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# Reconstructing historical freshwater geochemistry to inform the conservation of the Natterjack Toad (*Epidalea calamita*) in Surrey, UK

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## Background

The Natterjack toad (*Epidalea calamita*) is a small, rare amphibian native to Europe. In the UK and Ireland they are now largely confined to sandy heaths, coastal dunes, and shallow warm ponds, with only a limited number of breeding sites remaining following historical habitat loss. Populations have declined due to habitat fragmentation, hydrological changes, and breeding site scarcity (Abrahams et al., 2026), making the species a conservation priority and challenging to monitor using traditional methods. They are also sensitive to changes in water chemistry, including acidification, which can affect egg and larval survival (Beebee et al., 1990). As a result, the Natterjack Toad is a protected species in the UK and remains a key focus of habitat restoration and long-term freshwater management efforts.

## Aims

- Reconstruct historical environmental conditions in two heathland freshwater systems using sediment cores from Churt Small Flash (CHSF; dating back to 1855) and Frensham Little Pond (FRLP; dating back to to 1903) to assess long-term changes in pH, redox state, and hydrology.
- Wider aim of informing conservation strategies for Natterjack Toads in Surrey, UK.

## Methodology







**Figure 1 (Right) :** Map of CHSF and FRLP (Surrey, UK) with sediment coring sites indicated.

**Figure 2 (Left) :** Sediment sample preparation and processing workflow prior to XRF analysis. (Left) Weighing and homogenisation of dried sediment samples. (Centre) Labelled sample pots organised by depth interval for Churt Small Flash. (Right) Samples placed in the Rigaku NEX CG spectrometer for XRF analysis.

- Sediment samples from CHSF (n = 14) and FRLP (n = 21) were analysed using X-ray fluorescence (XRF) spectroscopy to determine elemental composition.
- The obtained data was cleaned and analysed in Excel and R to identify trends, correlations, and prepare variables for multivariate analysis.
- Multiple Factor Analysis was conducted in R to assess multivariate relationships among elemental variables, elemental ratios, and inferred environmental processes.
- Standardised elemental variables were grouped into five geochemical categories (redox-sensitive, nutrients, flooding, metals, erosion), and percentage contributions to principal dimensions were calculated and visualised (factor maps, bar plots, correlation circle).
- Sample distributions were examined using MFA factor maps, and an additional MFA was performed to assess variation in elemental composition with sediment depth.

## Results




**Figure 3 :** MFA factor maps showing sample distribution by depth for CHSF and FRLP. Depth groups illustrate stratigraphic variation and separation along redox and hydrological–erosional gradients (Dim 1 and Dim 2). Ellipses indicate depth clustering.

- At CHSF, deeper sediments (10–20 cm) align with Dim 2 (erosion and catchment input), while surface sediments (0–5 cm) align with Dim 1 (redox–flooding influence). This indicates a shift from externally driven erosion at depth to stronger redox and hydrological control in recent sediments.
- At FRLP, deeper sediments (30–50 cm) show greater Dim 2 influence (stable, lower disturbance), whereas surface sediments (0–15 cm) align with Dim 1 (metal enrichment and reducing conditions). This reflects a transition from relatively stable past conditions to increasingly redox-sensitive, metal-influenced recent sediments.

## Results

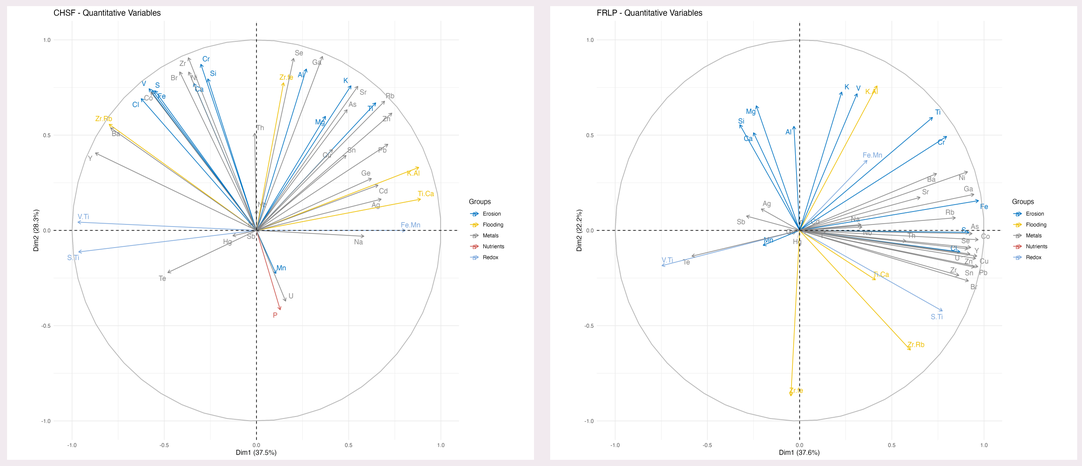



**Figure 4 :** MFA correlation circles of quantitative elemental variables for CHSF and FRLP. Vector length and direction show variable contributions to Dim 1 and Dim 2 across geochemical groups.

- **CHSF – Dimension 1:** Represents a coupled redox–hydrological gradient, with high V/Ti and S/Ti indicating increasingly reducing (anoxic) conditions, alongside elevated Ti/Ca, K/Al and Zr/Rb reflecting enhanced detrital input and flooding.
- **CHSF – Dimension 2:** Driven by catchment-derived and erosional inputs; elevated Al, Si, K and Ti, and high Zr/Fe and Zr/Rb ratios indicate intensified runoff, physical weathering, and grain-size variability linked to flood layers.
- **FRLP – Dimension 1:** Reflects redox dynamics and oxygen variability; strong contributions from V/Ti, S/Ti, Co and As suggest increasingly reducing conditions and enhanced metal mobilisation, with K, V and Mg indicating detrital runoff inputs.
- **FRLP – Dimension 2:** Represents a hydrologically driven flooding–erosion gradient; high Zr/Fe and Zr/Rb indicate coarser grain size and increased detrital input, while elevated K/Al suggests dominance of physical over chemical weathering.

## Conclusions

- MFA reveals clear redox–hydrological and erosion-driven gradients shaping sediment composition at both sites.
- Both CHSF and FRLP show temporal shifts from more stable or erosion-dominated past conditions to increasingly redox-sensitive recent sediments.
- Elevated redox-sensitive ratios suggest periods of low pH and anoxic conditions.
- These acidic and reducing phases are ecologically significant, particularly for sensitive species such as Natterjack Toads, which are vulnerable to environmental acidification.

## Future Direction

- These findings highlight potential implications for habitat quality and conservation management.
- Monitor redox conditions and pH regularly to identify periods of ecological stress and protect sensitive species.
- Integrate sediment geochemistry into long-term ecological monitoring programmes to inform adaptive freshwater management.

## Acknowledgements

This is part of a larger project between Surrey Wildlife Trust and Amphibian Reptile Conservation with the aim of informing conservation strategies for Natterjack Toads in Surrey, UK.

## References

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