International seminar
Monitoring and restoration of freshwater (mussel) habitats

Thursday 29th November 2018
Clervaux, Luxembourg

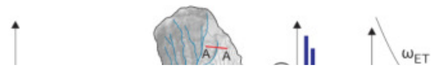
# On the potential for freshwater pearl mussels to serve as a stream water stable isotope recorder

*Laurent Pfister, Frank Thielen, Etienne Deloule, Nathalie Valle, Esther Lentzen, Cléa Grave, Jean-Nicolas Beisel, and Jeffrey J. McDonnell*

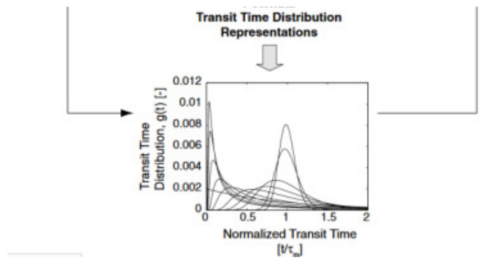
# THE AGE OF FLOWING WATER

## Stable isotopes of water: a cardinal tool in hydrology

- $\delta^{18}O$ & $\delta D$ flow paths analysis and stream water source apportionment
- Time series of precipitation and stream water isotope composition used for TT analyses

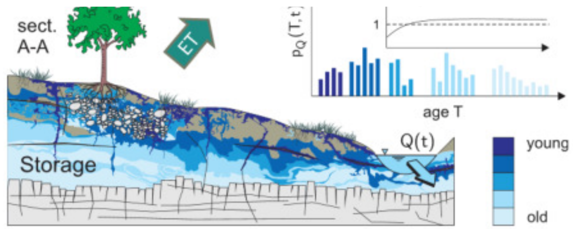




**One important barrier:**
**the extremely limited record of isotopes in stream water**




McGuire & McDonnell, 2006

Lumped parameter catchment transit time modelling




Rinaldo et al., 2015

Catchment storage supplies the outflows with water of different ages

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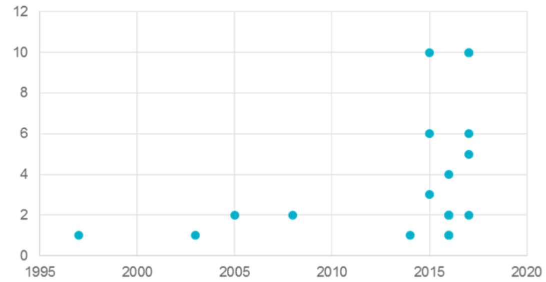
# THE AGE OF FLOWING WATER

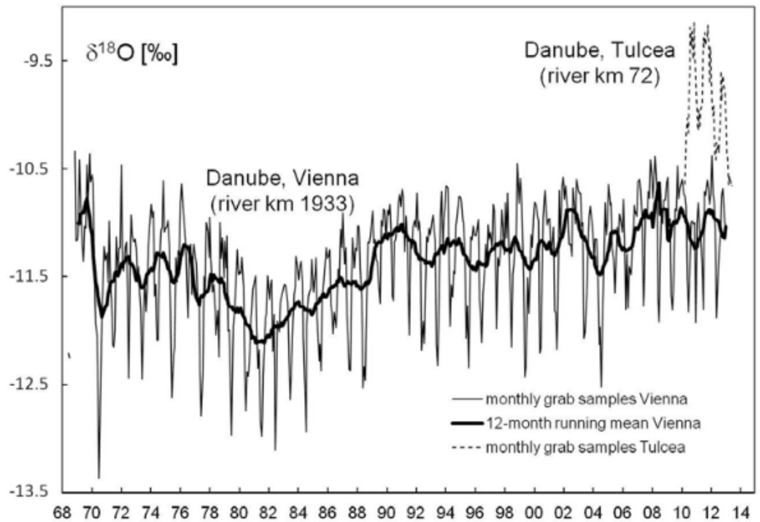
## Stream water isotope record length

- Long streamflow isotope records remain limited

- Isotope records of streamflow: full potential is hindered by short and truncated time series




- Global Network of Isotopes in Rivers (GNIR – IAEA)

