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Simplicity is the ultimate sophistication: Building capacity to meet the challenges of the Water Framework Directive

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ABSTRACT

The Water Framework Directive (WFD) embodies concepts of "ecological health". This essay extends this metaphor, looking at the ways in which ecologists should diagnose and treat "sick" ecosystems. Recent practice in the UK has been to develop multifunctional ecologists to act as ecological equivalents of "family doctors". This requires methods that can be used without high levels of specialisation and, in turn, allows individuals to gain deep knowledge of particular geographic areas. This system is under threat both from new scientific developments and from management innovations designed to reduce costs. The next stages of WFD implementation, however, will see a shift towards locally based problem-solving, where inherent uncertainties will require the exercise of professional judgement above and beyond evidence-based science. We need to encourage "breadth" as well as "depth" in ecological assessment methods and a three-tiered framework for this is described.

1. Introduction

The decade since the adoption of the Water Framework Directive (WFD: European Union, 2000) has seen a huge amount of effort devoted to the development of new methods for ecological assessment. This has included both defining the "expected" state of freshwater ecosystems (Pardo et al., 2012) and methods for measuring the deviation of biota from this ideal state (summarised in Birk et al., 2012). The outcome is a comprehensive suite of methods that permits the condition of all water bodies from the Arctic to the Mediterranean to be evaluated. Many questions and challenges remain (see Hering et al., 2010); one that looms large is how the outputs from this huge body of research can best be used to drive improvements in the quality of Europe's surface waters, towards the WFD's key objective of "good ecological status".

Monitoring implies capacities to hindcast, forecast and, crucially to act (an ecosystem was once pristine, is now impaired and, if appropriate measures are taken, will return to being only slightly different to this pristine state . . .) However, most of the research summarised in Birk et al. (2012) is based on spatial surveys, deriving relationships between ecological parameters and pressures, and therefore requires a spatial-temporal substitution (Pickett, 1988) to be made i.e. that the patterns observed in space will translate into patterns observed over time. It should be possible, for example, to use the relationship between chlorophyll concentration and total phosphorus (TP) derived from a dataset of lakes to set a target concentration of TP for any impacted lake, to invest money and effort in reducing TP inputs to the catchment, and to expect to see a shift in the chlorophyll concentration as a result. The reality is that such assumptions are sometimes justified (Sas, 1989) but often prove to be more complicated (Phillips in Harper, 1992; Jeppesen et al., 2005; Harris and Heathwaite, 2012). However, for many ecosystems, pressures and biological parameters, such assumptions have not yet been tested critically.

Yet the drive to improve the state of Europe's waters lies at the core of the WFD. Such improvements will require large-scale investment in water quality treatment, possibly leading to higher costs for households and businesses. This is taking place during a period of economic uncertainty in Europe, meaning that governments and the public will expect to see tangible benefits from this investment. A key challenge for the next decade is finding ways of integrating assessment methods into the organisations responsible for delivering improvements in environmental quality, to ensure that decisions are based on reliable ecological evidence.

This essay starts by looking at an example of how ecology has been integrated into water quality regulation over a 25 year period in the UK, in order to draw some lessons that may be more widely applicable for WFD implementation. It then goes on to look at some challenges facing this system. These challenges are, mostly, non-scientific, reflecting trends in public sector management more generally, but failure to recognise these may undermine the ability of ecologists to inform decision-making. My argument is that many papers on monitoring and assessment in Europe (and beyond) fail to consider the broader context within which these activities take

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place. Ensuring a good "fit" between ecological methods and the institutions and legal frameworks within which they function is essential if ecology is to play an effective role in water management. The WFD also encourages public participation in decision-making (Article 14) and, again, ecological methods need to be considered in terms of how they can be used to communicate to non-technical stakeholders as well as their ability to reflect pressure gradients.

2. Case study: the River Team, north east England

Invertebrate-based monitoring has been used widely in the UK since the 1960s. Though there were fewer legislative drivers before the WFD, the information derived from invertebrates complemented chemical monitoring and provided insights that would otherwise have been missed. The River Team is a tributary of the River Tyne which flows across a densely populated area of County Durham and Tyne and Wear in north-east England receiving a variety of inputs including sewage works, industrial plants and abandoned mine workings. Consequently, it is a good example of the UK approach to biological monitoring in practice.

