Instream flow assessment of a groundwater dependent ecosystem in southern Oklahoma.

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Introduction

The availability of high quality water is critical to both humans and ecosystems (Postel and Richter 2003). There is increasing pressure to transfer groundwater from the Arbuckle-Simpson aquifer, a sensitive sole-source aquifer in south-central Oklahoma, to central Oklahoma. Concerned citizens and municipalities living on and getting their drinking water from the Arbuckle-Simpson are concerned about this water supply, and a temporary moratorium on groundwater transfer was granted by the state legislature to allow for a comprehensive study of the aquifer and its link to surface waters. Spring habitats are ecologically unique compared to other river habitats because they have relatively constant flow and temperature, small and isolated habitat patches, and a general lack of predators (Glazier 1991).

Objectives

- Use the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation System (PHABSIM; Bovee 1982) to assess instream flow requirements of selected cyprinids and percids in the Blue River and Pennington Creek.
- Provide information to the Oklahoma Water Resource Board (OWRB) to assess impacts of groundwater withdrawal on fish habitat in streams of the Arbuckle-Simpson (OWRB 2003).
- Improve our understanding of the requirements and habitat use by spring dependent fish species in groundwater dependent ecosystems in Oklahoma.

Materials and Methods

Study Sites

- 2 small spring-fed streams and 1 larger spring stream (Fig. 1).

Methods

- 99 transects in all three sites surveyed for:
  - Channel elevation
  - Water surface elevation (Fig. 2)
  - Discharge
- Habitat suitability criteria (HSC)
  - Underwater observations by snorkelers
  - Depth, velocity, substrate, and cover recorded at each site occupied
  - Nonparametric confidence limits
- Simulations of flow (PHABSIM)
  - Focused on declines in discharge
- Water temperature (Fig. 3)

Target Species

Southern redbelly dace *Phoxinus erthyrogaster*

Redspot chub *Nocomis asper*

Least darter *Etheostoma microperca*

Orangethroat darter *E. spectabile*

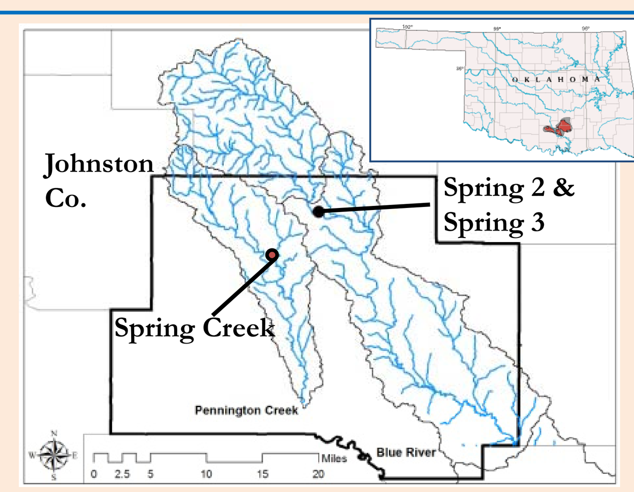


Figure 1: Location of study sites in Blue River and Pennington Creek watersheds.

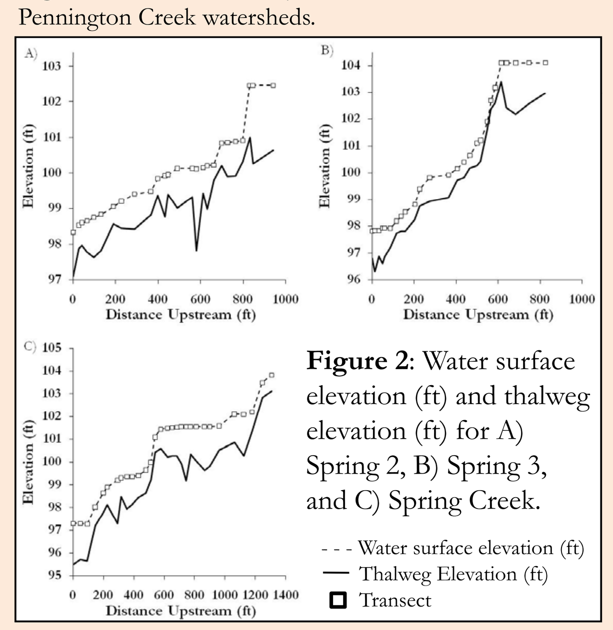


Figure 2: Water surface elevation (ft) and thalweg elevation (ft) for A) Spring 2, B) Spring 3, and C) Spring Creek.

