AN APPROACH TO THE USE OF MACROPHYTES FOR MONITORING STANDING WATERS

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Introduction

Under the EC Water Framework Directive, each Member State is required to devise a comprehensive national monitoring programme for surface waters, incorporating hydromorphological, physico-chemical and biological elements. Monitoring programmes must be operational by 2006. This paper describes a method of using one aspect of the biota - the macrophyte flora - to classify standing waters and to monitor their water quality. The evolution of this method is described and suggestions for its future development are made.

British statutory conservation agency classification of standing waters

In 1989, records of aquatic macrophytes from over 1100 standing water sites throughout England, Wales and Scotland were subjected to Two-way Indicator Species Analysis (TWINSPAN) (Hill 1979). The sites included lakes, gravel pits, reservoirs, ponds and canals, about two thirds of them being Scottish lochs. The data had been collected over a period of a decade by Nature Conservancy Council (NCC) staff and other surveyors. In England and Wales, surveying had been intensive in some areas such as the English Lake District (Charter 1984) and the West Midlands (Wigginton 1989), but was selective and sparse elsewhere. The approach was more systematic in Scotland, where a large-scale stratified random sampling survey of lochs was under way.

Ten site types were identified and linked to the trophic status of the sites (Palmer et al. 1992), as indicated by pH, conductivity and alkalinity.

- Site Type 1 - dystrophic
- Site Type 2 - oligotrophic (often peaty)
- Site Type 3 - oligotrophic (usually rocky)
- Site Type 4 - mixed (oligotrophic and eutrophic elements - possibly mesotrophic)
- Site Type 5 - mesotrophic
- Site Type 6 - brackish lochs in Scotland

Site Type 7 - eutrophic (mainly northern)
Site Type 8 - eutrophic (emergent vegetation often richer than that of open water)
Site Type 9 - eutrophic (white and yellow water lilies dominate)
Site Type 10 - eutrophic *(Elodea* and *Chara* sub-types).

This classification has been used as a framework for the selection of Sites of Special Scientific Interest (Nature Conservancy Council 1989) and for categorizing standing waters surveyed since the analysis was performed.

Trophic Ranking Score (TRS) and its use in monitoring

The distribution of individual macrophyte taxa was analysed in relation to site type. 114 commonly recorded taxa were each given a 'DOME code' to indicate range of trophic tolerance, using the elements dystrophic, oligotrophic, mesotrophic and eutrophic (Palmer et al. 1992). A Trophic Ranking Score (TRS) for each taxon was derived from the DOME code by the following simple method:

Element of DOME code	Score
D = strongly associated with dystrophic waters	1
d = weakly associated with dystrophic waters	2
o = weakly associated with oligotrophic waters (linked with D or d)	3
O = strongly associated with oligotrophic waters	4
o = weakly associated with oligotrophic waters (linked with M or m)	5
m = weakly associated with mesotrophic waters (linked with 0 or o)	6
M = strongly associated with mesotrophic waters	7
m = weakly associated with mesotrophic waters (linked with E or e)	8
e = weakly associated with eutrophic waters	9
E = strongly associated with eutrophic waters	10

For the pondweed *Potamogeton gramineus:*

DOME code oME

TRS $\frac{5 + 7 + 10}{3} = 7.3$

All scoring species present in a waterbody are recorded and the mean TRS for the site is calculated. The scheme can be used for monitoring because a change in the plant assemblage of a site in response to nutrient enrichment or acidification is reflected in a shift in mean TRS. The mean TRS can be calculated for parts of sites as well as whole sites, so the scheme can be used to indicate differences in water quality in separate areas of a single waterbody and thus to indicate possible sources of pollution.

Mean TRS is easy to apply. A refined TRS scheme could be used as a simple 'early warning' system or as one element in a multimetric approach to monitoring water quality. This would include the use of a range of bio-indicators, water chemistry and/or palaeolimnology, as recommended in reports commissioned by the Environment Agency (Johnes et al. 2000; Biggs et al. 1998) and the Countryside Council for Wales (Monteith 1997). A modified version of TRS, verified against conductivity and nitrogen, is incorporated in a proposed scheme for the classification of lake water quality (Johnes et al. 2000). The Predictive System for Multimetrics (PSYM) (Biggs et al. 1998), being developed for standing water quality assessment, uses the TRS scheme as one of the metrics (J. Biggs, personal communication).

A similar scheme using macrophytes (Environment Agency 1999) is now in use for monitoring rivers under the Urban Waste Water Treatment Directive. Individual macrophyte taxa have been given a Species Trophic Rank (STR). Stretches of river upstream and downstream of sewage outflows are surveyed and the abundance of all scoring species is recorded. The STRs are weighted for abundance and the mean score is calculated for the stretches of river. There is a significant correlation between STR and TRS (Fig. 1).

