human interference for increasing riverine sediment fluxes. Due to the large scatter, which results from the spatial lumping at the regional scale, the exact timing of the increase is difficult to assess and smaller climate driven variations are not detectable. Additionally, floodplains are only a part of the river sediment system—and in most cases only accretion rates have been determined. More detailed reconstructions of past sediment flux will be possible as database build-up proceeds.

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A meta-database for recent paleolimnological studies

Rick W. Battarbee, D. Morley, H. Bennion and G.L. Simpson

Environmental Change Research Centre, University College London, UK; ufcabat@ucl.ac.uk

Assessing how the status of lakes, or any ecosystem, changes through time and space requires an awareness and understanding of key processes acting and interacting on different scales. By combining observational and paleolimnological datasets (Battarbee, 2000, Battarbee et al., 2005) it is becoming increasingly possible to identify processes occurring on a continuum of time-scales. This includes seasonal and inter-annual variability related to short-term climate variability or internal food chain dynamics, decadal-scale processes associated with pollution pressures from human activity, and centennial and millennial scale processes related to catchment evolution and lake ontogeny.

Placing these temporal patterns across space at the regional, continental and global scales is, however, currently impossible, restricted by: (i) the rarity of multi-decadal instrumental time-series; (ii) the rarity of millennial scale paleolimnological records; and (iii) the lack of any central public domain database for either instrumental or paleolimnological records. So far spatial upscaling has only been attempted at the regional level using data owned by individual laboratories or by a project consortium (e.g. Cumming et al., 1992; Curtis et al., submitted).

However, not all paleolimnological records are rare. Indeed those that cover recent lake history (i.e. the last 100-200 years) are quite abundant, principally as a result of the close attention given by paleolimnologists over recent decades to problems of 19th and 20th century pollution (cf. Smol, 2002). Using such datasets we can begin to explore the spatial upscaling of paleolimnological data, starting by building a meta-database that lists geo-

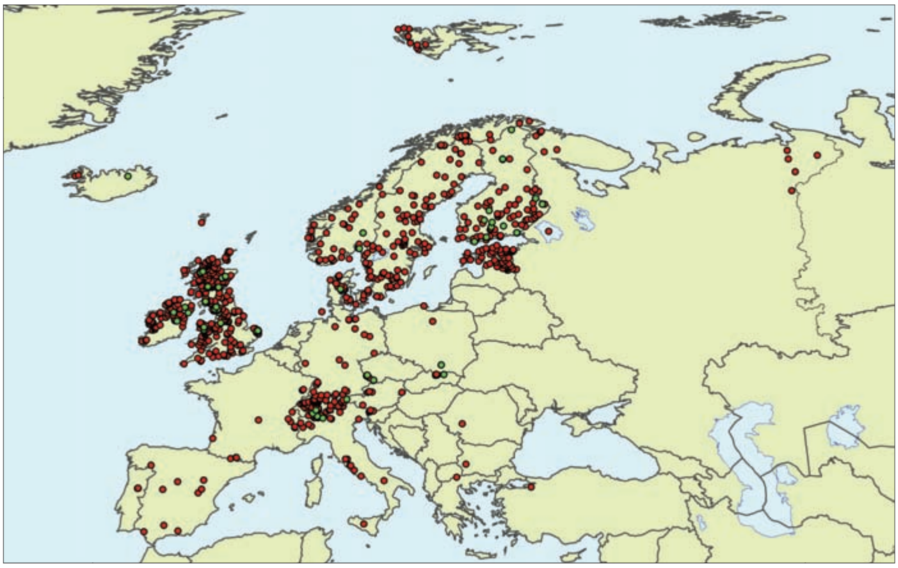

Figure 1: Distribution of sites across Europe in the Euro-limpacs paleo meta-database. Red circles indicate sites in the database where recent paleolimnological data are available, green circles indicate sites where both paleolimnological and monitoring time-series data are available.

referenced information availability site by site.

The meta-database described here is being developed under the auspices of the EU project Euro-limpacs ("Global Change Impacts on European Freshwater Ecosystems"). We have so far only included sites where cores have been taken with an intact mud-water interface, have been dated and, ideally, extend in time back to the early nineteenth century. Data fields include site geography (location, altitude etc), climate (temperature, precipitation), water chemistry (pH, alkalinity, Total Phosphorus (TP)), core information (length, age, sample, year, etc), core analyses (diatoms, metals etc) and associated literature. Currently there are records for 954 lake sites across Europe (Fig. 1) derived from our own studies and from a review of the literature (published and unpublished).

As a separate initiative we are also compiling a meta-database for sites in Europe where long-term monitoring programs are underway. We define these as sites with 10 or more years of annual or more frequent observations. The two databases together enable us to identify sites (i) where both long-term data-sets and recent sediment records are co-located (Fig. 1); (ii) where ecological trends and variability on different time-scales for individual sites can be defined; and (iii) where observational time-series data-sets can be used to verify or calibrate sediment records.

