Surface flow intermittency results in ecological traps for a fish assemblage

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- Working in fisheries since August 2000
- Primary work in the MRG is silvery minnow augmentation and rescue
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Background

- Work done in June – July 2020 with USFWS and USBR
- Lots of data, over-arching theme is looking at the potential effects of pumping (or not pumping) at the south boundary of Bosque del Apache
- This presentation covers changes in mesohabitat and fish catch-rates

Background

- Drying and drought are a major disturbance for stream fishes[1]
- Water use and climate change are increasing the frequency and duration of intermittency

[1]Magoulick, D.D. and Kobza, R.M. (2003), The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology, 48: 1186-1198. https://doi.org/10.1046/j.1365-2427.2003.01089.x

Fish: refuge use strategies

- Must move to refuge areas prior to disturbance or be trapped within them at the onset of intermittency[1]
- Refuge use strategies:
  - Behavioral
    - Migration[2]
  - Physiological
    - Estivation, tolerance to harsh conditions
  - Life-history
    - Opportunistic, demographic resilience
    - Annual species (African killifishes)

[2]DAVEY, A.J.H. and KELLY, D.J. (2007), Fish community responses to drying disturbances in an intermittent stream: a landscape perspective. Freshwater Biology, 52: 1719-1733. https://doi.org/10.1111/j.1365-2427.2007.01800.x

Conservation Importance

- Questions
  - What are refuges for fishes in the MRG during drying
  - **How are fish using them**
- Why?
  - Predict consequences of decreasing surface flow[3]
  - Understanding how fish persist through drought will help determine appropriate conservation actions

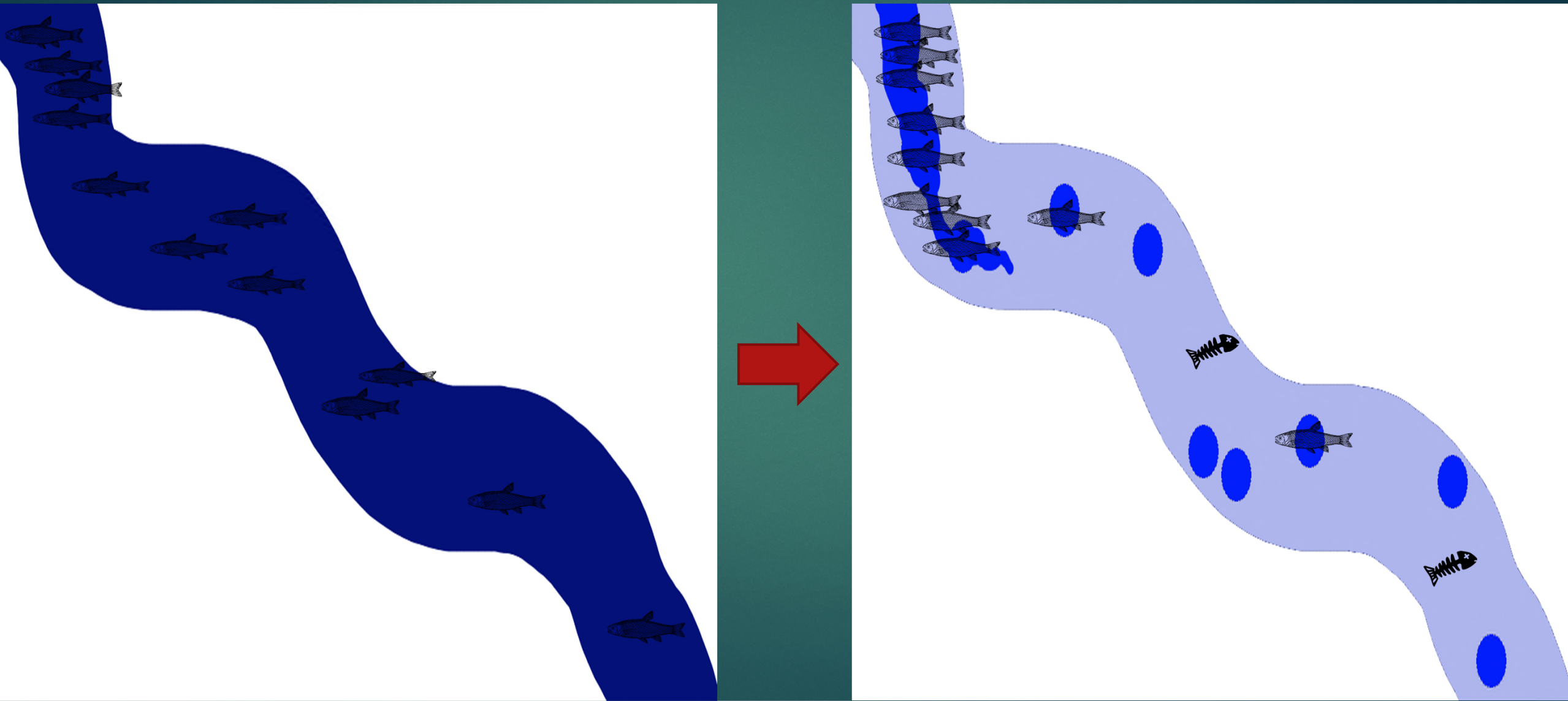
[3]Walters, A. W. (2016). The importance of context dependence for understanding the effects of low-flow events on fish. Freshwater Science. 35:1, 216-228.

