# Potential climate impacts on water resources and ecosystems in the Red River

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Red River. Photo credit: Henley Quadling

# Thank you!

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Red River. Photo credit: Henley Quadling

# What might happen if streams get hotter and drier?

"If warming 3-4$^{0}$C occurs, a substantial number of species in this region could face extinction" Matthews and Zimmerman 1990

Dewatering and fragmentation interact as stressor for Great Plains fish communities – Perkin et al. 2015

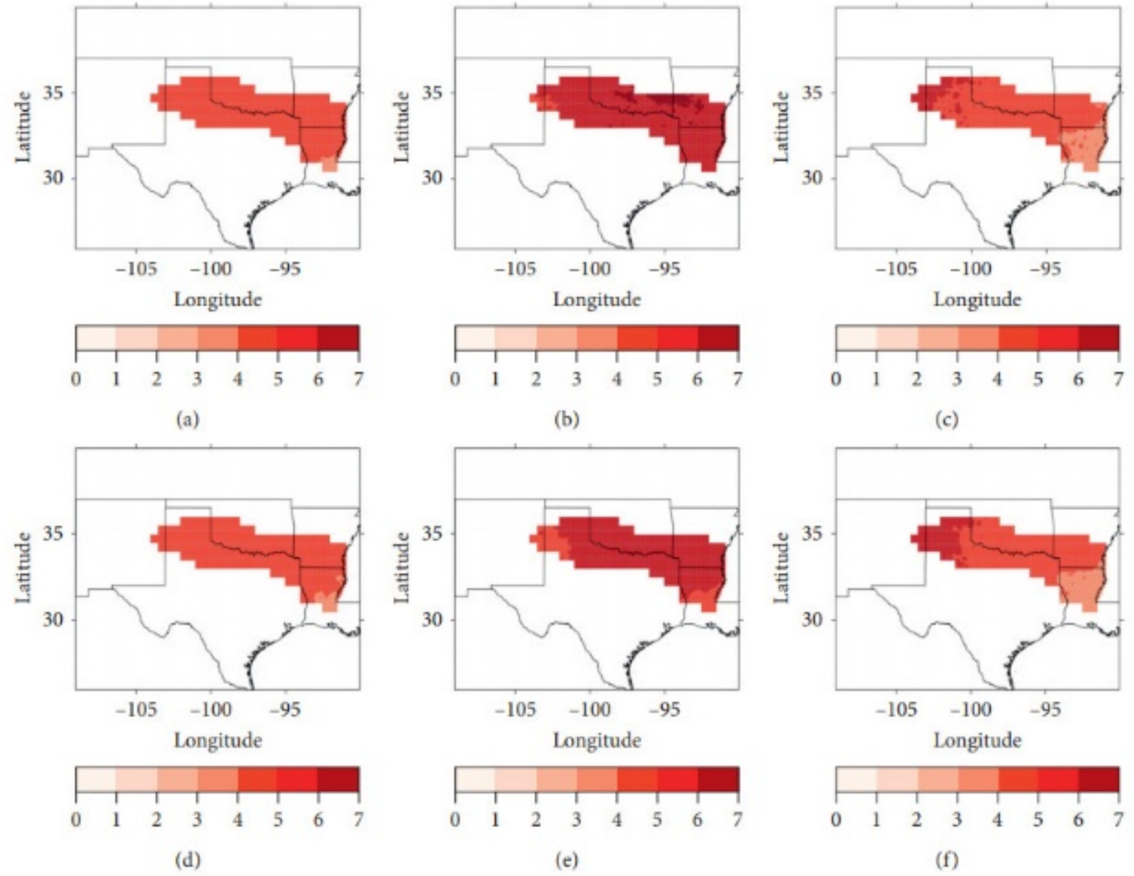



FIGURE 5: Difference fields for mean daily minimum temperature (°C) between historical (1981–2005) and end-of-century (2075–2099) time frames for RCP 8.5. Columns represent the GCMs (CCSM4, MIROC5, and MPI-ESM-LR, from left to right respectively); rows represent downscaling methods, with CDFt on top and EDQM on bottom. Darker shades of red represent higher minimum temperature values. (a) Model: CCSM4, SD: CDFt. (b) Model: MIROC5, SD: CDFt. (c) Model: MPI-ESM-LR, SD: CDFt. (d) Model: CCSM4, SD: EDQM. (e) Model: MIROC5, SD: EDQM. (f) Model: MPI-ESM-LR, SD: EDQM.

