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Coastal and Transitional waters North East Atlantic geographic intercalibration group

Opportunistic macroalgae ecological assessment methods

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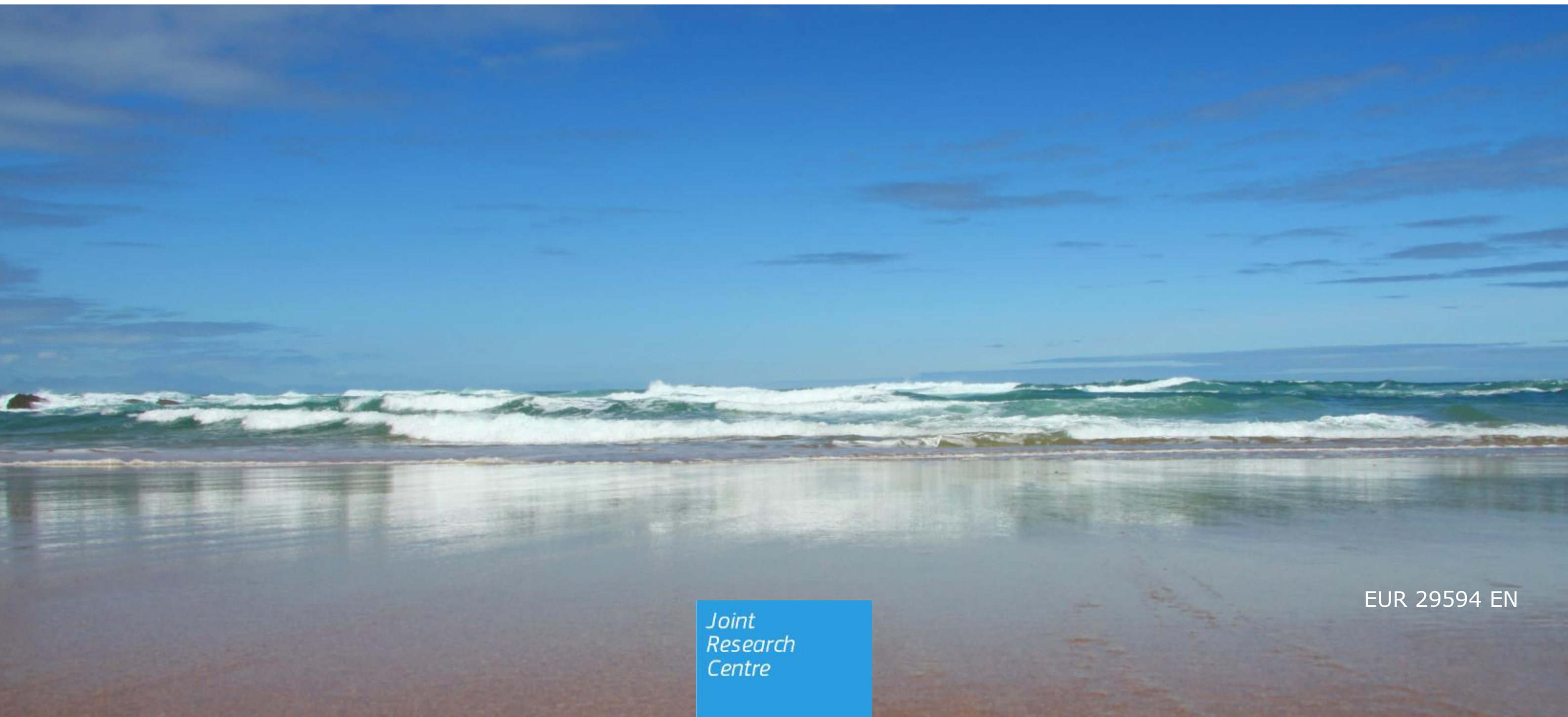

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Abstract

The European Water Framework Directive (WFD) requires the national classifications of good ecological status to be harmonised through an intercalibration exercise. In this exercise, significant differences in status classification among Member States are harmonized by comparing and, if necessary, adjusting the good status boundaries of the national assessment methods.

Intercalibration is performed for rivers, lakes, coastal and transitional waters, focusing on selected types of water bodies (intercalibration types), anthropogenic pressures and Biological Quality Elements. Intercalibration exercises are carried out in Geographical Intercalibration Groups - larger geographical units including Member States with similar water body types - and followed the procedure described in the WFD Common Implementation Strategy Guidance document on the intercalibration process (European Commission, 2011).

The Technical report on the Water Framework Directive intercalibration describes in detail how the intercalibration exercise has been carried out for the water categories and biological quality elements. The Technical report is organized in volumes according to the water category (rivers, lakes, coastal and transitional waters), Biological Quality Element and Geographical Intercalibration group. This volume addresses the intercalibration of the Coastal and Transitional Waters-North East Atlantic Opportunistic macroalgae ecological assessment methods.

1. Introduction

This note outlines the Intercalibration process for the Opportunistic Macroalgae BQE. It covers the countries France, Ireland and the United Kingdom in transitional waters (including UK and IE coastal areas) and France and Germany in Coastal waters. Please note that this report should be considered along with the previous Intercalibration work (EC 2008, EC 2013).

At the end of this IC2 process it was concluded by JRC and the reviewing panel that the following key issues remained outstanding:

- The differences in the UK, IE and FR assessments at the same pressure ranges needed to be clarified. FR sites at the same pressure range were Good/High whereas UK-IE sites were Moderate.
- Pressure relationship did not account for differences in physical condition.
- UK and IE coastal tool was not in agreement with the FR and DE coastal assessments.

1.1 Changes to the dataset for third round of intercalibration

For these analyses we have removed the PT data as they only have information for one waterbody. Although there is data for several years, splitting this into yearly EQRs amounts to pseudo-replication and makes the data incompatible with the mean values used for the other MS. While the PT methods do show some agreement with the other MS tools there is insufficient data to test the pressure response or compare the proposed boundary conditions.

1.2 Changes to the Coastal and Transitional waters assessments

Different assessment concepts are used in coastal waters by DE and FR compared to the UK and IE methods. The assessment by France and Germany for their coastal waters uses remote sensing of algal accumulations, measured several times throughout the growth season. The BQE assessed here consists generally of unattached mobile blooms of green algae. The transitional waters assessment for UK, IE and FR is undertaken in situ, once during the growth season. These blooms consist of attached growths of algae. Due to the differences in the FR/DE and UK/IE methodologies there were incompatibilities in the class boundaries, i.e. the assessment criteria for 'percentage cover of the intertidal' at the high-good boundary for the FR/DE method was 0.5% but 5% for the UK/IE tool.