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# RECONSTRUCTING STREAM WATER ISOTOPE DATA

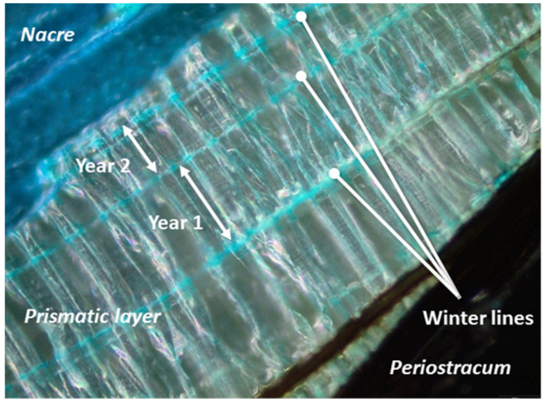
## Freshwater molluscs

- Some interesting facts about freshwater molluscs

# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Freshwater molluscs as isotope recorders?

- Shell growth process **calcium carbonate precipitates**
  *successive layers of calcite or aragonite*

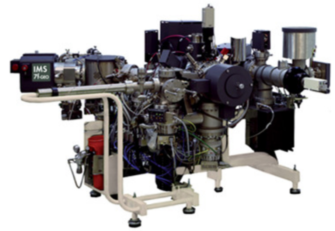

- Layers exhibit **different shadings**
  *calcite or aragonite layers, interlaid with organic matter*

- **Molluscs record geochemical information**
  *layers interpreted as annual or seasonal expressions of growth bands*

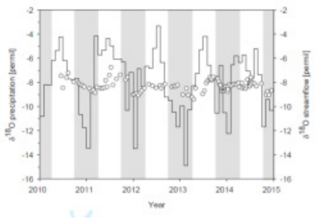
# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Research questions

I. Can we sample this material and analyze isotopic ratios of O with **secondary ion mass spectrometry** (SIMS)?



II. How does the **range, standard deviation and harmonics** of the annual cycle of freshwater pearl mussel shell material relate to precipitation and stream water isotope signals?




III. Is the idea of using freshwater mollusks as archives of streamwater isotopic signatures **globally valid**?

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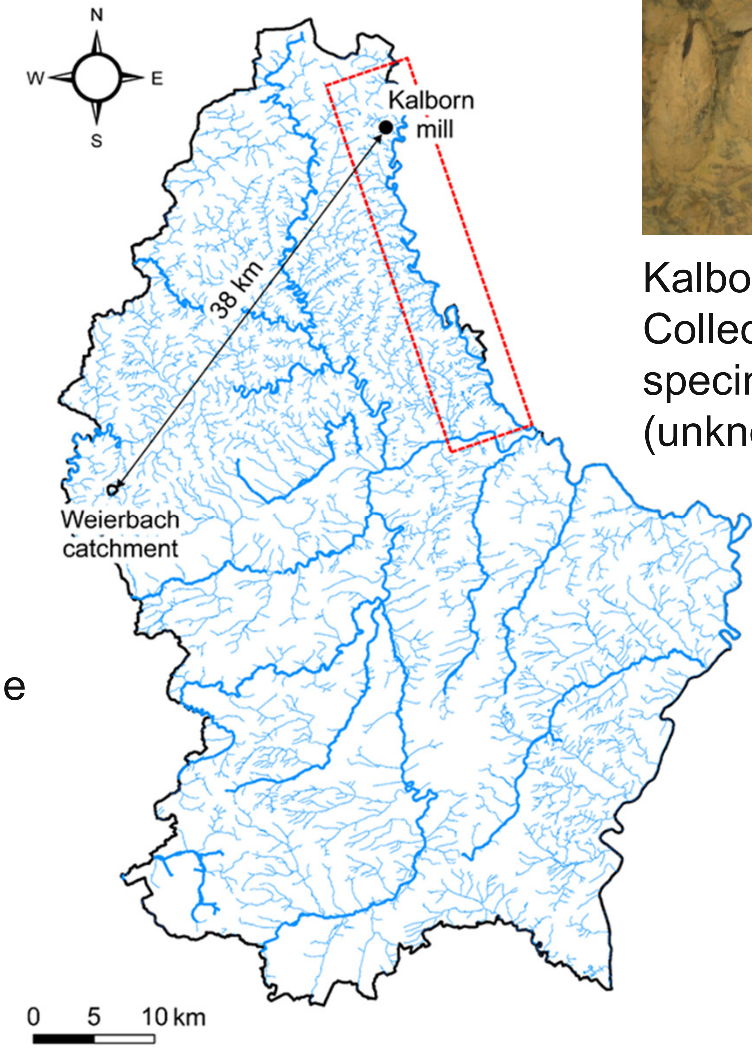
# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Study area

