Comparative vulnerability of riverine benthic and aquifer stoneflies in a large alluvial river floodplain

Rachel L. Malison, H.A. Woods, J. Frakes, J. Cotter, H. Dole, G. Luikart, B.K. Hand & J.A. Stanford

10 October 2025

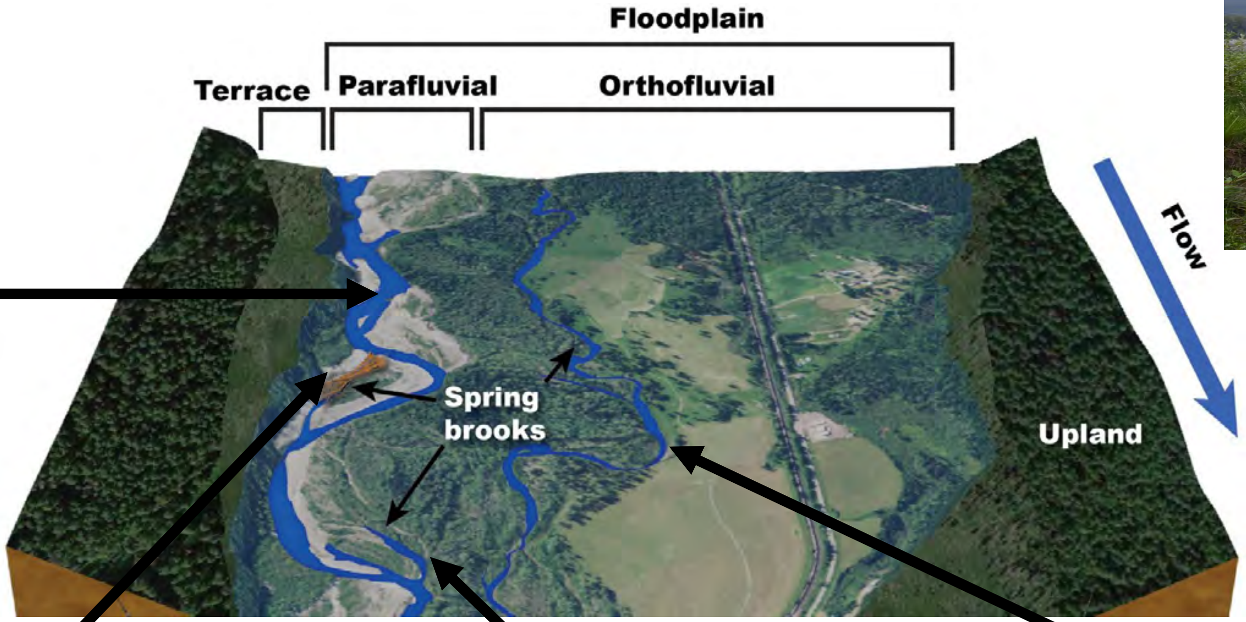
Montana AWRA

FLATHEAD LAKE BIO STATION
UNIVERSITY OF MONTANA

UNIVERSITY OF MONTANA

Habitat Complexity

Main channel shallow shoreline



Beaver ponds

Parafluvial ponds

Parafluvial spring brook

Orthofluvial spring brook

The Discovery - 1973

Science
AAAS

Hyporheic Communities of Two Montana Rivers
Author(s): Jack A. Stanford and Arden R. Gaufin
Source: *Science*, Aug. 23, 1974, New Series, Vol. 185, No. 4152 (Aug. 23, 1974), pp. 700-702
Published by: American Association for the Advancement of Science
Stable URL: http://www.jstor.com/stable/1738736

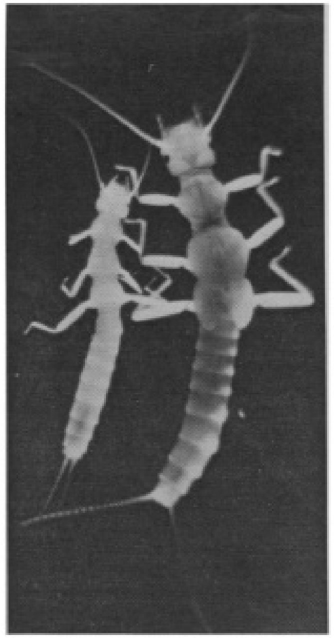


Fig. 1. Nymphs of *Paraperla frontalis* from underground habitat of the Tobacco River in northwestern Montana. Mature

Tobacco River. The galleries are approximately 10 m long and were constructed much like a sand-gravel filter; perforated pipes surrounded by graded gravels (0.6 to 2.5 cm) were embedded horizontally at a depth of 6 m (20 feet) in floodplain gravel. The three galleries deliver water to two cylindrical concrete reservoirs, each of which resembles a well 2.5 m in diameter and 6.2 m deep. The reservoirs are connected to allow simultaneous operation of two large pumps. Water stands static in the pump reservoirs at 1.8 m below ground level, corresponding to the water table in the immediate area. After chlorination, water is pumped from the reservoirs to a large holding tank for gravity dispersal to domestic users. Very little stress is placed on the galleries when the system is pumped at capacity [5700 liters (1500 gallons) per minute], and the static level does not change. Only during periods of high use in late summer is the system pumped at capacity. The water delivered is of high quality and remains

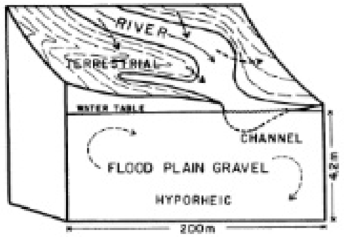
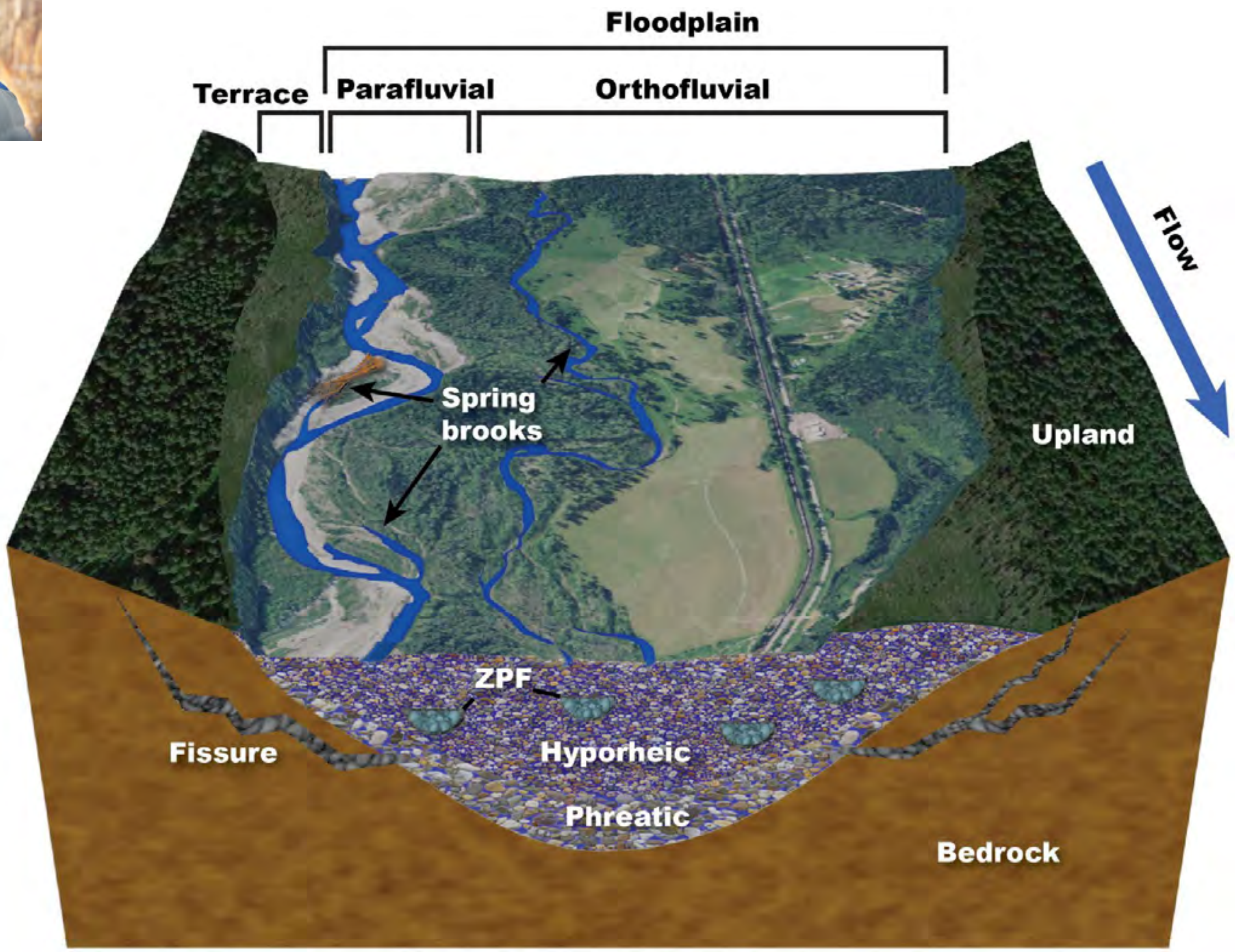


Fig. 2. Habitats utilized by stream organisms of the Flathead River. Dashed arrows indicate circulation of water from channel to hyporheic areas and vice versa. Dimensions refer to minimum floodplain width (200 m) and probable minimum vertical distribution (4.2 m) of hyporheic organisms.

gimes, substrata, and biota are remarkably similar in both rivers. Specifically, plecopteran species compositions are quite comparable.

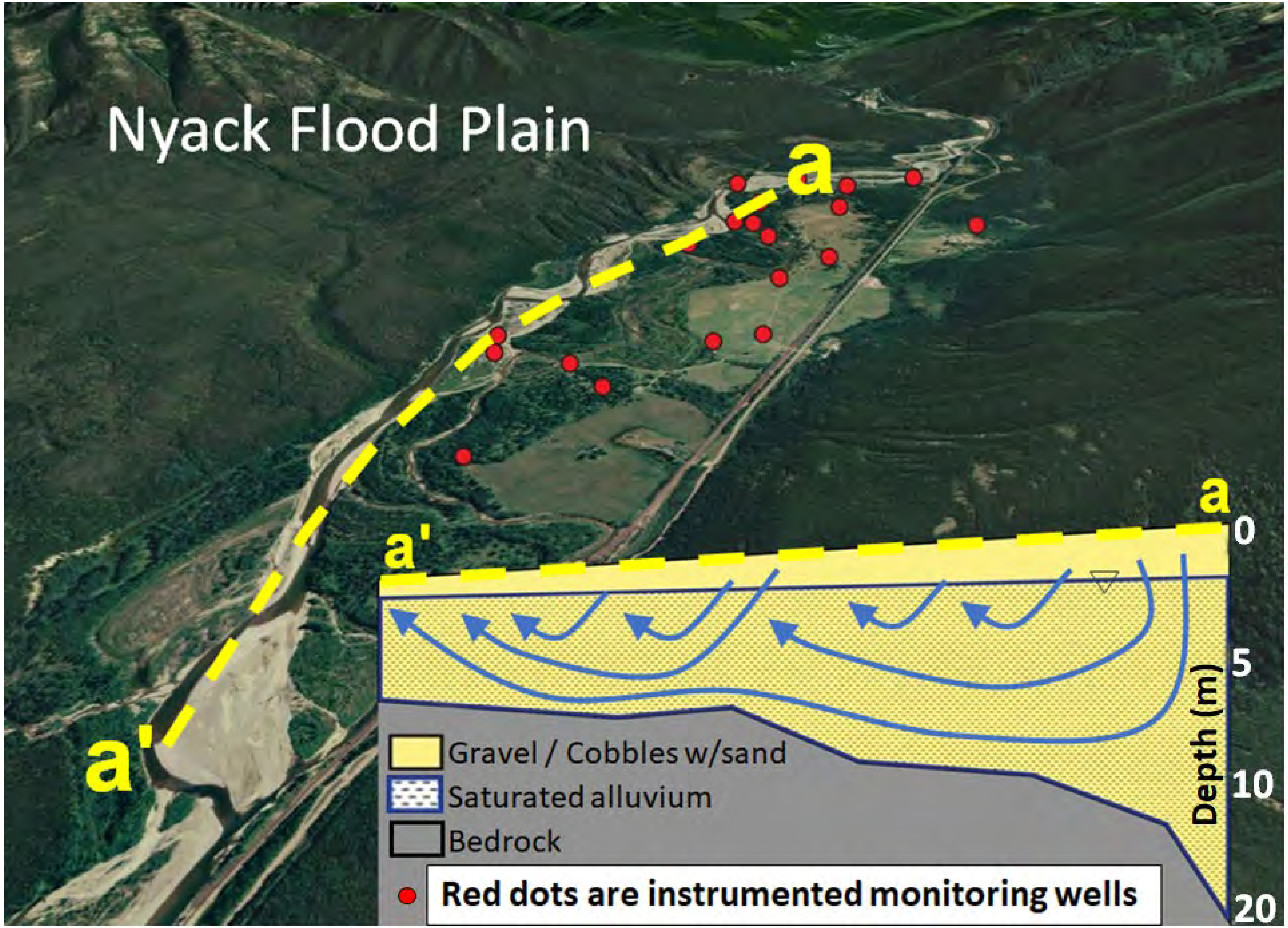
The galleries yielded *Paraperla frontalis* (Banks) most abundantly with as many as 100 nymphs accumulating in the nets each week (see Fig. 1). Sev-



