Water Framework Directive development of classification tools for ecological assessment:

Macroalgae Species Richness

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

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1. Summary

This report discusses the Water Framework Directive Rocky shore macroalgal species richness tool. The report consists of a general background to the WFD, the management groups, normative definitions and reference conditions.

With these in mind the provenance of the tool is discussed emphasising that species richness has been shown to remain constant in the absence of anthropogenic disturbance. Abundance is highly variable and dependent upon natural as well as anthropogenic pressures, therefore it is not considered to be a valid measure of quality. Ephemeral or opportunist algae come and go; often there is a cycle from Fucoid to barnacle domination, hence levels of species richness are more important than the individual levels of species coverage.

Ideally a "full species list" (FSL) is used; however, the identification of over 700 intertidal seaweed species requires high levels of taxonomic expertise. Therefore a "reduced species list" (RSL) was derived. There are 3 RSLs for the UK comprising around 70 taxa each and 100 taxa overall.

The development of the algal database, reference and threshold setting are discussed together with the need to take account of the variability of the shore and the response to pressures.

Consideration is also given to calculating the final EQR using worked examples, and of calculating the confidence of classification.

2. Background to the Water Framework Directive (WFD)

The Water Framework Directive 2000/60/EC (WFD, 2000) governs the protection, improvement and sustainable use of inland surface waters, transitional waters (TW), coastal waters (CW) and groundwater. The Directive, which came into effect on 22nd December 2000, updates existing water legislation and establishes a new integrated water management system based on river basin planning. The key aims of the WFD are out lined below:

- To prevent further deterioration and protect and enhance the status of aquatic ecosystems and associated wetlands;
- To promote sustainable use of water; and provide sufficient supply of good quality surface water and groundwater.
- To reduce pollution of waters from priority substances
- To prevent deterioration in the status and to progressively reduce pollution of groundwater; and

- To contribute to mitigating the effects of floods and droughts.

The main purpose under Water Framework Directive guidelines is to develop robust ecological quality objectives (EQOs) for assessment of anthropogenic / human induced pressures in TWs and CWs by looking beyond the drivers of change and linking physical and chemical conditions with a measurable biological response in the community.

The Water Framework Directive requires that defined areas of waters (i.e. water bodies) "achieve good ecological and good chemical status" by 2015 unless there are grounds for derogation. Annex V of the Water Framework Directive 2000/60/EC specifies the quality elements and normative definitions on which the classification of ecological and chemical status is based. Normative definitions outline what aspects of the biological elements should be assessed and is the main driver behind the tool development.

The Directive's requirements include ecological status and chemical status classification schemes for surface water bodies which will differ for rivers, lakes, transitional waters and coastal waters. Heavily modified and artificial water bodies will be assessed in relation to their ecological potential and chemical status classification schemes. The quality elements addressed in Annex V for assessing ecological status and ecological potential are:

- biological quality elements;
- general physico-chemical quality elements;
- environmental Quality Standards (EQSs) for synthetic and non-synthetic pollutants; and
- hydromorphological quality elements.

The specific biological requirements for transitional waters are:

- the composition and abundance of phytoplankton,
- macroalgae
- angiosperms,
- benthic invertebrates
- fish fauna.

For coastal waters the biological elements are:

- composition and abundance of phytoplankton,
- aquatic flora (macroalgae and angiosperms)
- benthic invertebrates.

For the ecological status and ecological potential classification schemes, the Directive provides detailed normative definitions of the degree of human disturbance to each relevant quality element that is consistent with each of the ecological status/potential classes. These definitions have been used to develop classification tools and appropriate numeric class boundaries for each quality element. The results of applying these classification tools are used to determine the status of each water body or group of water bodies.

Therefore the UK was required to put into place a regime of monitoring water bodies that supports monitoring their status in terms of risk of not meeting the objectives of WFD by 2006. This requires the UK to establish both national monitoring framework and classification schemes as well as contributing to the European intercalibration process. This report outlines progress to date on the development of the rocky shore macroalgae classification tools, mainly within coastal waters, to support assessment of the biological quality elements.

3. UK Process of WFD Development

3.1. UK TAG

The WFD UKTAG is the United Kingdom Technical Advisory Group (UKTAG) supporting the implementation of the European Community (EC) Water Framework Directive (Directive 2000/60/EC). It is a partnership of experts from the UK conservation and environment agencies and the Department of Environment and Local Government for the Republic of Ireland which meets quarterly. Its main function is to provide coordinated advice on technical aspects of the implementation of the Water Framework Directive (WFD). This aims to facilitate a coordinated approached to the identification and characterisation of water bodies based on their physical attributes and furthermore assessing the risk of such water bodies failing to achieve the WFD's environmental objectives. It works alongside various experts, and government and stakeholder groups, to develop common approaches to implementation based on classification systems within the UK, guided by UK environmental standards, and further used for intercalibration across Europe. This guidance work is timetabled enabling a framework for general WFD implementation including monitoring, which commenced in December 2006, and setting environmental objectives under the WFD within the UK and Europe.

Overall the UK TAG group initially provided guidance on;

- Development of **typology of surface waters** (describing water bodies into common types) and establishment of **type specific reference conditions** for the classification of UK waters;
- The definition and subsequent analysis of **pressures and impacts** for the assignment of water bodies to risk categories;
- The development of **classification tools and methods** that will support monitoring of ecological status.
- Development of an overall **monitoring framework** that supports meeting the different requirements of the Directives and future Program of Measures including **operational and surveillance monitoring** to track base-line changes in status of UK water bodies as well as **compliance monitoring**.

- Production of initial **reports for the European Commission** on characterisation and pressures and impacts analysis.

- Assist with **Europe intercalibration process** (known as ECOSTAT) that will support defining the thresholds between statuses of water bodies under the WFD (high, good, moderate, poor).

The UKTAG initiated the development of the classification tools, during the 2003/04 period, with the lakes, rivers and marine task teams formed and tasked to: *'coordinate the adaptation and development of suitable surface water classification tools for the biological quality elements'* under the compliance of the European Common Implementation Strategy (CIS). Some of these elements historically are part of UK classification systems whilst others pose new requirements to support assessment of ecological status. To help implement its work programme, UKTAG has established a number of specialist groups:

- Task teams and steering groups comprising experts from the environment and conservation agencies. These are focused on specific themes or actions (e.g. lakes, rivers, river basin planning etc). These groups may initiate new research programs.

- Drafting Groups - Small short-lived groups of experts charged with producing specific advice (e.g. drinking water guidance).

The Marine Task Team (MTT) leads the development of classification systems within Transitional and coastal, providing further guidance to the relevant subgroups including the Marine Plants Task Team (MPTT).

3.2. MPTT

The Marine Plants Task Team consists of a number of represents from various government agencies to provide expertise on the translation, development and implementation of the WFD. It met every 4-6 months to discuss progress within the phytoplankton, macroalgae and angiosperm classification tools as driven by the MTT and UK TAG. The Marine Plant Task Team's role has been to translate the WFD legislative report into practical ecological and scientific classification methods for marine plants and in so doing have developed a number of classification tools to represent the requirements of the WFD.

Within this group the UK and RoI representatives have had to ensure harmonisation of ecological classification systems across respective systems to ensure a coherent approach by both member states. The tools are being developed both 'in house' and by consultants and funded from a number of sources including the environment agencies, SNIFFER, and the Irish North South (SHARE) project, which is INTERREG funded and is being managed jointly between authorities in Northern Ireland and the Republic of Ireland. The approach includes the:

- review and adaptation of existing methods for potential to support classification schemes under the WFD;

- development of new tools for elements not previously monitored in the UK;

- assessing which parameters have the best correlation for assessing pressures and impacts;
- development of reference conditions from which to base boundary criteria;
- trialling such tools in the assessment of ecological quality status; and
- review, comparison and agreement of methods with EU Members States to comply with intercalibration requirements

This document describes the process involved in the development stages of the macroalgae tool considering its theoretical and practical elements, subsequent implementation and inclusion in the European Intercalibration process. The tools are grounded in scientific knowledge and published research, but wherever there is uncertainty or a scarcity of quantitative scientific evidence the precautionary principle has been invoked.

4. Normative definitions

The criteria by which ecological status should be evaluated are detailed in the normative definitions in Annex V (1.2) of the Water Framework Directive. Normative definitions provide definitions of ecological quality and the values for the quality elements of ecological status for coastal and transitional waters. They describe the various aspects of macroalgae that must be used in the ecological status assessment of a water body. Indices ('tools' or 'metrics') have been developed to address these aspects of the normative definitions for each of the five status classes. The WFD normative definitions specify which aspects of each biological quality element must be assessed, and the plants tools have been developed accordingly.

The normative definitions relating to macroalgae are outlined below for transitional and coastal waters.

Transitional Waters

HIGH	The composition of macroalgal taxa is consistent with undisturbed conditions. There are no detectable changes in macroalgal over due to anthropogenic activities.
GOOD	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.
MODERATE	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.
POOR	Major alterations to the values of the biological quality elements for the surface water body type. Relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions.
BAD	Severe alterations to the values of the biological quality elements for the surface water body type. Large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent.

Coastal Waters

HIGH	All disturbance-sensitive macroalgal associated with undisturbed conditions present. The levels of macroalgal cover are consistent with undisturbed conditions
GOOD	Most disturbance-sensitive macroalgae associated with undisturbed conditions are present. The level of macroalgal cover shows slight signs of disturbance.
MODERATE	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.
POOR	Major alterations to the values of the biological quality elements for the surface water body type. Relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions.
BAD	Severe alterations to the values of the biological quality elements for the surface water body type. Large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent.

4.1. Evolution of Expanded Normative Definitions

These Normative definitions have been expanded by the MPTT (Dublin 2004) to provide examples of how they apply directly to the composition of macroalgae within Coastal waters. These descriptions form the basis for the development of the rocky shore macroalgae tool currently being used for WFD ecological assessment. Expansion of the normative definitions have not been included for transitional waters as this tool can only be applied to coastal waters or where the outer reaches of transitional waters are representative of fully saline rocky shores. So the expanded definitions incorporate all instances in which the tool may be applied.

Coastal Waters

UK Interpretation Structural & functional relevance	Reference Conditions/High	Good	Moderate
Inter-tidal rocky shore 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.	*All disturbance-sensitive macroalgae associated with undisturbed conditions are present. The levels of macroalgal cover are consistent with undisturbed conditions.*	*Most disturbance-sensitive macroalgae associated with undisturbed conditions are present. The level of macroalgal cover shows slight signs of disturbance.*	*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.*
	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 species.	Slightly less diverse community of red, green and brown seaweeds. Cover variable depending on local physical conditions. Greatest reduction in red species and greater proportion of short-lived species present.	Less diverse community of red, green and brown seaweeds. Cover variable depending on local physical conditions. Fewer red species. With possible high cover of short-lived opportunistic macroalgae.

4.2. Reference Conditions

The Water Framework Directive states type-specific biological reference conditions may be spatially based, based on modelling, or derived using a combination of these methods. For spatially based type-specific biological reference conditions, Member States are developing a reference network for each surface water body type. Predictive models or hind-casting methods should use historical, palaeological and other available data. Where it is not possible to use these methods, expert judgement may be used to establish such conditions (Annex II 1.3).

To a large extent, suitable substrate dictates the potential macroalgae assemblage likely to colonise in a waterbody. Defining type-specific reference conditions is problematic because for transitional waters substratum characteristics only partially inform the typology, and in coastal waters the substratum is not a defining characteristic of typology at all. This means reference conditions are not type-specific; rather they may vary within a type or may be common across types. Three macroalgae tools have been developed for transitional and coastal waters depending on substratum.

For macroalgae on rocky shores predictive models of macroalgae community composition and abundance under varying environmental conditions do not exist; consequently this is not a viable approach for establishing reference conditions. Reference conditions have been established using a combination of expert judgement and data from sites considered to be near pristine. Historic macroalgal species lists exist for a small number of sites and these have been used to inform reference conditions. From the marine benthic algal database the species records from those sites deemed as 'high quality' were used from which to set reference conditions. This decision was taken as such comprehensive species lists should ideally be representative of high quality shores with which other shores will be compared, and will therefore act as a reference condition.

High Status
The taxonomic composition corresponds totally or nearly totally with undisturbed conditions and disturbance sensitive taxa are present. Also there are no detectable changes in macroalgae abundance due to anthropogenic activities. The species composition is unaltered from reference conditions. There is a diverse community of red, green and brown seaweeds with high levels of species richness. Cover is variable depending on local physical conditions but species richness remains relatively constant over time. Red species are present as richest group along with a high proportion of long-lived species including brown algae. Opportunist and green species should constitute a lower proportion of the algae present

Good status
Most disturbance-sensitive macroalgae associated with undisturbed conditions are present. The level of macroalgal cover shows slight signs of disturbance. There is a slight deviation from the reference conditions. There is a slightly less diverse community of red, green and brown seaweeds with a corresponding decrease in

species richness. Cover is variable depending on local physical conditions. The greatest reduction is in red species and a greater proportion of short-lived species is present. The proportion of brown species stays relatively constant.

Moderate status
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. Moderate status is characterised by a moderate deviation from the reference conditions. There is a less diverse community of red, green and brown seaweeds. Cover is variable depending on local physical conditions. There is a decrease in the proportion of red species with a possible high cover of short-lived opportunistic macroalgae. The algal community shows a greater dominance of green, opportunist and ephemeral species. Fewer brown species are present but in similar proportions.

4.3. Ecological Quality Status

Once reference conditions are established, the departure from these environmental settings can be measured. The degree of deviation sets boundaries for each of the ecological status classes. The boundaries between each of the status classes need to be described and criteria established which reflect the normative definitions.

Annex V 1.4.1 of the Directive states *"the results of the (classification) system shall be expressed as ecological quality ratios for the purposes of classification of ecological status. These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body. The ratio shall be expressed as a numerical value between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero."* Figure 1 illustrates this concept.

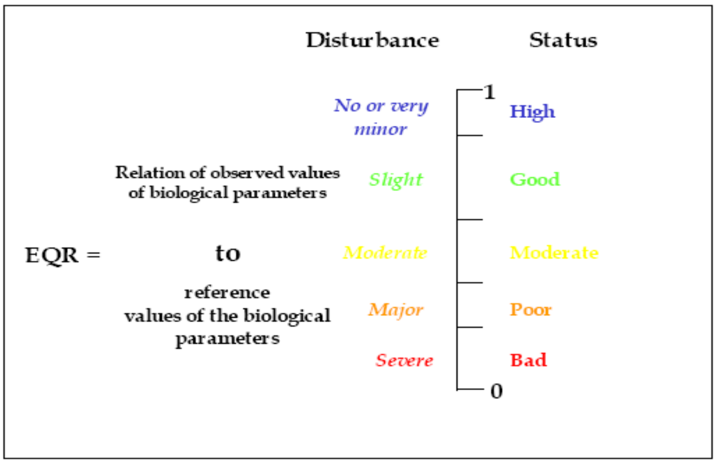

Figure 1: Suggested Ecological Quality Ratio; Annex V, 1.4.1 (From COAST Guidance, Vincent *et al*., 2002).

The comparison of monitoring results with the reference conditions derives the EQR. The values of the EQR then set for each ecological status class must ensure that the water body meets the normative definition for that status class given in Annex V (Tables 1.2, 1.2.3. or 1.2.4). As such the reference conditions form the anchor for the whole ecological assessment. Ecological status classes will be defined by their deviation from reference.

5. Macroalgae Species Composition Tool

This paper explains in greater detail the basis of the tool described in Wells *et al.* 2007.