Bertand and McPherson (2019) Advances in Meteorology

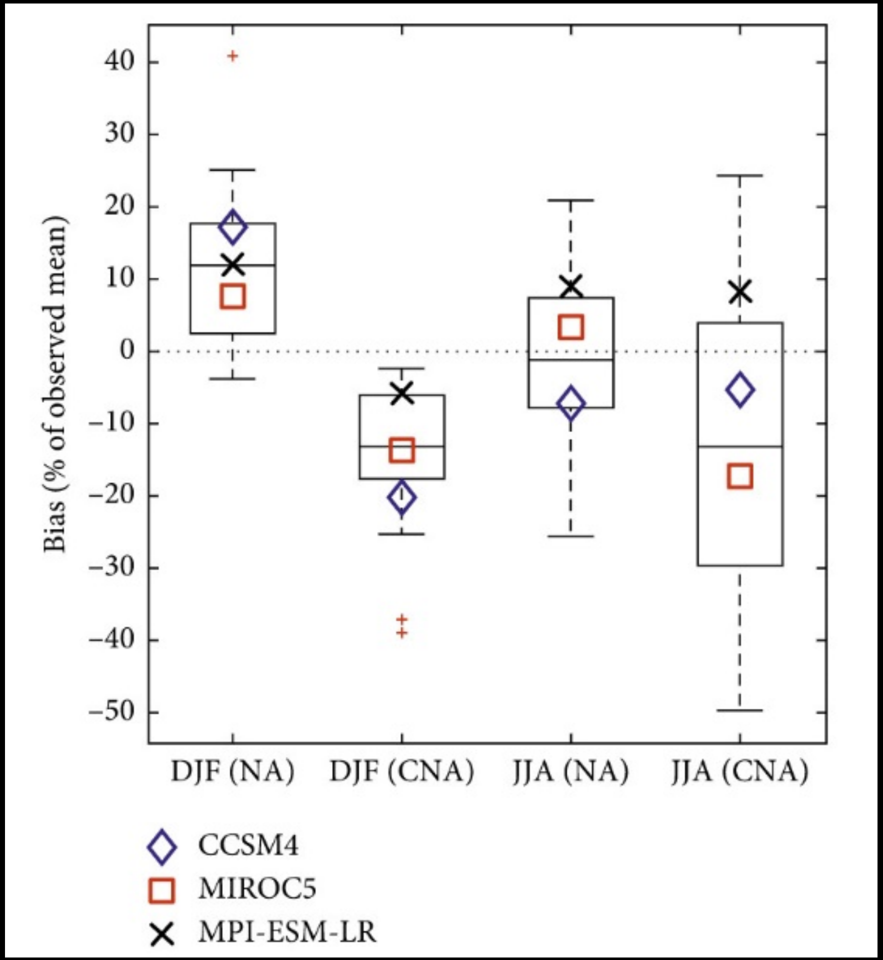
# Here, we focus on two questions:

1) How might water resources and the distributions of stream fish in the Red River change in future climate scenarios?
    - Zamani Sabzi et al. (2019) J. Hydrology – Regional Studies
    - Gill et al. *in review*

2) How might we mitigate these impacts?
    - Zamani Zabzi et al. (2019) Ecological Engineering
    - Fovargue et al. *in review*
    - Wineland et al. *in review*

