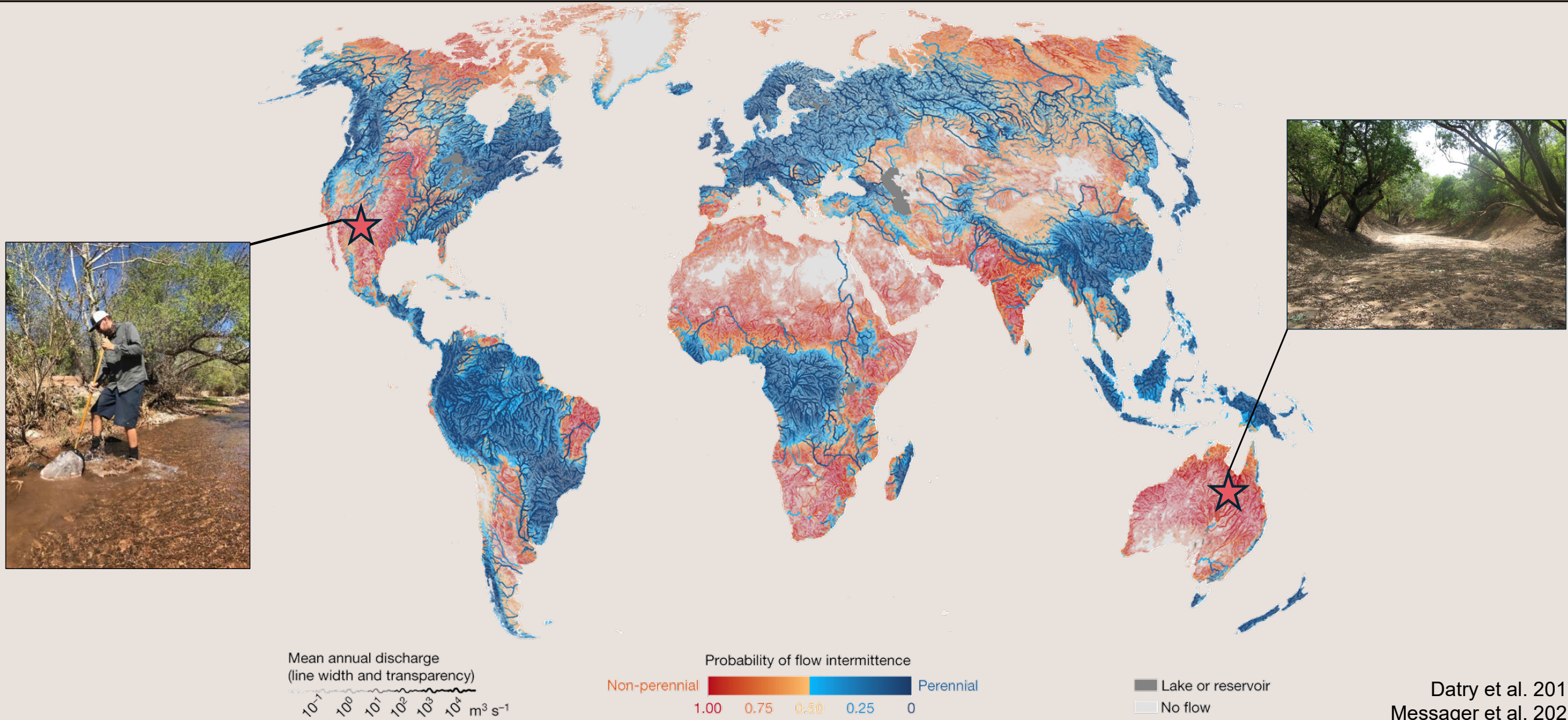


Irrigation ditches as novel intermittent streams that provide energetic subsidies via aquatic insect emergence



Intermittent streams are abundant but have been overlooked

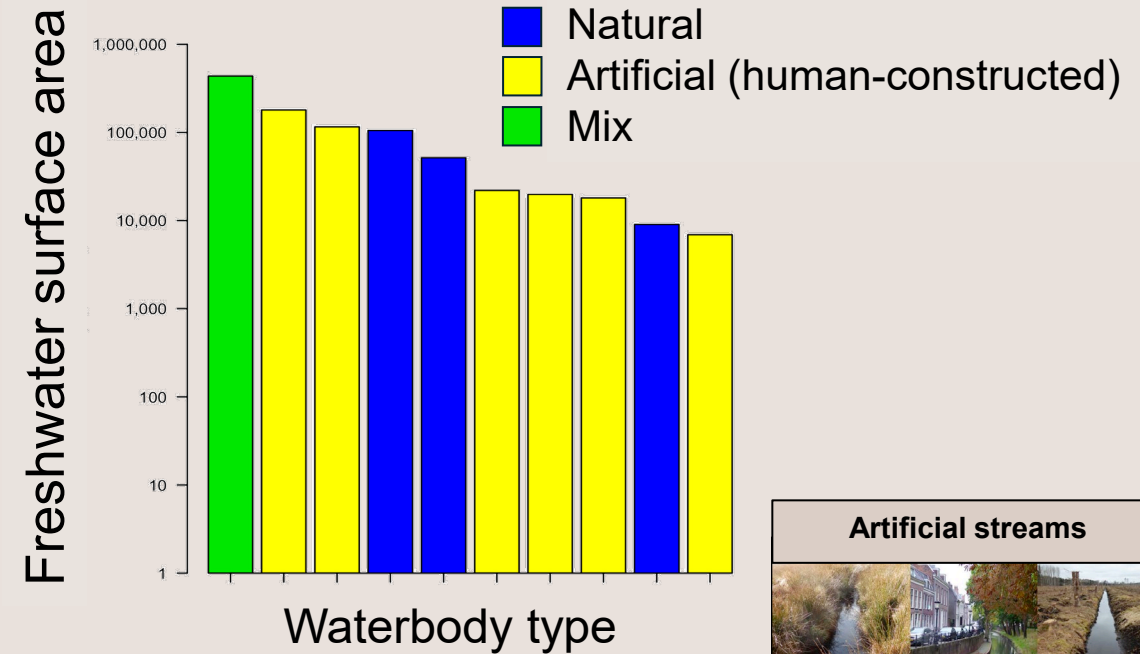


Artificial streams are widespread but remain overlooked

Human activities have reconfigured freshwater ecosystems globally

New (i.e., artificial) streams collect and convey water across the landscape

Artificial streams are rarely studied, especially those that are intermittent



Modified from Clifford and Heffernan 2018



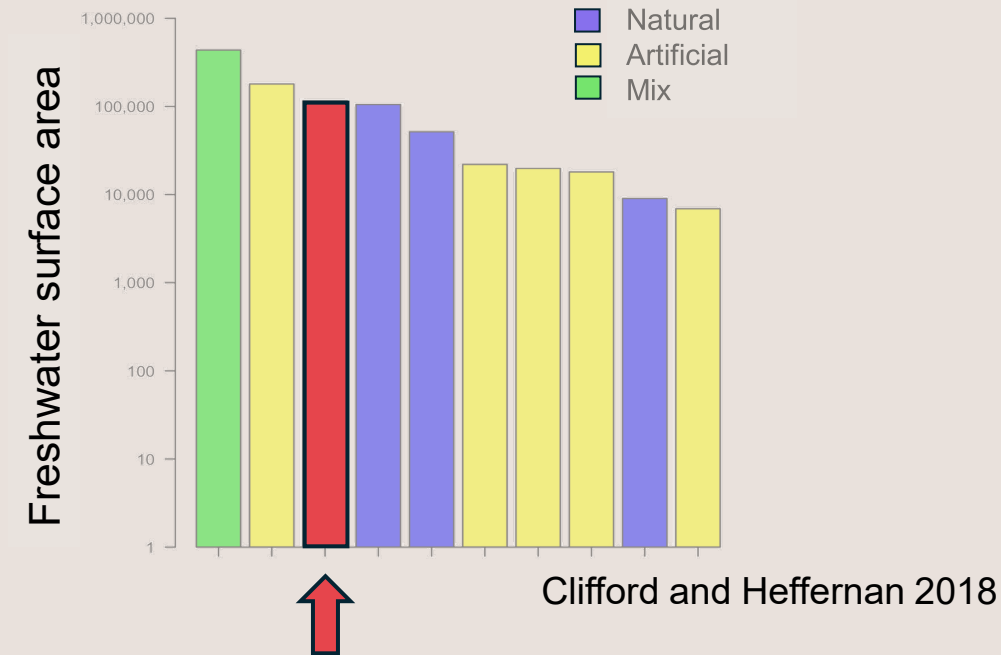
Peacock et al. 2021

Agricultural ditches are ubiquitous artificial intermittent streams

Twice the surface area of natural streams

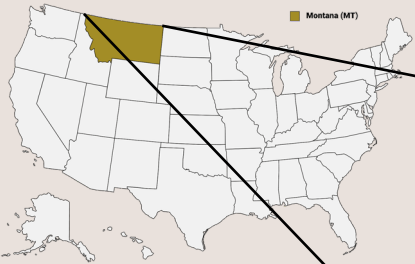
Although modified, ditches support hydrologic function and aquatic habitat