Discovery greatly expanded the scale of the hyporheic zone concept

Stanford & Gaufin 1974; Stanford et al. 2024

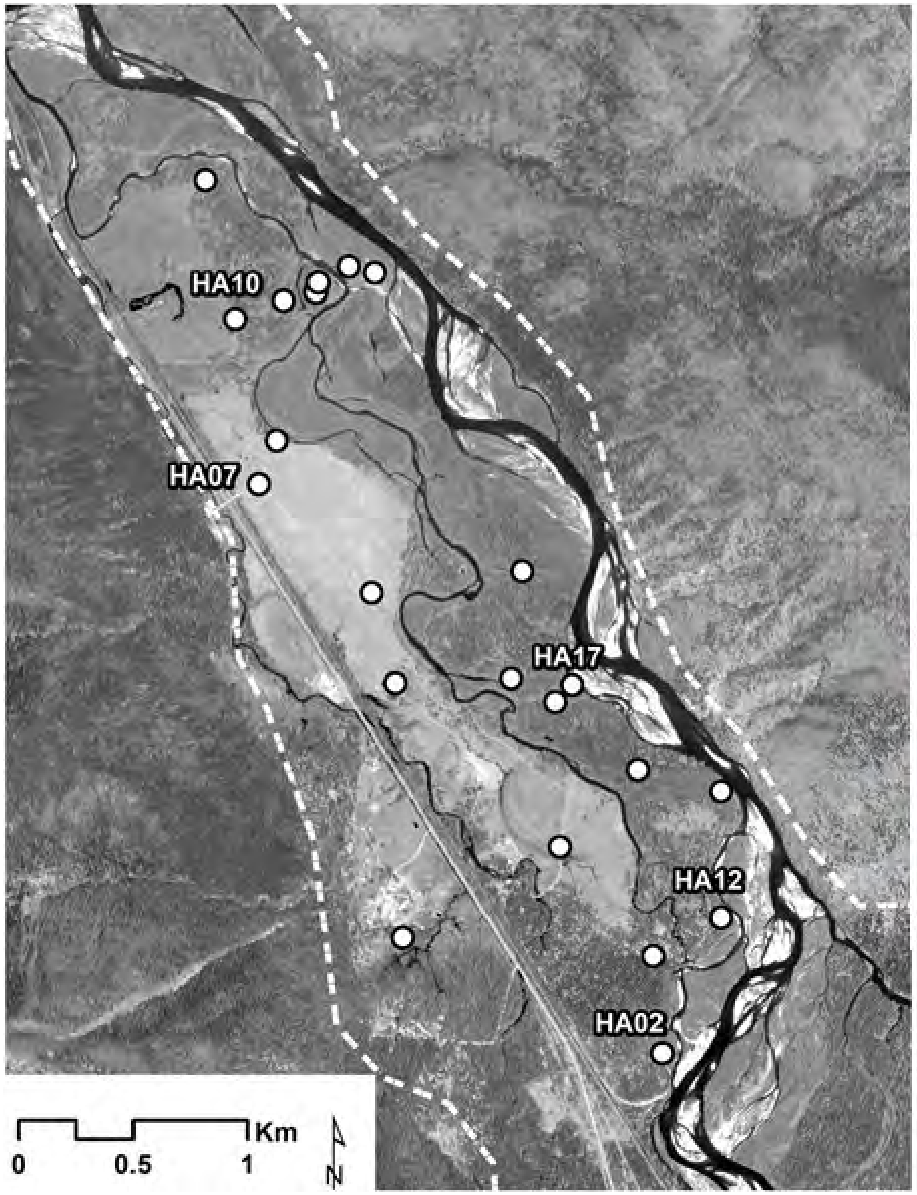
Geomorphology & Hydrology

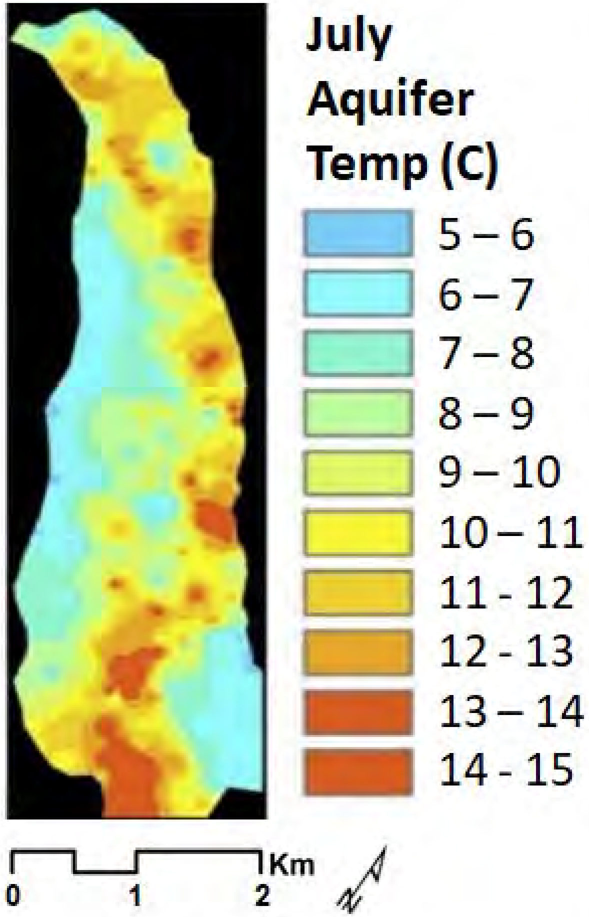


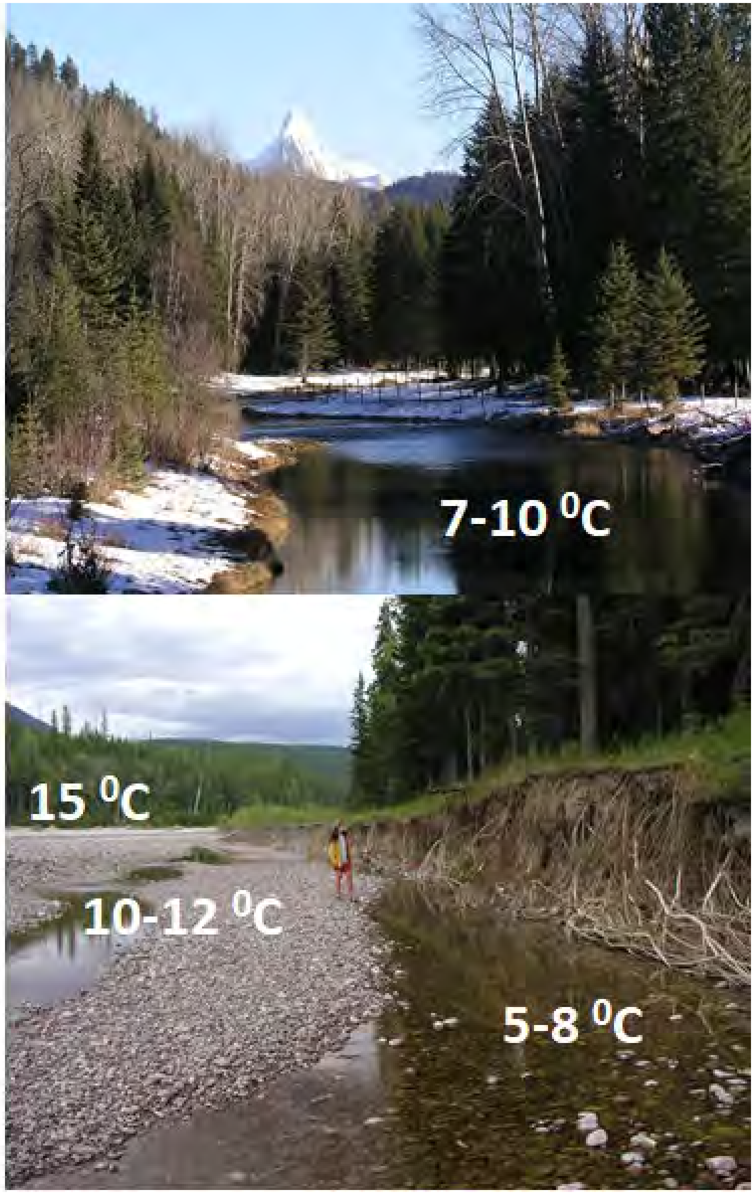
- ~10 km long by 2 km wide
- 30% of the river water enters the aquifer
- Flow paths are highly variable

Stanford et al. 2005; Whited et al. 2007, Helton et al. 2012; Poole et al. 2006;

Temperature Patterns





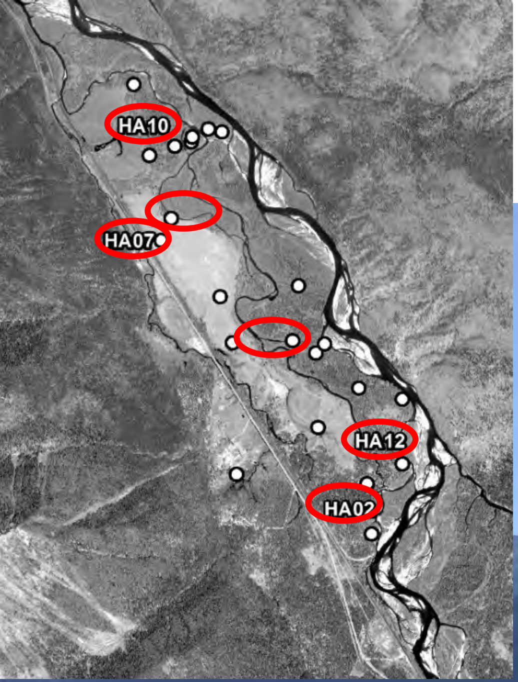


Stanford et al. 2016; Arrigoni et al. 2008; Stanford et al. 1975; Helton et al. 2012

Life Cycle

- Amphibitic: aquifer-river-terrestrial life cycle
- Nymphs must navigate the aquifer to return to the river
- Emerge from the river channel as winged adults

Field Collection Methods



- Species:
  Paraperla frontalis
  Kathroperla perdita
  Isocapnia grandis
  Isocapnia integra
  Isocapnia integra

- Sampling vertical profiles can be done using baffles

- This floodplain swale is 1.2km from the river channel

- Aquifer water out-wells in the spring

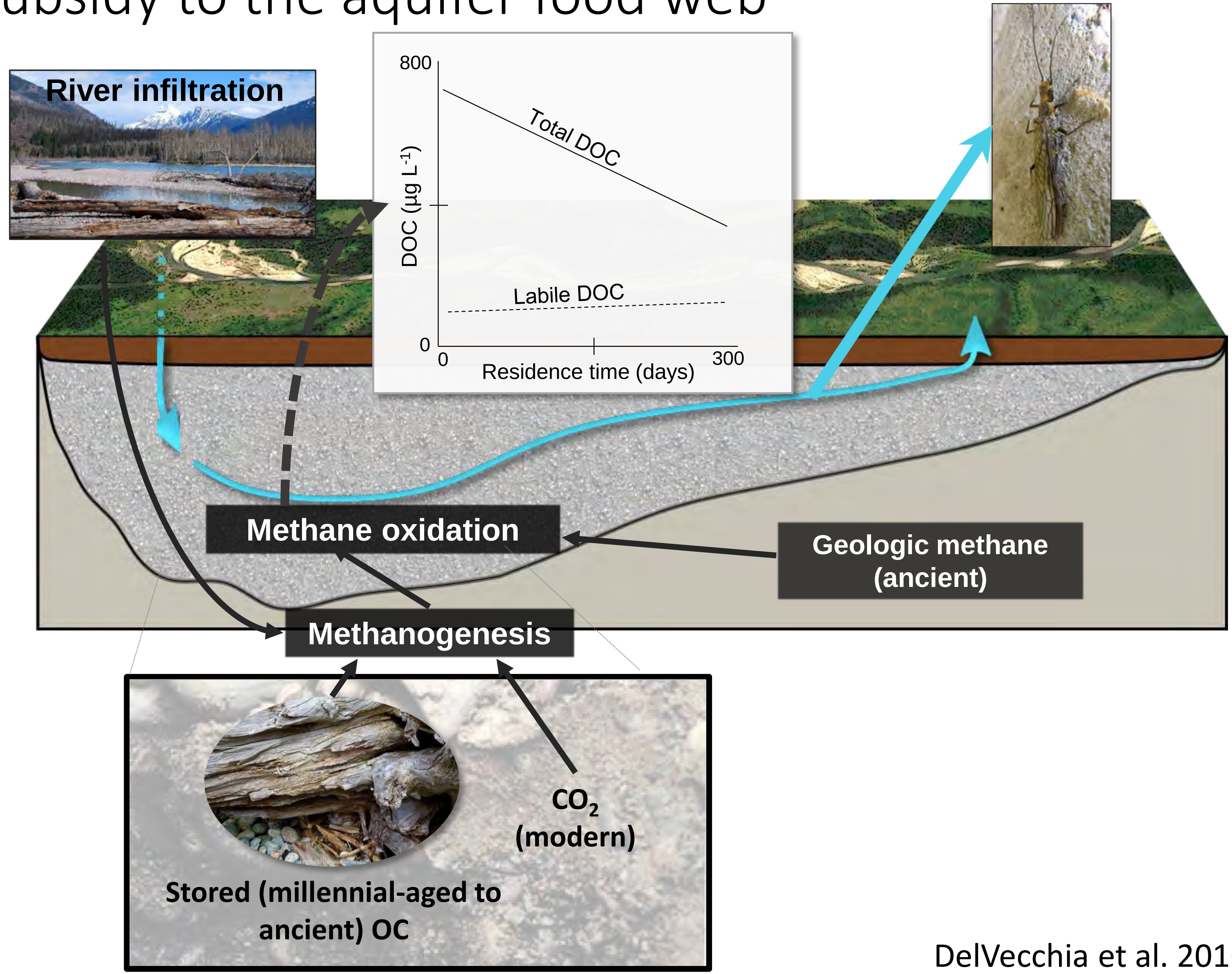
Over 3 Decades of Studies

- Hydrology, temperature patterns, aquifer biogeochemistry
- Distribution and abundance of aquifer stoneflies
- Adaptations of aquifer stoneflies

How can alluvial aquifers provide enough energy to support huge numbers of aquifer stoneflies?