Rain gauge

Stream gauge




Kalborn Mill growth station
Collected pearl mussel specimen
(unknown date of death)

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# RECONSTRUCTING STREAM WATER ISOTOPE DATA

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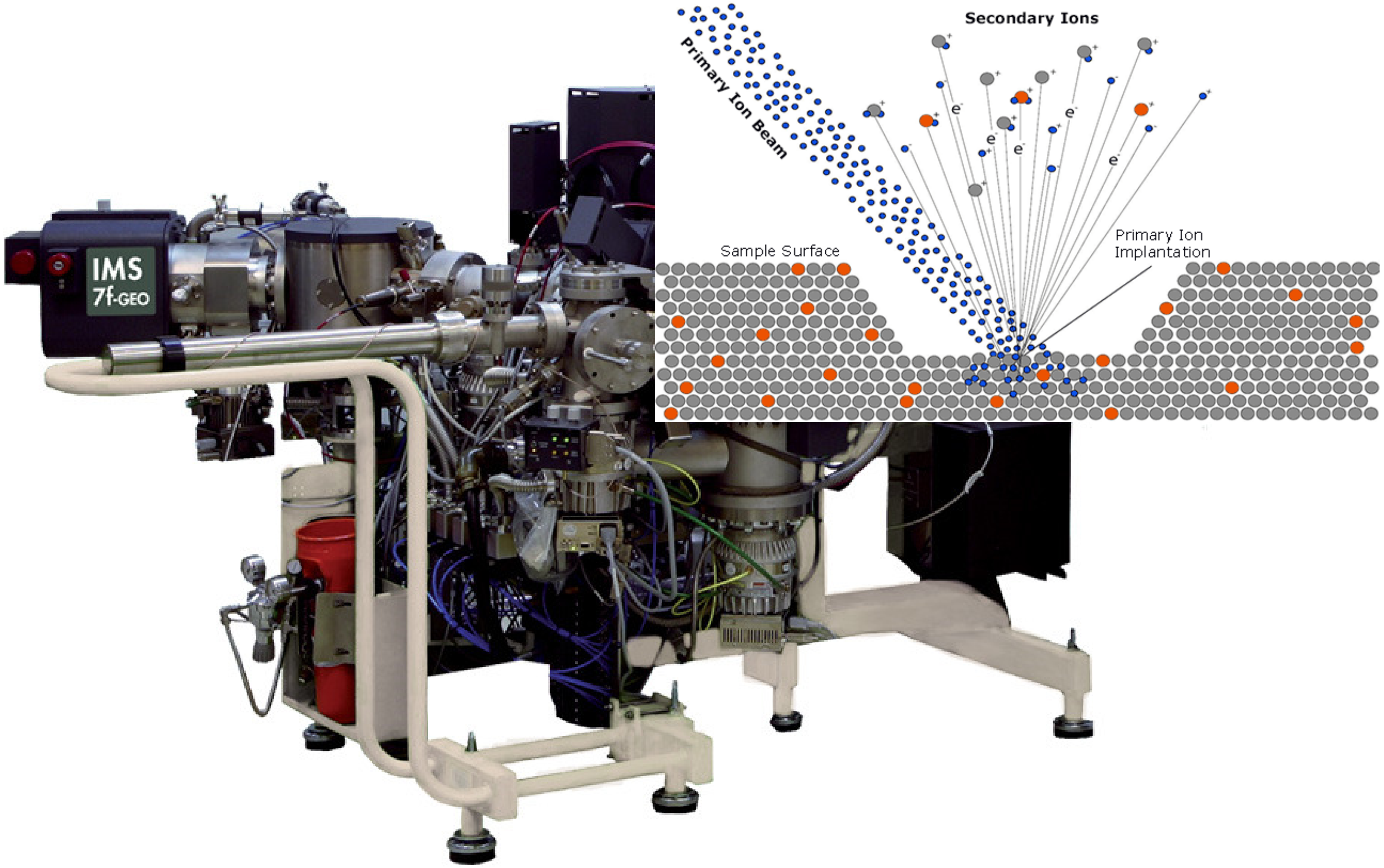
## Secondary Ion Mass Spectrometry (SIMS)