Annex V of the Water Framework Directive (WFD) states macroalgae are a *biological quality element* to be used in defining ecological status of a transitional or coastal water body. Specifically it outlines the criteria that need to be related to type-specific reference conditions for macroalgae:

- *Taxonomic composition corresponds totally or nearly totally with undisturbed conditions.*
- *There are no detectable changes in macroalgae abundance due to anthropogenic activities.*

Regarding the composition of macroalgae the WFD states that for high quality 'all sensitive taxa should be present'. However, it is not known which species are the sensitive ones in any particular situation, and as sensitive species tend to be less abundant members of the community, they will not be constantly present even under good water quality conditions. Additionally, the taxonomic composition of macroalgae displays considerable variation particularly in relation to the shift from a coastal to transitional water body requiring the community structure of the extremes of these two environments to be considered separately. Measuring species composition is also highly dependent upon the intertidal substrate, requiring hard and often stable substrate to which to attach. In contrast, detecting changes in macroalgae abundance is most applicable in sedimentary intertidal areas. Therefore the following tool was developed to be used primarily for coastal waters, but may be used on shores within the outer extent of transitional waters where hard substrate is present and salinity is not markedly reduced.

Macroalgae communities are able to provide a good means of assessing ecological quality. Such communities are quick to respond to changes in the environment often providing visible effects. Changes in species richness are often indicative of a change in the environment induced by human activity. These impacts are also reflected in a change in the macroalgae species assemblage, often causing a shift from larger long-lived perennial species to fast-growing, opportunist species, which are able to take advantage of the more adverse conditions and lack of competition. A shore may also visibly respond to an increase in anthropogenic activity through a general decline in algal abundance and cover whereby an algal-dominated community may be replaced by sessile and filter feeding fauna. High levels of suspended solids may interfere with the settlement and growth of macroalgal sporelings on rocks and may decrease the light penetration particularly within rock pools (Read *et al*., 1983). 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.

The effects of sewage pollution were observed at two sites within the Firth of Forth whereby a large reduction in species richness was accompanied by a high biomass of *Mytilus edulis* and *Balanus balanoides*, which proceeded to dominate the shore. Such replacement is regarded as typical of chronic pollution by domestic sewage with pools filled with high levels of suspended matter, deep mud and empty shells (Knight and Johnston, 1981 and Johnston, 1972). Changes in community structure, due to the presence of dominant *Mytilus* and *Balanus* communities, are capable of inhibiting growth of algae. This, combined with the direct and/or indirect stress of adverse effects such as increased suspended matter, reduced light for photosynthesis and competition for space, ensures recolonisation by macroalgal communities is inhibited.

However, within intertidal rocky shore communities ephemeral algal species come and go over several time scales, resulting in variable species composition between months, seasons and years. Records of species composition are also known to vary on consecutive days solely through variability in conducting algal field sampling (Wells, 2002). The abundance of macroalgae on rocky shores can also undergo massive changes over a period of a few years due to natural variability, for example from almost total fucoid domination to barnacle domination and back again over 10-15 years. In contrast species richness remains broadly constant, in the absence of environmental alteration, over days, months, seasons and years. This was originally shown by Wilkinson & Tittley (1979) for various shores in the Firth of Forth and proposed as a better measure of seaweed community stability than the detailed listing of actual species present, and later substantiated by Wells (2002).

Detailed records have also shown increases in species richness with recovery from severe pollution using shores subjected to coal mine waste in Co. Durham (Edwards, 1975, Wilkinson, 1998). Wells & Wilkinson (2003) have further confirmed the constancy of species richness on high quality shores using regular surveys in Orkney, during which species richness remained stable in consecutive years despite seasonal fluctuations with summer peaks and winter troughs. It is apparent from these studies that changes in the intertidal environment through adverse impacts are reflected in levels of species richness, suggesting this numerical value is a more appropriate measure of quality than detailed lists of species present.

Unfortunately, intertidal rocky shore environments are also highly variable and this not only affects the overall composition but also the level of species richness found, even within areas devoid of human interference. Intertidal algal communities generally display zonation patterns from the top to the bottom of the shore often with very distinct bands. These different zones can vary both in their relative height and extent on the shore as a result of levels of exposure. Sheltered shores are often characterised by a dense abundance of fucoids with a distinct transition from upper to lower shore. This presence of fucoids becomes less apparent as shores become more exposed, initially forming a more mosaic pattern of faunal and floral species and later becoming highly dominated by barnacles, mussels and limpets. However despite exposure appearing to contribute to the abundance and zonation patterns of algae in the intertidal there is no significant impact on the levels of species richness. Further studies of the overall shores structure, using data compiled for the Northern Ireland Littoral Survey (Wilkinson *et al*., 1988), have indicated a link between species richness and localised intertidal variables (Wells & Wilkinson, 2002).

These changes in macroalgal communities, as a response to changes in environmental health, are only reflected within coastal water bodies and occasionally the outer reaches of transitional waters depending on their shore structure. The nature of the transitional waters environment, particularly the upper reaches, is very varied and need to be considered separately. Other tools are being developed for transitional waters.

5.1. Background to the Rocky Shore Macroalgae Tool

As already stated, ephemeral species come and go from communities on various time scales varying from months to years. However species richness remains broadly constant in the absence of environmental alteration. This was originally shown by Wilkinson & Tittley (1979) for various shores in the Firth of Forth and proposed as a better measure of seaweed community stability than the detailed listing of actual species present, later found by Wells (2002). Subsequently it has been shown by Wilkinson (1998) that species richness increases with recovery from severe pollution using shores subjected to coal mine waste in Co. Durham (Edwards, 1975). Wells & Wilkinson (2003) confirmed the constancy of species richness on high quality shores using regular surveys in Orkney and have shown the importance of taking account of seasonal variation in establishing a level of species richness for a shore. Therefore the decision was made in July 2002 by the MPTT to concentrate on numerical species richness of intertidal rocky shores as a measure of quality rather than comprehensive listings of species presence.

Unfortunately, the identification of intertidal seaweed species requires high levels of taxonomic expertise. Therefore one alternative means of recording qualitative species data would be to implement the use of a reduced species list (RSL) whereby the number of species from the RSL will be in proportion to total species richness acting as a surrogate. The list would be composed of species (approximately 70) that contribute most significantly to the overall species composition of the rocky shores of a particular type within a geographical area, and this would act as a checklist.

The first requirement was to establish the level of total species richness to be expected on different shores of varying ecological quality and shore type. Therefore a database was compiled of species records on a range of shores throughout the British Isles and the Republic of Ireland. This database was used to seek a reduced species list to be used as a surrogate for total species richness. The definitive quality criterion is the full species richness, the reduced species lists merely acts as a link between the quality status and species richness. If we accept that a rich shore has between 60 and 100 species then we should be able to select a smaller species number, more or less universally present on such shores, which would be in proportion to the full richness. Such a reduced list could be selected to be those species that might be reasonably identified unambiguously by biologists in the agencies that were not seaweed experts.

5.2. Development of Database

An extensive database was developed to ascertain ranges of species richness, incorporating a variety of sites from around the UK and Republic of Ireland and consisting of species records from a number of known sources. Some were published in the scientific literature; some as industrial contract reports or PhD, MSc and BSc theses, but all were restricted to set criteria:

- Intertidal surveys only
- Single occasion sampling
- Expert taxonomy
- Summer month sampling
- Similar sampling effort
- No known anthropogenic influence

These criteria were imposed in order to provide broadly consistent records so comparisons between lists from various locations and times could be made. Many publications in the scientific literature obtain the maximum possible species list for a shore by amalgamating records collected over several seasons or years and may also collate recordings from different collectors at widely different dates. This leads to the majority of published lists being incomparable as they result in a cumulative taxa list; therefore, only surveys carried out on a single sampling occasion were included. Most single occasion lists compiled by environmental consultants are restricted to the common, easily identifiable species, whereas comprehensive lists compiled by authoritative workers of known taxonomic expertise were required. A similar degree of sampling effort for each survey was also required, incorporating time spent on the shore, area surveyed and the number of samplers involved in the survey. Surveys must also have been undertaken in summer months to standardise lists for seasonal species richness. Sublittoral records were omitted, as this is a different environment from the littoral. Shores that were considered to be subject to anthropogenic influences were also rejected. Other records omitted included those shores described as harbours, estuaries, saltmarshes and inner sea lochs as these would be expected to support a smaller number of species. Meeting these requirements limited the number of published lists that could be used. Species were recorded as present or absent since few sources gave abundance data. Several sources of species records met the inclusion criteria particularly well, as described in the following sections.

Northern Ireland Littoral Survey

This survey was carried out by Heriot-Watt University, Edinburgh for the Department of the Environment (Northern Ireland) to enable classification of the different types of littoral communities found around the coastline of Northern Ireland in order to appraise the conservation value of the intertidal region (Wilkinson *et al*., 1988). It was carried out between 1984 and 1988 and encompassed total seaweed presence and semi-quantitative abundance data from transects on 128 rocky seashores. This was accompanied by equally detailed information on the animal communities present and the physical nature of the environment. It is particularly useful in this respect as it allowed abundance and other abiotic factors to be taken into consideration. These Northern Irish results were supplemented by shore species records supplied by the Northern Irish Environment and Heritage Service (2002-2003), previously unrecorded shores and repeat surveys of shores from the Northern Ireland Littoral Survey (pers. comm. Dr. Emma Wells).

British Phycological Society Field Meetings

Members of the British Phycological Society (BPS) undertook surveys during field meetings, predominantly between 1969 and 1978. These field meetings covered a diverse range of coastal sites around the UK with broadly consistent sampling effort and level of taxonomic expertise. This provides truly comparable data and gives a fair representation of the level of seaweed species richness at that time, with site selection within the areas being biased in favour of shores un-impacted by anthropogenic influences.

Channel Tunnel Environmental Impact Assessment

The Institute of Offshore Engineering (IOE) of Heriot-Watt University carried out this survey for the Channel Tunnel Group. It was an Environmental Impact Assessment (EIA) on the effect of spoil disposal on two seashores near Dover, Kent, after the construction of twin railway tunnels (IOE, 1985). Subsequent monitoring during construction of the channel tunnel included full species lists and quantitative abundance of common species on fixed transects.

University Theses

Under the supervision of Dr. Martin Wilkinson many Heriot-Watt University undergraduates and postgraduates have provided useful species records to good levels of taxonomic quality. This is particularly the case with a Ph.D. thesis looking at seaweed biodiversity on intertidal rocky seashores (Wells, 2002). This thesis provides extensive species lists for surveys of shores in Kent, furthering IOE work, and shores around the Orkney Isles. Several M.Sc. and B.Sc. dissertations were also used.

Other Literature Sources

Firth of Forth unpublished records of Dr. M. Wilkinson and Mr. I. Tittley (Natural History Museum, London) collected in the 1980s have been included (Wilkinson, unpublished) as have several other sources ranging from published scientific literature to ‘grey’ literature such as consultancy reports by the Natural History Museum (NHM) for English Nature and Anglian Water, which were particularly useful.

The UK and RoI now has a large benthic marine algal database on which the original metric system was based and from which boundaries were derived. This dataset is held as an Excel file within the Environment Agency and SEPA. There was no national monitoring programme for macroalgae within the UK prior to the commencement of the WFD so the initial database consisted of records from known data sources and grey literature. Several sites have been studied within the last few years as a consequence of the WFD for both the Intercalibration process, as subsequent sampling under the requirements of the WFD programme, and as a part of the requirement to obtain additional data for a variety of different quality sites covering the full extent of the UK. Data from the RoI using different methodologies has also been included in this database.

5.3. Development of Tool

In order to develop such a monitoring tool, species records and site details held within the database were used in conjunction with expert opinion, within the MPTT, to extract the following information:

1. What are the effects of geographical location on the levels of species richness and overall composition? If there are regional variations, should there be a separate RSL for each of these regions (or member states)?
2. How many species should be used to compile a reduced species list to adequately represent community richness?
3. What is the level of taxonomic resolution deemed to be acceptable for the identification of those species in the RSL? Some species are relatively easy to identify taxonomically such as the fucoids, whereas within other genera such as *Ulothrix* and *Enteromorpha* the taxa are less morphologically distinct and therefore require a higher taxonomic competency.
4. What are the effects of environmental variables on the levels of species richness and overall composition, and how will this affect the final RSL and levels of species richness?
5. What is the general composition of algae to be found on shores of high quality?
6. How and where will the limits be set for high, good, moderate and poor quality, and how will the ecological quality classes from full species richness translate into numbers in the reduced species list?

5.3.1. Geographic Variation

Marine algae, like other organisms, show geographical distributions, whereby transitions are recognised by the changes in composition of the coastal flora and fauna and surface seawater isotherms. Water temperature was thought to be the main factor governing the geographical distribution of species (Lüning, 1990). However, Prescott (1969) suggested that the north-south distribution patterns are determined by temperature, and east-west distributions are related to a greater number of factors such as water currents and ancient inter-ocean connections. Often restrictions on algal growth are due to high or low survival limitations including lethal limits set by the tolerance of the hardiest life-history stage, reproductive limits and growth limits (Lüning, 1990; Lobban & Harrison, 1994).

It was suggested by Maggs (1986) that many species consist of geographical ecotypes with regards to environmental responses. In any one site the algal composition represents a complex mixture of species in different parts of their geographical ranges, regarded in the British Isles as northern, southern and widespread species (Maggs, 1986).

As a consequence the variable species composition of different areas around the British Isles should be incorporated into the establishment of a reduced species list in order to account for these geographical variations. It is likely that many of the species will be common to most areas, but it is also anticipated that some species may be more frequently recorded on southern or northern shores as a consequence of their distribution limits.

The coastline was broadly split into 10 different geographic areas based on the sites for which species records were present within the database (Table 1). An analysis of similarity (ANOSIM) was calculated to determine the level of similarity or dissimilarity between the sample groups. ANOSIM calculates a sample statistic R of between 0 and 1, where R=1 represents a strong difference between groups.

Table 1: Number of sampled shores held within the database for each of the geographical areas.

Region	No. of shores sampled
Northern Ireland	177
Republic of Ireland	16
West Scotland	37
Orkney	44
Shetland	18
East Scotland	62
Northern England	26
Southern England	59
Wales	17

The greatest degree of significant difference was found between Northern Ireland and all other areas with $R>0.5$ for all comparisons. Although there was a greater affinity between some areas than others, the rest of the results appeared relatively inconclusive (Figure 2). Data from Northern Ireland were subsequently removed from the analysis and a second ANOSIM calculation was run. The results of the second test showed some significant similarities between Wales and southern England and Republic of Ireland. The northern areas of Scotland, Shetland, Orkney and Northern

England also showed a similar affinity towards each other. These areas have been plotted on a multi dimensional scaling diagram (Figure 3). The northern regions appear to clump together, however the southern regions show a broad degree of scatter. Some of these more dispersed sites are located on the Island of Lundy, off the coast of Southern Wales where slightly more unusual species have been recorded. With few site records for such a large geographic area it is difficult to establish any significant boundaries for the southern half of England, Wales and the Republic of Ireland.

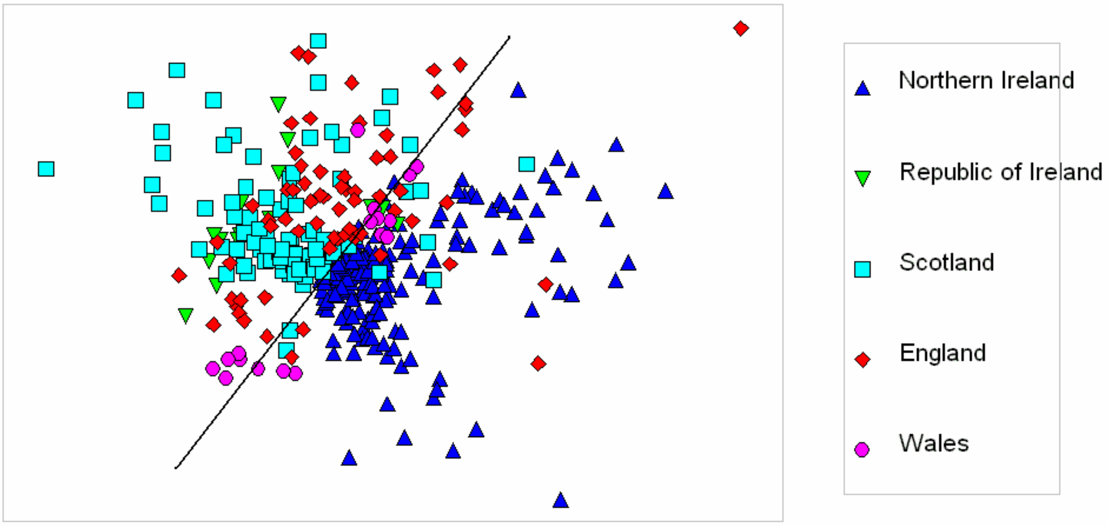

Figure 2: MDS plot showing the similarities in species composition and richness between countries in the UK and RoI.