Remain underappreciated as stream ecosystems

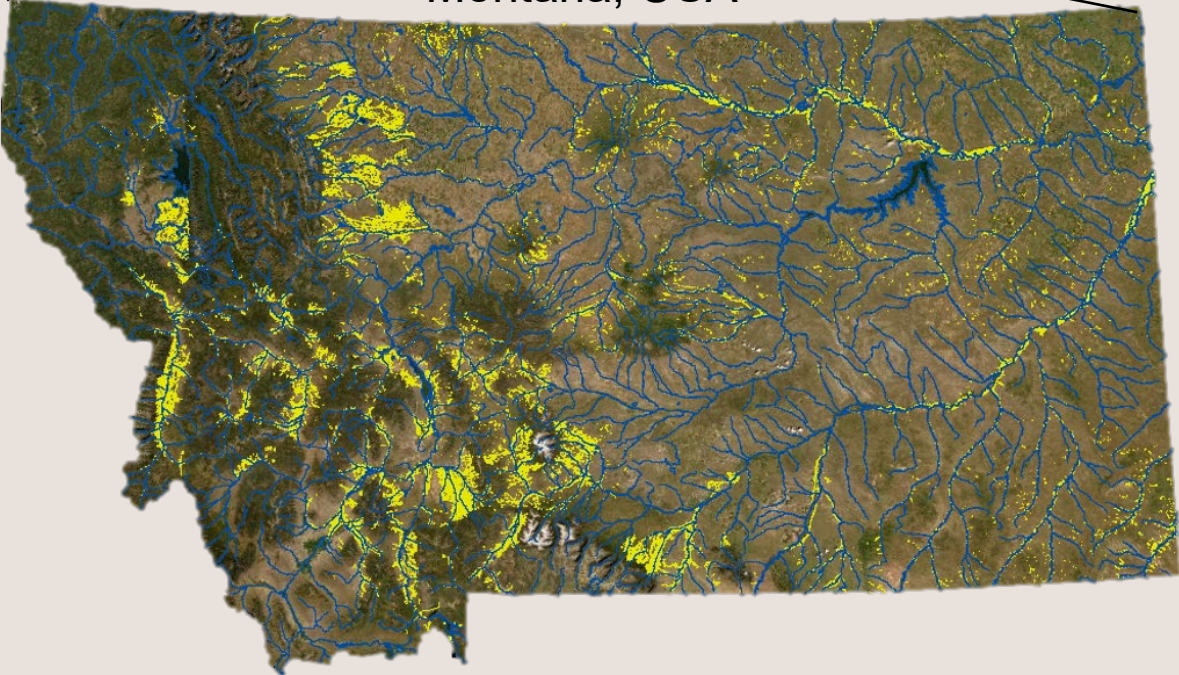


Chester and Robson 2013
Rideout et al. 2021
Tank et al. 2021

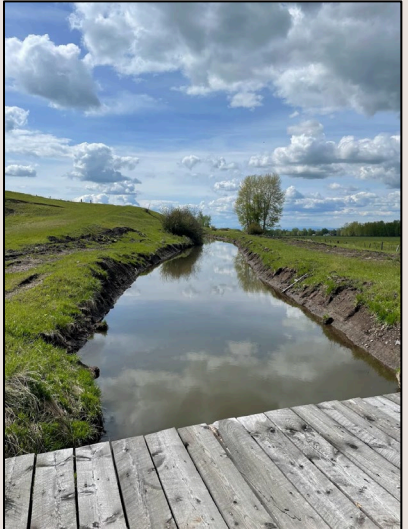
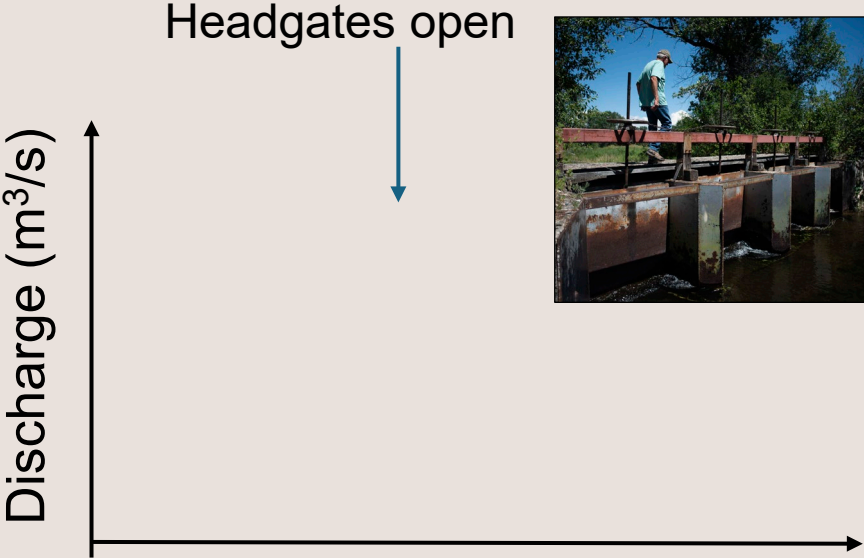
Irrigation ditches are essential in arid agricultural regions



Montana, USA



- Natural river
- Irrigation ditch



Ditches increase ecological connections between water and land

Movement of animals across ecological boundaries connect ecosystems

Emerging aquatic insects are an important subsidy for terrestrial ecosystems

Subsidies have community and ecosystem-level effects





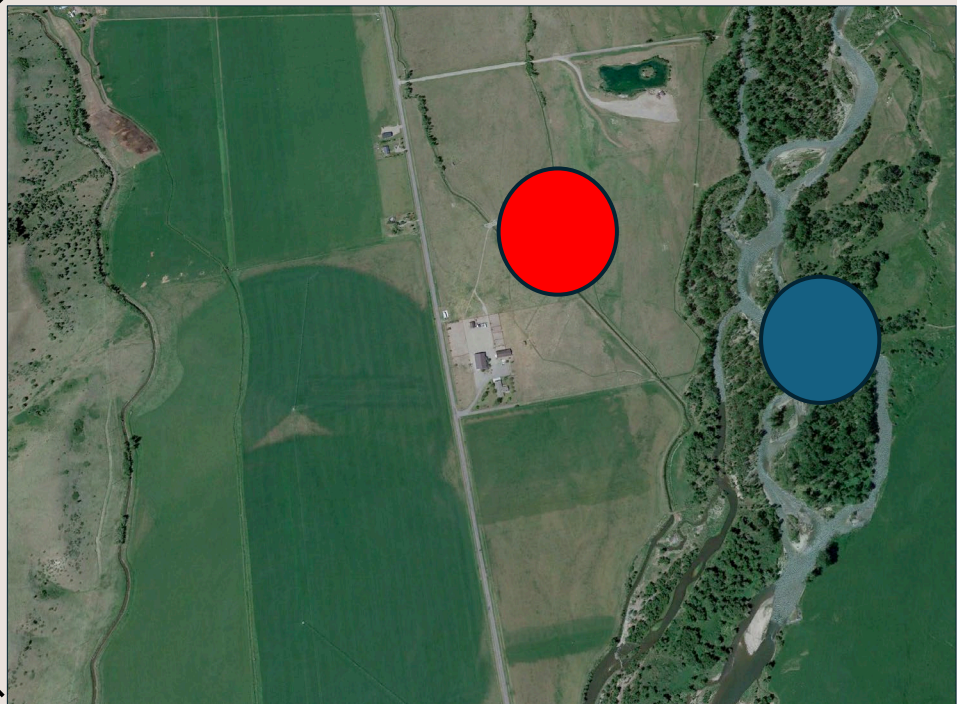
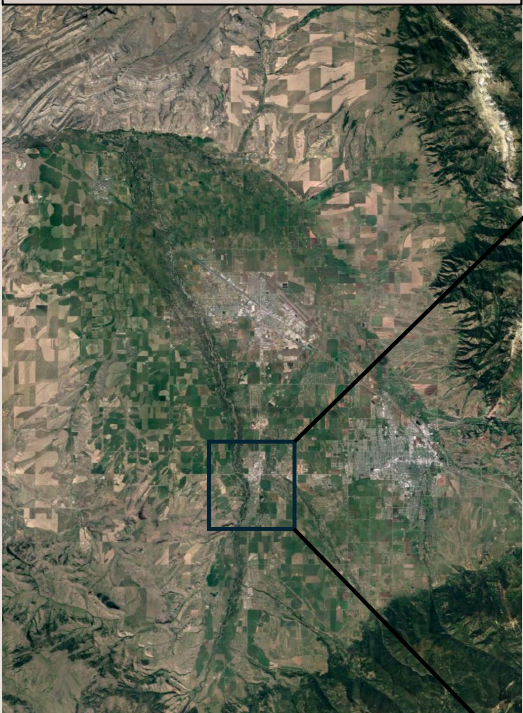
**Gallatin River Valley,
Montana, USA**



What is the contribution of irrigation ditches to stream habitat size in the Gallatin River Valley, Montana?



Gallatin River Valley,
Montana, USA

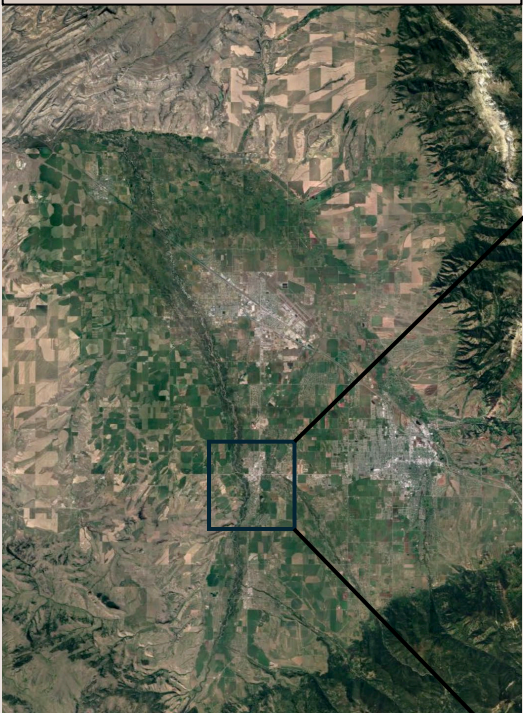


What is the contribution of irrigation ditches to stream habitat size in the Gallatin River Valley, Montana?

How does aquatic insect emergence differ between irrigation ditches and streams?



Gallatin River Valley,
Montana, USA



What is the contribution of irrigation ditches to stream habitat size in the Gallatin River Valley, Montana?

How does aquatic insect emergence differ between irrigation ditches and streams?

How does aquatic insect emergence vary across the ditch network during an irrigation season?

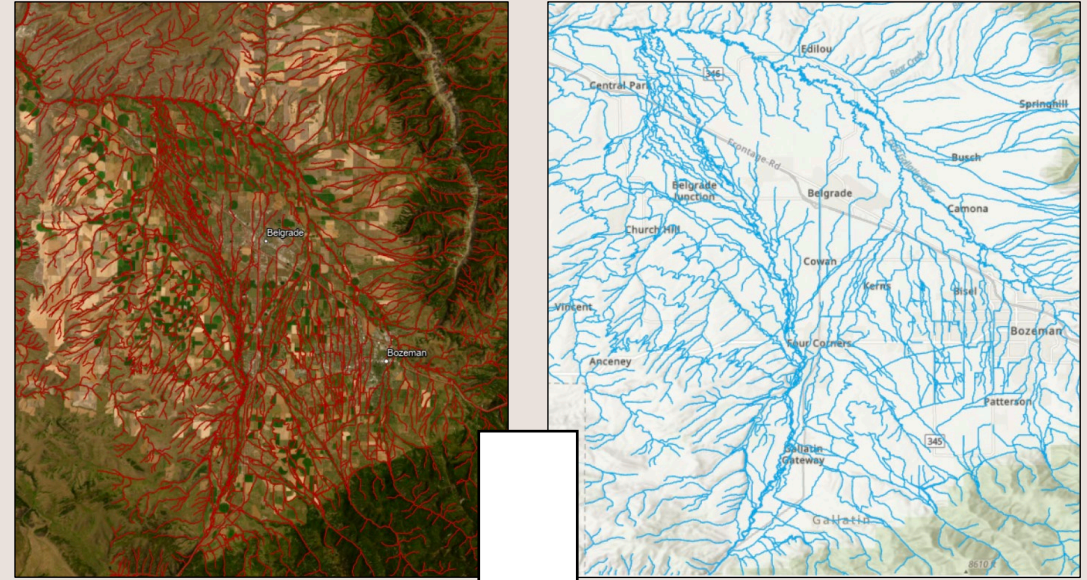
Methods: Geospatial analysis

Acquired previous stream and ditch shapefiles in the valley

Used aerial imagery to digitize or remove waterways

Summed the length of each stream type (irrigation ditch, perennial, and intermittent)