15 µm-diameter focused beam scans over a surface of 15×15 µm
Precision 0.1 ‰

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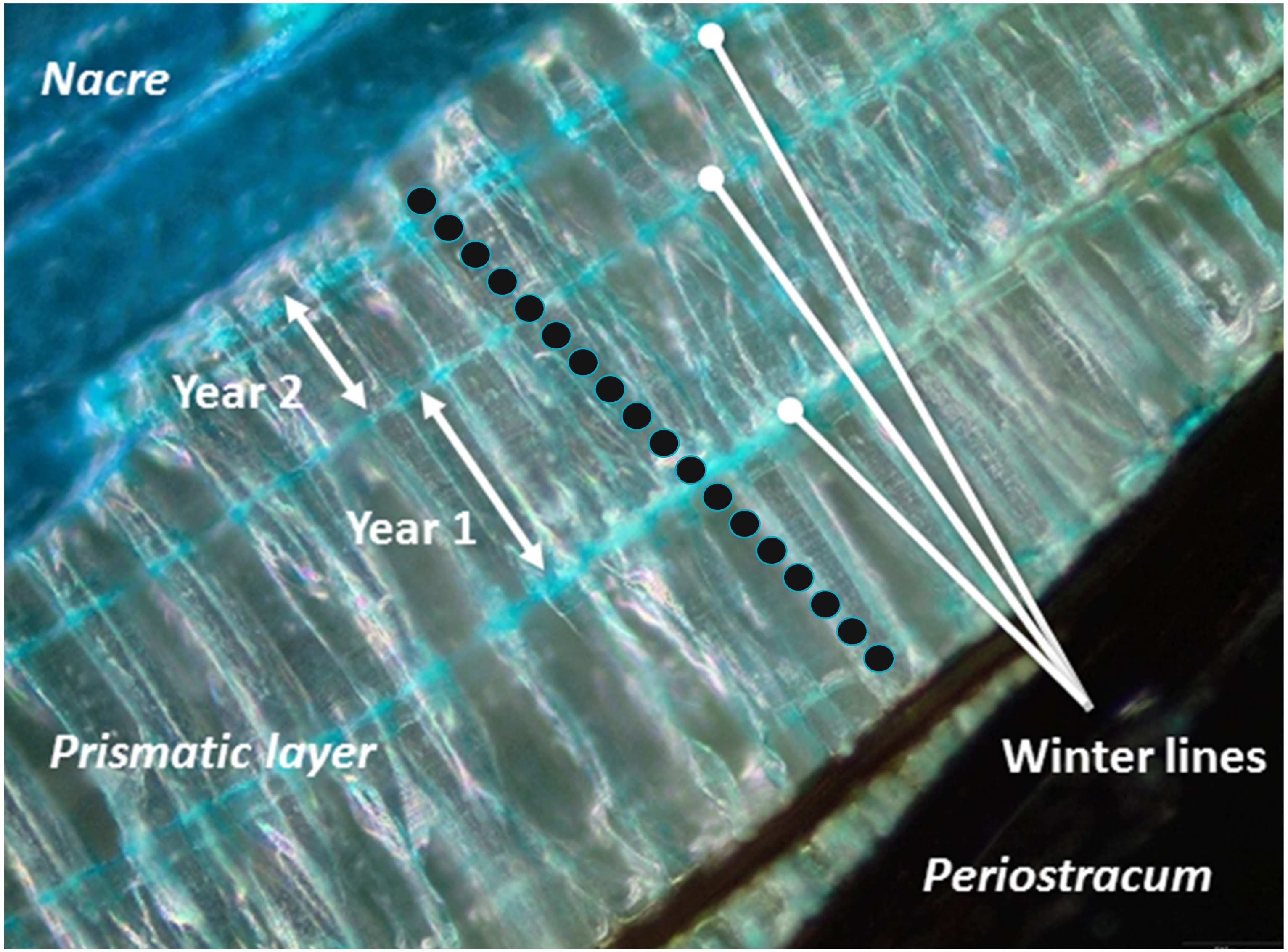


