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USE OF FIELD DATA TO DERIVE AN ENVIRONMENTAL QUALITY STANDARD FOR IRON IN FRESHWATERS

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Abstract

There are considerable uncertainties surrounding the relevance and reliability of laboratory ecotoxicity data for iron. However, there is a body of "matched" environmental monitoring data for both iron exposure and ecological quality for England and Wales. Iron may therefore be a case in which field evidence is critical for the derivation of an Environmental Quality Standard (EQS). In addition, field based approaches may be better than laboratory ecotoxicity testing when assessing a combination of both toxic and physical effects on organisms (e.g. smothering). Matched ecological quality and chemistry data from throughout England and Wales were analysed to assess the effects of iron on freshwater ecosystems. Ten macroinvertebrate taxa were identified as being potentially sensitive to total iron exposure. A quantile regression of the abundance of these taxa in response to increasing total iron concentrations suggests that total iron may need to be below 0.5 $mg\ l^{-1}$ in order to protect the most sensitive members of benthic macroinvertebrate communities.

Introduction

Iron has a potentially complex chemistry in freshwaters, due to the oxidation of Fe(II) to Fe(III), and the precipitation of Fe(III) to form colloidal or fine particulate material. In addition, iron may interact with dissolved organic carbon (DOC), either by direct binding of free Fe ions or through associations between DOC and precipitated forms of iron. Many historic ecotoxicity tests are considered to have tested the "toxicity" of a suspension of precipitated material, and often have limited detail on the actual exposure conditions. This means that most of the available test data are rather uncertain in relation to the potential for either toxicity or adverse effects due to precipitated material (e.g. smothering by precipitated iron oxide) [2]. Despite this, iron has been designated as a Specific Pollutant in England and Wales under the Water Framework Directive (WFD), which requires that an EQS for freshwaters is derived.

The current (draft) EU guidance for EQS derivation [1] indicates that field data will rarely be used to derive an EQS directly. However, given the uncertainties surrounding the relevance and reliability of the available laboratory ecotoxicity studies for iron, and the fact that a considerable body of monitoring data exists in England and Wales for both iron exposure and ecological quality, iron may be a case in which field evidence is critical for the derivation of an EQS. In addition, field based approaches may be better than traditional laboratory ecotoxicity testing when accounting for a combination of both toxicity and indirect physical effects on organisms.

Approaches have been proposed for the derivation or validation of EQS on the basis of ecological field data, most commonly for benthic invertebrates [3]. These approaches typically consider changes in benthic invertebrate assemblages and relate them to concentrations of contaminants in order to identify a contaminant concentration which is consistent with the protection of these ecological communities.

A variety of "reference based" tools for ecological assessment have been developed in England and Wales in recent years for use in assessment of surface water status, as required by the WFD. These tools include those for determining the ecological quality of benthic macroinvertebrates (RIVPACS/RICT), phytobenthos (DARLEQ), macrophytes (LEAFPACS), and fish (FCS2). Reference-based ecological assessment tools measure the quality of a site by comparing the difference between the observed assemblage and the assemblage which would be predicted to occur at a given site under "reference" (unimpacted) conditions. This is either in terms of presence or absence of taxa, abundance of taxa, or some other summary metric (e.g. number of taxa found). This deviation can be summarised as an Observed (O) to Expected (E) ratio, where values greater than one are indicative of an ecological assemblage close to reference conditions. In addition, specific ratio thresholds less than one have been established for each assessment tool, which are consistent with WFD definitions of High, Good, Moderate, Poor, and Bad ecological status.

Methods

Datasets of "matched" iron and ecological monitoring data were provided by the Environment Agency of England and Wales. Where possible, data for individual taxa were assessed in addition to whole community metrics.

Quantile regression analysis has recently been successfully applied to the analysis of data of this type. The quantile regression approach considers a limiting function and is particularly useful in instances such as these where it is not possible to remove all of the potentially confounding factors (e.g. the influence of chemicals other than iron on ecological response) [4]. The approach for this study is similar to that applied in previous assessments of field data [3].

The principle of the quantile regression approach to derive a limiting function is shown in Figure 1. Data with unimpacted responses at low exposures serve as controls, and impacted data at low exposures are effectively not considered in the analysis. A decline in the maximum response with increasing exposure is interpreted as due to the contaminant of interest.