The UK and IE use the same sampling methodology and assessments for both their coastal and transitional waters. This tool is applied using *in situ* methods and is generally the same as the assessment undertaken by FR in their transitional areas. In the second round of intercalibration assessment coastal and transitional waters were analysed separately whereas in the first phase the two types were combined.

For this final intercalibration check we have split the CW and TW, with FR and DE undertaking separate analyses for their coastal waters. The similarity in the two MS methods is such that an option 3 analysis is possible. The UK and IE data for coastal waters is now included in the transitional waters analysis.

The combination of the TW and CW data for UK and IE is justified on the basis that the assessment is undertaken under similar physical conditions using the same assessment methodology. The assessment tool was developed for use in transitional and sheltered, sedimentary coastal waters of UK and IE (Scanlan *et al.* 2007). Much of this development work was undertaken prior to the characterisation of each MSs water bodies into coastal and transitional types. The few coastal waterbodies assessed have similar characteristics to the TW water bodies included in the analyses. These water bodies have large areas of sedimentary intertidal sand/mud flats which are uncovered at low water. The algal blooms in these areas are found attached to the sediments and differ from the free-floating blooms assessed in the FR and DE coastal water bodies (Perrot *et al.* 2014).

Figure 1 Typical coastal opportunistic algal bloom the DE and FR

Figure 2 Coastal bloom in Malahide Bay, Ireland

The CW data only covers a small part of the pressure gradient available in the data set but the pressure response across this part of the scale is similar to the TW data (Figure 3). Additionally the average EQR for the CW sites is not significantly different to the average EQR for the TW sites (Figure 4).

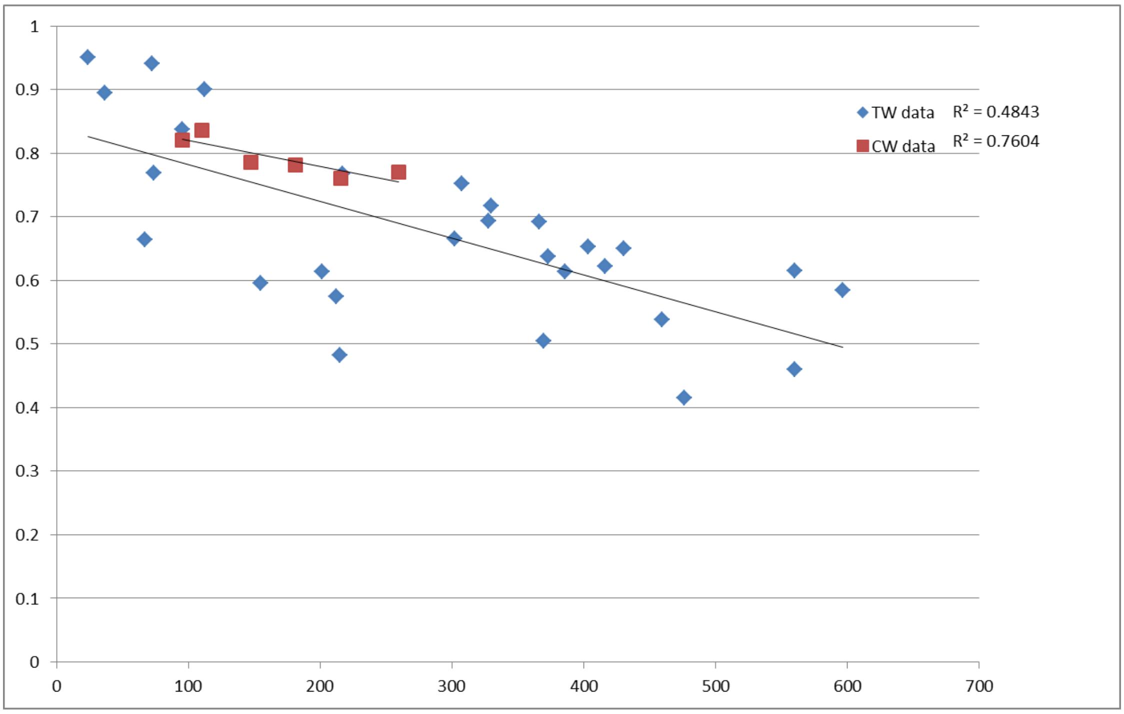


Figure 3 Coastal water sites (CW) and Transitional water sites (TW) versus the intercalibration pressure index (see Figure 8)

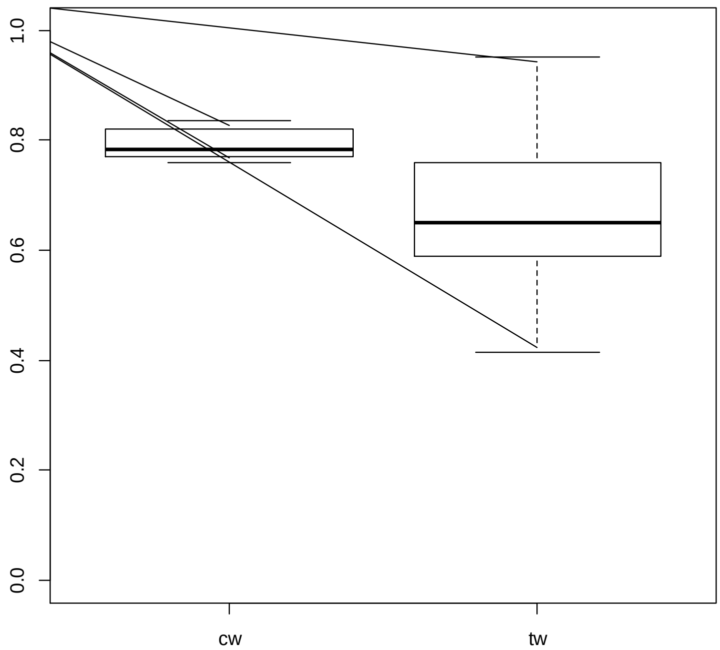


Figure 4 Boxplot of average CW and TW EQRs. ANOVA shows that the differences between CW and TW and not significant (although this is based on small samples sizes with unequal samples numbers).

If we compare the TX and CW data just across the pressure range they share the relationship is even closer (Figure 5) and is still non-significant.

