORTANT: Consideration must be given as to whether any other factors, lack of substrate, turbidity of water or physical barrier are preventing the upstream penetration of fucoids.

Table 5: Interpretation of the descriptive classes to WFD status classes.

	Median Annual Salinity	EQR lower class limit
Upstream fucoid site exists		
Fucoids present	0 - < 6	≥ 0.80
Fucoids present	6 - < 12	≥ 0.60
Fucoids present	≥12	≥ 0.40
No upstream fucoid site exists: i.e. No fucoids in the water body:		
Other macroscopic algae in the water body	Any	≥ 0.20
No macroscopic algae in the water body	Any	> 0.00

3. Undertaking an Assessment

3.1 Summary Flow Chart

The process for undertaking an assessment using the fucoid extent tool is summarised below (Figure 3).

Work Area	*Considerations*
Monitoring design ↓	• Is fucoid extent an appropriate assessment for the water body? (Consider suitable substratum, turbidity of water, presence of physical barriers, estuary form)
Sample collection ↓	• Location of upper fucoid limit ○ Record Date, Species and Grid Reference of upper fucoid limit in main estuary and any significant ‘arms’ ○ Where fucoid limit extends into salinities <6, also confirm continuous fucoid presence in rest of estuary • Salinity at upper fucoid limit ○ Measure salinity at upper fucoid limit (Quality assure all measurements, continuous measurements preferable) ○ Carry out a number of measurements to capture a typical range of flow conditions and tidal conditions
Data treatment ↓	• Where using continuous measurements: ○ Trim survey data to remove measurements where instrument is exposed to air ○ Trim data so tidal and flow conditions are fairly represented
Fucoid Extent calculation ↓	• Calculate median annual salinity and derive EQR class
Water body classification	• Where water body has data from several estuarine “arms”, use average of EQRs. • Calculate Confidence of Class(CofC) and Risk of Misclassification (RoM).

Figure 3: Flow chart summarising the main stages involved in undertaking an assessment using the fucoid extent tool.

3.2 Data Requirements

Assessment using the fucoid extent tool requires:

- the position of the upper fucoid limit
- salinity at the position of the upper fucoid limit
- presence /absence of other algal species (if no fucoids present to confirm less than moderate).

The recommended data requirements for the tool are shown in Table 6. If modifications are made using local expert judgement then the impact on the confidence of the assessment must be considered.

Table 6: Recommended data requirements for fucoid extent tool.

Data Type	Data Requirements	Recommended Frequency & Period	Recommended Accuracy
Upper Fucoid Limit	Grid Reference Species Identification	Any time of year 2 x per 6 years in reporting cycle (assuming no change in pressures on water body)	Grid references should be 10 digits Identify to species level.
Salinity	Continuous salinity data at upper fucoid limit	4 surveys for each upper fucoid limit location with a 6 year reporting cycle (if upper fucoid limit location changes then 4 surveys are required at the new location). Each salinity survey should be over a 2 week period to cover the Spring-Neap tidal cycle. Surveys should represent a range of tides and typical flow conditions found throughout the year e.g. a even length of time spent under both lower and higher flow conditions.	Salinity to +/- 1. All instruments should be quality assured and checked for accuracy.
Flow Data (to determine high and low flow events)	Flow data from freshwater input above water body (so to assign a flow quantile Qn, to each salinity survey)	Where data exist: 10 years of historic flow data for flow duration analysis. Flow data for each continuous salinity survey (inclusive of 2 week period prior to survey and period during survey).	
Other Macroalgae data	Records of extent of other macroscopic algae	Only required when fucoids are found to be completely absent 2 occasions in reporting cycle.	

3.3 Sampling strategy

Upper Fucoid Limit and other macroalgal data*:* The upper fucoid limit is the furthest upstream limit in the main estuary and its key tributaries at which any one of the three species (*F. ceranoides*, *F. spiralis* and *F. vesiculosus)* is found. There is no restriction to time of year for the assessment. Due to the low annual variability, WFD Surveillance monitoring frequency is recommended as two visits per six year for a reporting cycle unless other intervals are justified on the basis of technical knowledge.

