

Llodra-Illabres et al conducted a paleoenvironmental study of an alpine lake in the Sierra Nevada Mountains of Spain. They focused on using algal pigment concentrations and pigment composition to evaluate changes in the algal community in through time, attempting to link changes to climatic changes and atmospheric deposition. I think this effort has merits and could become an excellent paper, but as it stands needs major revisions.

ANSWER: Dear Reviewer2, thank you for your comments. We have carefully addressed the comments and criticisms provided. We believe these revisions have significantly strengthened the manuscript. The primary changes are as follows:

- Introduction: Revised and updated in accordance with the suggestions of Reviewer 1 and 2. Objectives have been reduced.
- Materials and Methods: Expanded the "Study Site" and "Methodology" sections with new data. We have also included a new table in the Supplementary Materials.
- Results: Entirely restructured and rewritten following Reviewer 1 and 2 recommendations to describe findings zone by zone. We have added a new table and a new figure to the Supplementary Materials, as requested by the reviewer 1.
- Discussion: Streamlined and more focused. The section has been reduced from eight pages to less than five.
- Figures: The total number of figures in the main manuscript has been reduced from ten to six to improve conciseness. Figures have been amended according to the reviewer's suggestion.
- Data in repositories- Raw data and statistical data have been placed in open- source platform Github.

General comments

- In general, the manuscript could use a stronger narrative, more cohesive arguments and clearer focus. At present, the study reads like an exploratory or "fishing" exercise: many variables are measured, compared broadly, and interpreted post hoc. This approach makes it difficult to build a clear, mechanistic story and does not lend itself to a cohesive narrative.

ANSWER: The manuscript has been changed substantially following your and reviewer 1 suggestions. Figures have been updated and discussion have been shortened and focused to our results. Please read the new version of our manuscript.

All of the key elements are present and the dataset is interesting, but the analyses need to be more directed. Specifically, hypotheses should be clearly articulated and explicitly linked to the data and figures. For example, if the authors propose that nitrogen deposition is not important but dust inputs are, they should present proxies for both alongside the relevant pigments in the same figure and directly evaluate those relationships. The likely mechanisms should also be clearly described. Paleo data inevitably limit causal inference, but plausible mechanistic links supported by statistics can still be developed.

- The manuscript also includes an excessive number of figures that do not highlight the key take-home results. The main text should be limited to ~4–5 figures, each telling a clear and focused story aligned with the primary conclusions. Currently, many plots present time on both axes or show variables independently, making it difficult or impossible to visually evaluate the relationships being claimed.

ANSWER: Figures have been reduced from ten to six figures. They have been changed following your and reviewer 1 comments. These updates facilitate a more intuitive visual evaluation of the relationships described in the text, ensuring better alignment between our graphical representations and the discussion of the results

For example, former Fig 3, fig 4 and fig 8 have been merged in a single figure.