Obtained wetted width across waterways to estimate surface area

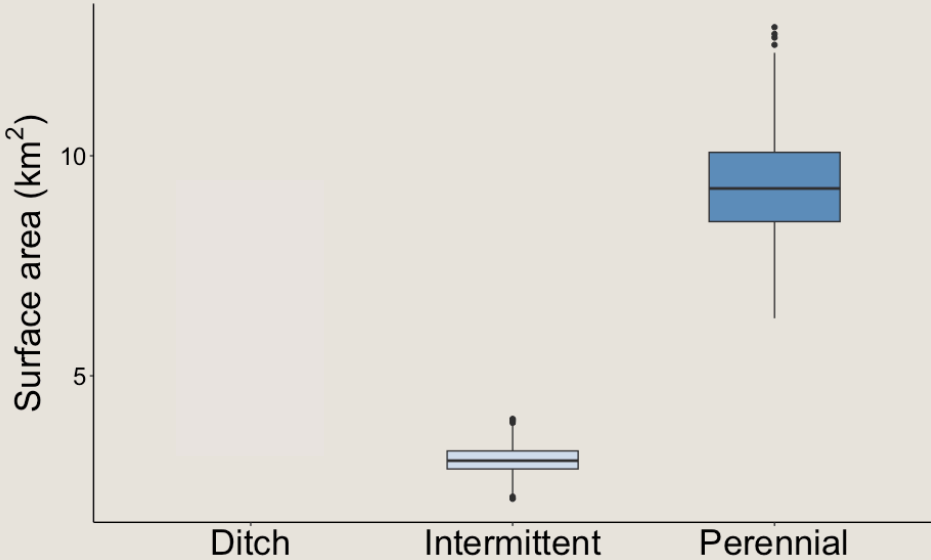
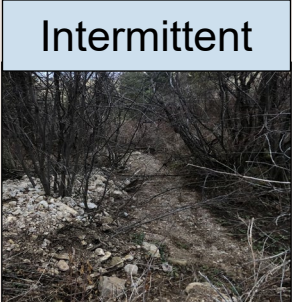
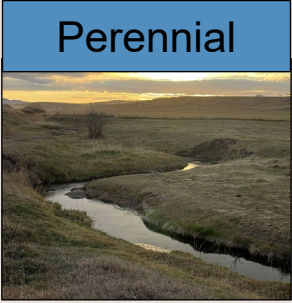
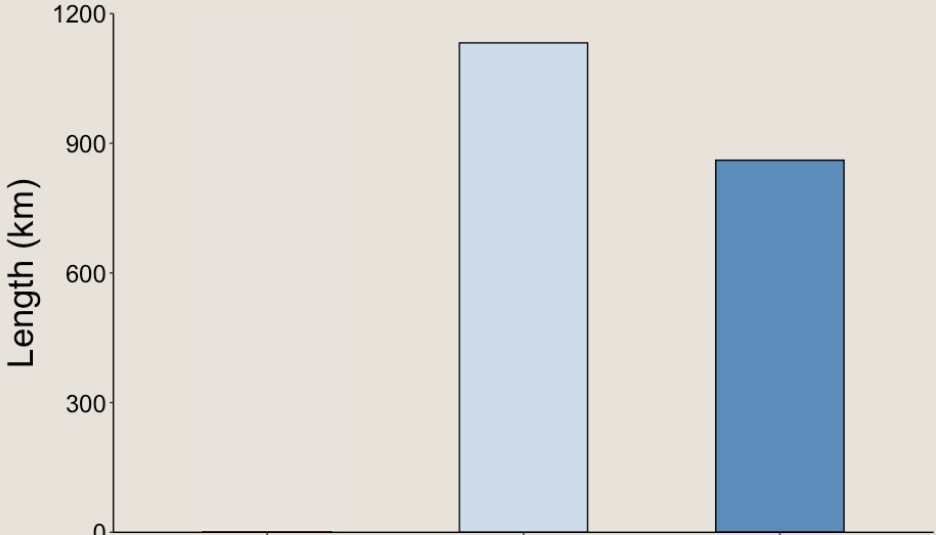


— Ditch

— Stream

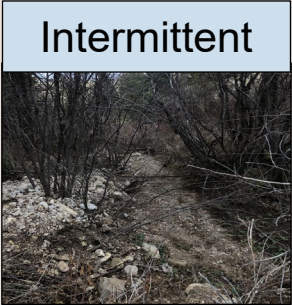
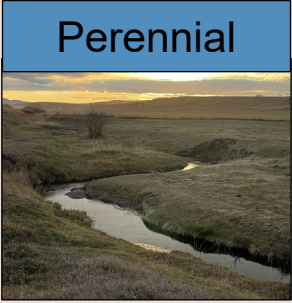
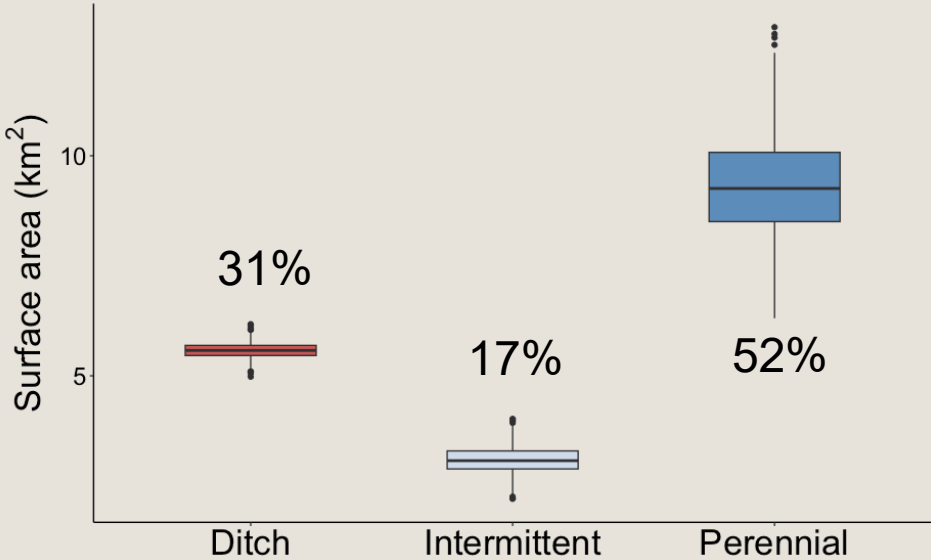
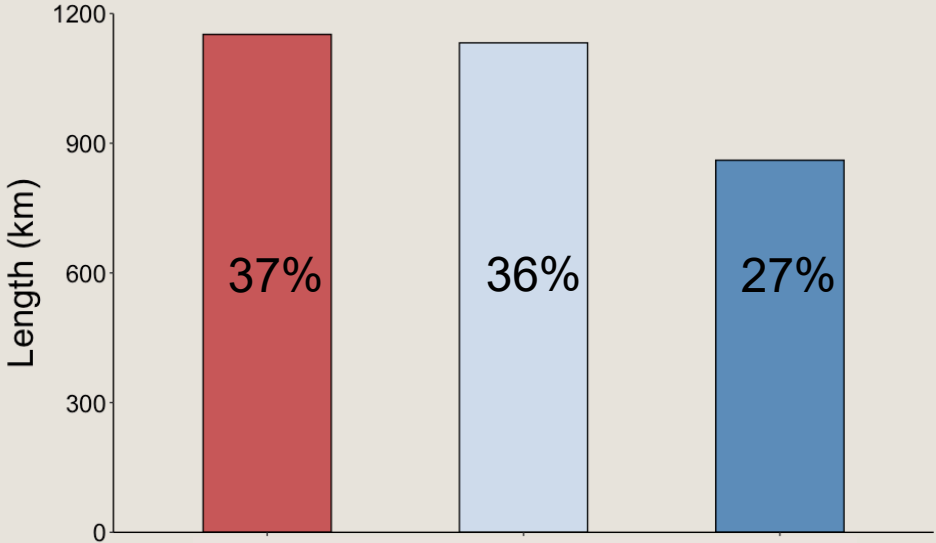
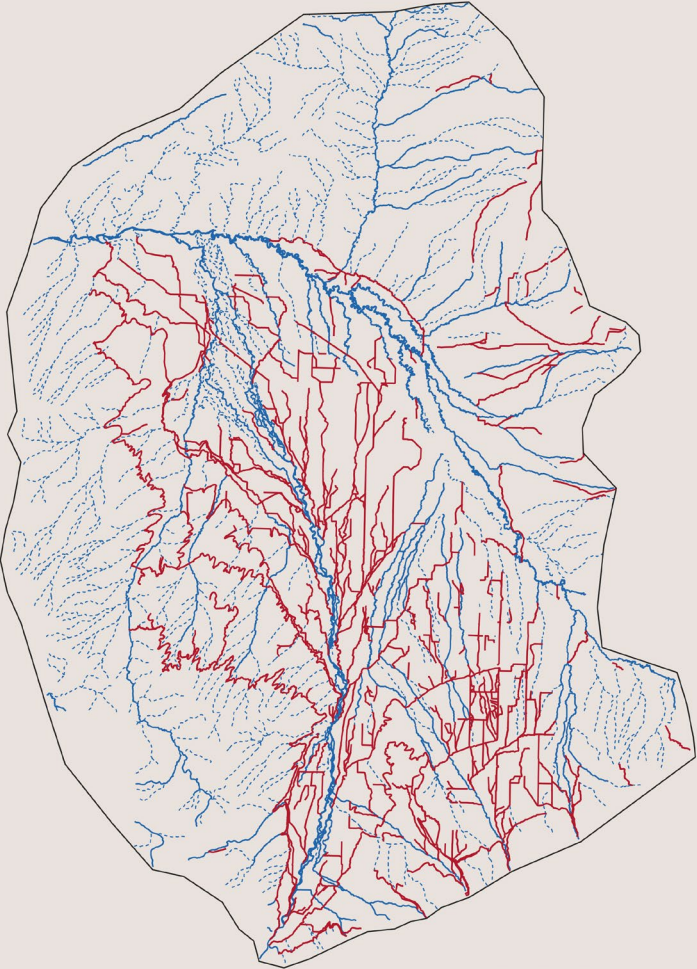
Surface-water network in the Gallatin Valley

Perennial and intermittent



Surface-water network in the Gallatin Valley

Perennial, intermittent, and ditch



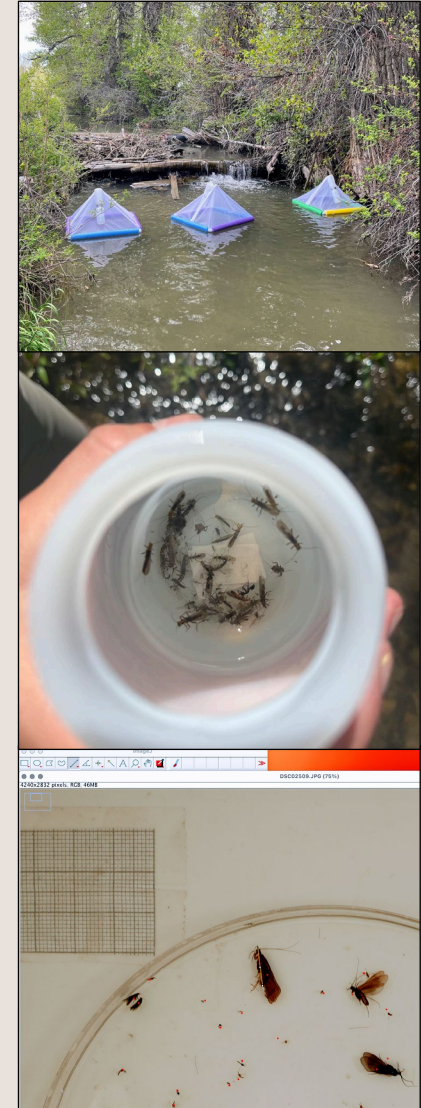
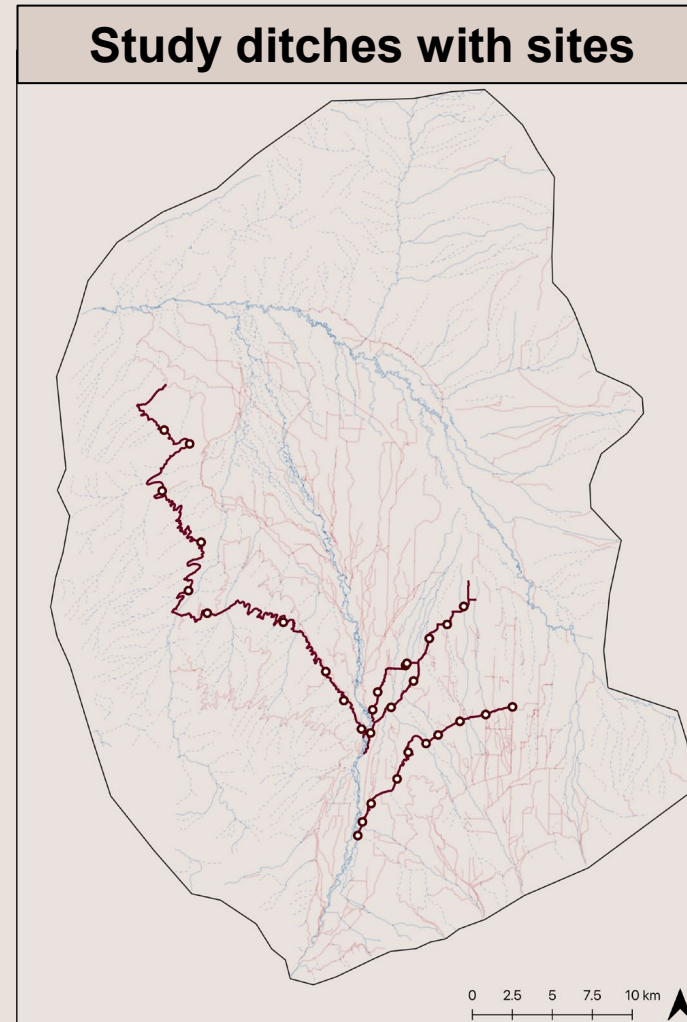
Methods: Aquatic insect emergence