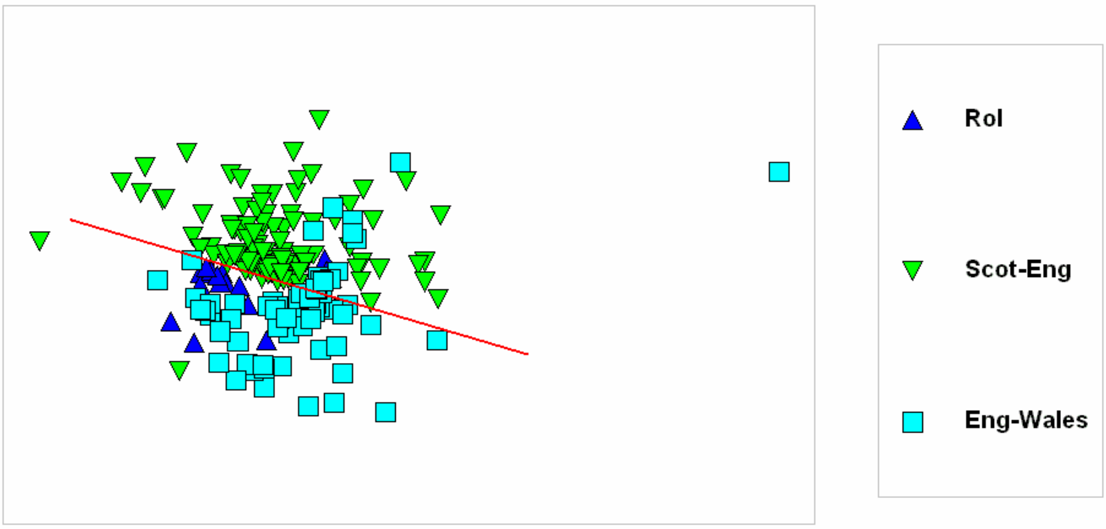

Figure 3: Multidimensional scaling showing the similarities in species composition and richness between England, RoI, Scotland and Wales only with a 2d minimum stress of 0.19.

Consequently the British Isles has been broadly segregated into three main areas (Figure 4) based on the geographic distribution of site records and the results these have produced. The exact boundary between northern and southern England has been partly driven by the physical nature of the dividing areas. The Wash, north Norfolk, Merseyside and Lancashire are primarily sedimentary areas with little or no algal growth and therefore provide a natural break in the rocky shore coastline. It is likely that with time and increased data the boundaries of these three geographic areas may shift, but these are the current geographic boundaries used for the compilation of the three reduced species lists.

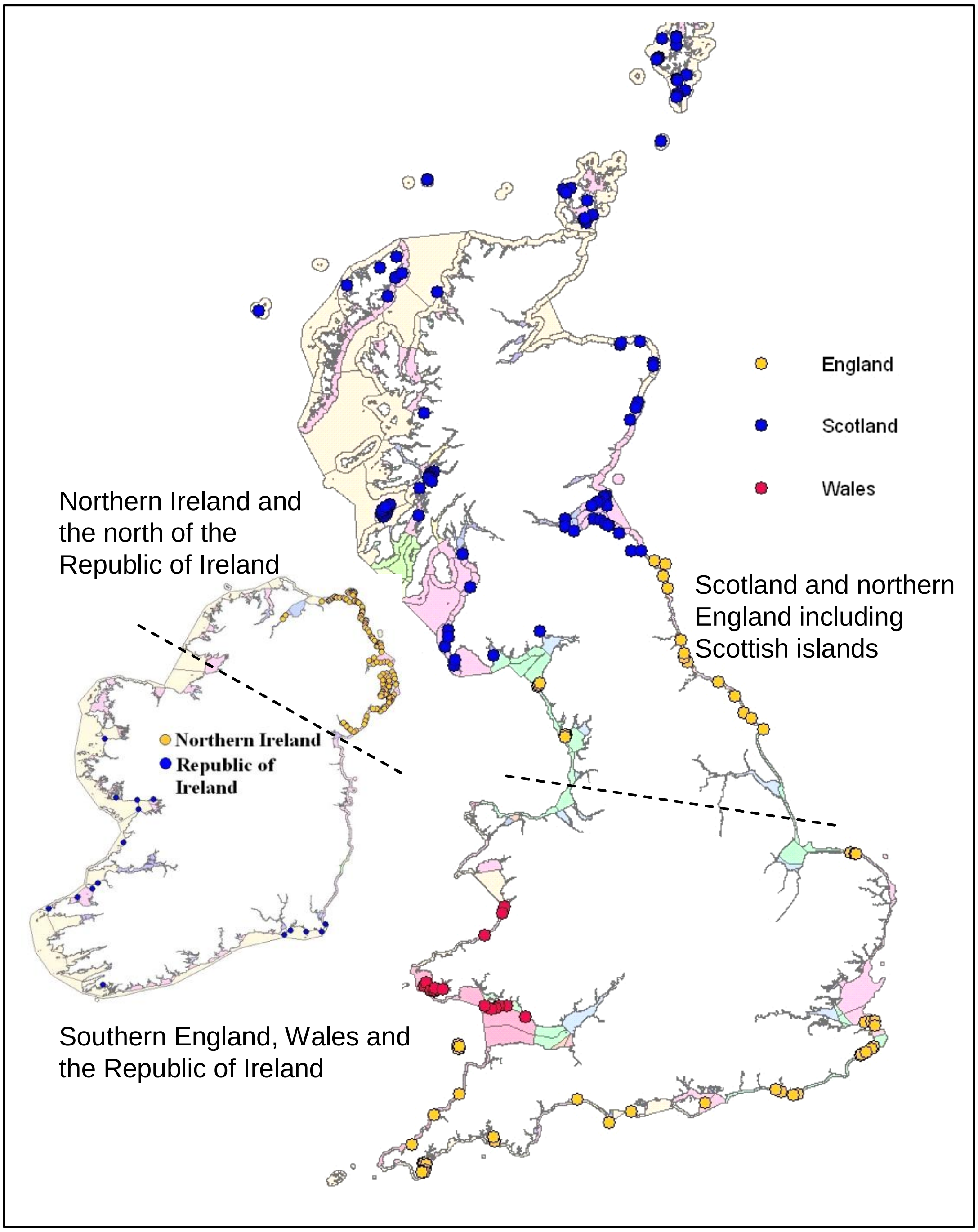

Figure 4: Map of the UK and Republic of Ireland indicating the boundaries used for the compilation of the three reduced species lists whereby spots represent those sites for which species records are available and have been used in the algal database for establishing such geographic boundaries.

5.3.2. Reduced Species List

Unfortunately, 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 qualitative species data is the implementation of a reduced species list (RSL) whereby the number of species from the RSL is in proportion 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, and this would act as a surrogate to the production of 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.

After compilation of the database, members of the UK Marine Plants Task Team tentatively assigned each site a level of quality, between poor and good, based on expert knowledge of each of the sites. Only the species records from those sites deemed as ‘high quality’ were used when extracting reduced species lists. This decision was taken as the final reduced species lists should ideally be representative of high quality shores with which other shores will be compared and therefore act as a reference condition.

The species lists were compiled by selecting those species which occurred most frequently throughout the range of shore types on high quality shores. The minimum frequency of occurrence of each species depended on the total number of sites available for analysis. There are approximately 885 species of seaweed recorded in the algal database based on the Marine Conservation Society checklist compiled by Guiry (1997), although some of these species may currently only have records for northern France, so the UK total is actually lower than 885. This tools aims to reduce the number of species required for identification to approximately 70 algal species. The frequency of the top 70 species varied according to the geographic area. For Northern Ireland species that occurred on >55 high quality shores out of a possible 142 were included, for Scotland and Northern England the frequency was a minimum of 36 out of 86 and for southern England, Wales and the Republic of Ireland species occurring on >17 out of 55 were included.

It was further decided that a number of species would be difficult to identify to species level or locate on the shore, even for many trained algal taxonomists. Therefore, for a select few species, identification has been limited to the level of genus only, although microscopic identification would still be required. These genera include *Blidingia, Enteromorpha, Ulothrix, Ectocarpus, Ralfsia, Gelidium, Audouinella*, *Ceramium except for C. nodulosum and C. shuttleworthianum and Polysiphonia* species except for *P. lanosa* and *P. fucoides,* as it was thought that these species of *Polysiphonia* and *Ceramium* would be comparatively easy to distinguish and are also common. Calcareous encrusting red algae were aggregated to the level only of “calcareous encrusters”. The final species to be used within the three reduced species lists are tabulated below (Table 2). *Note: The genus name* Enteromorpha *has been retained for practical purposes, rather than* Ulva*, as recommended by Hayden et al (2003). It has a different morphology, and is also recognised as a separate taxon for the purposes of the WFD macroalgal blooming tool.*

Table 2: 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**	**England / Wales**	**Northern Ireland**
Alaria esculenta	Phaeophyta		1	*		*
Ascophyllum nodosum	Phaeophyta		1	*	*	*
Asperococcus fistulosus	Phaeophyta		1	*		*
Chorda filum	Phaeophyta		1	*	*	
Chordaria flagelliformis	Phaeophyta		2	*		
Cladostephus spongious	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	*	*	
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 mediterranea	Chlorophyta	*	2		*	*
Chaetomorpha melagonium	Chlorophyta		2	*	*	
Cladophora albida	Chlorophyta		2			*
Cladophora rupestris	Chlorophyta		2	*	*	*
Cladophora sericea	Chlorophyta		2	*	*	*
Enteromorpha sp.	Chlorophyta	*	2	*	*	*
Monostroma grevillei	Chlorophyta		2			*
Rhizoclonium tortuosum	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	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	*	*	*

5.3.3. Natural Environmental Variables

The ability to produce a single reduced species list with which to represent and categorise all shores around the British Isles is a rather optimistic approach as there are likely to be several geographical and environmental variables that will interfere with this proposal. There is also a need to acknowledge the various typologies established for the purpose of the WFD and how to account for these including reference conditions for each typology. Therefore, the initial approach used in establishing the reduced species list was to analyse the effects of certain environmental factors, specifically those used to categorize the typologies. The NILS (Wilkinson *et al,* 1988) provided the best information for a large area of coastline from which to assess the effects of exposure, shore type, and habitat type/number on the overall species composition of a shore. These data included not only biologically rich sites, but also ‘typical’ and ‘poor’ sites as well as representing a full range of physical habitat types and their associated biological communities. In addition geographic location and the effects of latitude were analysed using the benthic algal species database.

A recent study of the effects of environmental variables (Wells & Wilkinson, 2002) showed certain factors contributed more significantly than others to the overall species richness and species composition. The conclusions drawn from this study helped to contribute to the development of the tool by enabling the MPTT to establish those factors that need to be considered in the compilation of the RSL and whether a single list would suffice for the whole of the British Isles and Republic of Ireland and cover all typologies.

Exposure is known to affect the distribution of intertidal algal species. Sheltered shores tend to be characterised by a dense covering of fucoids, moderately exposed shores exhibit a less abundant but mosaic distribution of fauna and flora and exposed shores are characterised by their limited algal abundance and wide lichen zone on the upper littoral. However despite exposure appearing to contribute to the abundance and zonation patterns of algae in the intertidal there is no significant impact on the levels of species richness. Exposed shores did result in slightly lower average species richness (but not significantly different to shores of other exposure ratings); this may well be due to their limited abundance making them harder to locate. There was also little difference in species composition between shores of varying exposure level, therefore it was concluded that exposure is likely to have very little impact on the final RSL(s).

The physical type of shore is broadly described by the most dominant substrate type or structure present such as rock platforms, outcrops, boulders and pebbles; this is referred to as the dominant shore type. This has been shown to contribute significantly to the levels of species richness with certain substrates more habitable due to their stability and attachment properties. Statistical comparisons were made of average species richness between different shore types using one way analysis of variance with Tukey’s test (with family error rate of 5%). The results indicated rock ridges, outcrops and platforms have significantly higher species richness than shores consisting predominantly of boulders, pebbles and vertical rock. This is probably due to the levels of stability offered by large fixed areas of hard substrate compared with pebbles and boulders, which are less stable and unable to support climax communities as effectively. Therefore the following shore types are listed in descending order of their contribution to the level of species richness:

Rock ridges/outcrops/platforms > Irregular rock and boulders > steep/vertical rock > pebbles, stones and small rocks > shingle and gravel.

Subhabitat type and number have a similar effect to shore type with statistical analysis indicating the presence of particular subhabitat types resulting in higher levels of species richness. Large, wide rock pools provide very favourable habitats by limiting the effects of desiccation providing a more tolerable environment than is experienced on open rock. The following subhabitat types are given in descending order of their contribution to the level of species richness:

wide shallow/large/deep rockpools > basic rockpools and crevices > overhangs > caves.

Equally, with increasing number of subhabitat types there is a significant increase in the levels of algal species richness recorded, as higher subhabitat diversity results in higher species diversity. The presence of naturally occurring turbidity and sand scour can also result in reduced numbers of perennial taxa and domination by opportunist annuals such as *Enteromorpha* and *Ulva* (Mathieson *et al*., 1991; Chapman, 1943; Daly & Mathieson, 1977; Sousa, 1979 & 1984), which may similarly be experienced by unstable chalk shores located in the south east of England (Tittley & Price, 1978) and can therefore decrease species richness further. These variables need to be considered when establishing levels of species richness to be expected on shores of varying ecological quality status.

The requirement to encompass the natural variations that occur over the coastline of the British Isles such as shore details has led to the development of a field sampling sheet (Figure 3) and scoring system which then contributes to the overall quality classification. The use of shore descriptions within the development of a rocky intertidal macroalgae tool is to normalise the species richness whereby shores that have high species richness due to favourable environmental conditions can be compared equitably with shores of low species richness due to unfavourable natural conditions. The numbers in the sampling sheet attached to each of the shore types/habitat types are based on how much they contribute to the overall species richness, for example rock ridges/platforms/outcrops has a high value of 4 whereas shingle/gravel only scores 0 because this substratum type does not lend itself to high numbers of algal species. The sampling sheet also leaves space for brief shore descriptions as well as basic details on the site name, times of sampling etc. The dominant biota information does not contribute to the overall scoring system but may be useful in subsequent years to explain any ecological change and may help to identify shifts in the benthic invertebrate community.

The individual scores from the field sampling sheet are subsequently totalled to produce a final score which is later applied to the 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 scoring system.

Table 3: 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			>4	3	2	1	0
Limpets							
Periwinkles							
General Comments							

5.3.4. Species Composition

Species richness provides an excellent tool for using macroalgae communities as a measure of ecological quality; however, this does not incorporate any 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. In order to identify the potential occurrence of correlations between community composition and quality status, members of the Marine Plants Task Team tentatively assigned each site within the marine benthic algal database a level of quality; High, Good, Moderate, Poor or Bad. This was based on expert knowledge of each of the sites irrespective of their species number and considering the proximity and magnitude of direct and indirect pollution sources. This could later be used to establish the quality status boundary levels for each class. Such measures of community structure include the proportions of Rhodophyta and Chlorophyta calculated as the number of species within these divisions as a percentage of the total species richness.

