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GLASTIR MONITORING & EVALUATION PROGRAMME

FINAL REPORT – Annex 17

Effect of the Glastir land management scheme on phytobenthos assemblages in Wales

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Introduction

This reports presents an overview of analyses of diatom samples collected from headwater streams within catchments subject to the Glastir land management scheme in Wales between 2013 and 2016. Full details of the project, including the rationale for selection of headwater stream sites, are presented elsewhere (https://gmep.wales/freshwater/).This report focuses on a high-level analysis of the data in order to compare the condition of streams on land in or out of the Glastir scheme. The report provides an indication of the effectiveness of the scheme at protecting rural water courses, however this will need to be confirmed over time, with repeated sampling, in order to reach firm conclusions about the influence of Glastir on the condition of streams.

Methods

Field sampling

Benthic diatoms were collected using DARES/DARLEQ methodology (WFD UKTAG, 2008, 2014). Biofilm samples were collected from the preferred substratum of cobbles (>64 and <256 mm, after Wentworth, 1922), or where necessary large pebbles or small boulders, at all the sites). The methodological variations for sampling among macrophytes and filamentous algae were not required.

Five cobbles were collected at random from the sample area (10m long stream reach) and placed in a tray with ~ 50 ml of filtered stream water. A clean toothbrush was used to scrub the upper surface of the cobbles into the tray of water, this was then transferred to a sample bottle and preserved immediately with Lugol's iodine.

Environmental variables used in this report for the calculation of the expected values of the metrics were collected using standard GMEP survey procedures (Scarlett et al, 2016).

Sample analysis

Samples were digested using hydrogen peroxide to remove organic matter and finally mounted on slides using the mountant Naphrax. At least 300 valves on each slide were identified to the highest resolution possible using a Nikon BX40 microscope with 100x oil immersion objective with phase contrast. The primary floras and identification guides used were Krammer and Lange-Bertalot (1986, 1997, 2000, 2004), Hartley, et al. (1996) and Hofmann et al. (2011). All nomenclature was adjusted to that used by Whitton et al. (1998) which follows conventions in Round, Crawford & Mann (1990) and Fourtanier & Kociolek (1999). Members of the *Achnanthidium minutissimum* complex showed considerable morphological variability and were classified using the conventions in Potapova and Hamilton (2006).

Calculations

Data were evaluated using four metrics. One of these, DARLEQ2, has been adopted by UK administrations as part of a suite of metrics for WFD assessments. DARLEQ evaluates the extent to which the microscopic flora of a stream has been altered due to anthropogenic enrichment. The approach used for GMEP, however, was not identical to that used for WFD classifications and results here should be regarded as indicative of likely status rather than as full WFD assessments.

A second metric, DAM ("Diatom Acidification Metric"), was developed with funding from UK administrations and has been published in the peer-reviewed literature (Juggins et al., 2016) but is not a formal part of the UK's WFD assessment framework. DAM provides an indication of the extent to which the microscopic flora has been altered due to acidification. In formal WFD assessments, this evaluation is performed using benthic invertebrates; however, this approach was not adopted in this study so, again, the results presented here should be regarded as indicative of likely status. DAM assessments were only applied to streams where alkalinity was < 20 mg L^{-1} $CaCO_3$. Sites with higher alkalinity are sufficiently well-buffered for acidification to be very unlikely, and these were all assumed to be "high status" with respect to this pressure.

The calcium concentration of the stream is required in order to assess status using DAM. This was not collected as part of GMEP; however, an approximation was obtained from the conductivity measurement (see Appendix 1).

Total number of taxa is presented to give an overview of the diversity of the sample. At any one site, number of diatom taxa can vary due to a number of natural and pressure-related factors, and care is needed when interpreting a single sample. However, a consistently low number of taxa from a site or associated with samples from similar sites may be evidence of a high level of stress. It is not possible to cite a threshold for the number of taxa indicative of stress but the 10^{th} and 25^{th} percentiles of the number of taxa in a large dataset spanning a wide range of ecological conditions was 10 and 17 taxa respectively. The median number of taxa was 24, whilst the 75^{th} and 90^{th} percentiles were 31 and 38 taxa respectively.