Hypotheses

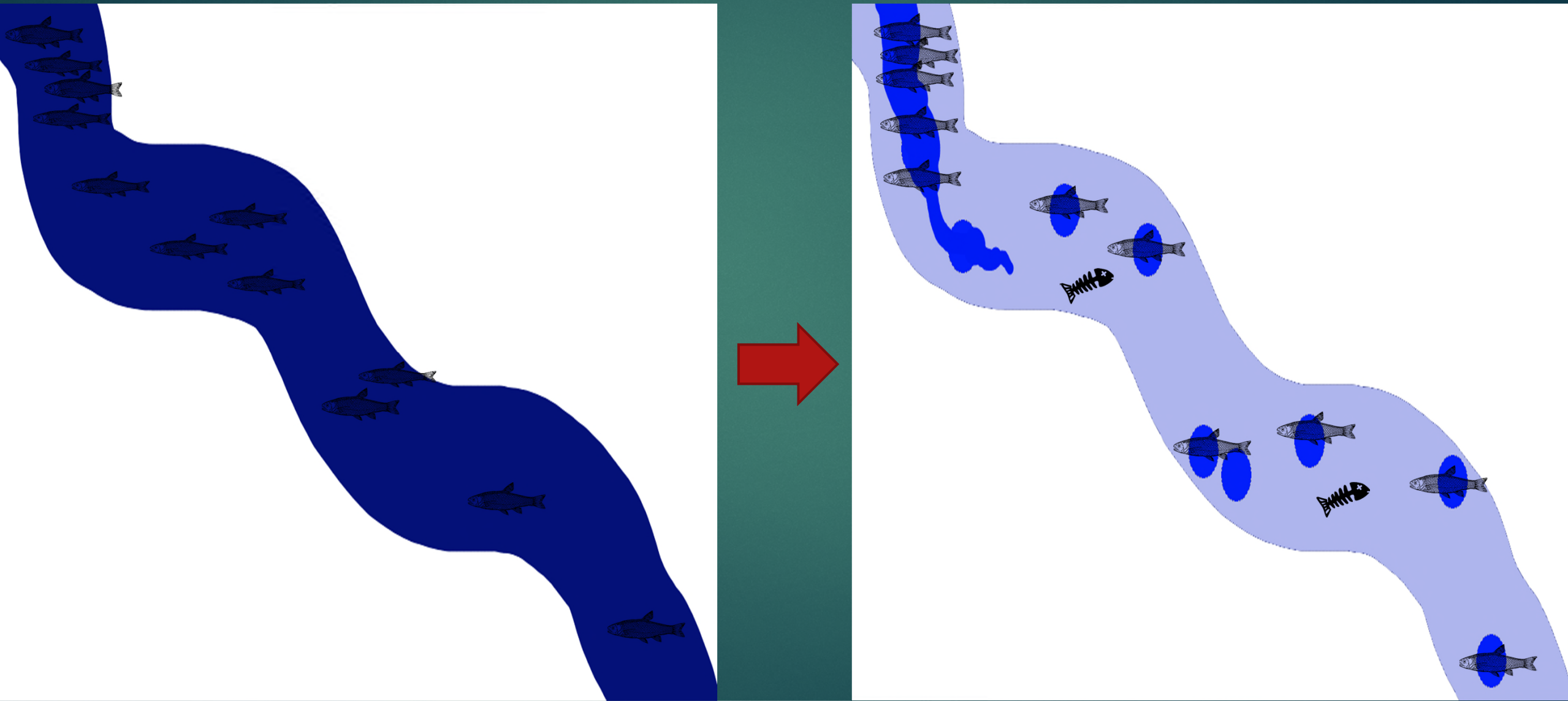
- Fish move to refuge[2]
  - Spatial change in fish density
- Fish trapped in proximal habitat[4]
  - No spatial change in fish density

[4]Archdeacon, TP, Reale, JK. No quarter: Lack of refuge during flow intermittency results in catastrophic mortality of an imperiled minnow. *Freshwater Biology*. 2020; 65: 2108– 2123. https://doi.org/10.1111/fwb.13607

Conceptual refuge use: movement to refuge



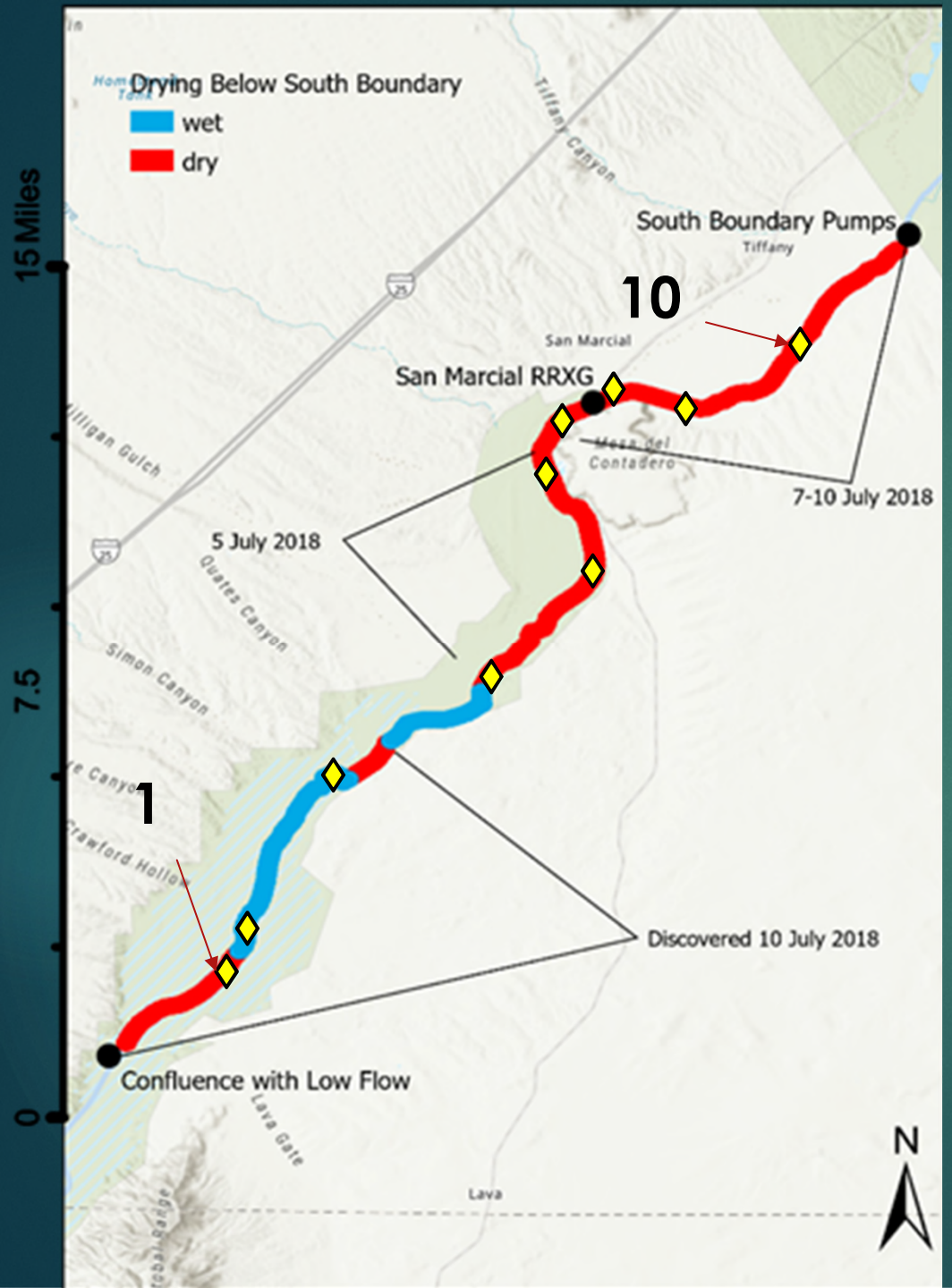
Conceptual refuge use: Trapped within proximal habitats