The Rhodophyta constitute a high proportion of small filamentous and delicate species and show an increase in species numbers with increasing environmental quality. The Chlorophyta species, although small and often filamentous, are able to adapt more readily to changes in the environment whereby proportions increase with decreasing quality status. In contrast many Phaeophyta species are large, solid, fleshy and relatively hardy, and are more likely to remain constant. Consequently the changes in proportion of Rhodophyta and Chlorophyta species have been considered to be indicative of anthropogenic influences and shifts in quality status.

Other alternative measures of species composition include the ratio of ecological status groups (ESG's) and proportion of opportunist species. ESG's can be used to indicate shifts in the ecosystem from a pristine state (ESG 1 – late successionals or perennials) to a degraded state (ESG 2 – 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) (Table 4).

The opportunist species include *Blidingia spp., Chaetomorpha linum, Chaetomorpha mediterranea, Enteromorpha spp., Ulva lactuca, Ectocarpus spp., Pilayella littoralis, Porphyra spp.* Nuisance blooms of particularly rapidly growing macroalgae can have deleterious effects on intertidal communities (Soulsby *et al*., 1982; Tubbs & Tubbs, 1983; den Hartog, 1994) whereby excessive biomass would be considered as moderate, poor or bad quality status (Wilkinson & Wood, 2003), albeit primarily on sedimentary shores.

Table 4: Descriptions of the different functional groups used in placing species into the two ecological status groups indicating functional groups as modified by Wells (2002) from Littler *et al.* (1983).

	Functional groups
ESG 1	Late successionals or perennials including: • Coarsely branched and highly corticated forms • Thick, leathery and corticated forms • Jointed calcareous forms • Crustose forms including those microscopic forms found epiphytically or endophytically
ESG 2	Opportunists or annuals including: • Unicellular and epiphytic, endophytic, epizoic and endozoic microscopic forms • Foliose, thin, membranous and sheet-like forms • Uniseriate filamentous forms • Multiseriate and/or corticated filamentous forms

5.4. Establishing Class Boundaries

Each of the species richness and composition attributes was compared with the subjective quality status to ensure they followed the expected trends. Species richness and the proportion of opportunists and Rhodophyta show a distinct trend with subjective increases in quality status, however, the proportion of Chlorophyta and the ESG ratio are less defined with less distinct boundaries between the good and moderate status classes. This is the most significant boundary as this distinguishes between an acceptable and unacceptable level of quality requiring mitigation according to the WFD. Further statistical analyses were run on the results to establish a level of significant difference between quality status groups.

All datasets were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene's test) to see if a one-way Analysis of Variance (ANOVA) could be used. All datasets failed at least one of these tests so a non-parametric equivalent Kruskal-Wallis test was used, whereby there is a statistically significant difference (P = <0.001) when the differences in the median values among the treatment groups are greater than would be expected by chance.

Each of the species parameters showed a significant difference between groups with p=<0.001. High and poor quality status contributed most to this significant difference, with the moderate class showing less difference with the other groups. The less distinguishable boundary around the moderate quality class may be attributed in part to the low number of shores represented within this class and the high level of variability within each group, indicated by the levels of standard deviation. Further data would be required to clarify some of these trends and refine the boundaries.

From these predicted levels of ecological quality, boundary levels were established for the levels of species richness to be expected. The same was achieved for the proportions of Chlorophyta, Rhodophyta, the ratio of ESGs and the proportion of opportunist species. Each of the parameters has a range of values which equates to a quality status of High, Good, Moderate, Poor and Bad. The final metric system works by establishing the ranges for each parameter and finding its associated quality status score. These individual scores are averaged to produce a final score of ecological quality status.

The boundary values were based solely on the predicted quality status values and by matching these up with the overall scoring system; no statistical methods were used as the results were far too variable.

5.5. Metric System

5.5.1. Full Species Richness Metric

The metric system is based on the five main parameters of the tools;

Species Richness (Total number of taxa – N_t); This is normalised to shore diversity acting as a correction for the level of species richness.

Using data from reference or near reference sites a graph was plotted to show the level of correlation between species richness and shore description (Figure 5) displaying a non-linear relationship between the two variables. This relationship can be 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. This can be seen in Table 5. 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’. An example is given below:

Site X in the North-east of England has a shore description of 10 and a species richness of 51. The expected level of species richness for this shore description is 40.73 with a de-shoring factor of 1.50 (see Table 5). Therefore the final value for species richness is:

RICHNESS = 51 x 1.50 = **76.50**

This is the final value to be input to the metric system.

Table 5: Calculation of normalisation for all possible shore description values based on the predicted levels of species richness for the 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	47.71	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

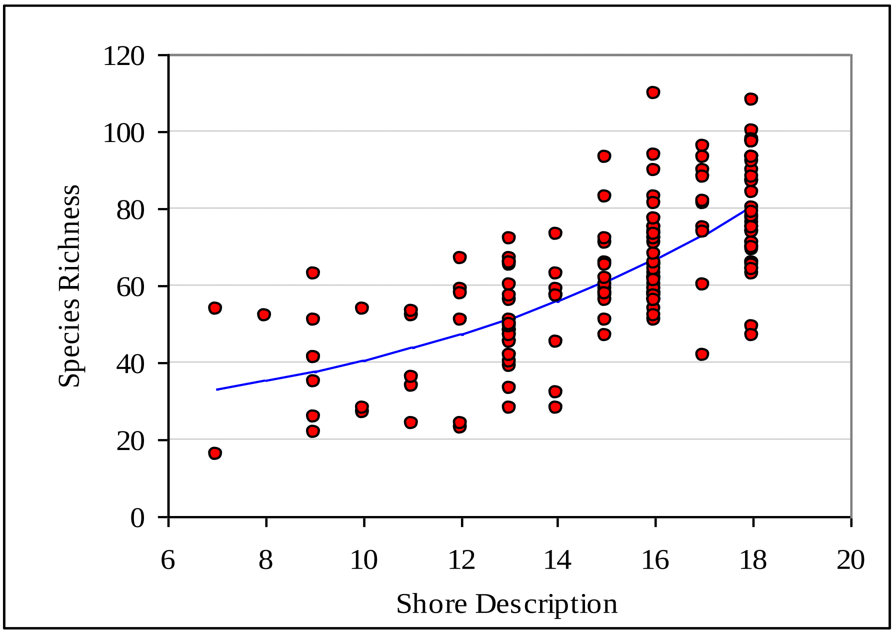

Figure 5: Exponential model for the relationship between shore description and species richness for the Full Species List

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:

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

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:

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

For each of the described parameters the ecological quality status range for classes bad, poor, moderate, good and high was calculated using the following metrics (Table 6). These levels were based broadly on the midpoint between the upper and lower points of error bars from adjacent quality classes.

Table 6: Macroalgae species richness and composition index scoring system and final classification boundaries For the Full Species List

Quality	High	Good	Moderate	Poor	Bad
Subscore	**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
Proportion of Chlorophyta	≤ 25 (-0)	25-30	30-40	40-60	60-100
Proportion of Rhodophyta	≥ 47 (-100)	42-47	32-42	15-32	0-15
ESG Ratio	≥ 0.65 (-1.0)	0.5 – 0.65	0.35 – 0.5	0.1 – 0.35	0-0.1
Proportion of opportunists	≤ 15 (-0)	15-22	22-35	35-45	45-100

The final metric system works on a sliding scale to enable an accurate EQR value to be calculated for each of the different parameters, an average of these values is then used to establish the final classification status. For the calculation of the sub-score for each of the parameters this requires two variations of a basic equation.

For **Species Richness**, **Proportion of Rhodophyta** species and the **Ratio of ESG's**, all of which increase in value with increasing EQR, use the following equation:

$$\textbf{EQR} = \left\{ \left(\frac{\textbf{Value – Lower class range}}{\textbf{Class width}} \right) \textbf{x EQR band width} \right\} \textbf{+ Lower EQR band range}$$

Example using a value for species richness: **34** – this lies between 20 and 35 and with an EQR between 0.4-0.6) therefore:

Score = {(34 – 20)/15 x 0.2} + 0.4

Score = 0.187 + 0.4 = **0.587**

For the **Proportion of Chlorophyta** and **Proportion of Opportunist** species both of which decrease in value with increasing EQR, use the following equation:

$$\textbf{EQR = Upper EQR Band range -} \left\{ \left(\frac{\textbf{Value – Lower class range}}{\textbf{Class width}} \right) \textbf{x EQR band width} \right\}$$

Example using a value for the proportion of greens: **29.4** – this lies between 25 and 30 and with an EQR between 0.6-0.8)

Score = 0.8 - {(29.4 – 25)/5 x 0.2}

Score = 0.8 – 0.176 = **0.624**

5.5.2. *Reduced Species Richness Metric*

As with the use of a full species list five parameters were also used, for which ecological quality status boundaries were devised. To establish the quality boundaries for each of the parameters the reduced species lists were applied to all the records within the database including those sites considered to be of good, moderate and poor quality. Quality status boundaries were then established using the same method as with the full species list i.e. the midpoint between upper and lower error bars on adjacent quality classes.

The boundary values were based solely on the predicted quality status values and by matching these up with the overall scoring system; no statistical methods were used as the results were far too variable. Unfortunately there have been no shores surveyed within Northern Ireland that were thought to be of poor quality so the moderate/poor boundary value for this area would need to be refined once further data have been collected. The boundary values vary between the different areas but this is mainly as a result of the difference in reduced species lists between areas. Tables 7, 8 and 9 show the classification scoring system for each of the geographic areas.

Table 7: Boundary values for the five parameters for Scotland/Northern England

	Score				
EQR	≥0.8 – 1.0	≥0.6– <0.8	≥0.4 – <0.6	≥0.2 – <0.4	0 – <0.2
	High	Good	Moderate	Poor	Bad
RSL	35-70	25-35	17-25	5-17	0-5
Greens	0-12	12-20	20-30	30-80	80-100
Reds	55-100	45-55	35-45	15-35	0-15
ESG	1.0-1.2	0.8-1.0	0.7-0.8	0.2-0.7	0-0.2
Opportunist	0-10	10-15	15-25	25-50	50-100

Table 8: Boundary values for the five parameters for England/Wales/RoI

	Score				
EQR	≥0.8 – 1.0	≥0.6– <0.8	≥0.4 – <0.6	≥0.2 – <0.4	0 – <0.2
	High	Good	Moderate	Poor	Bad
RSL	35-69	25-35	15-25	5-15	0-5
Greens	0-15	15-20	20-25	25-80	80-100
Reds	55-100	45-55	40-45	15-40	0-15
ESG	1.0-1.2	0.80-1.0	0.55-0.8	0.2-0.55	0-0.2
Opportunist	0-10	10-15	15-25	25-50	50-100

Table 9: Boundary values for the five parameters for Northern Ireland

	Score				
	≥0.8 – 1.0	≥0.6– <0.8	≥0.4 – <0.6	≥0.2 – <0.4	0 – <0.2
	High	Good	Moderate	Poor	Bad
RSL	34-68	20-34	10-20	3-10	0-3
Green	0-20	20-30	30-45	45-80	80-100
Red	45-100	35-45	25-35	10-25	0-10
ESG	0.80-1.2	0.6-0.80	0.40-0.6	0.2-0.40	0-0.2
Opportunist	0-15	15-25	25-35	35-50	50-100

A de-shoring factor has also been calculated for the reduced species lists and was achieved in the same way as for the full species list. The parameters for a, b and c are estimated to be:

a = 14.210 b = 4.925 c = 0.108

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 'de-shoring factor' has been produced. This can be seen in Table 10 with the exponential model displayed in Figure 6. 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'.

Table 10: Calculation of the 'de-shoring' 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

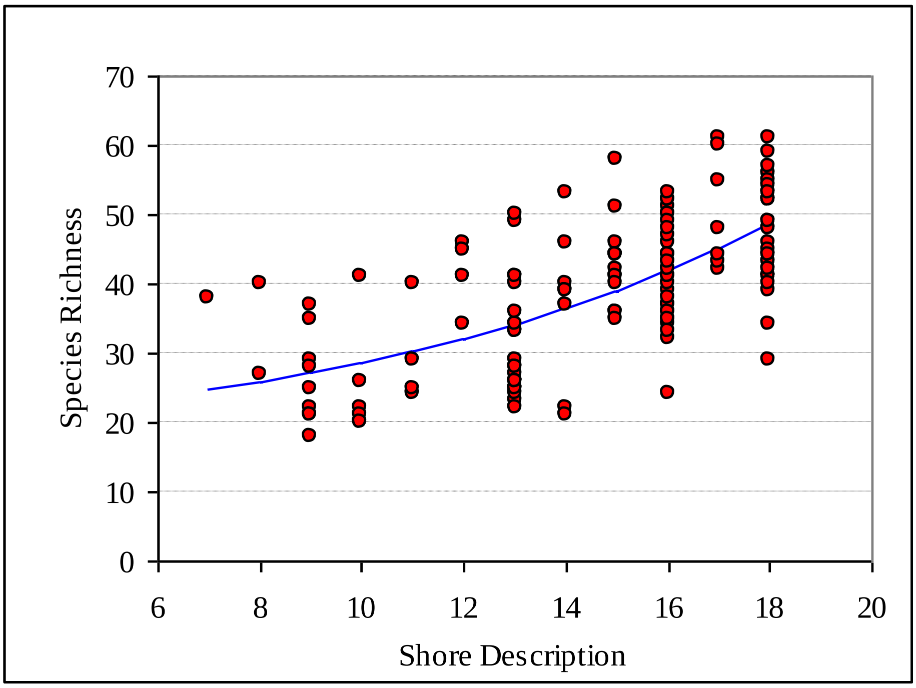

Figure 6: Exponential model for the relationship between shore description and species richness using a reduced species list

The final metric system also works on the same sliding scale, as with the full species list, to enable an accurate EQR value to be calculated for each of the different parameters: an average of these values is then used to establish the final classification status. For the calculation of the EQR value for each of the parameters this requires two slightly different calculations.

For **Species Richness**, **Proportion of Rhodophyta** species and the **Ratio of ESG's**, all of which increase in value with increasing EQR, use the following equation:

$$\textbf{EQR} = \left\{ \left[\frac{\textbf{Value – Lower class range}}{\textbf{Class width}} \right] \textbf{x EQR band width} \right\} \textbf{+ Lower EQR band range}$$

For the **Proportion of Chlorophyta** and **Proportion of Opportunist species,** both of which decrease in value with increasing EQR, use the following equation:

$$\textbf{EQR = Upper EQR Band range -} \left\{ \left[\frac{\textbf{Value – Lower class range}}{\textbf{Class width}} \right] \textbf{x EQR band width} \right\}$$

5.5.3. Summary of the Classification Process

The full classification process can be more clearly understood following the flow chart below (Fig.7).

