Practitioners Guide to the Intertidal Rocky Shore Macroalgal Index
Water Framework Directive: Coastal Waters

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

Note*:* this document does not describe all aspects of the rocky shore macroalgal index development and application; for this please refer to the full technical report (Wells *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 often specific to the WFD and 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’ 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), where an EQR of one represents minimally disturbed conditions (reference) and zero 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 (Fig. 1).

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

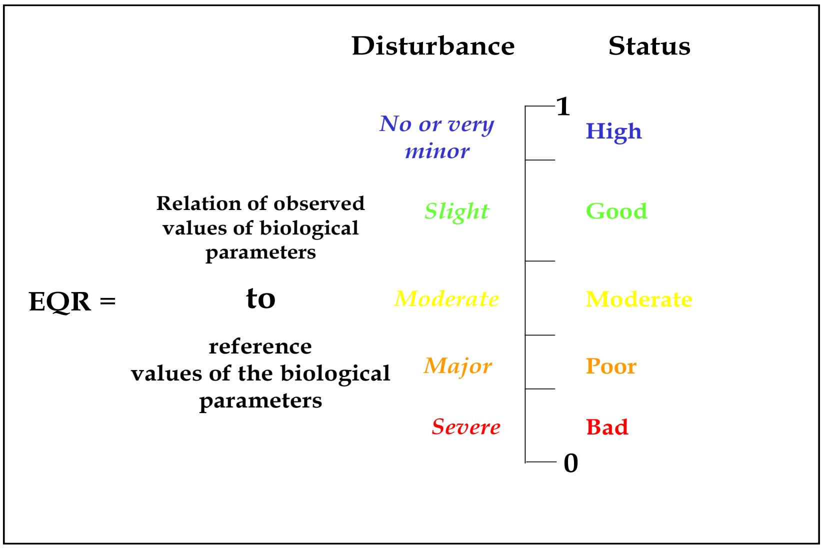


Fig. 1: Illustration of the Ecological Quality Ratio and how it relates to the level of disturbance and ecological status. The class band widths relate to biological changes as a result of disturbance. (WFD CIS Guidance Document No. 5, 2003).

1. Key Facts

1.1 Index Overview: Rocky shore macroalgal multimetric

The rocky shore macroalgal index enables an assessment of the condition of the quality element, "Macroalgae", as listed in Table 1.2.4 of Annex V to the Water Framework Directive (2000/60/EC). The WFD requires that the assessment of the macroalgal quality element considers taxonomic composition (disturbance sensitive taxa) and macroalgal cover.

The multimetric is composed of five metrics:

- Species richness (normalised using a shore factor)
- Proportion of Chlorophyta (green) species
- Proportion of Rhodophyta (red) species
- Proportion of opportunists (fast-growing nuisance algae)
- Ratio of ecological status groups

Individual metrics have been equally weighted and combined within a multimetric index, in order to best describe the changes in the structure and composition of intertidal rocky shore macroalgae communities due to anthropogenic pressure. The species richness component is normalised against a shore factor to enable different shore types to be directly comparable regardless of localised natural environmental factors such as diversity of sub-habitats.

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

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

To calculate the index, the taxonomic composition (as presence/absence of individual taxa) of macroalgae communities within a defined area of intertidal rocky shore and definition of the overall shore habitat are required. The index can be calculated using data identified from a full species list (FSL) or a reduced species list (RSL). For the FSL, taxa are identified to the lowest taxonomic level (species or sub-species), but for the RSL, identification is to a mixed taxon level (mainly species) defined within a standard geographically based list. A sample is defined as a single site or stretch of rocky shore.

The index was developed using full species list data, and from these the reduced species lists were derived. There are three RSLs covering the whole of the British Isles; one for Scotland and northern England, one for Southern England and Wales and one for Northern Ireland. Note: The Southern England and Wales list also covers the Republic of Ireland. The RSL operates as a surrogate for the FSL, and is now generally used as the WFD method by UK agencies.

1.2 Applicability

Where: The index is suitable for use in coastal waters of the British Isles where there is suitable natural, hard substratum for macroalgae to grow. *Note*: it may be applied to the outer reaches of *some* transitional waters where substratum allows and where salinity is not considerably reduced. The index is not suitable for assessment of highly reduced salinity environments or those of a sedimentary nature. For WFD reporting, the index is *only* used for coastal waters assessment. The index is not used for assessing saline lagoons due to the particular challenges in setting suitable type-specific reference conditions for these water bodies.

Macroalgae require suitable substratum to attach to, i.e. rocks or other hard structures. Artificial structures should not be considered. The index is not suitable for assessing ecological status of a water body where there is an absence of suitable substratum.

When: The macroalgal index has been developed to classify data using single sampling events. Where several sampling occasions are carried out in a reporting period then the average of the results is reported. Sampling is carried out between late April and early October but is not recommended outside of this period due to seasonal variations that could affect the outcome of the index and possibly lead to misclassification. Sampling should be carried out during spring low tides in order to expose the maximum area of intertidal shore.

Response to Pressure: The index is designed primarily to detect the impact on intertidal macroalgae communities of toxic substances, habitat modification and general disturbance (e.g. smothering). Organic enrichment and nutrient impacts may be detected if the impact is severe.

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 Waters Rocky shore macroalgae
– *High level non-technical summary*

*Wells, E., 2010. Water Framework Directive development of classification tools for ecological assessment: Macroalgae Species Richness. *UK TAG Report for Marine Plants Task Team*, January 2010, Publ. UK TAG

Wells, E., Wood, P., Wilkinson, M. & Scanlan, C. 2007. The use of macroalgal species richness and composition on intertidal rocky seashores in the assessment of ecological quality under the European Water Framework Directive. *Marine Pollution Bulletin*. 55, 151 – 161.

Precision in rocky shores Analysed to Extract Statistics (PIRATES) - *Excel workbook to estimate the precision of the assessment.*

2. Background

2.1 Ecological principles: Macroalgal communities respond to changes in the environment, with changes in species richness often indicative of a difference in the environment induced through human activity. These impacts are also reflected in a change in the macroalgae species assemblage showing a shift from larger long-lived perennial species to fast-growing, opportunist species. Such changes in macroalgal community structure are regarded as typical of chronic pollution particularly by domestic sewage. However, abundance is highly variable and dependent upon natural as well as anthropogenic pressures, and therefore is not an ideal measure of quality, whereas species richness is known to remain constant in the absence of anthropogenic disturbance (Wilkinson & Tittley, 1979).

Ephemeral algae species come and go from rocky shore communities on various time scales varying from months to years. Records of species composition are also known to vary on consecutive days solely through the lack of consistency that is experienced with algal field sampling (Wells, 2002). The abundance of macroalgae on rocky shores may also undergo massive changes over a period of a few years due to natural variability; in contrast species richness remains broadly constant in the absence of environmental alteration despite seasonal fluctuations (Wells and Wilkinson, 2003). Detailed historical records have shown increases in species richness with recovery from severe pollution such as shores subjected to coal mine waste (Edwards, 1975) and sewage pollution (Knight and Johnston, 1981; Johnston, 1972). It was apparent that changes in the intertidal environment through adverse impacts were reflected in levels of species richness suggesting this numerical value to be a more appropriate measure of quality rather than comprehensive listings of species presence (Wilkinson & Tittley, 1979).