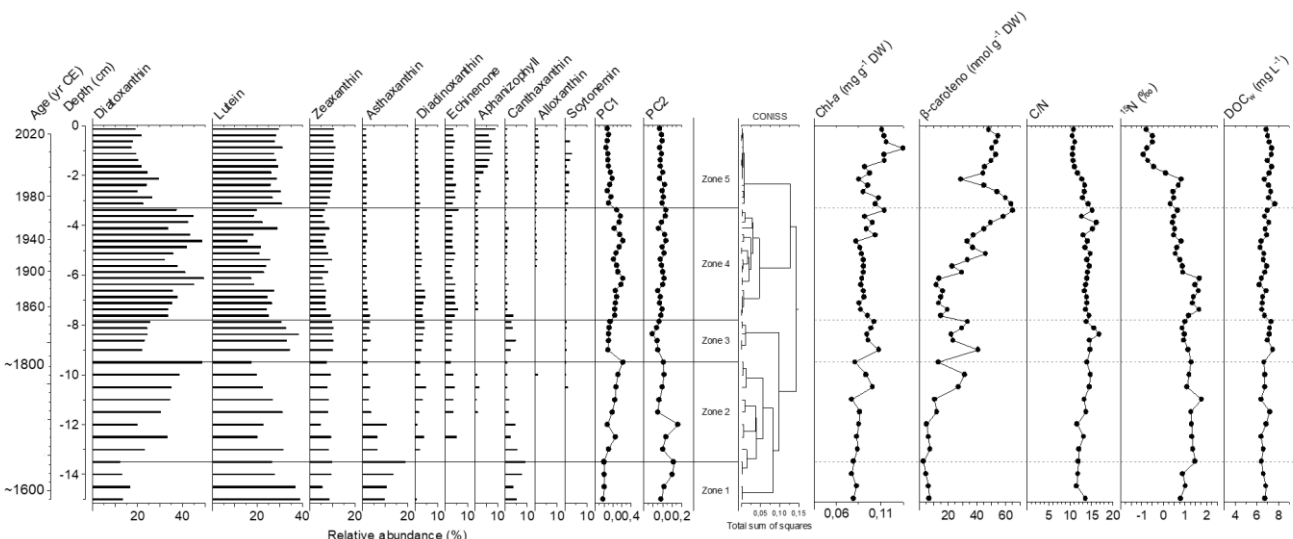


Figure 3: Relative abundance diagrams of the sedimentary pigments and evolution of selected paleoenvironmental variables recorded in the sediment core SSBG-21 in Borreguil Lake. The axis 1 and 2 of the PCA performed on pigment data and the result of a cluster analysis of pigment assemblage data using constrained incremental sum of squares (CONISS) are shown. The black lines represent the main zonation identified by the broken stick model. The data are plotted against the sediment depth (cm, primary y-axis) and on age (yr CE, secondary y-axis). Dates prior to 1850 should be interpreted with caution, as the age provided is beyond the confidence dating provided by stable radioisotopes.

Greater care is needed when drawing conclusions from correlations. For example, showing a statistical relationship between pigment PCA results and a climate metric does not demonstrate that dust is driving pigment changes. The manuscript does not clearly articulate the mechanisms behind these relationships, instead relying heavily on literature examples. While prior work provides context, it cannot substitute for evidence within this dataset. Similarly, C/N ratios are not exclusive indicators of algal versus terrestrial material. Interpreting them this way, particularly in a lake above treeline, is questionable. These types of interpretations suggest insufficient consideration of what each proxy truly represents, its limitations, and the mechanisms that could explain observed changes.

We agree that PCA does not demonstrate that dust is responsible for pigment changes. This is not stated in the manuscript. On the contrary, we state that PCA analysis is used “to summarize the major patterns of variability in pigment assemblages into a few axes” (lines XX)

To demonstrate that dust is driving pigment changes we use RDA analysis “Redundancy analysis (RDA) was conducted to identify the climate and atmospheric explanatory variables of algal assemblage changes” (line 269 of the revised manuscript)

We have shortened the discussion, particularly the literature examples, from eight pages to five pages, and explained the mechanisms behind the observed relationships between pigment and explanatory variables.

C/N is now discussed in relation to possible N limitation of the primary production (please, see lines 524-528): “Saharan phosphorus input into the lake may have caused a stoichiometric imbalance, leading to N-limitation of the primary production that favoured potentially N₂-fixing cyanobacteria (aphanizophyll). If N is limited, N₂-fixing cyanobacteria (aphanizophyll) may still result in high productivity and lower the $\delta^{15}\text{N}$ data as the isotopic signature of N₂ is also low. The decline of the C/N ratio after 1970 could be partly the result of an enrichment of organic matter in nitrogen due to nitrogen fixation”.

However, the interpretation of organic material origin is also being maintained. There are numerous studies in which the authors interpret the C/N ratio in terms of the origin of the organic material (terrestrial versus algal) in alpine lakes around the world. For example, Hu et al. (2014) in two alpine lakes in Tibet, Thevenon et al. (2012) in an alpine lake in Switzerland, Jiménez-Espejo et al. (2014) in a Sierra Nevada Lake, Wolfe et al. (2003) in Rocky Mountain lakes or Lami et al. (2000) in eight European alpine lakes.

Both interpretations could be correct. The lake is above the tree line, but it has an extensive catchment area compared to its surface area (lake area = 0.187 ha; catchment area = 50.9 ha; catchment:lake ratio = 272). For example, Hu et al. (2014) state that C/N ratio values in an alpine lake depend on terrestrial organic matter inputs (again reflecting the greater catchment-to-lake ratio). The C/N ratio of this lake is 39, which is much lower than that of Borreguil Lake. Furthermore, Borreguil Lake is also above the tree line, but it is surrounded by alpine meadows (0.563 ha), which can contribute with organic material to the lake.

Of course, the two explanations presented above are not mutually exclusive, and this has been reflected in our manuscript.

- Hu, Z., Anderson, N. J., Yang, X., & McGowan, S. (2014). Catchment-mediated atmospheric nitrogen deposition drives ecological change in two alpine lakes in SE Tibet. *Global Change Biology*, 20(5), 1614-1628.
- Thevenon, F., Adatte, T., Spangenberg, J. E., & Anselmetti, F. S. (2012). Elemental (C/N ratios) and isotopic ($\delta^{15}\text{N}_{\text{org}}$, $\delta^{13}\text{C}_{\text{org}}$) compositions of sedimentary organic matter from a high-altitude mountain lake (Meidsee, 2661 m asl, Switzerland): Implications for Lateglacial and Holocene Alpine landscape evolution. *The Holocene*, 22(10), 1135-1142.
- Jiménez-Espejo, F. J., García-Alix, A., Jiménez-Moreno, G., Rodrigo-Gámiz, M., Anderson, R. S., Rodríguez-Tovar, F. J., ... & Pardo-Igúzquiza, E. (2014). Saharan aeolian input and effective humidity variations over western Europe during the Holocene from a high altitude record. *Chemical Geology*, 374, 1-12.
- Lami, A., Guilizzoni, P., & Marchetto, A. (2000). High resolution analysis of fossil pigments, carbon, nitrogen and sulphur in the sediment of eight European Alpine lakes: the MOLAR project. *Journal of Limnology*, 59: 15-28.
- Wolfe, A. P., Van Gorp, A. C., & Baron, J. S. (2003). Recent ecological and biogeochemical changes in alpine lakes of Rocky Mountain National Park (Colorado, USA): a response to anthropogenic nitrogen deposition. *Geobiology*, 1(2), 153-168.