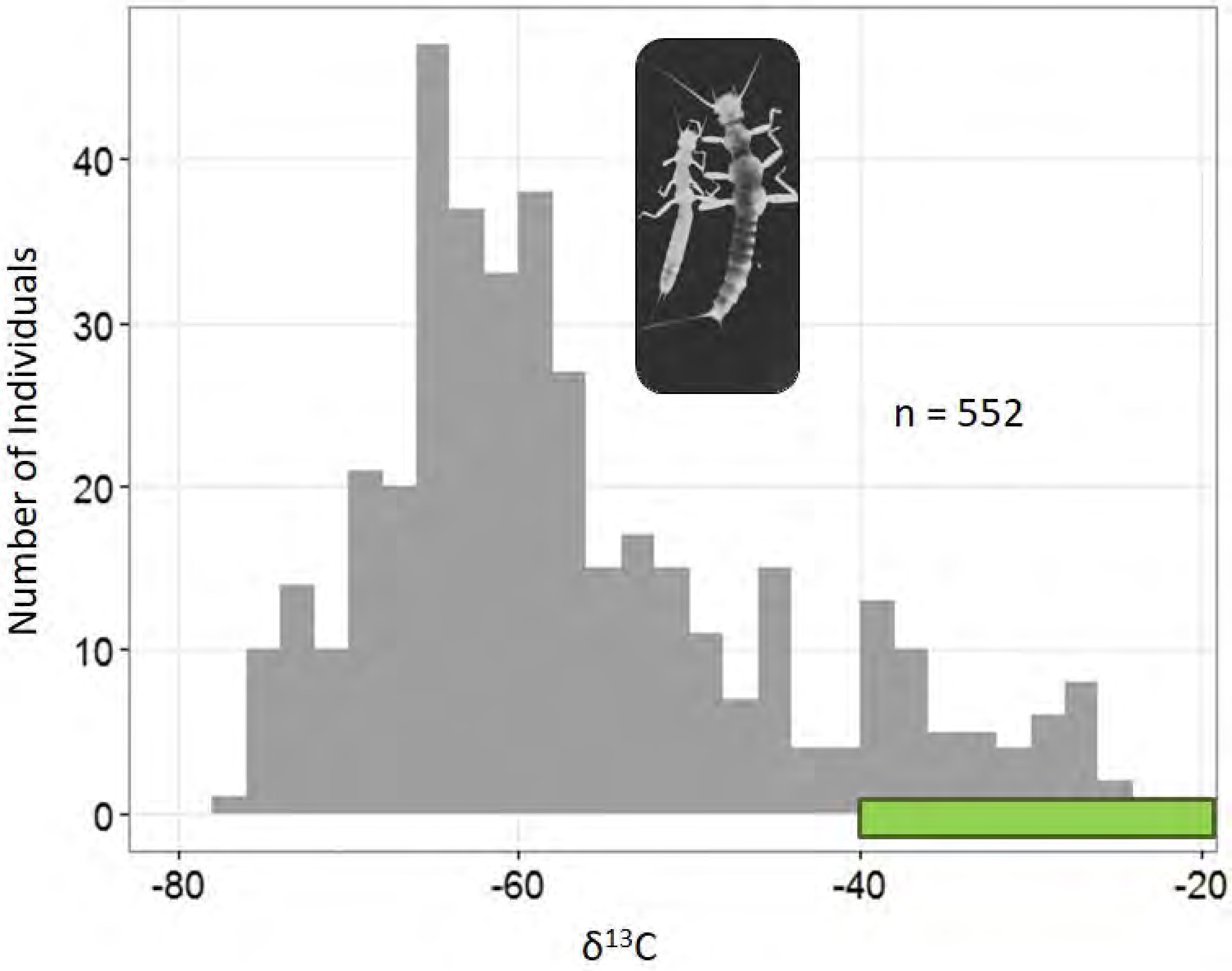
- The paradox of the hyporheos – low microbial production and DOC

Methane subsidy to the aquifer food web



DelVecchia et al. 2016; Helton et al. 2015

Biomass incorporated into the aquifer food web

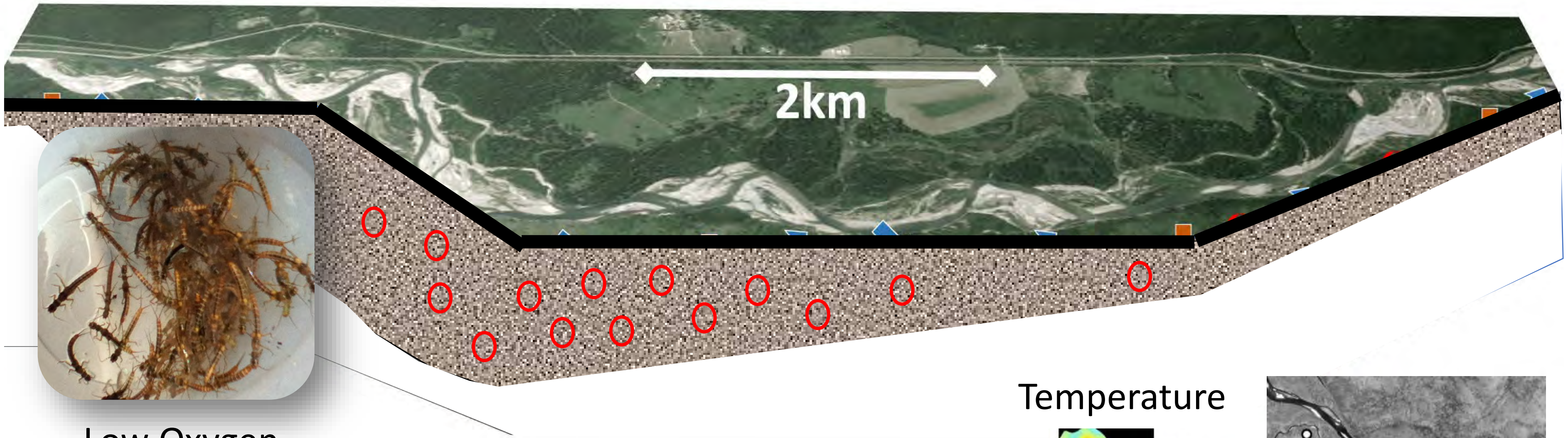


- Aquifer stonefly tissues substantially depleted

DelVecchia et al. 2016

Overarching Questions

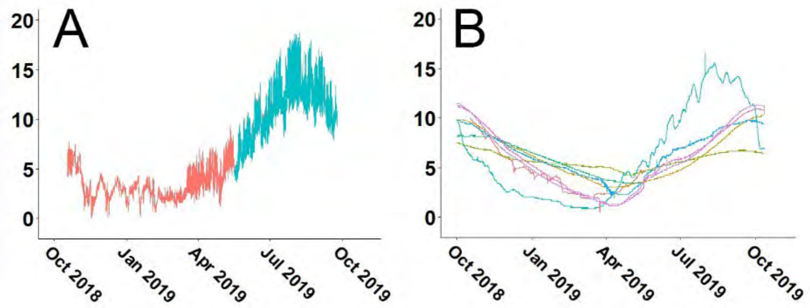
How are aquifer stoneflies adapted to live in this unique environment and how vulnerable are they to climate change?



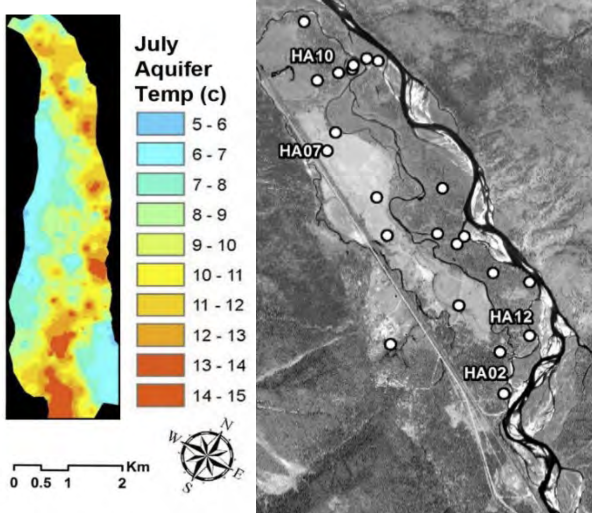
Low Oxygen Tolerance?

Mechanisms underlying tolerance?

Ability to Forage?

