science summary

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Risk Assessment Methodology for Determining Nutrient Impacts in Surface Freshwater Bodies

Science Summary SC020029/SS

The Water Framework Directive (WFD) requires Member States to review the environmental impact of human activity on the status of their water bodies (Article 5). As part of this review, information must be collected on the type and magnitude of significant pressures to which surface waters are exposed. Also, on the basis of the characteristics, or susceptibility, of water bodies to these pressures, an assessment must be carried out of the risk that water bodies will fail to meet the WFD's objective of achieving 'good status'.

This project's aim was to develop a method to carry out the initial risk assessment for lakes, specifically in relation to nutrient pressures. Approaches of increasing sophistication were developed to assess the size of diffuse and point-source nutrient pressures. A nutrient classification for different lake types was produced to assess the impact of these pressures. Approaches to ecological classification for phytoplankton composition and abundance in lakes and slow-moving rivers were also developed, taking phytoplankton as the biological element most sensitive to nutrient pressures.

To develop the nutrient (total phosphorus (TP)) classification, reference conditions were determined first. Five approaches to identify site-specific reference conditions were examined and reference conditions specific to each lake ecotype developed for risk assessment. The analysis highlighted distinct differences between different lake types - the lowest reference TP concentrations were determined for deep, low alkalinity lakes whereas the highest were for very shallow high alkalinity lakes.

TP concentrations were derived for boundary values of the five WFD status classes (high, good, moderate, poor, bad) for each lake ecotype, with the good–moderate boundary set to represent a doubling of reference concentrations. Any sites observed or predicted to have TP concentrations higher than this boundary would be considered as not achieving good status (i.e., at risk of failing the WFD quality objectives).

Relationships between observed in-lake concentrations of TP and phytoplankton chlorophyll$_a$ were explored for each lake ecotype, to develop an appropriate classification for phytoplankton abundance. In general, there was no significant difference in the response between different lake ecotypes, either in relation to depth or alkalinity type. A TP–chlorophyll$_a$ relationship specific to all Great Britain (GB) lakes was calculated, potentially to derive chlorophyll$_a$ reference conditions. Alternative approaches to developing chlorophyll targets for lake types, independent of TP, were also developed, but require further development and validation before they can be applied to risk assessment.

A novel approach to an ecological classification of the phytoplankton community structure was developed using phytoplankton functional groups. Morphological or physiological characteristics of phytoplankton taxa were used to populate the phytoplankton functional groups. This project developed probabilities for the occurrence of these functional groups in different lake and river types with increasing trophic status at different times of the year or, for rivers, in different flow regimes. A WFD-style assessment of ecological status is possible by comparing the similarity of observed phytoplankton assemblages with that of a pre-determined reference assemblage. This approach applied to Windermere suggests that the phytoplankton classification effectively represents the changing ecological impact associated with changing nutrient loading to the lake. The classification structure and its application to a number of lake ecotypes, however, must be validated more widely before it can be adopted nationally for WFD purposes.

The assessment of P pressures from point sources considered three types: sewage treatment works (STWs), septic tanks and cage fish farms. Inputs from the first were thought to be relatively well understood, but a review of the methods and data available showed this not to be so. The numbers of people served by STWs are poorly known (only design capacity is readily available), and also

the P export coefficients for humans after sewage treatment are not well defined. The TP load from septic tanks is also difficult to evaluate separately from that which emanates from STWs because the number, location and level of maintenance of private septic tanks is unknown. Given these uncertainties, an average TP export coefficient value for humans is recommended for the initial risk assessment, applicable to either secondary sewage treatment or treatment through a septic tank system. The TP load from fish farms can be assessed for locations where the type of fish cultured and the annual tonnage produced are known. At present, these data are incomplete for Scotland and unavailable for England and Wales. A database needs to be compiled that contains location, size (e.g., consented biomass) and fish species data for all fish farms in GB to allow TP loads from these systems to lakes to be evaluated properly.

The assessment of diffuse P pressures for a water body considered three approaches of increasing sophistication. A basic 'risk screening' approach (tier 1), applicable to all GB lakes, uses export coefficient values based on land cover and animal stocking data. A slightly more sophisticated approach, the Pressure Delivery Risk Screening matrix (PDRS; tier 2), links estimates of P pressures associated with agricultural activity with characteristics of the catchment that indicate the likelihood of nutrients reaching a water body. A third modelling approach (tier 3), the Phosphorus Indicators Tool (PIT), has three layers: (1) P loss-potential from agricultural activities, (2) P transfer pathways in the catchment and (3) P delivery. Both an uncalibrated version of PIT applicable at a national scale (tier 3a) and a site-specific calibrated version of PIT (tier 3b) were evaluated. Comparisons of measured and modelled data for 50 test lakes suggest the tier 1 approach to be relatively consistent for general risk assessments across the whole of GB. The tier 2 approach, however, is recommended as a national tool for an assessment of pressures only. The tier 3a and 3b approaches provide much more detailed site-specific methods for understanding the main sources and pathways of nutrients within a catchment. To date, coefficients within the PIT model have been calibrated for the Windermere, Slapton Ley, Esthwaite Water, Barton Broad and Blelham Tarn catchments.

An initial risk assessment using the recommended guidance for a tier 1 approach was carried out for all the lakes in Great Britain >1 hectare in size (over 14,000 lakes). Overall, 51 percent of sites are predicted to not meet the TP targets identified for high or good status and must be considered at risk. Of the six lake ecotypes examined, very shallow, medium alkalinity lakes appear to be at greatest risk (92 percent of GB sites). Major regional differences are that Scotland has by far the fewest sites at risk (18 percent), England by far the most (88 percent), and Wales an intermediate number (56 percent). A large number of sites were identified as 'unknown' status, mainly peaty lochs in Scotland. Probably most of these are not at risk from nutrient pressures, being in the more undisturbed parts of northern Scotland. Further work is required not only to establish reference nutrient conditions for peaty, marl and brackish lake ecotypes (so their nutrient classification can be developed), but also to improve our understanding of the ecological impact of nutrient pressures in these lake types.

An initial validation of the approach was carried out on 50 well-studied test lakes to examine whether the GB-wide results can be taken as representative. Expert opinion on the project team was generally in agreement with the predicted status classes for the test lakes. It appeared to identify sites generally considered of high (Loch Ness) or good (Loch Lomond) status, those around the good–moderate boundary (Loch Leven, Loweswater, Malham Tarn), those for which there exists some concern (e.g. Esthwaite Water and Loch Earn) and sites clearly of poor or bad status (Rostherne Mere and Marsworth Reservoir). A few sites were predicted as not at risk, when observed data actually suggest they are at risk. This also supports the recommendation that all 'important' sites are automatically selected for further investigation or operational monitoring. Likewise, representative sites predicted to be near the good–moderate class boundary should be selected for further investigation.

The findings of this research confirm that a large number of lakes in GB are at risk from P pressures. The risk assessment process is, however, the first step only in a tiered process to identify sites at risk. Those identified require further investigation, both monitoring and modelling, using the more sophisticated approaches outlined in the report. The 2004 risk assessment is also the first stage in delivering an improved management of water resources through the WFD. Later stages deal with how we manage these risks at both a national and local scale. More sophisticated approaches to both the assessment of pressures (e.g. tier 3b PIT) and the assessment of impact (e.g. metabolic models) are necessary for this.

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