- The discussion section is also unfocused, reads largely as a literature review, and is overly long. It should instead concentrate on interpreting the results of this study specifically.

ANSWER: The discussion has been shortened and focused. The previous discussion extended to eight pages, whereas the new discussion extends less than five pages. We have reduced the references to previous work and examples of literature and explained the mechanisms behind the variable relationships.

- In addition to the issues with the narrative and presentation, I think more explicit data could be used to link the algal proxies to deposition. If you are not going to use proxies of either in your own sediment record (which would be best). You could at least temporally compare them to your data; there are well constrained records of both dust and N deposition in this region, why not explicitly use those in your statistical evaluations and data presentation.

ANSWER: Unfortunately, we could not find any records of nitrogen deposition for such a long period of time. Holtgrieve et al. (2011) develop a signal of anthropogenic Nitrogen deposition to Northern America continent. Anyway, these data are not available. In Spain, there are records of nitrogen deposition in the Pyrenees dating back to the 1990s

(Camarero & Catalan, 2012). In the Sierra Nevada, our research group measured total nitrogen deposition in 2001–2002 (Morales-Baquero et al., 2006).

We found extensive data on nitrogen emissions in Europe, but none on nitrogen deposition. In this regard, Engardt et al. (2017), that used historical data to simulate the deposition of acidifying and eutrophying pollutants in Europe between 1900 and 2050, relied on N emission data (rather than deposition data) to construct their model. These authors used data from the European Air Chemistry Network (EACN), which operated from the 1950s to the early 1980s, as well as more recent emission data from the EMEP monitoring network from 1990 onwards (<https://www.ceip.at/>).

There are dust deposition data in our region, but the records are also short. Vincent et al. (2016) compiled the existing records in the Western Mediterranean (see Table 1). The longest record (Palma de Mallorca, Spain) collects data from 1982 to 2003. Jiménez-Espejo et al (2014) reconstruct Saharan dust input for the Holocene from a sediment core of a Sierra Nevada lake. However, the number of samples representing 430 years (1600 to the present) is limited and not evenly distributed in Jiménez-Espejo study. The possibility of making statistical analysis with this data is reduced.

Camarero L, Catalan J (2012) Atmospheric phosphorus deposition may cause lakes to revert from phosphorus limitation back to nitrogen limitation. *Nat Commun* 3:1118

Engardt, M., Simpson, D., Schwikowski, M., & Granat, L. (2017). Deposition of sulphur and nitrogen in Europe 1900–2050. Model calculations and comparison to historical observations. *Tellus B: Chemical and Physical Meteorology*, 69(1), 1328945.

Holtgrieve, G. W., Schindler, D. E., Hobbs, W. O., Leavitt, P. R., Ward, E. J., Bunting, L., ... & Wolfe, A. P. (2011). A coherent signature of anthropogenic nitrogen deposition to remote watersheds of the northern hemisphere. *Science*, 334(6062), 1545-1548.

Jiménez-Espejo, F. J., García-Alix, A., Jiménez-Moreno, G., Rodrigo-Gámiz, M., Anderson, R. S., Rodríguez-Tovar, F. J., ... & Pardo-Igúzquiza, E. (2014). Saharan aeolian input and effective humidity variations over western Europe during the Holocene from a high altitude record. *Chemical Geology*, 374, 1-12.

Vincent, J., Laurent, B., Losno, R., Bon Nguyen, E., Roullet, P., Sauvage, S., ... & Bergametti, G. (2016). Variability of mineral dust deposition in the western Mediterranean basin and south-east of France. *Atmospheric Chemistry and Physics*, 16(14), 8749-8766.

Detailed comments.

1. Consider quantifying the “richness” of nutrients in dust by comparing them to local bedrock and calculating enrichment factors. Saharan dust is generally low in organic matter and phosphorus, and phosphorus is often mineral-bound and slow to become bioavailable. Also, “rich in alkalinity” is imprecise; consider rephrasing as “rich in alkalizing minerals” or “minerals that increase acid-neutralizing capacity.”

ANSWER: You are right. The sentence has been changed (lines 126-127): “Saharan dust input fertilizes in phosphorus, calcium, and alkalizing minerals the oligotrophic lakes that receive it (Morales-Baquero et al., 2006b)”.