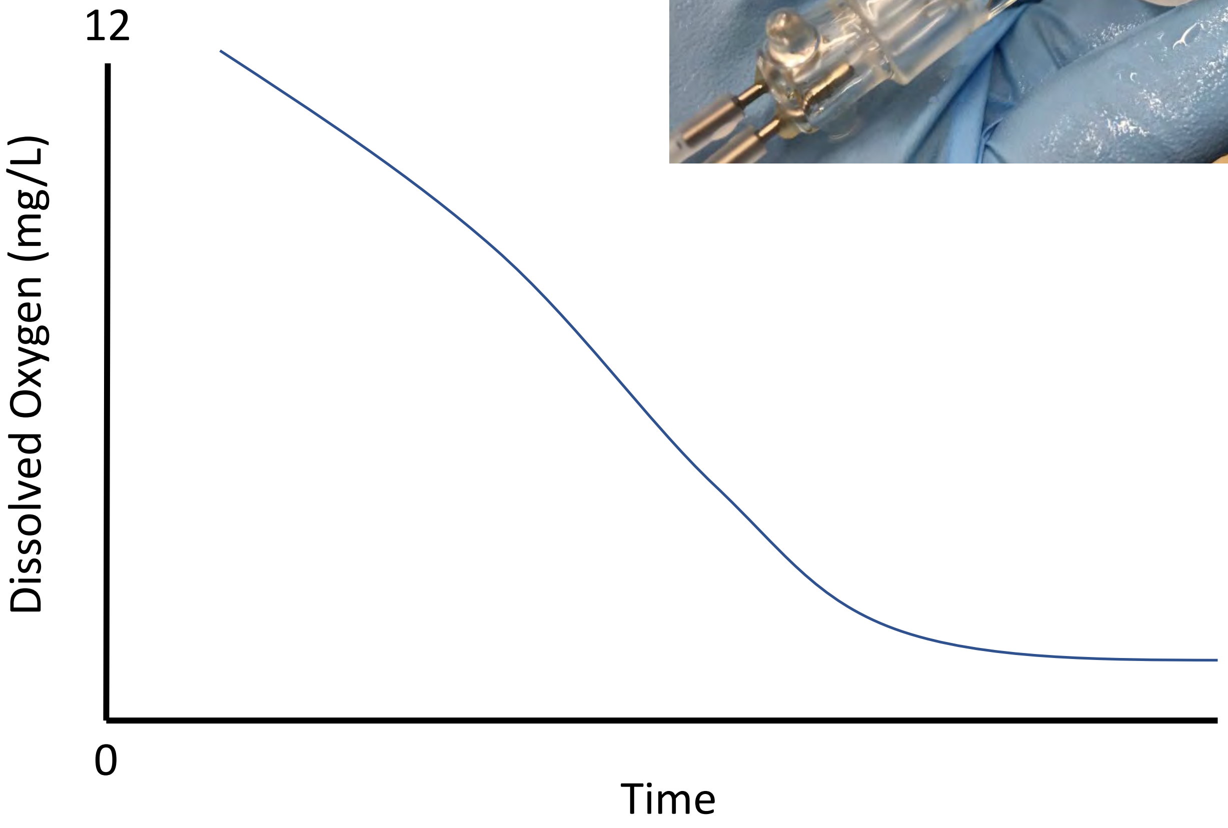


Temperature



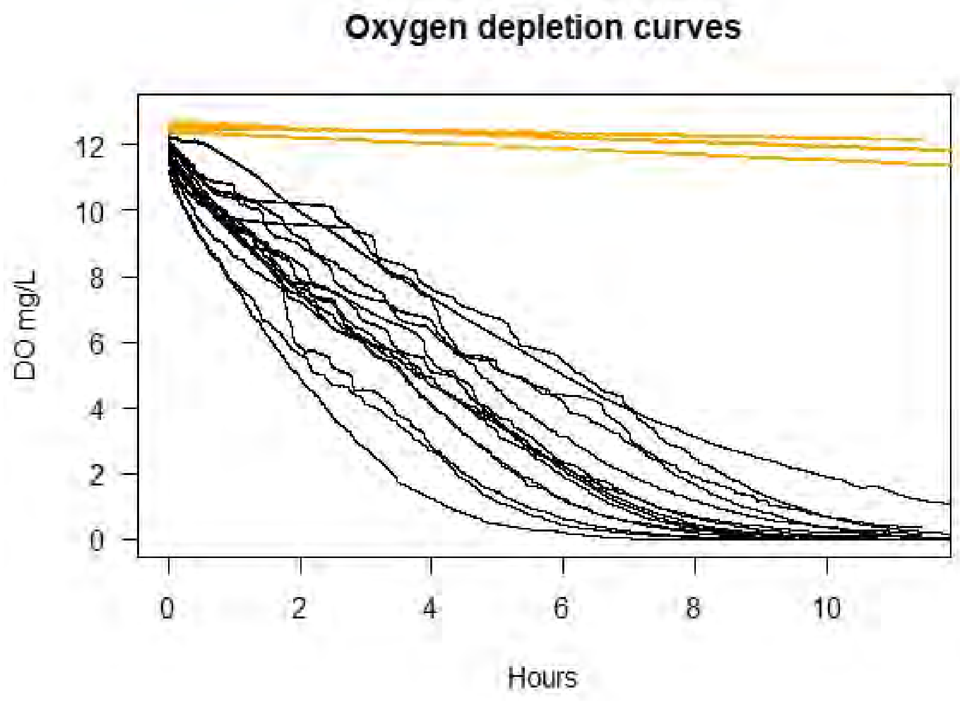
Metabolic Rate Methods

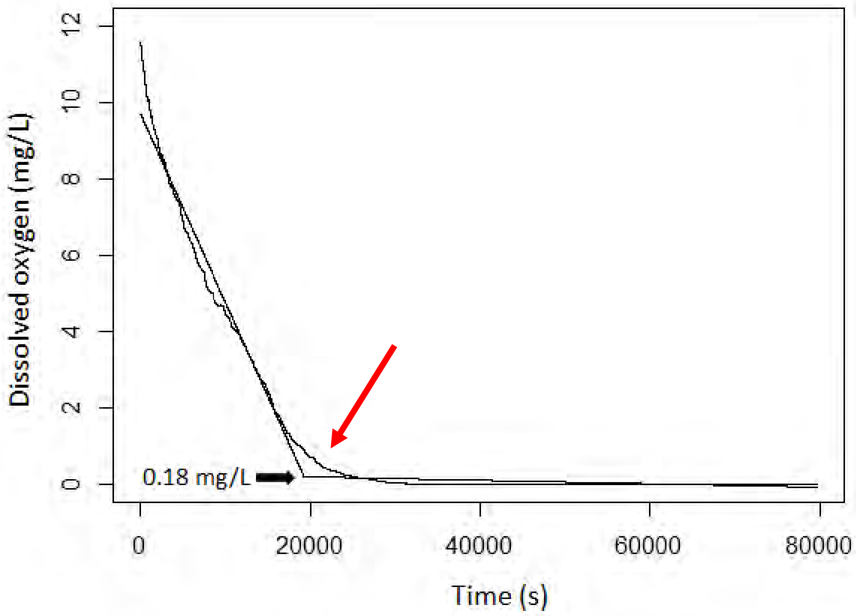
Metabolic Rate Methods



Metabolic Rate Methods

Aquifer – *P. frontalis*

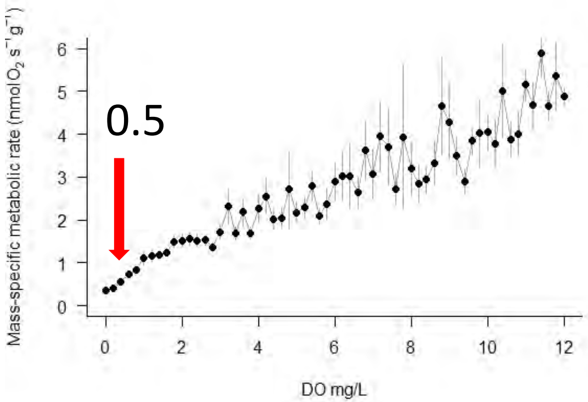




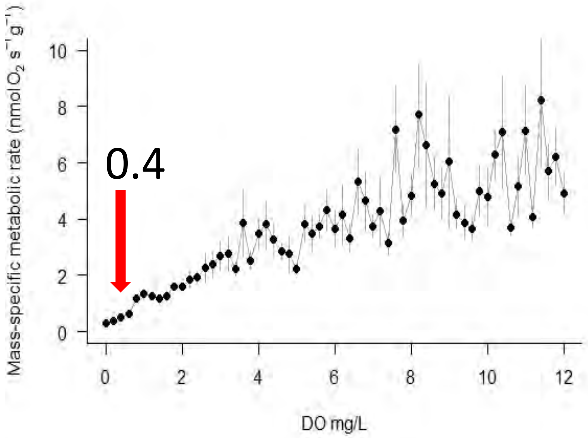
- Mass specific metabolic rates
- Break points