The final parameter presented is the percentage of motile valves. Diatoms capable of independent movement have particular advantages when there is competition for resources as they are able to adjust their position in the biofilm in order to maximise productivity. High proportions of motile diatoms may be associated with thick biofilms or with situations where there is unstable inorganic particulate matter. The thickness of the biofilm may also reflect interactions with the hydrological regime and grazers but, in general, samples collected from streams at high or good status during the summer typically have thin biofilms due to grazing and are associated with low proportions (i.e. < 20%) of motile diatoms. There is often a general tendency for the proportion of motile taxa to increase along an enrichment gradient.

Results

1. Context

Samples collected from streams that were on land managed under the Glastir scheme tended to have lower alkalinity and conductivity than those that were on land that were outside the scheme (Fig. 1). This, in turn, suggests a bias towards less productive upland catchments and needs to be borne in mind in particular when considering how Glastir may have influenced ecological status in streams.

Fig. 2 shows the relationships between the key abiotic variables and diatom metrics used in this study. In some cases (e.g. alkalinity v TDI) calculation of an EQR effectively cancels out the influence of the abiotic variable on subsequent interpretations of ecological status.

Although samples were collected from land within the Glastir scheme, there will also be land within the catchment upstream of the sampling point that is outside the scheme and this is also likely to have an influence on ecological quality. Fig. 3 shows the relationship between the metrics used in this report and the proportion of land in the upstream catchment that is within the scheme. This graph includes samples from sites that are outside of Glastir but which are downstream of land that is in Glastir. One site (12768) has been excluded from this plot. This site had a much higher proportion of the upstream catchment within Glastir (81%) but also had a high TDI value. The alkalinity for this sample was also very high and a closer look at the features of this location are needed in order to understand the anomalous behaviour.

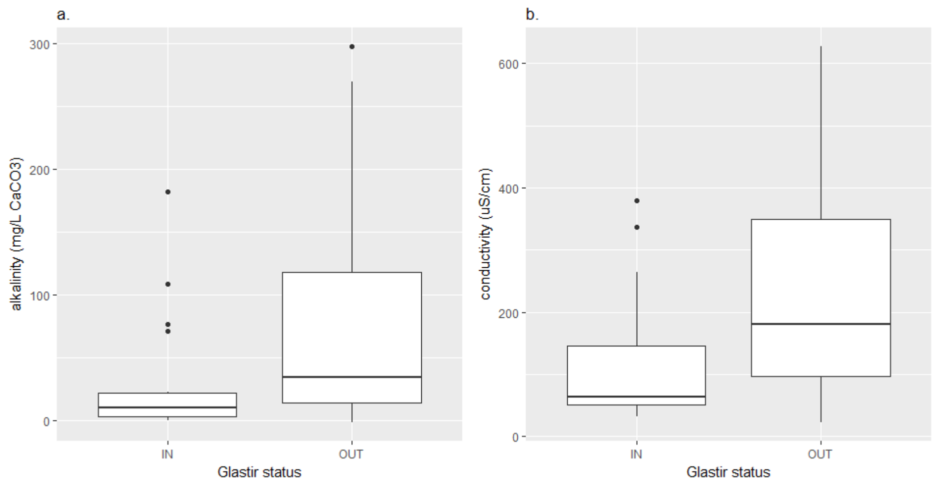

Fig. 1. Differences in alkalinity (a.) and conductivity (b.) between samples collected from locations in and out of the Glastir scheme.