Saharan dust is rich in phosphorus for the phosphorus-starved ecosystems that receive it, despite containing only modest concentrations by geochemical standards. For example, in the Mediterranean basin, major sources of P to atmosphere are Saharan dust (Migon and Sandroni 1999; Guieu et al. 2002). When aerosols come in contact with water, a part of the particulate inorganic phosphorus associated with the particles can dissolve into orthophosphate form that may be assimilated by the biological community (Ridame & Guieu, 2002). Phosphorus solubility varied substantially across studies and dust sources but some researchers found values of solubility close to 40% in water (Herut et al., 1999; Pulido-Villena et al., 2010)

The influence of Saharan dust nutrients in Sierra Nevada lakes has been previously proved by members from our research group (Morales -Baquero et al., 2006; Reche et al., 2022).

Alkalinity has been changed to alkalizing minerals.

Guieu, C., Loÿe-Pilot, M. D., Ridame, C., & Thomas, C. (2002). Chemical characterization of the Saharan dust end-member: Some biogeochemical implications for the western Mediterranean Sea. *Journal of Geophysical Research: Atmospheres*, 107(D15), ACH-5.

Herut, B., Krom, M. D., Pan, G., & Mortimer, R. (1999). Atmospheric input of nitrogen and phosphorus to the Southeast Mediterranean: Sources, fluxes, and possible impact. *Limnology and Oceanography*, 44(7), 1683-1692.

Migon, C., & Sandroni, V. (1999). Phosphorus in rainwater: Partitioning inputs and impact on the surface coastal ocean. *Limnology and Oceanography*, 44(4), 1160-1165.

Morales-Baquero, R., Pulido-Villena, E., & Reche, I. (2006). Atmospheric inputs of phosphorus and nitrogen to the southwest Mediterranean region: Biogeochemical responses of high mountain lakes. *Limnology and Oceanography*, 51(2), 830-837.

Pulido-Villena, E., Rerolle, V., & Guieu, C. (2010). Transient fertilizing effect of dust in P-deficient LNLC surface ocean. *Geophysical Research Letters*, 37(1).

Reche, I., Mladenov, N., Pulido-Villena, E., & Morales-Baquero, R. (2022). Atmospheric inputs and biogeochemical consequences in high-mountain lakes. In *The Landscape of the Sierra Nevada: A Unique Laboratory of Global Processes in Spain* (pp. 293-306). Cham: Springer International Publishing.

Ridame, C., & Guieu, C. (2002). Saharan input of phosphate to the oligotrophic water of the open western Mediterranean Sea. *Limnology and Oceanography*, 47(3), 856-869.

Em dashes seem to be a mark of AI writing these days aren't normally used so frequently in standard text. This is just my personal opinion, but they should be restricted to when you really need to highlight something. I would remove them.

ANSWER: Em dashes have been removed

174 – High C/N ratios can also reflect nitrogen limitation and/or diagenesis, both of which may be more plausible interpretations given that the lake is above treeline.

ANSWER: As we stated above C/N can be interpreted in terms of N limitation or in terms of organic material origin. Wolfe et al. (2003) note that the C/N ratio is associated with N availability, but it can also be interpreted in terms of the origin of organic material (terrestrial vs algal) in alpine lakes In Rocky Mountains.

On the other hand, there are numerous articles in which the authors interpret the C/N ratio in terms of the origin of the organic material (terrestrial versus algal) in alpine lakes around the world. For example, Hu et al. (2014) in two alpine lakes in Tibet, Thevenon et al. (2012) in an alpine lake in Switzerland, Jiménez-Espejo et al. (2014) in a Sierra Nevada Lake or Lami et al. (2000) in eight European alpine lakes.

Both interpretations can be plausible. The lake is above the tree line but has an extensive catchment area compared to the lake area (Lake area= 0.187 ha; Catchment area =50.9 ha; Catchment :lake ratio = 272). For example Hu et al (2014) state that the C/N ratio values in an alpine lake are dependent of the terrestrial organic matter inputs (again a reflection of the greater catchment to lake ratio). The C/N ratio of this lake is 39, much lower than those of Borreguil lake. Moreover The lake is above the tree line but is surrounding by alpine meadows (0.563 ha) that can apport organic material to the lake.

Of course, the two explanations presented above are not mutually exclusive, and this has been reflected in our manuscript.

- Hu, Z., Anderson, N. J., Yang, X., & McGowan, S. (2014). Catchment-mediated atmospheric nitrogen deposition drives ecological change in two alpine lakes in SE Tibet. *Global Change Biology*, 20(5), 1614-1628.
- Thevenon, F., Adatte, T., Spangenberg, J. E., & Anselmetti, F. S. (2012). Elemental (C/N ratios) and isotopic ($\delta^{15}\text{N}_{\text{org}}$, $\delta^{13}\text{C}_{\text{org}}$) compositions of sedimentary organic matter from a high-altitude mountain lake (Meidsee, 2661 m asl, Switzerland): Implications for Lateglacial and Holocene Alpine landscape evolution. *The Holocene*, 22(10), 1135-1142.
- Jiménez-Espejo, F. J., García-Alix, A., Jiménez-Moreno, G., Rodrigo-Gámiz, M., Anderson, R. S., Rodríguez-Tovar, F. J., ... & Pardo-Igúzquiza, E. (2014). Saharan aeolian input and effective humidity variations over western Europe during the Holocene from a high altitude record. *Chemical Geology*, 374, 1-12.
- Lami, A., Guilizzoni, P., & Marchetto, A. (2000). High resolution analysis of fossil pigments, carbon, nitrogen and sulphur in the sediment of eight European Alpine lakes: the MOLAR project. *Journal of Limnology*, 59: 15-28.
- Wolfe, A. P., Van Gorp, A. C., & Baron, J. S. (2003). Recent ecological and biogeochemical changes in alpine lakes of Rocky Mountain National Park (Colorado, USA): a response to anthropogenic nitrogen deposition. *Geobiology*, 1(2), 153-168.