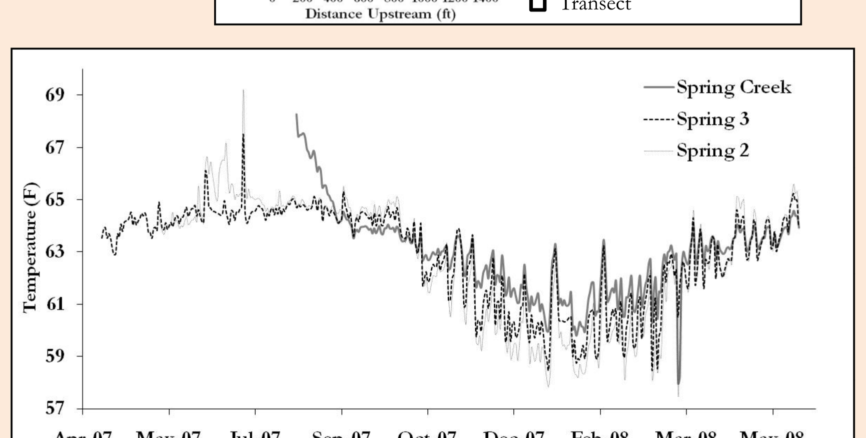
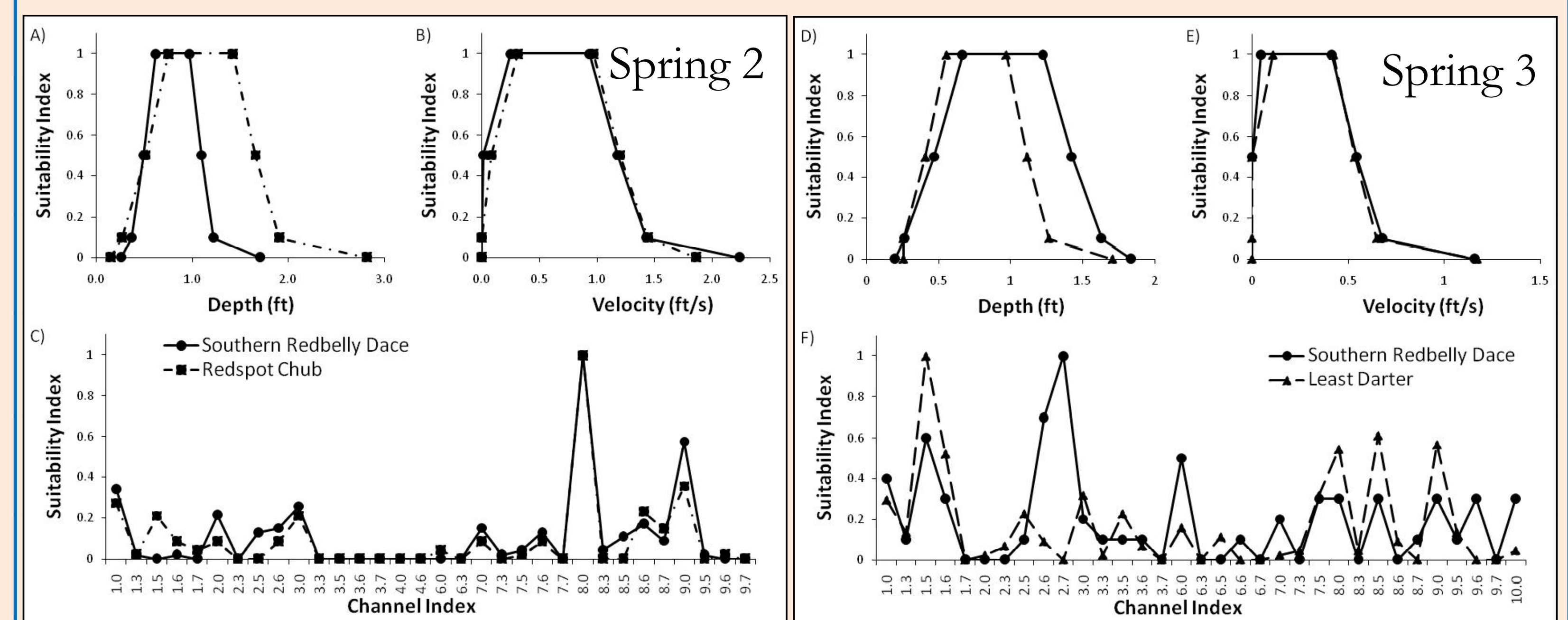


Figure 3: Daily mean water temperature (F) measured from April 2007 to May 2008.