4 study ditches, 30 total sites, 3 traps / site

Sampled weekly from June - November 2022

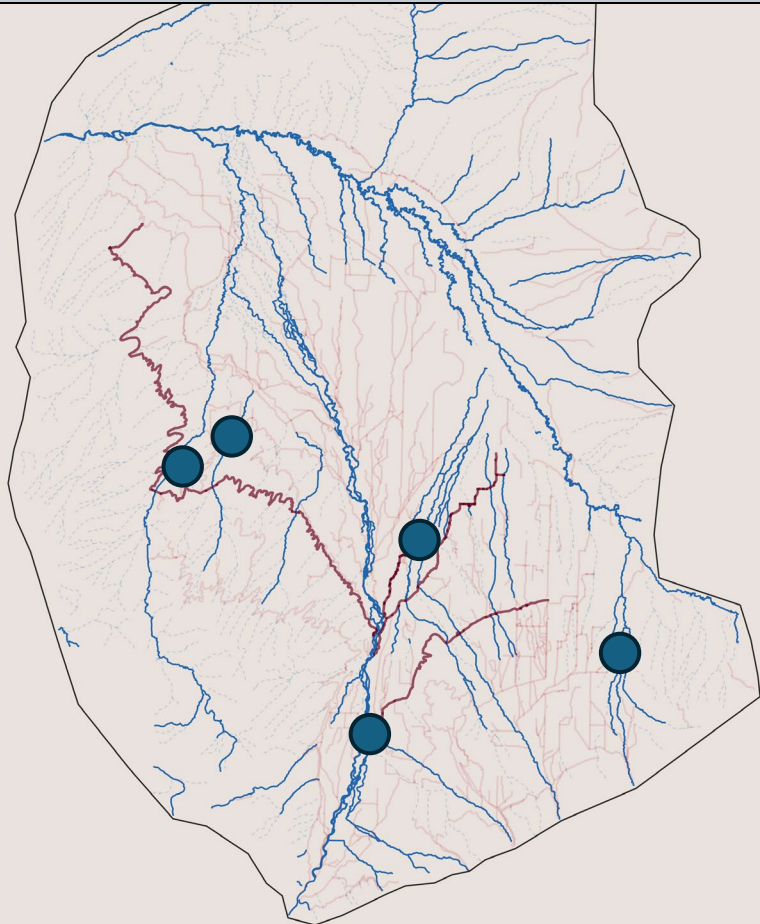
Counted, ID, length measurement

Converted emergence biomass to production (mg dry mass [DM] m⁻² day⁻¹)



Comparing emergence in ditches to natural streams

5 perennial stream sites

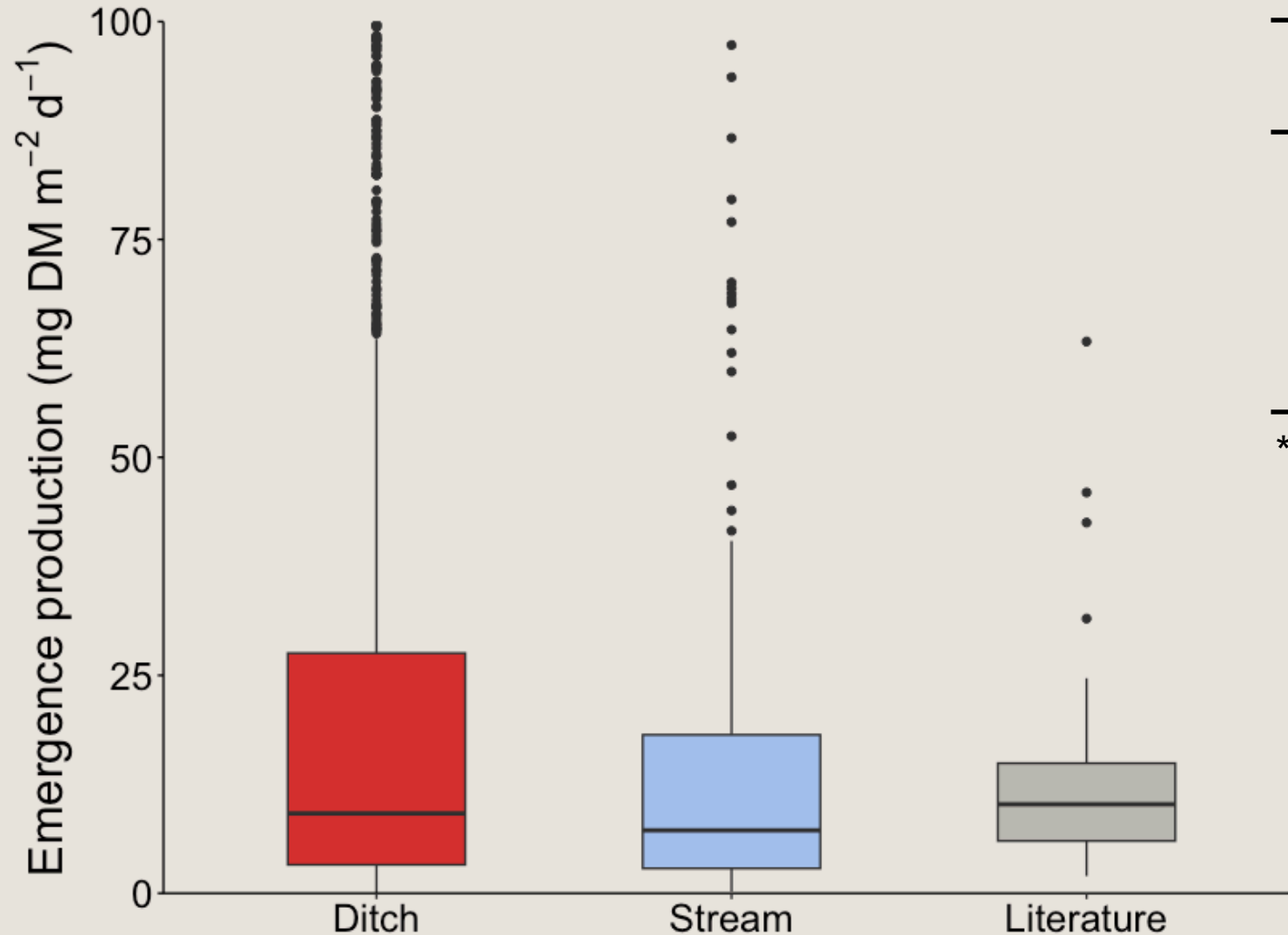


Compared ditch emergence to 32 published values in natural streams

How does aquatic insect emergence differ between irrigation ditches and streams?



Median emergence from ditches was comparable to streams



| | Median (mg m ⁻² d ⁻¹) | Mean (mg m ⁻² d ⁻¹) |
|-------------------|---|---|
| Ditch | 9.0 | 42.0 |
| Stream | 8.3 | 28.4 |
| Literature | 10.2 | 18.2 |

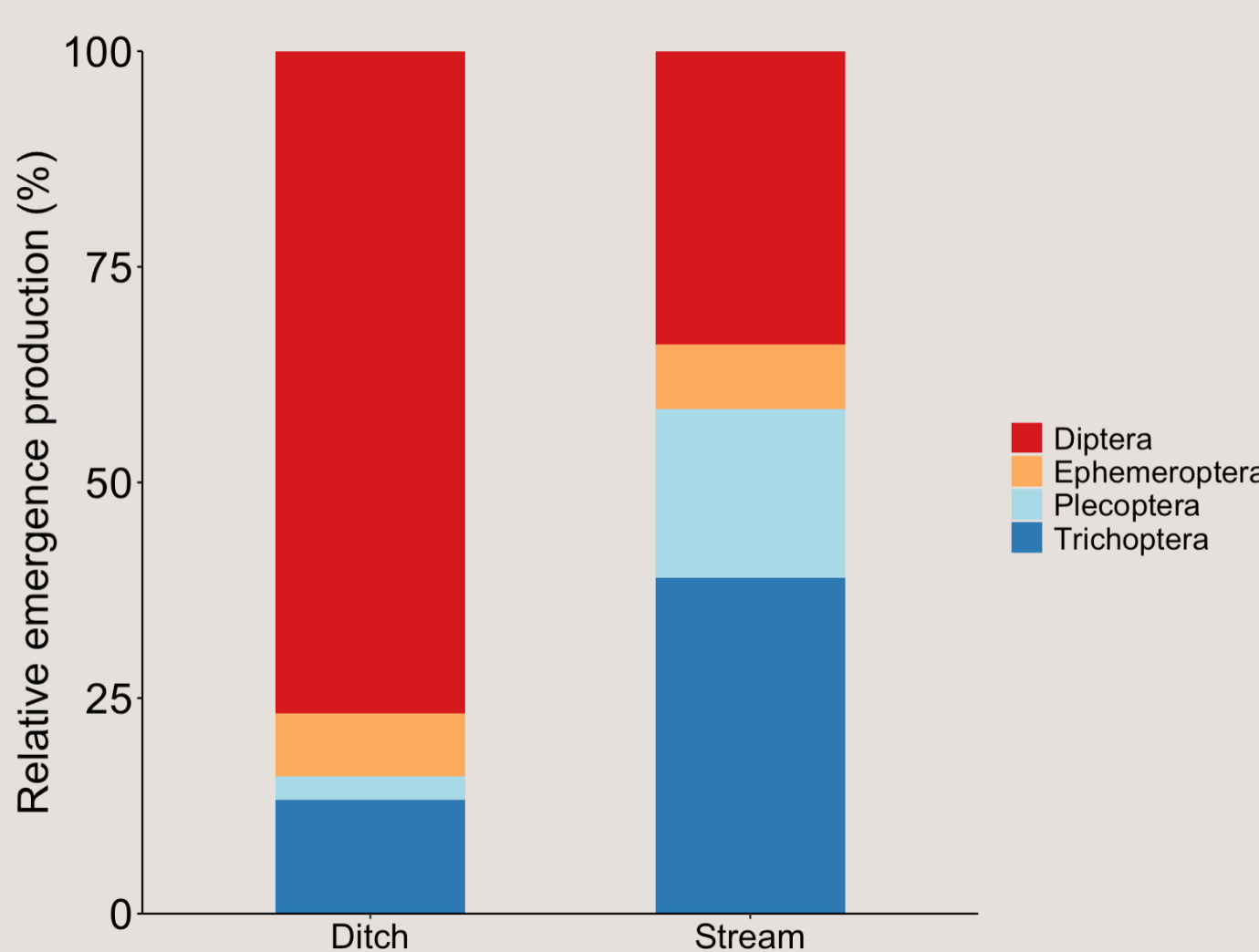
* 32 values published in natural streams