Work Area	*Considerations*
Monitoring Design	• Is rocky shore macroalgae an appropriate assessment to use? • Determine which region shore is in to obtain correct RSL list if using RSL • Determine appropriate number of sites within waterbody
Sample collection	• Select appropriate shore type for survey • Define shore extent • Determine shore score • Record/collect as many taxa as possible
Sample analysis	• Quality assurance procedures – ensure these are in place • Record as many taxa as practical in the field, but identify others in the laboratory as appropriate • Log data
Calculation: Face value	• Calculate initial species richness • Calculate "normalised" species richness • Calculate: ○ Percentage of Chlorophyta taxa ○ Percentage of Rhodophyta taxa ○ Percentage of opportunist taxa ○ Ecological status group ratio
EQR calculation	• Normalise and rescale values to equidistant 0-1 range • Use correct table for geographic area to obtain correct class boundaries (see Tables 6 to 10) *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	• Calculate each site EQR • Derive WB EQR by averaging site EQRs • Assign Class Status (use defined class boundaries)

Fig. 7. Flow chart summarising the main stages of an assessment of macroalgae on rocky shores

5.6. Application of the Rocky Shore Macroalgae Tool

The rocky shore macroalgae tool has been designed primarily for use in open coastal water bodies. It may be applied to the outer reaches of transitional water bodies where hard substrate is present and salinity is not markedly reduced, but care should be taken in interpreting results. The natural decrease of species diversity from the mouth to the head of a transitional water along with the decreased presence of natural rocky substrate is likely to result in a low ecological quality ratio and status when compared with the open coast. Therefore it is recommended that where possible an alternative biological tool be used such as monitoring the extent of fucoid growth (Wilkinson *et al*, 2007) or the presence of macroalgae blooms (Scanlan *et al*, 2007; Wells *et al.,* 2010), depending on the pressure present in the transitional waterbody.

This tool is also only applicable where the natural substratum consists primarily of solid bedrock, such as rocky outcrops, ridges and platforms or extensive areas of large boulders. Cobble, shingle 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 yield a high diversity of algae and may misclassify the water body.

It is suggested that a minimum of 3 shores should be sampled within any water body (depending on waterbody size), and that each individual shore should ideally be sampled a total of 3 times during the first 6 year reporting cycle in order to gain some idea of natural variation. It is recommended that on at least one occasion in the six year cycle a full comprehensive species list be compiled. The reduced species lists act as a surrogate to the full species list, which achieves a higher level in the confidence of classification. The reduced species lists enable a more rapid survey to be completed. Where classification status using the reduced species list lies on or near a status class boundary, or does not achieve a good or high status, it is recommended that ideally a full species list be compiled to validate the classification and ensure correct classification is obtained. A full species list would always be the more desirable method as it will account more accurately for natural variation and natural turnover of species, but may not always be possible.

Sampling should commence no earlier than late April and be extended no later than early October. Consideration should be given to possible effects of severe winter/spring weather on the start of the growth season. There is an annual turnover of species diversity and richness with the winter months exhibiting a much lower algal richness; therefore it is essential that sampling be achieved at the time of maximum species richness. It is possible for natural blooms of opportunists to occur on the rocky shore, i.e. not as a result of anthropogenic influences. These are not to be considered as detrimental to the natural environment, especially if recorded during late spring when it is common for small algal blooms to occur. Naturally high levels of algal coverage do not tend to result in a decrease of species richness. Algal coverage exhibits high levels of variability both throughout the year and between years. If a slight bloom of an opportunist such as *Ulva, Enteromorpha, Ectocarpus* or

Pylaiella has been recorded it would be advisable to revisit the site at a later date when the bloom will have had a chance to dissipate. If there is still cause for concern, a full species list should be compiled to ascertain whether the coverage is affecting the levels of species richness.

Where a water body is known to have localised anthropogenic influences, the area of concern should be sampled to enable the impacts to be assessed. However, in this instance it may also be necessary to sample more sites; if the impact is very localised this may have too much weighting on the overall classification of the water body. A small source of anthropogenic disturbance may be having minimal impact on the wider surrounding environment.

The major issue concerned with monitoring species richness is the level of taxonomic expertise and field survey ability required. This has been tackled in part by the use of the reduced species lists, but there is still a requirement for appropriate training and quality assurance. Field survey guides and detailed identification guidance have been produced to assist with this task but these need to be used in conjunction with an appropriate training regime and the maintenance of competence in survey technique and algal identification.

5.7. Worked Example

The tool has been applied to two areas from which macroalgae species lists were collected as part of the development stage of the tool.

5.7.1. Case Study – Milford Haven

Five intertidal rocky shore sites within the water body of Milford Haven were sampled in 2004 for the application of both the full species list tool and the reduced species list tool (Figure 8).

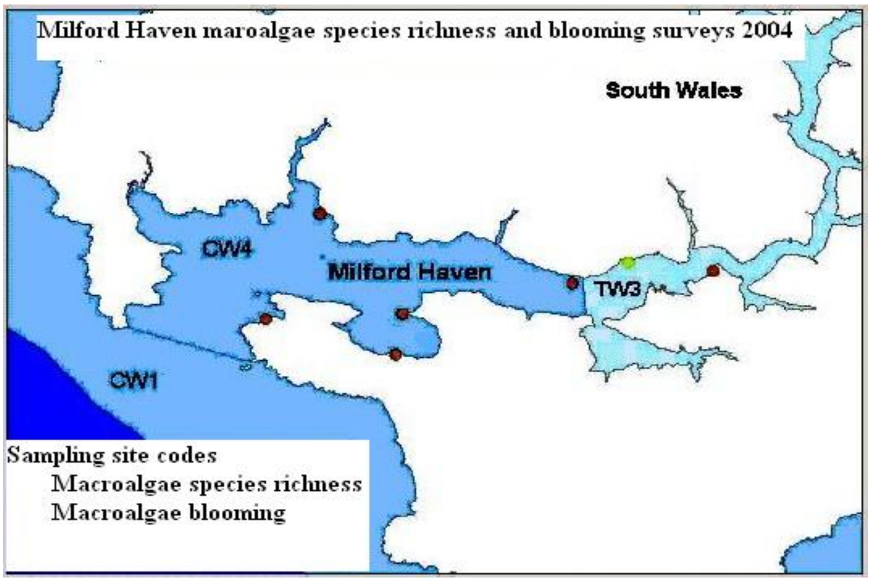

Figure 8: Map of macroalgae sampling locations in Milford Haven

For each of the sites a full species list was recorded from which the reduced species list could also be abstracted. The previously described metric system could then be applied to both the full and reduced species lists, including the appropriate correction factors for species richness. For each of the sites an overall site EQR was calculated; these results are given in Tables 11 and 12.

Table 11: Metric component results for 5 sites within Milford Haven using the full species list

Full Species list														
Site Name	**Shore Description**	**Species richness**	**Corrected SR**	**Value**	**% greens**	**Value**	**% Reds**	**Value**	**ESG**	**Value**	**% Opport**	**Value**	**EQR**	**Quality Class**
West Angle	16	94	84.6	1.00	19.15	0.85	55.32	0.83	0.71	0.83	11.70	0.84	0.87	HIGH
Angle Bay	7	33	79.86	1.00	30.30	0.59	33.33	0.43	0.57	0.70	24.24	0.57	0.66	GOOD
Sawdern Point	9	54	104.76	1.00	20.37	0.84	50.00	0.81	0.64	0.78	12.96	0.83	0.85	HIGH
Fort Hubberston	13	66	81.84	1.00	22.73	0.82	46.97	0.80	0.43	0.51	16.67	0.75	0.78	GOOD
Pembroke Ferry	13	56	69.44	0.92	32.14	0.56	48.21	0.80	0.47	0.56	21.43	0.62	0.69	GOOD

Table 12: Metric component results for 5 sites within Milford Haven using the reduced species list

Reduced species list for Wales														
Site Name	**Shore Description**	**Species richness**	**Corrected SR**	**Value**	**% greens**	**Value**	**% Reds**	**Value**	**ESG**	**Value**	**% Opport**	**Value**	**EQR**	**Quality Class**
West Angle	16	53	49.29	0.88	15.09	0.80	54.72	0.79	1.12	0.92	13.21	0.67	0.81	HIGH
Angle Bay	7	23	35.19	0.80	17.39	0.70	39.13	0.39	0.92	0.72	21.74	0.47	0.62	GOOD
Sawdern Point	9	38	54.72	0.92	13.16	0.82	55.26	0.80	1.00	0.80	13.16	0.67	0.80	HIGH
Fort Hubberston	13	41	46.74	0.87	14.63	0.80	53.66	0.77	0.86	0.66	17.07	0.56	0.73	GOOD
Pembroke Ferry	13	33	37.62	0.82	18.18	0.67	51.52	0.73	1.20	1.00	21.21	0.48	0.74	GOOD

The final EQR value and ecological status class were further calculated using the average of each individual shore within the waterbody. Tables 13 and 14 show the level of variation attached to the EQR values within each of the individual elements for each shore and for each shore within the waterbody. This is achieved for both full and reduced species lists.

Table 13: Final quality status and EQR for Milford Haven including the maximum & minimum EQR values for the individual components, standard deviation and standard error using the Full Species List

Full Species list						
Site Name	**EQR**	**Quality Class**	**Min**	**Max**	**St Dev**	**St Error**
West Angle	0.87	HIGH	0.83	1.00	0.072	0.032
Angle Bay	0.66	GOOD	0.43	1.00	0.214	0.096
Sawdern Point	0.85	HIGH	0.78	1.00	0.086	0.038
Fort Hubberston	0.78	GOOD	0.51	1.00	0.175	0.078
Pembroke Ferry	0.69	GOOD	0.56	0.92	0.160	0.072
Average	0.77	GOOD			**0.141**	**0.063**

Table 14: Final quality status and EQR for Milford Haven including the maximum & minimum EQR values for the individual components, standard deviation and standard error using the Reduced Species List

Reduced species list						
Site Name	**EQR**	**Quality Class**	**Min**	**Max**	**St Dev**	**St Error**
West Angle	0.81	HIGH	0.67	0.88	0.096	0.043
Angle Bay	0.62	GOOD	0.39	0.80	0.177	0.079
Sawdern Point	0.80	HIGH	0.67	0.92	0.087	0.039
Fort Hubberston	0.73	GOOD	0.56	0.87	0.123	0.055
Pembroke Ferry	0.74	GOOD	0.48	1.00	0.192	0.086
Average	0.74	GOOD			**0.135**	**0.060**

The final classification for the water body of Milford Haven is based on the assumption that for this individual metric the final EQR is an average of the EQR for each site. The average EQR for the FSL is 0.77 equating to Good status and with a standard error of 0.066 this results in a range of 0.70 – 0.84. Applying the calculation for confidence of class discussed in Section 7 the standard error is 0.042 with 74.8% confidence that it lies within the Good status class and 99% of the water body being of Good or higher status. The EQR using the reduced species list is slightly lower at 0.74 with a range of 0.68 – 0.8. This range is also still well within the Good class with a confidence of 93.7 of the quality status being Good and 99.3% of it being Good or higher. The high level of consistency between the full and reduced species lists suggests at this stage the reduced species list acts well as a surrogate to the full species list. Although the sites sit well within the good class some individual site classifications are close to the Moderate boundary, and therefore it would be advisable to monitor such areas more closely to ensure classification status does not decline. This is further emphasized by viewing the individual site error bars which shows the range at Angle Bay to cross into Moderate status (Figures 9 and 10). However using the confidence of class this still shows a high confidence of Good classification.

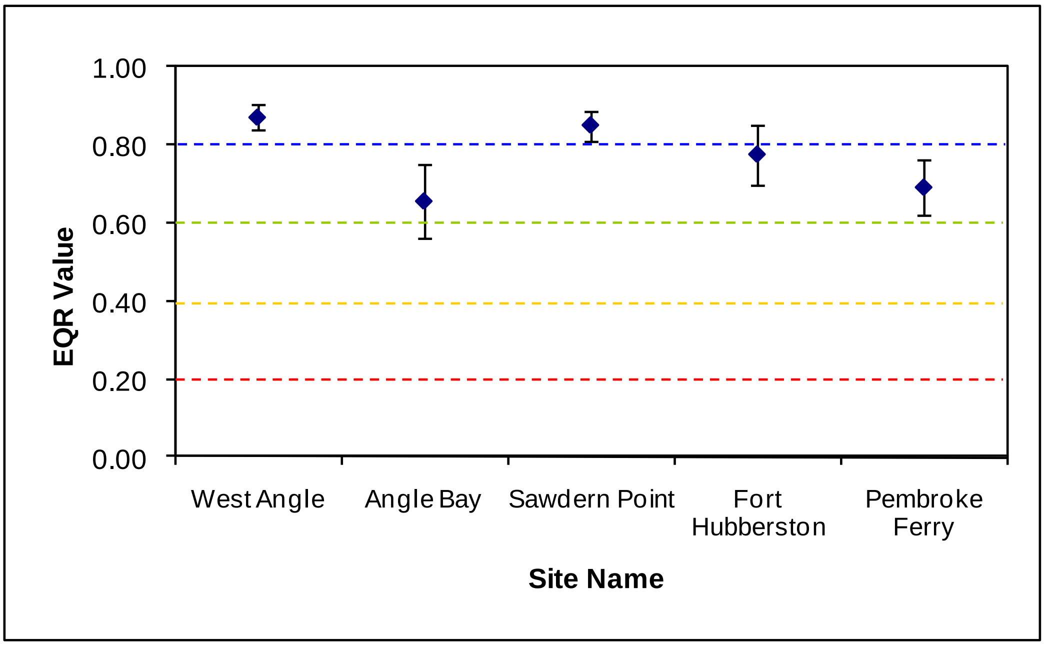

Figure 9: EQR values for the Full Species List for individual sites within Milford Haven with error bars representing the standard error

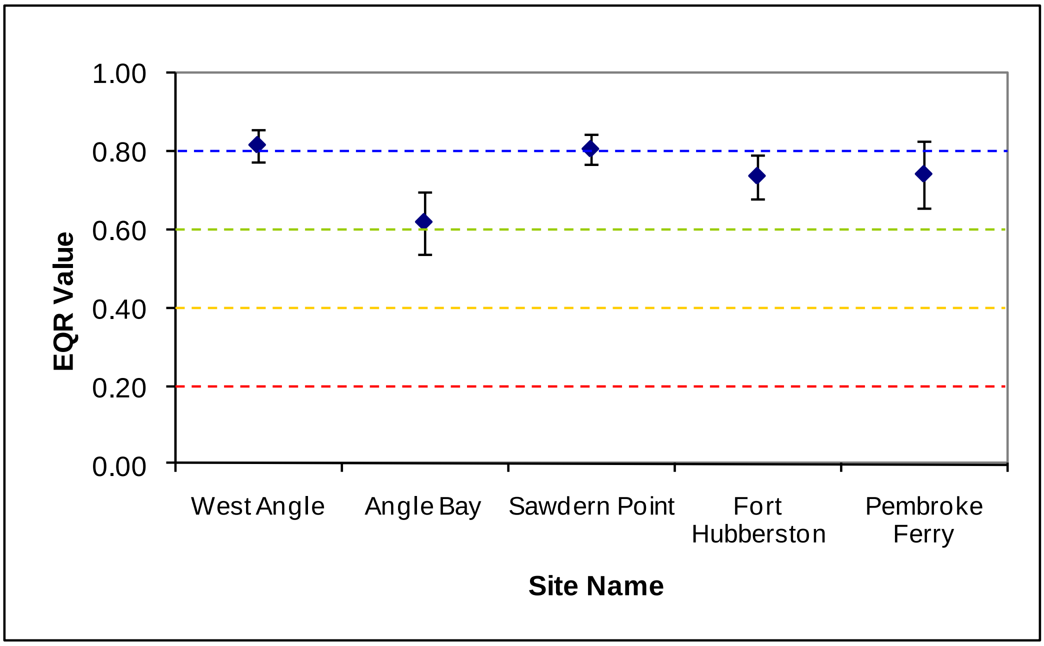

Figure 10: EQR values for the Reduced Species List for individual sites within Milford Haven with error bars representing the standard error

5.7.2. Case Study – Outer Solway South

The Outer Solway South is in contrast to Milford Haven with numerous adversely affected sites on this stretch of coast. This was used as a case study to ensure that the de-shoring factor did not overestimate the quality status of the water body once applied to the species richness. The results are shown in Tables 15 and 16 and indicate two sites of definite Bad quality status, with the remaining sites sitting on or near the Good/Moderate boundary. This is further illustrated in Figure 11, which also shows the standard error at each site. The average EQR for the water body is 5.0 equalling Moderate quality status. The EQR range based on the average standard error is 0.438 to 0.562. Applying the confidence of class calculation indicates this water body to have 85.6% confidence in Moderate status with an overall level of 92.8% confidence that the waterbody is of Moderate status or worse.

