OPPORTUNISTIC MACROALGAL BLOOMS AND THE WATER FRAMEWORK DIRECTIVE

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Introduction

The EU Water Framework Directive (WFD) requires water bodies to be classified by their chemical and ecological status. Macroalgae are one of the biological quality elements to be used in defining the ecological status of a transitional or coastal water body. A key task in developing the classification system for surface water bodies is to identify appropriate reference conditions, i.e. those conditions found at pristine sites, undisturbed by anthropogenic activities. Calculating the extent of a quality element's deviation from reference conditions provides an ecological quality ratio used to classify water bodies as high, good, moderate, poor or bad.

The WFD suggests that the features of macroalgal communities to be used for assessment of ecological quality should include taxon composition and presence and abundance of disturbance sensitive taxa. For blooms of opportunistic macroalgae (e.g. *Enteromorpha* spp., *Ulva* spp.) the proposal is to use abundance (estimated by a combination of spatial coverage and biomass) and adverse environmental effects, as indicators of ecological quality. This poster considers the criteria being developed to establish reference conditions and the degree of deviation from these conditions that defines each quality class (Table 1). The crucial questions for the WFD are: to what extent opportunistic macroalgal blooms are naturally existent in pristine reference conditions and at what levels they have actual adverse ecological impact.

Ecological Status

Classification is based on deviation from "reference" conditions, defined as "conditions of a biological element that exist at high status, with **no** or **very minor** disturbance from human activities" (Table 1).

The overall objective is **No deterioration** and **restoration** to good status by 2015

Because reference conditions must incorporate natural variability, in most instances they will be expressed as *ranges*.

Transitional and coastal waters in the UK are divided into water bodies grouped into a number of physical types. The reference conditions for a specific water body type must describe all possible natural variation within that type.

Table 1: Ecological status classes and definitions.

HIGH	**High status** being defined as **no** or **minimal disturbance** of the biological elements
GOOD	**Good** being slight disturbance
MODERATE	**Moderate** being moderate disturbance
POOR	**Poor** being major disturbance
BAD	**Bad** being severe disturbance

Recognising excessive growth of opportunistic macroalgal mats

Anthropogenic forces have visibly affected some estuaries and bodies of marine water with restricted flushing (Lotze *et al.*, 1999). A key cause of change in the distributions and abundance of benthic community species is attributable to the effects of eutrophication (Kruk-Dowgiallo, 1991). Large macrophytes such as *Fucus vesiculosus* and *Zostera marina* are more restricted than several decades ago (Vogt & Schramm, 1991) whilst there has been a concurrent increase in abundance of annual filamentous and foliose algae (Kruk-Dowgiallo, 1991). Such algal forms may be regarded as opportunistic species characterised by high rates of mineral nutrient uptake and enhanced reproductive capability (Wallentinus, 1984; Hoffmann & Ugarte, 1985).

Evidence from well-studied UK sites demonstrates considerable inter-annual variation in the extent and location of cover (Wither, 2003). When assessing a site a run of several years' data is preferred, although this will not always be possible. The impact of weed cover will be greatest on those sites consistently covered by opportunistic seaweed during the growing season. Sites affected only intermittently have the opportunity to recover, with recycling of sediment-bound nutrients. The majority of algal mats encountered in UK locations are of *Enteromorpha* and/or *Ulva*, although *Cladophora* and *Chaetomorpha* have also been reported. Brown filamentous algae such as *Pilayella* or *Ectocarpus* and the red foliose alga *Porphyra* can also form blooms. As the season progresses so does the spread of *Ulva* with peak blooms forming in late summer.

Assessing excessive growth of opportunistic macroalgal mats

(A) Assessing percentage cover

The intertidal areas included in an assessment are soft-sediment only, as high levels of macroalgae can naturally occur on rocky shorelines. This may present difficulties in coarser sandy areas or mixed sediment estuaries as to how much of the intertidal area is suitable for such growth, and further investigation is necessary so that potentially significant problems are not hidden.