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# RECONSTRUCTING STREAM WATER ISOTOPE DATA

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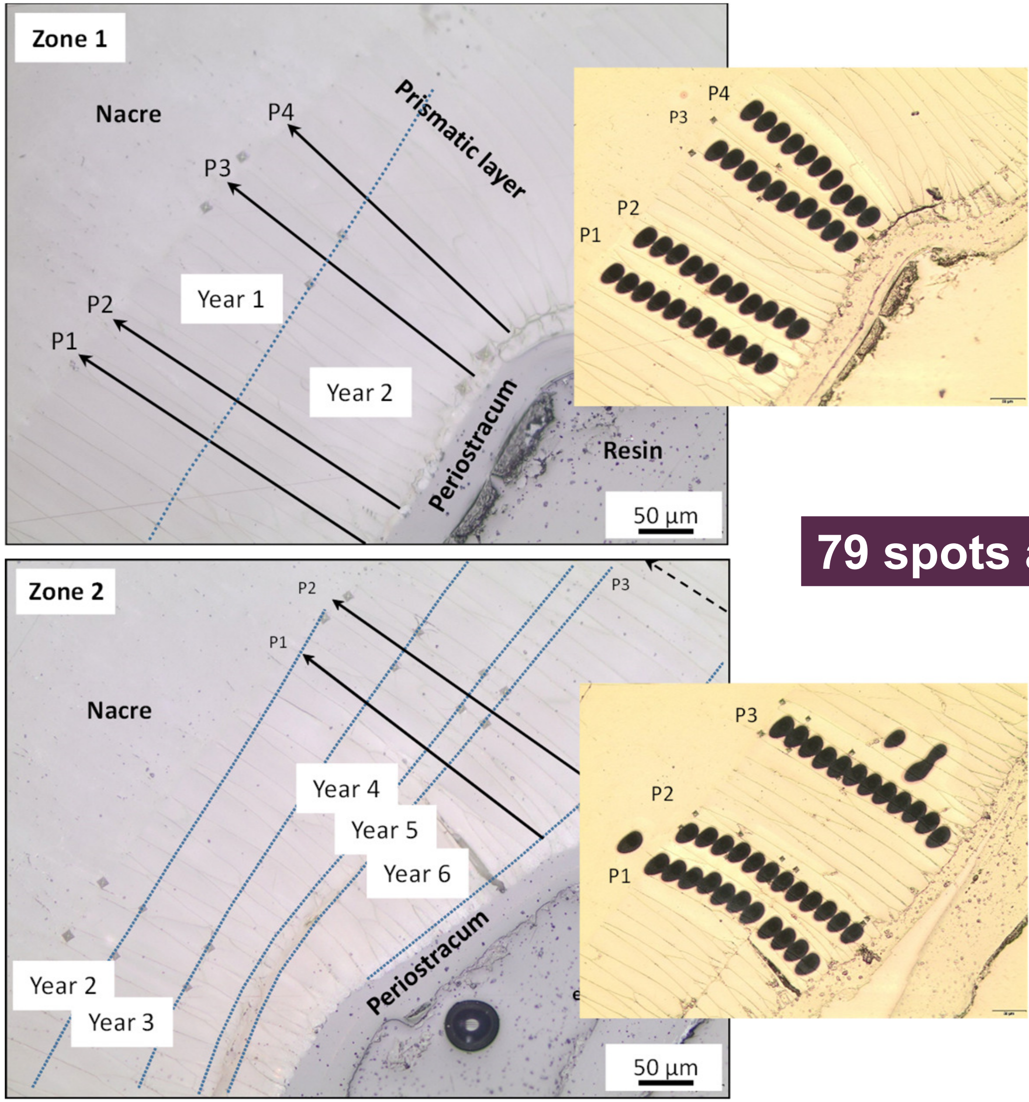


**79 spots analysed**

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# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Secondary Ion Mass Spectrometry (SIMS)

- Signal translation

We followed Friedman and O'Neil (1977) for inferring $\delta^{18}O$ ratios in water from $\delta^{18}O$ ratios in shell material:

$$1000 \ln\alpha = 2.78\,(10^{6}\,T^{-2}) - 2.89 \qquad (1)$$

where T = stream water temperature (in °K) and $\alpha$ = fractionation between water and calcite.

$$\alpha^{calcite}_{water} = \frac{[1000 + \delta^{18}O_{ca}\,(VSMOW)]}{[1000 + \delta^{18}O_{w}\,(VSMOW)]} \qquad (2)$$

where *ca* is shell calcite and *w* is water. Note that $\delta^{18}O_{ca}$ values were initially relative to the Vienna Pee Dee Belemnite (VPDB) reference. They were converted to the Vienna Standard Mean Ocean Water (VSMOW) as per Gonfiantini et al., 1995):

