SENSITIVE SEAGRASSES AND THE EU WATER FRAMEWORK DIRECTIVE

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Introduction

The EU Water Framework Directive requires water bodies to be classified by their chemical and ecological status. The latter is principally a measure of the effects of human activities on water ecosystems. Of the biological parameters angiosperms (flowering plants) are one of the quality elements to be used in defining the ecological status of a transitional or coastal water body. The attributes to be monitored include taxonomic composition, presence of disturbance sensitive taxa and abundance. One of the key tasks in developing the classification systems for surface water bodies will be to identify appropriate reference conditions. Reference conditions are established from biological surveys and constitute an expectation of ecology found at reference sites; i.e. those relatively undisturbed by anthropogenic activity. Calculating the extent of a quality element's deviation from reference conditions provides an ecological quality ratio used to classify water bodies.

All UK seagrass (marine angiosperm) species are included in the UK Biodiversity Action Plan, 1994, and are considered nationally scarce, sensitive taxa. Seagrass beds characteristically comprise of one or two species supporting a highly diverse epifloral and faunal community.

A selection of tools has been identified for seagrasses based on those attributes that would describe or indicate the response of angiosperms to disturbance. Proposed tools are: **abundance**, measured as area cover and density; **taxonomic composition** and evidence of excessive opportunistic **algal cover**; and levels of **wasting disease** in sub-tidal species. The latter is an indicator of seagrass health may be an appropriate approach for monitoring existing seagrass beds and recognising early warning signs of disturbance so that remedial action may be taken.

Seagrass tools are presented here, with examples comparing monitoring data against the proposed classification schemes.

Ecological Status

- HIGH
- GOOD
- MODERATE
- POOR
- BAD

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

High status being defined as **no** or **minimal disturbance** to the biological elements

Good being slight disturbance

Moderate being moderate disturbance

Poor being major disturbance

Bad being severe disturbance

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.

Abundance: Distribution/area cover and density

Precise mapping of an area offers a means of obtaining evidence of natural or anthropogenically induced disturbances in time and space (Agostini *et al.*, 2002). Anthropogenic impacts can destroy or degrade seagrass beds, evidenced as spatial change in areal extent. Seagrass resources can be mapped using a range of approaches from *in situ* observation to remote sensing. The choice of technique is scale and site dependent and may require more than one approach at each site; for example ground-truthing of aerial photography.

Shoot density of seagrass responds faster than cover or biomass to changes in light and may be the most sensitive of seagrass abundance indicators (Krause-Jensen *et al.*, 2000). However, natural variability may be high in shallow water populations easily disturbed by physical parameters. Monitoring a seagrass bed's spatio-temporal changes in areal cover and changes in density will provide a more accurate and sensitive picture of growth or decline. As seagrass beds are highly responsive to their local hydrodynamic conditions it is more appropriate to consider spatio-temporal changes in a bed rather than to compare beds across sites. Table 1 interprets the definitions of Ecological Status into descriptors and ranges for the abundance tools.

The time frame to determine real changes brought about by human disturbance may take 5-10 years (Duarte & Kirkman, 2001) so long term annual monitoring is essential for accurately classifying ecological status. The Skomer example considers annual sampling and the Isles of Scilly example considers a 5-year rolling mean of shoot density to reduce noise in the data and identify underlying trends of change.

Table 1: Interpretation of Directive definitions into ecological status classes
NB: These ranges are subject to change when more data are available for tool testing

Angiosperm abundance: distribution/area cover and density					
Reference conditions	**Tool**	**High**	**Good**	**Moderate**	**Poor**
Bed at maxima of potential physical **extent** and **density** (allowing for natural variability), given the local climate, substrate and hydrodynamic regime. No evidence of direct anthropogenic impact.	*Annual change in seagrass bed extent.*	0% reduction of areal extent – evidence of seagrass bed at or close to maximum potential extent. No evidence of direct anthropogenic impact.	0% reduction of areal extent. Bed at less than maximum potential extent for local physical regime. No or minimal evidence of direct anthropogenic impact.	Disturbance evident: 15-25% loss of area covered compared with previous highest recorded areal extent. And/or evidence of direct anthropogenic impact	Seagrass bed size decrease by >25% compared with previous highest recorded areal extent. And/or evidence of direct anthropogenic impact.
	Change in shoot density or % leaf cover	Increased /unchanged abundance, (allowing for natural variability)	5–19% reduction (allowing for natural variability)	20–30% reduction (allowing for natural variability)	30% reduction (allowing for natural variability)

Example – Skomer Marine Nature Reserve (MNR), Pembrokeshire

Surveys were undertaken of North Haven sub-tidal *Zostera marina* bed, Skomer. Divers used boat cover and GPS systems for mapping the boundary of the bed (Figure 1). Shoot counts were conducted along 14 transects to create density contour maps (Figure 2). These results are presented in Table 2.