Methods

- Before-After[5,6] Quasi-experimental design
  - Multiple pre-impact samples
  - Sampling immediately before and after impact
  - Known, controlled impact

[5]Smokorowski KE, Randall RG (2017) Cautions on using the Before-After-Control-Impact design in environmental effects monitoring programs. FACETS 2:212–232. doi10.1139/facets-2016-0058.
[6]Rytwinski, T., Taylor, J. J., Donaldson, L. A., Britton, J. R., Browne, D. R., Gresswell, R. E., Lintermans, M., Prior, K. A., Pellatt, M. G., Vis, C. & Cooke, S. J. (2019). The effectiveness of non-native fish removal techniques in freshwater ecosystems: a systematic review. Environmental Reviews 27, 71– 94.



- Selected 10 random locations between the low-flow conveyance channel and the south boundary pumping station
- Surveys from June 16 – July 16, 2020

Methods – Flow Reduction

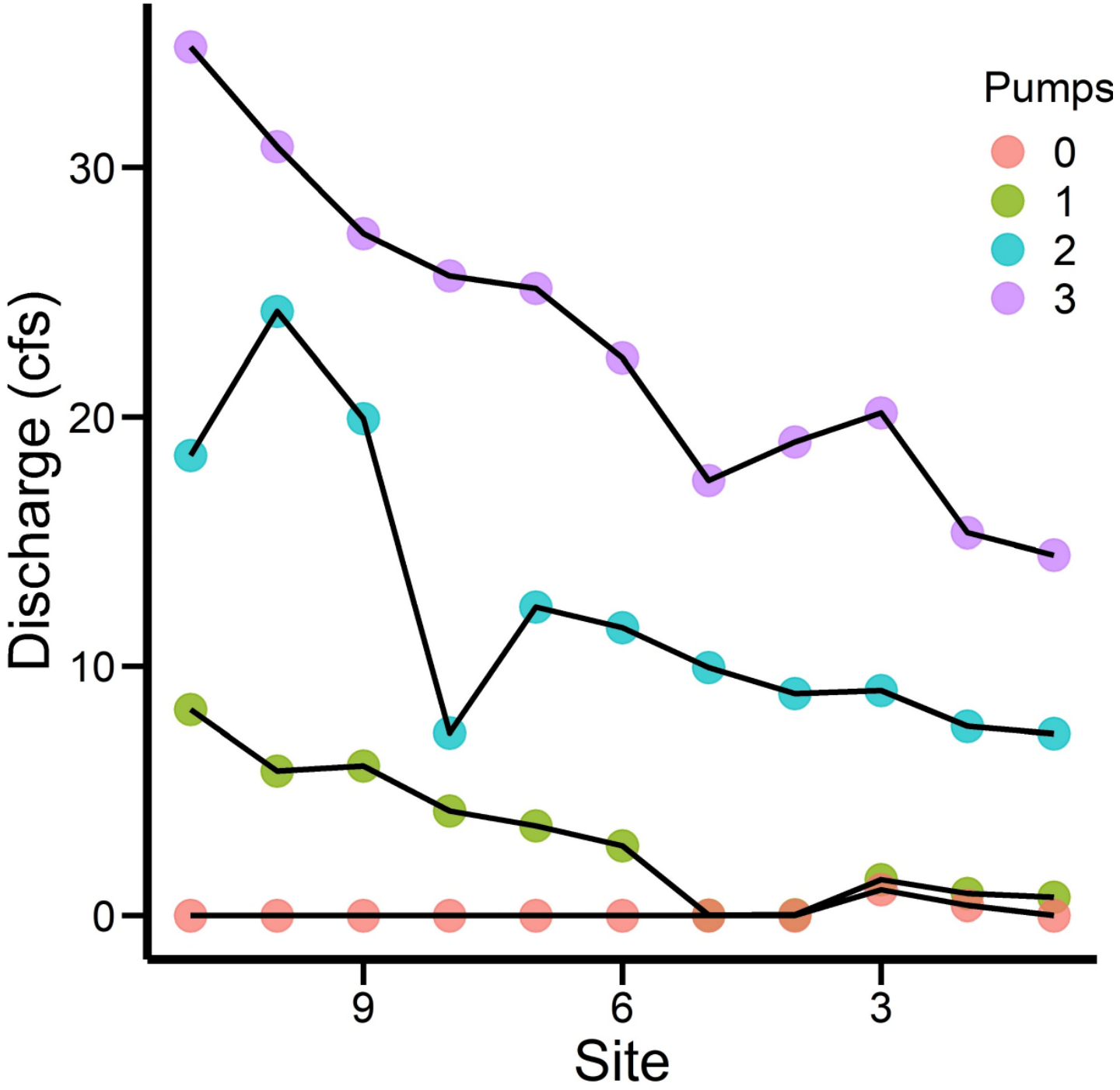
- 3 pumps, ~35 cfs (1 $m^3 s^{-1}$)
- 2 fish surveys, 1 habitat
- Pumping rate reduction
- Repeat weekly
- Fish rescue after last pump
- 40 total surveys