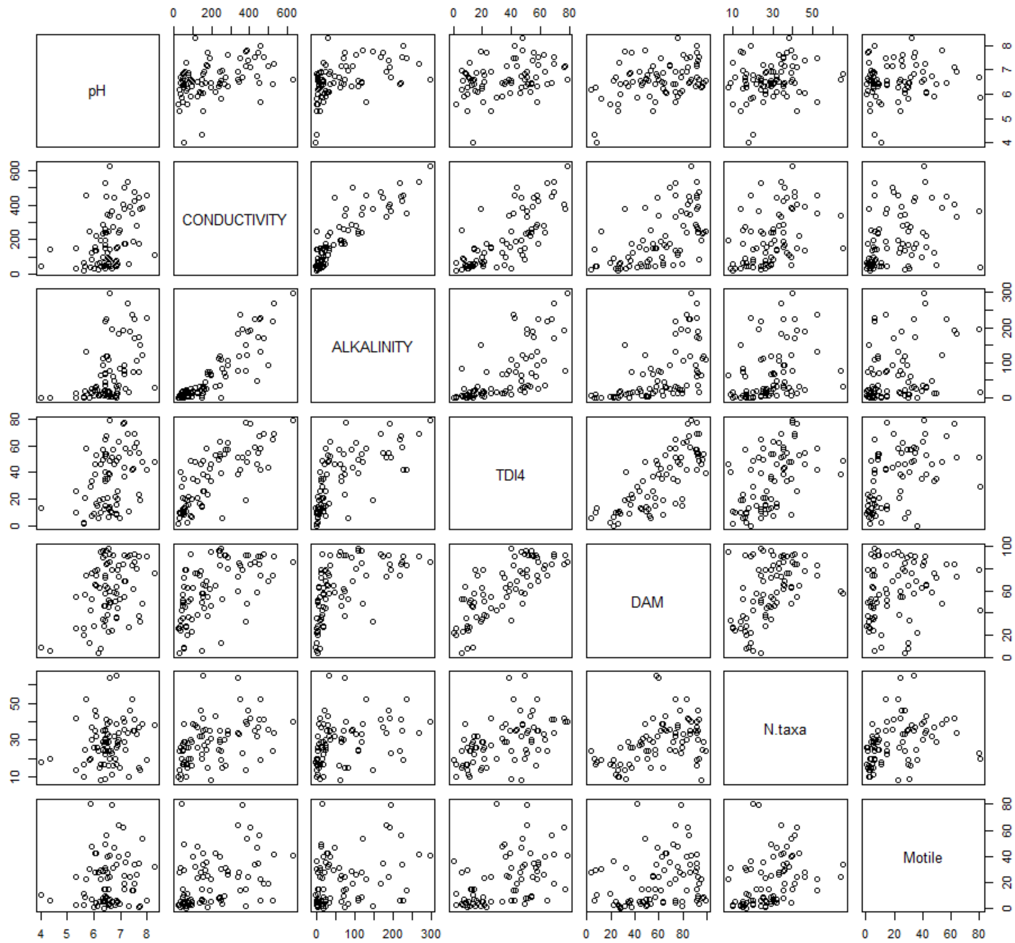

Fig. 2. Scatter plot matrix showing the relationships between the key abiotic variables and diatom metrics used in this study.

With this sample removed, the distributions of three of the four ecological metrics described "wedge"-shapes along the Glastir gradient. The exception was DAM, the acidification metric, which showed no discernible relationship. A "wedge" suggests that the explanatory variable (proportion of land in Glastir, in this case) is one of a number of factors influencing the response variable, and that it sets a "ceiling" on the value of the response variable but that, in many cases, other factors intervene, resulting in a lower TDI4 value. Thus, for TDI4 (Fig. 3a), there is a low probability of a site with > 10% of the upstream land in Glastir having a TDI > 30, although it is possible to find samples with similar representation in Glastir with lower TDI values. It is important, however, to bear in mind the effect of alkalinity on TDI (see Figs 1 and 2) and to consider broader scale interactions between geology, land use and agricultural practice (see below). The response of the number of taxa may appear counter-intuitive, appearing to decrease as the proportion of land within Glastir increases. Number of taxa approximates to "alpha diversity", insofar as a sample at any point in time is representative of the site, and it is also possible that the proportion of land in Glastir increases as stream order decreases. Headwater streams often have lower levels of alpha diversity than higher order streams, and there is also a negative relationship between the proportion of land in Glastir and alkalinity, which may also contribute to the lower number of taxa recorded.