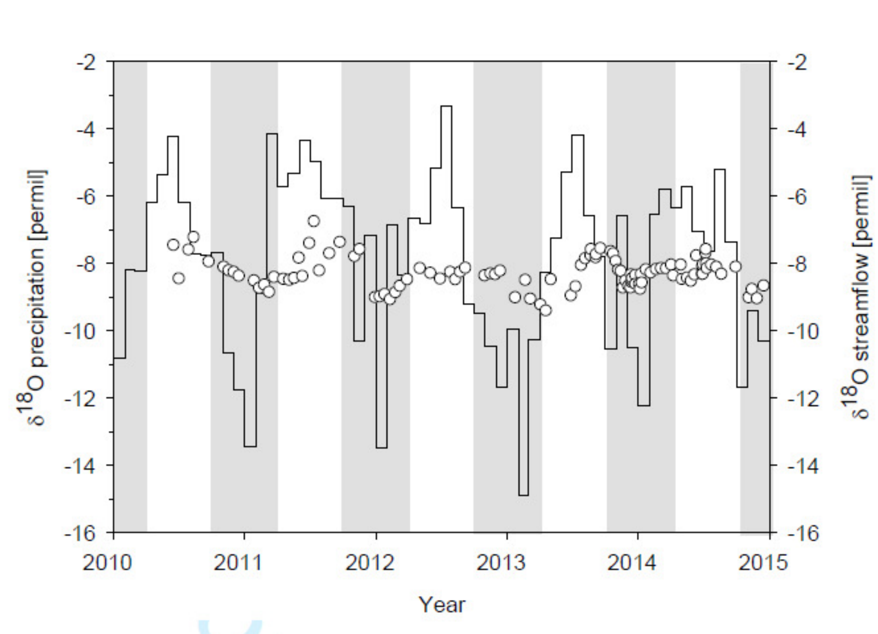
$$\delta^{18}O_{ca}\,(VSMOW) = \alpha^{calcite}_{water}\,(1000 + \delta^{18}O_{ca}\,(VPDB)) - 1000 \qquad (3)$$

Ultimately, $\delta^{18}O$ ratios in water were obtained via:

$$\delta^{18}O_{w}(VSMOW) = \frac{[1000 + \delta^{18}O_{ca}\,(VSMOW)]}{\alpha} - 1000 \qquad (4)$$

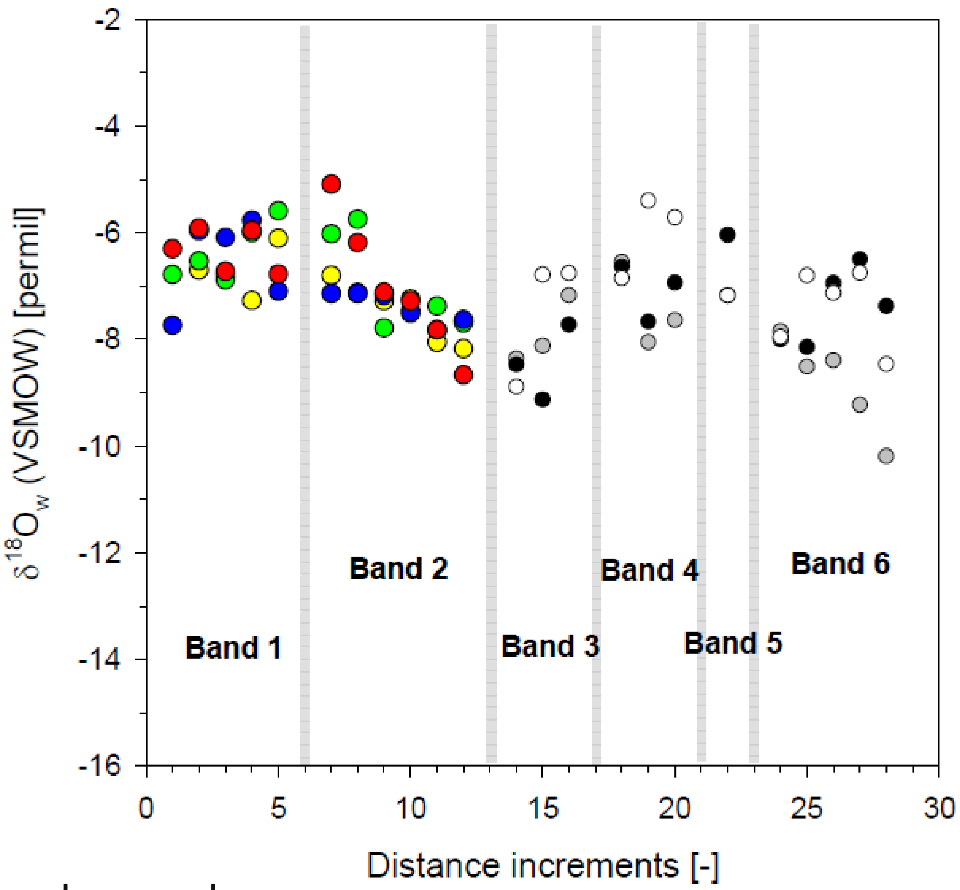
# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Results