There are no universally recognised disturbance-sensitive taxa *per se*, but opportunist species are incorporated into the index.

To establish a WFD compliant classification tool for assessing rocky shore macroalgae communities, suitable measures of species richness and composition relating to the structure and functioning of macroalgae assemblages were combined to produce the multimetric index. These metrics measure ecological health based on its deviation from reference conditions.

2.2 Normative definitions: In Annex V (1.2.4) of the WFD, normative definitions describe the aspects of the macroalgal community in coastal waters that must be included in the ecological status assessment of a water body; these are -

(i) macroalgal cover
(ii) disturbance sensitive taxa

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 macroalgae assemblages 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	Perennial (long-lived) species have no identified highly sensitive indicator-species. High species richness will include sensitive taxa – thought to remain broadly constant over time. Opportunistic (short-lived) macroalgae may be present in low density where physico-chemical conditions allow.	
Reference Conditions **High**	*All disturbance-sensitive macroalgae associated with undisturbed conditions are present. The levels of macroalgal cover are consistent with undisturbed conditions.*	Diverse community of red, green and brown seaweeds. Cover variable depending on local physical conditions but species richness relatively constant temporally. Red species present as richest group along with a high proportion of long-lived spp. Absence of opportunistic macroalgal blooms.
Good	*Most disturbance-sensitive macroalgae associated with undisturbed conditions are present. The level of macroalgal cover shows slight signs of disturbance.*	Slightly less diverse community of red, green and brown seaweeds. Cover variable depending on local physical conditions. Greatest reduction in red spp. and greater proportion of short-lived spp. present. Absence of opportunistic macroalgal blooms.
Moderate	*A moderate number of disturbance-sensitive macroalgae 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.*	Less diverse community of red, green and brown seaweeds. Cover variable depending on local physical conditions. Decrease in the proportion of red spp., with possible high cover of short-lived opportunistic macroalgae. Community showing greater dominance of green opportunist and ephemeral species. Opportunistic macroalgal blooms possibly present.

2.3 Development of the multimetric index

The index combines suitable measures of macroalgae species richness and community composition into a multimetric to describe the ecological status of intertidal rocky shore macroalgae communities. Historical and current macroalgae datasets were used with pressure data and expert opinion to design a suitably responsive multimetric. Initially the multimetric was established using data from the full species list from over 400 sites sampled on single occasions.

The index is based on the concept that *species richness* on a shore remains broadly constant over time in the absence of anthropogenic influence. However, species richness alone is not considered an adequate measure of composition as required by the WFD. Individual species present vary considerably due to the constant turnover of ephemeral species, but general measures of composition may be used as an alternative means of indicating a shift in the community structure. Correlations between community composition and quality status were identified as the proportions of Rhodophyta, Chlorophyta and opportunist species and the ratio of Ecological Status Groups (ESG). These metrics were calculated and then checked to ensure that their response correlated to pressure (environmental variables).

Proportions of Chlorophyta: Although some are small and may be filamentous these species are able to adapt more readily to changes in the environment whereby proportions increase with decreasing quality status.

Proportions of Rhodophyta: These constitute a high proportion of small, filamentous and delicate species and show an increase in species numbers with increasing environmental quality.

Proportions of Opportunists: Opportunist species include *Blidingia spp., Chaetomorpha linum, Chaetomorpha ligustica, Ulva spp., Ulva lactuca, Ectocarpus spp., Pilayella littoralis and Porphyra spp.*

Ecological Status Group ratio: ESGs can be used to indicate shifts in the ecosystem from a pristine state (dominated by ESG 1 algae – late successionals or perennials) to a degraded state (dominated by ESG 2 algae – opportunists or annuals). This is achieved by using the following ratio: ESG 1 / ESG 2 (Orfanidis *et al.*, 2001).

The allocation of each species into one of the two ESG groups is also broadly based on a functional group system devised primarily by Littler *et al.* (1983) and later adapted by Wells (2002). The allocation currently in use may be obtained from the relevant environment agency.

These measures of species richness and composition were given equal weighting and formed the basis of a five part multimetric.

Further consideration had to be given to the levels of species richness recorded from shores of differing environmental variables and how this might influence the expected levels of species richness. Intertidal rocky shore environments are highly variable affecting the overall composition and level of species richness, even within areas devoid of human interference. Studies of the overall shores structure and assemblage, using data from the Northern Ireland Littoral Survey (Wilkinson *et al*., 1988), indicated a link between species richness and localised intertidal variables (Wells and Wilkinson, 2002). In response to this, localised environmental factors were incorporated into the metric system to enable the shore to be normalised ("de-shored") for their levels of species richness and therefore be directly comparable regardless of the shore type.

Those factors used to determine the level of correction required to normalise each shore are detailed below:

Dominant substrate type - the physical type of shore is broadly described by the most dominant substrate type or structure present such as rock platforms, boulders or pebbles.

Subhabitat type - the presence of particular subhabitat types is known to result in higher levels of species richness such as large, wide rock pools.

Subhabitat number – with increasing number of subhabitat types there is a significant increase in the levels of algal species richness recorded.

Turbidity, Sand Scour and Chalk Shores – The presence of naturally occurring turbidity and sand scour can result in reduced numbers of perennial taxa and domination by opportunist annuals which may similarly be experienced by unstable chalk shores.

These natural variations have been incorporated into a field sampling sheet (Table 2) and scoring system which then contributes to the overall quality classification. The shore description is used to normalise species richness, so that shores that have high species richness due to favourable environmental conditions can be compared equally with shores of low species richness due to natural conditions. The individual scores from the field sampling sheet are totalled to produce a final score which is later applied to the species richness metric. For those factors, such as shore type and habitat type, where more than one description may be recorded on the sampling sheet, only the highest score is used in the final “de-shoring” scoring system.

Table 2: Field sampling sheet to record basic shore descriptions with scores indicating the weighting of each of the shore characteristics to be used in the final scoring system.

General Information			
Shore Name		**Date**	
Water Body		**Tidal Height**	
Grid Ref.		**Time of Low Tide**	
Shore Descriptions			

Presence of Turbidity (known to be non-anthropogenic)	**Yes**	=0	**Sand Scour**	**Yes**	=0	**No**	=2
	No	=2	**Chalk Shore**	**Yes**	=0	**No**	=2

Dominant Shore Type		**Subhabitats**	
Rock Ridges/Outcrops/Platforms	=4	Wide Shallow Rock Pools (>3m wide and <50cm deep)	=4
Irregular Rock	=3		
Boulders large, medium and small	=3	Large Rockpools (>6m long)	=4
Steep/Vertical Rock	=2	Deep Rockpools (50% >100cm deep)	=4
Non-specific hard substrate	=2	Basic Rockpools	=3
Pebbles/Stones/SmallRocks	=1	Large Crevices	=3
Shingle/Gravel	= 0	Large Overhangs and Vertical Rock	=2
Dominant Biota		Others habitats (please specify)	=2
Ascophyllum			
Fucoid			
Rhodophyta mosaics		Caves	=1
Chlorophyta		None	=0
Mussels		**Total Number of Subhabitats**	
Barnacles			
Limpets			
Periwinkles			

>4	3	2	1	0

General Comments

The "de-shoring" factor was established using data from reference or near reference conditions (defined by lack of known pressures and expert opinion); the level of correlation between species richness and shore description (Figure 2) displayed a non-linear relationship between the two variables. This relationship is described by an exponential-type model of the form:

$$RICHNESS = a + b\exp(cSHORE)$$

where a, b and c are parameters to be estimated from the data. Using least squares, these parameters were estimated to be:

a = 16.543 b = 7.150 c = 0.122

Therefore for each value of shore description there is a level of species richness that is to be expected for reference conditions from which a normalisation factor has been produced (Table 3). This factor was based around an average shore description of 15. The actual level of species richness can then be compared with the predicted level of species richness by applying the 'de-shoring factor' whereby:

Species Richness (N_n) = Number Taxa (N_t) x Correction Factor (C_f)

The normalised species richness should be used in the final FSL multimetric calculation. *Note*: There is a separate equation and table for the RSL multimetric calculation (Section 2.3, Table 5)

Table 3: Calculation of normalisation factor for all possible shore description values based on the predicted levels of species richness from a full species list.