A mean TRS can be calculated for areas (e.g. 10 x 10 km grid squares) as well as sites. Using aquatic plant records from the Biological Records Centre database at the Centre for Ecology and Hydrology, Monks Wood, a mean TRS can be calculated for each 10 x 10 km square in Britain. The country can then be divided into mean TRS bands (Palmer & Roy 2001). The bands are clearly related to geology and topography, with the upland areas of Britain having a mean TRS less than 7, most of the lowlands scoring 8 or more and intermediate altitudes generally scoring 7 to 8. However, certain places in southern England, such as the New Forest and other heathland areas, are distinguished from the surrounding land by having lower TRS values. The map of TRS bands is very similar to that for critical loads of acid deposition in fresh waters (Critical Loads Advisory Group 1995). TRS bands provide a context for individual site values, although some TRS bands are more heterogeneous than others. If a site has a mean TRS outside the predicted natural range for an area, this could be an indication of eutrophication or acidification.

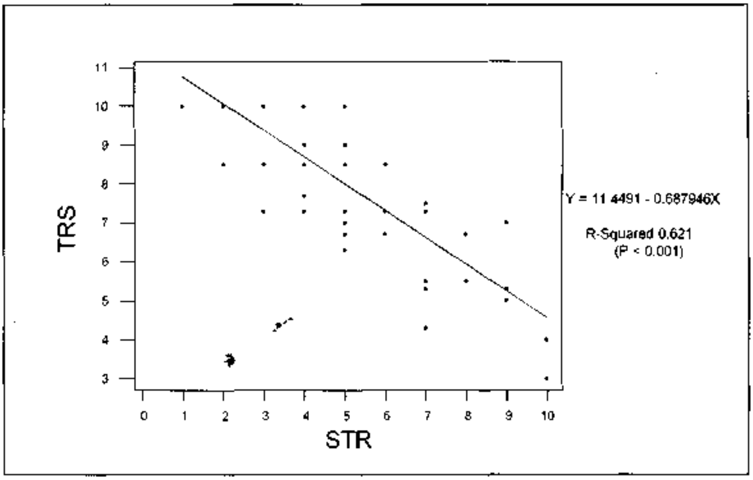

FIG. 1. Relationship between Trophic Ranking Score (TRS) and Species Trophic Rank (STR).

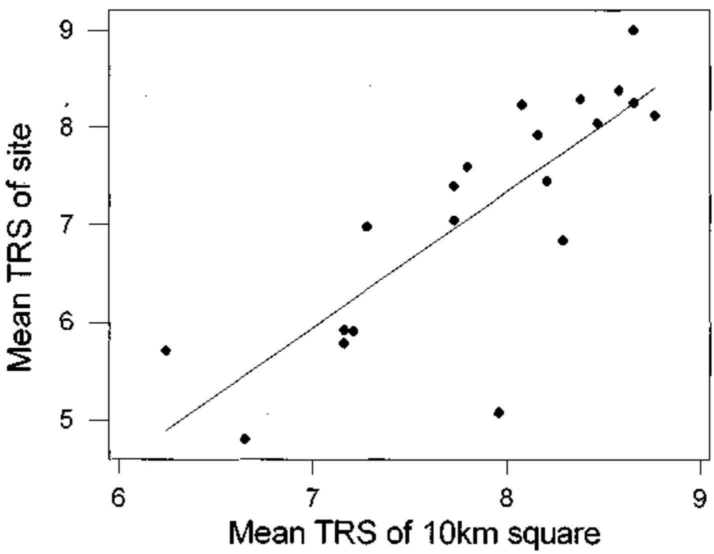

FIG. 2. Relationship between mean Trophic Ranking Scores of twenty standing waters in England and mean TRS of the 10 x 10 km grid squares in which they are situated; $R^2 = 0.64$ (P<0.001).

Fig. 2 shows the relationship between the mean TRS of sites and the 10 x 10 km squares in which they are situated, using data from 20 lakes, tarns and ponds distributed throughout England. According to the NCC standing waters classification, one of these sites is dystrophic, seven are oligotrophic, two are mesotrophic and ten are eutrophic.

Development work needed in order to make a TRS scheme suitable for monitoring standing waters under the EC Water Framework Directive

Since 1989, the Scottish botanical loch survey (Lassiere 1995) has accumulated a large amount of information, so data from 3250 lochs are now held on a Scottish Natural Heritage database. A new analysis of the macrophyte flora from about 3500 standing waters in Scotland, Wales and England is to be undertaken by the conservation agencies. If links can again be established between species occurrence and trophic status, DOME codes could be revised and TRS values refined. A revised scheme could be extended to cover the whole of the UK by incorporating data from the Northern Ireland lake survey and classification (Wolfe-Murphy et al. 1992).