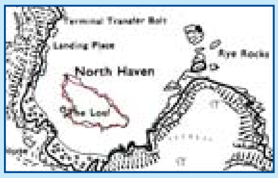


Figure 1: Z. marina bed boundary map, North Haven, 2000 and 2002 (2000 – black line, 2002 – red line) (reproduced from Lock, 2003 OS base maps reproduced with permission of HMSO. Crown copyright reserved. CCW licence No. GD272825G)

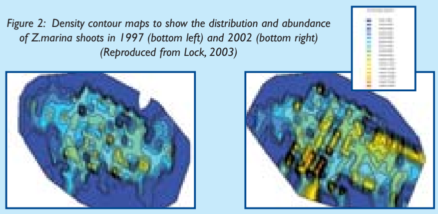


Figure 2: Density contour maps to show the distribution and abundance of Z.marina shoots in 1997 (bottom left) and 2002 (bottom right) (Reproduced from Lock, 2003)

Table 2: Z. marina bed areas 1982–2002 (Lock, 2003)

Year	*Area* (m^2)	*Anthropogenic Impacts*	*Shoot density* (m^{-2}) *Mean*	*Max.*
1982	5475	Anchorage unrestricted	–	–
1997	6771	No anchorage area established (1991) and provision of visitor moorings elsewhere.	36.2	104
2000	6979	Significantly reduced anchorage in the bed; however occasional anchored boats and lobster pots observed.	–	–
2002	7652 & 6700 (2 methods)	Restricted specimen collection.	54	156

Comparison of the spatio-temporal changes in areal cover and shoot density, and anthropogenic impacts with the descriptors in Table 1 classifies Skomer as being of **Good** ecological status.

Example – Isles of Scilly

From long-term data sets 5-year rolling mean calculations allow identification of underlying trends and may minimise noise from natural variability. Such an analysis has been performed on shoot density m^{-2} data from 7 Isles of Scilly *Zostera marina* beds monitored between 1993-2003 and results are presented in Figure 3.

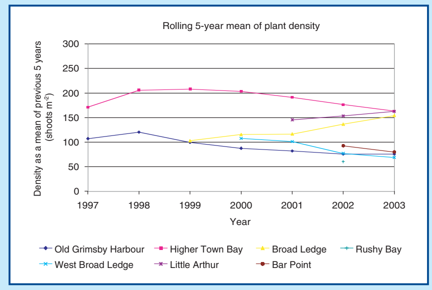


Figure 3: Shoot density in 7 Isles of Scilly beds as rolling 5-year means bed^{-1} (data from Cook, 2004)

Assuming the highest recorded density in each bed becomes the target reference condition the percentage gain/loss in shoot density can be used for classification as setout in Table 1. The classification of each site is given below. Bar Point, St Mary's is tentatively classified on the Good/Moderate boundary because the data set is much shorter than for other beds and underlying trends are not possible to identify.

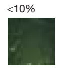
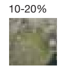
Site	% Change from previous highest density	WFD classification (based on Table 1)
Old Grimsby Harbour, Tresco	-37.04	**Poor**
Higher Town Bay, St. Martin's	-21.60	**Moderate**
Broad Ledge, Tresco	+50.04	**High**
West Broad Ledge, St. Martin's	-36.05	**Poor**
Little Arthur, Eastern Isles	+6.05	**High**
Bar Point, St. Mary's	-13.69	**Good/Moderate**
Rushy Bay, Bryher	Too sparse to record	**Poor**

Taxonomic composition and algal cover

The taxonomic composition of transitional waters and the presence of disturbance sensitive taxa in coastal waters are considered together. Seagrasses are naturally disturbance sensitive species as are the ecological communities dependent on them. Epiphytes inhabiting the exposed surfaces of seagrass blades are highly productive, constitute a valuable food source for herbivores and play an important role in the trophodynamics of seagrass communities (Pinkney *et al.*, 1998). The composition of a highly diverse seagrass community might include obligate species such as the hydroid *Laomedea angulata*, the algae *Rhodophysema georgii*, *Halothrix lumbricalis*, *Leblondiella densa*, *Myrionema magnusii*, *Cladosiphon zosterae*, *Punctaria crispata* and *Cladosiphon contortus*. Also the rare Foxtail stonewort (*Lamprothamnium papulosum*) is found in association with *Ruppia* spp. The presence of disturbance sensitive taxa and degree of species richness can be used to classify a water body's ecological status.