Shore Description	Predicted Richness	De-shoring factor
5	29.69	2.06
6	31.40	1.94
7	33.32	1.83
8	35.50	1.72
9	37.96	1.61
10	40.73	1.50
11	43.87	1.39
12	47.41	1.29
13	51.42	1.19
14	55.94	1.09
15	**61.04**	**1.00**
16	66.81	0.91
17	73.33	0.83
18	80.69	0.76
19	89.01	0.69
20	98.40	0.62

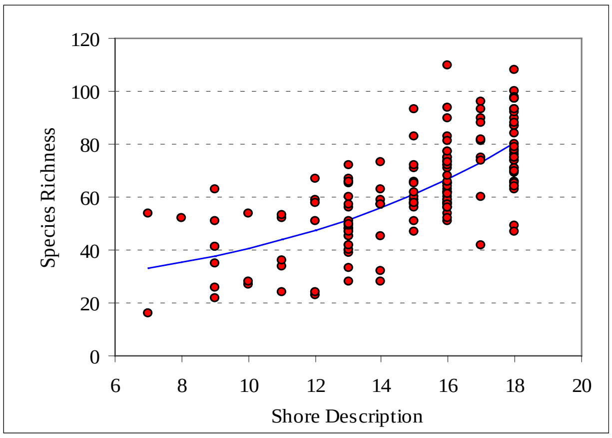


Fig. 2: Exponential model for the relationship between shore description and species richness using a full species list.

Note: Abundance, a criterion specified by the WFD to assess the biological quality element of macroalgae, was not included within the index, as it had been shown to be inappropriate on ecological grounds.

2.3.1 Development of the RSL

The identification of intertidal seaweed species, necessary to record an accurate level of species richness, requires high levels of taxonomic expertise. An alternative means of recording fully comprehensive species data is the implementation of a reduced species list (RSL) whereby the number of species from the RSL is proportional to the total species richness. The list is composed of species (approximately 70) that contribute most significantly to the overall species composition of rocky shores of a particular type within a geographical area, thereby acting as a surrogate for a full species list. The benefits of this approach are the requirement of a lower level of taxonomic experience and familiarisation with fewer algal species and less time spent on analysis.

A large database of species lists from over 400 sites was compiled for the UK and Ireland, and subjected to multivariate analysis (Wells *et al*., 2007, Wells, 2010). This resulted in three RSLs for the UK (Fig. 3). Delineation is driven by the geographical distributions according to natural environmental tolerances of certain species. The east of England boundary may be partly driven by the physical nature of the coast changing from predominantly sediment to hard substratum.

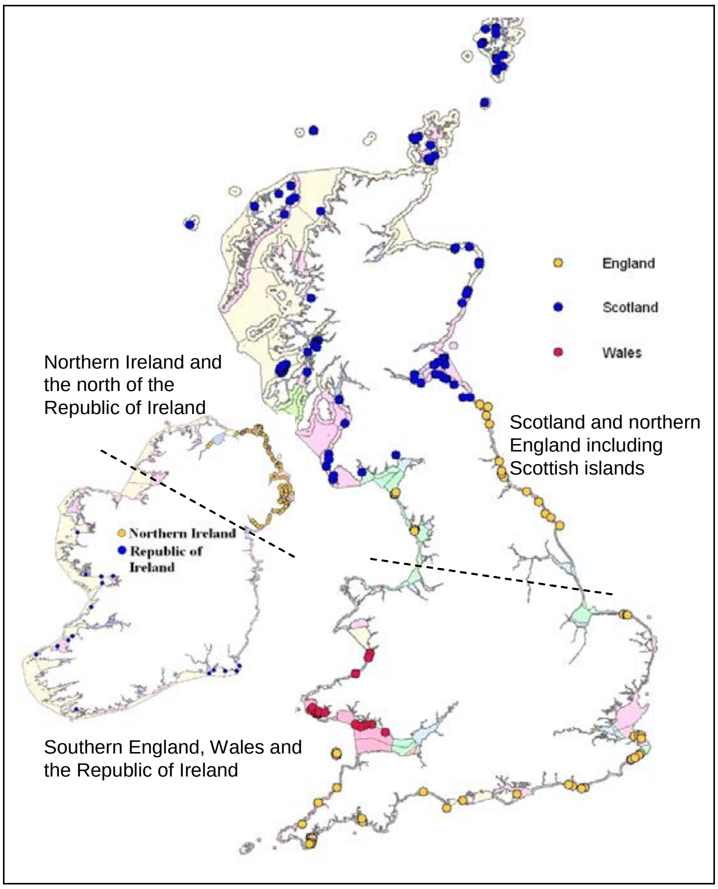


Fig. 3: Map of the UK and Republic of Ireland indicating the boundaries used for the compilation of the three reduced species lists whereby spots represent those sites for which species records are available and have been used in the algal database for establishing such geographic boundaries.

A number of taxa were considered difficult to identify to species level or locate on the shore, even for many trained algal taxonomists. Therefore, for a few select species, identification has been limited to the level of genus only. These genera include *Blidingia, Ulva, Ulothrix, Ectocarpus, Ralfsia, Gelidium, Audouinella*, *Ceramium except for C. virgatum and C.*

shuttleworthianum and Polysiphonia species except for *P. lanosa* and *P. fucoides,* as it was thought that these species would be comparatively easy to distinguish. *Aglaothamnion* and *Callithamnion* are taken as one unit, and coralline encrusting algae are taken to a high level simply as 'coralline encrusters'. The final species to be used within the three reduced species lists are tabulated below (Table 4).

Table 4: Species lists for each of the defined geographic areas of Northern Ireland, Scotland and Northern England, and Southern England, Republic of Ireland and Wales.