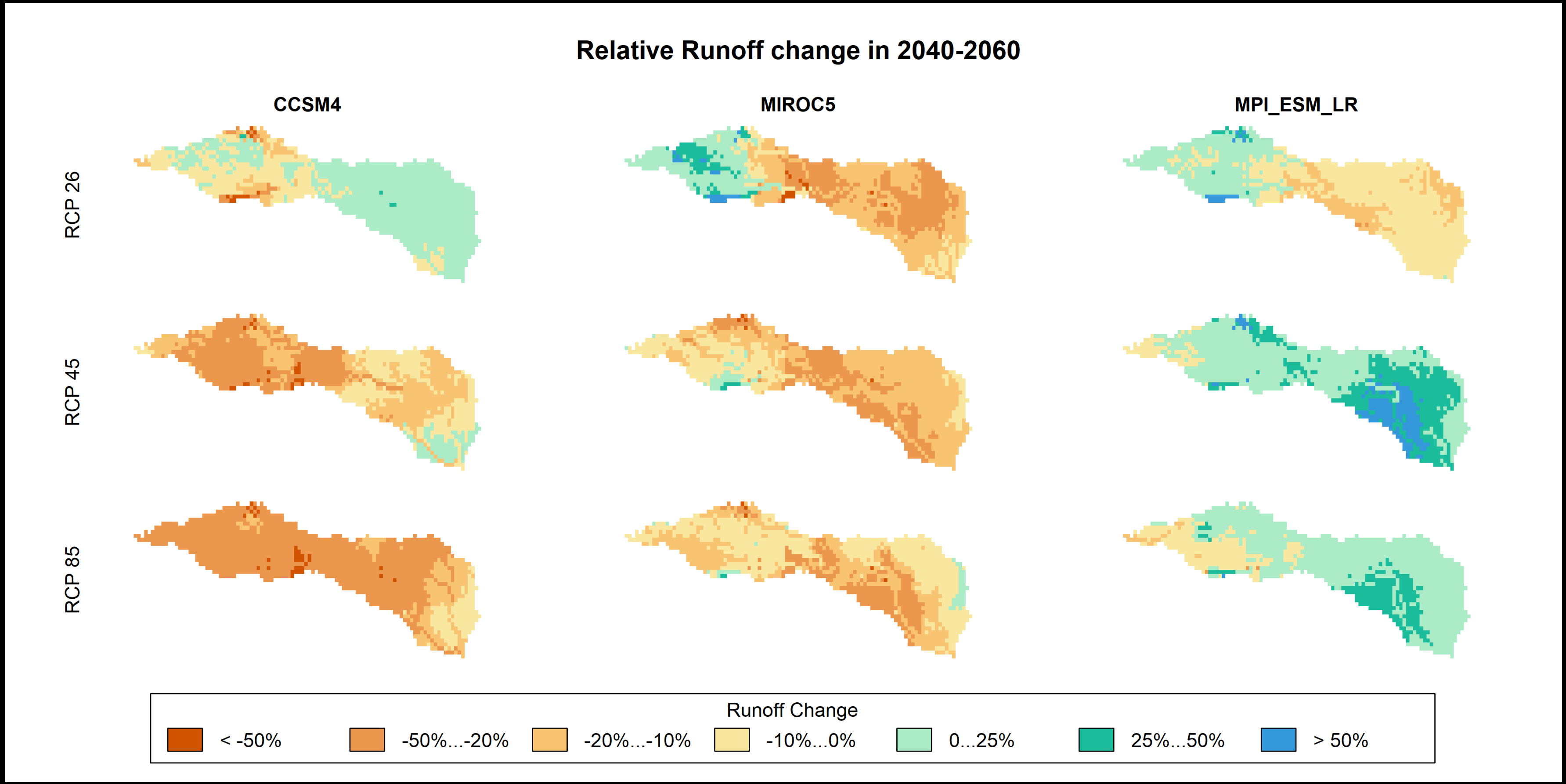
We build on regional climate downscaling (McPherson et al. 2016, Betrand and McPherson 2018, 2019) and hydrological modeling (Xue et al. 2016) for the Red River across climate scenarios.

We focus on three GCMs (CCSM4, MIROC5, MPI-ESM-LR) that span a range of wet/dry bias among climate models.




McPherson et al. (2016) SC-CASC final project report
Xue et al. (2016) J. Hydrologic Engineering
Bertrand and McPherson (2018) J. Applied Meteorology and Climatology
Bertrand and McPherson (2019) Advances in Meteorology

Projected surface water varies among climate scenarios, and spatially within each scenario.




Percent change in surface runoff (2040-2060 vs. recent historical) across nine climate scenarios.