In disturbed conditions of elevated nutrient environments excessive growth of opportunistic algal species such as *Ectocarpus*, *Enteromorpha*, *Ulva* and *Chaetomorpha* can compromise the health and viability of seagrass acting as substrate, seemingly inhibiting or eliminating eelgrass (Kemp *et al.*, 1983; Dennison *et al.*, 1993). Algal competitors out-compete seagrass, shading and blanketing dependent species. This leads to reduced taxonomic diversity and change in composition towards greater opportunistic macroalgal species.

Table 3: Interpretation of Directive definitions into ecological status classes for taxon composition and epiphytic algal cover (images courtesy of Foden)
NB: These ranges are subject to change when more data are available for tool testing

Angiosperm taxonomic composition and epiphytic algal cover					
Tool	Reference Conditions	High	Good	Moderate	Poor
Taxonomic diversity and sensitive species	Taxonomic composition is undisturbed. All disturbance sensitive taxa present	No or minor changes in species richness/ composition	Slight decline in species richness and/or slight change in composition	Loss of sensitive species and moderate decline in richness. Change in composition	Loss of sensitive species and major change in composition
Mean opportunistic algal cover for bed.	<10% 	< 10% 	10-20% 	21-50 % 	51-80% 

Indicator of health: wasting disease

Wasting disease outbreaks throughout western Europe were widespread during 1920s and 1930s (Davison & Hughes, 1998). The disease appears as small black spots on seagrass leaves which may coalesce and finally cause death to the shoot (Burdick *et al.*, 1993). If infection is not severe the plant will remain viable and continue to grow. The slime-mould *Labyrinthula zosterae* has been identified as the causative pathogen (Muehlstein, 1989), and progression of the disease from oldest to youngest leaves in a shoot is illustrated in Figure 4. *Labyrinthula* does not generally cause disease in salinities <10 explaining why only sub-tidal *Z. marina* appear to be affected.

It is known that the quantity of *Labyrinthula* lesions can be used as a good indicator of the stress induced by the environmental conditions (Burdick *et al.*, 1993). Adverse conditions such as increased turbidity, low levels of insolation and raised temperatures during the growing season, cause weakening of the plants and make them susceptible to pathogens and secondary decomposers. Levels of wasting disease infection in a *Zostera* population are indicative of the suitability of the local environmental conditions for health and growth. The extent of infection on leaves can be classified using the Wasting Disease Index (Figure 5). Percentage infection is estimated for each leaf using the index key and interpolating if leaves appear to have a percentage of the disease between the numbers on the key. The percentage of infected area of each shoot's most infected leaf is estimated and averaged to obtain the Wasting Index.

Once the youngest or second youngest leaves in a shoot become infected at levels of 20-40% the plant usually dies (Burdick *et al.*, 1993). Older leaves are likely to have high levels of infection at this stage (e.g. >>40%). The interpretation of Wasting Index into WFD classification ranges is based on this research (Table 4).

Figure 4: Zostera marina infected with Labyrinthula zosterae. Progression of wasting disease in a typical eelgrass plant growing in high salinity Leaves are numbered (1=oldest), so that diseased areas may be traced over time (Burdick et al., 1993)

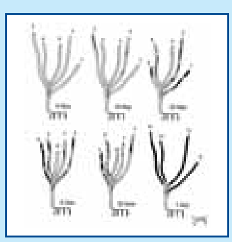


Figure 5: Wasting Index Key (Burdick et al., 1993)

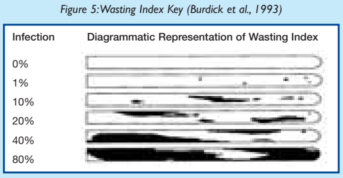


Table 4: Proposed Wasting Disease classification
NB: These ranges are subject to change when more data are available for tool testing

Angiosperm Wasting Disease Tool					
	Reference Conditions	High	Good	Moderate	Poor
Wasting Index bed^{-1} yr^{-1}	0: Absence of infection	0-10%	10-<20%	20-40%	>40%

Conclusion

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. Research is currently being undertaken to confirm the proposed classification ranges for each tool and as such they are subject to change. Together these tools 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.

Acknowledgements

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