Results

Habitat suitability criteria

Figure 4: Depth, velocity, and channel index suitability for target species in: A-C) Spring 2, D-F) Spring 3, and G-I) Spring Creek.

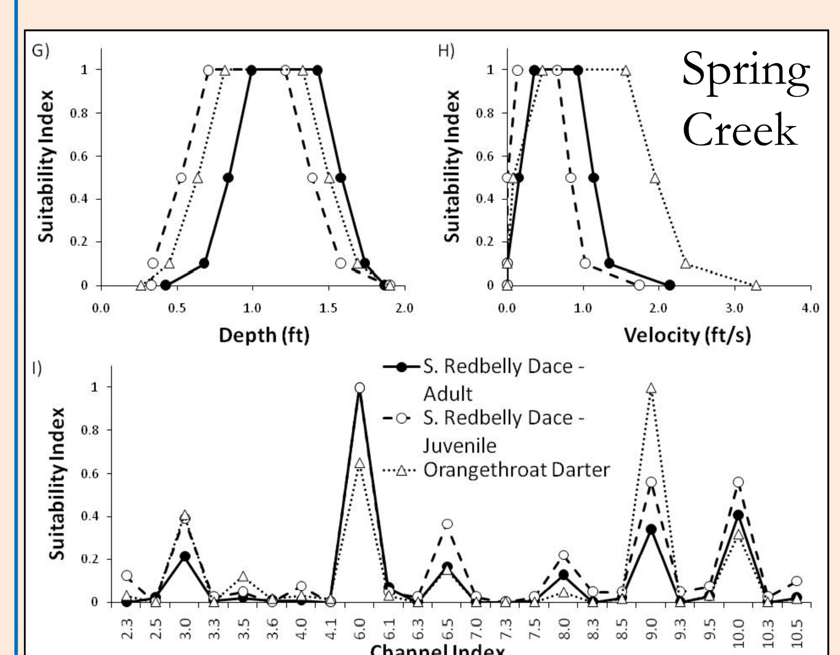


Spring 2

- Depth: Redbelly dace < Redspot chub (Fig. 4a).
- Velocity: Low velocity habitats (Fig 4b).
- Substrate/Cover: Sand/gravel or gravel/cobble and no cover (Fig. 4c).

Spring 3

- Depth: Redbelly dace > Least darter (Fig. 4d).
- Velocity: Low velocity habitats (Fig. 4e).
- Substrate/Cover: Redbelly dace = gravel with banks or woody debris; Least darters = silt substrate and submergent vegetation (Fig. 4f).



Spring Creek

- Depth: Adult redbelly dace (pools) > Orangethroat darter (pools and riffles) > Juvenile redbelly dace type); Orangethroat darters = gravel/cobble (Fig. 4g).
- Velocity: Orangethroat darter > Adult redbelly dace > Juvenile redbelly dace (Fig. 4h).
- Substrate/Cover: Adult and Juvenile redbelly dace = bedrock with no cover (most common channel index type); Orangethroat darters = gravel/cobble (Fig. 4i).

Channel Index

SUB: 1 silt, 2 sand, 3 gravel, 4 cobble, 5 boulder, 6 bedrock.

COV: 0.1 rock, 0.3 emergent plants, 0.4 floating plants, 0.5 submerged plants, 0.6 woody debris, 0.7 bank.