				Zone in which taxa applicable for assessments		
Species	Colour	Opportunists	ESG	Scotland / Northern England	Southern England / ROI /Wales	Northern Ireland
Alaria esculenta	Phaeophyta		1	*		*
Ascophyllum nodosum	Phaeophyta		1	*	*	*
Asperococcus fistulosus	Phaeophyta		1	*		*
Chorda filum	Phaeophyta		1	*	*	
Chordaria flagelliformis	Phaeophyta		2	*		
Cladostephus spongiosus	Phaeophyta		2	*	*	*
Desmarestia aculeata	Phaeophyta		2	*		
Dictyosiphon foeniculaceus	Phaeophyta		2	*		
Dictyota dichotoma	Phaeophyta		2	*	*	*
Ectocarpus sp.	Phaeophyta	*	2	*	*	*
Elachista fucicola	Phaeophyta		2	*	*	*
Fucus serratus	Phaeophyta		1	*	*	*
Fucus spiralis	Phaeophyta		1	*	*	*
Fucus vesiculosus	Phaeophyta		1	*	*	*
Halidrys siliquosa	Phaeophyta		1	*	*	*
Himanthalia elongata	Phaeophyta		1	*	*	*
Laminaria digitata	Phaeophyta		1	*	*	*
Laminaria hyperborea	Phaeophyta		1	*	*	
Saccharina latissima (formerly Laminaria saccharina)	Phaeophyta		1	*	*	*
Leathesia difformis	Phaeophyta		1	*	*	*
Litosiphon laminariae	Phaeophyta		2	*		
Pelvetia canaliculata	Phaeophyta		1	*	*	*
Petalonia fascia	Phaeophyta		2			*
Pilayella littoralis	Phaeophyta	*	2	*	*	*
Ralfsia sp.	Phaeophyta		1	*	*	*
Saccorhiza polyschides	Phaeophyta		1		*	
Scytosiphon lomentaria	Phaeophyta		1	*	*	*
Sphacelaria sp.	Phaeophyta		2			*
Spongonema tomentosum	Phaeophyta		2	*		*
Blidingia sp.	Chlorophyta	*	2	*	*	*
Bryopsis plumosa	Chlorophyta		2		*	
Chaetomorpha linum	Chlorophyta	*	2	*	*	*
Chaetomorpha ligustica (formerly mediterranea)	Chlorophyta	*	2		*	*
Chaetomorpha melagonium	Chlorophyta		2	*	*	
Cladophora albida	Chlorophyta		2			*
Cladophora rupestris	Chlorophyta		2	*	*	*
Cladophora sericea	Chlorophyta		2	*	*	*

Ulva sp. (tubular form, formerly Enteromorpha sp.)	Chlorophyta	*	2	*	*	*
Monostroma grevillei	Chlorophyta		2			*
Rhizoclonium riparium	Chlorophyta		2			*
Spongomorpha arcta	Chlorophyta		2			*
Sykidion moorei	Chlorophyta		2	*		
Ulothrix sp.	Chlorophyta		2			*
Ulva lactuca	Chlorophyta	*	2	*	*	*
Aglaothamnion/Callithamnion sp.	Rhodophyta		2	*	*	*
Ahnfeltia plicata	Rhodophyta		1	*	*	*
Audouinella purpurea	Rhodophyta		2			*
Audouinella sp.	Rhodophyta		2			*
Calcareous encrusters	Rhodophyta		1	*	*	*
Callophyllis laciniata	Rhodophyta		1	*		
Catenella caespitosa	Rhodophyta		1		*	*
Ceramium nodulosum (=virgatum)	Rhodophyta		2	*	*	*
Ceramium shuttleworthanium	Rhodophyta		2	*	*	*
Ceramium sp.	Rhodophyta		2		*	
Chondrus crispus	Rhodophyta		1	*	*	*
Corallina officinalis	Rhodophyta		1	*	*	*
Cryptopleura ramosa	Rhodophyta		2	*	*	*
Cystoclonium purpureum	Rhodophyta		1	*	*	*
Delesseria sanguinea	Rhodophyta		2	*		
Dilsea carnosa	Rhodophyta		1	*	*	*
Dumontia contorta	Rhodophyta		1	*	*	*
Erythrotrichia carnea	Rhodophyta		2	*	*	
Furcellaria lumbricalis	Rhodophyta		1	*	*	*
Gastroclonium ovatum	Rhodophyta		1		*	
Gelidium sp.	Rhodophyta		1		*	*
Gracilaria gracilis	Rhodophyta		1		*	
Halurus equisetifolius	Rhodophyta		2		*	
Halurus flosculosus	Rhodophyta		2		*	
Heterosiphonia plumosa	Rhodophyta		2		*	
Hildenbrandia rubra	Rhodophyta		1		*	*
Hypoglossum hypoglossoides	Rhodophyta		2		*	
Lomentaria articulata	Rhodophyta		1	*	*	*
Lomentaria clavellosa	Rhodophyta		1	*		
Mastocarpus stellatus	Rhodophyta		1	*	*	*
Melobesia membranacea	Rhodophyta		1			*
Membranoptera alata	Rhodophyta		2	*	*	*
Nemalion helminthoides	Rhodophyta		1		*	
Odonthalia dentata	Rhodophyta		1	*		*
Osmundea hybrida	Rhodophyta		1	*	*	*
Osmundea pinnatifida	Rhodophyta		1	*	*	*
Palmaria palmata	Rhodophyta		1	*	*	*
Phycodrys rubens	Rhodophyta		2	*		
Phyllophora sp.	Rhodophyta		1	*	*	*
Plocamium cartilagineum	Rhodophyta		2	*	*	*
Plumaria plumosa	Rhodophyta		2	*	*	*
Polyides rotundus	Rhodophyta		1	*	*	
Polysiphonia fucoides	Rhodophyta		2	*	*	*
Polysiphonia lanosa	Rhodophyta		2	*	*	*

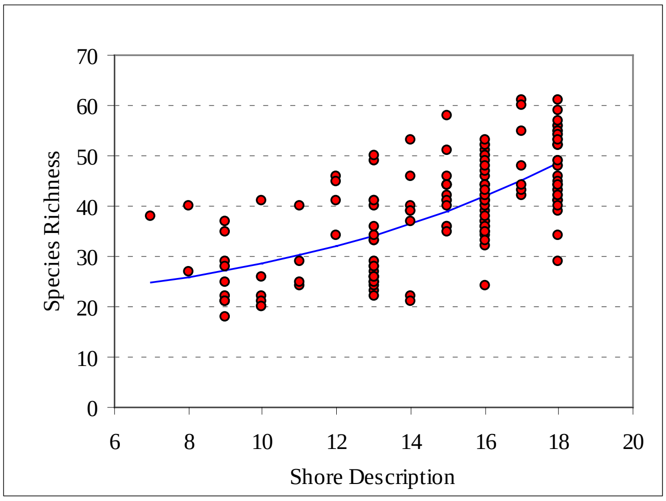
Polysiphonia sp.	Rhodophyta		2	*	*	*
Porphyra leucosticta	Rhodophyta	*	2	*		
Porphyra umbilicalis	Rhodophyta	*	2	*	*	*
Ptilota gunneri	Rhodophyta		2	*		
Rhodomela confervoides	Rhodophyta		2	*	*	*
Rhodothamniella floridula	Rhodophyta		2	*	*	*

As for the FSL the RSL requires normalisation for its species richness value according to the same model, but with the values a = 14.210 b = 4.925 c = 0.108.

Values are determined from Table 5 below.

Table 5: Calculation of normalisation factor for all possible shore description values based on the predicted levels of species richness from a reduced species list.

Shore Description	Predicted Richness	De-shoring Factor
5	22.66	1.72
6	23.62	1.65
7	24.70	1.58
8	25.89	1.51
9	27.22	1.44
10	28.70	1.36
11	30.36	1.29
12	32.20	1.21
13	34.25	1.14
14	36.53	1.07
15	**39.08**	**1.00**
16	41.91	0.93
17	45.07	0.87
18	48.58	0.80
19	52.50	0.74
20	56.87	0.69



2.4 Reference conditions (RSL and FSL)

The use of appropriate reference conditions is essential for a meaningful WFD assessment of the rocky shore macroalgae community. All metrics used to describe the structure and function of macroalgae assemblages are influenced by a multitude of factors:

(i) true differences in the data (i.e. changes to the assemblages due to differing environmental conditions such as rock type)

(ii) artefacts in the data (i.e. changes as a result of how the macroalgae communities are sampled such as levels of expertise).