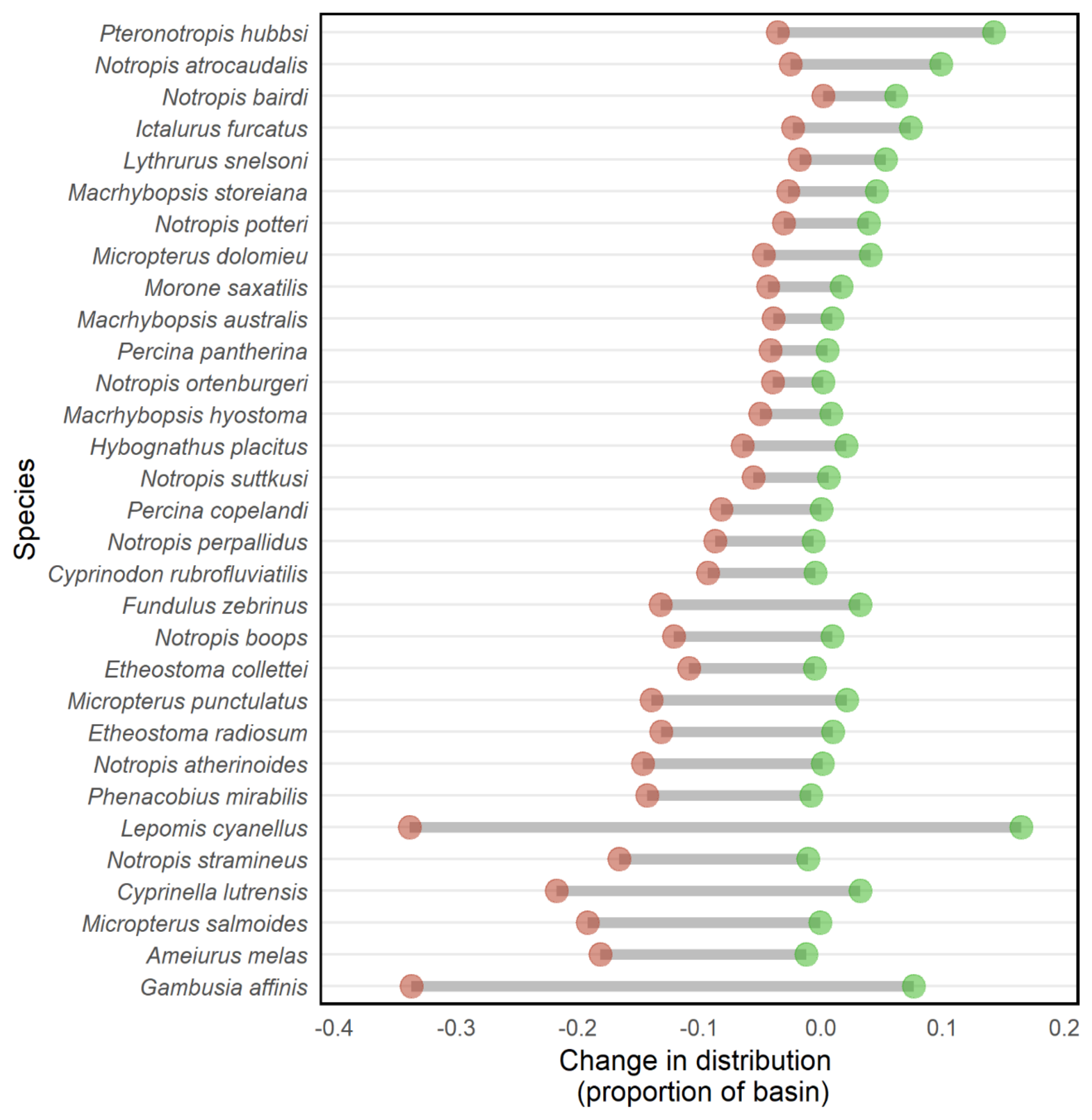
Zamani Sabzi et al. (2019) Journal of Hydrology – Regional Studies

## How might species' distributions change across climate scenarios?

Gill et al. used a suite of climatic and biophysical covariates to drive MaxEnt species distribution models.