Macro-algae need to be more fully incorporated into the TRS scheme. At present, charophytes are included only at generic level and other algae are not scored. Most charophytes are indicators of good water quality. Many specimens from the conservation agency surveys have now been identified to species level, so it should be possible to allot scores to a number of stonewort species. The inclusion of macro-algae such as *Enteromorpha, Cladophora* and *Vaucheria,* if only at generic level, would help the scoring system to distinguish highly eutrophic sites, where aquatic vascular plants and charophytes may be absent. Of the bryophytes, only *Fontinalis antipyretica* and *Sphagnum* sp. are included in the scheme, and ideally the range of mosses should be extended.

The use of quantitative records (rather than presence/absence) should be investigated. It is not clear whether the added effort of collecting and applying quantitative records would be justified by producing greater accuracy in monitoring. Although there is a DAFOR rating (Dominant-Abundant-Frequent-Occasional-Rare) for most of the records accumulated by the conservation agencies, there is no standardised approach to using this scale. Other past records from standing waters may have no abundance rating, so they would be difficult to use in establishing baselines, should a quantitative TRS scheme be adopted.

The revised TRS scheme should be reference-based, to enable the degree of departure from pristine or near pristine water quality to be measured. This is a two-stage process, involving the establishment of a series of reference sites, and giving trophic and geographical contexts to site TRS values.

A series of reference sites can be established by taking a suite of sites with botanical data and using a hindcasting method, for instance that used by the Scottish Environmental Protection Agency or the one described in Johnes et al. (2000), to establish the original water quality, with reference to standards laid down by the OECD (OECD 1982). The mean TRS of sites that are shown to be minimally impaired can then be used as a standard against which to measure the mean TRS of other sites that may have been damaged through eutrophication or acidification.

In order to compare like with like, it would also be necessary to establish the natural trophic category of a site being assessed, so that an enriched mesotrophic site, for instance, is not included in the same category as naturally eutrophic sites. The range of site types and site TRS within each TRS band in Britain needs to be investigated. Within the framework of the TRS bands and trophic categories, reference sites and standards for unpolluted waters could be determined and acceptable amounts of deviation from this norm could be established. The TRS bands could perhaps be used to define British 'ecoregions', within which individual standards would apply.

Fig. 3 shows the relationship between mean TRS of sites and mean TRS of 10 x 10 km squares, as in Fig. 2, but this time only data for the eutrophic and oligotrophic sites are used and these two categories are dealt with separately. It is known that some of these sites are enriched and it is suspected that at least one is acidified. Their current condition cannot be assessed using TRS without reference to regression lines based on a series of unimpaired sites.

The possibility of integrating the TRS and STR schemes should be examined, bearing in mind that different suites of species are present in rivers and lakes, also that the nutrient requirements of a single species may be different in lake and river situations. As the Urban Waste Water Treatment Directive river monitoring system is quantitative, it may be necessary to evolve a quantitative TRS scheme for the sake of compatibility. A single scheme for lakes and rivers, or at least some way of relating the two schemes, would be of greater use than two completely separate schemes when planning for whole catchments, as is required under the Water Framework Directive.

Any revised TRS scheme would need thorough testing in the field or on existing British data, as has been done with the Urban Waste Water Treatment Directive monitoring method. There is also the possibility that the TRS scheme could be extended to other European countries. All that is needed to give a species a TRS is to know its trophic range (i.e. its DOME code) within any country or region.