Results

Can you show the Chlorophyll-a to Pheophytin-a ratio, this will assist with interpreting degradation. I know some of these pigments are more or less susceptible to degradation, like diatoxanthin.

ANSWER: Regarding degradation, and given that this is a critical aspect for interpreting the pigment profile, we selected marker pigments following two criteria: (1) specificity to a taxonomic group (generally at the Division or Class level) and (2) low lability (i.e., a low number of functional groups), which ensures their persistence in the sedimentary record. Carotenoid stability depends largely on molecular structure and generally decreases with the number of functional groups (Britton et al., 1995; Sinninghe Damsté & Koopmans, 1997).

The set of 10 selected pigments provides coverage of all major algal and cyanobacterial groups while avoiding markers that, although highly indicative of specific taxa, such as fucoxanthin for diatoms, are too labile to be reliably used in down-core analyses. For this reason, we avoided chlorophyll-based pigments and focused on carotenoids. In particular, diatoxanthin is a highly reliable marker for diatoms due to its low number of functional groups, which makes it considerably more stable than fucoxanthin (Supplementary Table S2).

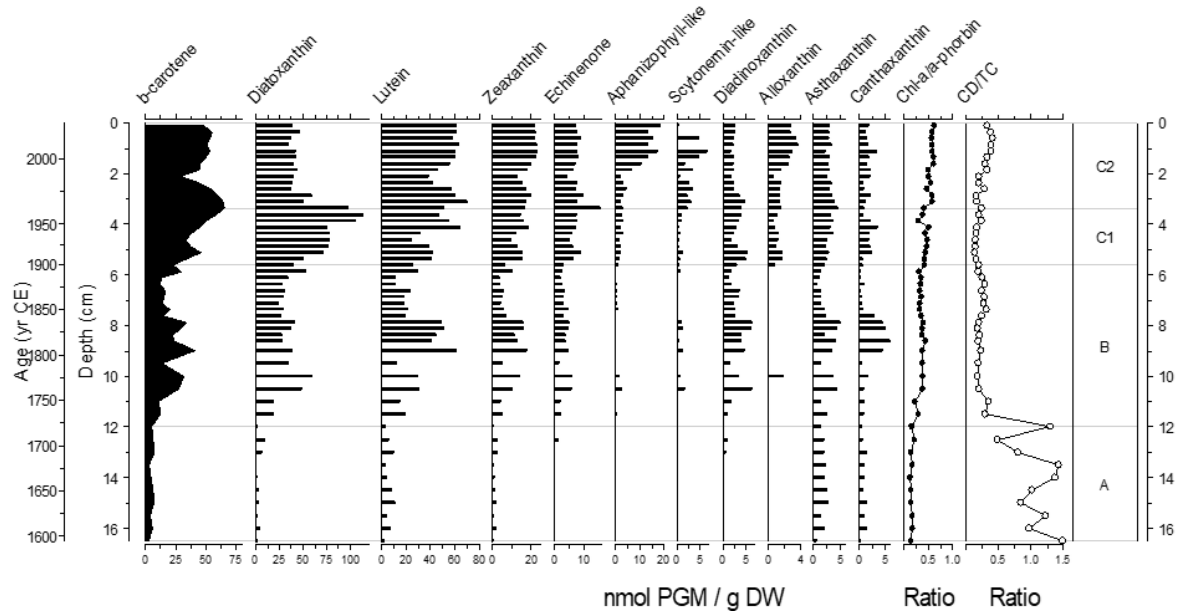
We also analysed Chl-a and several Chl-a degradation products, including chlorophyllide a, one allomer and two epimers of Chl-a, one pheophorbide, and two pheophytins (Table S2). We defined the sum of Chl-a and its derivatives as a-phorbin. Additionally, we calculated a Chl-a preservation index using the Chl-a/a-phorbin ratio. This index ranges from 0 (low Chl-a preservation) to 1 (high Chl-a preservation) (Buchaca & Catalan, 2007). When plotted along the sediment record, the index shows slightly higher values in the more recent sediments, ranging from 0.25 to 0.5 (Figure S2 in Supplementary). We interpret these results as evidence that pigment degradation is not a major concern in this record.

We have included a new table and a new figure in Supplementary Material.

Britton, G. (1995). Structure and properties of carotenoids in relation to function. *The FASEB Journal*, 9(15), 1551-1558.

