Sedimentary dynamics and heavy metal deposition in central Pyrenean high altitude lakes during the last 2000 years

Alejandra Vicente de Vera García¹, Fernando Barreiro Lostres¹, Ana Moreno Caballud¹, María del Pilar Mata Campo², Juan Pablo Corella Aznar³, Sergi Pla Rabes⁴, and Blas Lorenzo Valero Garcés¹

¹Pyrenean Institute of Ecology, Geoenvironmental processes, Montañana, Spain (a.vicentevera@csic.es)
²Instituto Geológico y Minero de España, Madrid, Spain
³Universite Grenoble Alpes, Grenoble, France
⁴CREAF, Barcelona, Spain

High altitude mountain lakes archive high-resolution records of environmental variability (climatic and anthropic). The REPLIM project funded by the INTERREG program (POCTEFA 2014-2020) has implemented a network to understand current and past changes in Pyrenean lakes. In this work, we compare six high altitude lake records along a W-E transect in the South Central Pyrenees: Acherito (1877 m.a.s.l.), La Sierra (2022 m.a.s.l.), Sabocos (1900 m.a.s.l.), Marboré (2600 m.a.s.l.), Urdiceto (2364 m.a.s.l.) and Cregüeña (2633 m.a.s.l.).

In each lake we have analyzed short sediment cores across transects applying sedimentological (facies, grain size, sediment composition, thin sections), geochemical (XRF scanner, elemental and trace metals) physical (Magnetic Susceptibility), isotopic (δ¹³C and δ¹⁵N of bulk organic matter) and biological (diatoms) techniques. The age models have been constructed with ¹³⁷Cs, ²¹⁰Pb and ¹⁴C dates.

The sedimentary dynamics and heavy metals depositional history for the last 2000 years provides a temporal context for recent changes. Sedimentary facies variability correlates with climate phases and reflect varied human pressures. In general, during the colder and more humid periods, usually associated with glacier advances (LIA and Late Antiquity LIA), higher surface runoff was generated and, therefore, sediment delivery to the lake increased, in some cases with deposition of coarser facies. Intense watershed disturbances due to human impact were noticeable in lower altitude lakes since early medieval times. All lakes show larger sediment rate variability during the last centuries, but the timing of the onset varies. Lakes located at higher altitudes (Marboré and Cregüeña) show larger changes in sedimentation rates and dynamics around the end of the LIA (ca. 1850 CE), while in lower altitude lakes (Sierra, Sabocos, Acherito) occurred later (ca. 1950 CE). In most lakes, a significant increase in organic matter accumulation started at the end of the 19th century and the trend accelerated since mid 20th century. Diatom and isotopes analyses suggest an increase in lake primary productivity during the last decades. The results indicate that the combined impacts of climate change and increased human pressure in the Pyrenees at the end of the LIA had a greater impact on high-altitude lakes, but recent
changes in the 20th century have affected the lakes at all altitudes

All lakes show a similar heavy metal deposition pattern, with enrichment during Roman and Medieval times and a progressive increase since the end of the 18th century (industrialization) and reaching its peak in the middle and late 20th century. Some metals, such as Pb, show a subsequent decline at the end of the 20th century related to the reduction of industrial emissions and the ban on leaded gasoline.

This integrated approach demonstrates the sensitivity of high altitude lake systems to record past changes and highlights the need for multi-archive studies to support regional reconstructions of past environmental and climate changes.