

Review Human and climate-environment interactions Pyrenean landscapes: a Lateglacial-Holocene multiproxy reconstruction

This manuscript presents a multi-proxy palaeoecological record from a subalpine lake in the Pyrenean mountains. The authors combine pollen and charcoal analysis with a previously published sedaDNA record to reconstruct vegetation and fire dynamics for the last 12000 years, however their pollen analysis reaches back further. The combination of different proxies and the comparison with existing climate records allows the authors to discuss the different drivers of vegetation change and disentangle the impacts of climate and land use on the vegetation. They propose that cooling during the Neoglacial led to an opening of the vegetation, which was exacerbated by anthropogenic activities. Overall, the data is of high quality, the analyses support their statements, and the manuscript is well prepared. However, I do have some comments, suggestions and questions I would like the authors to address before publication.

Geographical setting

It would be interesting to expand the information regarding the geographical setting with information on today's temperatures (summer, winter, mean) and the altitude of the tree- and timberline. This would allow readers to better assess some of the discussed changes.

Methods

It is unclear from the methods how the 5 sections (1U-5U) were assigned. Is this purely based on changes in the lithofacies or was a statistical method used?

Do you think that the sections 1U and 2U are the result of the damming of the lake?

You describe the creation of a master core, but based on the rest of the results it seems you stayed on one core drive for the pollen and charcoal analysis and used the other core drive for the sedaDNA analysis. Did you use the parallel drives (TRAM21-1A and TRAM20-1A) at all for core correlation and master core building?

In Line 383 you mention a hiatus in the lower section of your cores, but this hiatus is not clear in any of the figures, nor modelled in your age-depth model. I would recommend including the hiatus in your Bacon model, if you are sure, it is there. As that would create a better age-depth model. Furthermore, in some of the figures in the supplemental material, the hiatus is included in the age/depth axis, but in the manuscript it is never.

Could you clearly specify for which section of the core (xxx cm- xxx cm) you constructed the age-depth model?

Why did you choose to date bulk samples? Where there no terrestrial plant macrofossils available?

Table 1: I would add some additional info to the table including the calibrated age range of the 95% confidence interval, plus the mean or median calibrated age.

For the XRF analysis (line 119), the integration time is missing.

Lines 134-137: I find this section a bit confusing to read. PAR and influxes are the same. Maybe structure it like this: We calculated pollen accumulation rates (PAR or influx: number of pollen grains cm⁻² yr⁻¹) as a proxy for plant abundance. PAR is a metric... counts. Since pollen output....

Is the charcoal analysis contiguous? Would be nice to mention.

Results

Line 191: It is interesting you have indications for low lake levels, as I would expect the lake levels to be much higher due to the damming of the lake. Do you have an explanation for this?

Line 215: Do you think the lake wasn't frozen for most of the time before the period 22-15 ka BP? Also, this interpretation is in stark contrast with the later mentioning/interpretation of a hiatus for this section of your core. Please stick to one interpretation, either a hiatus or low sedimentation rates. Then all the figures, discussion, but also supplemental figures should reflect the final interpretation.

Figure 3: Could you add 'Age (cal yr BP)' to the x-axis. The label in the top left corner of the model is unnecessary, I suggest removing it.

Line 230: I would already mention this in the methods section

Figure 4: Why is this figure not plotted on age, it would make it much easier for the readers to see when things are happening? If you would prefer to plot on depth, could you at least add an age axis.

It would also be nice to add a summary diagram, so changes in trees, shrub and herb vegetation are easier to see.

Figure 5: Maybe you could add some more labels to this graph. For example, that e and f are coniferous trees, g and h deciduous species.

I would also show the results for domesticated animals from the sedaDNA here. It would enhance your discussion.

In the text a chironomid temperature reconstruction is mentioned. Maybe this could be shown as well?

You mentioned that the low taxonomic resolution of pollen analysis could lead to an overestimation of human impact on the landscape, and you use the example of *Plantago*, which I don't think is a good example. It is possible to distinguish several *Plantago* pollen types including *Plantago lanceolata* type, which is a strong indicator of anthropogenic impact (see Beug 2004, Behre et al. 2023).

Lines 359-363: They hypothesis that excrement from animals could bring DNA into the lake is interesting, but I can't imagine this to be a large contributor to the sedaDNA signal. Are there any studies that have shown a contribution of excrement to the sedaDNA signal in a lake? To further study this hypothesis the inclusion of dung fungal spores in the palynological analysis would be very valuable. Increases in dung fungal spores such as *Sporormiella* would show if there was an increase in herbivory around the lake, and if this is related to change in herbs/grasses. Furthermore, it is not surprising there is a difference between Poaceae pollen

and Poaceae sedaDNA representation. Poaceae pollen are wind-pollinated, very abundant and always well represented in pollen records, whereas grass biomass is usually not very high and Poaceae do not seem to work so well with sedaDNA metabarcoding.

Lines 366-375: Did you also look at the modern surface sample (pollen and sedaDNA) to better understand the connection between the pollen, sedaDNA and vegetation? This could help with understanding the results.

Did you also consider using proxies such as conifer stomata or macrofossil analysis? Especially conifer stomata could have been analysed on the same slides as the pollen analysis and could confirm the local presence of conifer trees.

Line 403: You mention the plant communities were not very diverse during the Late Glacial. Did you think about calculating richness for the sedaDNA and the pollen, that could have been a nice addition to the discussion about plant diversity. Do you think it is possible for the Late Glacial vegetation to also have a rich herbaceous vegetation composition? Some sites in the Alps do suggest this (e.g. van Vugt et al. 2022).

Lines 454-460: Could continentality have played a role in the *Betula* and *Corylus* dynamics? In the Alps the dominance of *Corylus* during the Early Holocene is often related to high summer insolation and continentality (e.g. Aregger et al. 2025).

Lines 473-476: Couldn't differences in dispersal also lead to this pattern. The winged fruits of *Betula* are more easily dispersed than the heavy hazel nuts of *Corylus*.

Line 483-484: So ground fires instead of crown fires?

Lines 518-521: Could the pollen or sedaDNA data even record hunting activities. The anthropogenic taxa are not related to hunting activities, but show arable and pastoral farming.

Lines 549-552: Where is the treeline today? Do you see any indications for a lowering of the treeline? Or are there any records from region that looked at treeline ecotone dynamics?

Line 568-571: People could also have opened the niche for *Abies* and *Fagus*?

Figure 7: Would it be possible to also plot the charcoal records for the records? So it's nicer to see the vegetation-fire dynamics?

The subchapters of the discussion are called greelandian, northgrippian etc. but in the text Early Holocene, Mid Holocene etc. is used. Is there a particular reason to switch between these different names?

General comments

Line 45: I have never heard of transterminance, is this the same as transhumance?

Line 154 ...sieve and the fraction recovered with distilled water.

Line 247: I find the usage of 'timidly' strange in this context. Maybe low or subdued?

Line 281: Again, I find the usage of timidly strange. Low values of *Fagus*?

Line 341: Pollen can be extra-local to regional, depending on catchment size. What do you think is the pollen catchment for Tramacastilla?

Line 389: What does NE stand for?

Line 412: Steppe -> steppe

Line 416: along -> during

Line 433: refuge -> refugial

Line 453: strengthening -> increase?

Line 456: coexist on -> coexist in?

Line 461: “continuous though not frequent” seems a bit contradictive. Maybe ‘regular low intensity fires’ would be more logical?

Line 531: summer thunderstorms