Emergence composition differed between ditches and streams



Diptera
(true fly)



Ephemeroptera
(mayfly)



Plecoptera
(stonefly)



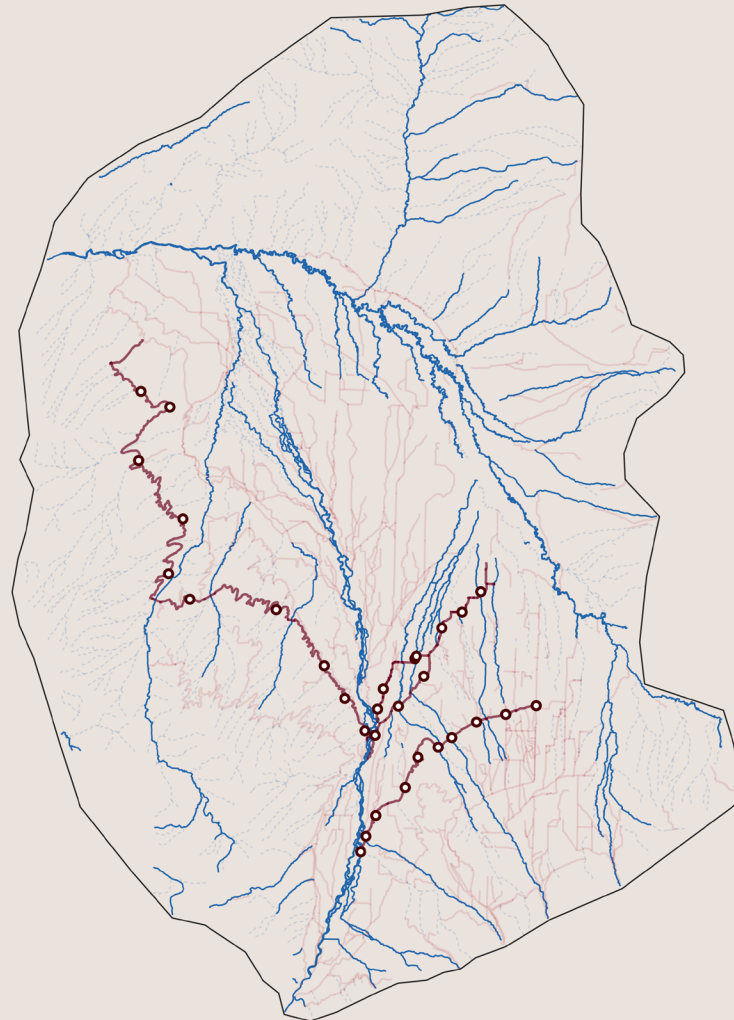
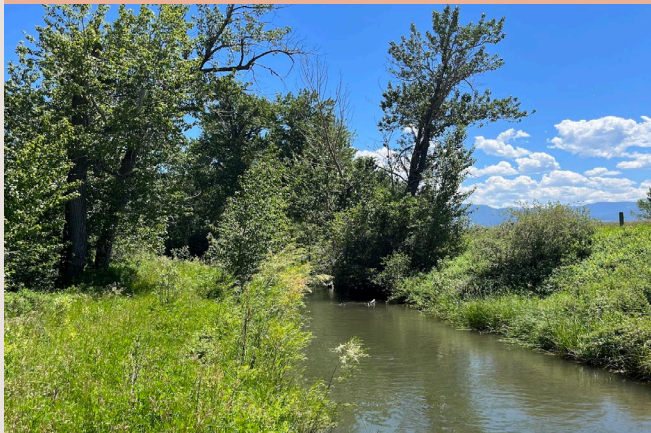
Trichoptera
(caddisfly)

How does emergence vary among ditches throughout an irrigation season?

Lowline Canal



Farmer's Canal



Beck Border

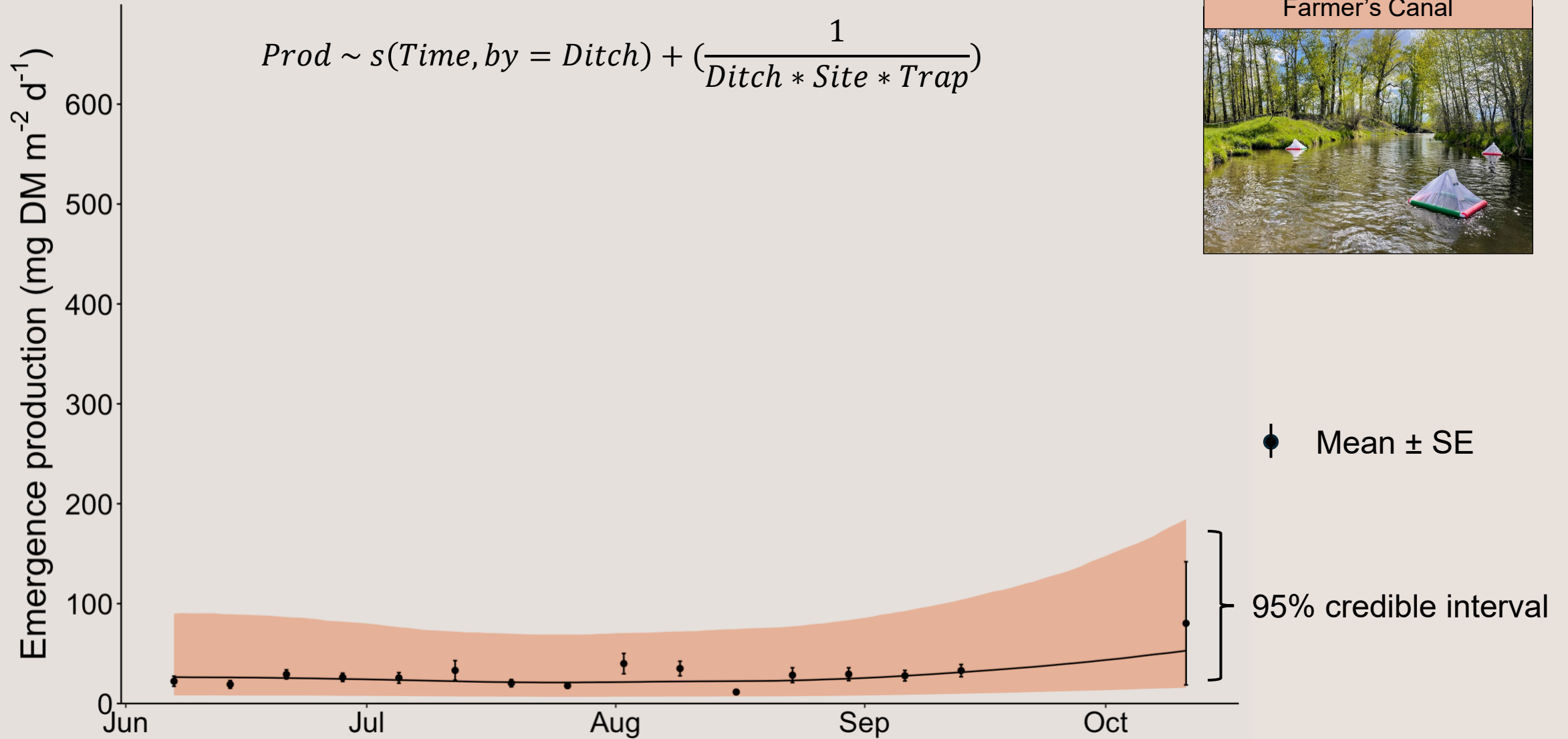


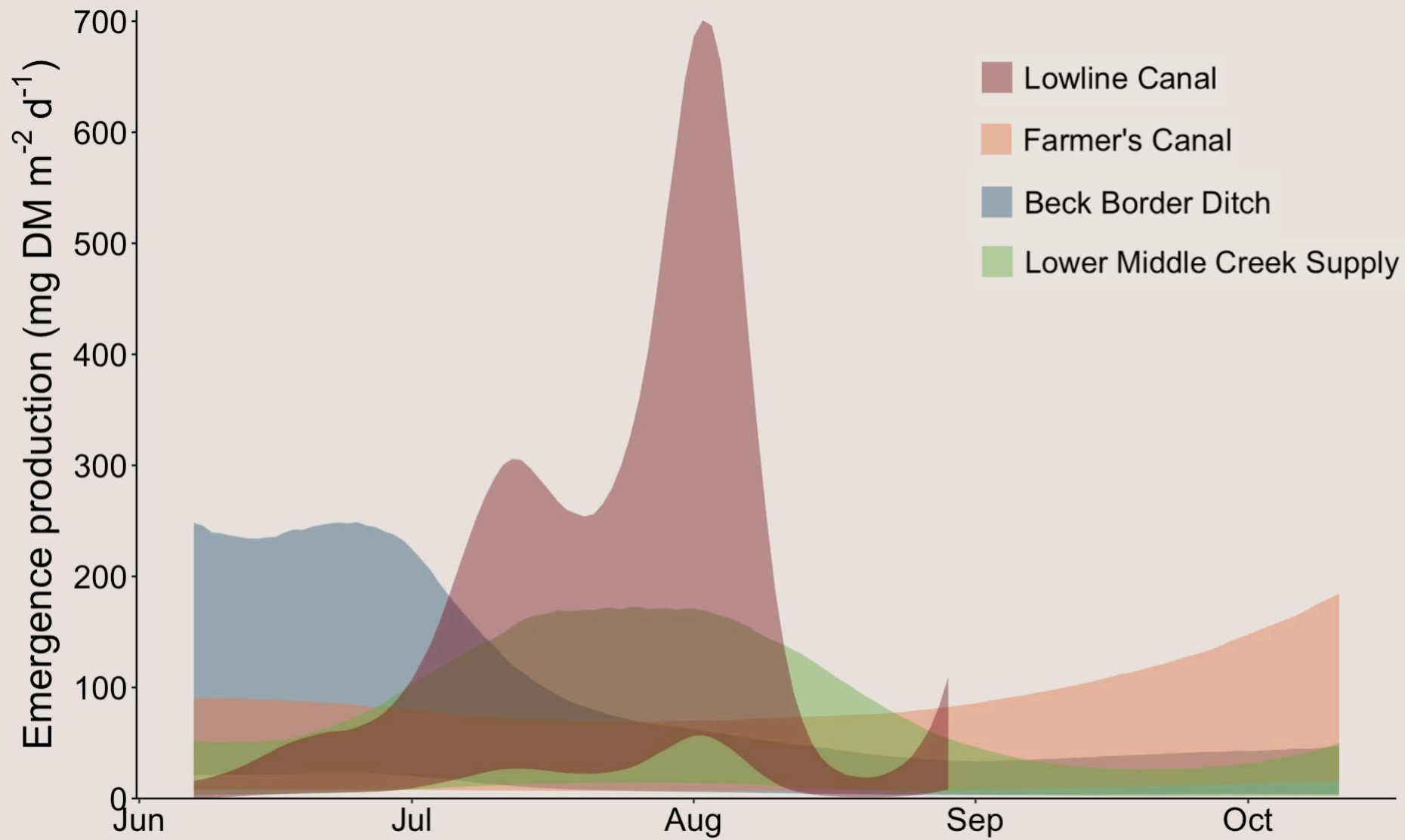
Lower Middle Creek Supply



Bayesian Generalized Additive Mixed Model:

$$Prod \sim s(Time, by = Ditch) + \left(\frac{1}{Ditch * Site * Trap} \right)$$





Lowline



Farmer's



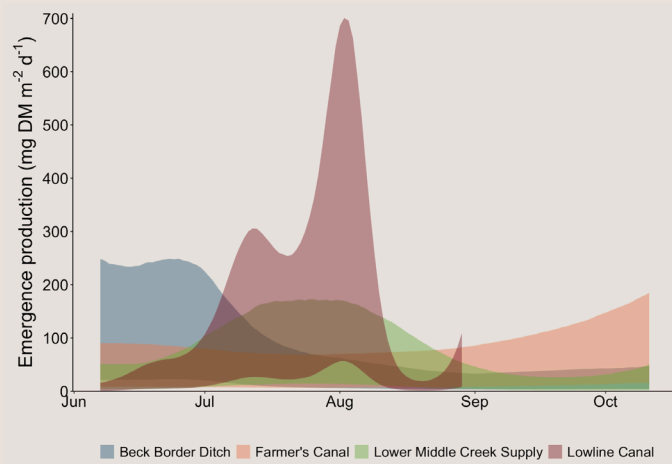
Beck Border



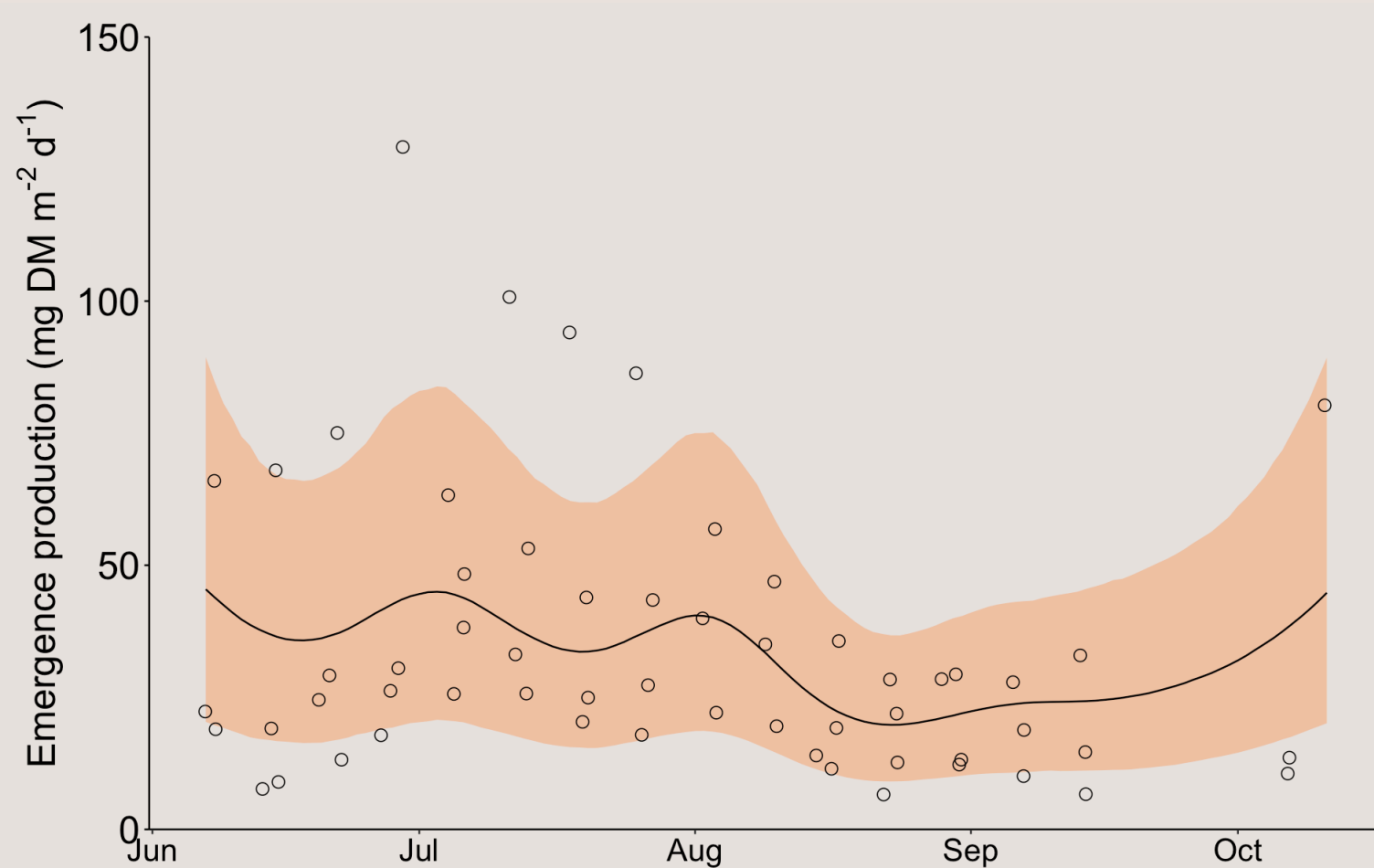
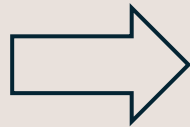
Lower Middle



Ditch-level emergence variation drove subsidy stability



Local-level model



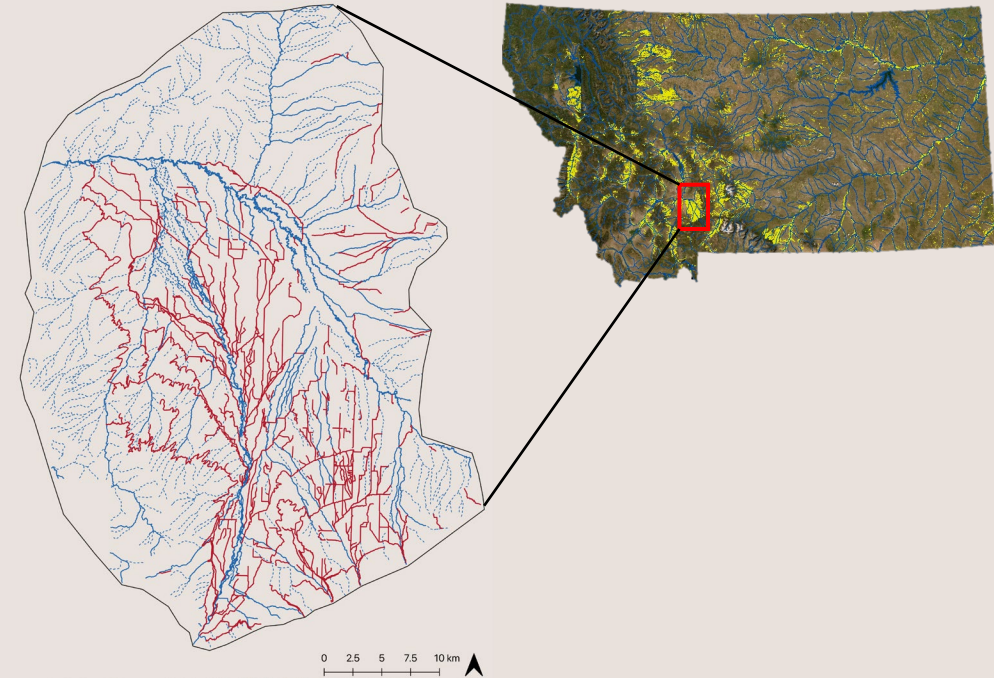
Network-level model

Conclusion: Ditches are novel intermittent streams

Irrigation ditches are major components of river networks modified by water diversions

Biomass export from intermittent ditches was comparable to perennial streams

Spatial heterogeneity in emergence provided temporally stable subsidies at the network scale



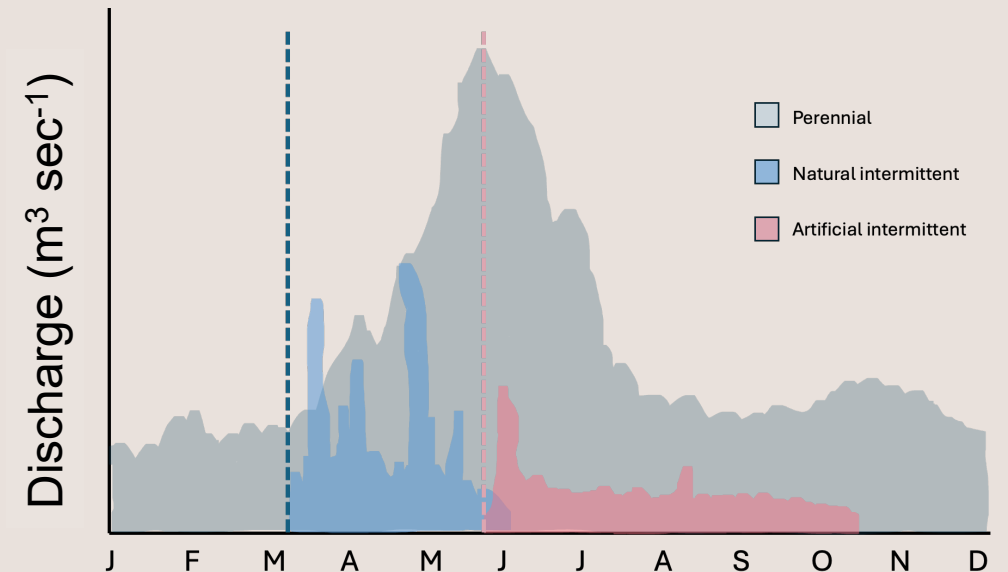
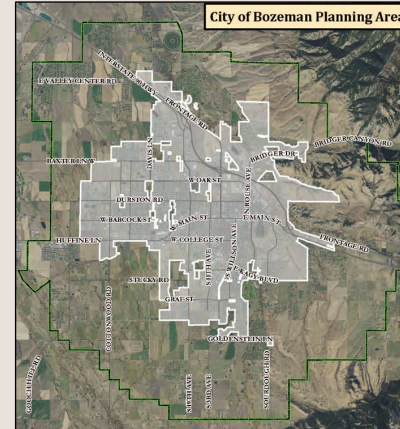
Future directions and ideas

Prioritize comprehensive mapping of irrigation ditches

Characterize flow patterns in intermittent streams and ditches



Do ditches contribute to regional biodiversity?