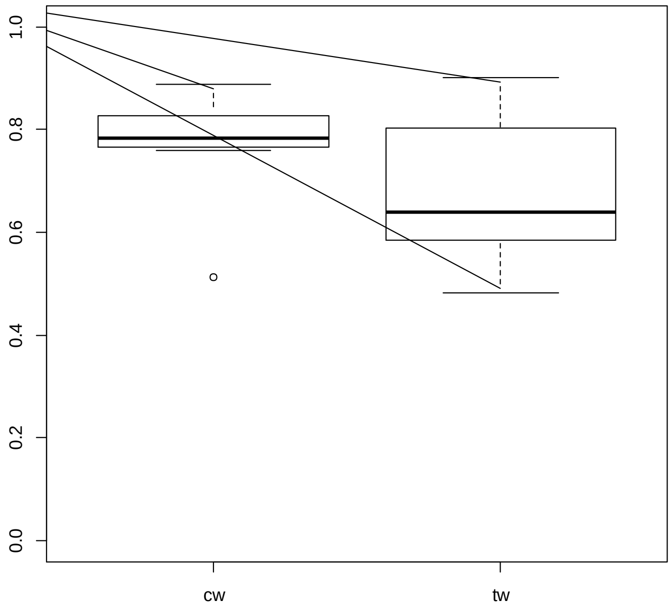


Figure 5 Boxplot of average CW and TW EQRs across common pressure range. ANOVA shows that the differences between CW and TW and not significant

The primary feature for characterisation of TW and CW bodies included physical conditions, such as bed type and exposure, and other parameters such as salinity values (SNIFFER 2003). This approach can be very difficult to apply along a continuum (McLusky and Elliott 2007); particularly when there was a paucity of data when this analysis was undertaken. Since the initial characterisation, changes to the classification of some of these areas are being proposed, as more information is gathered in the course of the WFD monitoring programme. This is likely to include the changing of some of the CWs assessed for the BQE to TW. Another factor to consider in assessing these areas together is that in some cases the algal growths span multiple waterbodies and cross a putative TW/CW boundary. In such cases it is logical to assess the BQE using the same boundaries and tools.

This combination of CW and TW waters is also being proposed for the seagrass assessment tools for UK and IE.

2. Transitional Waters analyses (UK, IE and FR)

2.1 National assessment methods

FR	Macroalgal Bloom Assessment (Opportunistic Green macroalgae) - TWOGA	Agreed national method (WISER ID 353)
IE	Opportunistic Green Macroalgal Abundance (OGA Tool)	Finalized formally agreed national method (WISER ID 101), intercalibrated in IC1
UK	Macroalgal Bloom Assessment (Opportunistic macroalgae) (OGA Tool)	Intercalibrated in IC1 (WISER ID 24); finalized formally agreed national method

2.2 WFD compliance check

Compliance criteria	Compliance checking conclusions
1. Ecological status is classified by one of five classes (high, good, moderate, poor and bad).	Yes
2. High, good and moderate ecological status are set in line with the WFD's normative definitions.	Yes (equidistant division in five classes)
3. All relevant parameters indicative of the biological quality element are covered (see Table 1 in the IC Guidance). A combination rule to combine parameter assessment into BQE assessment has to be defined. If parameters are missing, Member States need to demonstrate that the method is sufficiently indicative of the status of the QE as a whole.	Yes for FR, IE, UK (taxonomic composition is not relevant in this tool; justification accepted previously by ECOSTAT)
4. Assessment is adapted to intercalibration common types that are defined in line with the typological requirements of the WFD Annex II and approved by WG ECOSTAT.	Yes
5. The water body is assessed against type-specific near-natural reference conditions.	Yes
6. Assessment results are expressed as EQRs.	Yes
7. Sampling procedure allows for representative information about water body quality/ ecological status in space and time.	Yes
8. All data relevant for assessing the biological parameters specified in the WFD's normative definitions are covered by the sampling procedure.	Yes
9. Selected taxonomic level achieves adequate confidence and precision in classification.	Not relevant to this BQE

2.3 Location of sites

Figure 6 Distribution of sites in UK, IE and FR, showing WFD class

2.4 Pressure response

Previous analyses examined the use of Winter DIN as a driving pressure and the problems associated with using this across a wide range of differing water bodies.

Initial pressure analyses with Winter DIN as the pressure measurement gave the following results:

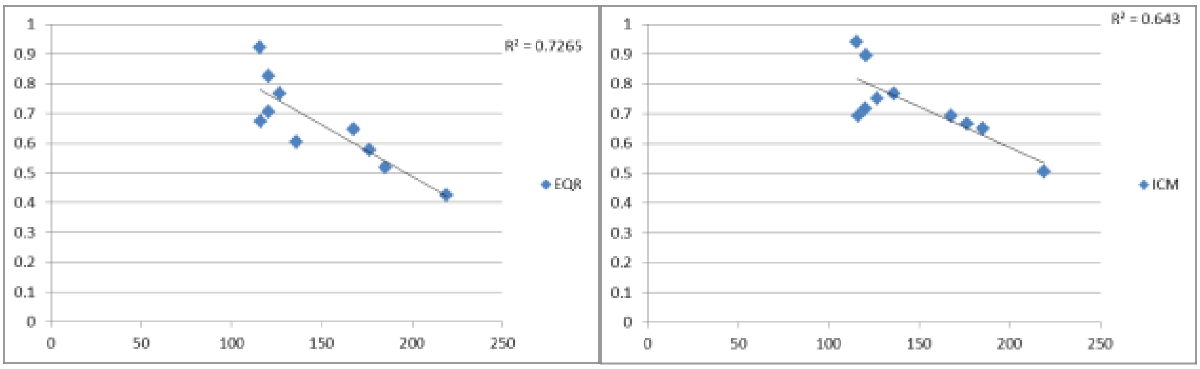


Figure 7 France- EQR and ICM vs Winter DIN

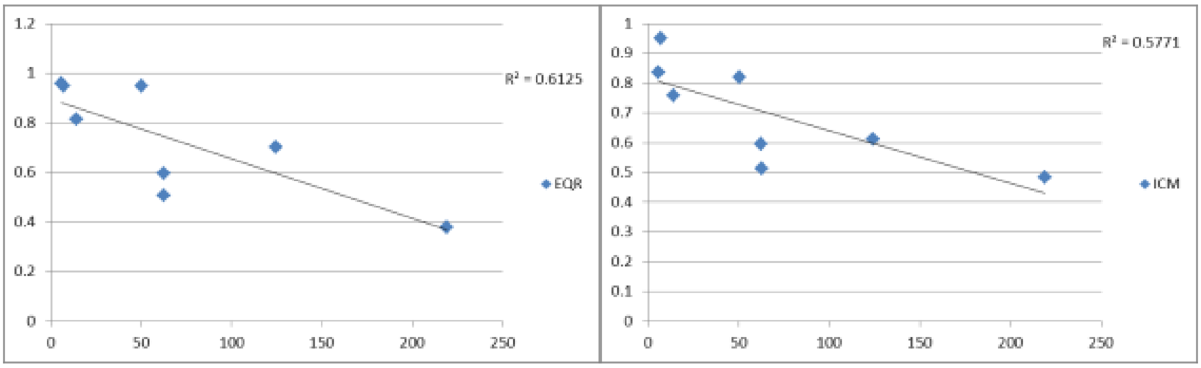


Figure 8   Ireland- EQR and ICM vs Winter DIN

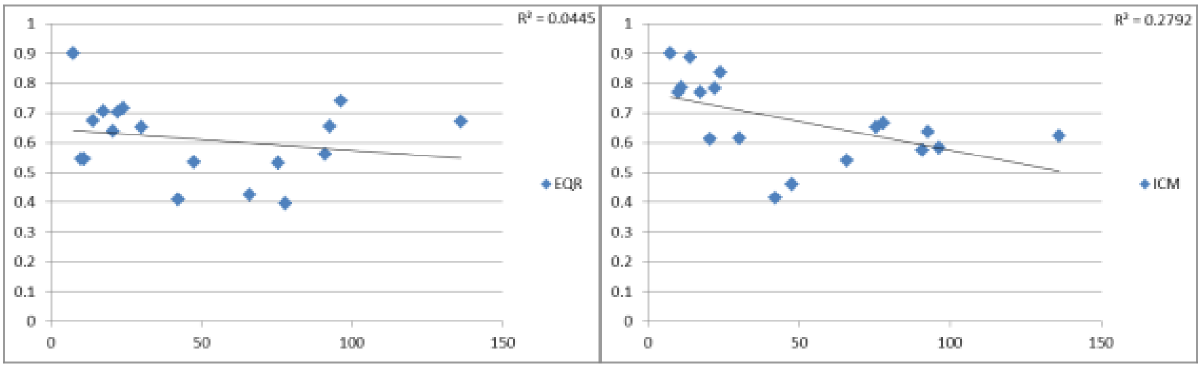


Figure 9   UK- EQR and ICM vs Winter DIN

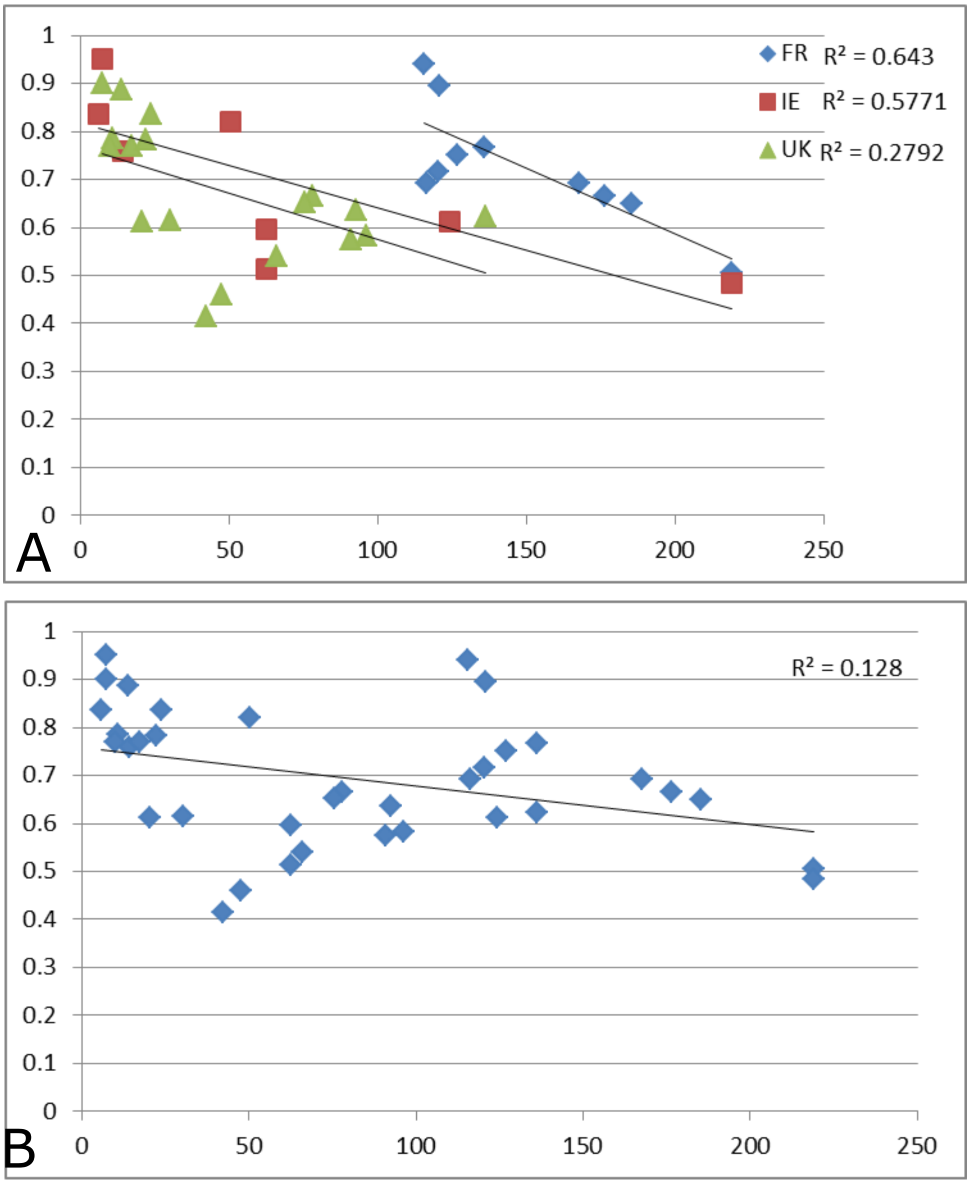


Figure 10 All member states combined- ICM vs Winter DIN (A= by individual MS, B= all data combined)

This mismatch in the MS pressure responses and the relatively weak relationship is similar to the results at the end of phase2, which were considered unacceptable for completion of the intercalibration process. A key complaint from these analyses was that different MSs had High EQRs at different pressure levels.

While it is clear that DIN has a relationship with this BQE this is confounded by the multiple pressures present in the estuarine environment. To account for this other factors known to affect OGA growth were considered.

A review of data from all the participating MSs suggested that winter DIN was the key pressure variable acting on the OGA tools. This corresponds to the historical use of OGA as an indicator of eutrophication in TraC waters. In an attempt to account for as much environmental variation as possible, salinity, turbidity and sediment type information were used as correction factors. This allowed for a common assessment of pressure across all MSs corrected for national differences in the physical conditions.