Corresponding reference condition values are similarly influenced. The reference conditions derived for use with the FSL or RSL (Tables 6, 7, 8, 9) need to be adapted to ensure that the influence of habitat and sampling method is not misinterpreted as anthropogenic disturbance. For example, comparing a turbid boulder shore with natural freshwater influence with a large area of rocky platform and deep rock pools with full salinity throughout will return a false indication of disturbance.

Reference conditions have been established using a combination of expert judgement and data from sites considered to be near pristine. Historic macroalgal species records from sites deemed as 'high quality' were used to set reference conditions (this approach is discussed in Wilkinson and Wood (2003) in addressing reference conditions for Scotland.

The WFD requires the characteristics used in the assessment of water bodies to show evidence of response to changes in the natural environment through both direct and indirect pressures. Assessing the impacts of anthropogenic disturbance is often difficult due to the lack of long term or historical data and the ability to discriminate between natural and artificially induced changes. This is hindered further by the lack of algal data pre and post adverse influence.

Work on the coastline of the City of Edinburgh, summarised in Wells (2002), demonstrated anthropogenically induced changes to intertidal algal communities as a result of significant changes in the pollution loading and subsequent abatement of sewage pollution. These current and historical data provided a quantifiable pressure gradient from which to assess changes in macroalgae species richness and composition (Fig. 4).

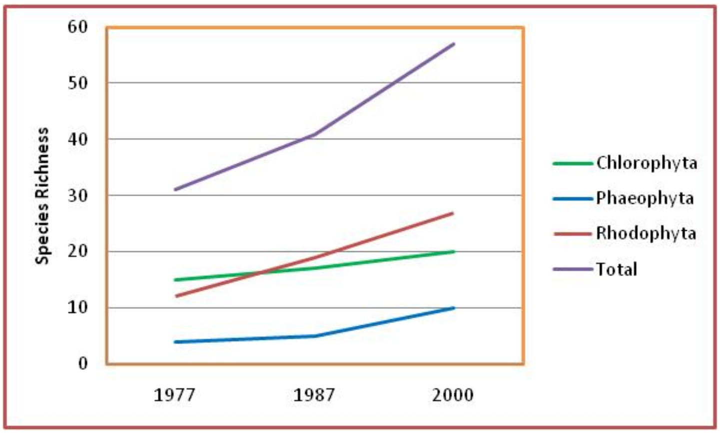


Fig. 4: Numerical species richness totals for Joppa during 1977 and 1987 (Wilkinson et al unpublished) and (Wells, 2002) including separate totals for each of the algal divisions, Chlorophyta, Phaeophyta and Rhodophyta.

The species composition responds well to predictions. The initial high levels of Chlorophyta suggest a dominance of opportunist species and a much lower level of perennial and sensitive species. Over time the number of perennial and sensitive Rhodophyta species has responded well to the improved environmental conditions allowing a more diverse community to establish. These observations, along with similar findings from other sites, allowed expected boundaries as defined by expert opinion to be refined against known values for a variety of shore types. This was primarily achieved by comparing each of the species richness and composition attributes against the subjective quality status to ensure they followed the expected trends.

2.6 Class boundaries (FSL and RSL)

Once reference conditions were established for high ecological status, the departure from these environmental settings was measured to define ecological status classes for both the FSL and RSL indices.

Class boundaries were defined through a UK process. After compilation of a database, members of the UK Marine Plants Task Team tentatively assigned sites a level of quality to reflect the normative definitions, between poor and good, based on expert knowledge of each of the sites. Each of the species richness and composition metrics was compared with the subjective quality status to ensure they followed the expected trends and then statistical analyses were run on the results to establish the level of significant difference between quality status groups. From these predicted levels of ecological quality, boundary levels were established for the metrics.

As described previously the index is composed of five metrics. When using the FSL to populate the index, all UK waters have the same metric class boundaries (Table 6). However, the metric boundary values when using the RSL differ slightly between geographic areas due to the differing species lists (Tables 7, 8 and 9).

Table 6: Boundary values for the five metric components when using the FSL for any UK waters.

Quality Status/ Metrics	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
Species richness	≥55 (-80)	35 - 55	20 - 35	5 - 20	0 - 5
Percentage of Chlorophyta	≤25 (-0)	25 - 30	30 - 40	40 - 60	60 - 100
Percentage of Rhodophyta	≥47 (-100)	42 - 47	32 - 42	15 - 32	0 - 15
Percentage of opportunists	≤15 (-0)	15 - 22	22 - 35	35 - 45	45 - 100
ESG Ratio	≥0.65 (-1.0)	0.5 - 0.65	0.35 - 0.5	0.1 - 0.35	0 - 0.1

Table 7: Boundary values for the five metric components when using the RSL for Scotland/Northern England area.

Quality status/ Metrics	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
Species richness	35 - 70	25 - 35	17 - 25	5 - 17	0 - 5
Percentage of Chlorophyta	0 - 12	12 - 20	20 - 30	30 - 80	80 - 100
Percentage of Rhodophyta	55 - 100	45 - 55	35 - 45	15 - 35	0 - 15
Percentage of opportunists	0 - 10	10 - 15	15 - 25	25 - 50	50 - 100
ESG Ratio	1.0 - 1.2	0.8 - 1.0	0.7 - 0.8	02 - 0.7	0 - 0.2

Table 8: Boundary values for the five metric components when using the RSL for England/Wales area.

Quality status/ Metrics	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
Species richness	35 - 69	25 - 35	15 - 25	5 - 15	0 - 5
Percentage of Chlorophyta	0 - 15	15 - 20	20 - 25	25 - 80	80 - 100
Percentage of Rhodophyta	55 - 100	45 - 55	40 - 45	15 - 40	0 - 15
Percentage of opportunists	0 - 10	10 -15	15 - 25	25 - 50	50 - 100
ESG Ratio	1.0 - 1.2	0.8 - 1.0	0.55 - 0.8	0.2 - 0.55	0 - 0.2

Table 9: Boundary values for the five metric components when using the RSL for Northern Ireland area.

Quality status/ Metrics	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
Species richness	34 - 68	20 - 34	10 - 20	3 - 10	0 - 3
Percentage of Chlorophyta	0 - 20	20 - 30	30 - 45	45 - 80	80 - 100
Percentage of Rhodophyta	45 - 100	35 - 45	25 - 35	10 - 25	0 - 10
Percentage of opportunists	0 - 15	15 - 25	25 - 35	35 - 50	50 - 100
ESG Ratio	0.8 - 1.2	0.6 - 0.8	0.4 - 0.6	0.2 - 0.4	0 - 0.2

3. Undertaking an assessment

3.1 Summary of the process

The process for undertaking an assessment using the rocky shore macroalgal index is summarised below (Fig. 5).