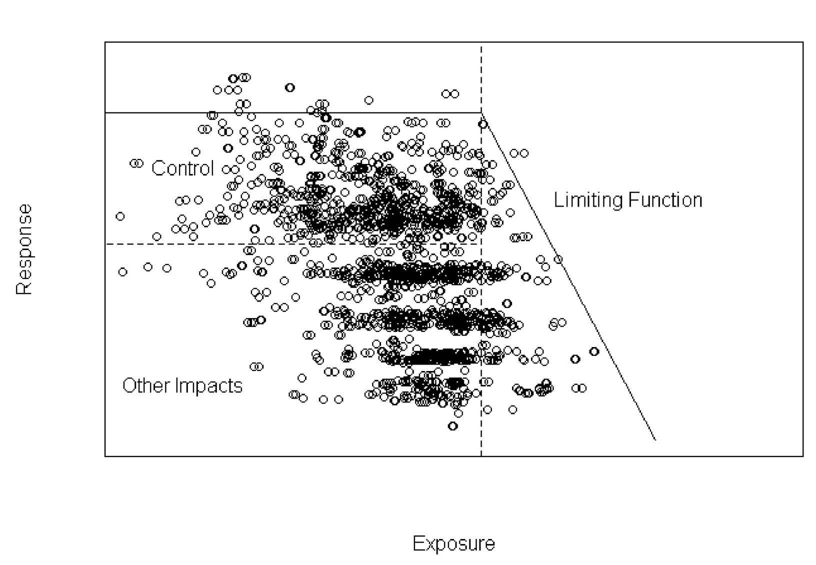

Figure 1. Interpretation of combined chemical and ecological field data.

Identification of Sensitive Taxa

Potentially sensitive taxa were identified by calculating Observed to Expected ratios for the presence or absence of each taxon at each site, and selecting those taxa with the lowest average O/E values, corresponding to the highest quartile of the total iron exposure data (total iron concentrations greater than 0.8 $mg\ l^{-1}$). In addition to presence/absence data, the O/E values based on taxon abundance were also calculated. This was done to assess whether taxon abundance was a more sensitive endpoint on which to base assessments, compared with presence or absence only.

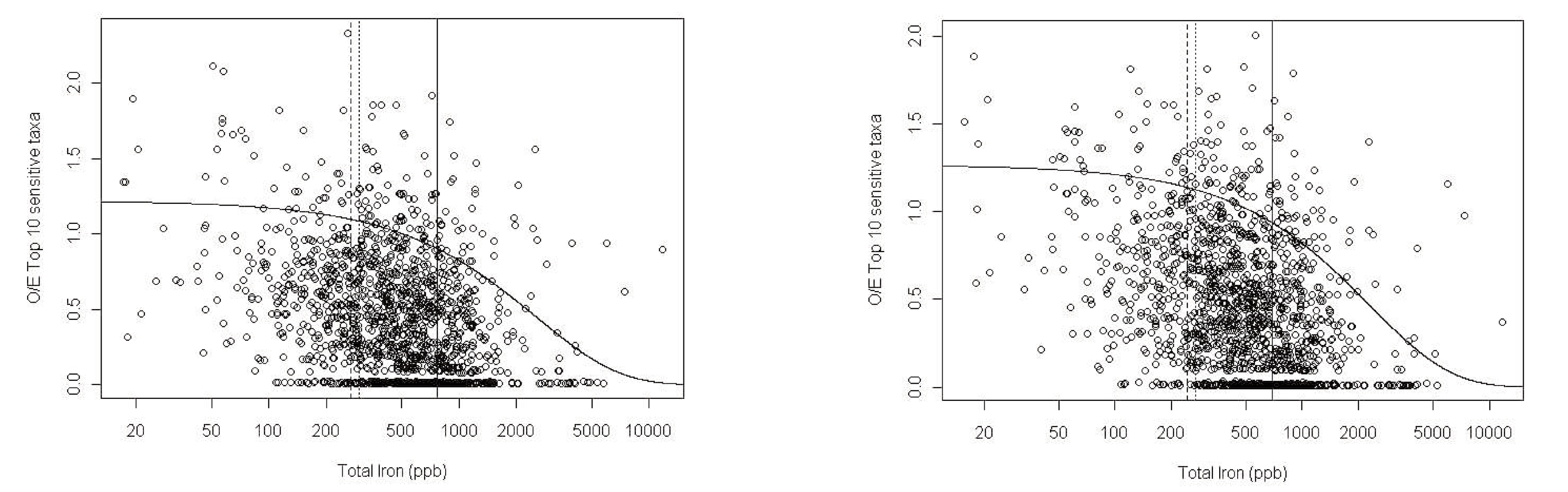

Figure 2. Abundance of the 10 most sensitive benthic macroinvertebrate taxa in Spring (left) and Autumn (right), vertical lines indicate the EC10 (dashed), High-Good status boundary (dotted), and Good-Moderate status boundary (solid).