The Intercalibration Pressure Index (IPI) was calculated as follows:

IPI: N= LnDIN normalised for salinity

T= Turbidity; H=1, M= 1.5, L= 2

PSA= Particle Size; % <63µm

IPI= N*T*PSA

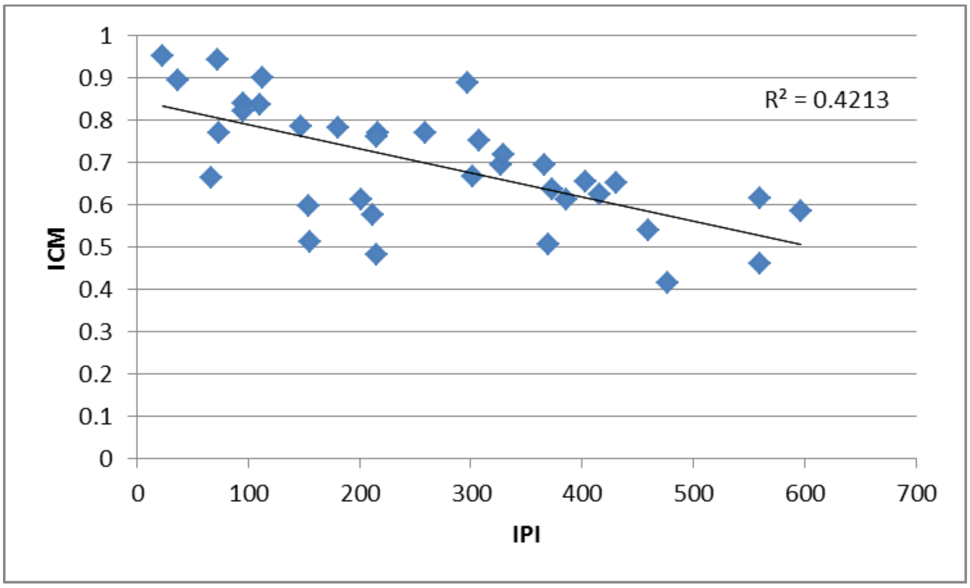


Figure 11 All MS data versus Intercalibration Pressure Index

This new IPI scale has an R^2 of 0.42 compared to 0.1 for DIN alone.

Individual MS responses to this new pressure scale are:

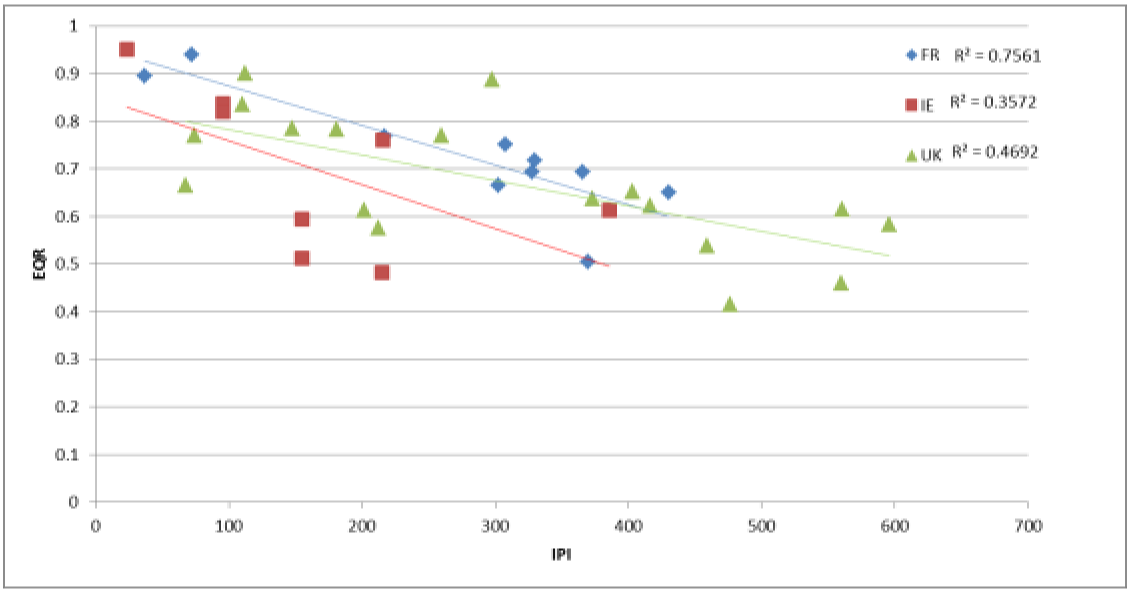


Figure 12 Individual MS EQRs versus Intercalibration Pressure Index

This adjusted scale allows for an assessment of each member states along a comparable gradient. The obvious mismatches in the DIN-only analyses have been somewhat corrected for by the inclusion of the physical correction factors.

Table 1 Pressure-response relationship for each MS

MS	R2	P
FR	0.76	0.001
IE	0.36	0.1
UK	0.47	0.001
All MS	0.42	<0.001

There is still a great deal of variation in the pressure responses and, while the relationships are variable, this is not unexpected given the known complexity in factors affecting the growth and development of macroalgal blooms (See Appendix 1).

2.5 Benchmarking

Due to lack of adequate reference sites in each of the MS and also due to the small datasets available, an alternative benchmarking approach was required. The 'continuous benchmarking' procedure, as outlined in Birk *et al.* 2013, was applied.

The procedure involved using General Linear Modelling to calculate offset values for the ICM vs Pressure relationship for each MS.

UK and IE both use the same methods consisting of a 5-metric toolbox assessing spatial extent, percentage cover, biomass and entrainment. The FR method does not use the biomass or entrainment metrics. Due to differences in the assessment tools, an option 2 approach was used for comparison of national methods.

2.6 The Intercalibration Common Metric (ICM)

The Intercalibration Common Metric (ICM) is calculated the same way as in previous IC work and uses the percentage of the available intertidal affected by algal growth as the common measurement. The relationship between National EQR and ICM for the dataset gives R^2 0.6 (p<0.001).