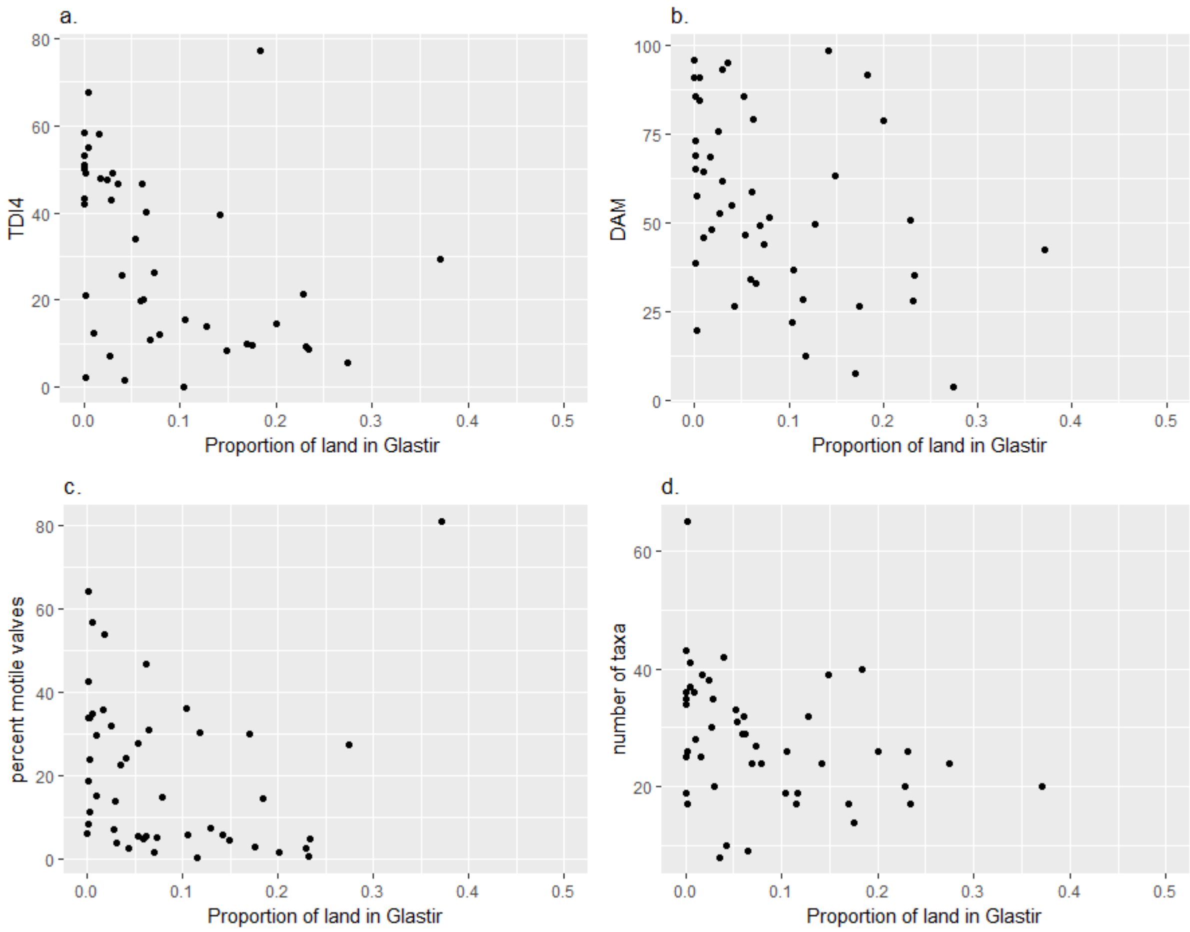

Fig. 3. Relationship between biological metrics and the proportion of land in the upstream catchment that is farmed under the Glastir scheme.

2. Phytobenthos-inferred ecological status

Altogether, 92% of samples from land managed within the Glastir programme have high or good status, computed using DARLEQ2, compared to 88% of samples from land outside the Glastir scheme (Fig. 3). There were more sites inside Glastir at high status (67%) than outside (56%) but this may be partly due to differences in the types of farming rather than of land management regime.