Methods - Habitat

- *Discharge
- *Temperature (15-min, 6 sites plus 3 LFCC)
- 10 transects, 11 points, 110 points per site per survey
  - Depth, velocity, categorical mesohabitat(4,400 measurements)
- Estimated surface area of each mesohabitat
- Depth and velocity of each mesohabitat

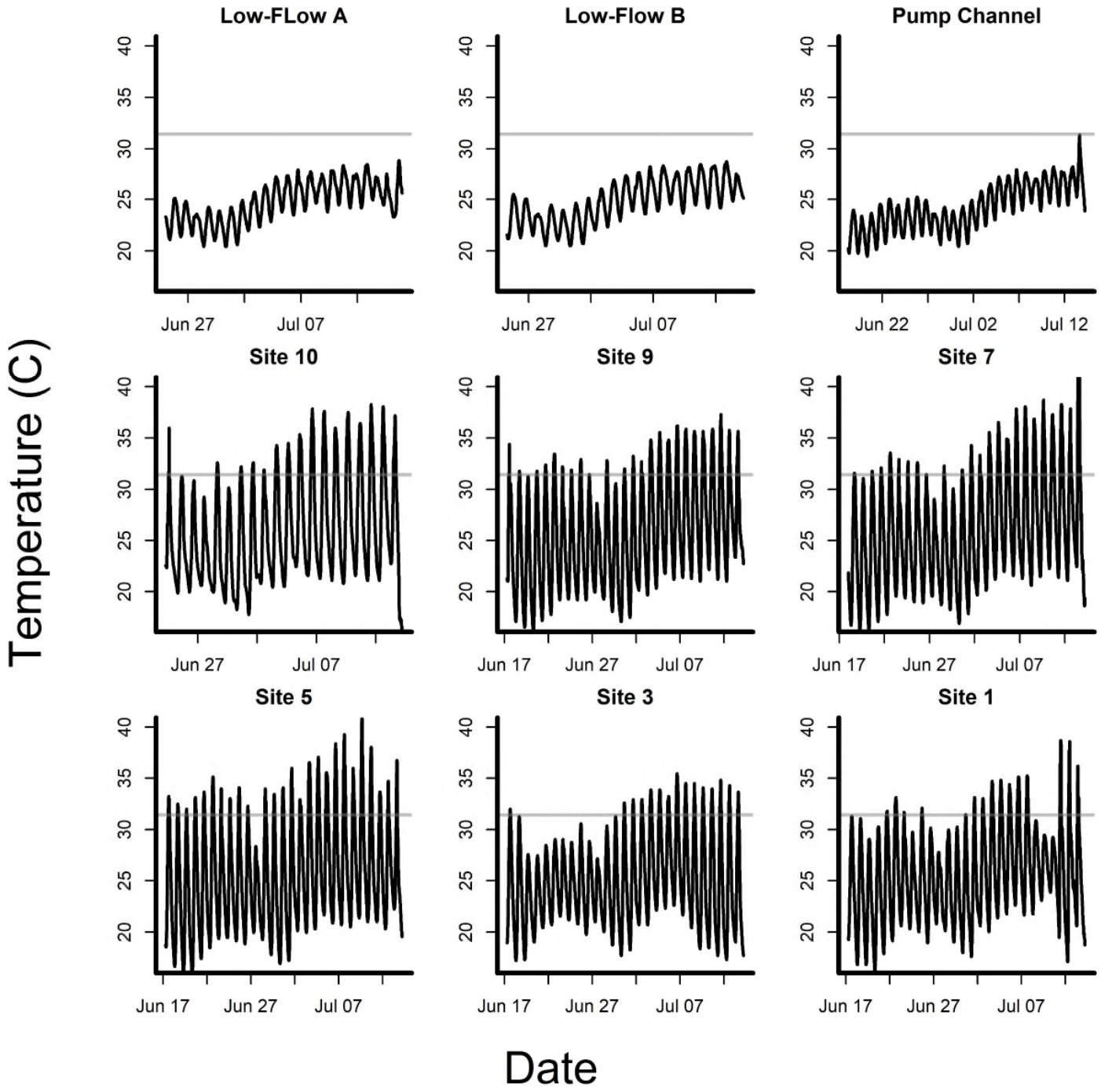
Methods - Fish

- 15-20 hauls per site weekly (799 total)
- Two pre-impact surveys
- Once for each pumping reduction
- This presentation:
  - Number of fish caught ÷ proportion of area sampled = total fish
- Next steps:
  - Mesohabitat specific CPUE x Mesohabitat availability = total fish