Table 15: Metric component results for 10 sites within the Outer Solway South using the full species list

Full Species List - Outer Solway South							
Site Name	**Shore Description**	**Species richness**	**Corrected SR**	**% greens**	**% reds**	**ESG ratio**	**% opport**
Parton	15	51	51	35.29	45.10	0.46	19.61
Tom Hurd Rock	14	39	43.68	30.77	38.46	0.44	17.95
Redness	14	44	49.28	36.36	38.64	0.47	25.00
Harrington	14	24	26.88	16.67	41.67	0.50	33.33
Cunning point (mine water site)	14	32	35.84	37.50	46.88	0.78	25.00
Cunning point (control)	14	57	63.84	33.33	38.60	0.54	24.56
Saltom Bay	14	35	39.2	31.43	37.14	0.35	22.86
Huntsman outfall	12	6	8.34	83.33	16.67	0.00	66.67
Whitehaven, Byerstead Fault	12	6	8.34	100.00	0.00	0.00	33.33
Tom Hurd Rock	12	28	38.92	46.43	42.86	0.33	39.29

Table 16: Final quality status and EQR for the Outer Solway South including the individual site classifications, Standard deviation and standard error using the reduced species list

Full Species List - Outer Solway South									
Site Name	Corrected SR	% greens	% Reds	ESG	% Opport	EQR	Quality Class	StDev	St Error
Parton	0.76	0.49	0.77	0.54	0.67	0.65	GOOD	0.126	0.056
Tom Hurd Rock	0.69	0.58	0.53	0.53	0.72	0.61	GOOD	0.088	0.040
Redness	0.74	0.47	0.53	0.56	0.55	0.57	MODERATE	0.101	0.045
Harrington	0.49	0.87	0.59	0.60	0.43	0.60	MODERATE	0.168	0.075
Cunning point (mine water site)	0.61	0.45	0.80	0.87	0.55	0.66	GOOD	0.175	0.078
Cunning point (control)	0.87	0.53	0.53	0.65	0.56	0.63	GOOD	0.143	0.064
Saltom Bay	0.64	0.57	0.50	0.40	0.59	0.54	MODERATE	0.094	0.042
Huntsman outfall	0.24	0.08	0.22	0.00	0.12	0.13	BAD	0.100	0.045
Whitehaven, Byerstead Fault	0.24	0.00	0.00	0.00	0.43	0.13	BAD	0.194	0.087
Tom Hurd Rock	0.64	0.34	0.74	0.39	0.31	0.48	MODERATE	0.195	0.087
Average						**0.50**		**0.139**	**0.062**

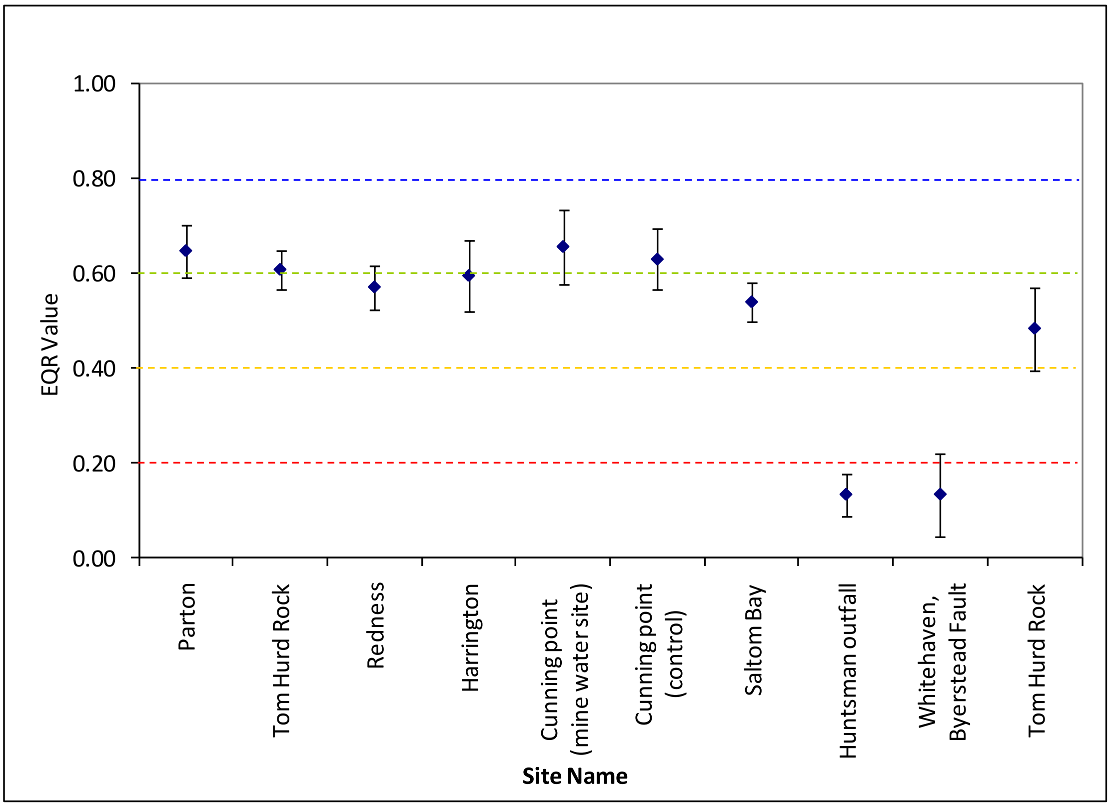

Figure 11: EQR values for the full species list for individual sites within the Outer Solway South with error bars representing the standard error

6. Response to Pressure

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 anthropomorphic pressures such as;

- toxic substances
- morphological pressures & alterations more specifically habitat modification,
- point source discharges or general pollution,
- increased nutrients leading to eutrophication,
- abstraction & flow regulation,
- presence of alien species, and
- general stress

The primary pressures thought to cause a shift in the balance of intertidal macroalgae communities are toxic substances, habitat modification and point source discharges, which may in turn lead to problems of eutrophication through increased nutrients.

Toxic Substances

Increased toxic substances present on intertidal areas through industrial run-off and trickle streams can produce seriously undesirable conditions, the presence of sulphur reducing bacteria and a general decrease in species richness and abundance. Freshwater run-off or outflows reducing salinity can also lead to a dominance of more tolerant species such as the opportunist macroalgae, whereby less tolerant species may be restricted in both richness and abundance. Mine water is an example of toxic waste that often filters through rocky shores often causing an orange colouration on the rock surface and changing the pH of the surrounding area (e.g. Whitehaven, Byerstead fault in the Outer Solway South (see worked example).

Habitat Modification

Habitat loss or degradation may occur through coastal morphological change including construction of flood defences, harbours or slipways, dredging activity causing removal of habitats, and increased sedimentation and excess deposition. Increased morphological pressure can lead to loss or complete removal of coastal habitats with a change or loss of algal communities, and a shift in community structure from long lived perennial species to ephemeral, opportunist species which can dominate the community and restrict continued growth of other faunal and floral species.

Degradation through coastal morphological change or increased pressure, specifically dredging activity, also causes increased sedimentation and excess deposition. This can lead to smothering and light limitation causing a dominance of tolerant macroalgae species and restricting growth of less tolerant species resulting in a community transition from algal dominated to animal dominated due to an increase in filter feeders and an overall change in environmental conditions

As morphological pressures increase, the available intertidal habitat for suitable attachment of marine benthic algae decreases, causing a decrease in levels of species richness and ESG ratio and a shift in the proportions of red and green algal species. These effects may also result from increased sediment deposition.

Point Source Discharges

This mainly refers to sewage outfalls which were known to be located close to shore often contributing to increased sedimentation. These can lead to increased levels of nutrients and contribute to problems of eutrophication as detailed below. Discharges are often responsible for shifts in community structure and can lead to complete removal of algal communities as described in section 5.1.

Increased Nutrients and Eutrophication

Marine plants are a key component of the ecology of shallow coastal and transitional water environments. In healthy shallow coastal waters with a balanced nutrient regime the dominant primary producers are perennial benthic macrophytes such as seagrasses or long-lived seaweeds, with seasonal opportunistic macroalgae or phytoplankton playing a lesser role in biomass and production (Schramm & Nienhuis, 1996).

Increased nutrient inputs from both direct and indirect sources such as sewage outfalls and land run-off contribute to eutrophication problems and increased suspended sediment levels. Increasing nutrient loading increases blooms of 'nutrient opportunists' in particular fast-growing epiphytic macroalgae and bloom-forming phytoplankton taxa; macrophytes and perennial macroalgae decline and finally disappear. These heavy, uncontrolled, opportunist macroalgal blooms (e.g. *Ulva* and *Enteromorpha* spp.) replace perennial slow-growing macrophytes with further nutrient increases. The changes in benthic vegetation due to eutrophication are a series of direct and indirect affects that feedback and self-accelerate and are which are difficult to control once initiated (Schramm & Nienhuis, 1996).

Increased nutrient levels can lead to excessive algal growth, which may then smother the diverse understorey. This can cause decreased species richness and a transition in species composition from long-lived perennial algae to fast-growing ephemeral algae restricting the abundance of sensitive species. Additional responses may be an undesirable shallow anoxic level in more sedimentary habitats, as well as excess suspended particulate matter resulting from increased nutrients and runoff leading to light limitation. This impact can result in a community transition from algal dominated to animal dominated due to an increase in filter feeders and an overall change in environmental conditions.

Therefore intertidal macroalgae communities are likely to show a response to elevated nutrient concentrations through increasing proportions of opportunistic macroalgae with a corresponding decline in the levels of species richness.

6.1. Response to Pressure Gradient

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 anthropogenically induced changes. This is hindered further by the lack of algal data pre and post adverse influence. However, two shores within the Firth of Forth, Edinburgh provide an ideal opportunity for observing long term changes in macroalgae community composition, owing to the unique set of data collected during significant changes in the pollution loading and subsequent abatement of sewage pollution.

The City of Edinburgh, on the east coast of Scotland, stretches over 15km of coastline on the southern shore of the Firth of Forth (Smyth, 1968). It used to be the most extensively used sea area around Scotland (McLusky, 1987), receiving approximately 270 consented effluent discharges including a series of nine main outfall pipes subjected to varying degrees of treatment (Read *et al*, 1982; Leatherland, 1987). The Seafield Sewage Treatment Works were commissioned in April 1978, and by 1980 the new system treated 92% of Edinburgh's sewage with a subsequent dramatic improvement in water quality (Read *et al*, 1982).

Since the improved sewerage system, there have been marked changes in the intertidal benthic fauna and flora. Observations before 1978 showed definite effects of pollution stress, with an absence of macroalgae and macroinvertebrate species and increased presence of indicator species (Read *et al*, 1983). The reduced diversity was attributed partly to the presence of high suspended solids interfering with the settlement and growth of macroalgal sporelings on rocks and decreasing light penetration (Read *et al*, 1983). As water quality improved, populations of pollution indicator species either declined or totally disappeared such as mat formations of *Polydora ciliata* and *Fabricia sabella*. In response many new and previously unrecorded species became established including *Laminaria* spp., *Verrucaria* sp. (a lichen) and *Chondria* sp. (Read *et al*, 1983). Some of the most notable changes occurred at Joppa and Granton.

Initial macroalgae records by Traill (1886) provide evidence of high levels of diversity, which showed considerable decline by 1961 (Knight & Johnston, 1981). The large reduction in species richness since Traill (1886) was accompanied by a high biomass of *Mytilus edulis* and *Balanus balanoides*, which proceeded to dominate the shore. Such replacement is regarded as typical of chronic domestic sewage pollution with pools filled with high levels of suspended matter, deep mud and empty shells (Knight & Johnston, 1981; Johnston, 1972). Similarly, at Granton a decline in species richness was observed, but was replaced by extensive mats of polychaetes (Wilkinson *et al*, 1987). These communities can inhibit growth of algae and ensure macroalgal communities are prevented from recolonising the habitat.

Following sewage abatement, Granton initially returned to a macroalgae community believed to be comparable to Traill (1886), but this was later replaced by mussel-barnacle dominance. At Joppa the shore remained mussel-barnacle dominated. Joppa's failure to return to its prior state may be attributed to the pollution-induced mussel-barnacle community being regarded as a climax community, and highly stable compared with the easily dislodged replacement community of polychaetes at Granton.

In many situations any attempts to assess pollution effects is faced with lack of baseline data from which to work, such as the absence of accurate records of the presence and status of individual species in a given area at a given time (Johnston, 1971). At Joppa detailed species lists are provided for 1977 and 1987 (Wilkinson, Scanlan & Tittley, unpublished) and in 2000 (Wells, 2002). These data show the impact of pollution and subsequent recovery.

Species records at Joppa show a considerable change in species richness from 1977 to 2000 (Figure 12). During 1977 there were only 31 species recorded, which amounts to 54% of the species recorded in more recent years. The gradual increase in species richness to 57 recorded in 2000 correlates with the cessation of pollution in 1978 and reflects the subsequent recovery. This increase is reflected in all the algal divisions, although the dominant division has changed from Chlorophyta in 1977 to Rhodophyta in 2000 suggesting a significant shift in species composition and general community structure. The species composition responds well to the 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 become established.

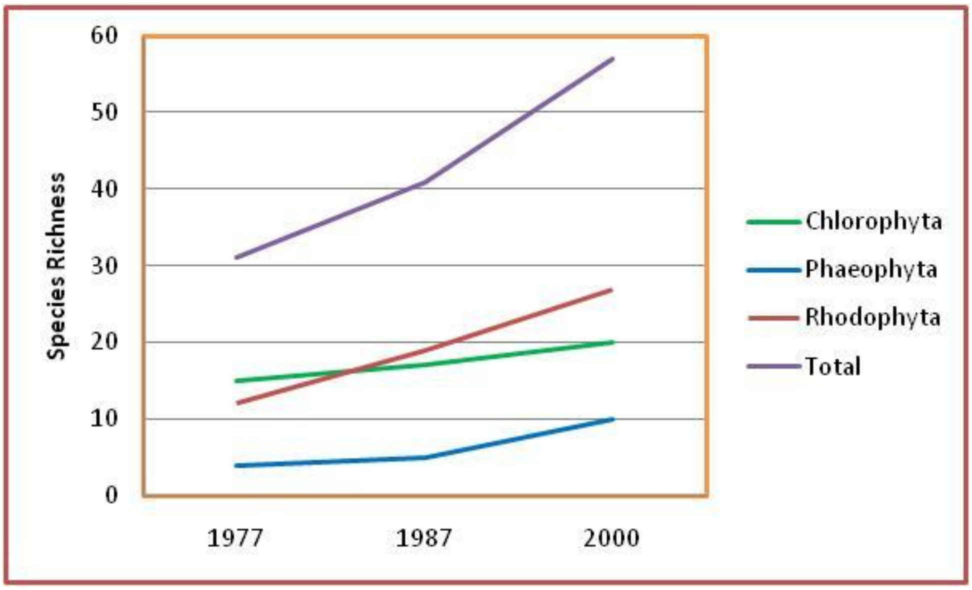

Figure 12: Numerical species richness totals for Joppa during 1977 and 1987 (Wilkinson *et al,* unpublished) and 2000 (Wells, 2002) including separate totals for each of the algal divisions, Chlorophyta, Phaeophyta and Rhodophyta

Table 17: Cumulative species lists for Joppa from Traill, Wilkinson & Scanlan, and Wells demonstrate the initial high levels of diversity prior to the outfalls, followed by decline during the period of effluent discharge (1986-1987) and subsequent and gradual recovery

	Traill 1881-1886	*Wilkinson and Scanlan 1986-1987*	*Wells 2000-2001*	*Total 20th and 21st century*
Chlorophyta	17	27	29	31
Phaeophyta	37	15	17	21
Rhodophyta	58	37	40	50
Total	112	79	86	102

7. Levels of Confidence

The outcomes of the tools being developed will govern the action, if any, to be taken on a particular area. Therefore, there needs to be a high level of confidence in the sampling frequency, data collected and the tools ability to accurately classify the ecological status of a water body.

