Coastal cutthroat trout navigate a temperature oxygen squeeze in floodplain thermal refuge habitats
Primer for Identifying Cold-Water Refuges to Protect and Restore Thermal Diversity in Riverine Landscapes

Torgersen, Ebersole, and Keenan, USEPA, 2012
Spatial resolution 1-km

Isaak et al. 2017
Water Resources Research

Spatial resolution ~2-km

Siegel et al. 2023
Freshwater Science
Temperature oxygen squeeze

Striped Bass, Temperature, and Dissolved Oxygen:
A Speculative Hypothesis for Environmental Risk

Charles C. Coutant
Novel dimensionless index for physically based assessment of thermal refugia characterizes off-channel habitat on gravel bed river

Carolyn E. Gombert | Stephen T. Lancaster | Gordon E. Grant | Rebecca L. Filcroft
~30cm!!

- Dissolved oxygen (mg/L)
- Temperature (°C)

Frequency

Temperature (°C) standardized by profile

Available temperature
The boat-shock-meat-probe method
A small slice of the alcove offers intermediate T-DO conditions that fish select.
Studying fish behavior provides inference on the useable size of these alcoves.

- Total alcove - large
- Portion with cool water - small
- Portion with cool water and high DO - very small

There is a shortcoming of our work so far – we’ve only sampled during the day…
Diel variation: stressors occur asynchronously
Stressors are asynchronous for fish

- Night
  (+) lower temperature
  (-) lower DO
- Day
  (-) higher temperature
  (+) higher DO
- Constraints are toggling – asynchrony softens trade off
- Fish can navigate these trade offs by moving
  - Fine scale diel vertical movement (DVM)
Evening – higher DO, higher temperature
Dawn – lower DO, lower temperature
Simulation

Depth selection
- DOmax
- TDOopt
- Tmin

Depth (m)

Hour of day
Tagged fish incur low DO in exchange for cold temperatures
Refuges formed by hyporheic upwelling can generate a temperature-oxygen squeeze

In stratified alcoves, intermediate conditions in temperature and oxygen existed in a relatively small boundary layer spanning as little as \( \sim 30 \text{cm} \) of the water column.

Fish body temperatures indicate limited vertical use of habitat

Oxygen constraints on thermal refuge use may be a blind spot for climate adaptation planning of cold-water fishes – oxygen data is limited compared to temperature data.

Temperature and dissolved oxygen are critical to cold-adapted fishes, and these conditions can vary both spatially and through a 24-hour timeframe

Asynchronous threats of hypoxia and heat stress create a pronounced trade-off for fish, which became more severe at night during the oxygen minimum

Diel vertical migration is an emergent property for fish balancing these dynamic trade-offs