Modelling macroinvertebrate hydraulic preferences across broad geographic and environmental gradients using a limiting factor approach

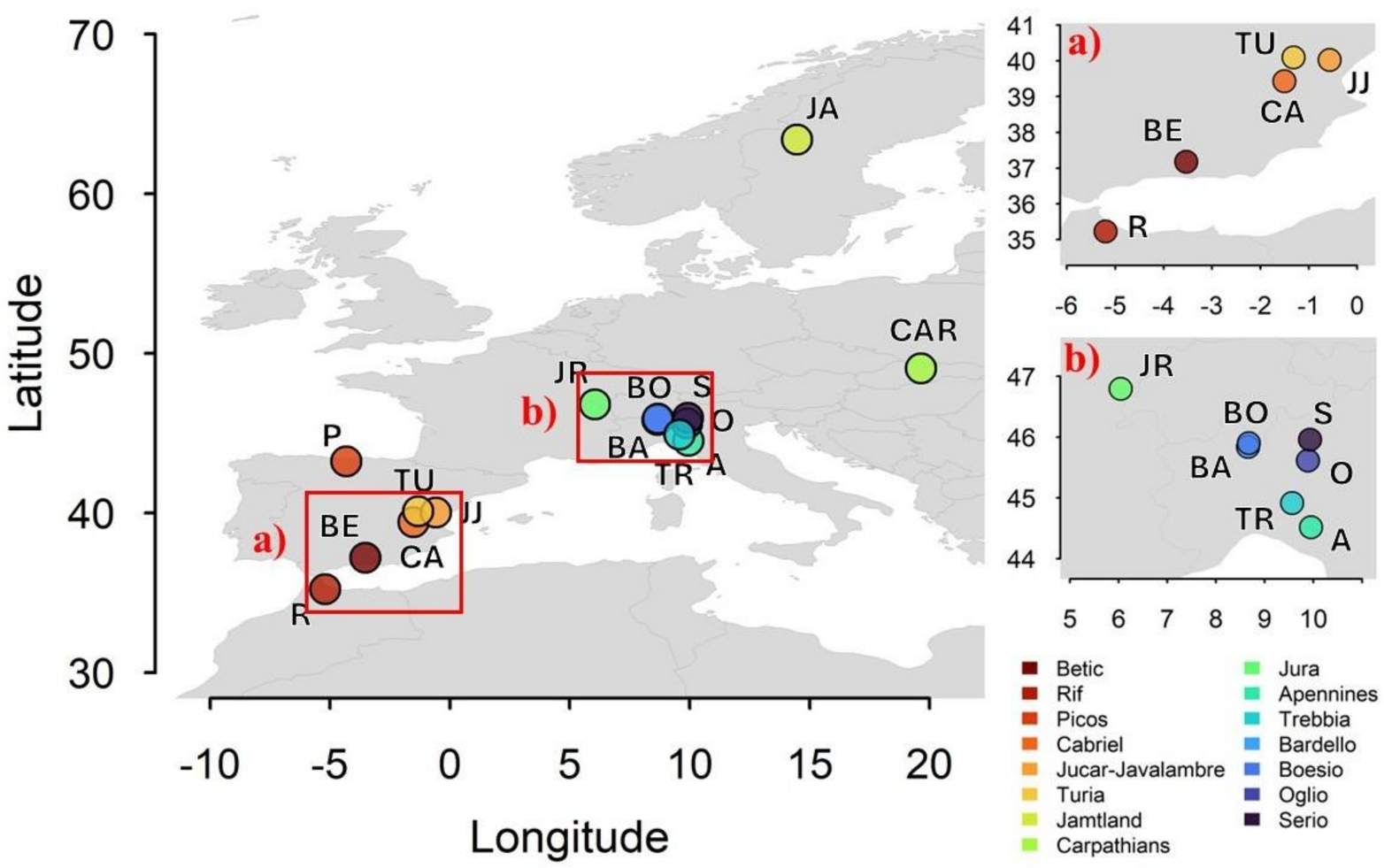
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Introduction:

- Rivers host high biodiversity and provide key ecosystem services but are increasingly affected by hydrological alterations.
- Macroinvertebrates are shaped by filters acting from regional to microhabitat scales, with hydraulics pivotal at the finest scale.
- Over recent decades, several studies assessed taxon-specific hydraulic preferences to mitigate flow alterations, demonstrating that hydraulic conditions filter similar taxa across distinct rivers, and supporting the transferability of hydraulic-based models.
- However, previous research has mainly focused on individual taxa or traits, typically evaluating average responses among reaches within a restricted geographical context.

Aim: Model invertebrate hydraulic habitat suitability, identify key metrics, and test response consistency across contrasting regions.