Metabolic Rate Results

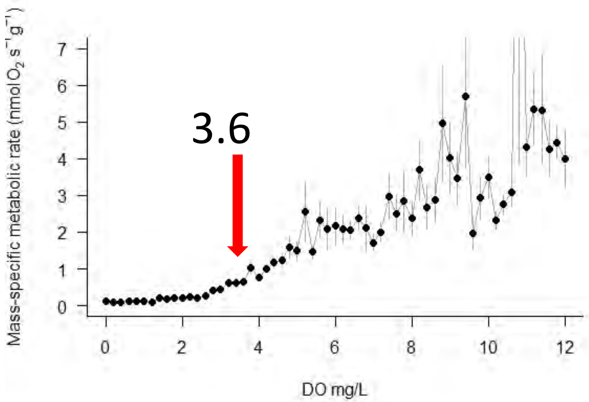
Aquifer – *P. frontalis*



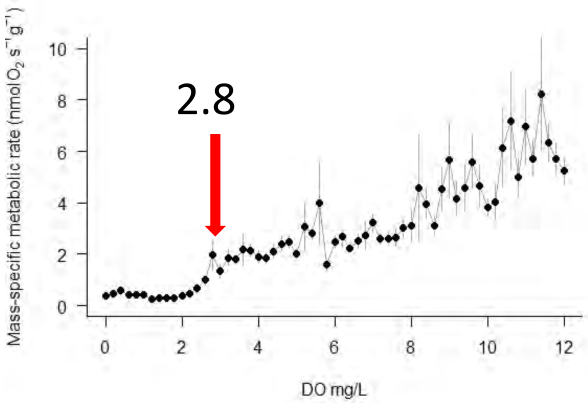
Aquifer – *Isocapnia*



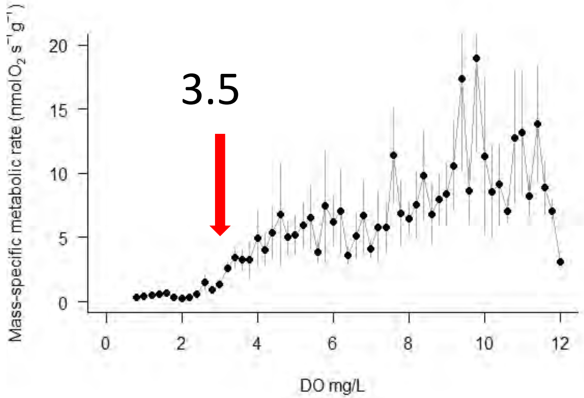
Benthic – *P. californica*



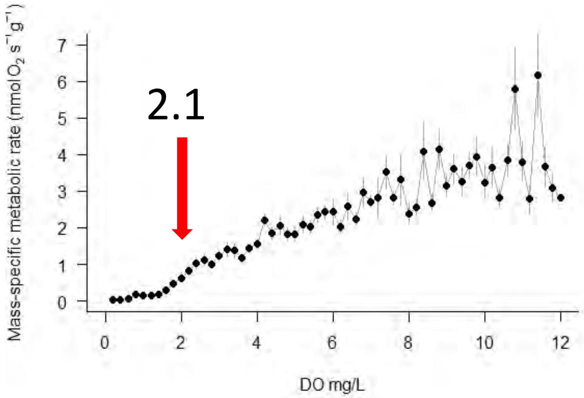
Benthic – *P. badia*



Benthic – *C. sabulosa*

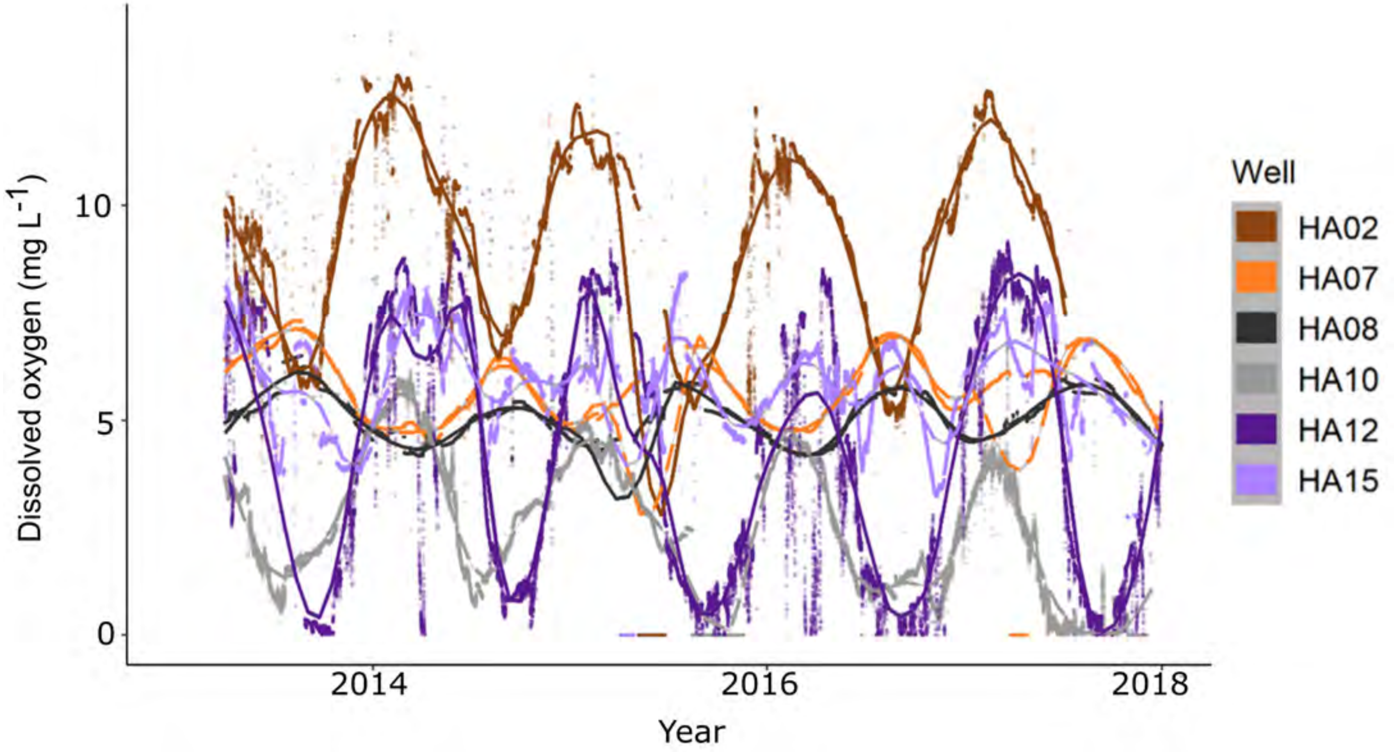


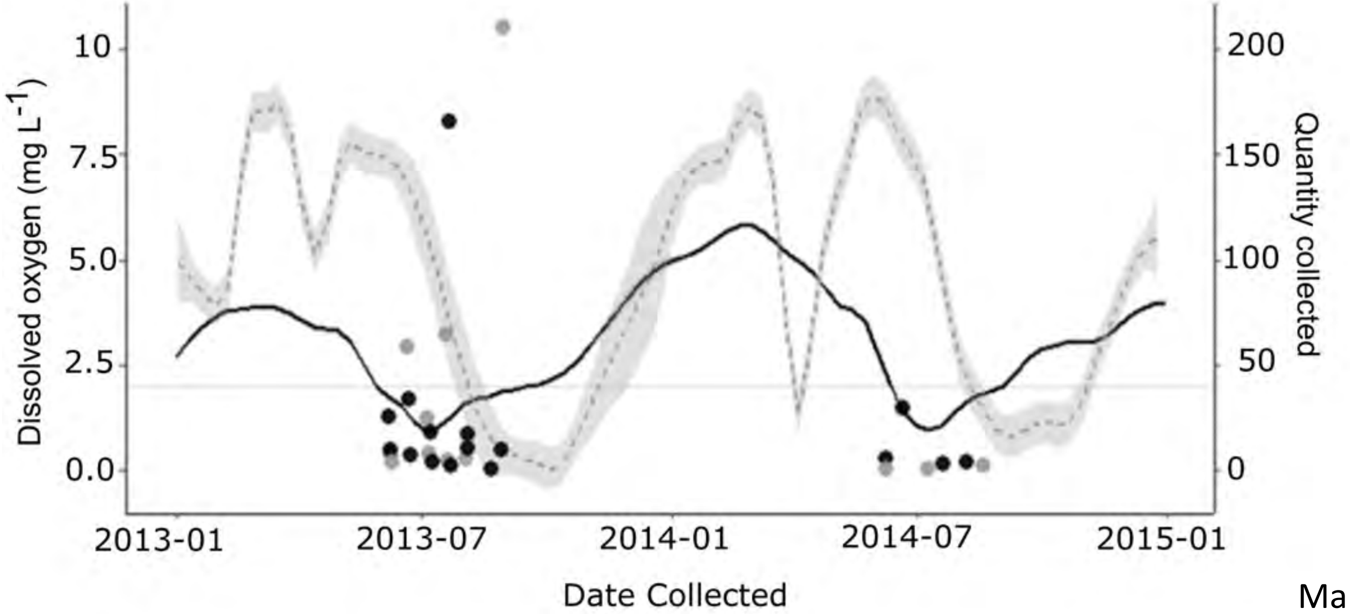
Benthic – *H. pacifica*



Aquifer Oxygen Dynamics and Stonefly Tolerance to Hypoxia

- Aquifer is “mostly” well oxygenated
- Stoneflies routinely collected from low oxygen wells

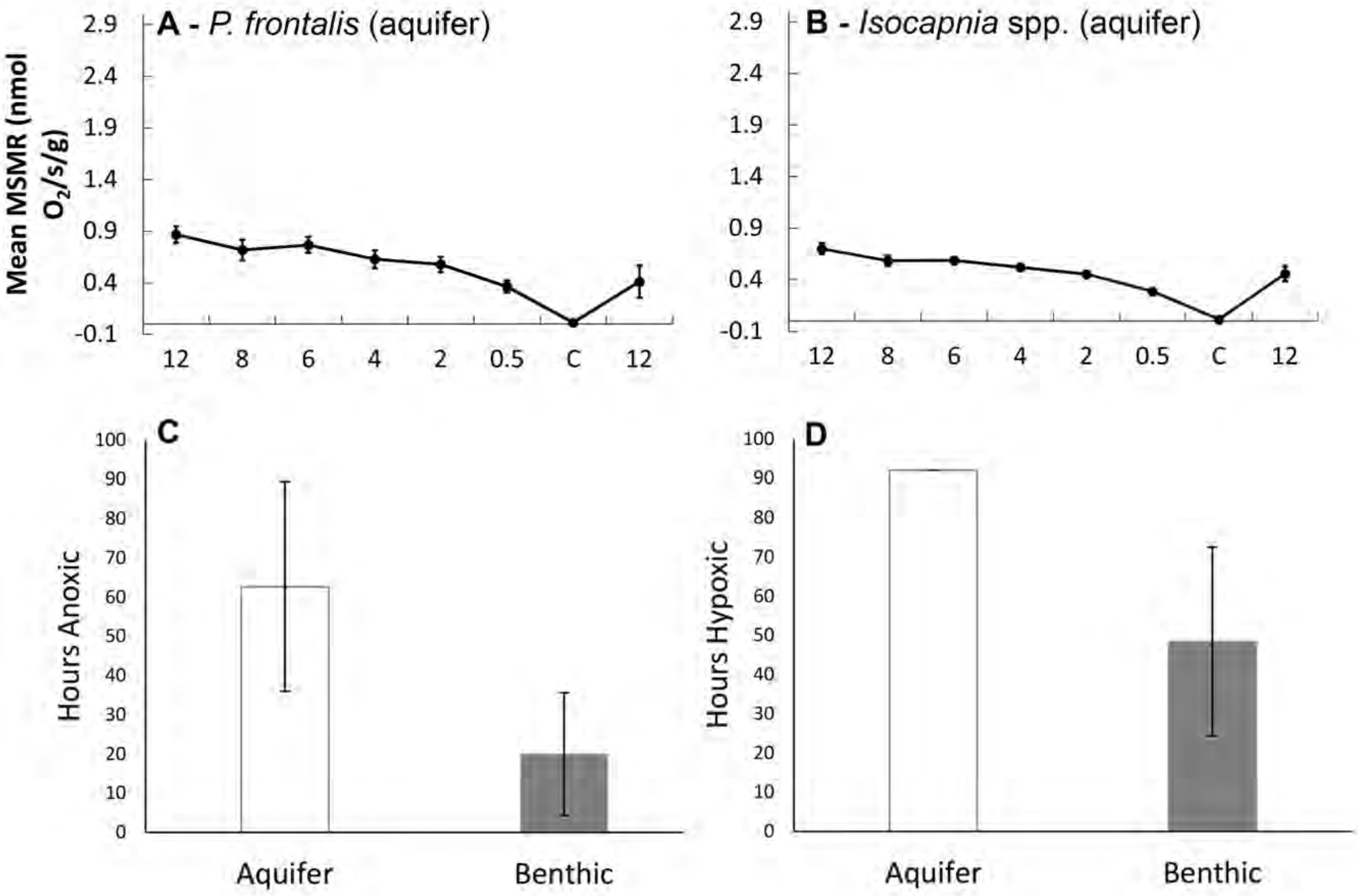




Malison et al. 2020ab

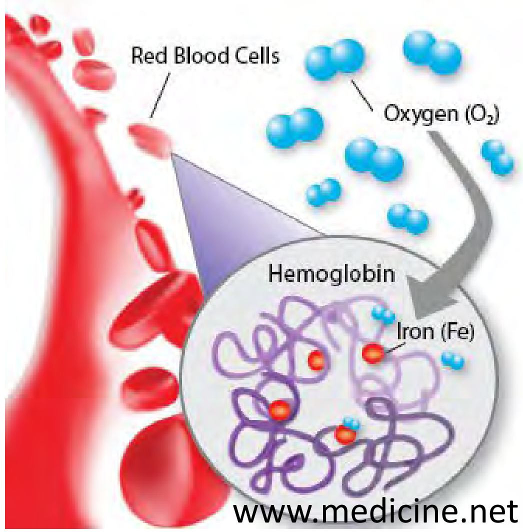
Aquifer stoneflies are adapted to anoxia & hypoxia

- Survival and metabolic rates studies
- Stoneflies can survive and continue moving for days in hypoxia & anoxia
- Stoneflies are able to tolerate repeated exposure to hypoxia and anoxia



Malison et al. 2020ab

Respiratory Protein?



www.medicine.net

www.nigms.nih.gov

Brittle Star


www.nespmarine.edu.au

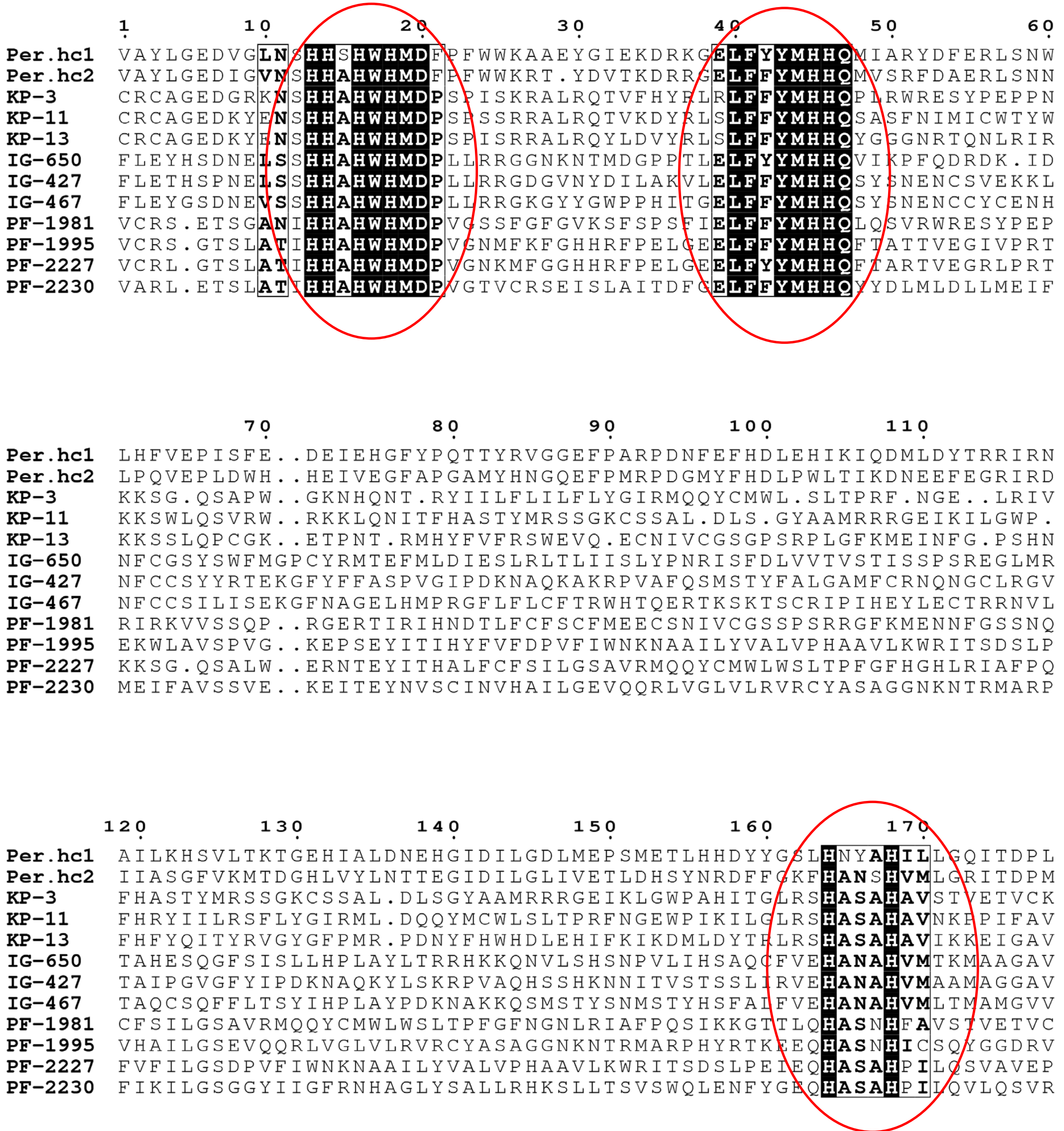
Perla marginata - Italy


https://www.flickr.com/photos/132574141@N04/42576292762

Hemocyanin genes detected!

Paraperla frontalis
Isocapnia grandis
Kathroperla perdita

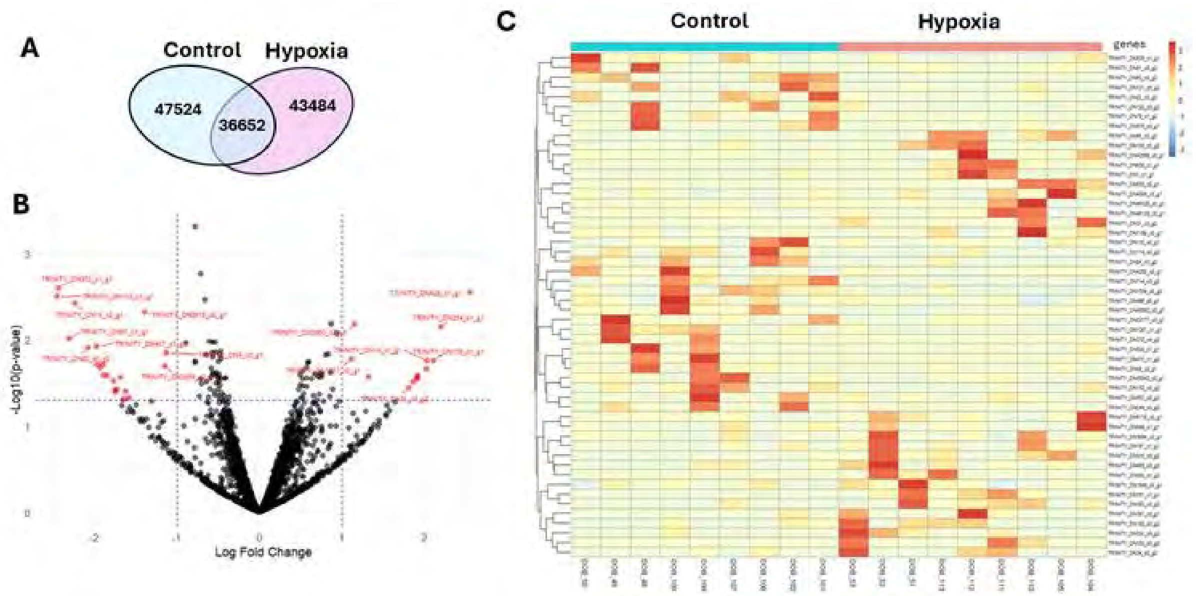
Black highlights =
Oxygen binding sites



Potential mechanisms

- Specialized abilities to extract oxygen from water given higher MR at low oxygen
  - Differential gene expression?