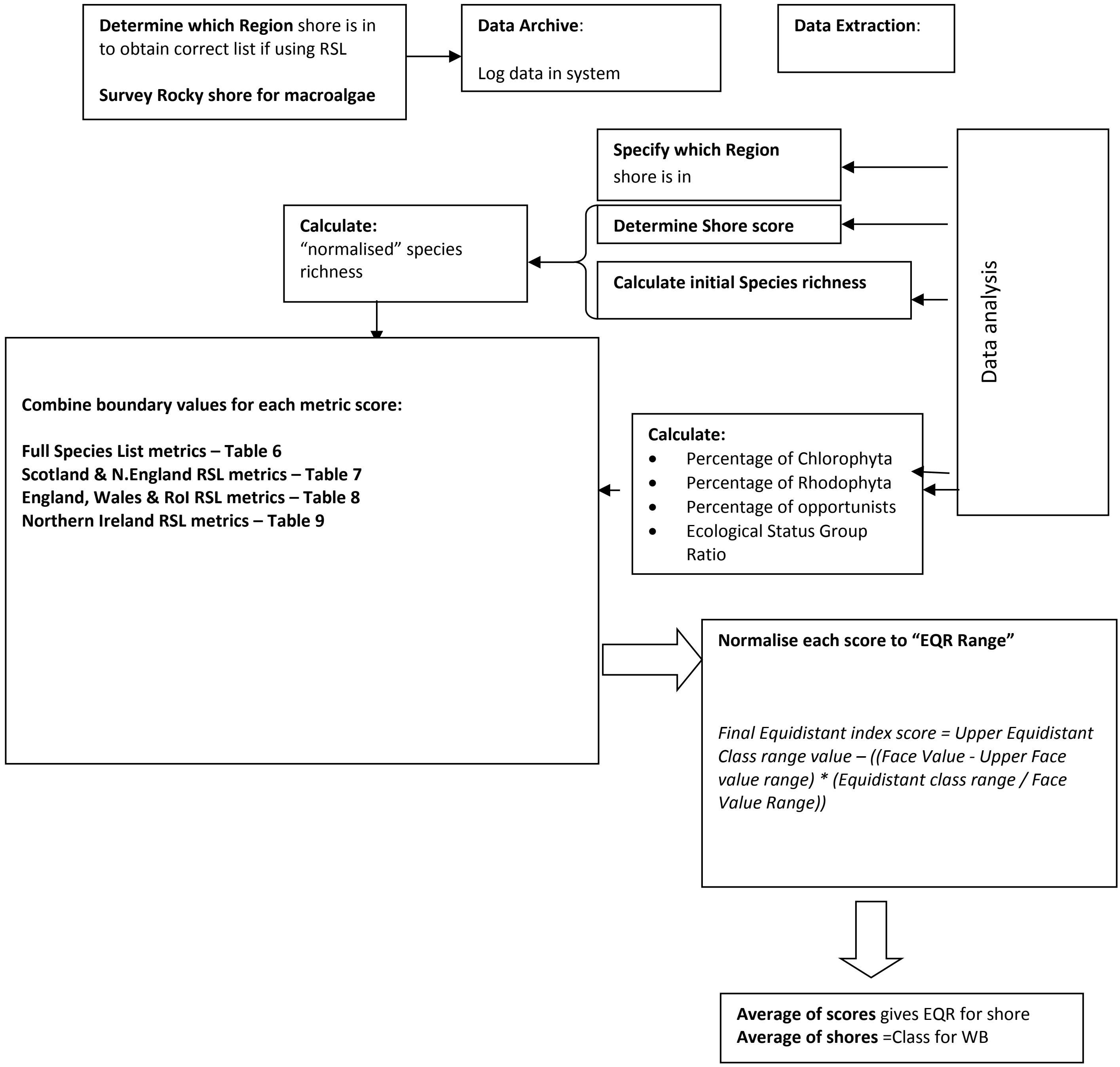


Fig. 5. Flow chart summarising the main stages of an assessment of macroalgae on rocky shores.

3.2 Data requirements

Calculation of the rocky shore macroalgal index requires definition of the habitat sampled and general sampling information. The FSL requires sample level macroalgae identification to lowest taxonomic level possible while the RSL is to a defined list at mixed taxon level.

3.3 Sampling strategy

Assessment is based on the presence/absence of macroalgal species identified during a shore survey. It is recommended that a minimum of 3 shores per water body should be sampled, but the number of shores should be proportionate to the size of the water body and the severity and range of pressures identified. UK WFD monitoring authorities aim to sample each shore at least twice during a 6 year WFD reporting cycle to encompass some estimate of natural fluctuation. This may be adjusted depending on the pressures in the water body and knowledge of the natural variability. It is recommended that a full species list assessment be carried out on at least one occasion in a reporting cycle, or where classification status using the RSL lies on or near a boundary, or the water body is assessed as being less than good status.

3.4 Sampling methodology

There is no guarantee of recording all species present on a stretch of shore but the WFD sampling methodology aims to maximise the number of species recorded and ensure repeatability.

The rocky shore macroalgal index is only applicable where the natural substrate consists primarily of solid bedrock, such as rocky outcrops, ridges and platforms or extensive areas of large boulders. Shingle, pebble and sandy shores are too unstable to support the attachment of a diverse community of algae and although it may be possible for some opportunist species to survive such conditions this will not naturally yield a high diversity of algae and may misclassify the water body. Appropriate shores for sampling must also consider accessibility and associated health and safety implications such as landslides, steep rock or any potential hazards that warrant the site unsafe.

Sampling should be between late April and no later than early October, to facilitate finding maximum species richness. Sampling should take place as close as possible to the low water of spring tides, whereby sampling in the lower littoral and sub-littoral fringe takes place at the time of low water to ensure access to the upper kelp zone, where this is present. The whole intertidal range should be sampled with particular attention paid to the following sub-habitats: large and small rock pools; deep pools; turfs in moist crevices; the sides of boulders or steep rocks and overhangs; turfs and mats.

The precise length or area of shore to be sampled will be determined predominantly by geographical features. It is suggested that a minimum horizontal shore length of ca.100 metres should be included in the sampling area extending up to 300 metres where time and shore type allows. If an interesting sub-habitat lies outwith, but close to, the 300 metres this should still be included. To ensure all habitats are explored, searching should cover a wide extent of the shore and not be restricted to a single transect line.

The full intertidal range should be sampled; this takes around 90 – 120 minutes on average but will vary according to the extent, length, physical diversity and richness of the shore. Sampling effort should be proportionate to the relative diversity and size of the shore. Ideally a full shore survey should be conducted by no fewer than two people with experience and knowledge of rocky shore algal communities and identification skills.

Photographs of the shore and surrounding area should be taken for future reference. These should include dominant rock types, biota, subhabitats as well as anthropogenic influences and general conditions that can later be used to provide evidence of the conditions during the time of sampling. A shore description should be compiled so as to record the presence or absence of all categories and descriptors (see Table 2).

Only those species clearly attached to the shore should be recorded or collected, unattached specimens are to be excluded as they may have originated from another shore, but may be noted though not included in species totals. When macroalgal specimens cannot be identified with certainty in the field, a sample should be collected and retained for later identification. Samples should be kept cool for transportation and stored in a fridge for up to ca. five days.

Algal surveys should include not only those species attached directly to the rock surface but also those algae growing in/on other host algal species and animals such as hydroids and shells. Full sampling guidance is given in Wells (2005).