Precipitation
& streamflow

Time series of $\delta^{18}$O signatures




Freshwater pearl mussel

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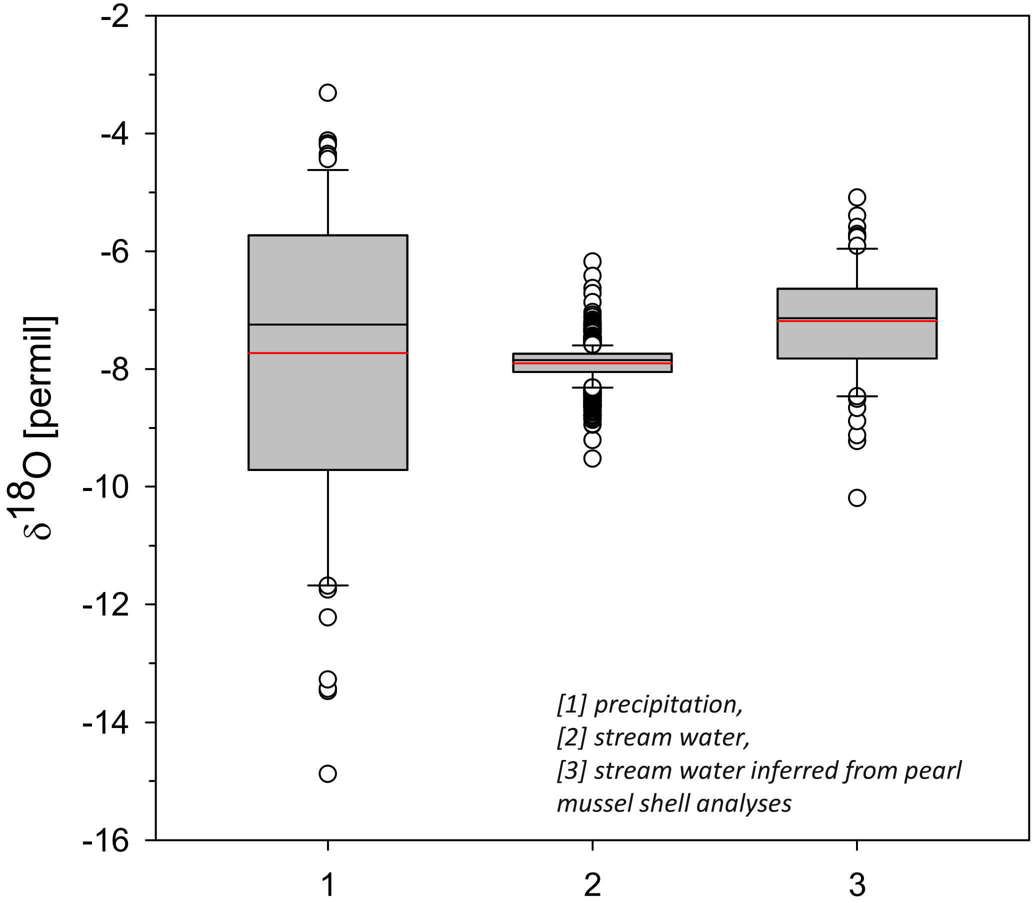
# RECONSTRUCTING STREAM WATER ISOTOPE DATA

## Results

Box plots of $\delta^{18}O$ signatures




| | Precipitation | Stream water | Pearl mussel shell |
|---|---|---|---|
| Average | -7.73 ‰ | -7.90 ‰ | -7.19 ‰ |
| Median | -7.25 ‰ | -7.85 ‰ | -7.14 ‰ |
| Range | 11.57 ‰ | 3.34 ‰ | 5.10 ‰ |