Weighted Usable Area and Discharge

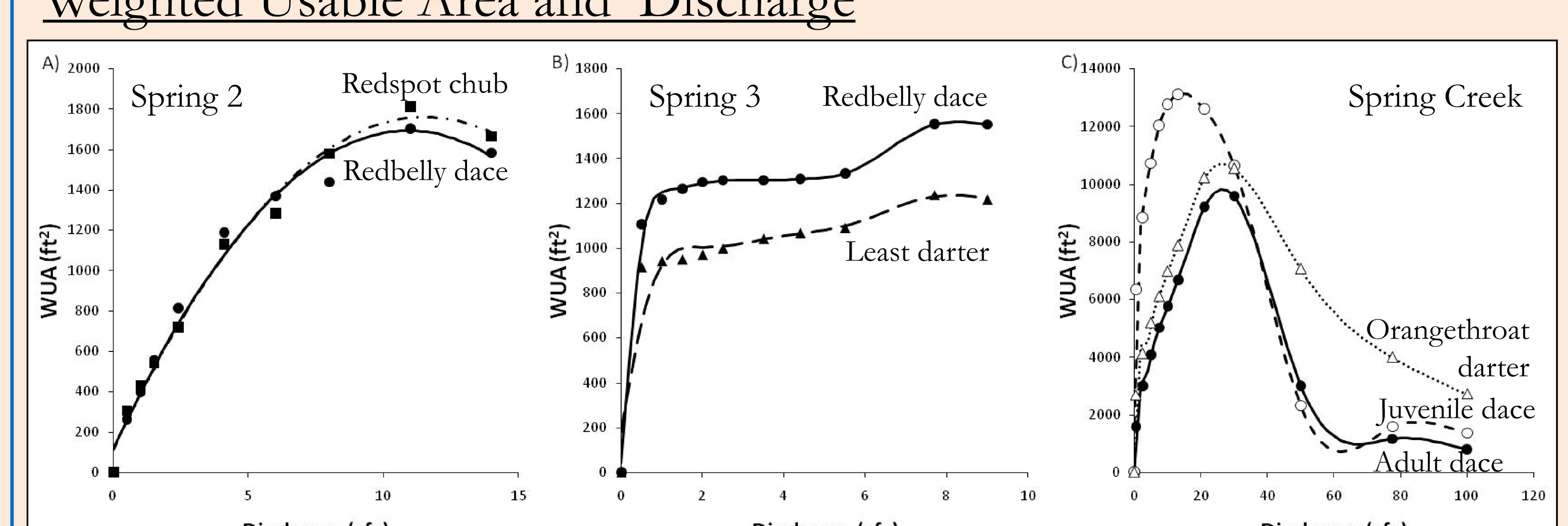


Figure 5: Discharge and Weighted Usable Area (WUA) relationship for target species in: A) Spring 2, B) Spring 3, and C) Spring Creek.

- **Spring 2:** Max WUA at 11 cfs (quadratic regression, redbelly dace: R^2 = 0.98, P<0.01 and redspot chub: R^2 = 0.99, P<0.01; Fig. 5a).
- **Spring 3:** Max WUA at 8.5 cfs (spline regression, redbelly dace: R^2 = 0.99 and least darter: R^2 = 0.91; Fig. 5b)
- **Spring Creek:** Max WUA for juvenile dace at 19 cfs and for adult dace and orangethroat darter at 30 cfs (spline regression, adult redbelly dace: R^2 = 0.99, juvenile redbelly dace: R^2 = 0.97, and orangethroat darter: R^2 = 0.99; Fig. 5c)

