Long-term lake responses to a changing landscape: evidence from Dallund Sø, Funen, Denmark

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Figure 1 Map of Denmark indicating the location of the lake and aerial photograph of Dallund Sø. The lake lies on the plains of north Funen in a landscape that is today strongly impacted by agriculture. The lake has an area of 15ha, max. depth of 2.6m and catchment area of 1.46 km².

The Danish Cultural Landscape has developed over the last 6,000 years. Forest clearance and the increasing intensification of agricultural activity over this time period have shaped the pattern of wooded and open landscape that we see today.

Increasing human populations and increased human activity in lake catchments result in the nutrient enrichment and increased productivity (eutrophication) of lakes, although many other factors influence the level of impact (e.g. local geology, soil type).

Danish Lakes today are characteristically shallow, turbid and nutrient rich. Assuming that the present state is not their natural condition, it is unclear over what timescales the lakes have been disturbed. Anthropogenic impacts on the Danish landscape have resulted in extremely high rates of sediment accumulation in lake basins. These sediments can be used as environmental archives to explore lake and catchment history and because of the high accumulation rates, they offer the possibility of good temporal resolution.

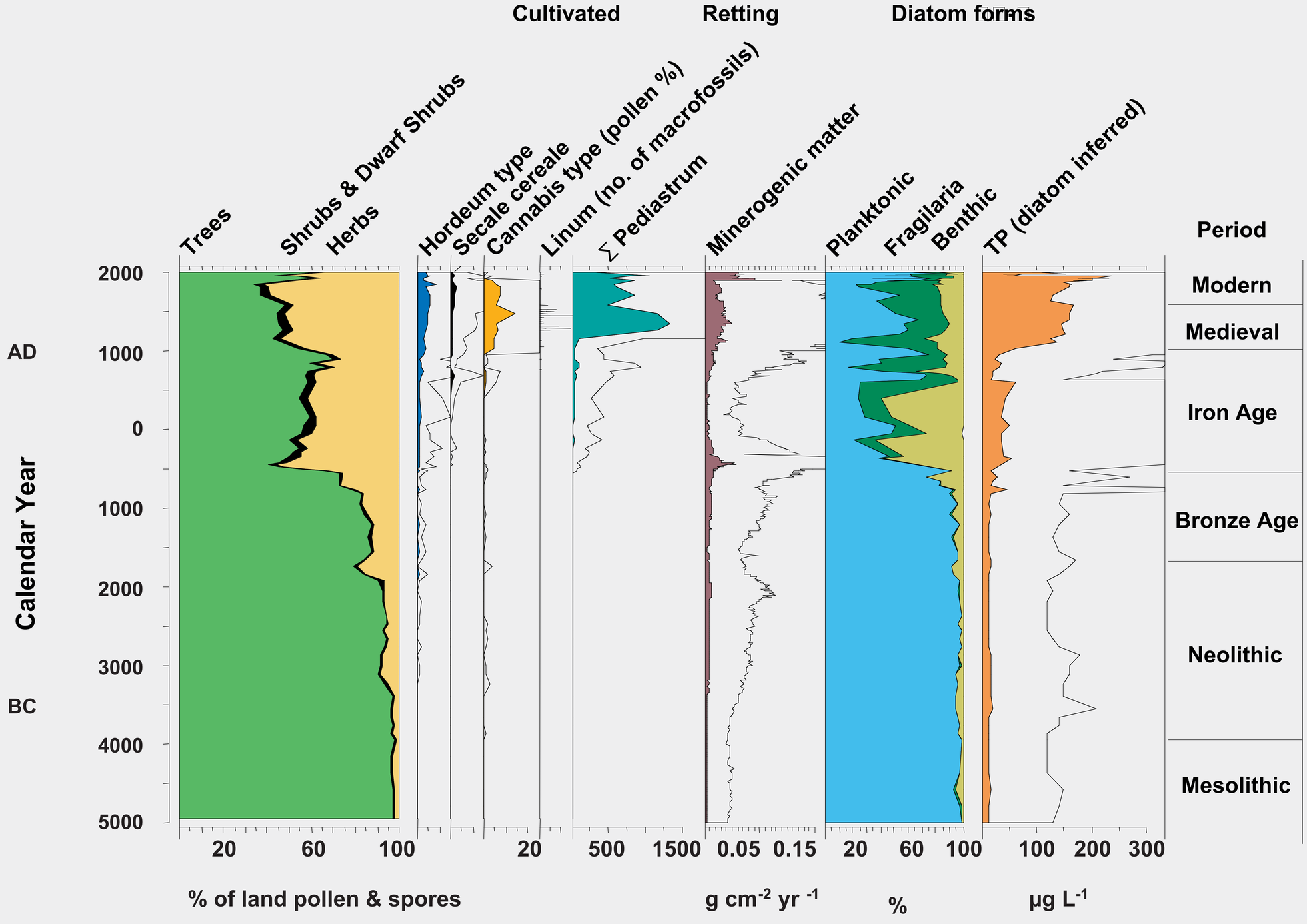
Palaeolimnology can be used to evaluate historical changes in a lake and its surroundings through the analysis of preserved plant and animal remains in the lake sediment. A long sediment sequence (11m represents c. 7,000 years) from Dallund Sø, Denmark (Figure 1) provides a high-resolution record of the changing landscape and concurrent effects on the lake biota. Pollen, plant macrofossil, Pediastrum (green algae) and diatom data are presented here, together with measurements of minerogenic matter in the samples. The latter is used as a proxy for catchment erosion as internal production inputs (e.g. diatom silica) are considered to be negligible.
The sediment sequence has been AMS ^{14}C dated.