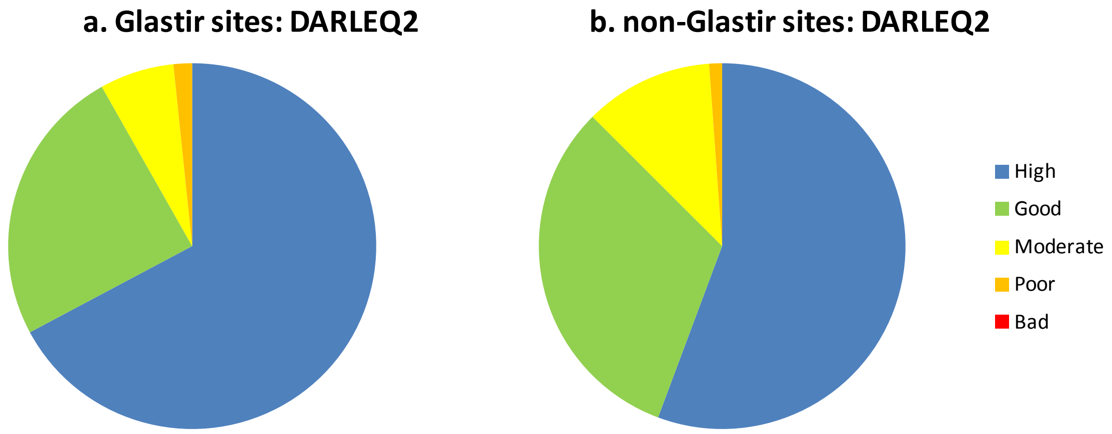

Fig. 3. Pie-charts showing ecological status of samples that are in or out of the Glastir scheme, computed using DARLEQ2.

Samples from land managed as part of the Glastir scheme had a greater tendency to show the effects of acidification, with 22% having assessments of less than good status, compared to 10% for those outside the scheme (Fig. 4). This is likely to be largely due to the greater vulnerability of these catchments to acidification (see Fig. 1).

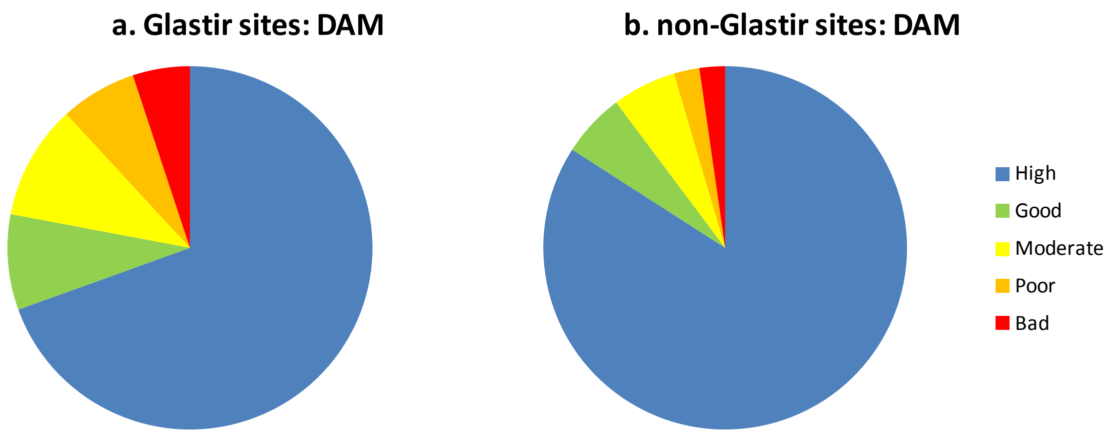

Fig. 4. Pie-charts showing ecological status of samples that are in or out of the Glastir scheme, computed using DAM.

When results of assessments using DARLEQ and DAM are combined using the "one out, all out" rule, 70% of samples from land within the Glastir scheme would be classified as high or good status, compared to 77% of samples from land outside the scheme (Fig. 5). This difference appears to be driven more by DAM, which is more likely to downgrade a stream classified at high status using

DARLEQ than vice versa. However, the caveats above regarding differences from formal status assessment procedures mean that these results should be interpreted with care.