(Pfister et al., 2018)

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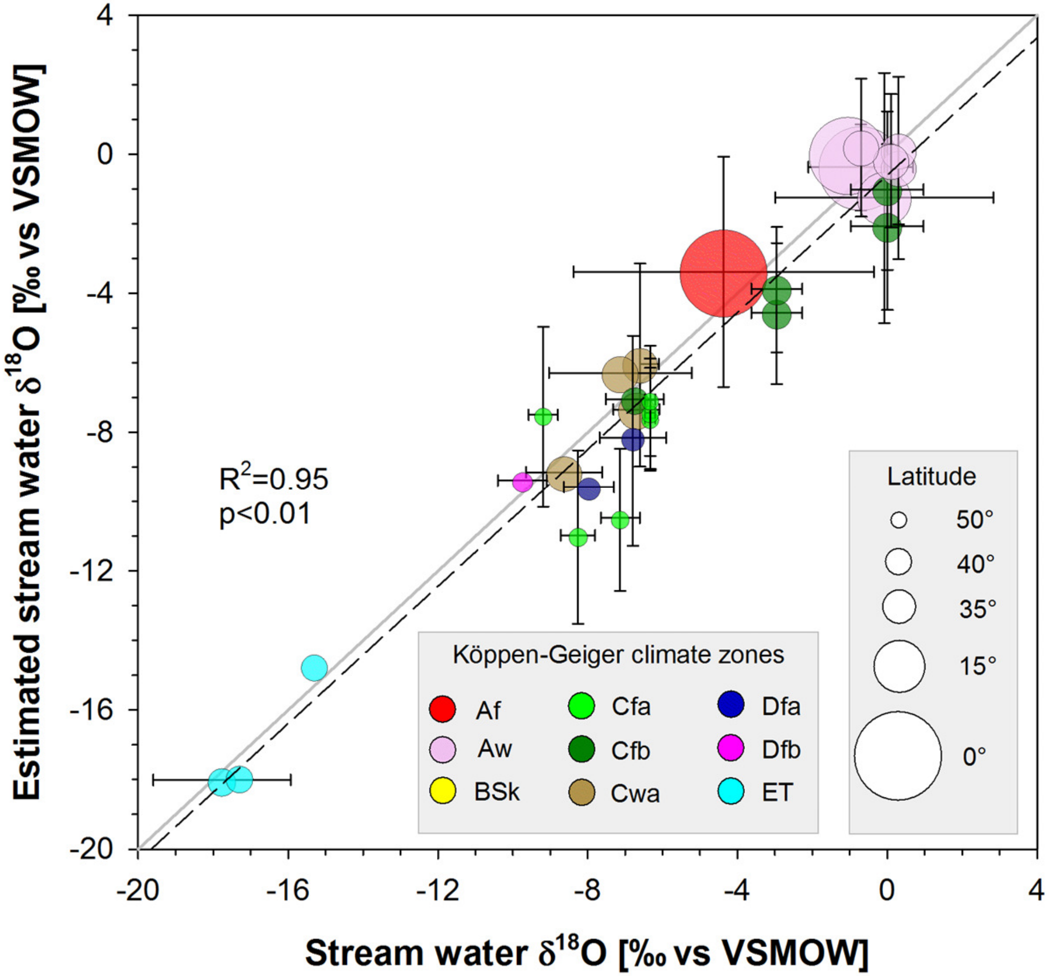
## Global validity of the concept




$R^2 = 0.95$

Results from 18 river basins
(Pfister et al., *submitted*)

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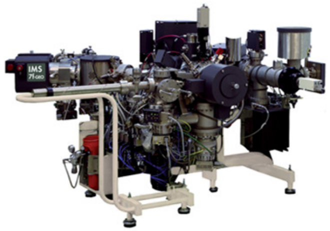
# CONCLUSIONS

YES

I. Can we sample this material and analyze isotopic ratios of O with **secondary ion mass spectrometry** (SIMS)?



YES

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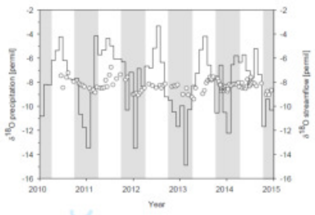

YES

III. Is the idea of using freshwater mollusks as archives of streamwater isotopic signatures **globally valid**?

Next step: apply the protocol to entire sequence of mussel shell growth rings

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# QUESTIONS?