Analysis using established WFD Ecological Thresholds

Performing analyses to derive thresholds for iron which are aligned with established ecological quality boundaries under the WFD should enable a better degree of comparability between direct measures of ecological quality and quality assessed as compliance against chemical standards. If chemical standards are not aligned to the ecological boundaries there is the potential for a mismatch between the different indicators of "ecological quality".

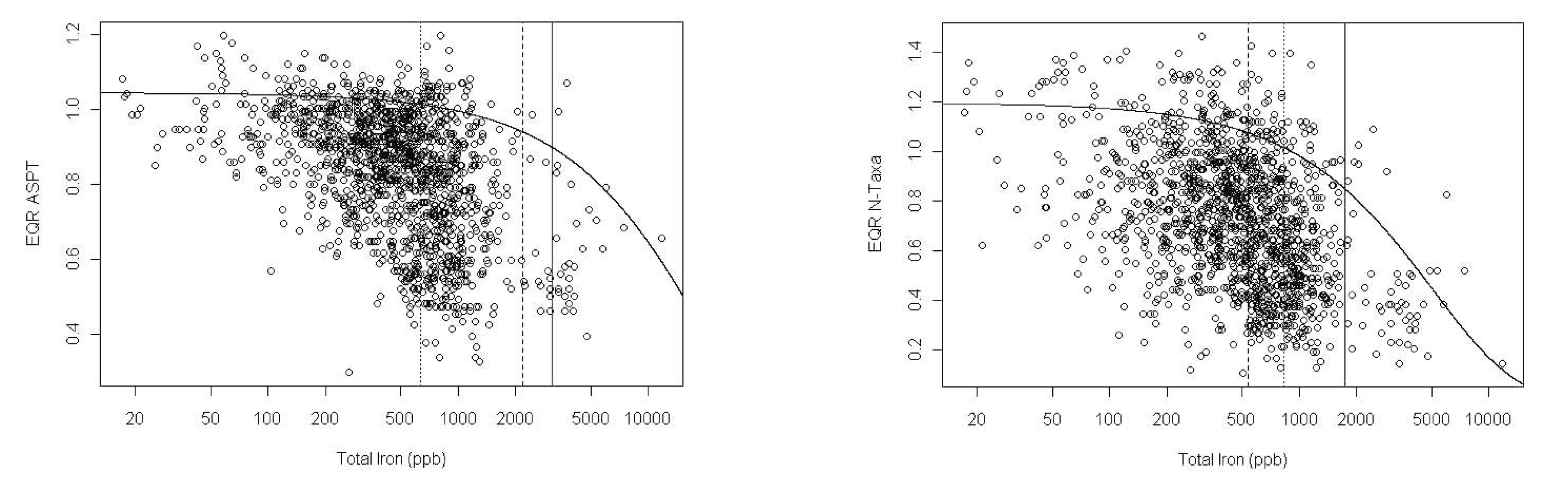

Figure 3. Response of whole community metrics (ASPT and N-taxa) for invertebrates to iron exposure, vertical lines indicate the EC10 (dashed), High-Good status boundary (dotted), and Good-Moderate status boundary (solid).

Conclusions

This project has focused on the use of field data with matched monitoring for both ecology and chemistry. These datasets have been used to derive thresholds for iron concentrations which are consistent with the ability of benthic macroinvertebrate communities to achieve particular predefined Ecological Status objectives under the WFD.

Analyses of data for fish, macrophyte, and diatom communities did not show any statistically significant decline in the maximum achievable ecological quality with increasing total iron exposures (i.e. they were not apparently as sensitive as macroinvertebrates). Assessments based on benthic macroinvertebrate communities did show a statistically significant decline in ecology quality with increasing total iron concentration, and thresholds have been derived on both a whole community basis, for direct comparison with ecological quality standards, and also for the most sensitive fraction of the community. Thresholds have been derived for the boundary between High and Good ecological status (HGB), the boundary between Good and Moderate ecological status (GMB), and also for a 10% effect level (EC10). These analyses suggests that total iron may need to be below 0.5 $mg\ l^{-1}$ in order to protect the most sensitive members of benthic macroinvertebrate communities. DOC appears to reduce the effects of iron on benthic invertebrates; further investigation may enable site-specific standards to be developed so that the most sensitive sites can be readily identified.

References

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