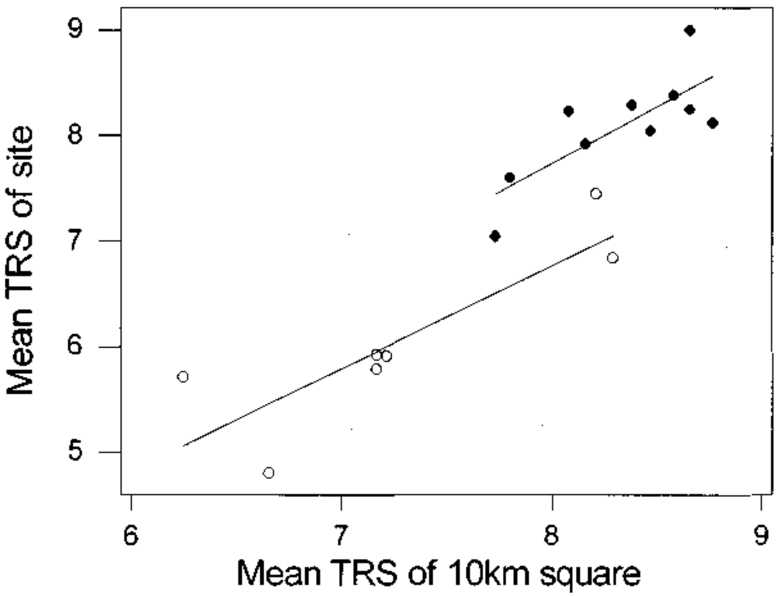

FIG. 3. Relationship between mean Trophic Ranking Scores of 17 eutrophic and oligotrophic sites in England and mean TRS of the 10 x 10 km squares in which they occur. Solid circles, eutrophic sites; $R^2 = 0.56$ ($P<0.01$). Open circles, oligotrophic sites; $R^2 = 0.68$ ($P<0.05$).

Other important considerations for monitoring the macrophyte flora

The TRS scheme can be of use in classifying waters and in monitoring water quality. However, there are other important features of the macrophyte flora that should be taken into account when making a comprehensive ecological assessment of the condition of standing waters (Palmer 1998). These aspects include species richness, the presence and abundance of rare species, vegetation structure (e.g. hydrosere development) and invasion by non-native species.

Conclusion

The Trophic Ranking Score system for macrophytes is potentially a useful tool for monitoring the water quality of lakes and other bodies of standing water. However, the TRS method needs some development and further testing before it can be used for the Water Framework Directive. In particular, reference data are required to facilitate comparison with a minimally impaired baseline condition and to set targets for improvement.

Acknowledgements

Fig. 1 is reproduced, with the permission of the Joint Nature Conservation Committee, from Palmer, M. A. & Roy, D. B. (2001): *An estimate of the extent of dystrophic, oligotrophia, mesotrophic and eutrophic standing fresh water in Great Britain.* JNCC Report No. 317. Joint Nature Conservation Committee, Peterborough. I am grateful to David Roy for producing Figs 2 and 3.

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References

Biggs, J., Whitfield, M, Williams, P., Corfield, A., Fox, G. & Adare, K. (1998). *Biological techniques of still water quality assessment: Phase 2. Method development.* R&D Project i642. Environment Agency, Bristol.

Environment Agency (1999). *Mean Trophic Rank: a user's manual.* Research and Development Technical Report E38. Environment Agency, Bristol.

Charter, L. (1984). *A survey, classification and evaluation of small open waters in Cumbria.* Unpublished MSc Thesis. University College, London.

Critical Loads Advisory Group (1995). *Critical loads of acid deposition for United Kingdom freshwaters.* Institute of Terrestrial Ecology, Edinburgh.

Hill, M. O. (1979). *TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Ecology and Systematics, Cornell University, Ithaca, New York.

Lassiere, O. (1995). *Botanical survey of Scottish freshwater lochs.* Information and Advisory Note No. 4. Scottish Natural Heritage, Edinburgh.

Johnes, P. J., Curtis, C, Moss, B., Whitehead, P., Bennion, H. & Patrick, S. (2000). *Trial classification of lake water quality in England and Wales: a proposed management strategy.* Research and Development Technical Report E53. Environment Agency, Bristol.

Monteith, D. T. (Editor) (1997). *Integrated classification and assessment of lakes in Wales: Phase IV - Final Report.* CCW Science Report No. 214. Countryside Council for Wales, Bangor.

Nature Conservancy Council (1989). *Guidelines for selection of biological SSSIs.* Nature Conservancy Council, Peterborough.

OECD (1982). *Eutrophication of waters. Monitoring, assessment and control.* Organisation for Economic Cooperation and Development, Paris.

Palmer, M. A., Bell, S. L. & Butterfield, I. (1992). A botanical classification of standing waters in Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems* 2, 125-143.

Palmer, M. A. (1998). *SESWACON: System for evaluating standing waters for conservation. Version I manual.* Scottish Natural Heritage, Edinburgh.

Palmer, M. A. & Roy, D. B. (2001). A method for estimating the extent of standing fresh waters of different trophic states in Great Britain. *Aquatic Conservation: Marine and Freshwater Ecosystems* (in press).

Wigginton, M. (1989). *Survey of Shropshire and Cheshire meres, 1987.* England Field Unit Report No. 59. Nature Conservancy Council, Peterborough.

Wolfe-Murphy, S. A., Laurie, E. W., Smith, S. J. & Gibson, C. E. (1992). *The Northern Ireland lake survey. Part 3. Lake classification based on aquatic macrophytes.* Department of the Environment and Queen's University, Belfast.