Salinity*:* Salinity data collected must be representative of the salinity range that the fucoids are subjected to. Salinity readings should represent the water overlying the *Fucus* when it is submerged in each of the arms of the estuary. If data are taken from other sources, then these data must be located close to the fucoid's position (within 100 metres) and not be affected by any other freshwater sources. Four continuous monitoring surveys, each two weeks long, should be carried out within the reporting cycle. If the upper fucoid limit location changes, then salinity surveys need to be repeated at the new location.

Flow data*:* Flow data collected must be associated with the salinity data from the same time and represent the general flow within the fucoid extent location. Freshwater flow data from the catchment local to the fucoid upper limit is used to confirm flow conditions leading up to and during salinity surveys. Ideally four weeks of low flow data and four weeks of high flow should be collected. The median flow relevant to each continuous salinity survey should be compared to a long term (ideally 10 year) flow duration line to ensure a fair spread of data from high and low flows is collected. Appropriate flow data can be requested from the relevant UK authority. It is unlikely that there would be any requirement to set up a flow monitoring programme specifically for this tool.

3.4 Sampling methodology

Note: the WFD competent monitoring authorities have their own operating procedures and instructions (please refer to the relevant Agency for further details).

Upper fucoid limit**:** Fucoids require a hard substratum to attach to, so known hard substrates should be assessed but also consider soft sediment areas if there are rocks, concrete or wood pilings present for the fucoids to attach to. If no suitable substratum is observed above the last recorded upstream point, then this should be noted as a possible restriction to further upriver penetration. The presence of barriers to upstream penetration should also be recorded such as weirs and barrages.

Where there are several significant arms to a water body, the upper fucoid point of all arms must be identified. Exclude any small confluences and any tributaries outside the boundary of the designated WFD water body.

Salinity: Salinity data should ideally be obtained from continuous sondes with supporting measurements of temperature and pressure. This additional information will assist the quality assurance of the data. Sondes are placed somewhere within the bed of the *Fucus* so measurements reflect the salinity range that the fucoids are actually subjected to. At least eight weeks of data (from four two-week surveys) should be collected over a range of flow conditions (an even spread of high and low flow periods).

Salinity data from elsewhere in a water body can be used to model the median salinity of the upper fucoid limit. An example where this could be done is where fixed continuous monitoring stations exist above and below the upper fucoid limit. If the salinity gradient along an estuary is known or can be calculated, then modelling may be an acceptable strategy.

Flow: Flow data can be obtained from flow gauging sites above the tidal limit of the water body. If there are no suitable flow data available above the water body, flow data from another nearby river catchment can be used. Flow data are used to assign a flow quantile value (Qn) to each continuous salinity survey. A median flow for each continuous salinity survey is compared to a long term duration curve to derive a Qn value. By assigning a Qn value to each survey an overall median can then be fairly calculated.

Other macroalgal data: If no fucoid taxa are present then confirmation of the presence or absence of any other macroalgal taxa must be confirmed via a visual survey on foot or using remote imagery.

3.5 Sample Analysis

Identification of fucoids should be made by an ecologist experienced in identifying fucoids. Brown and Wilkinson (2010) have produced a photographic identification guide to aid assessment.

Sonde salinity accuracy should be +/- 1unit. This accuracy should be demonstrated with the use of quality assurance checks and procedures.

Calculating the median salinity*:* The fucoid extent tool requires a median salinity at the long-term median flow (Q_{50}), for each arm of the water body being assessed.

A median salinity is calculated for each two-week survey within each arm. To calculate the median salinity place all measurements in ascending order, then the median is the middle value. Where you have an even number of measurements then the median is halfway between the two middle values.

The median flow during each two-week survey and the preceding two weeks is calculated using data from a suitable upstream gauging station. The median flow is then expressed as a quantile of the long-term (10 year) unconfined flow duration curve.

The median salinity during each survey is regressed against the corresponding median flow using a standard linear regression model. The regression relationship is then used to predict the median salinity at the long-term median flow (Q_{50}). This is the normalised salinity metric (S_{Q50}) and the Face Value Score required for EQR calculation.