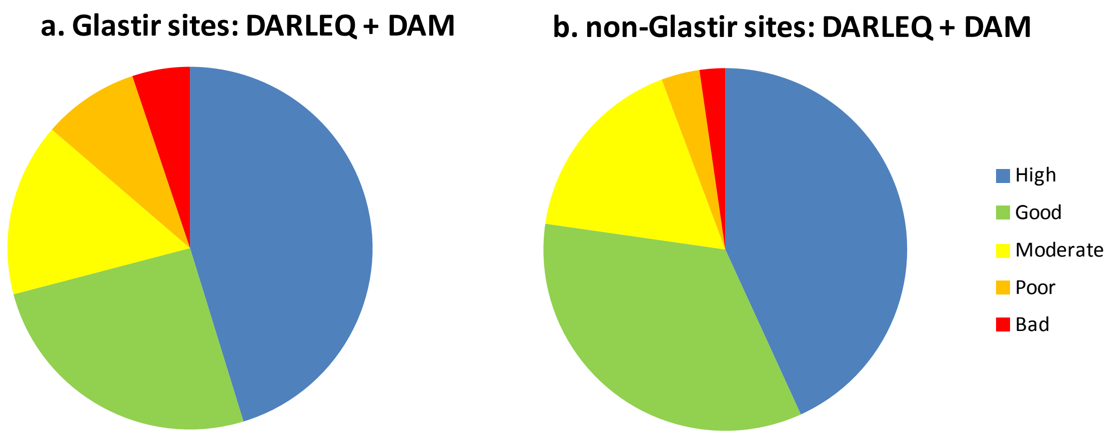

Fig. 5. Pie-charts showing ecological status of samples that are in or out of the Glastir scheme, computed using DAM.

3. other metrics

Most samples from catchments within the Glastir scheme had taxa numbers that fell within the 25th and 75th percentiles of a large UK-wide dataset (Fig. 6a), whilst the non-Glastir samples did contain a few species-poor samples and a few that were very species rich. Overall, the median number of taxa was lower in Glastir samples than in non-Glastir samples although, again, this may reflect general habitat factors rather than differences in ecological status although acidification can suppress the number of taxa recorded.

Samples from land managed under the Glastir scheme have much lower proportions of motile valves than those from catchments that are outside the scheme (Fig. 6b). Few samples in the former category have > 20% motile taxa, whilst several samples from locations outside the scheme have between 20 and 40% motile valves.

Discussion

In most respects, samples from catchments within the Glastir scheme compare favourably with those from elsewhere in Wales. Interpretation is complicated because the two sets of sites have different spectra of alkalinity and conductivity, which in turn will influence vulnerability to acidification as well as the choice of farming and management options. If acidification is discounted as a pressure beyond the influence of individual farmers, then samples from catchments within Glastir schemes does appear to have a slightly higher likelihood of being at high or good status than land outside.