The 13 radiocarbon dates currently available will be complemented by further dates and by ^{210}Pb dates for the uppermost sediments but as yet the younger dates are estimated on the basis of soot particles in the sediment.

Diatoms (unicellular algae) provide an excellent record of past limnological conditions and diatom-based transfer functions have been developed to infer past trophic status (e.g. Bennion *et al*., 1996; Anderson, 1997).

The transfer function is a set of equations which formalises the relationship between diatom species abundances (derived from a dataset of modern surface-sediment diatom assemblages) and contemporary environmental data (Birks, 1995), in this case total phosphorus (TP). Here a diatom transfer function based on the plankton assemblages of 27 Danish lakes was used to reconstruct in-lake TP concentrations at Dallund Sø.

Land and Lake.
There is a known link today between human activity within a lake catchment and lake water quality and biota. Combining pollen, plant macrofossil and diatom palaeolimnological analyses with the analysis of physical characteristics of lake sediment provides a means to investigate the impact of the changing landscape on lake water quality through time. The data from this study (Figure 2) show that changing cultural activities in the catchment of Dallund Sø have been reflected by in-lake responses for thousands of years. The present state of the lake is clearly not natural but has been influenced by processes of land-use change over this timescale.
These data will be complemented further by historical and archaeological research currently in progress, plus mineral magnetics and zooplankton data from the same core series.



Results - Figure 2 presents some of the data so far collated from the Dallund Sø sediment core series. These data are now being assessed in terms of historical landscape development. The late Mesolithic period (see right hand column) is characterised by high tree pollen percentages, indicative of a densely forested catchment and a diatom assemblage typical of oligotrophic (low nutrient concentration) conditions. Early in the Neolithic period, there are signs of forest clearance and this coincides with increasing soil erosion and slight increases in diatom inferred TP (DITP). Herb pollen percentages increase slightly in the Neolithic period at the same time as changes in the diatom assemblage are seen.
Herb pollen percentage increases slowly through the Bronze Age, erosion rates again increase, there is an increase in the proportion of benthic diatom species and DITP values are higher.
In the early Iron Age, the herb pollen percentage increases rapidly, reflecting a sudden and pronounced expansion of the open landscape. Unfortunately, at exactly this time, there is poor preservation of diatoms in the sediment. The sharp increase in minerogenic matter input prior to the disappearance of diatoms suggests that their poor preservation is due to catchment erosion. Later in the Iron Age, the diatom species assemblage is much changed and DITP is higher. Benthic forms and *Fragilaria* species become much more important coincident with a rapid expansion of macrophytes (as evidenced from plant macrofossil data, not shown here). DITP peaks and then decreases rapidly towards the end of the Iron Age. It is as yet unclear what causes this sudden change in the diatom flora. At the end of the Iron Age (Viking Period) the percentages of cereal pollen types begin to increase, catchment erosion rates also increase and TP levels slowly rise.
The Medieval period shows further radical changes in both the catchment and the lake. The pollen record suggests rapid forest clearance. An increase in *Cannabis* (hemp) pollen (an indication of retting – a means of extracting fibres for cloth) and other herb pollen coincides with erosion rates rising further. Eutrophic-indicator diatom species increase and DITP rises rapidly at the same time as the catchment changes. Pediastrum (green algae) % abundance increases soon after the sharp rise in DITP. Peaks in *Cannabis* and *Linum* (flax) retting indicators, increased erosion, and high TP, mark the rest of this period.
A slight drop in minerogenic matter input in the early Modern period is coincident with a drop in DITP but levels soon rise again. A peak of ~240 µg TP L^{-1} is associated with a peak in *Hordeum* type (barley) pollen, dated to the mid-1930s.

References
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Acknowledgements
This research is funded by the Danish Environmental Research Programme and GEUS. We wish to thank Beth Stavngaard (GEUS) for laboratory help and Jan Heinemeier (Inst. of Physics, University of Aarhus) for providing the radiocarbon dates.