## Key results:

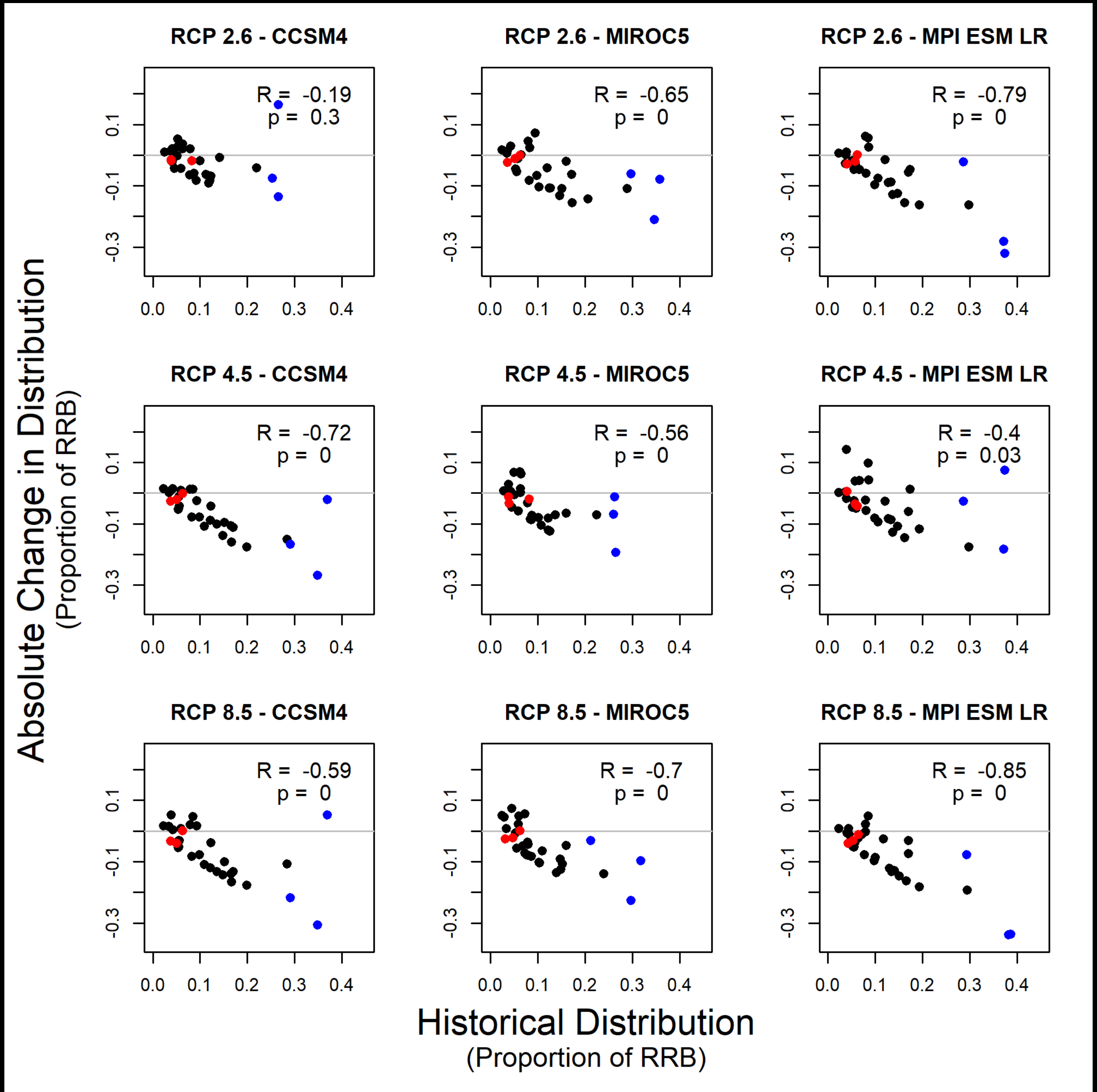
- Changes in distribution for each species (historical vs. 2050) vary among climate scenarios.
- Uncertainty varies ~10x among species.




Gill et al. *in review*

Common species (i.e., historically widespread) show the greatest absolute changes in distribution across future climate scenarios.

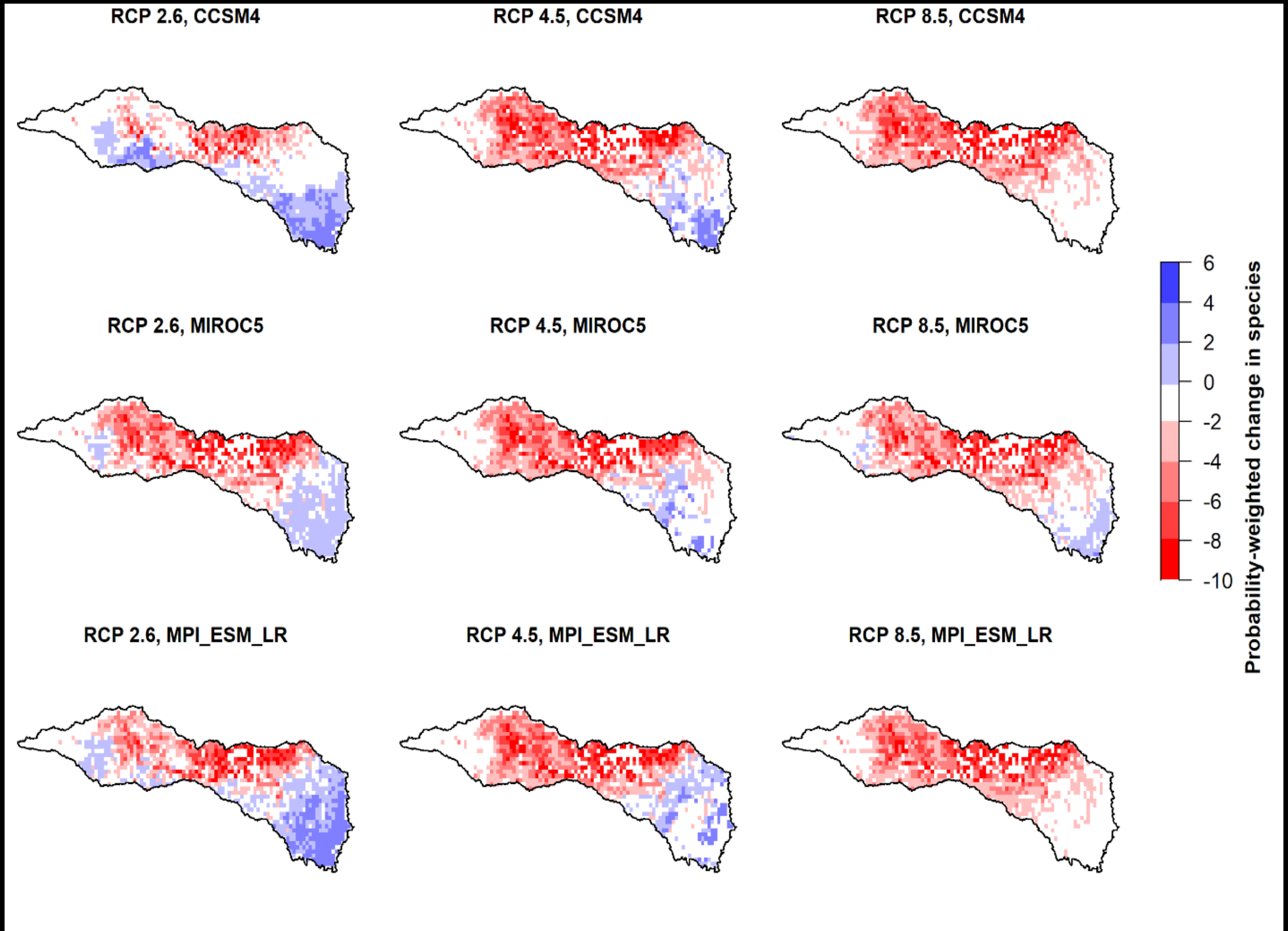
However, we could not reject a null hypothesis that absolute changes were proportional to historical distributional extent.