Buchaca, T., & Catalan, J. (2007). Factors influencing the variability of pigments in the surface sediments of mountain lakes. *Freshwater biology*, 52(7).

Sinninghe Damsté, J. S., & Koopmans, M. P. (1997). The fate of carotenoids in sediments: an overview. *Pure and applied chemistry*, 69(10), 2067-2074.



Supplementary Figure S2. Pigment profiles of the 10 selected marker pigments and β -carotene expressed as concentrations (nmol PGM / g DW) and the ratios of Chl-a/a-phorbins as a Chl-a preservation index and the ratio CD/TC (chlorophyll-a derivatives vs. total carotenoids) as indicative of higher contribution of autochthonous production when the ratio is low. Four main biostratigraphic zones were established based on constrained incremental sum of squares partitioning of pigment concentration with Rioja-package version (0.9-15.2) (Juggins, 2017) using R version 3.5.3 (R Core Team 2019).

Supplementary Table S2. Pigments identified from lake sediments included in this study and their taxonomic affinities. The number of functional groups (FG) of the pigment molecular structure is also indicated for carotenoids.

Peak	RT (min)	PeakCode	Full name	lmax (nm)	Taxonomic affinity	FG
1	0.69	Ph_0	Chlorophyllide-a	432, 665	Chl-a degradation product, abundant in diatoms	
2	1.02	Ph_3	Chl-c1	441, 635	Diatoms and Chrysophytes	
3	1.04	Car_7_8	UVA2- Scytonemin	387	Cyanobacteria exposed to high UV radiation	4
4	1.09	Ph_5b	Chl-c2	448, 636	Cryptophyta, Dinoflagellates, Diatoms and Chrysophytes	
5	1.53	Car_5	Fucoxanthin	452	Chrysophytes and diatoms	5
6	1.44	Ph_2	Phaeophorbide-b1	438, 650	Chl-b degradation product (grazing processes)	
7	1.92	Ph_1a	Phaeophorbide-a	411, 664	Chl-a degradation product (grazing processes)	
8	2.19	Ph_2a	Phaeophorbide-b2	438, 650	Chl-b degradation product (grazing	

					processes)	
9	2.32	Car_9z	Astaxanthin	478	Zooplankton (Crustacea)	4
10	2.40	Car_17d'	Aphanizophyll	450, 477, 507	N2-fixing cyanobacteria	3
11	2.52	Car_10a	Diadinoxanthin	449, 479	Dinoflagellates, chrysophytes and diatoms	3
12	2.71	Car_12_5	Antheraxanthin	448, 477	Charophyceae, Rodophyta and vascular plants	3
13	2.91	Car_18	Alloxanthin	456, 484	Cryptophytes	2
14	3.11	Car_17	Diatoxanthin	456, 485	Diatoms and chrysophytes	2
15	3.21	Car_11	Lutein	448, 475	Chlorophyta	2
16	3.31	Car_12	Zeaxanthin	454, 483	Cyanobacteria, Chlorophytes	2
17	3.55	Car_16	Canthaxanthin	472	Cyanobacteria and zooplankton (Cladocera)	2
18	3.85	Ph_13	Chl-b	462, 650	Chlorophyta	
19	3.95	Car_17_3	Unknown	448, 475		
20	4.21	Ph_19a	allomer Chl-a	433, 663	Chl-a degradation product	
21	4.40	Ph_19	Chl-a	431, 662	Cyanobacteria, algae and vascular plants	
22	4.51	Ph_19e	epimer1 Chl-a	431, 662	Chl-a degradation product	
23	4.65	Ph_19e'	epimer2 Chl-a	431, 662	Chl-a degradation product	
24	4.73	Car_21	Echinenone	470	Cyanobacteria and zooplankton (Cladocera)	1
25	4.95	Ph_23	Phaeophythin-b1	435, 651	Chl-b degradation product (senescence)	
26	4.99	Car_25a	b-carotene	421, 454, 480	Cyanobacteria, algae and vascular plants	0
27	5.07	Ph_25	Phaeophythin-a1	410, 665	Chl-a degradation product (senescence)	
28	5.19	Ph_26	Phaeophythin-b2	436, 651	Chl-b degradation product (senescence)	
29	5.27	Ph_28	Phaeophythin-a2	410, 665	Chl-a degradation product (senescence)	

Also, I know its common to plot pigments etc by relative abundance with similar sized x axis, but it makes it hard to see the temporal changes in indicator pigments where the

concentrations are less than 10%. Can you plot your explanatory variables along side your data? You have a mix of graphs with time on the y or x axis, which makes it difficult to evaluate temporal relationships. Pick one way of showing the data, and stick to it. There is a lot of figure space given to PCA plots and plots that are repetitions (d15N vs Aphanizophyll (repeated from fig 3), but I would rather see more interpretable graphs, e.g. showing temporal changes in proxies alongside the predictor variables as well as predictor plots.

ANSWER: Manuscript figures have been thoroughly changed following your and reviewer 1 suggestions. Please, see the new figures.