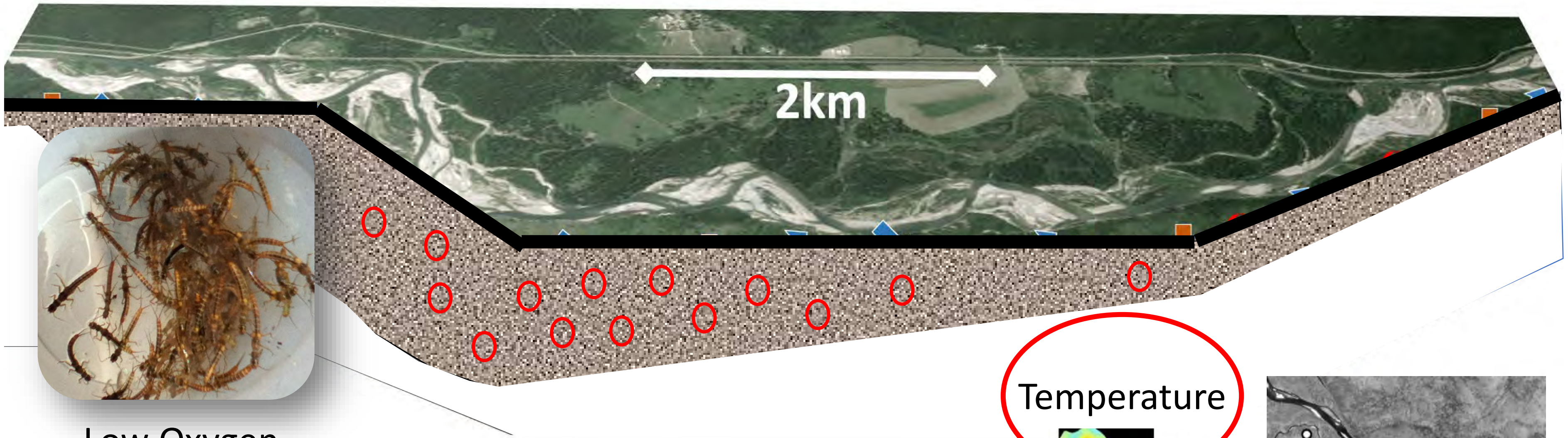
- Removed pairs: 0 min, 5 min, 1 hr



32 genes differentially expressed!

Overarching Questions

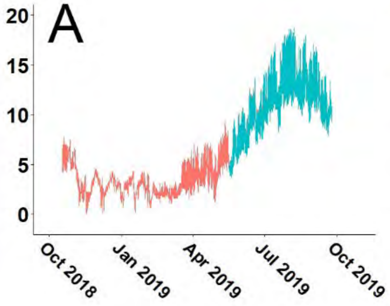
How are aquifer stoneflies adapted to live in this unique environment and how vulnerable are they to climate change?

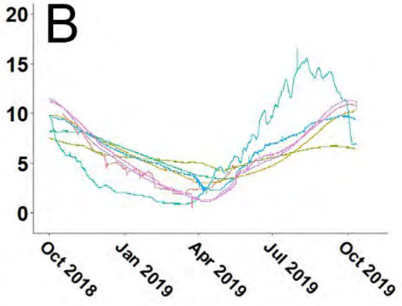


Low Oxygen Tolerance?

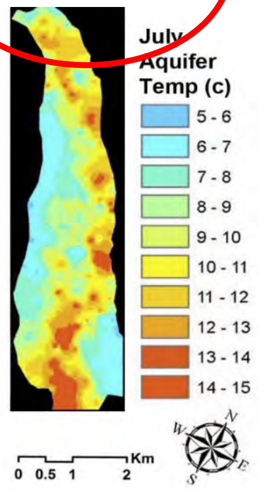
Mechanisms underlying tolerance?

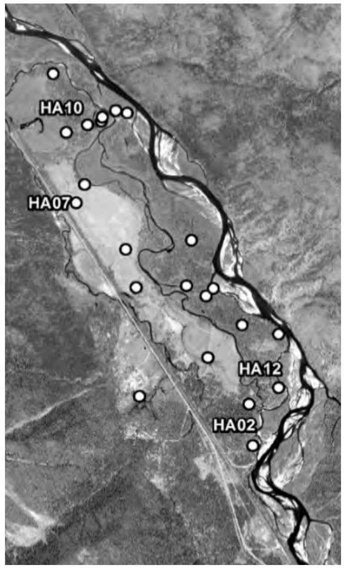
Ability to Forage?



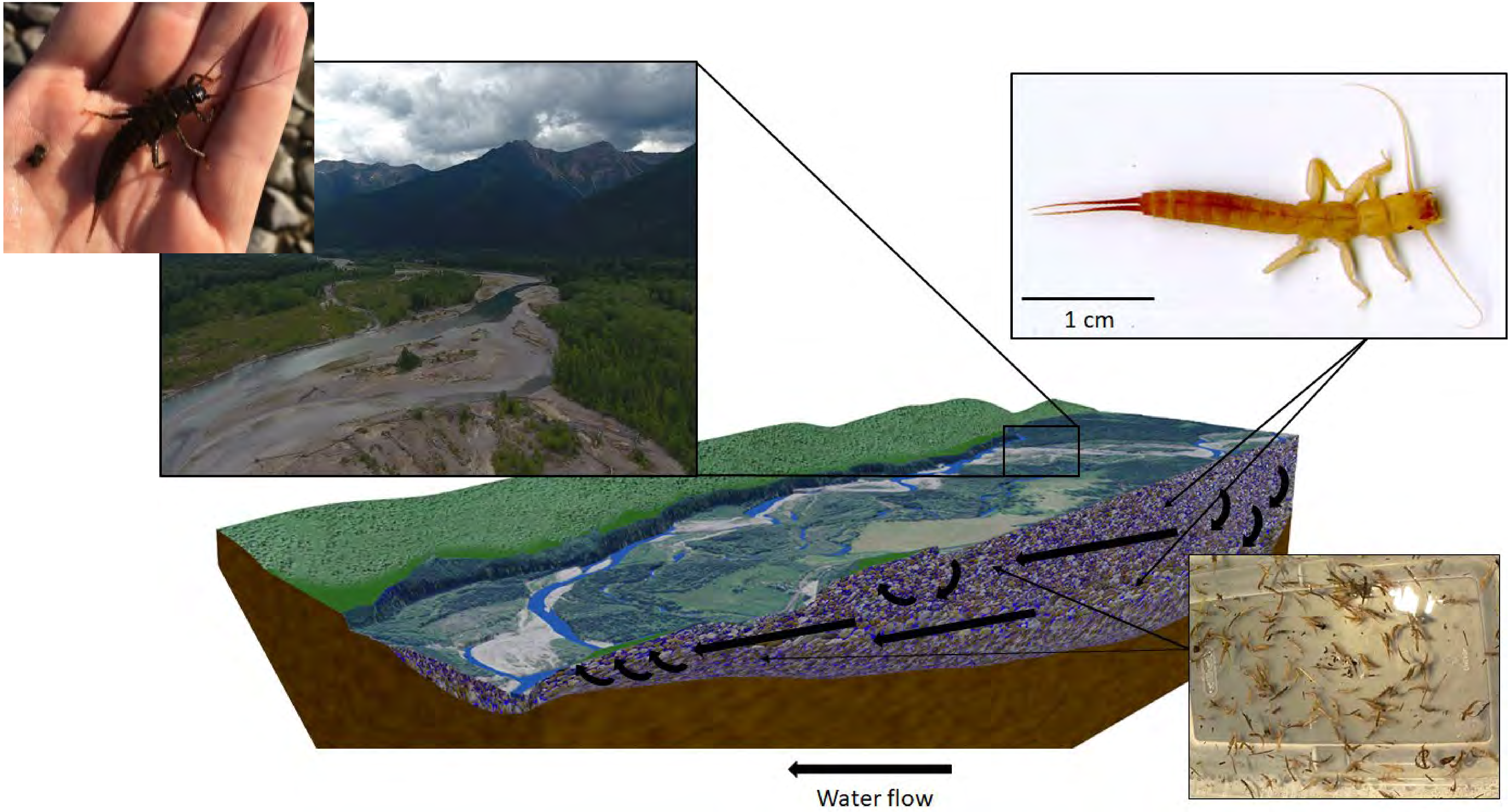


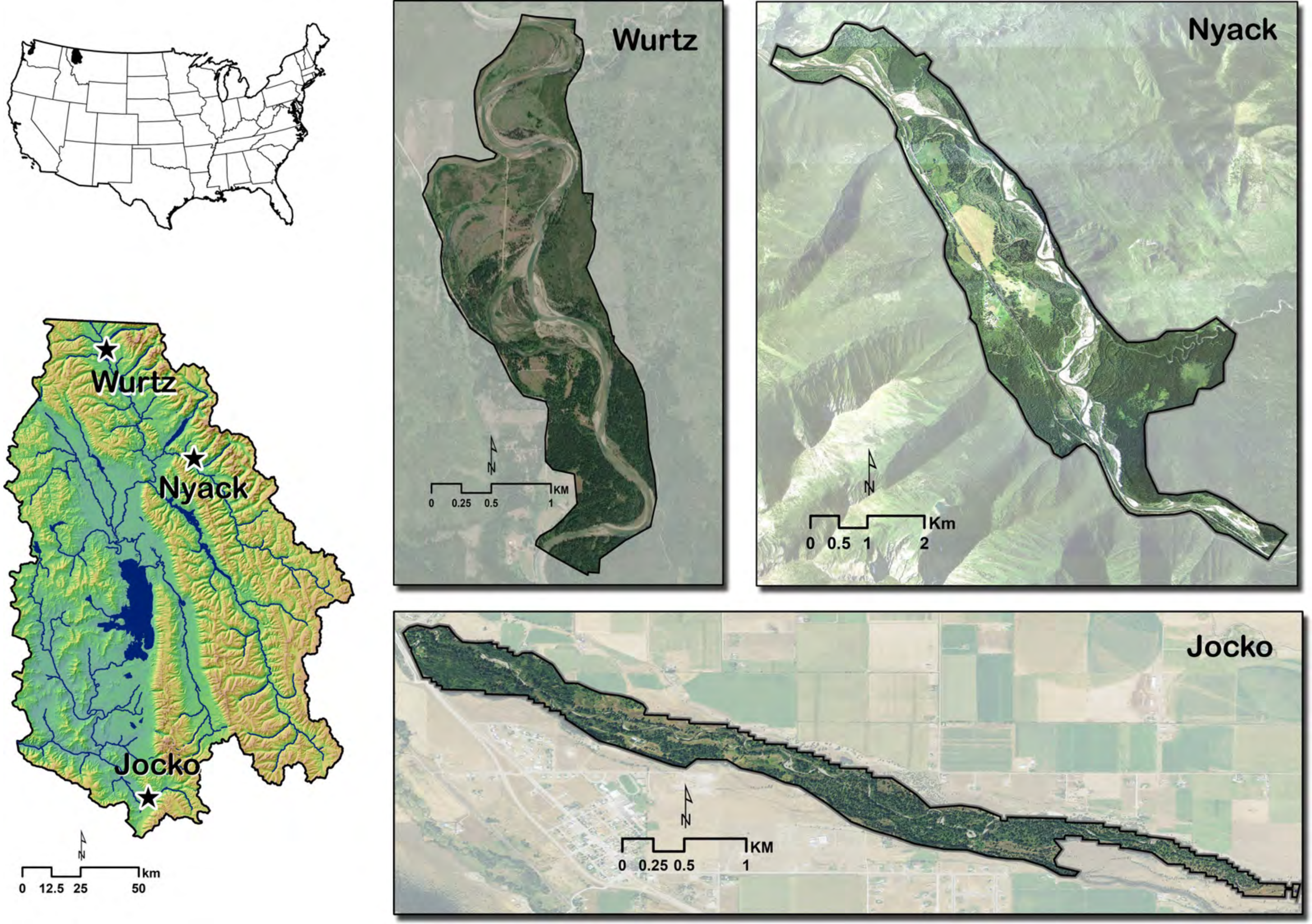
Temperature





Prediction: Benthic stoneflies would be less sensitive to warming temperatures compared to aquifer taxa