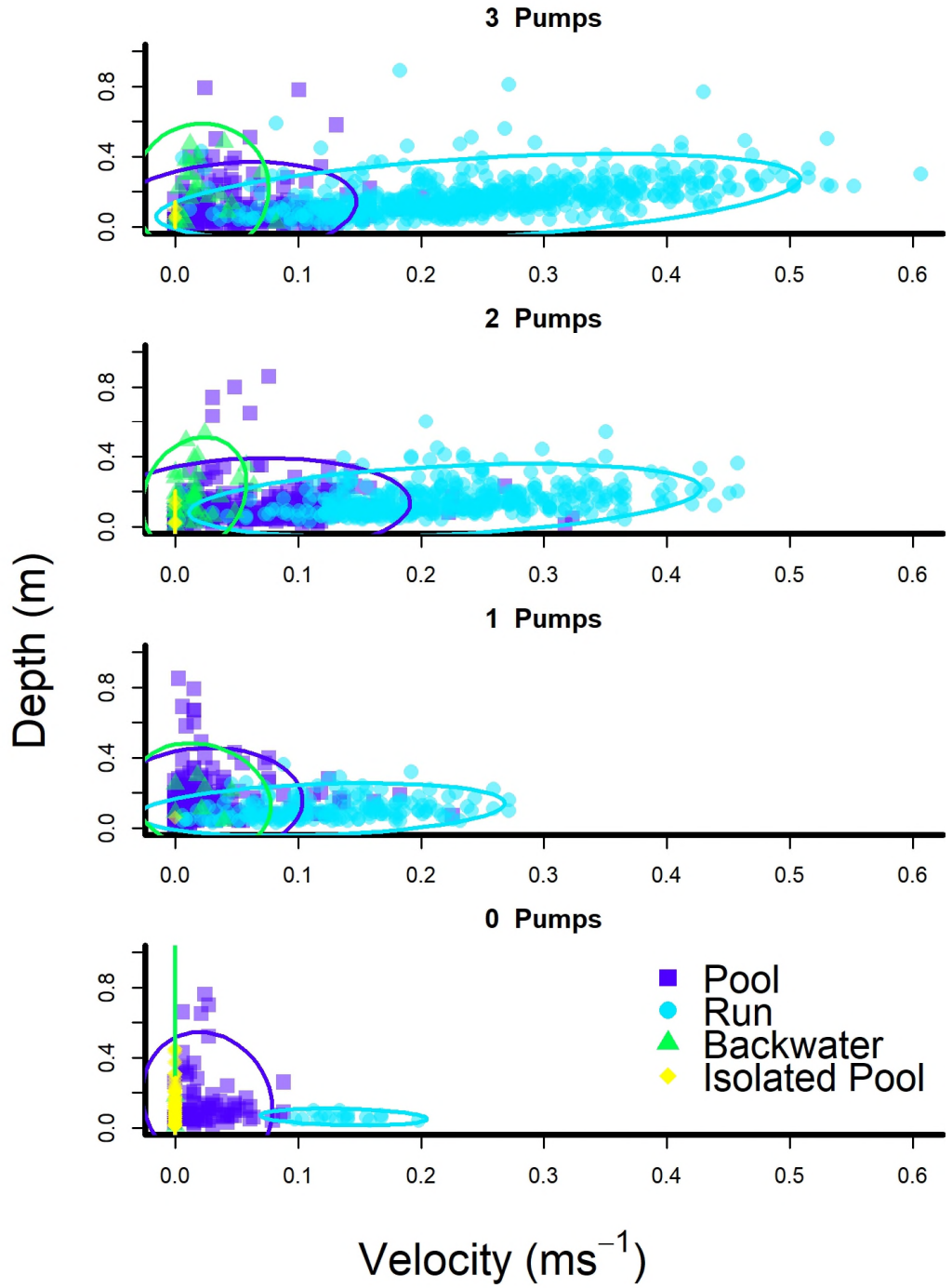
Results - Discharge

- Drying imminent at Sites 4-5
- No pumps running:
  - 2 sites with surface flow
  - 4 sites with isolated pools
  - 4 sites completely dry