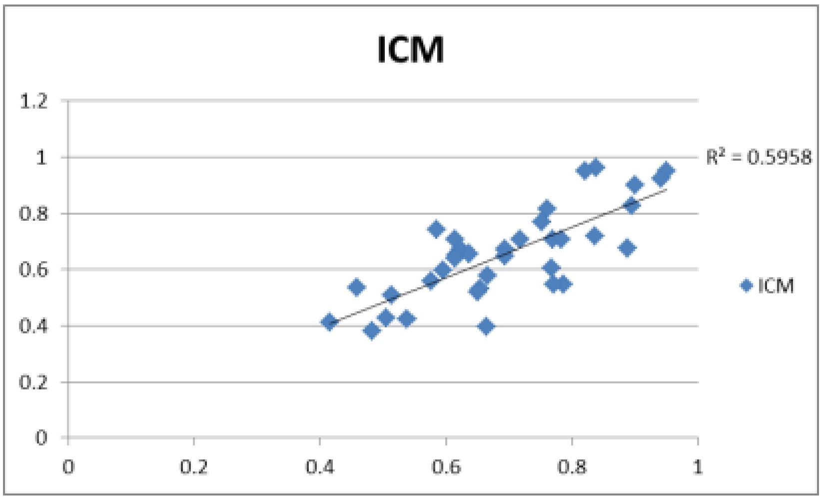


Figure 13 MS EQR versus the ICM

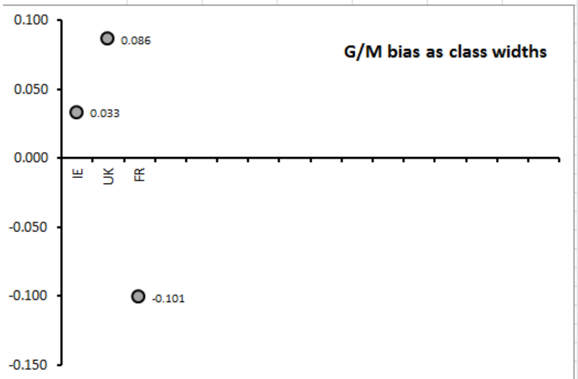
MS	R2	P
FR	0.86	<0.0001
IE	0.91	<0.0001
UK	0.4	<0.001

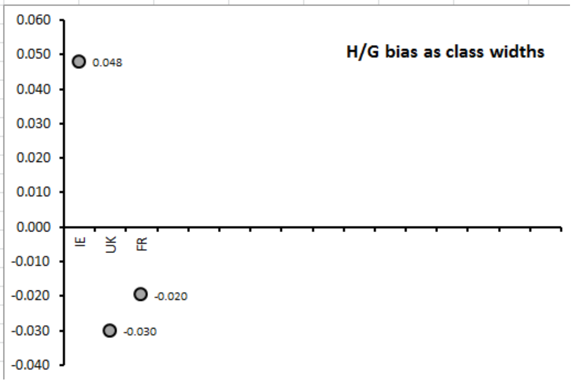
2.7 Boundary comparison and harmonisation

These analyses can then be used as the basis for the continuous benchmarking process to compare the assessment criteria of the different member states. Offsets were calculated using a General Linear Model (using R) and input into the spreadsheets developed by (Birk *et al.* 2013). Giving the following output (benchmarking excel sheet Appendix 2):

	IE	UK	FR
H/G	0.800	0.800	0.800
G/M	0.600	0.600	0.600

	IE	UK	FR												
Max	1.000	1.000	1.000												
H/G	0.800	0.800	0.800												
G/M	0.600	0.600	0.600												
M/P	0.400	0.400	0.400												
P/B	0.200	0.200	0.200												
H/G bias_CW	0.048	-0.030	-0.020	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N,
G/M bias_CW	0.033	0.086	-0.101	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N,
N of Bm sites	0														





These analyses suggest that the three methods are in excellent agreement with class bias less than 0.25 class widths for both the HG and GM boundary.

MS	Original G/M boundary	Corrected G/M boundary	Original H/G boundary	Corrected H/G boundary
UK	0.6	0.6	0.8	0.8
FR	0.6	0.6	0.8	0.8
IE	0.6	0.6	0.8	0.8

To finalise these analyses and conclude the intercalibration process the following questions need to be answered by JRC and the review panel:

1. Is the combination of CW and TW data for UK and IE acceptable?
2. Is the calculated pressure measurement acceptable?
3. Is the pressure relationship adequate given the confounding factors outlined in appendix 1?
4. Are the statistical analyses acceptable given the relatively small amount of data?

3. Coastal Waters analyses (FR and DE)

One of the key issues outstanding at the end of the phase 2 work was the issue of the differences in the methodology of the FR and DE coastal tool versus the UK and IE methods. The two groups of methods used different sampling techniques (remote vs. *in situ*) making it difficult to run a comparison.

For this final work it was decided to split the analyses and remove the UK and IE data from the coastal group and run an option 3 intercalibration between FR and DE

3.1 National assessment methods

Member state	Method	Status
DE	Opportunistic Macroalgae-cover/acreage on soft sediment intertidal in coastal waters (OMAI)	Finalized formally agreed national method (WISER ID 132)
FR	Macroalgal Bloom Assessment (Opportunistic Green macroalgae) - CWOGA	Intercalibrated finalized method (Wiser ID 359)

3.2 WFD compliance check

Table for Blooming Macroalgae-Intertidal (CW)	
Compliance criteria	**Compliance checking conclusions**
1. Ecological status is classified by one of five classes (high, good, moderate, poor and bad)	Yes
2. High, good and moderate ecological status are set in line with the WFD's normative definitions (Boundary setting procedure)	Yes
3. All relevant parameters indicative of the biological quality element are covered (see Table 1 in the IC Guidance)	Species composition not included, covered by other macroalgal tools.
4. Assessment is adapted to intercalibration common types that are defined in line with the typological requirements of the WFD Annex II and approved by WG ECOSTAT	Yes
5. The water body is assessed against type-specific near-natural reference conditions	Reference conditions are based on historical data, expert judgment and a small number of sites with very low pressures.
6. Assessment results are expressed as EQRs	Yes
7. Sampling procedure allows for representative information about water body quality/ ecological status in space and time	Yes
8. All data relevant for assessing the biological parameters specified in the WFD's normative definitions are covered by the sampling procedure	Yes
9. Selected taxonomic level achieves adequate confidence and precision in classification	Taxonomic composition not relevant to this tool