Snorkeler collecting fish habitat use data in Spring 2

Alternatives Analysis

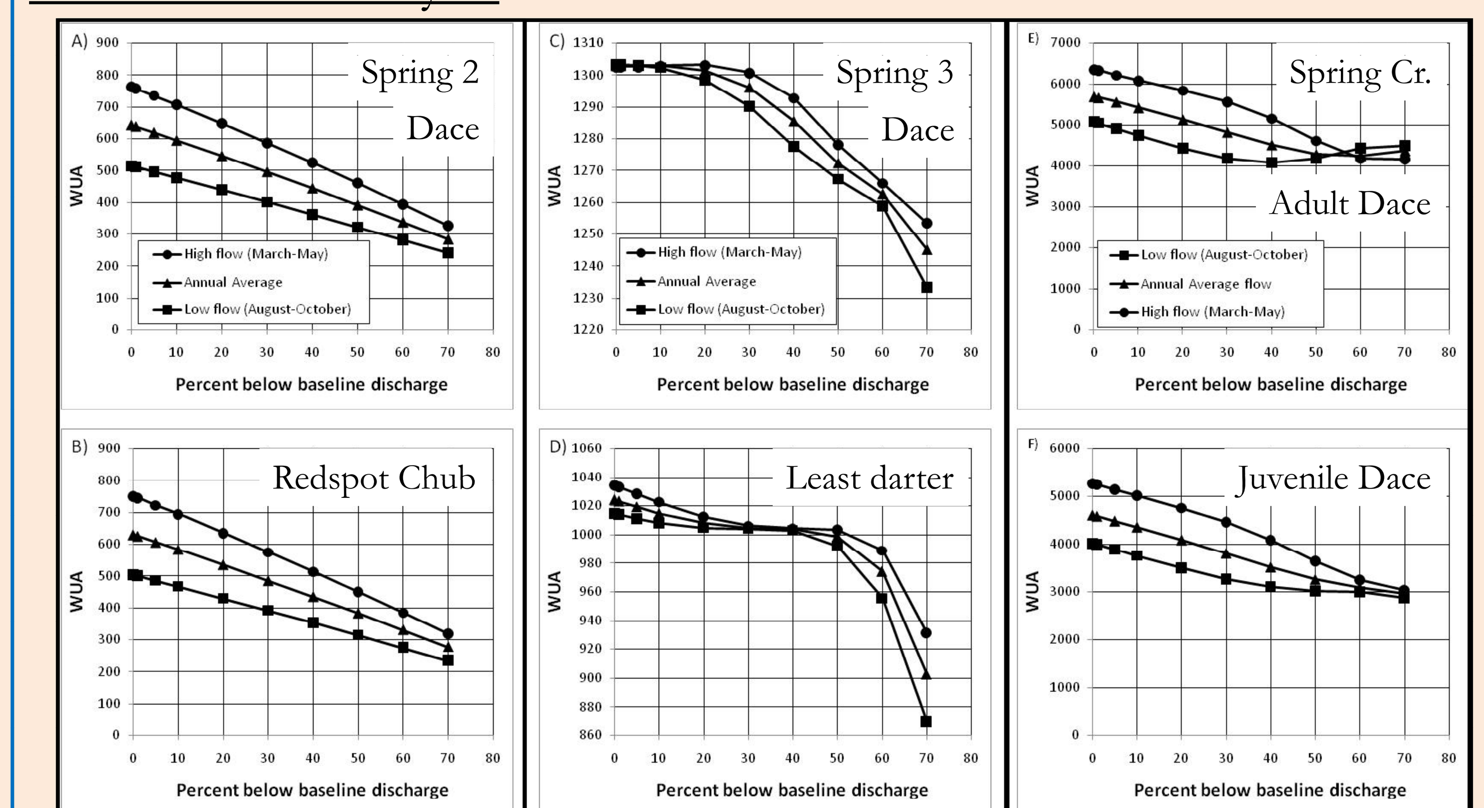
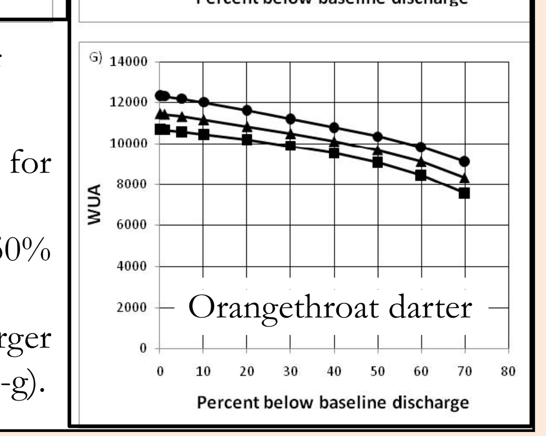


Figure 6: Change in WUA with different reductions in baseline flow for average annual flow, high flow (spring), and low flow (late summer).



- **Spring 2:** steady decline in WUA with reduced flows for redbelly dace and redspot chub in Spring 2 (Figure 6a-b).
- **Spring 3:** abrupt decline in WUA with reduced flows >50% for redbelly dace and least darter (Figure 6c-d).
- **Spring Creek:** small WUA reduction at 1-30% and larger WUA reductions at 40-70% with reduced flows (Figure 6e-g).

Conclusions

- Localized groundwater removal may have adverse impacts on fish habitat.
- Reductions in streamflow would reduce habitat:
  - Overall, as much as 58% redbelly dace and redspot chub, 14% least darter, 35% orangethroat darter.
  - In small spring-runs, a reduction of baseline flow from 10 to 20% will result in modest reductions in WUA (8-15%).
  - In larger streams, slightly larger reductions in flow of 20 to 30% will result in a similar degree of WUA reduction (11-17%).
- Usable habitat in the mainstem Blue River adjacent to Springs 2 and 3 would occur at lower streamflows, which could serve as a potential refuge habitat.
- Water allocation in the Arbuckle-Simpson aquifer could provide an opportunity to use adaptive management during groundwater removal to ensure minimal impact on spring habitat and fishes.

For more information

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