All the figures have now the same axis to evaluate temporal relationships. Some figures have been merged (see figure 3). d15N vs Aphanizophyll figure has been removed.

You should use statistics to evaluate whether or not you are observing significant changes in your proxies through time.

ANSWER: We are sorry, but we are not sure what you are asking for. We considered applying a regression or another model to the proxies and time, but we are not sure if that is what you mean. We hope you can clarify this for us in the second round of reviews.

Why is the C/N ratio being compared to climate and atmospheric variables, what are you specifically testing here?

ANSWER: You are right. The C/N ratio can result from changes in climate, such as an increase in temperature enhancing algal production, provoking changes in degradation, or N limitation. However, it is difficult to determine the mechanism behind it using our data.

C/N is not a considered response variable in this article, in which we discuss the increase in algal biomass (chlorophyll-a and β -carotene). Moreover, we do not use this result in the Discussion section, so it makes no sense to include it in the Results section. This analysis has been eliminated.

Regarding dust, I did not see Zr/Al or similar elemental proxies presented. Were these measured, or are you relying on external studies to make these links for you? It is important to show how dust inputs are linked to your dataset. Plotting dust indices (e.g., wNAO, SPI) directly alongside pigment proxies would help establish clearer connections between drought, dust production, and specific pigment responses. Or better yet, find other clear data streams showing the relevant data. I'm not saying these relationships don't exist in the real world or even in your data, I'm just saying that they way you have presented the data is very cursory and does not make it clear.

ANSWER: The relationship between Zr/Al ratio from Río Seco Lake and Saharan Ca from an ice core from the Alps with Saharan deposition drivers (wNAO and SPI) were extensively explained in Jiménez et al (2018).

In Jiménez et al., (2018) we compared the sedimentary Zr/Al ratios directly measured in Río Seco Lake sedimentary record and the Saharan Ca concentration record derived from an Alps ice core (Preunkert & Legrand, 2013) with the wNAO (winter North Atlantic

Oscillation) index and the Sahel precipitation index records as representatives of Saharan deposition tendencies in Sierra Nevada. The Zr/Al ratio from RS and the Ca record derived from the Alps ice core show a highly significant correlation ($r = .785$, $p = 8.8 \times 10^{-4}$). The significant correlations found between Zr/Al ratio and both indices SPI ($r = .0862$, $p = 2.0 \times 10^{-6}$) and wNAO ($r = .361$, $p = .049$) and between the Ca ice core and SPI ($r = -0.448$, $p = 2.8 \times 10^{-5}$). These results support the assumption that we can consider wNAO and SPI to be predictors of the transport and intensity of Saharan dust events in Sierra Nevada and representative of P deposition trends in Sierra Nevada

We believe that it is clearly stated in the M&M section that we use the drivers of Saharan dust deposition to evaluate deposition in the Sierra Nevada (please, see lines 238-244): “The intensity of Saharan dust emission and transport has been linked to wNAO (winter North Atlantic Oscillation; Moulin et al., 1997) and to the Sahel drought (Chiapello et al., 2005; Moulin and Chiapello, 2004). Furthermore, Jiménez et al. (2018) demonstrated that the SPI and wNAO indices can be utilised as predictors of the transport and intensity of Saharan dust events in Sierra Nevada, reflecting atmospheric P and Ca deposition trends in this region. These indices exhibited strong correlations with the zirconium-to-aluminium (Zr/Al) ratio—a proxy for Saharan dust deposition—measured in a sediment core from one of the Sierra Nevada lakes, as well as with Saharan calcium concentrations in an ice core from the French Alps, which are indicative of Saharan dust events (Preunkert and Legrand, 2013). Consequently, SPI was employed for this purpose in the present study”.

Please note that the wNAO variable has been removed from the revised manuscript in response to a comment from Reviewer 1.

We do not believe to be necessary to show again the graph and to write about this relationship in M&M and Results. These are data and results from a previous article and we are trying to shorten the manuscript following your and reviewer 1 suggestion.

Jimenez, L., Rühland, K. M., Jeziorski, A., Smol, J. P., & Pérez-Martínez, C. (2018). Climate change and Saharan dust drive recent cladoceran and primary production changes in remote alpine lakes of Sierra Nevada, Spain. *Global change biology*, 24(1), e139-e158.

Preunkert, S., & Legrand, M. (2013). Towards a quasi-complete reconstruction of past atmospheric aerosol load and composition (organic and inorganic) over Europe since 1920 inferred from Alpine ice cores. *Climate of the Past*, 9(4), 1403-1416.

Line 415, did you explicitly show markers of increased dust deposition in your lake or is this entirely based off of other publications from nearby lakes? You haven't not made this relationship clear or explicit.

ANSWER: No, we do not have markers of Saharan dust deposition in the study lake but in a nearby lake (Río Seco Lake, Jiménez et al., 2018).

In Jiménez et al., (2018) we compared the sedimentary Zr/Al ratios directly measured in Río Seco Lake sedimentary record and the Saharan Ca concentration record derived from an Alps ice core (Preunkert & Legrand, 2013) with the wNAO (winter North Atlantic

Oscillation) index and the Sahel precipitation index records as representatives of Saharan deposition tendencies in Sierra Nevada.