7.1. Confidence in Sampling Frequency

It has been suggested that for intertidal rocky shore macroalgae sampling a single sampling occasion per year undertaken during the spring/summer period is adequately representative of the state of that individual site. However species composition is known to vary considerably throughout the year due to species tolerances and life histories; this level of variability may also be experienced when sampling the same site on consecutive days. This may affect the proportions of greens, reds and opportunists and ESG ratio. Similarly species richness, although remaining broadly constant on an annual cycle in the absence of anthropogenic impact, does experience slight seasonal fluctuations. Therefore it is important to ensure that these variations in species composition and richness do not affect the result and final classification using the tool. A second aspect required to ensure confidence in the data is the amount collected within a waterbody. Sampling a single site over an extended area of coastline is not a true representation of the quality status of the waterbody as a whole.

The factors that need to be considered in the confidence of sampling frequency include the following

1. The size of the water body – for small water bodies 2-3 sites should be adequate to classify the area, however for much larger water bodies a greater number of sites should be considered (3-5).

2. Presence of hard substrate – intertidal macroalgae communities require the presence of hard substratum, however some areas of the coastline are predominantly sedimentary with some water bodies having no appropriate sites to survey. In this instance the tool should not be considered and only used where applicable. This may limited the amount of data collected.

3. Presence of localised impacts – in water bodies where there is known localised impact it would be advisable to sample a variety of sites to include both affected and non-affected areas, as focusing solely on affected sites will produce a false overview of the waterbody as a whole. These may require investigative monitoring.

The number of sites is likely to vary between waterbodies and therefore cannot be detailed specifically, but it is useful to combine it with the number of sampling occasions to give a good estimate of the general level of confidence. Therefore, sampling a single site on one occasion over the 6 year reporting cycle is likely to give a lower confidence result than sampling 3 sites within a water body every 2 years (Table 19).

Table 19: Level of confidence associated with sampling effort based on the number of sampling occasions within the 6 year sampling period and the total number of sites sampled within a single water body

	Number of Sites (indicative)			
Number of sampling occasions		1	2	3
	1	Very Low Confidence	Low	Medium Confidence
	2	Low confidence	Medium Confidence	High Confidence
	3	Medium Confidence	High Confidence	Very hIgh Confidence

7.2. Confidence in Data

The confidence here lies with the field surveyors' ability to adequately collect all the required data to an appropriate standard. This is something which is being addressed both internally within each of the competent monitoring authorities and externally through proficiency testing schemes and workshops. For example an external proficiency testing scheme is run by the National Marine Biological Analytical Quality Control (NMBAQC) Committee using identification ring tests circulated to participants. The participating laboratories are able to test their identification skills and identify areas needing additional training; where identification and field skills are lacking there will be limited confidence in data collected.

7.3. Confidence of Classification

Collaborations between the EA and WRc have produced a statistically robust means of calculating the overall level of confidence in the quality status assessment using the full and reduced species lists. Extracts have been taken from the initial draft report from WRc (see Davey, 2009) to demonstrate how the confidence of class (C of C) calculation works. The system has been termed PIRATES (Precision In Rocky shores Analysed To Extract Statistics). It has been designed to perform calculations for multiple waterbodies simultaneously and gives the confidence of class over the whole reporting period.

Surveys of macroalgal community composition are conducted on one or more rocky shores in each waterbody, on one or more occasions during each reporting period. Each survey yields five sub-metric values, which are averaged to give a Survey EQR between 0 and 1. Status is defined by a Final EQR, which is the mean of the Survey EQR values (Figure 13). The confidence of class takes account of the uncertainty in the final status assessment arising from spatial and temporal variation in the Survey EQR results.

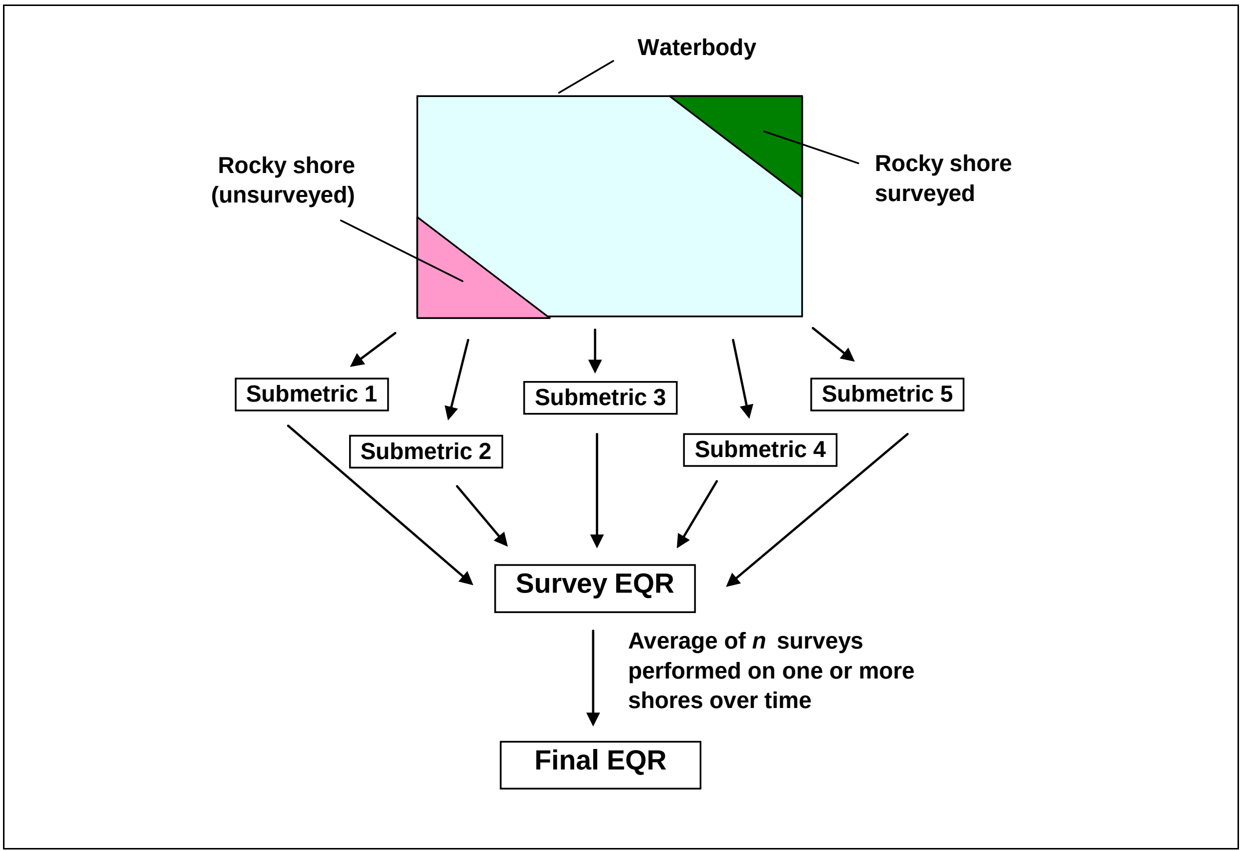

Figure 13: Sampling scheme for RSL tool

Where only one survey is undertaken with a single EQR result, the variability cannot be measured directly, but can be estimated indirectly using data from other waterbodies. 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 waterbody (Figure 13).

The approach seeks to model the combined spatial and temporal variability in survey EQR results, as measured by their standard deviation, as a function of the mean EQR in a waterbody. Variability is expected to be greatest in waterbodies of moderate status (EQR ≈ 0.5), and to get progressively smaller as the mean EQR tends towards 0 or 1, e.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. A power curve is used to capture this ∩-shaped relationship.

Figure 14 illustrates a typical dataset with a power curve fitted to it. Each black dot represents one waterbody, the blue squares represent the anchor points at Mean EQR = 0 and Mean EQR = 1, and the red line represents the best-fit power curve. The curve can be used to estimate the standard deviation in a water body with a single survey.

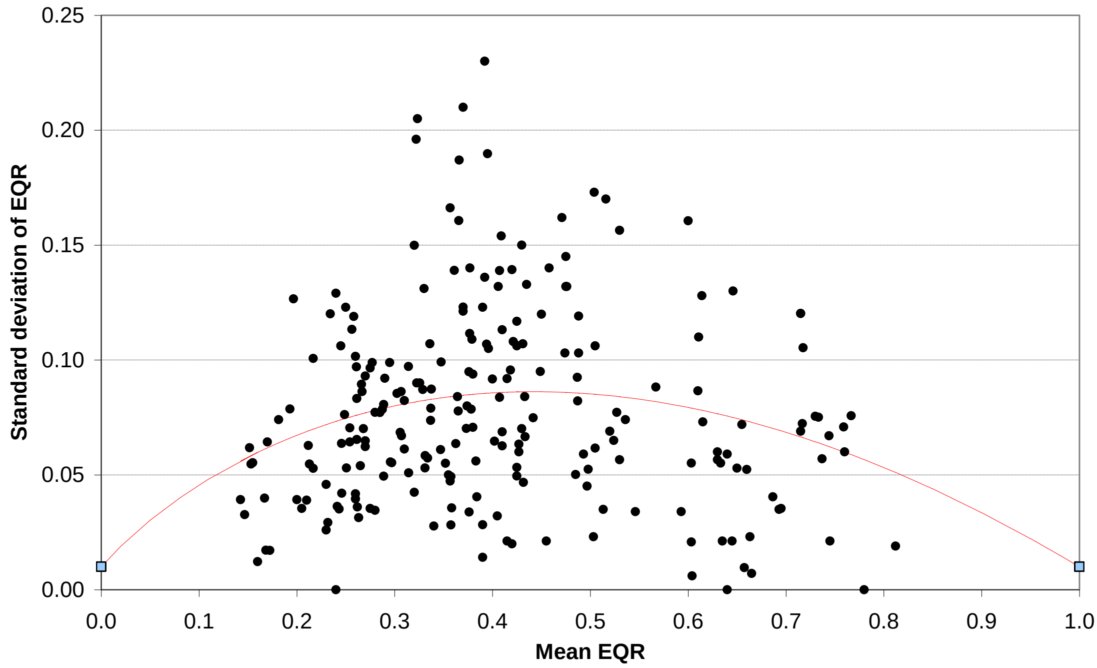

Figure 14: A power curve describing the relationship between EQR variability and mean EQR

After estimating the EQR and its associated uncertainty, it is necessary to decide on a suitable statistical model for the uncertainty in the EQR. The simplest option is to assume that the EQR uncertainty is normally distributed around the specified true EQR value, with the predicted standard deviation. However, although this model is quite acceptable for most values of EQR it becomes unsatisfactory at either extreme, because the assumed normal distribution 'spills' outside the permitted 0-1 range. For this reason Ellis & Adriaenssens (2006) adopted the logit transformation.

Figure 15 shows the situation in which the assumed EQR mean and standard error are 0.85 and 0.10, respectively. Under the simple normality assumption, an appreciable part of the right-hand tail spills beyond EQR = 1. In contrast, the logit transformation ensures that the error distribution ends asymptotically at 1 (at the expense of a longer left-hand tail so as to achieve the required standard deviation).

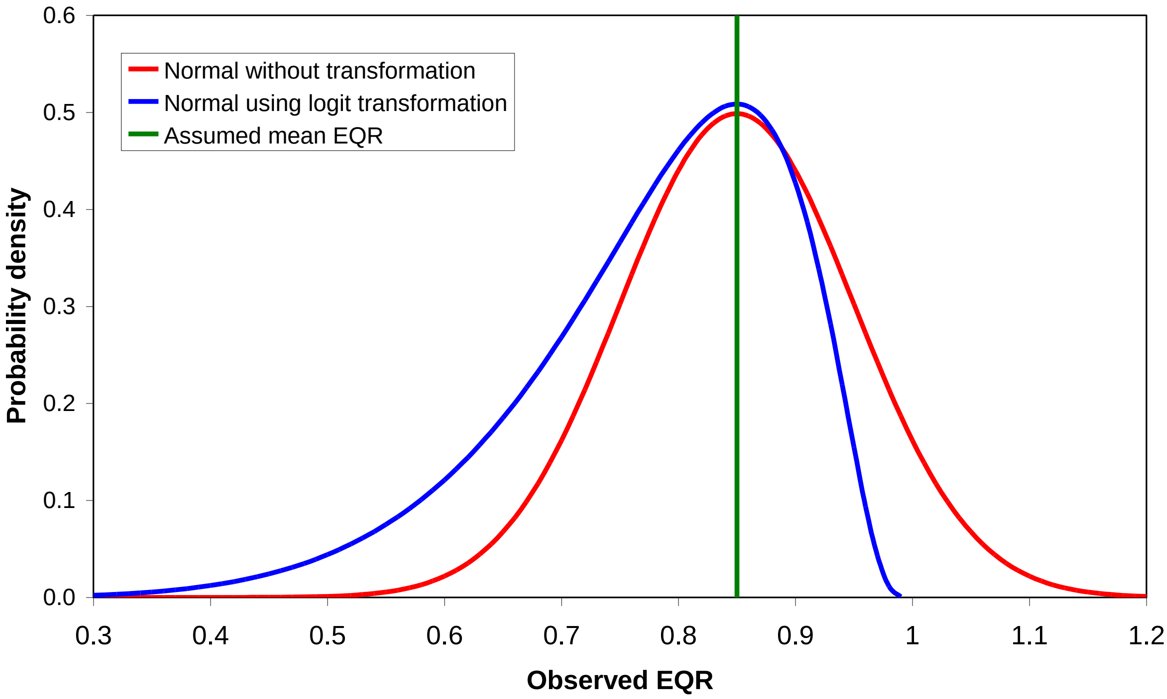

Figure 15: Illustration of the effect of the logit transformation of EQR

Because the EQRs that make up the Mean EQR result are just a random sample from a population of possible EQR results, the Final EQR and its standard error are then converted to a confidence of class using the *t*-distribution, which takes into account the additional sampling error.

PIRATES is held within an Excel spreadsheet which calculates the mean EQR and confidence of class for the FSL and RSL Tools. It performs calculations for multiple waterbodies and gives the confidence of class over the whole reporting period. The system assumes that surveys are conducted across the waterbody and throughout the reporting period to give a representative measure of the level of spatial and temporal variability and sampling error around the Final EQR is normally distributed.

PIRATES calculates both the face value class (based on the Final EQR) and probability of the waterbody being in each of the five status classes. Occasionally the face value class may not be the same as the most probable class given by the CofC assessment. This is perfectly correct, and arises because the EQR is constrained to take values between 0 and 1. It typically occurs when the mean EQR is close to a boundary between two classes. For example, consider a waterbody with a Final EQR of 0.78, just below the High/Good boundary - the face value class will be Good, but the CofC may say 50% High, 40% Good and 10% Moderate, which 'averages out' at Good. Thus, there is no contradiction between the face value result, which relates to the long-term expected EQR value, and the CofC, which presents the distribution of outcomes that are expected to arise due to random variation.

An example is provided in Table 18 below to show how the CofC works. Where only a single EQR is available the standard deviation is predicted by fitting a power curve to predict the SD of Survey EQRs from the Final EQR.

Table 18: Application of the Confidence of Class.