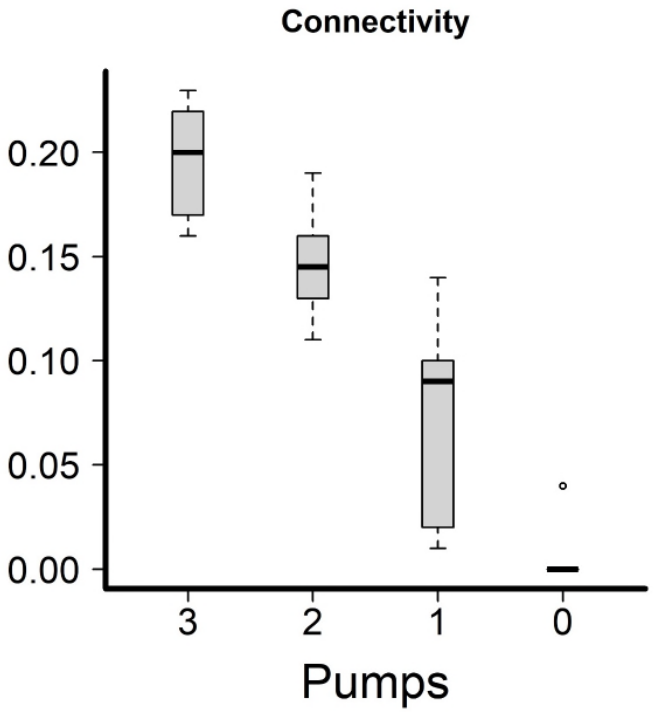
Results - Temperature

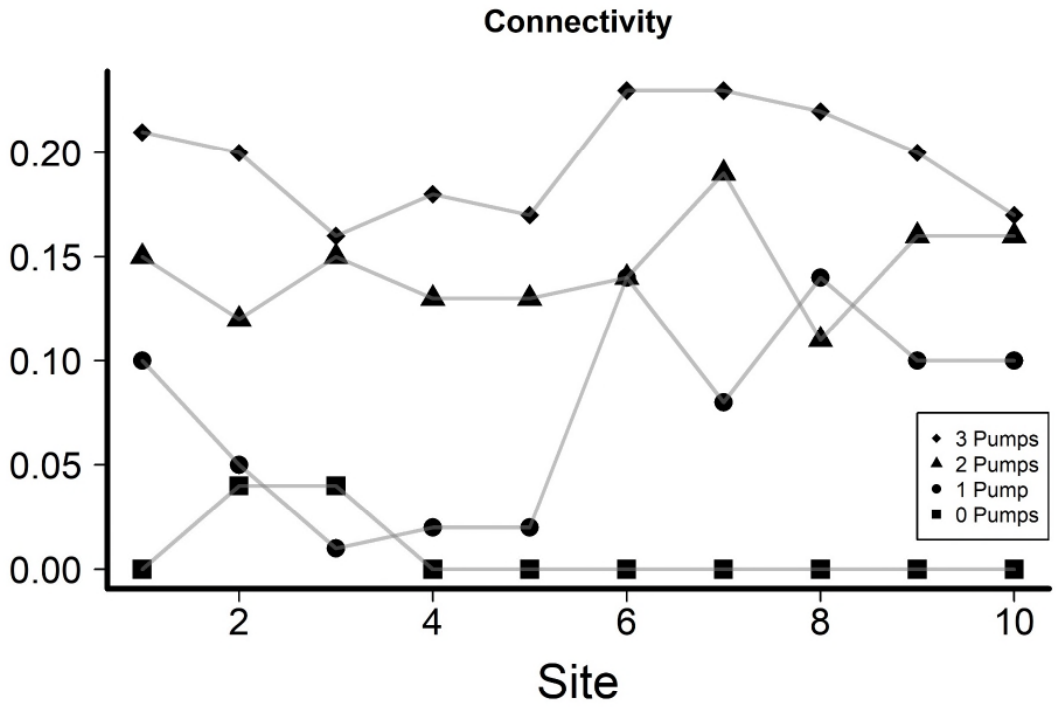
- LFCC thermally buffered
- No buffer 2 miles downstream
- Groundwater buffer at site 3
- Highly variable
- Exceeds 30 °C