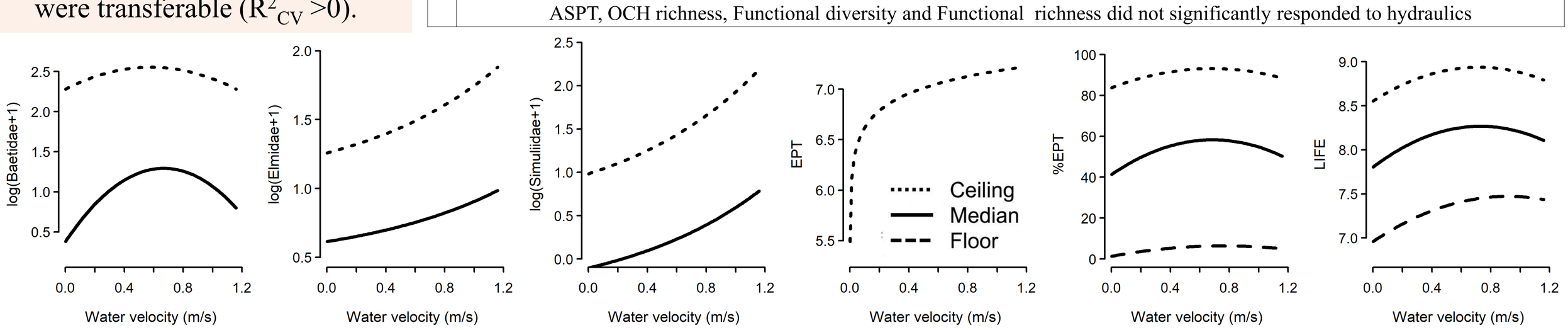
Methods:

- 1,430 macroinvertebrate samples from 89 rivers across **15 environmentally contrasting regions (R)** spread in North Africa (Morocco) and Europe
- **Quantile regression models** were used to test hydraulic influences evaluating responses at floor (F), median (M) and ceiling (C) quantiles
- Models relate the abundance of **17 dominant macroinvertebrate families and 12 community-level metrics** to water velocity (VEL), depth (DEPTH) and substratum (SUB).
- **Model transferability** across regions was evaluated using the Leave-One-Region-Out Cross-Validation.

Results:

- 47% (8/17) of the dominant taxa and 67% (8/12) of the community metrics **responded significantly to hydraulics**.
- **Velocity** emerged as the main microhabitat filter, with stronger effects at high values, supporting the use of limiting factor approach.
- Baetidae, Elmidae, and Simuliidae abundance, as well as EPT richness and proportion, and the LIFE index exhibited **consistent hydraulic preferences across regions** and were transferable (R^2_{CV} >0).

	Metric	VEL	DEPTH	SUB	Region	F	M	C	Formula	N° R	R^2cv (%)
Family abundances	log(Baetidae)	X	X	X	NO	-	X	X	poly(VEL, 2) + poly(DEPTH, 2) + R + SUB	15	4.3
	log(Elmidae)	X	X	-	NO	-	X	X	exp(VEL) + log10(DEPTH) + R	15	1.7
	log(Simuliidae)	X	X	X	NO	-	X	X	exp(VEL) + exp(DEPTH) + R + SUB	15	5.7
	log(Gammaridae)	X	-	-	YES	-	X	X	VEL + (VEL):R + R	13	-0.3
	log(Rhyacophilidae)	X	-	-	YES	-	X	X	VEL + (VEL):R + R	15	-1.5
	log(Heptageniidae)	X	-	-	YES	X	X	X	VEL + (VEL):R + R	14	-8.1
	log(Hydropsychidae)	X	-	X	YES	-	X	X	VEL + (VEL):R + R + SUB	15	3.2
	log(Leuctridae)	X	-	-	YES	-	X	X	VEL + (VEL):R + R	14	-0.8
	Athericidae, Caenidae, Chironomidae, Empididae, Ephemerellidae, Limonidae, Lumbriculidae, Limnephilidae and Naididae did not significantly responded to hydraulics										
Community metrics	log(Total Abundance)	X	X	-	YES	X	X	X	VEL + poly(DEPTH, 2) + (VEL):R + R	15	0.6
	Family richness	X	X	-	YES	X	X	X	VEL + DEPTH + (VEL):R + R	15	3.1
	EPT richness	X	X	X	NO	-	-	X	log10(VEL) + DEPTH + R + SUB	15	5.9
	EPT proportion	X	-	X	NO	X	X	X	poly(VEL, 2) + R + SUB	15	5.2
	OCH proportion	-	X	-	NO	-	X	-	log10(DEPTH) + R	15	-0.3
	EPT / EPTOCH	X	-	-	YES	X	X	X	log10(VEL) + (log10(VEL)):R + R	15	0.3
	Shannon diversity	-	X	-	NO	X	X	X	exp(DEPTH) + R	15	0.4
	LIFE	X	X	X	NO	X	X	X	poly(VEL, 2) + exp(DEPTH) + R + SUB	15	5.6
	ASPT, OCH richness, Functional diversity and Functional richness did not significantly responded to hydraulics										



Conclusion: This univariate pattern suggests that these metrics can be used to assess ecological status at both reach and microhabitat scales across broad geographic gradients, extending flow-ecology generality and offering robust tools for river management.