3.6 Data Treatment

Raw continuous salinity data collected by loggers will normally require some treatment before use for statistical and EQR calculation. For example, data will normally have to be trimmed to remove measurements taken when exposed to air. This includes periods before and after deployment, and periods during low water when the sonde is not submerged. If the sonde has been deployed in mid-channel and is continuously submerged then measurements around low water should still be removed. To decide on the period of data to retain, an estimate of the length of period around high water when the fucoid is expected to be submerged should be applied.
Survey data should also be trimmed to ensure neap and spring tides are equally represented and survey periods should be checked against flow data to ensure both low and high flow are also equally represented.

3.7 EQR Calculation

For each arm where there are fucoid species present the median salinity face value must be transformed to a normalised equidistant score on a scale 0.4 – 1.0 (to align with the moderate, good and high status classes on the EQR 0 to 1 scale.)

To calculate the EQR, the values in Table 7 and the following formula are used:

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

Table 7: Values for the normalisation and rescaling of face values to EQR metric ranges.

Class	Lower Face Value range value (the measurements towards the "bad" end of this class range)`	Upper Face Value range value (them measurements towards the "High" end of this class range)	Face Value class range	Lower 0.4-1 equidistant range value	Upper 0.4-1 equidistant range value	Equidistant class range
High	<6	>0	5.99	≥0.8	1	0.2
Good	<12	≥6	5.99	≥0.6	<0.8	0.2
Moderate	<30	≥12	17.99	≥0.4	<0.6	0.2

Where there is a complete absence of fucoids in the water body but other macroscopic algae are present an EQR score of 0.30 is given (= poor status).

Where there is a complete absence of fucoids and a complete absence of macroscopic algae then an EQR score of 0.10 is given (= bad status).

3.8 Water body level classification

Water body classifications are based on the arithmetic mean EQR score of all EQR scores from each arm of the water body. If the water body has a single arm, the EQR of the arm is taken to be the EQR of the water body.

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). A methodology for calculating a measure of the Confidence of Class (CofC) has been developed. Full details of the methodology are provided in 'Confidence of Class for Saltmarsh and Fucoid Extent WFD Classification Tools' (Davey, 2013).

An Excel workbook, "TRansitional Ecological Assement: Salinity Uncertainty Robustly Evaluated" (TrEASURE), calculates the CofC for the fucoid index. It performs calculations for multiple water bodies simultaneously.

A source of error is the possibility of under-estimating the upstream extent of fucoid growth. The degree of error depends in part on access to the shore to undertake fucoid surveys and in part on the expertise of the surveyor to positively identify fucoid species. Since the upstream extent is unlikely to be over-estimated, this is likely to introduce a small pessimistic bias to the classification results (i.e. give a worst-case result).

It is assumed that the measurements taken during each two-week survey provide an accurate measure of the salinity conditions experienced by the fucoids at that location.

The main source of error is therefore 'the lack of fit' in the salinity-flow regression model, which leads to uncertainty in the calculated salinity metric. The uncertainty in the normalised salinity metric is quantified by the standard error of the regression prediction (SE).

The standard error of the EQR is approximated by taking the salinity metric score and its SE to calculate upper and lower 95% confidence limit, assuming normally distributed errors. The upper and lower 95% confidence limits are converted from metric scores to EQRs. Upper and lower confidence limits of <0.4 are truncated to 0.4. The SE EQR measures the degree of uncertainty in the EQR estimate.