Gill et al. *in review*

Aggregating species outcomes within each climate scenario reveals hotspots of potential species loss.

Despite climate uncertainty, hotspots of species loss tend to occur in same regions.

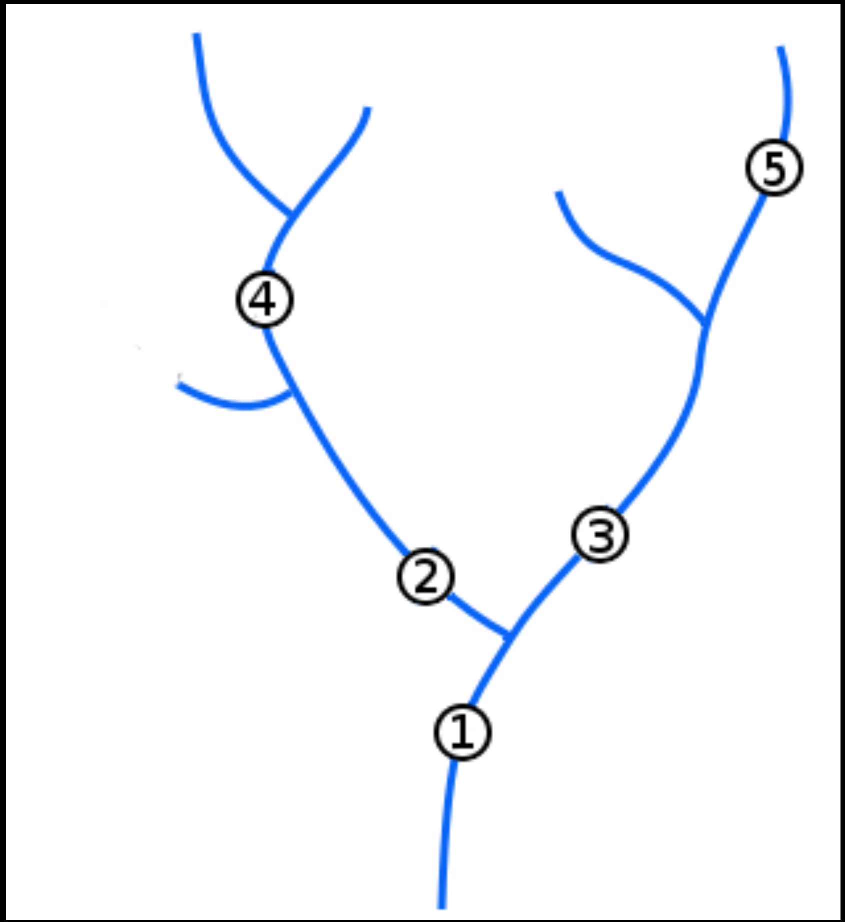



Expected change in the number of species within the Red River basin by the year 2050 across nine future climate scenarios, as projected by MaxEnt. The value for each raster 1/8$^0$ cell represents the difference in species' probability of occurrence between the historical period and the year 2050, summed across all species. Gill et al. *in review*

## Spatial Planning Tools for Water Conservation

Consider five water users on simple river network. When and where might we incentive users to consume less water? Downstream reaches differ in societal water needs and environmental water needs, and actions propagate downstream.