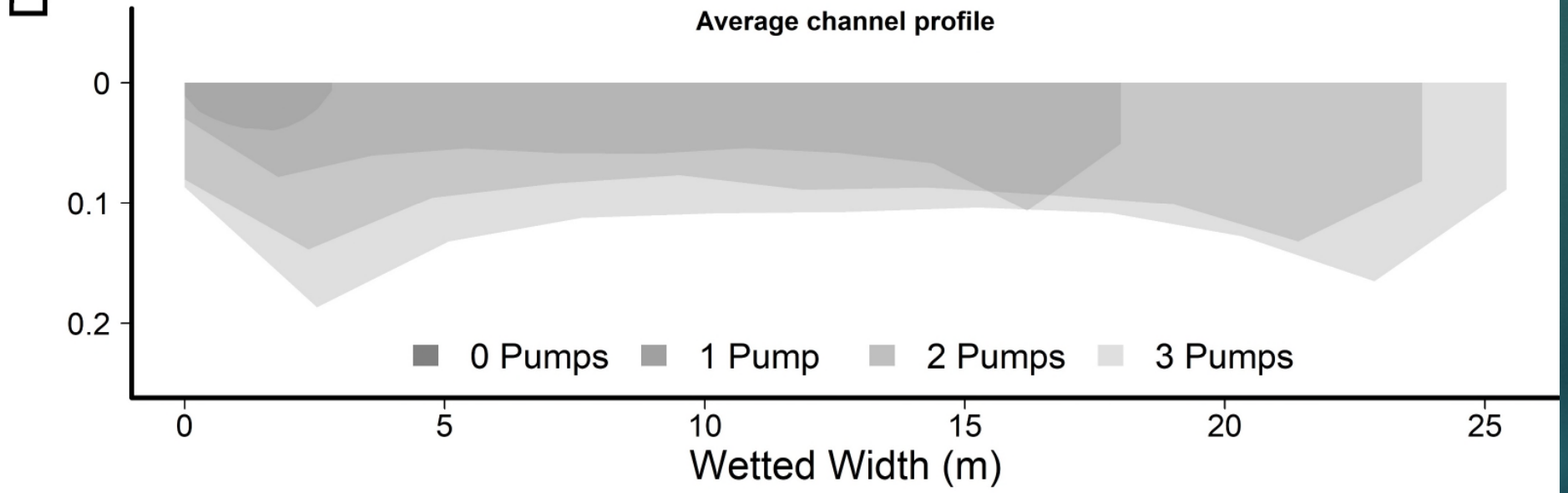


Results - Habitat

- Run habitat lost first
- Pool habitat increases
- All habitats decrease

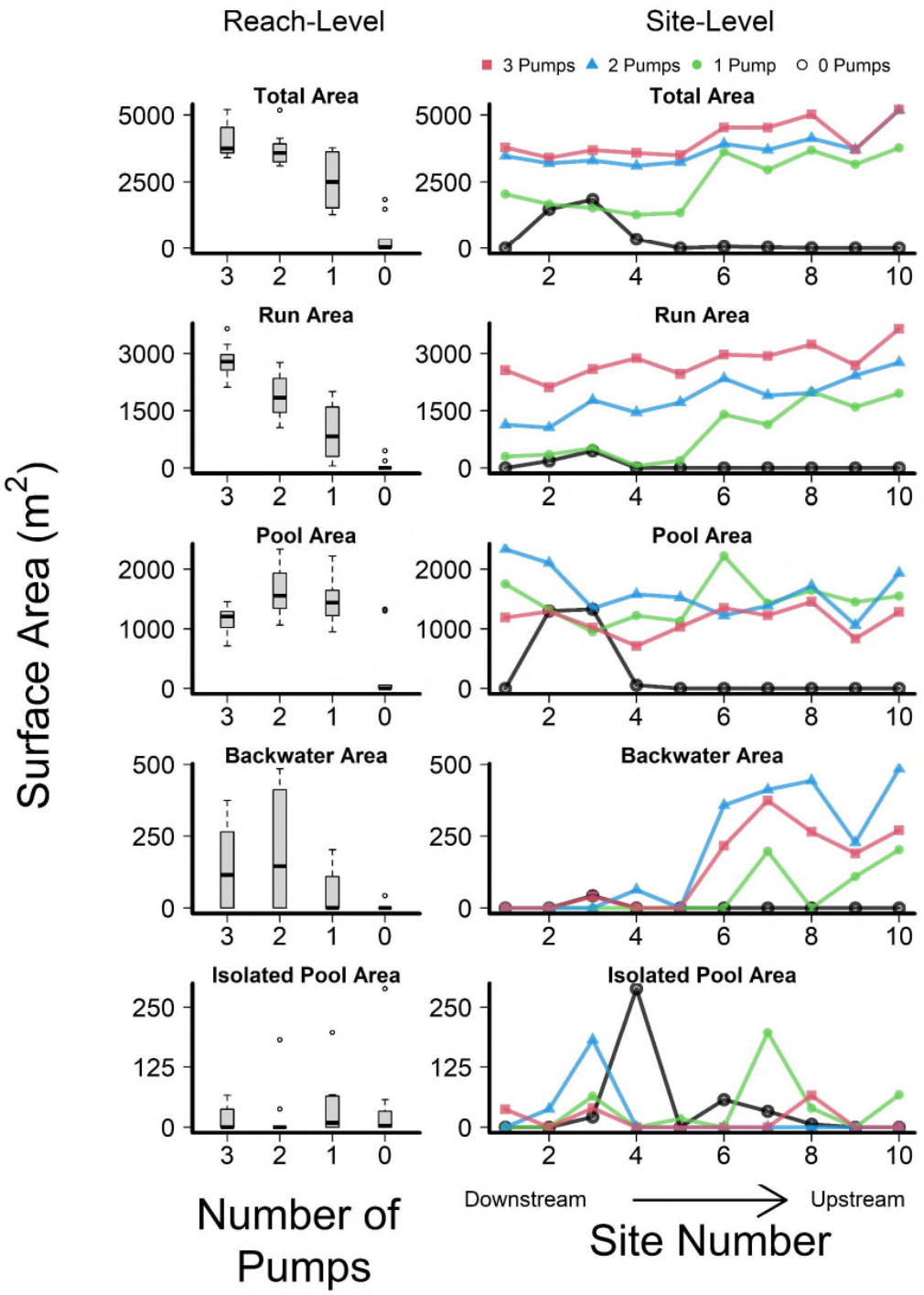






Results - Habitat

- Shallowest transect per site
- Lateral and longitudinal connectivity are reduced
- Behavioral if not physical barriers to fish movement

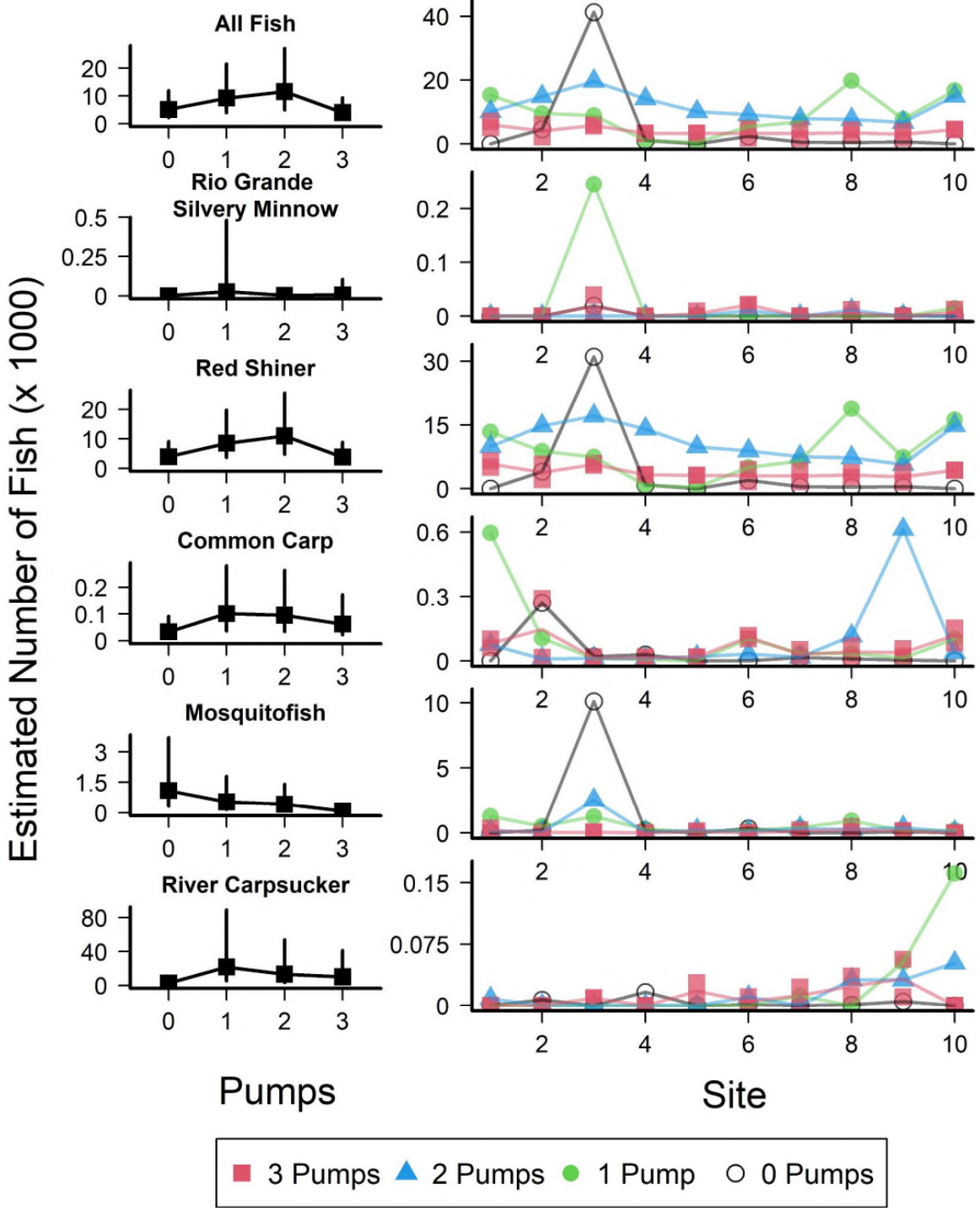


Results - Habitat

- Run habitat decreases
- Pool habitat increases
- All habitats decrease on final pumping reduction