3.5 Sample analysis

Identification of macroalgae species should be made by an ecologist experienced in identifying marine macroalgae. Taxa should be identified to the lowest taxonomic level possible for the FSL and should be reported against a standardised taxonomic list which should not exclude those species of an epiphytic, endophytic, epizoic and endozoic nature. RSL identification can be achieved using the specialised RSL key provided on the National Marine Biological Analytical Quality Control website (www.nmbaqcs.org), or via standard taxonomic literature.

Note: although changes to the taxonomic classification of marine algae are currently frequent (www.algaebase.org) contains up to date synonyms and taxonomic information), for the purpose of the WFD assessment the species lists will remain as detailed in the current document until subsequent taxonomic reviews and relevant updates are applied and distributed.

3.6 Data treatment

Raw data requires processing prior to calculation of the metrics (EQR).

Species richness requires normalisation against the shore description (Section 2.3) which uses the following calculation:

Species Richness (N_n) = Number Taxa (N_t) x Correction Factor (C_f)

Proportion of Chlorophyta (green) species – P_{Ch}: The observed parameter value, proportion of Chlorophyta taxa should be calculated as such:

$$P_{Ch} = \frac{N_{Ch}}{N_t} \times 100$$

Proportion of Rhodophyta (red) species – P_{Rh}: The observed parameter value, proportion of Rhodophyta taxa should be calculated as such:

$$P_{Rh} = \frac{N_{Rh}}{N_t} \times 100$$

Proportion of Opportunist species – P_{Opp}: The observed parameter value, proportion of opportunist taxa should be calculated as such:

$$P_{Opp} = \frac{N_{Opp}}{} \times 100$$

N_t

Ratio of ESG1 to ESG2 – R_{ESG}: Taxa should be assigned to either of two ecological status groups, ESG1 and ESG2. The observed parameter value, ratio of ESG groups should be calculated as such:

$$R_{ESG} = \frac{N_{ESG1}}{N_{ESG2}}$$

3.7 EQR calculation

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 in section 3.1 (Figure 5).

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 5 metrics can be combined. A stepwise process is followed:-

(i) calculation of the face value (eg species richness or proportion of reds) for each metric (outlined in section 3.6).
(ii) normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index.
(iii) calculation of Rocky Shore Macroalgal Index – average of equidistant metric scores.

Normalisation and rescaling of face values to metric range.

The face values need to be converted to an equidistant EQR scale to allow combination of the indices. Initially this was carried out in a two step process, normalisation of face values to an EQR (0-1) scale (non-equidistant class boundaries) and then rescaling to an equidistant class EQR scale. These steps have now been mathematically combined in the following equation: -

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

Tables 10-14 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, hence the negative values for species richness, proportion of reds, and ESG ratio.

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’. It is important to note that values in the FV class range are identified as positive or negative in order that these values can be used directly in the equation above.

Table 10. Values for the normalisation and rescaling of face values to EQR metric ranges using the full taxa list.

		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
UK "Full" List							
Species Richness (FSL)	High	≥55	80	-25	≥0.8	1	0.2
	Good	≥35	<55	-19.999	≥0.6	<0.8	0.2
	Moderate	≥20	<35	-14.999	≥0.4	<0.6	0.2
	Poor	≥5	<20	-14.999	≥0.2	<0.4	0.2
	Bad	0	<5	-4.999	0	<0.2	0.2
Proportion of "Greens" [%]	High	≤25	0	25	≥0.8	1	0.2
	Good	≤30	>25	4.999	≥0.6	<0.8	0.2
	Moderate	≤40	>30	9.999	≥0.4	<0.6	0.2
	Poor	≤60	>40	19.999	≥0.2	<0.4	0.2
	Bad	100	>60	39.999	0	<0.2	0.2
Proportion of "Reds" [%]	High	≥47	100	-53	≥0.8	1	0.2
	Good	≥42	<47	-4.999	≥0.6	<0.8	0.2
	Moderate	≥32	<42	-9.999	≥0.4	<0.6	0.2
	Poor	≥15	<32	-16.999	≥0.2	<0.4	0.2
	Bad	0	<15	-14.999	0	<0.2	0.2
ESG Ratio	High	≥0.65	1.0	-0.35	≥0.8	1	0.2
	Good	≥0.5	<0.65	-0.149	≥0.6	<0.8	0.2
	Moderate	≥0.35	<0.5	-0.149	≥0.4	<0.6	0.2
	Poor	≥0.1	<0.35	-0.249	≥0.2	<0.4	0.2
	Bad	0	<0.1	-0.09	0	<0.2	0.2
Proportion of opportunists [%]	High	≤15	0	15	≥0.8	1	0.2
	Good	≤22	>15	6.999	≥0.6	<0.8	0.2
	Moderate	≤35	>22	12.999	≥0.4	<0.6	0.2
	Poor	≤45	>35	9.999	≥0.2	<0.4	0.2
	Bad	100	>45	54.999	0	<0.2	0.2

Table 11. Values for the normalisation and rescaling of face values to EQR metric ranges using the reduced taxa list for Scotland and Northern England.

		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
Scotland / Northern England (RSL)							
Species Richness (RSL)	High	≥35	70	-35	≥0.8	1	0.2
	Good	≥25	<35	-9.999	≥0.6	<0.8	0.2
	Moderate	≥17	<25	-7.999	≥0.4	<0.6	0.2
	Poor	≥5	<17	-11.999	≥0.2	<0.4	0.2
	Bad	0	<5	-4.999	0	<0.2	0.2
Proportion of "Greens" [%]	High	≤12	0	12	≥0.8	1	0.2
	Good	≤20	>12	7.999	≥0.6	<0.8	0.2
	Moderate	≤30	>20	9.999	≥0.4	<0.6	0.2
	Poor	≤80	>30	49.999	≥0.2	<0.4	0.2
	Bad	100	>80	19.999	0	<0.2	0.2
Proportion of "Reds" [%]	High	≥55	100	-45	≥0.8	1	0.2
	Good	≥45	<55	-9.999	≥0.6	<0.8	0.2
	Moderate	≥35	<45	-9.999	≥0.4	<0.6	0.2
	Poor	≥15	<35	-19.999	≥0.2	<0.4	0.2
	Bad	0	<15	-14.999	0	<0.2	0.2
ESG Ratio	High	≥1.0	1.2	-0.2	≥0.8	1	0.2
	Good	≥0.8	<1.0	-0.199	≥0.6	<0.8	0.2
	Moderate	≥0.7	<0.8	-0.099	≥0.4	<0.6	0.2
	Poor	≥0.2	<0.7	-0.499	≥0.2	<0.4	0.2
	Bad	0	<0.2	-0.199	0	<0.2	0.2
Proportion of opportunists [%]	High	≤10	0	10	≥0.8	1	0.2
	Good	≤15	>10	4.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤50	>25	24.999	≥0.2	<0.4	0.2
	Bad	100	>50	49.999	0	<0.2	0.2

Table 12. Values for the normalisation and rescaling of face values to EQR metric ranges using the reduced taxa list for England and Wales.