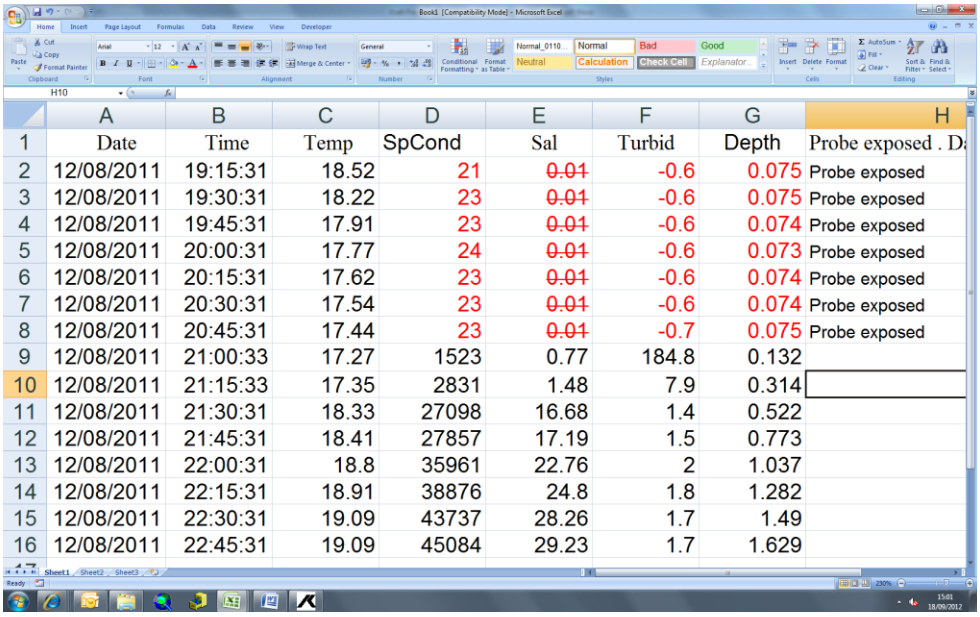
Given that multiple arms are likely to be surveyed at the same times, the errors in the arm EQRs are assumed to be perfectly correlated. This is a worst-case assumption, and yields a pessimistic confidence of class assessment. The SE of the water body EQR is therefore calculated by averaging the SEs of the EQRs for the various arms.

The water body EQR and its associated SE are then used to calculate the CofC that the true EQR falls in each of the five status classes. This is presented by calculating a percentage probability of the water body EQR falling into each of the classes. Full details on how this is performed are provided in the WRc document 'Confidence of Class for Saltmarsh and Fucoid Extent WFD Classification Tools' (Davey, 2013).

4. Worked example

Step 1 – Data Collection: Location of Upper Fucoid Limit
The upper fucoid extent is identified on the 2 arms of the upper reaches of the transitional water body. Several salinity surveys are carried out at each upper fucoid limit.

Step 2 – Data Treatment
Raw data from the continuous salinity probes is treated to ensure air measurements are removed and the spring/neap cycle is equally represented.



	A	B	C	D	E	F	G	H
1	Date	Time	Temp	SpCond	Sal	Turbid	Depth	Probe exposed . D
2	12/08/2011	19:15:31	18.52	21	~~0.01~~	-0.6	0.075	Probe exposed
3	12/08/2011	19:30:31	18.22	23	~~0.01~~	-0.6	0.075	Probe exposed
4	12/08/2011	19:45:31	17.91	23	~~0.01~~	-0.6	0.074	Probe exposed
5	12/08/2011	20:00:31	17.77	24	~~0.01~~	-0.6	0.073	Probe exposed
6	12/08/2011	20:15:31	17.62	23	~~0.01~~	-0.6	0.074	Probe exposed
7	12/08/2011	20:30:31	17.54	23	~~0.01~~	-0.6	0.074	Probe exposed
8	12/08/2011	20:45:31	17.44	23	~~0.01~~	-0.7	0.075	Probe exposed
9	12/08/2011	21:00:33	17.27	1523	0.77	184.8	0.132	
10	12/08/2011	21:15:33	17.35	2831	1.48	7.9	0.314	
11	12/08/2011	21:30:31	18.33	27098	16.68	1.4	0.522	
12	12/08/2011	21:45:31	18.41	27857	17.19	1.5	0.773	
13	12/08/2011	22:00:31	18.8	35961	22.76	2	1.037	
14	12/08/2011	22:15:31	18.91	38876	24.8	1.8	1.282	
15	12/08/2011	22:30:31	19.09	43737	28.26	1.7	1.49	
16	12/08/2011	22:45:31	19.09	45084	29.23	1.7	1.629	