In the first instance opportunistic macroalgal blooms may be assessed using the Comprehensive Studies Task Team (CSTT) criterion (CSTT, 1997). This states that a symptom of eutrophication is when more than 25% of the available intertidal area is covered with opportunistic macroalgae with greater than 25% cover of those sub-areas.

A Department of Environment, Transport and the Regions (DETR) workshop held in 2001 made the following recommendations:

- The preliminary reference level = 5% cover;
- A problem area is one with > 15% cover of intertidal area on soft sediments;
- Some rocky shore areas can naturally have a high percentage of opportunistic macroalgal cover with no adverse impact.

The criteria scoring system has been based on this guidance (Table 2).

NB: On some rocky shores very high cover (up to 100%) by *Enteromorpha* and *Ulva* spp. is not necessarily deleterious, as this can occur naturally under certain circumstances such as freshwater inflow or sand scour.

(B) Assessing macroalgae biomass

The CSTT (1997) guidelines state the following for macroalgae biomass wet weight m^{-2}:

- Reference level for mass of weed = <100gm m^{-2} wet wt.
- Up to 500 gm m^{-2} wet wt. is not a problem if there are no other impacts.
- 1 000 gm m^{-2} wet wt. is a problem.

As with percentage cover, the criteria scoring system in Table 2 has been based on this guidance.

(C) Assessing adverse environmental effects

Consideration needs to be given to the consequences of excess algal coverage for the functioning of the ecosystem (Wither (EA), 2003). To demonstrate a problem there should be some supporting evidence of adverse effects, for example:

- Invertebrate fauna reduced,
- Wading bird feeding distribution modified (although it can be very difficult to establish precise cause and effect of such changes due to bird populations, transients in particular being affected by a large variety of factors),
- Cockle numbers reduced,
- Deposited weed smothers seagrass and salt marsh vegetation (e.g. Figure 1),
- Public complaints about odour,
- Floating rafts of weed affecting boating activity,
- Anoxia in surface sediment layer; e.g. top 2 cm (Figure 2).

If sediments are consistently anoxic, de-nitrification processes will break down and the system may become self-sustaining. The criteria scoring system (Table 2) is based on the presence and number of adverse effects noted at a site.

Figure 1: Deposited weed smothering salt marsh vegetation in Pagham harbour (reproduced courtesy of Sivyer, 2002)

Figure 2: Anoxia in surface sediment layer in Pagham harbour (reproduced courtesy of Sivyer, 2002)

Table 2: Calculating impact of opportunistic macroalgal presence using criteria scoring system

Criteria	Score
(A) % Cover of total available intertidal area, covered by weed	
< 5%	4
5-15%	2.5
>15%	1
(B) Mass of weed (wet weight)	
<100 gm-2	4
100-500 gm-2	3
500-1000 gm-2	2
>1000 gm-2	1
(C) Evidence of adverse disturbance	
No	4
Yes – minimal signs of disturbance	2
Yes – significant disturbance	1

Once an estuary has been scored under each of the above criteria, the mean score can be compared with Table 3, which interprets the ecological status guidance (Table 1) into ranges for WFD classification purposes.

Table 3: Proposed opportunistic macroalgae abundance classification; based on mean scores for 3 parameters

NB: Ranges are under investigation and subject to change

Opportunistic Macroalgae – intertidal soft sediments					
Classification	High	Good	Moderate	Poor	Bad
Mean score	3.5 – 4	2.5 – 3.4	1.5 – 2.4	1.1 – 1.4	1

Sampling Considerations

Sampling and photography are best carried out during the peak seasonal biomass. There is usually a broad seasonal trend in the UK of highest cover in spring/summer and much lower cover in winter. The growth level maxima often occur as 2 peaks, in spring and late summer with a decrease in the interim. *Enteromorpha* and *Ulva* spp. can grow densely enough to form a swathe that may begin to roll up in the autumn (Figure 3), though if the weather remains calm they can persist until October. For the purposes of this tool it is necessary to monitor when weed cover is at it's maximum, before rolling in this way.