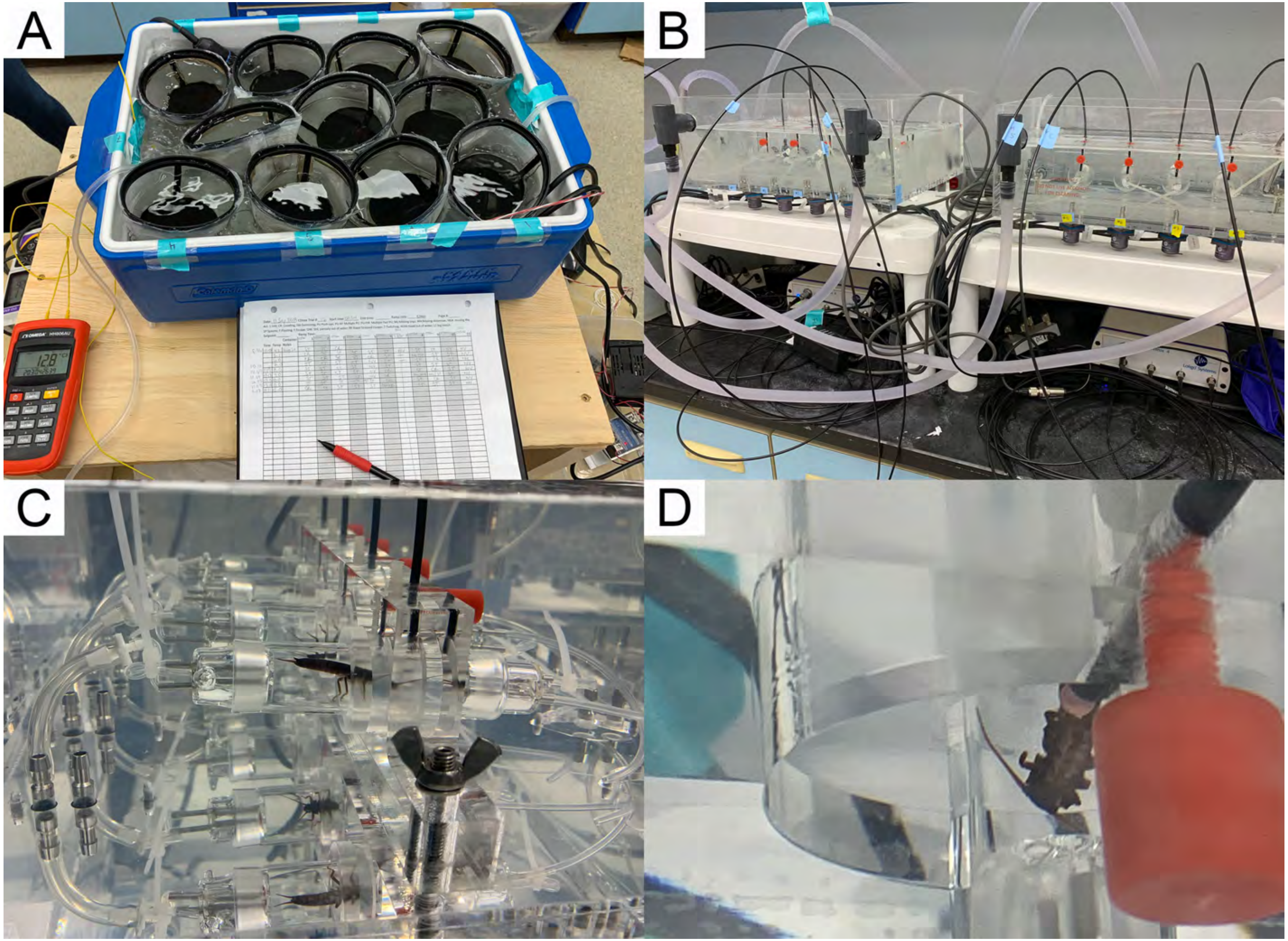

Wurtz
Nyack
Jocko
N
km
0 12.5 25 50
KM
0 0.25 0.5 1
Km
0 0.5 1 2

Methods:

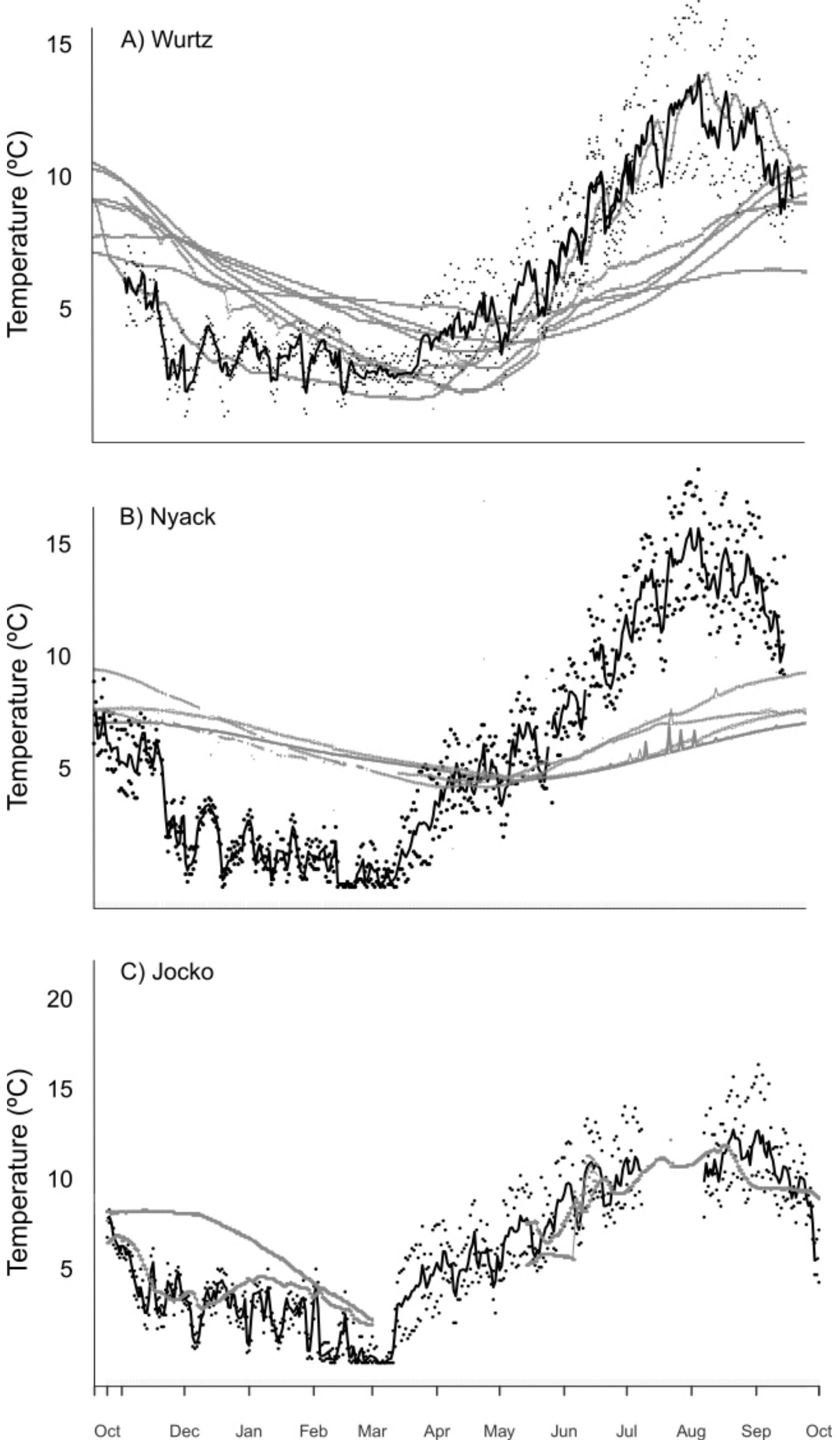
- Temperature data
- CT_{MAX}
- Metabolic rates

Benthic:
Claassenia sabulosa
Hesperoperla pacifica
Pteronarcys californica
Pteronarcella badia
Sweltsa coloradensis

Aquifer:
Isocapnia spp.
Paraperla frontalis
Kathroperla perdita



Results:



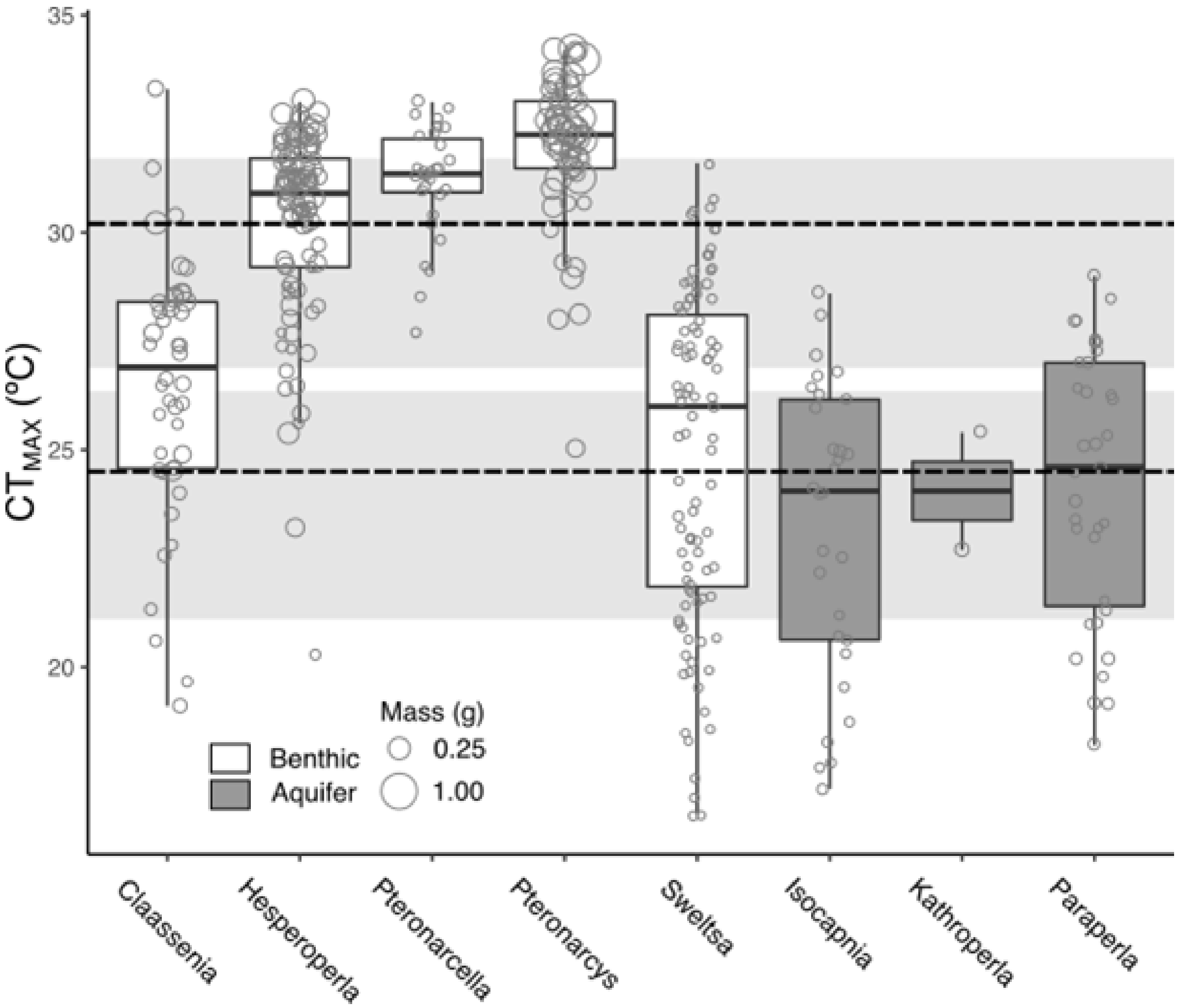
■ Mean daily river temperature

■ Mean daily aquifer temperature

Mean temperature was similar for aquifer and benthic habitats at the Nyack and Jocko, but was warmer in benthic vs. aquifer habitats at Wurtz