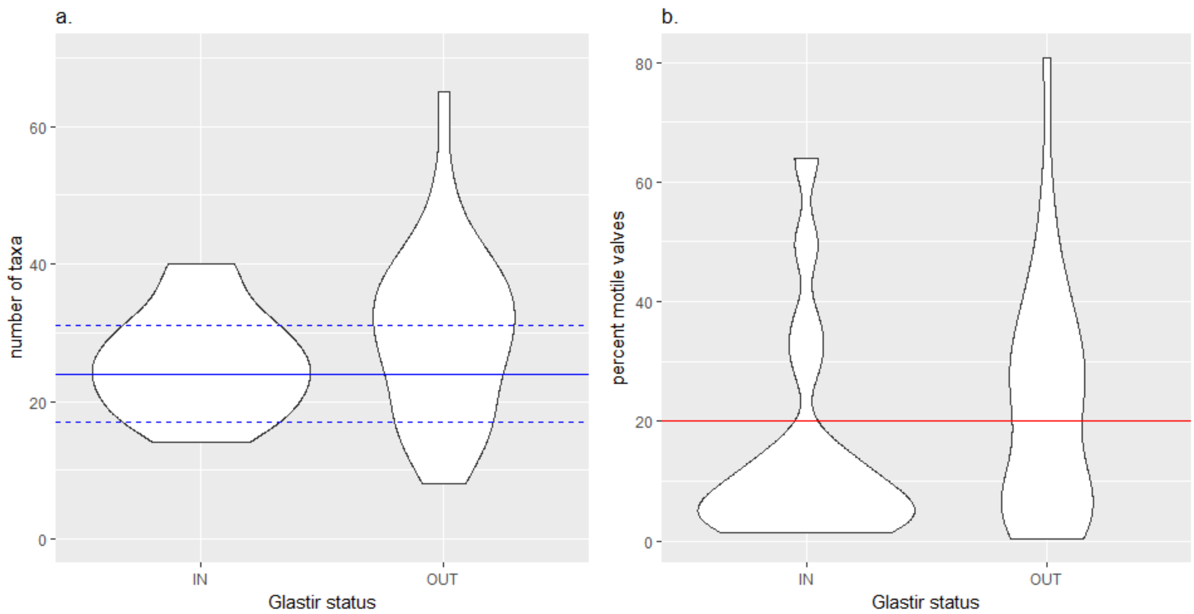

Fig. 6. Differences in percent motile valves (a.) and number of taxa (b.) between samples collected from locations in and out of the Glastir scheme. Horizontal blue lines indicate the 25th, 50th and 75th percentiles of number of taxa recorded in the DARES dataset from which the original DARLEQ model was derived; the horizontal red line indicates 20% motile valves.

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Appendix 1: Deriving an estimate of Ca in a sample from conductivity

Ca is required to predict "expected" values of the Diatom Acidification Metric, from which ecological status can be estimated (Juggins et al., 2016). Although Ca was not measured during the GMEP surveys, it is possible to obtain an estimate of ecological status using Conductivity rather than Ca as a predictor variable.

The analyses in this appendix are based on a dataset of 440 sites in Ireland from which diatom assemblage composition and abiotic variables are available (mostly n=2 samples per site). As Ca is the dominant cation in freshwater, this should contribute a major part of the conductivity of the water sample. This means that conductivity could be used to estimate Ca concentrations at sites where Ca has not been measured. Fig. A1 confirms this relationship, although it breaks down when both Ca and conductivity are low (i.e. lower left corner). This, unfortunately, is the region where acidification is most likely to be encountered and, therefore, where the inference of status will be most useful. Note, too, that the line of best fit (blue) underestimates Ca at higher conductivities. If the regression line is forced through the origin (red line), the relationship is better at low conductivity but severely underestimates Ca when conductivity is > 150 µS cm^{-1}.

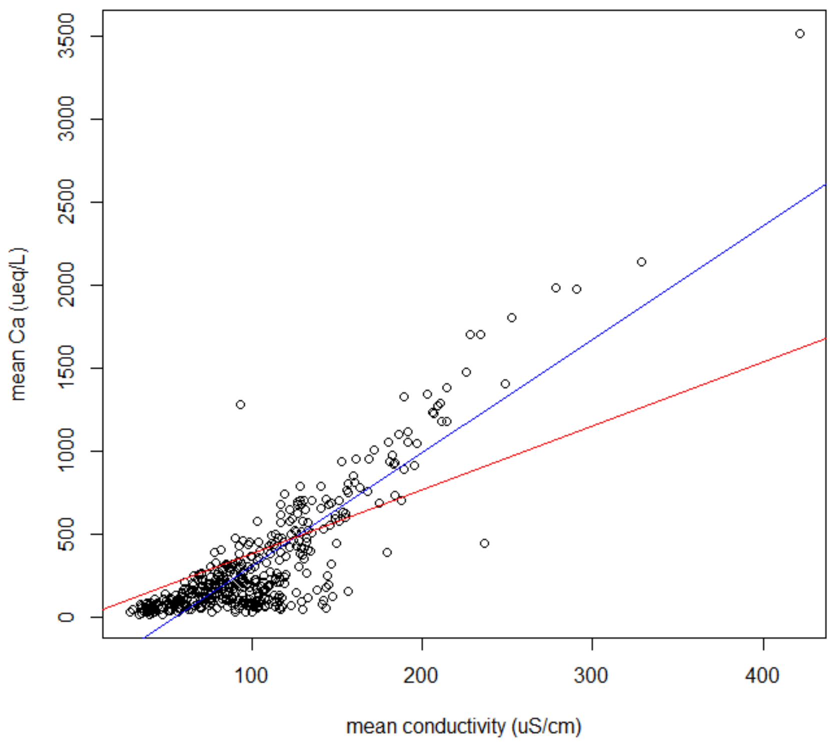

Fig. A1: relationship between conductivity and Ca for 440 sites in Ireland with regression lines plotted (blue: with calculated intercept; red: intercept = 0)