The Zr/Al ratio from Río Seco Lake and the Ca record derived from the Alps ice core show a highly significant correlation ($r = .785$, $p = 8.8 \times 10^{-4}$). Significant correlations were found between Zr/Al ratio and both indices SPI ($r = .862$, $p = 2.0 \times 10^{-6}$) and wNAO ($r = .361$, $p = .049$) and between the Ca ice core and SPI ($r = -0.448$, $p = 2.8 \times 10^{-5}$). These results support the assumption that we can consider wNAO and SPI to be predictors of the transport and intensity of Saharan dust events in Sierra Nevada and representative of P deposition trends in Sierra Nevada.

To avoid confusion, we explicitly state “Saharan dust deposition drivers” instead of ‘Saharan dust deposition’ (line 435). Furthermore, we believe that it is clearly stated in the M&M section that we use the drivers of Saharan dust deposition to evaluate deposition in the Sierra Nevada (please, see lines 238-244): “The intensity of Saharan dust emission and transport has been linked to the Sahel drought (Chiapello et al., 2005; Moulin and Chiapello, 2004). Furthermore, Jiménez et al. (2018) demonstrated that the Sahel Precipitation Index (SPI) can be utilised as predictor of the transport and intensity of Saharan dust events in Sierra Nevada, reflecting atmospheric P and Ca deposition trends in this region. These indices exhibited strong correlations with the zirconium-to-aluminium (Zr/Al) ratio—a proxy for Saharan dust deposition—measured in a sediment core from one of the Sierra Nevada lakes, as well as with Saharan calcium concentrations in an ice core from the French Alps, which are indicative of Saharan dust events (Preunkert and Legrand, 2013). Consequently, SPI was employed for this purpose in the present study”. Please note that the wNAO variable has been removed from the revised manuscript in response to a comment from Reviewer 1.

Preunkert, S., & Legrand, M. (2013). Towards a quasi-complete reconstruction of past atmospheric aerosol load and composition (organic and inorganic) over Europe since 1920 inferred from Alpine ice cores. *Climate of the Past*, 9, 1403–1416.

Jimenez, L., Rühland, K. M., Jeziorski, A., Smol, J. P., & Pérez-Martínez, C. (2018). Climate change and Saharan dust drive recent cladoceran and primary production changes in remote alpine lakes of Sierra Nevada, Spain. *Global change biology*, 24(1), e139-e158.

Why are you comparing your results to examples of lakes below treeline?

ANSWER: There are few examples of pigment analysis in alpine lakes. We have tried to eliminate references to non-alpine lakes. Following reviewer 1's suggestion, the paragraph containing examples of non-alpine lakes (former lines 420-425) has been removed in order to shorten the discussion.

The discussion should be written as to highlight your main take home messages. What have we learned from your study, specifically? It is ok to compare and contrast to other studies, but this discussion opens paragraphs with other publications, more like a literature review, and is consequently excessively long.

ANSWER: Discussion has been shortened and focused in our results following your and reviewer 1 suggestions. Discussion has been reduced from eight pages to less than five pages.

Personal opinion, but the titles of the subheadings are a bit long

ANSWER: Subheading titles have been considerably shortened

439 How are you defining ‘alpine’, alpine is above treeline. Not all these publications are for lakes in the alpine. Mountain does not equal alpine. Please also be precise with citations.

ANSWER: You are right, alpine is above the tree line and some of the lakes referenced are not alpine lakes. We have changed alpine lakes by mountain lakes (line 451).

645 would you expect very colored DOC at this elevation though? ... a few lines later you mention a bog. Is this in the catchment? What vegetation is in the bog? You probably should include that in the site description!

ANSWER: No, we do not expect very colored DOC at this elevation.

In relation to our mention to bog: Sorry, we meant a peat bog (i.e. wet alpine meadows) surrounding the lake. Algae can develop in these habitats. We have changed the sentences to avoid misunderstanding (lines 557-559): “It seems reasonable to suggest that the observed increase in scytonemin and zeaxanthin may be linked to the growth of cyanobacteria, Chlorophyceae and Zygnematophyceae in radiation-exposed environments within the lake and associated wet alpine meadows (Hauer et al., 1997)”.

We have included a brief description of the alpine meadow vegetation in the study area (lines 130-133): “The lake is surrounded by approximately 0.56 hectares of alpine meadows, the flora of which is mainly composed of Cyperaceae, Poaceae and Fabaceae, with frequent genera including Carex, Nardus, Festuca and Scorzoneroideae (Pérez-Luque et al., 2015). The wetter meadow shows bryophyte species such as Drepanocladus fluitans”.

Pérez-Luque, A. J., Sánchez-Rojas, C. P., Zamora, R., Pérez-Pérez, R., & Bonet, F. J. (2015). Dataset of Phenology of Mediterranean high-mountain meadows flora (Sierra Nevada, Spain). *PhytoKeys*, (46), 89.