3.3 Location of sites

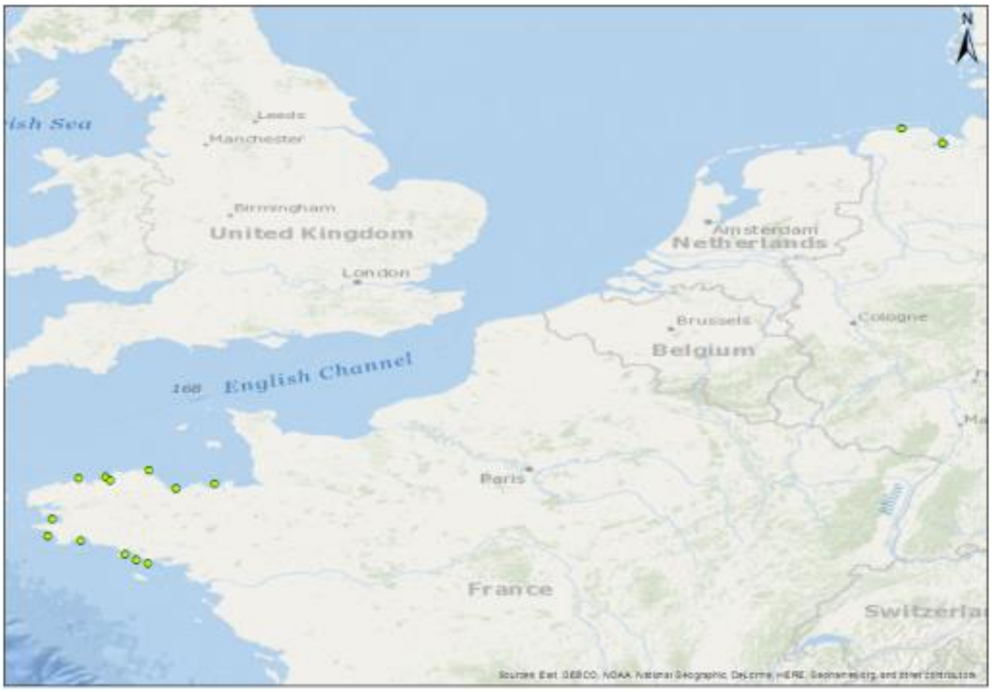


Figure 14 Sites used for FR and DE coastal intercalibration

3.4 Pressure response

The pressure response was calculated using winter DIN as the pressure metric and was significant for both MS methods.

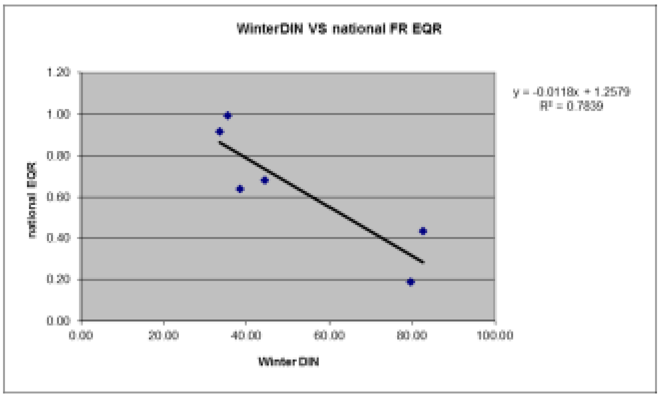


Figure 15 EQRs calculated for all data using FR method vs Winter DIN

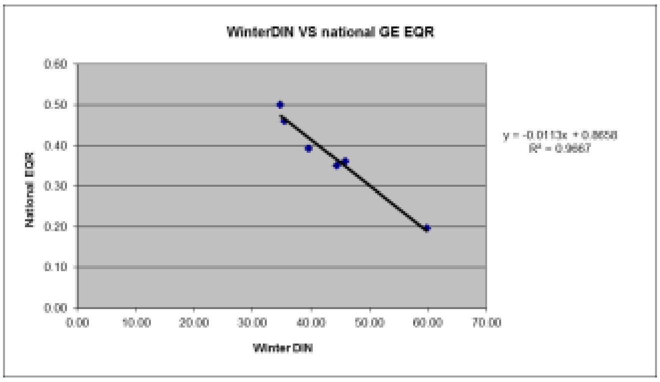


Figure 16 EQRs calculated for all data using DE method vs Winter DIN

3.5 Benchmarking

Due to lack of adequate reference sites in each of the MS and also due to the small datasets available, an alternative benchmarking approach was required. This involved an adapted 'continuous benchmarking' procedure adapted for only two MSs. This analysis was undertaken by JRC

Adequate information was available to allow each MS to calculate an EQR for the other using their national tool. The relationship between the two methods gave an R^2 of 0.9 ($p<0.001$). An option 3 approach was used.

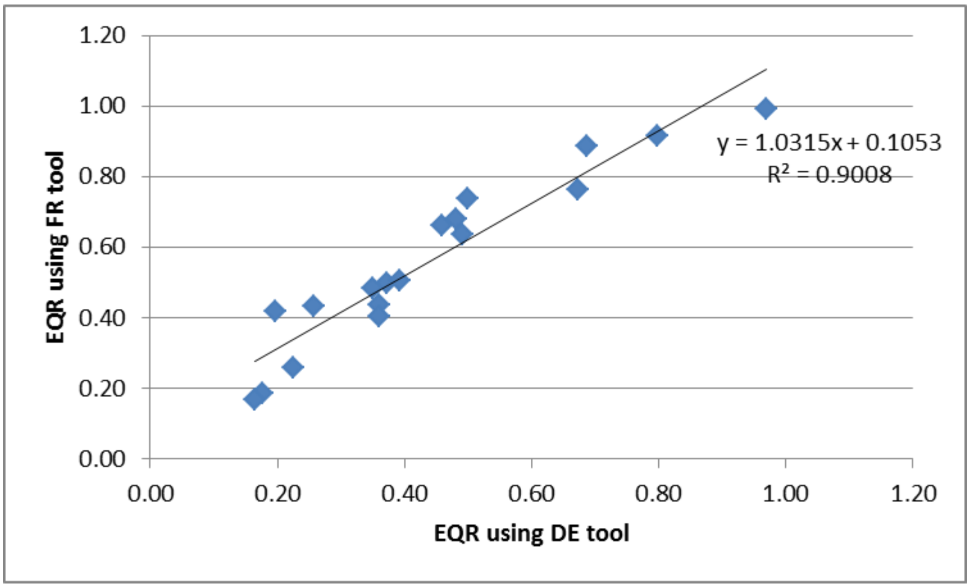


Figure 17 EQR of full dataset calculated by FR methods versus EQR calculated by DE method

3.6 Boundary comparison and harmonisation

An option 3 benchmarking step adapted for two member states was undertaken on this dataset and the following changes to national boundaries were suggested (appendix 3 Coastal Benchmarking):

MS	Original G/M boundary	Corrected G/M boundary	Original H/G Boundary	Corrected H/G boundary
DE	0.6	0.589	0.8	0.781
FR	0.6	0.617	0.8	0.825

4. Conclusion

The national assessment methods meet the WFD compliance criteria, and responds mainly to eutrophication.

A proposal for class boundaries after the Intercalibration exercise has been established for coastal and transitional waters. In the case of FR and DE original boundaries have been adjusted.

The class boundaries will be applied for the establishment of high and good ecological status in the water bodies of the national types included in the common Intercalibration types.

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List of abbreviations and definitions

Key Terms:

Assessment method: The biological assessment for a specific biological quality element, applied as a classification tool, the results of which can be expressed as EQR.