							Confidence of class (%)						
WaterBody Name	No. of surveys	Mean EQR	SD - observed	SD - predicted	SE of mean	Face Value Class	High	Good	Moderate	Poor	Bad	GoodOrBetter	ModerateOrWorse
Anglesey North	1	0.801		0.049	0.049	High	50.7	39.8	4.2	1.9	3.5	90.5	9.5
AVON	1	0.821		0.045	0.045	High	63.4	28.2	3.5	1.7	3.3	91.5	8.5
Barnstaple Bay	2	0.804	0.081		0.057	High	52.4	42.1	3.6	1.1	0.8	94.5	5.5
Bideford Bay	1	0.746		0.059	0.059	Good	25.3	60.9	7.2	2.6	4.0	86.2	13.8
Bridgwater Bay	1	0.543		0.098	0.098	Moderate	10.1	23.1	47.7	11.2	7.9	33.2	66.8
Bristol Channel Inner South	2	0.743	0.008		0.006	Good	0.4	99.5	0.1	0.0	0.0	99.9	0.1
Bristol Channel Outer North	4	0.632	0.116		0.058	Good	1.4	67.7	29.9	0.9	0.1	69.1	30.9
Caernarfon Bay North	2	0.827	0.044		0.031	High	75.0	23.3	1.1	0.3	0.3	98.3	1.7
Cardigan Bay Central	2	0.757	0.002		0.001	Good	0.0	99.9	0.0	0.0	0.0	100.0	0.0
Cardigan Bay North	3	0.797	0.031		0.018	Good	44.2	55.6	0.1	0.0	0.0	99.8	0.2
Carmarthen Bay	4	0.740	0.038		0.019	Good	1.4	98.5	0.1	0.0	0.0	99.9	0.1
Cornwall North	2	0.800	0.009		0.006	Good	49.9	50.0	0.1	0.0	0.0	99.9	0.1
Cornwall South	4	0.794	0.047		0.024	Good	39.8	60.0	0.1	0.0	0.0	99.9	0.1
Cumbria	2	0.587	0.126		0.089	Moderate	5.3	39.6	46.3	6.7	2.1	45.0	55.0
Dorset / Hampshire	1	0.795		0.050	0.050	Good	46.9	43.3	4.4	1.9	3.5	90.1	9.9
EASTERN YAR	1	0.714		0.065	0.065	Good	19.0	63.2	10.3	3.2	4.4	82.1	17.9
Fal / Helford	4	0.775	0.031		0.016	Good	8.8	91.2	0.0	0.0	0.0	100.0	0.0
Farne Islands to Newton Haven	3	0.835	0.031		0.018	High	91.5	8.4	0.1	0.0	0.0	99.9	0.1
HELFORD	2	0.777	0.113		0.080	Good	39.8	49.7	7.0	2.0	1.5	89.5	10.5
Holyhead Bay	1	0.788		0.051	0.051	Good	42.2	47.4	4.8	2.0	3.6	89.6	10.4
Holyhead Strait	1	0.885		0.032	0.032	High	85.6	8.3	2.0	1.2	2.9	93.9	6.1
Isle of Wight East	2	0.863	0.014		0.010	High	98.5	1.4	0.1	0.0	0.0	99.8	0.2
Kent North	4	0.680	0.019		0.010	Good	0.0	99.9	0.1	0.0	0.0	99.9	0.1

8. European Intercalibration

The UK takes part in the European intercalibration process (known as Intercal and managed for the European Commission by the Joint Research Centre [JRC], ECOSTAT). This process is designed to ensure comparability of assessment across Member States, and to harmonise quality status thresholds. The intercalibration process is aimed at consistency and comparability of the classification results of the monitoring systems developed by member states for each of the biological quality elements. Its main aims are to establish boundary values between High and Good status, and Good and Moderate status, and that these correspond between member states. This is achieved by ensuring each member state's assessment method is calibrated against agreed benchmark conditions to ensure results from different methods are equivalent in measuring the impacts of pressures. The intercalibration exercise is also designed to ensure that the Good status class boundaries used in the classification schemes are in-line with the WFD's normative definitions.

Many of the member states have been monitoring different aspects of the marine environment and different biological parameters. Therefore, data may not always be available to enable a direct comparison or to establish a tool/classification system which can be carried across all countries.

The tool that has been developed by the UK to encompass the composition aspect of algal communities focuses solely on rocky intertidal seashores. Unfortunately many of the countries within the North East Atlantic geographic area do not possess shores with comparable environmental conditions. Within the UK there are many shores with large intertidal extent subjected to broad tidal ranges, often with dense communities of algae growing within a number of habitats and subhabitats. Although France exhibits a similar coastline, other countries such as the Netherlands, Denmark and Sweden are subjected to a limited tidal range, lack of hard substrate and little in the way of intertidal algal communities. As a result many of these countries have very limited data on intertidal algal species lists and are unable to participate in this particular tool development and classification system.

However, during the first round of intercalibration Norway (not an EU member state, but part of the European Economic Area) showed interest in adopting the tool for CW-NEA1/26 and data were submitted for comparison. These data have been tested using the UK macroalgae composition tool, the results of which can be used to assess the intercalibration capabilities of this particular tool.

The data from Norway showed the species lists to be less extensive, with a lower level of species richness. This may have a negative effect on the tool resulting in a lower level of classification. However, the other elements within the tools should help even this out slightly. This should also be a good indication as to the robust nature of the tool.

As of June 2007 the scoring system for the common indices below were agreed by Ireland, Norway, and the UK. These common indices for this intercalibration metric describe species richness and composition based on a reduced species list (Table 21) devised specifically for the boundary setting protocol and classification tool development process. The boundary values are slightly different between regions due to the varying levels of diversity and composition (Table 20).

Table 20: Macroalgae reduced species list metric scoring system for the UK, RoI and Norway.

EQR Quality Class		0.8 - 1.0 High	0.6 - 0.8 Good	0.4 - 0.6 Moderate	0.2 - 0.4 Poor	0 - 0.2 Bad
RSL	Scotland	35-70	25-35	17-25	5-17	0-5
	England/Wales/RoI	35-69	25-35	15-25	5-15	0-5
	NI	34-68	20-34	10-20	3-10	0-3
	Norway	33-68	20-33	10-20	4-10	0-4
Greens	Scotland	0-12	12-20	20-30	30-80	80-100
	England/Wales/RoI	0-15	15-20	20-25	25-80	80-100
	NI	0-20	20-30	30-45	45-80	80-100
	Norway	0-20	20-30	30-45	45-80	80-100
Reds	Scotland	55-100	45-55	35-45	15-35	0-15
	England/Wales/RoI	55-100	45-55	40-45	15-40	0-15
	NI	45-100	35-45	25-35	10-25	0-10
	Norway	40-100	30-40	22-30	10-22	0-10
ESG	Scotland	1.0-1.2	0.8-1.0	0.7-0.8	0.2-0.7	0-0.2
	England/Wales/RoI	1.0-1.2	0.8-1.0	0.55-0.8	0.2-0.55	0-0.2
	NI	0.8-1.2	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2
	Norway	0.8-1.2	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2
Opportunist	Scotland	0-10	10-15	15-25	25-50	50-100
	England/Wales/RoI	0-10	10-15	15-25	25-50	50-100
	NI	0-15	15-25	25-35	35-50	50-100
	Norway	0-15	15-25	25-35	35-50	50-100

The 'de-shoring factor' has also been incorporated to adjust the level of species richness according to the overall description of the shore using 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:

$a = 14.210$ $b = 4.925$ $c = 0.108$

The final metric system works on a sliding scale to enable an accurate EQR value to be calculated for each of the different parameters, an average of these values is then used to establish the final classification status.

Where a shore description is not available the uncorrected level of species richness is to be put into the final metric, although the level of confidence in the overall result may be reduced slightly.

The above scoring system for the indices for this metric gives EQR boundaries of:

H/G 0.80

G/M 0.60

M/P 0.40

P/B 0.20

The average EQR is used to classify this metric.

Table 21: Reduced species list for the intercalibration process for the UK, RoI and Norway.

				Zone in which taxa applicable for assessments			
Species	**Colour**	**Opport**	**ESG**	**Norway**	**England / Wales / Ireland**	**Northern Ireland**	**Scotland / Northern England**
Blidingia minima	Chlorophyta	*	2	1	1	1	1
Bryopsis plumosa	Chlorophyta		2		1		
Chaetomorpha sp.	Chlorophyta		2	1			
Chaetomorpha linum	Chlorophyta	*	2		1	1	1
Chaetomorpha mediterranea	Chlorophyta	*	2		1	1	
Chaetomorpha melagonium	Chlorophyta		2	1	1		1
Cladophora albida [4]	Chlorophyta		2			1	
Cladophora rupestris	Chlorophyta		2	1	1	1	1
Cladophora sericea [4]	Chlorophyta		2		1	1	1
Cladophora sp incl.[4]	Chlorophyta		2	1			
Enteromorpha sp.	Chlorophyta	*	2	1	1	1	1
Monostroma grevillei	Chlorophyta		2	1		1	
Rhizoclonium tortuosum	Chlorophyta		2			1	
Acrosiphonia sp incl.[1]	Chlorophyta		2	1			
Spongomorpha aeruginosa / pallida [2]	Chlorophyta		2				
Spongomorpha arcta [1]	Chlorophyta		2			1	
Spongomorpha sp.incl.[2]	Chlorophyta		2	1			
Halochlorococcum moorei	Chlorophyta		2				1
Ulothrix sp [3]	Chlorophyta		2			1	
Ulothrix/Urospora [3]	Chlorophyta		2	1			
Ulva lactuca	Chlorophyta	*	2	1	1	1	1
Prasiola sp.	Chlorophyta		2	1			
Alaria esculenta	Phaeophyta		1	1		1	1
Ascophyllum nodosum	Phaeophyta		1	1	1	1	1
Asperococcus fistulosus	Phaeophyta		1	1		1	1
Chorda filum	Phaeophyta		1	1	1		1
Chorda tomentosa	Phaeophyta		2	1			
Chordaria flagelliformis	Phaeophyta		2	1			1
Cladostephus spongious	Phaeophyta		2	1	1	1	1
Desmarestia aculeata	Phaeophyta		2	1			1
Dictyosiphon foeniculaceus	Phaeophyta		2	1			1
Dictyota dichotoma	Phaeophyta		2		1	1	1
Ectocarpus sp.	Phaeophyta	*	2	1	1	1	1
Elachista fucicola	Phaeophyta		2	1	1	1	1
Fucus evanescens	Phaeophyta		1	1			
Fucus serratus	Phaeophyta		1	1	1	1	1
Fucus spiralis	Phaeophyta		1	1	1	1	1
Fucus vesiculosus	Phaeophyta		1	1	1	1	1
Halidrys siliquosa	Phaeophyta		1	1	1	1	1
Himanthalia elongata	Phaeophyta		1	1	1	1	1

Laminaria digitata	Phaeophyta		1	1	1	1	1
Laminaria hyperborea	Phaeophyta		1	1	1		1
Laminaria saccharina	Phaeophyta		1	1	1	1	1
Leathesia difformis	Phaeophyta		1	1	1	1	1
Litosiphon laminariae	Phaeophyta		2				1
Mesogloia vermiculata	Phaeophyta		2	1			
Pelvetia canaliculata	Phaeophyta		1	1	1	1	1
Petalonia fascia	Phaeophyta		2	1		1	
Pilayella littoralis	Phaeophyta	*	2	1	1	1	1
Ralfsia sp.	Phaeophyta		1	1	1	1	1
Saccorhiza polyschides	Phaeophyta		1		1		
Scytosiphon lomentaria	Phaeophyta		1	1	1	1	1
Sphacelaria sp	Phaeophyta		2	1		1	
Spongonema tomentosum	Phaeophyta		2	1		1	1
Saccorhiza dermatodea	Phaeophyta		1	**1**			
Acrochaetium alariae	Rhodophyta		2	1			
Aglaothamnion/Callithamnion	Rhodophyta		2	1	1	1	1
Ahnfeltia plicata	Rhodophyta		1	1	1	1	1
Aglaothamnion sepositum	Rhodophyta		2	1			
Audouinella purpurea	Rhodophyta		2	1		1	
Audouinella sp	Rhodophyta		2	1		1	
Bangia atropurpurea	Rhodophyta		2	1			
Brogniartella byssoides	Rhodophyta		2	1			
Calcareous encrusters	Rhodophyta		1	1	1	1	1
Callophyllis laciniata	Rhodophyta		1				1
Catenella caespitosa	Rhodophyta		1		1	1	
Ceramium nodulosum	Rhodophyta		2	1	1	1	1
Ceramium shuttleworthanium	Rhodophyta		2	1	1	1	1
Ceramium sp.	Rhodophyta		2	1	1		
Chondrus crispus	Rhodophyta		1	1	1	1	1
Corallina officinalis	Rhodophyta		1	1	1	1	1
Cryptopleura ramosa	Rhodophyta		2		1	1	1
Cystoclonium purpureum	Rhodophyta		1	1	1	1	1
Delesseria sanguinea	Rhodophyta		2				1
Dilsea carnosa	Rhodophyta		1		1	1	1
Dumontia contorta	Rhodophyta		1	1	1	1	1
Erythrotrichia carnea	Rhodophyta		2	1	1		1
Furcellaria lumbricalis	Rhodophyta		1	1	1	1	1
Gastroclonium ovatum	Rhodophyta		1		1		
Gelidium sp.	Rhodophyta		1		1	1	
Gracilaria gracilis	Rhodophyta		1		1		
Halurus equisetifolius	Rhodophyta		2		1		
Halurus flosculosus	Rhodophyta		2		1		
Heterosiphonia plumosa	Rhodophyta		2		1		
Hildenbrandia rubra	Rhodophyta		1	1	1	1	
Hypoglossum hypoglossoides	Rhodophyta		2		1		
Lomentaria articulata	Rhodophyta		1	1	1	1	1
Lomentaria clavellosa	Rhodophyta		1	1			1
Mastocarpus stellatus	Rhodophyta		1	1	1	1	1
Melobesia membranacea	Rhodophyta		1	1		1	
Membranoptera alata	Rhodophyta		2	1	1	1	1
Nemalion helminthoides	Rhodophyta		1	1			

Odonthalia dentata	Rhodophyta		1	?		1	1
Osmundea hybrida	Rhodophyta		1		1	1	1
Osmundea sp	Rhodophyta		1	1			
Osmundea pinnatifida	Rhodophyta		1		1	1	1
Devaleraea ramentacea	Rhodophyta		2	1			
Palmaria palmata	Rhodophyta		1	1	1	1	1
Phycodrys rubens	Rhodophyta		2	1			1
Phyllophora sp. incl. Coccotylus truncata	Rhodophyta		1	1	1	1	1
Plocamium cartilagineum	Rhodophyta		2	?	1	1	1
Plumaria plumosa	Rhodophyta		2	1	1	1	1
Polyides rotundus	Rhodophyta		1	1	1		1
Polysiphonia fucoides	Rhodophyta		2	1	1	1	1
Polysiphonia lanosa	Rhodophyta		2	1	1	1	1
Polysiphonia sp.	Rhodophyta		2	1	1	1	1
Porphyra leucosticta	Rhodophyta	*	2	?			1
Porphyra linearis	Rhodophyta	*	2	1			
Porphyra umbilicalis	Rhodophyta	*	2	1	1	1	1
Ptilota gunneri	Rhodophyta		2	1			1
Rhodomela confervoides	Rhodophyta		2	1	1	1	1
Rhodothamniella floridula	Rhodophyta		2		1	1	1
Nemalion helminthoides	Rhodophyta		1	1	1		
Total					**69**	**68**	**70**
Other species that might be considered are:							
Cruoria pellita (southern to sector 19), Chylocladia verticillata (southern to sector 15),							
Gloiosiphonia capillaris (southern to sector 19)							

The RSL tool was intercalibrated successfully in Phase 1 of intercal (European Commission, 2008; Carletti & Heiskanen, 2009) with no changes to the UK's tool class boundaries. However, further guidance from the Commission on response to pressures requires to be investigated in Phase 2 of Intercalibration.

9. References

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