Acknowledgements



Wyatt Cross



Robert Payn



Lindsey Albertson



Scott Powell

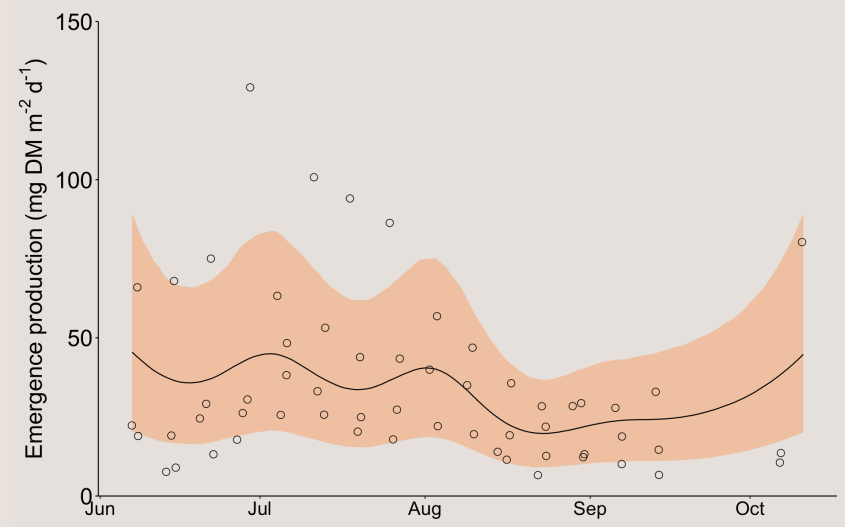
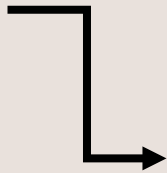
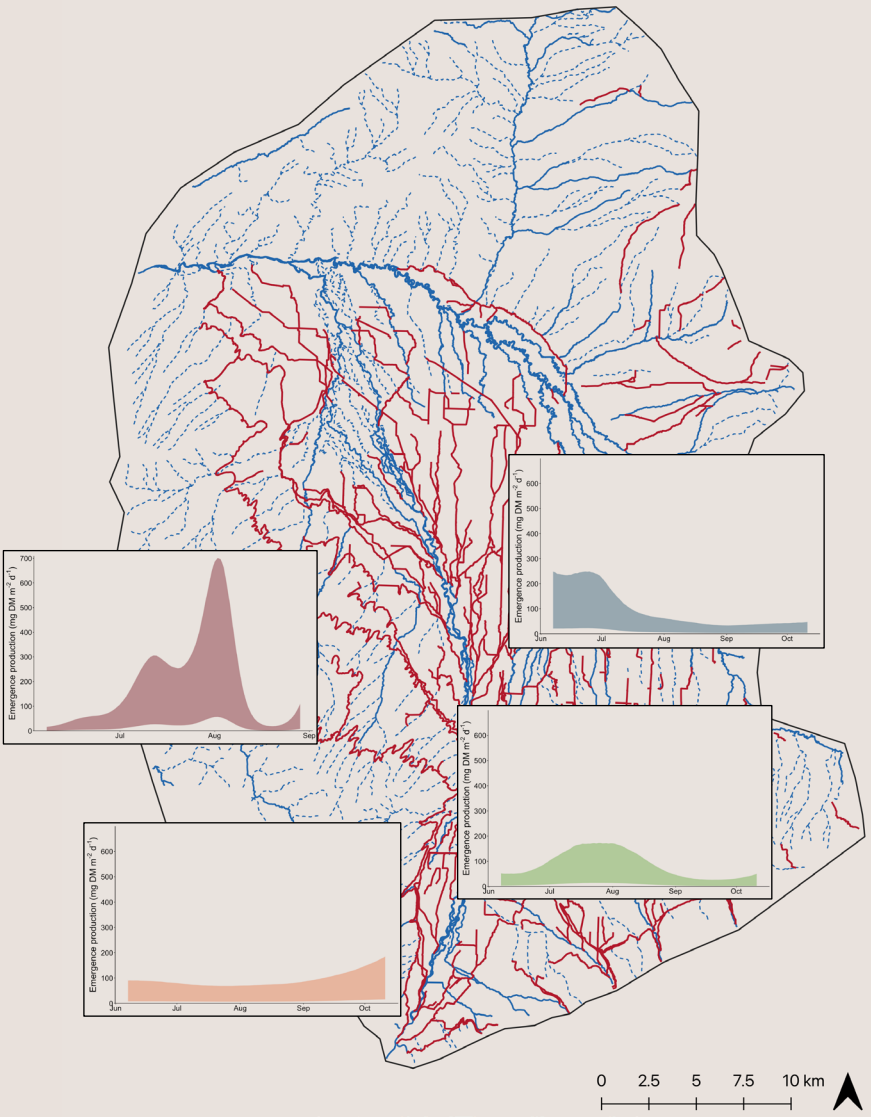
Technicians: Lilly Strong, Kieran Wilder, Dakota Rygh, Ian Uland, Charles Miller, Jadyn Bellander

AlberCross Lab, past and present: especially Eric Scholl and Jose Sanchez-Ruiz (Tosti)

Gallatin Valley irrigators (AGAI): especially Mike Gaffke, Susan Duncan, and Kurt Dykema

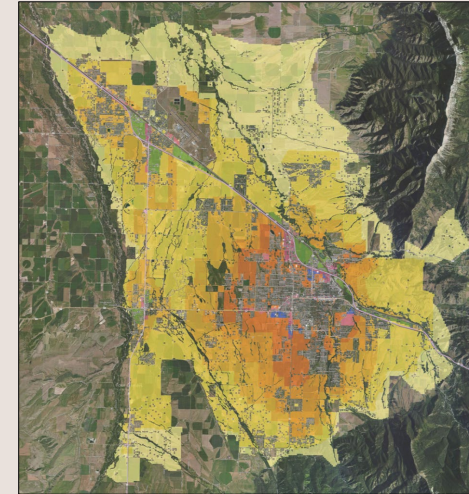
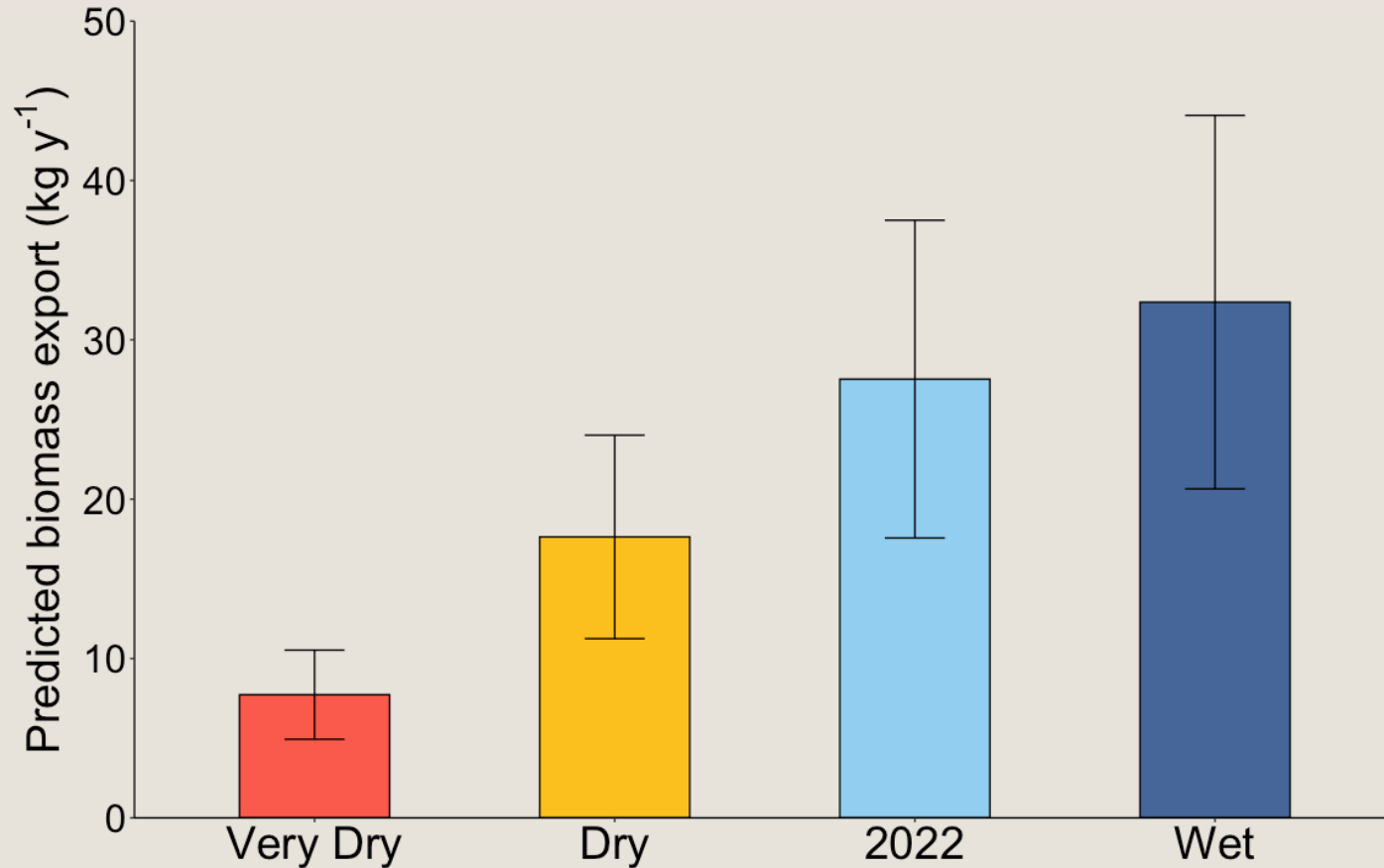


Questions?