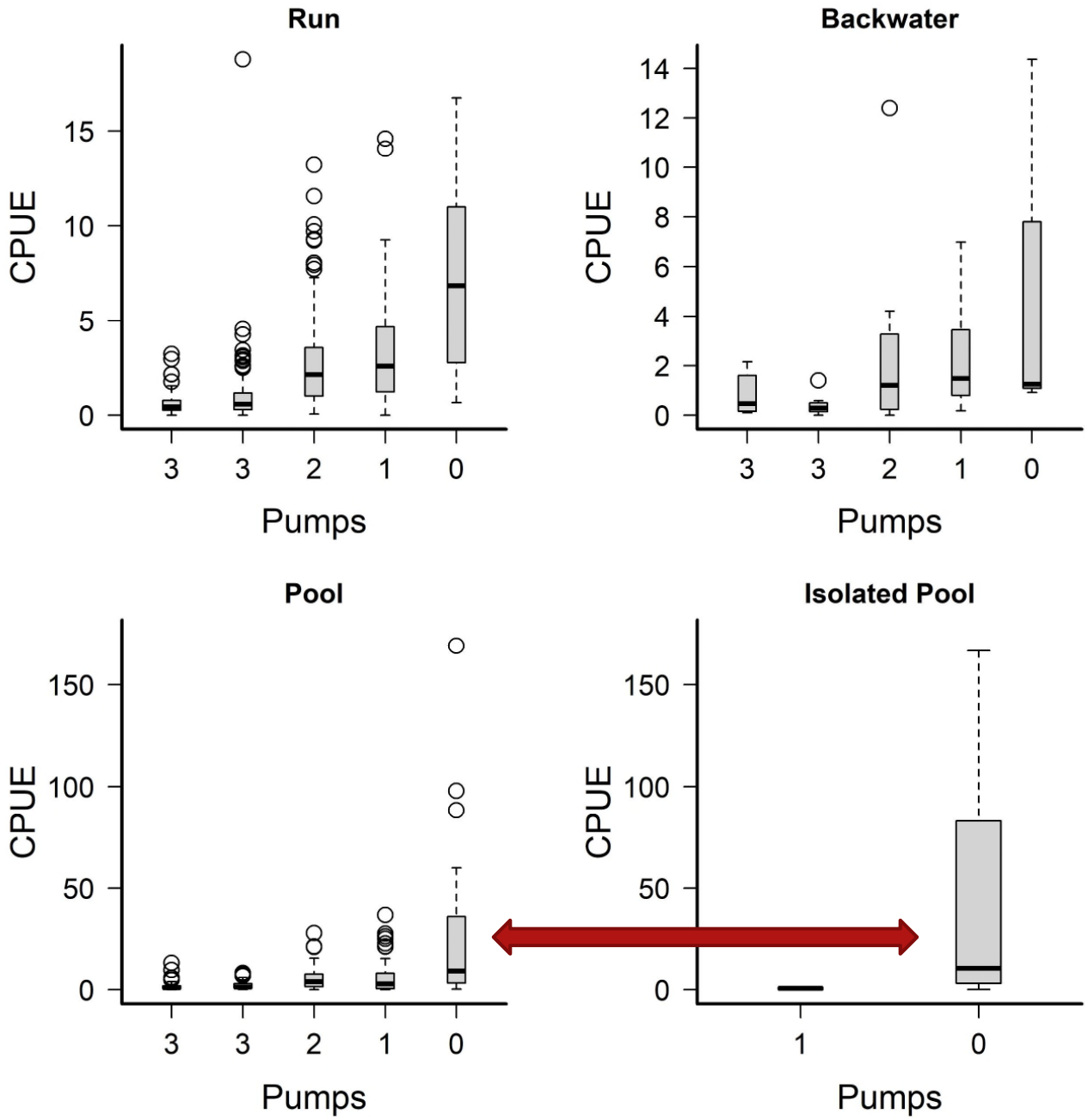
Results - Fish

- 46 surveys (4 sites had no surface water remaining)
- 15 species
- 32,973 individuals
- 30,268 Red Shiner
- 2,050 Western Mosquitofish
- 39 Rio Grande Silvery Minnow (18 in single haul)



Results - Fish

- Some extreme high outliers
- No decreasing densities at sites that dry vs. increase at sites that had surface flow



Results- Fish

- CPUE = Fish per 1 m^2 (individual hauls)
- Increases with reduced flow
- Isolated pools and pools have similar CPUE with no pumps
- Fish are trapped and die

Discussion

- Lateral and longitudinal connectivity decreased
- No evidence of long movements to escape drying
- E.g. fish make small-scale movements to refuge, which then become isolated and they die
  - Isolated pools have tens of thousands of fish
  - Initially better than surrounding landscape, then lower survival
  - Ecological trap[8]

[8]Carson Jeffres & Peter Moyle (2012) When Good Fish Make Bad Decisions: Coho Salmon in an Ecological Trap, North American Journal of Fisheries Management, 32:1, 87-92, DOI: 10.1080/02755947.2012.661389

Discussion – why?

- No real cues
  - WQ similar
  - Low turbidity (not measured) – seeking cover
- Behavioral or physical deterrent to move through shallow water
- Bioenergetics? Fish moving in hot waters?

Conservation implications

- Persistence through drought – historically abundant and widespread, opportunistic life-history,
  - Small, short-lived, fecund, early maturity, vagile, demographic resilience
- Already occur in refuges, able to quickly repopulate
  - Not effective when there are few fish (demographic resilience)
  - Red Shiners vs. Silvery Minnow
    - 30,000 vs 39
    - How to improve Silvery Minnow demographic resilience?

Questions?

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