**Goal:** For a given budget, find the optimal reservoir releases and portfolio of water conservation projects that best balance societal and environmental water needs.

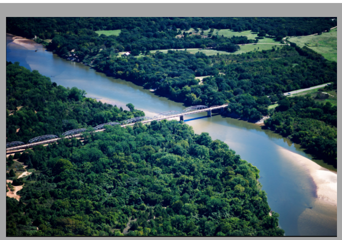



Zamani Sabzi et al. (2019) Ecological Engineering

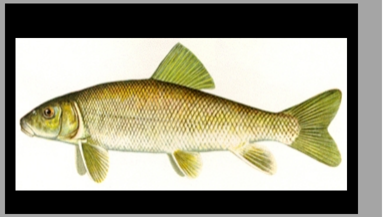
# Spatial planning tools for water sustainability in the Red River

**Water rights & usage**


**Hydrologic Data & models**



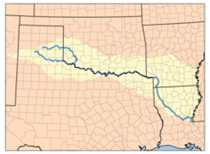
**Ecological weightings**



**Optimization model**

$$\max z = \sum_{j \in J} \sum_{g \in G} v_{jg} \alpha_{jg}$$

**Decision support**



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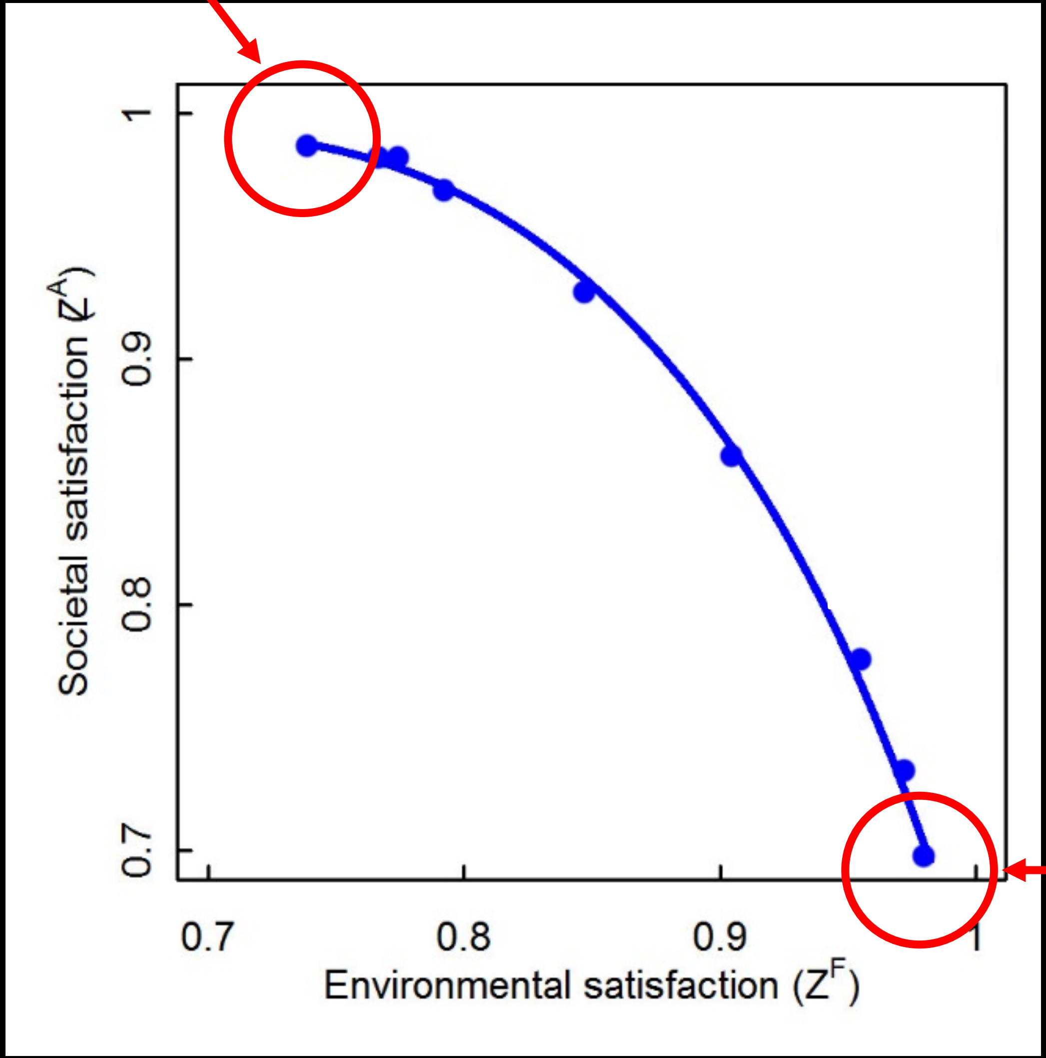
Prioritize societal water goals