Biological Quality Element (BQE): Particular characteristic group of animals or plants present in an aquatic ecosystem that is specifically listed in Annex V of the Water Framework Directive for the definition of the ecological status of a water body (for example phytoplankton or benthic invertebrate fauna)

Class boundary: The Ecological Quality Ratio value representing the threshold between two quality classes

Common Intercalibration type: A type of surface water differentiated by geographical, geological, morphological factors (according to WFD Annex II) shared by at least two Member States in a GIG

Common metric: A biological metric widely applicable within a GIG or across GIGs, which can be used to derive a comparable understanding of reference conditions/alternative benchmark and boundary setting procedure among different countries/water body types
Compliance criteria: List of criteria evaluating whether assessment methods are meeting the requirements of the Water Framework Directive.

Continuous benchmarking: Option to perform the benchmark standardisation: Biological differences between national datasets were determined based on the country offsets (i.e. intercept and/or slope deviates) from the global pressure-biology relationship established using general linear models across the combined extent of the pressure gradient afforded by all countries

Ecological Quality Ratio (EQR): Calculated from the ratio observed value/reference value for a given body of surface water. The ratio shall be represented 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

Geographic Intercalibration Group (GIG): Organizational unit for the intercalibration consisting of a group of Member States sharing a set of common intercalibration types

Intercalibration: An exercise facilitated by the Commission to ensure that the high/good and good/moderate class boundaries are consistent with Annex V Section 1.2 of the Water Framework Directive and comparable between Member States

IC Option: Option to intercalibrate (IC) different national assessment methods

Joint Research Centre (JRC): European Commission Joint Research Centre which provides scientific and technical support for EU policy-making

Method Acceptance Criteria: List of criteria evaluating whether assessment methods can be included in the intercalibration exercise

Pressure: Human activities such as organic pollution, nutrient loading or hydromorphological modification that have the potential to have adverse effects on the water environment.

Reference/Benchmark sites: Reference sites meet international screening criteria for undisturbed conditions. Benchmark sites meet a similar (low) level of impairment associated with the least disturbed or best commonly available conditions

Water Framework Directive: Directive 2000/60/EC establishing a framework for Community action in the field of water policy

Abbreviations:

CW: Coastal waters

DE: Germany

DIN: Dissolved Inorganic Nitrogen

FR: France

G/M: Good-Moderate Boundary

H/G: High-Good Boundary

ICM: Intercalibration Common Metric

IE: Ireland

IPI: Pressure Index

N: Nitrogen

OGA: Opportunistic Algal Bloom

PSA: Particle size

PT: Portugal

T: Turbidity

TW: Transitional waters

UK: United Kingdom

WFD: Water Framework Directive

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Appendix 1: Justification of variable press-response relationship for Opportunistic macroalgal Blooms

Macroalgal blooms are a world-wide phenomenon, e.g. (Soulsby *et al.* 1982, Raffaelli *et al.* 1989, McComb and Humphries 1992, Sfriso *et al.* 1992, den Hartog 1994, Reise and Siebert 1994, Fletcher 1996) and most often occur in areas of restricted flushing (Lotze *et al.* 1999), and are considered to be the result of nutrient enrichment (Ryther and Dunstan 1971, Kruk-Dowgiallo 1991, Nienhuis and Schramm 1996, Wilkes 2005). In Europe they have been recorded in many member states including Portugal (Patrício *et al.* 2007), France (Perrot *et al.* 2014), UK (Scanlan *et al.* 2007), Ireland (Jeffrey *et al.* 1995) and Germany (Reise and Siebert 1994).

The species composition of these blooms varies but they are generally composed of a mix of *Ulva*, *Cladophora* and other chlorophyte species. Some areas may also experience blooms of brown (e.g. *Ectocarpus*) or red (e.g. *Gracilaria*) species but in general the assessment considered here focusses on green algal accumulations. These species in themselves are not indicators of disturbed conditions and are in fact key components of the natural flora (Abbott and Hollenberg 1976). They can even be present in large amounts where natural conditions favour their growth (e.g. salinity intrusions, groundwater inflows). It is only when the biomass and spatial cover of these species increase to undesirable levels that they are considered as indicators of disturbed conditions.

While the relationship between OGA and nutrient enrichment is widely reported, the precise relationship is highly complex. There are differences due to geographic, morphological, physical and biological factors. The complex relationship between biological elements and the associated physico-chemical parameters is highlighted in WFD guidance (EC 2009) and has been discussed by others in the development of marine monitoring tools (Niemi *et al.* 2004, Goberville *et al.* 2011).

Controlled laboratory and mesocosm experiments show that there is a strong relationship between nutrients and opportunistic macroalgal growth (e.g. (Pedersen and Borum 1997, Kamer and Fong 2001, Fong *et al.* 2004)). However, the difficulty in applying these relationships to real world conditions was highlighted by (Villares and Carballeira 2004) *"Laboratory experiments under constant temperature and irradiance conditions enabled the analysis of other factors that influence photosynthetic and growth rates. The periods of maximum and minimum growth and photosynthesis <u>cannot</u> be extrapolated to natural conditions..."*

In constructing a model for *Entermorpha* growth in the Mondego estuary, (Martins and Marques 2002) stated: *"...predicted growth rates were closer to real ones for data obtained in the laboratory than for field values. This is explained by the higher number of random effects and processes which occur in the field compared to laboratory experiments."*

In natural systems there are a large number of confounding factors that hide this simple relationship. Evidence suggests that factors such as:

- Nutrient supply (including the concentrations, NP ratios, sources, pulsing, reductions and time lags in the system), (Dailer *et al*. 2012, Ren *et al.* 2014);
- Species mix;
- Temperature, (Pérez-Mayorga *et al.* 2011);
- Salinity (Fong et al. 1996, Martins *et al*. 1999);
- Light (Peckol and Rivers 1995);
- local weather / climate (Pihl *et al.* 1996);
- turbidity (Josselyn 1985, Krause-Jensen *et al.* 2007);
- hydrography (Nedwell *et al.* 2002);
- bed stability (Albrecht 1998);
- particle size distribution (Wharfe 1977, Bolam *et al.* 2000, Eriksson and Johansson 2005);

- bed slope; and
- the total surface area of the intertidal region suitable for algal growth (Scanlan *et al.* 2007).

are important limiting factors where macroalgal blooms are concerned (see also, (Lowthion *et al.* 1985), (Poole and Raven 1997), (Rees-Jones unpublished), (CEFAS 2004)).

It is clear that the occurrence, persistence and impacts of macroalgal blooms are governed by a number of physical, chemical and biological factors, which may *interact in a complex fashion*, and are often difficult to characterise and understand fully.

Yet another confounding factor not considered above is the presence and distribution of other faunal communities. Algal blooms have been shown to be influenced by the presence of *Lanice* communities where attachment points and an additional source of nutrients are provided by the crowns of these animals (Jeffrey *et al.* 1995, van der Wal *et al.* 2014). Other fauna such as fish can affect the presence and distribution of species (Korpinen *et al.* 2007).

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