Figure 3: Opportunistic macroalgae lying in rolls at the high water mark in Poole harbour (reproduced courtesy of Sivyer, 2002)

Example – Kench, Langstone harbour, UK

During the growing season all 4 Kench sites supported >100gm^{-2} wet wt macroalgae (Figure 4).

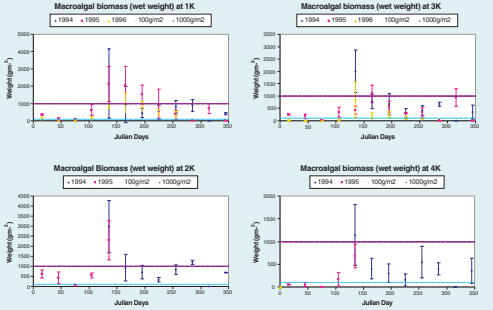

Figure 4: Macroalgae biomass wet weight, against Julian Days for 4 sites at The Kench, Langstone Harbour (data from Pye, 2000). Blue dashed line = 100 g m^{-2}. Maroon dashed line = 1000 g m^{-2}

Over the whole monitoring period macroalgae biomass were scored using the criteria scoring system as follows:

Biomass (wwt)	Biomass score (Table 2) Kench results		
< 100 gm^{-2}	4 (High)	14 samples	18%
100 – 500 gm^{-2}	3 (Good)	28 samples	36%
500 – 1000 gm^{-2}	2 (Moderate)	23 samples	32%
> 1,000 gm^{-2}	1 (Poor)	11 samples	14%

Total no. samples = 76

Mean biomass score = $\frac{(14 \times 4)+(28 \times 3)+(23 \times 2)+(11 \times 1)}{76} = 2.44$

Langstone Harbour is widely recognised as having high levels of opportunistic macroalgal growth in most years. This score of 2.44 for the whole monitoring (summer and winter) period classifies the Kench area as being of **Moderate** status macroalgal biomass (see Table 3).

During 1994 all monthly samples in all 4 areas show macroalgae cover to be >25% (Figure 5). In 1995 mean cover at all 4 sites was > 25% during the period April – September, which encapsulates the growth period. In January and February of that year macroalgal cover was never absent. Similarly, during 1996 mean cover was >25% between April and September and was between 0 and 17% in January and February. Referring to the criteria scoring system cover of > 25% scores as 1, classifying the Kench as **Poor**.

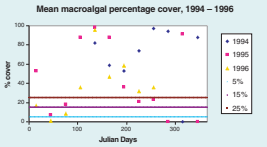

Figure 5: Macroalgae percent cover over 3 years, against Julian Days; for all sites at The Kench, Langstone Harbour (data from Pye, 2000). Blue line = 5% cover, maroon line = 15% and brown line = 25%.

When biomass (gm^{-2}) and cover (%) are taken in tandem and compared with Table 2, it is apparent that this area of Langstone Harbour would be classified as falling on the **Moderate/Poor** boundary.

In this instance information regarding adverse effects was not recorded. With such information a single definitive classification may be made for this area with increased confidence.

Discussion

All potential bloom-forming species are a natural component of shore ecosystems, which, under certain conditions, may become a nuisance. On rocky shores macroalgal opportunists like *Enteromorpha* may be abundant in the upper shore as they are euryhaline and able to cope with elevated salinity in top shore pools, and also with reduced salinity adjacent to freshwater inflows. They may also be abundant in areas of sand scour. In such cases their presence may be neither anthropogenic in origin nor deleterious. In soft sediment environments such as estuaries or lagoons, however, their presence as bloom-forming mats may be of nuisance proportions, indicative of anthropogenically elevated nutrient inputs. The ecological impacts can be highly variable. Assessing intertidal areas for opportunistic macroalgal blooms using a scoring system that combines 3 criteria provides increased confidence in the overall classification.

It is not expected that any single tool would be used in isolation to understand the ecology or to derive a classification, though initially the availability of data in the correct form is limited. Tools are being developed for other biological quality elements such as angiosperms, phytoplankton and perennial macroalgae. Together these form part of the biological quality elements' toolkit for establishing reference conditions, setting class boundaries and the classification of water bodies for the Water Framework Directive.

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