So far we have used the paleo meta-database to define, on the basis of transfer functions, reference values of pH and (TP) for lakes suffering from acidification and eutrophication respectively in Europe (Fig. 2), and to identify the approximate date (decade) at which the first evidence for

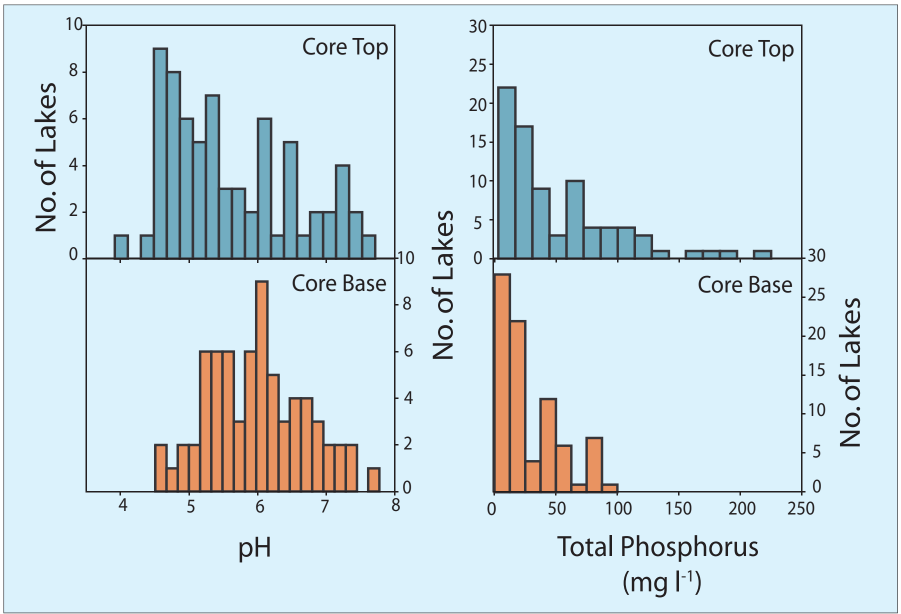

*Figure 2: Histograms showing changes in diatom-inferred pH: **a**) and total phosphorus values; **b**) between 1850 AD and the present day based on literature data (see text for fuller explanation).*

acidification and eutrophication occurred (Fig. 3).

The reference value data for pH and TP can be compared with contemporary values of pH and TP (as represented by core top samples) to reveal the status of lakes across Europe with respect to these pressures (Fig. 2). For pH there has been a decrease in median pH in 1800 AD (representing reference values) of 5.7 to 6.2 to pH 4.5 to 5.5 at the "present day" (as represented by the date of coring). In the case of eutrophication the data show a reduction in the number of oligotrophic sites since 1850 and the increase of eutrophic sites, including the creation of some hyper-trophic sites that have no reference state analogue. It should be noted, however, that whilst these conclusions are intuitively accurate, they are based on a very biased sample of European lakes principally reflecting the sites where paleolimnologists have chosen to work. The data also do not reflect the current status of many lakes as the core top values that are used to represent "present-day" conditions are of very variable age, and in many cases reflect conditions when lake water quality was at its lowest rather than real present-day conditions where many sites now have improved water quality following the implementation of pollution mitigation measures across Europe.

Figure 3 illustrates the approximate date (rounded to the decade) at which the first signs of acidification or eutrophication are recognized in the respective diatom diagrams from each site included in the database. In many cases these "points of change" are easy to recognize, in others assigning a first point of change to a specific depth or age in a core is more difficult depending on how gradual the transition period is and the background variability of the diatom record. The approach is inevitably subjective and relies upon expert judgment. Nevertheless, the data taken together do provide an important insight into the history of acidification and eutrophication, showing in both cases that the earliest impacts were in the middle and late nineteenth century and confirm the use of 1800 AD or even 1850 AD as suitable dates for fixing reference conditions in most instances. The histories of the two impacts, however, are different. Whereas the majority of new cases of acidification occur in the late 19th and early 20th century, most cases of eutrophication occur in the 20th century, especially since 1950. Few new cases have appeared in the last two decades probably indicating the success of measures taken in European countries to reduce sulfur emissions (acidification) and nutrient loading (eutrophication).

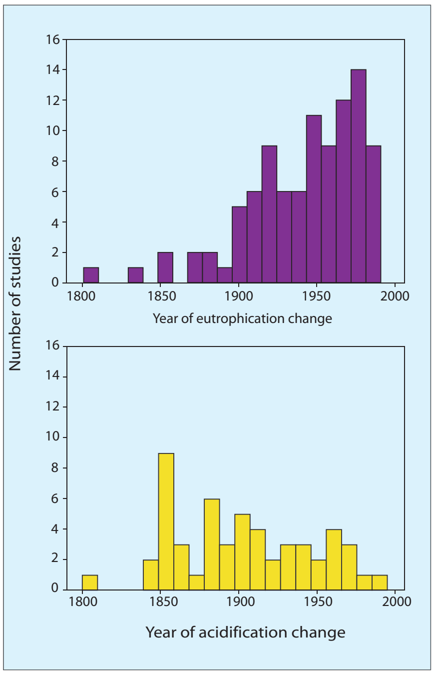

*Figure 3: Histograms showing the date of the first point of change in diatom-inferred pH: **a**) and total phosphorus; **b**) based on literature data. 16 sites showed no change in pH and 13 no change in TP.*

For the future, the paleolimnological research community should be encouraged to contribute their primary data to central databases to enable data-sets to be combined and used for more sophisticated regional and global upscaling. For diatoms such a central database, the Diatom Paleolimnology Data Cooperative (DPDC), already exists hosted by the Academy of Natural Sciences, Philadelphia (http://diatom.acnatsci.org/dpdc/). In the meantime, progress can be made by developing a meta-database along the lines of the Euro-limpacs meta-database described here. The results presented are not intended to be definitive, but to illustrate the usefulness of such a meta-database and to encourage regional and global-scale thinking in the paleolimnology community. During 2007 the Euro-limpacs database will be made available on line (www.eurolimpacs.ucl.ac.uk/) providing an opportunity to extend its coverage beyond Europe.

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