Linking limnology and palaeolimnology using algal pigments at Windermere

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Windermere has a special place in the development of limnology and palaeolimnology (the study of lake sediment cores). The lake has been continuously monitored for phytoplankton since 1945 and is the site of some of the earliest palaeolimnological studies. Sixty-five years later, the simultaneous accretion of sedimentary and algal records, coupled with the development of new palaeolimnological techniques means that Windermere can give us unprecedented insights into the causes and consequences of lake eutrophication. Windermere has a long history of human disturbance and enrichment, including the development of tourism and agriculture in its catchment over the last two centuries. The intensity of eutrophication varies among basins, with the North basin less severely enriched than the South. This project aimed to build on this extraordinary history, firstly to compare sedimentary records with phytoplankton collected from the water column and secondly to extend the history of algal change in both basins of Windermere using the longer records provided by sediment cores.

Fig. 1. Suzanne McGowan with a 'mini-Mackereth' sediment core from the South basin of Windermere.

We took sediment cores from the North and South basins of Windermere to reconstruct past communities of algae using chlorophyll and carotenoid pigment biomarkers. Cores measuring approximately 80cm in length (Fig. 1) were retrieved by a team from Lancaster University (Phil Barker, Andy Quin and Paul Williams). Dating of sediments by Jackie Pates of Lancaster University using ^{210}Pb isotopes showed that the sediments dated back approximately 200–300 years. Interestingly, we found some fragments of coke close to the bottom of one of the North basin cores, which we think was probably deposited from the steamers that used to cross the lake, and provided an independent means of constraining the age of the sediments. The chlorophyll and carotenoid pigments were extracted at half-centimetre intervals down the sediment cores, in organic solvents. Pigment extracts are usually yellowish-orange or greenish in colour (Fig. 2). This colour derives from the mixture of chlorophylls (which are green), carotenoids (orange in colour) and chlorophyll derivatives (usually yellow). Carotenoids can vary in hue; for example fucoxanthin from siliceous algae is orange-yellow whilst oscillaxanthin from Cyanobacteria is orange-red. The specific combination and abundance of each pigment determine the colour of the extract.

Fig. 2. Extracts of chlorophyll and carotenoid pigments from the Windermere South basin core.

Characterisation of pigments down the sediment core is achieved using high-performance liquid chromatography (HPLC) separation, and then diagnostic marker pigments are used to quantify changes in different algal groups.

We correlated sedimentary pigments and phytoplankton datasets to provide a long-term validation of the use of palaeo-pigment records. The phytoplankton dataset from Windermere is now stored by the Centre for Hydrology and Ecology, where Stephen Maberly and Heidrun Feuchtmayr were responsible for collating the dataset for comparison with the sedimentary record. Comparisons between the two records agreed well, although the strength of correlations varied among pigments, providing insights into how pigments can provide records of different features of the phytoplankton in the lake. For example, phytoplankton samples provide a record of communities in the upper waters whereas pigments integrate algal production from the entire basin and so can provide records of deep-water blooms. Because we sampled replicate cores in lakes of high (South) and low (North) productivity, we will be able to assess how sediment burial rate and lake trophic status influence the formation of palaeolimnological records.

The pigment records at Windermere have extended our knowledge of algal changes in the lake back to the late 18th century. Perhaps the most surprising finding of this work is the discovery that the establishment of the towns of Bowness and Windermere on the shores of the South basin after 1847 coincided with a marked increase in Cyanobacteria (blue-green algae) in the lake. Although Victorian tourism has long been implicated in having a detrimental impact on the lake, this work illustrates a fundamental shift in the primary producers of the lake, as sewage loading on the basin increased in the absence of adequate systems of sewage treatment. We are further investigating the impact of these early changes on carbon and nitrogen cycling using stable isotopes in the sediments analysed by Peter Leavitt (University of Regina). The final part of the jigsaw is to build up information on as many potential drivers of change in the Windermere catchment as possible. Elizabeth Haworth (Freshwater Biological Association) has been especially helpful in this regard because of her expertise in working with sediments from Windermere and her knowledge of local changes. Therefore, we have been collating data from various sources including agricultural census records, fertiliser application rates, local council records on changes in sewerage and sewage treatment, climate data, and old press articles and archives in the FBA's Unpublished Collection documenting local observations on the lake. We would like to hear from anyone with other historical sources that may be helpful in reconstructing the picture of change in Windermere over the last few centuries.