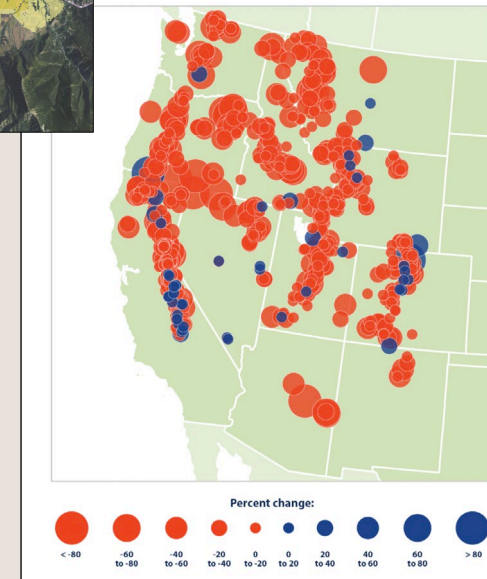


Nate Heili
nheili42@gmail.com

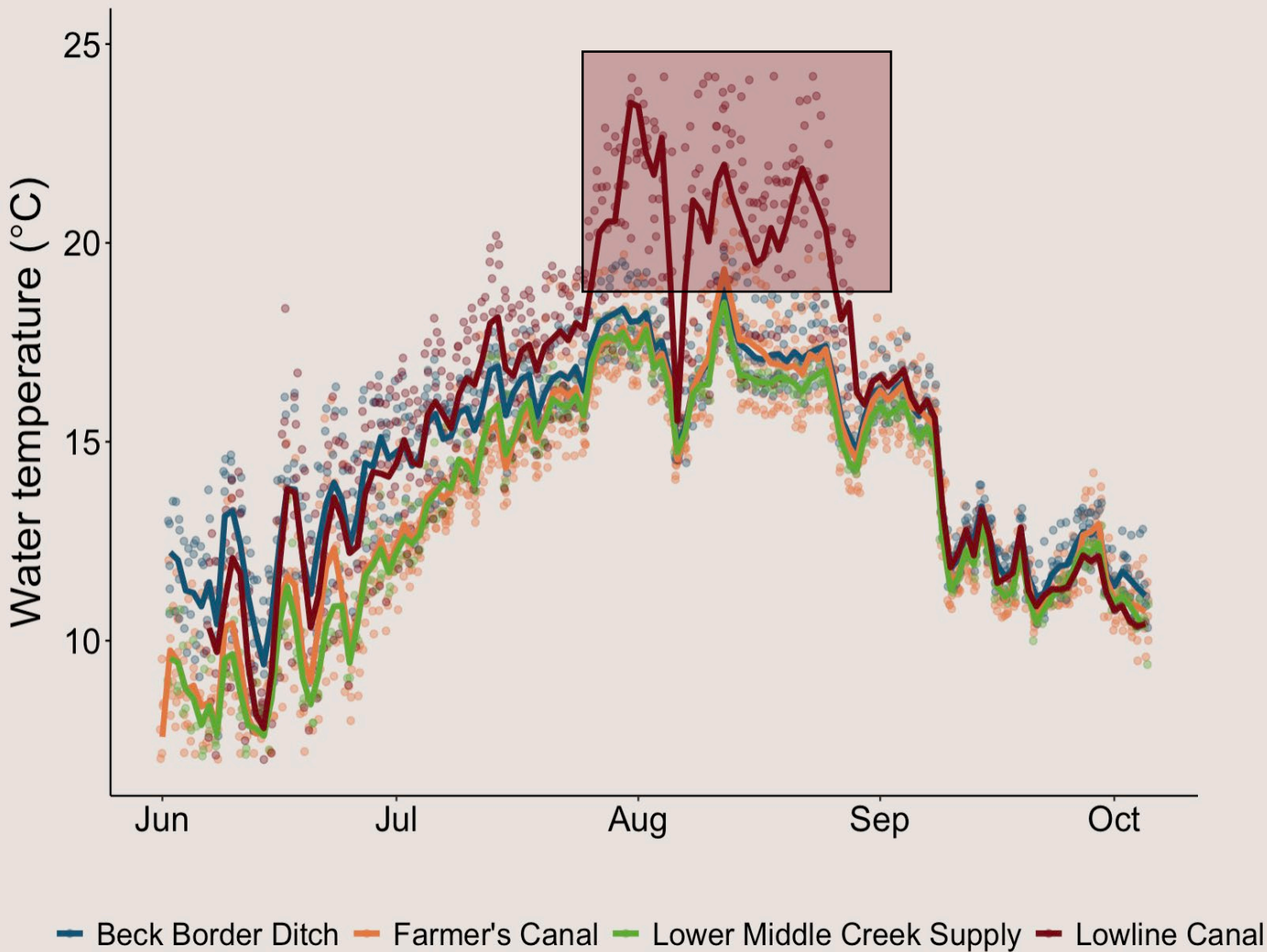
Land conversion and climate-driven flow reductions will lessen energy subsidies from ditches



Trends in April Snowpack in the Western US, 1955-2016



Lowline warmer and experienced drying during the irrigation season



Temperature increased and substrates transitioned to smaller sizes as distance from stream increased

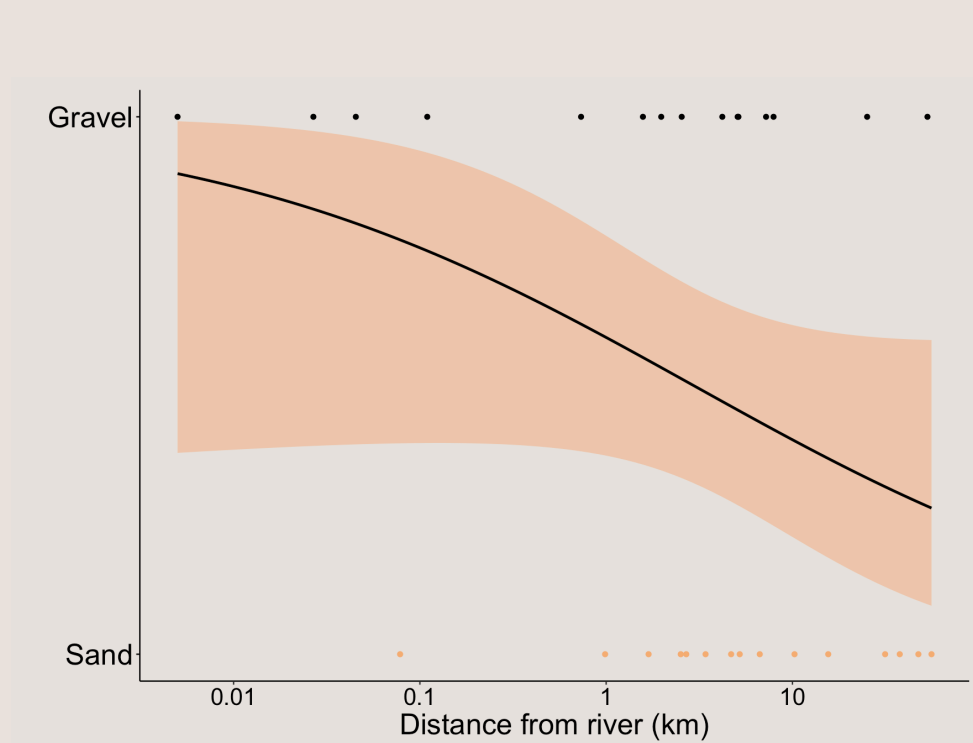
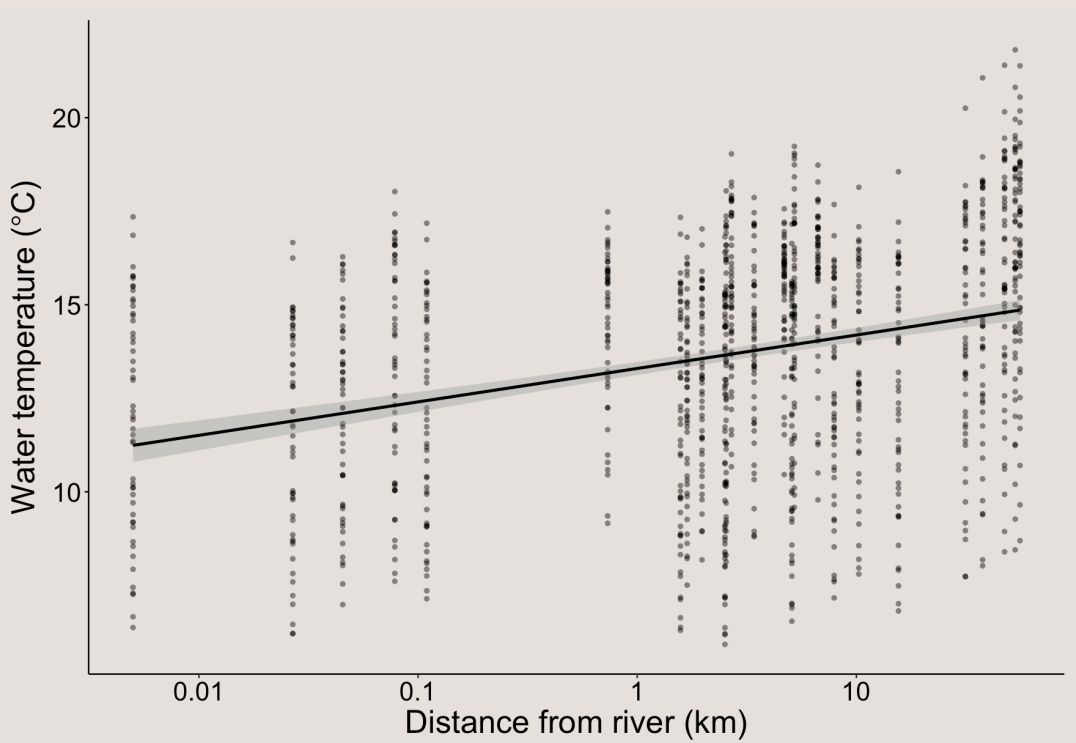
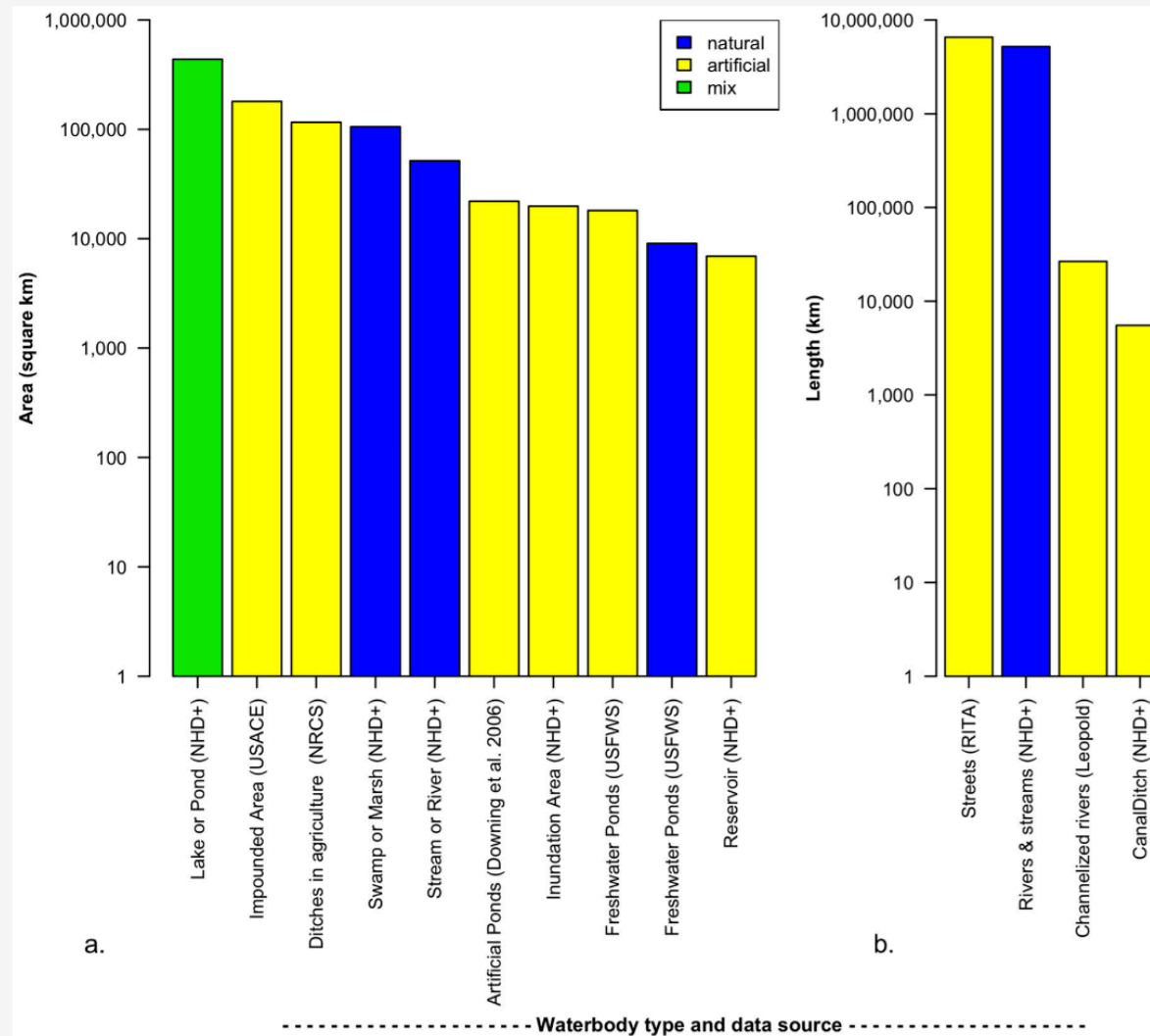


Figure 2. Extent of artificial as compared to natural waterbodies in the U.S. Data drawn from a variety of sources, shown in parentheses. (a) areal features; (b) linear features. Data are taken from the National Hydrography Dataset (NHD+) [48], U.S. Army Corps of Engineers National Inventory of Dams (USACE) [49], U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) [41], Downing et al. [6], U.S. Fish and Wildlife Service (USFWS) [50], Research and Innovative Technology Administration (RITA) [46], and Leopold [42].



Emergence phenology in ditches was similar to streams