		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
England / Wales (RSL)							
Species Richness (RSL)	High	≥35	69	-34	≥0.8	1	0.2
	Good	≥25	<35	-9.999	≥0.6	<0.8	0.2
	Moderate	≥15	<25	-9.999	≥0.4	<0.6	0.2
	Poor	≥5	<15	-9.999	≥0.2	<0.4	0.2
	Bad	0	<5	-4.999	0	<0.2	0.2
Proportion of "Greens" [%]	High	≤15	0	15	≥0.8	1	0.2
	Good	≤20	>15	4.999	≥0.6	<0.8	0.2
	Moderate	≤25	>20	4.999	≥0.4	<0.6	0.2
	Poor	≤80	>25	54.999	≥0.2	<0.4	0.2
	Bad	100	>80	19.999	0	<0.2	0.2
Proportion of "Reds" [%]	High	≥55	100	-45	≥0.8	1	0.2
	Good	≥45	<55	-9.999	≥0.6	<0.8	0.2
	Moderate	≥40	<45	-4.999	≥0.4	<0.6	0.2
	Poor	≥15	<40	-24.999	≥0.2	<0.4	0.2
	Bad	0	<15	-14.999	0	<0.2	0.2
ESG Ratio	High	≥1.0	1.2	-0.2	≥0.8	1	0.2
	Good	≥0.8	<1.0	-0.199	≥0.6	<0.8	0.2
	Moderate	≥0.55	<0.8	-0.249	≥0.4	<0.6	0.2
	Poor	≥0.2	<0.55	-0.349	≥0.2	<0.4	0.2
	Bad	0	<0.2	-0.199	0	<0.2	0.2
Proportion of opportunists [%]	High	≤10	0	10	≥0.8	1	0.2
	Good	≤15	>10	4.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤50	>25	24.999	≥0.2	<0.4	0.2
	Bad	100	>50	49.999	0	<0.2	0.2

Table 13. Values for the normalisation and rescaling of face values to EQR metric ranges using the reduced taxa list for Northern Ireland.

		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
		Northen Ireland (RSL)					
Species Richness (RSL)	High	≥34	68	-34	≥0.8	1	0.2
	Good	≥20	<34	-13.999	≥0.6	<0.8	0.2
	Moderate	≥10	<20	-9.999	≥0.4	<0.6	0.2
	Poor	≥3	<10	-6.999	≥0.2	<0.4	0.2
	Bad	0	<3	-2.999	0	<0.2	0.2
Proportion of "Greens" [%]	High	≤20	0	20	≥0.8	1	0.2
	Good	≤30	>20	9.999	≥0.6	<0.8	0.2
	Moderate	≤45	>30	14.999	≥0.4	<0.6	0.2
	Poor	≤80	>45	34.999	≥0.2	<0.4	0.2
	Bad	100	>80	19.999	0	<0.2	0.2
Proportion of "Reds" [%]	High	≥45	100	-55	≥0.8	1	0.2
	Good	≥35	<45	-9.999	≥0.6	<0.8	0.2
	Moderate	≥25	<35	-9.999	≥0.4	<0.6	0.2
	Poor	≥10	<25	-14.999	≥0.2	<0.4	0.2
	Bad	0	<10	-9.999	0	<0.2	0.2
ESG Ratio	High	≥0.8	1.2	-0.4	≥0.8	1	0.2
	Good	≥0.6	<0.8	-0.199	≥0.6	<0.8	0.2
	Moderate	≥0.4	<0.6	-0.199	≥0.4	<0.6	0.2
	Poor	≥0.2	<0.4	-0.199	≥0.2	<0.4	0.2
	Bad	0	<0.2	-0.199	0	<0.2	0.2
Proportion of opportunists [%]	High	≤15	0	15	≥0.8	1	0.2
	Good	≤25	>15	9.999	≥0.6	<0.8	0.2
	Moderate	≤35	>25	9.999	≥0.4	<0.6	0.2
	Poor	≤50	>35	14.999	≥0.2	<0.4	0.2
	Bad	100	>50	49.999	0	<0.2	0.2

A shore level assessment is the average score from all the metrics expressed on the equidistant 0-1 EQR scale.

Shore EQR = $(N_n + P_{Ch} + P_{Rh} + P_{Opp} + R_{ESG}) / 5$

3.8 Water body level classification

The water body classifications are based on the arithmetic mean of the EQR scores of all shores sampled within a 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). 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 rocky shore macroalgae tool was developed by WRc (Davey, 2009).

For classification purposes, the estimated EQR is translated directly into a face value class (i.e. High - Bad). However, because it is not possible to survey the biological community across a whole water body continuously throughout the whole reporting period, there will always be some sampling error, which will lead to uncertainty in the estimate of the EQR. This uncertainty can be quantified as the expected difference between the observed EQR and the true underlying EQR, which can then be used to calculate the probability of the water body being in each of the five status classes. From this it is possible to determine the most probable class (the one with the highest probability) and state what level of confidence we have that the true status is good or better, and moderate or worse.

The confidence of class tool assumes that surveys for macroalgae are conducted in such a way as to give a representative and unbiased measure of biological conditions across the whole water body throughout the whole reporting period. Statistical manipulation of the resulting data cannot compensate for poorly planned and executed field sampling; there is no substitute for a sampling scheme that measures directly the spatial and temporal variation in the target population.

An Excel spreadsheet ‘Precision in Rocky shores Analysed To Extract Statistics’ (PIRATES) has been derived to define the precision of the assessment. The PIRATES workbook can be found on the UKTAG website www.wfduk.org. PIRATES performs calculations for multiple water bodies simultaneously and gives the confidence of class over the whole reporting period. As each metric integrates spatial and temporal variability in the macroalgal community, the uncertainty in the Final EQR is estimated by combining estimates of the uncertainty within each metric EQR (for full details see Davey, 2009).

4. Worked example

A shore site in England was surveyed using the RSL with the following results:
The number of taxa (N_t) was 31 and the shore description value (V) was 13;

The proportion (P_{ch}) of Chlorophyta taxa was 19.35;

The proportion (P_{rh}) of Rhodophyta was 51.61;

The proportion (P_{op}) of opportunistic taxa was 22.58;

The proportion (ESGR) of ESG1: ESG2 Groups was 1.21.

Normalised species richness, N_n

From Table 5, the correction factor, C_f, for a shore score of 13 is 1.14

The normalised number (N_n) of macroalgal taxa is given by equation as

N_n = 1.14 x 31 = 35.34

Calculation of the metric EQR values

The critical values to calculate the EQRs are taken from the geographically relevant table for England (Table 11) using the equation:

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

For *Species Richness*:

= 1 – ((35.34 – 69) * (0.2 / -34))

= 1 – ((-33.66) * (-0.00588))

= 1- 0.198

= 0.802

Proportion of Greens:

= 0.799 – ((19.35 – 15.001) * (0.2 / 4.999))

= 0.799 – ((4.349) * (0.025))

= 0.799 - 0.174

= 0.625

Proportion of Reds:

= 0.799 – ((51.61 – 54.99) * (0.2 / -9.999))

= 0.799 – ((-3.38) * (-0.02))

= 0.799 – 0.068

= 0.731

ESG ratio:

= 1 – ((1.21 – 1.2) * (0.2 / -0.2)

= 1 – ((0.01) * (-1))

= 1 – (-0.01)

= 1.01 (rounded down to 1)

Proportion of Opportunists:

= 0.599 – ((22.58 – 15.001) * (0.2 / 9.999))

= 0.599 – ((7.579) * (0.02))

= 0.599 – 0.152

= 0.447

The overall EQR for the shore is:

= (0.802 + 0.625 + 0.731 + 1.0 + 0.447) / 5

= 0.721 (GOOD)

This is repeated for all shores in the water body and the average of all the shore EQRs represents the final EQR for that water body.

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