Invertebrates have been sampled regularly here since the 1970s. From about 1980 a consistent approach to sampling and data analysis has been in place, with family-level data used to calculate the Average Score Per Taxon (ASPT: Fig. 1), derived from the Biological Monitoring Working Party (BMWP) score (Armitage et al., 1983; Hawkes, 1997). This is a measure of organic pollution and general degradation and is incorporated into the UK's WFD assessment system. A predictive model derived from RIVPACS (Wright et al., 1989) is used to calculate the expected ASPT (dashed line on Fig. 1). Fig. 1 shows a gradual increase in ASPT over a 20 year period and is underpinned by a number of aspects of good practice:

1. The ASPT is based on a good understanding of the causal mechanisms by which organic pollution influences the composition of benthic invertebrate assemblages (Hynes, 1960; Allen, 1995; Maltby, 1995). This, in turn, informs an understanding of the composition of the fauna of undisturbed sites, from which "expected" values can be predicted (Wright et al., 1989).
2. The methods, themselves, are straightforward, based on 3-min kick samples and identification of invertebrates to family. The uncertainty associated with each stage, from field sampling to analysis in the laboratory, is known (Pinder and Farr, 1987; Clarke et al., 2002; Haase et al., 2006) and assessments take place within a Quality Assurance framework (Dines and Murray-Bligh, 2000). This ensures that there is a high level of reproducibility, leading to comparability between data collected in 1990 and 2010, despite several personnel changes over this time.

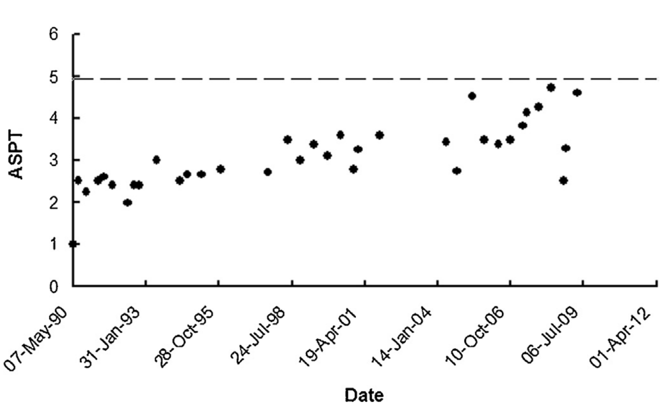

Fig. 1. Long-term changes in average score per taxon (ASPT) at River Team at Lamesley, County Durham.

3. For most of this period, the River Team was monitored by a team of biologists from a nearby office of the Environment Agency. Within the teams, individuals were responsible for particular catchments, sampling, analysing and interpreting data from a number of sites and liaising with colleagues concerned with the management of these rivers. The biologists are often multifunctional, performing macrophyte surveys, diatom analyses and other assessments as well as invertebrate analyses. Over a number of years, the biologists develop considerable local knowledge which, in turn, informs the advice that they can give.

Yet whilst the biologists were able to demonstrate an improvement in the ecological state of the River Team over this period, they were not directly responsible for this improvement. They took and analysed samples and processed the data into information which, in turn, fed into a wider dialogue with colleagues more directly concerned with regulation within the organisation, and with others outside. Biological data were combined with chemical data to identify particular inputs which were causing problems, the regulators negotiated (backed up by the threat of litigation) to persuade polluters to address these problems and, slowly, the state of the Team improved. The biologists, in other words, provided both data and a broader knowledge of the catchment and freshwater ecology to the decision-making process.

I have described this approach at some length because it has a record of contributing to improvements in water quality in the UK, particularly since 1989 (DEFRA, 2009) but also because it is unusual, in that there are a relatively large number of ecologists employed directly by government agencies. That they are public servants is not, itself the key issue: rather, it is the integration of data-gathering functions with other aspects of catchment management that, in turn, permits the formal evidence to be supplemented by informal observations and by experience.

3. The "family doctor" model of applied freshwater ecology

The concept of "ecosystem health" is widely used as a means of expressing the integrity (or status) of aquatic ecosystems (Suter, 1993) and the example above allows us to extend this analogy to influence the way in which ecologists should diagnose and treat problems. Following this reasoning, the team of ecologists become the equivalents of a medical practice serving a region. Family doctors rely on simple equipment (stethoscopes, blood pressure monitors) and procedures combined with knowledge derived from their formal academic training, practical experience and in-service training, to diagnose ailments and prescribe treatments. They may decide to refer patients to specialists, or send away samples for more detailed tests, but they often have the benefit of a long-term relationship with the patient which also informs their judgement. This is still "evidence-driven", although the "evidence" may well be derived from experience from previous cases and extrapolated to the patient in question.

The characteristics of this "family doctor" model of applied freshwater ecology in the UK are:

- Multifunctional freshwater biologists with a broad awareness of several trophic levels;
- In order to enable this, the core methods need to balance sensitivity to pressures against ease of use (exemplified by the use of family-level data to calculate metrics such as ASPT);
- Individuals have an involvement with a particular region for a number of years; and,
- Ecologists work closely with colleagues trained in other disciplines in order to identify sources of problems, to use the