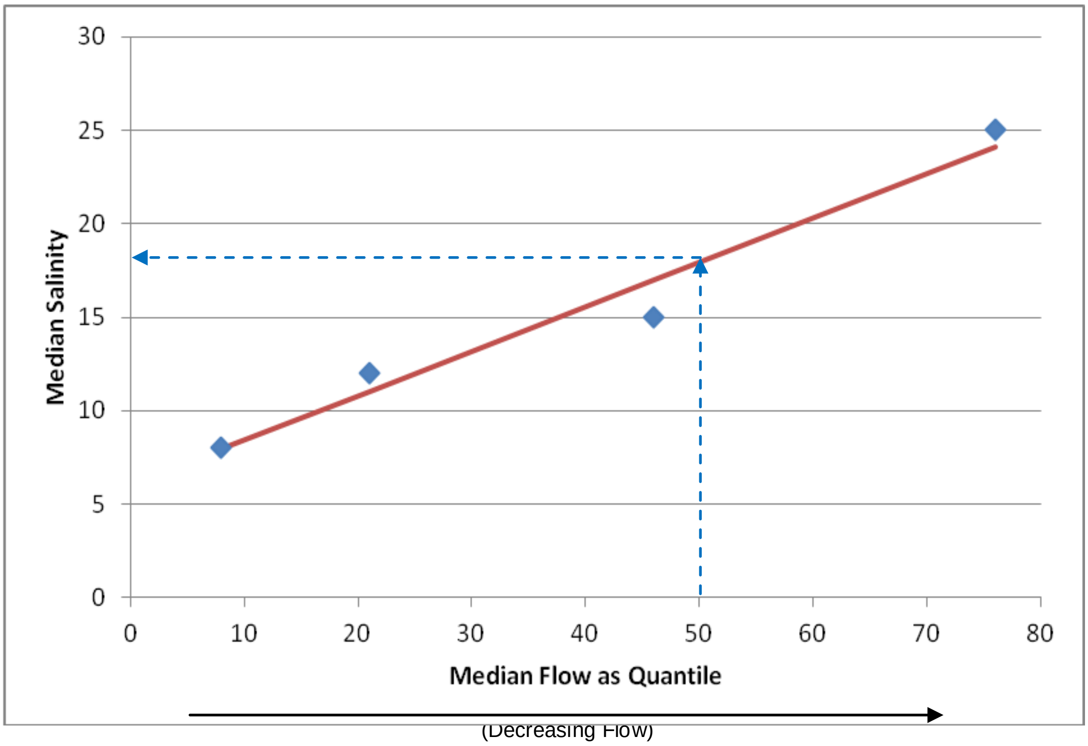
Step 3 – Salinity at Upper Fucoid Limit
The median salinity for each survey is calculated. Survey periods are checked against flow data and a Flow Quantile is assigned to each survey.

	Survey Period	Median Flow (before and during survey) m^3s^{-1}	Flow Quantile (Qn)	Median Salinity
Arm one				
Survey 1	21/08/10 - 04/09/10	2.1	82.0	17.0
Survey 2	01/10/10 - 15/10/10	5.0	64.0	16.0
Survey 3	21/01/11 - 04/02/11	7.5	24.0	8.0
Survey 4	02/03/11 - 16/03/11	9.2	11.0	3.0
Arm two				
Survey 1	21/08/10 - 18/09/10	1.1	76.0	25.0
Survey 2	01/10/10 - 14/10/10	5.5	46.0	15.0
Survey 3	21/01/10 - 18/02/10	8.1	21.0	12.0
Survey 4	02/03/11 - 16/03/11	9.9	8.0	8.0

Step 4 – Normalised Median Salinity Calculation

A linear regression model is used to calculate a median salinity normalised to the median flow.

Example Regression model for Arm 2



Arm 1 – Normalised Salinity Metric S_{Q50} = 11.93
Arm 2 – Normalised Salinity Metric S_{Q50} = 17.81

Step 5 - EQR Calculation

Arm One EQR = 0.8 – (11.93-6.0)*(0.2/5.99) = 0.60

Arm Two EQR = 0.6 – (17.81-12.0)*(0.2/17.99) = 0.53

Water body EQR = (0.60+0.53)/2 = 0.57

= **Moderate** status

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