The possibility that the deviation from a linear relationship between Ca and conductivity is due to the large contribution from hydrogen ions at acidified sites was investigated by removing acidified sites following criteria in Juggins et al. (2016; based on balance between Ca and Acid Neutralising Capaacity). This removes a number of sites where relationship between conductivity and Ca is most distorted (Fig. A2a), but there are still a substantial number of sites which deviate from linearity. Removing the acidified sites 381 sites (Fig. A2b) with the "tail" of low Ca sites at the bottom left hand corner indicating sites where other cations are dominant. These may include sites where there is substantial deposition from sea salt as well as, potentially, contributions from heavy metals.

Quantile regression was then used to define the upper boundary of the relationship between Ca and conductivity, which we interpret as sites where Ca is the predominant cation. The coefficients for a regression line fitted to the 95th percentile of these data is:

Ca = (8.11 x conductivity) – 243

Where Ca is measured in µeq L^{-1} and conductivity in µS cm^{-1}

This will provide an approximate indication of the Ca concentration at a site which, in turn, can be used to calculate an approximate EQR for the diatom acidification metric.

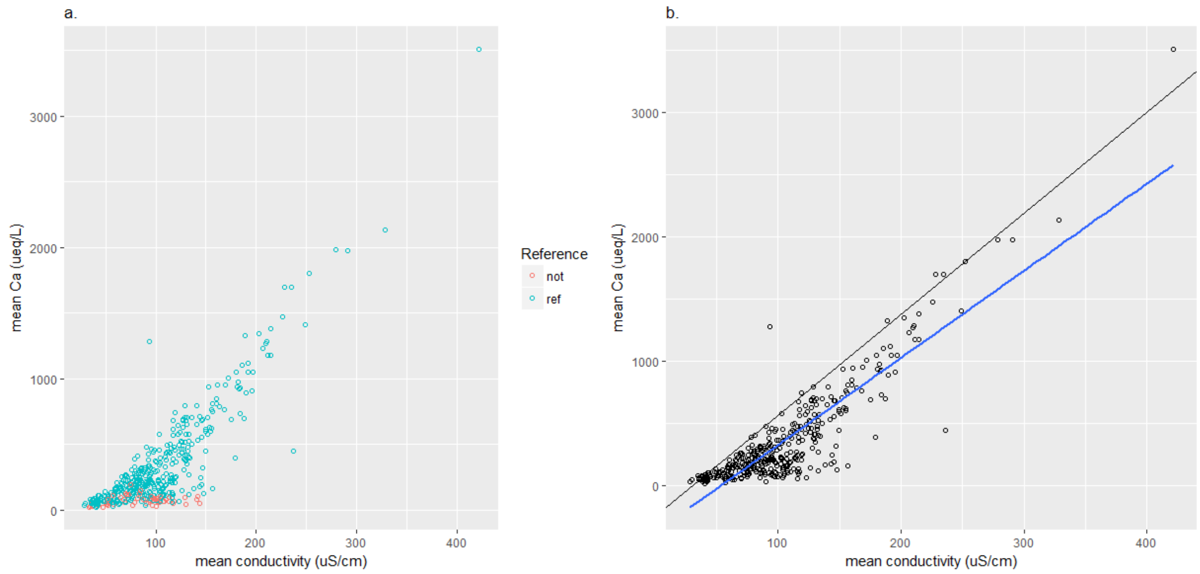

Fig. A2. a.: relationship between Ca and conductivity for 440 sites in Ireland with non-acidified sites ("ref") differenciated from acidified sites ("ref"); b. subset of 381 "reference" sites with line of best fit (blue) plus a regression line fitted to the 95th percentile of the data (black)

Juggins, S., Kelly, M., Allott, T., Kelly-Quinn, M. & Monteith, D. (2016). A Water Framework Directive-compatible metric for assessing acidification in UK and Irish rivers using diatoms. Science of the Total Environment 568: 671-678.