Benthic habitats were much more variable

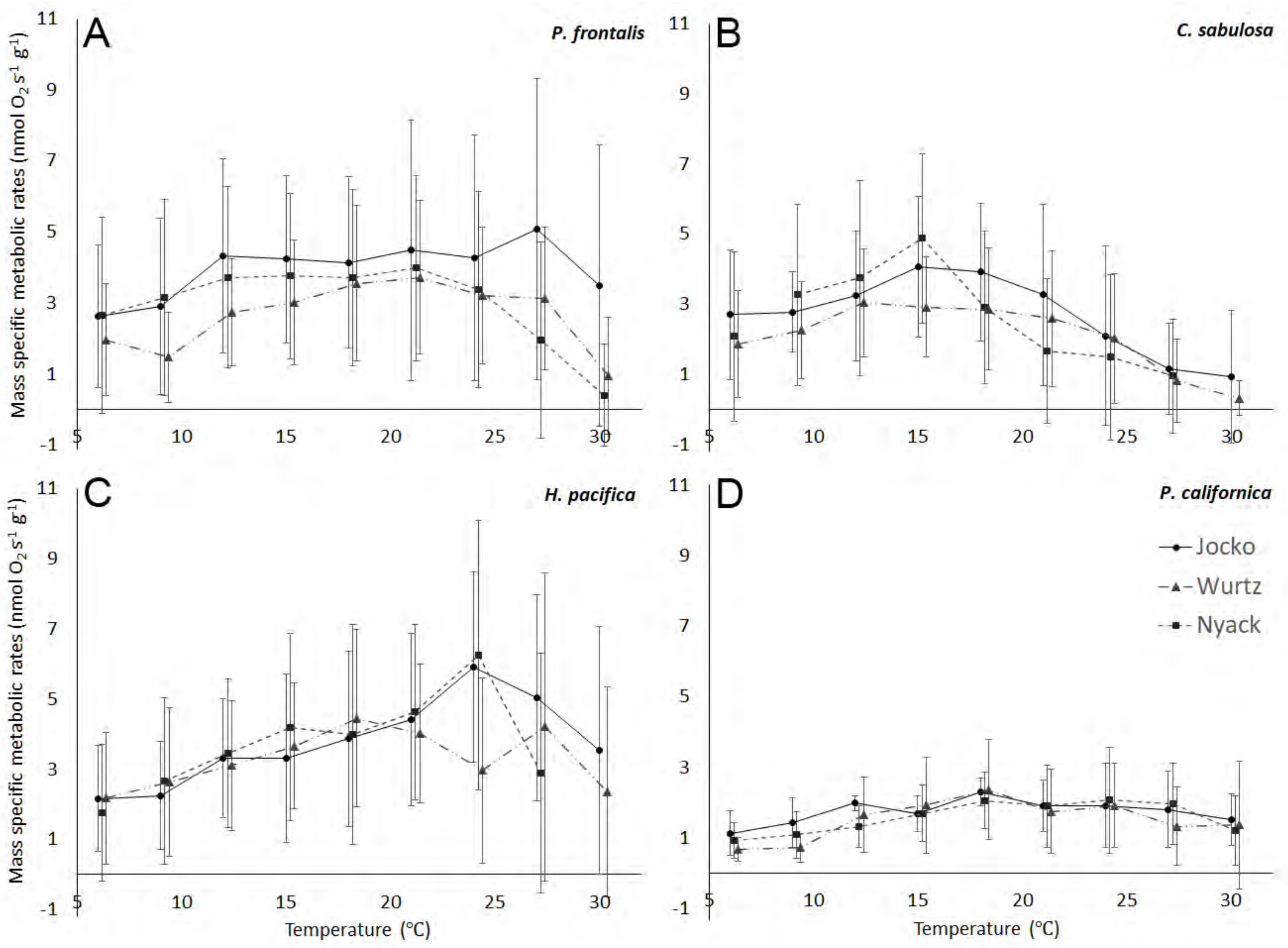
Results:



Benthic stoneflies had significantly higher CT_{MAX} values (F = 6.68, *P* = 0.021)

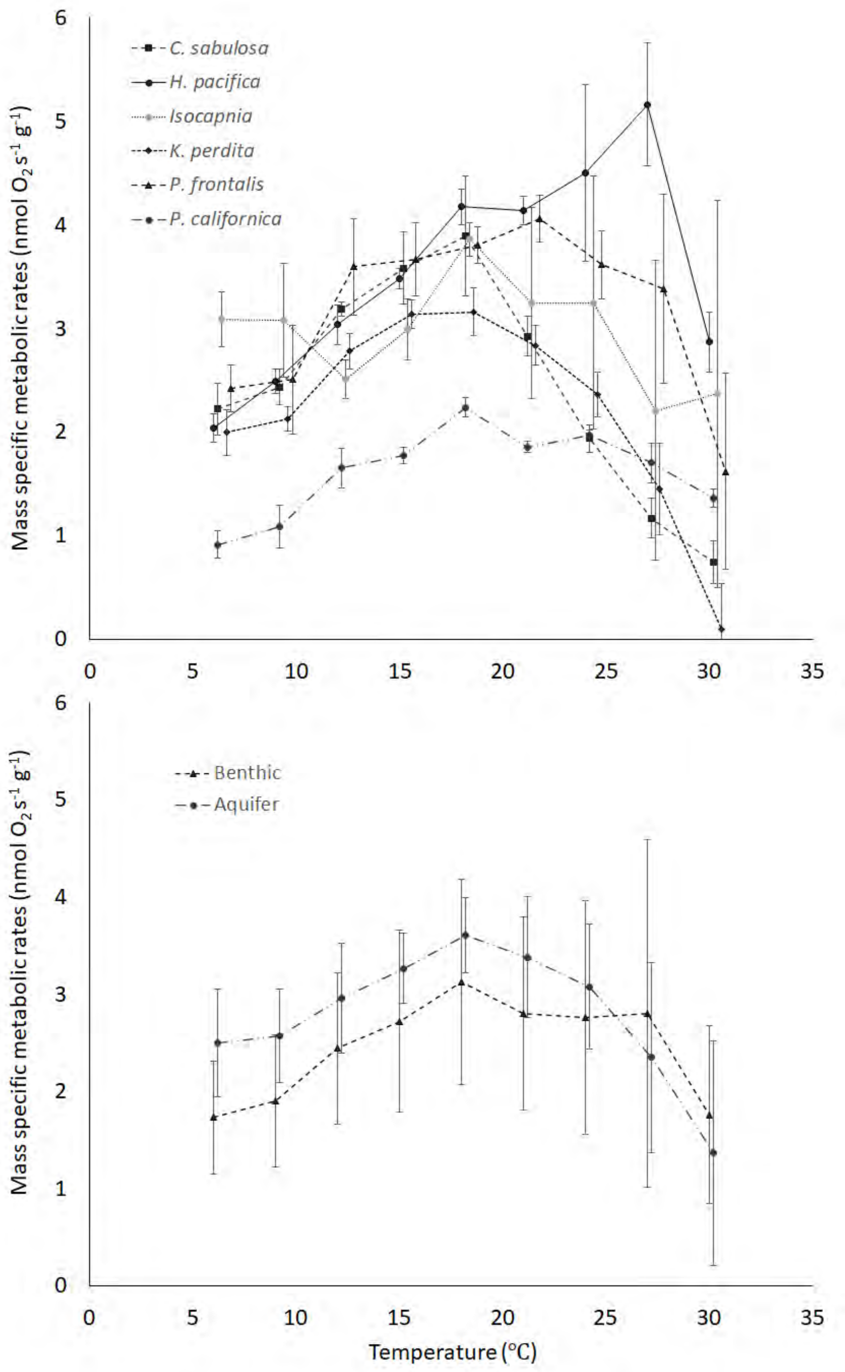
Also significant differences between genera and mass was significant

Results:



No difference in metabolic rates among floodplains (F = 1.78, P = 0.171)

Results:



No difference in metabolic rates between habitats (F = 2.24, *P* = 0.194)

But benthic stoneflies had a greater metabolic breath (difference between starting and max MR)

Aquifer stoneflies may be more vulnerable to warming temperatures because they had lower critical thermal maximum and lower metabolic breath

Take Home Messages:

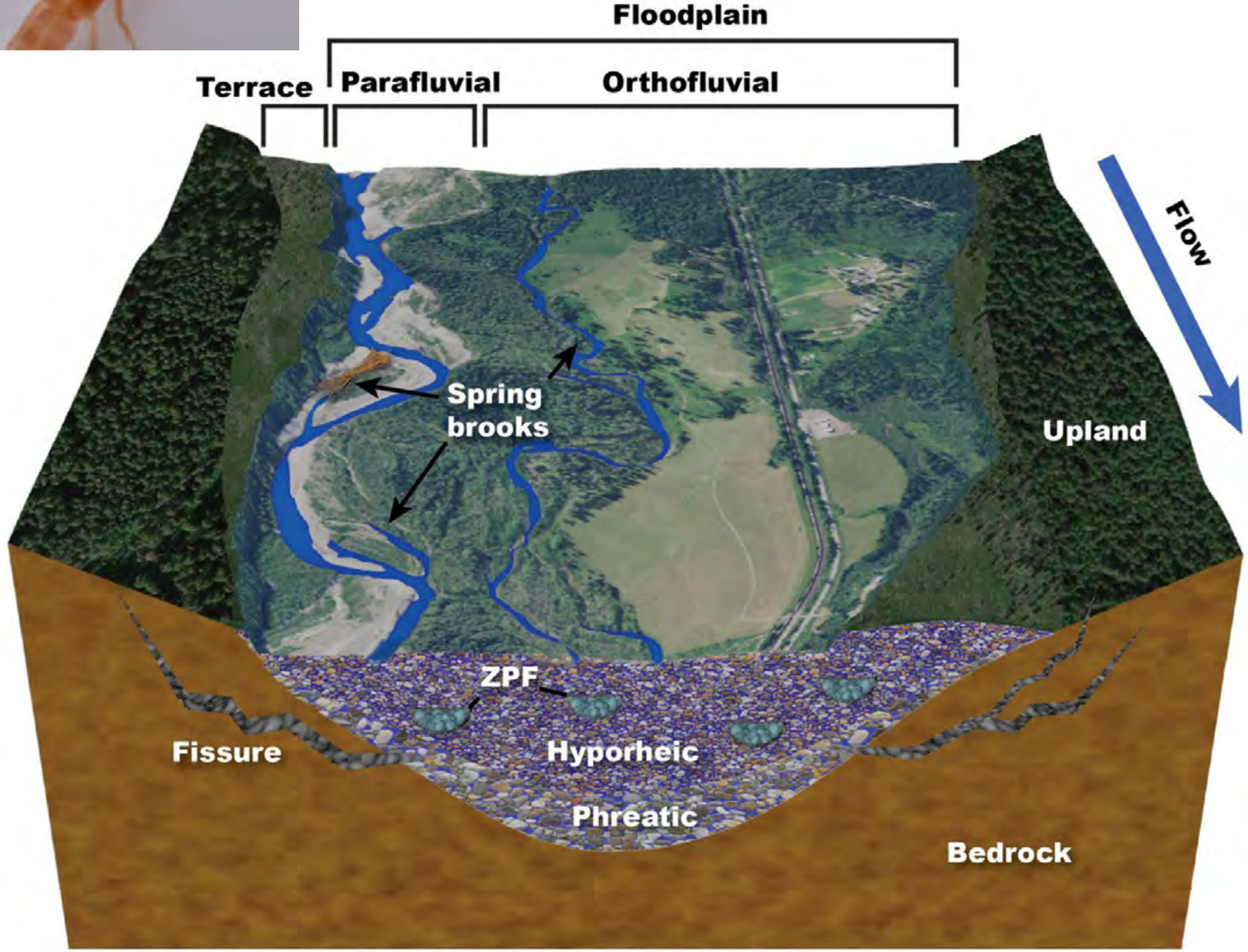
The discovery of aquifer stoneflies has helped shaped our understanding hyporheic zones and alluvial aquifers

Aquifer stoneflies are adapted to low oxygen conditions, surviving and moving much longer

Aquifer stoneflies may be less tolerant than benthic taxa to warming temperatures but also less vulnerable in alluvial aquifers

Investigation of temperature tolerance, plasticity, and mechanisms of adaptations is ongoing

There is still more to learn



Acknowledgments

Collaborators
We thank all scientists, partners and students that have been Involved over the years

Field and Lab Crew Members

Stoneflies: Faith Breen, Keridwen Whitmore, Elizabeth Keksi, Erin Lee, Melanie McMillan, Brenna Prevelige, Megan Ritter, Wesley Sigl, Taylir Schrock, Garrett Frandson, Hailey Jacobson, Julia Cotter, Haley Dole, Clara Mankowski, Grant Marshall, Jared Glass, Claire Kirk, Jackson Birrell, James Frakes, Grace Hauer, Kenzye Spears, Aspen Jaeger, Chester Wooldridge, Anna Brown, Tristenne Cranford, Kilynn Groen

FLBS Staff and Researchers
Adam Bauman
Sydni Racki
Diane Whited
Phil Matson

Nyack Landowners
Dalimata Family

Funding
NSF Grants:
DOB-1639014, DEB-1830178, MCB-0348773, EAR-0120523, DEB-8705269
Gordon & Betty Moore and Walton Family Foundations, Other private funders

My Family

Questions?

Rachel Malison
rachel.malison@umontana.edu
@rlmalison

Received: 15 September 2023 | Revised: 9 January 2024 | Accepted: 17 January 2024
DOI: 10.1002/wat2.1720

OVERVIEW

WIREs WATER WILEY

Amphibitic stoneflies (Plecoptera) are integrators of ecosystem processes in alluvial aquifers of gravel-bed river floodplains

Jack A. Stanford[1] | Amanda G. DelVecchia[2] | J. Joseph Giersch[1] | Rachel L. Malison[1]

Stanford, J.A., A.G. DelVecchia, J.J. Giersch, and **R.L. Malison**. 2024. Amphibitic stoneflies (Plecoptera) are integrators of ecosystem processes in alluvial aquifers of gravel-bed river floodplains. *WIREs Water*, e1720. https: //doi.org/10/1002/wat2.1720

FLATHEAD LAKE BIO STATION
UNIVERSITY OF MONTANA

UNIVERSITY OF MONTANA