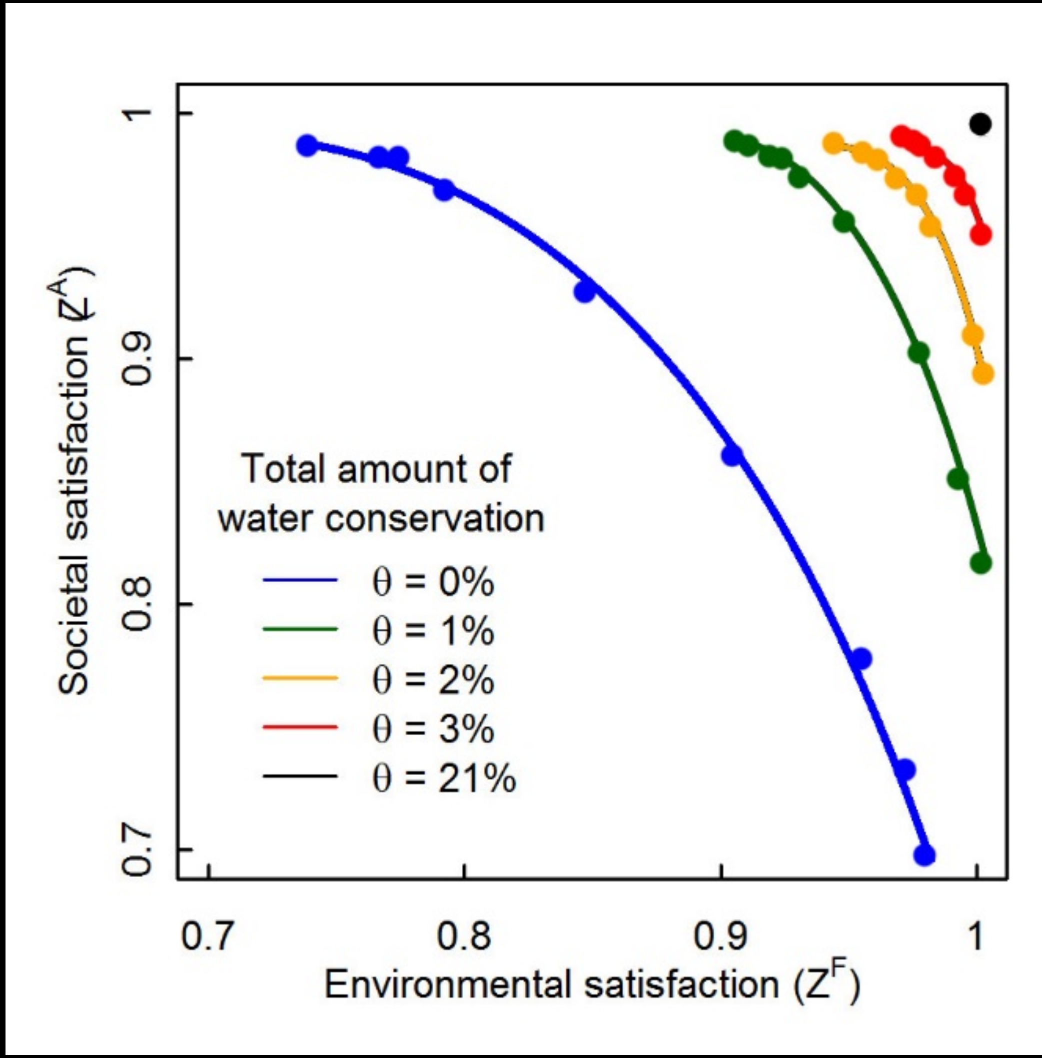

Prioritize environmental water goals

Zamani Sabzi et al. (2019) Ecological Engineering

1) By manipulating the weights (relative importance) of meeting societal vs. environmental water needs, we can find a tradeoff curve.

2) Even optimal allocation of water across network cannot simultaneously meet societal and ecosystem flow goals

# Results – Tradeoffs Under Conservation




Zamani Sabzi et al. (2019) Ecological Engineering

1) Small changes in water consumption (< 3%) can have big impacts.

2) Diminishing returns on water conservation: very large reductions in societal consumption might be needed to fully satisfy both goals. Feasibility?

# How might these tradeoffs shift under future climates?

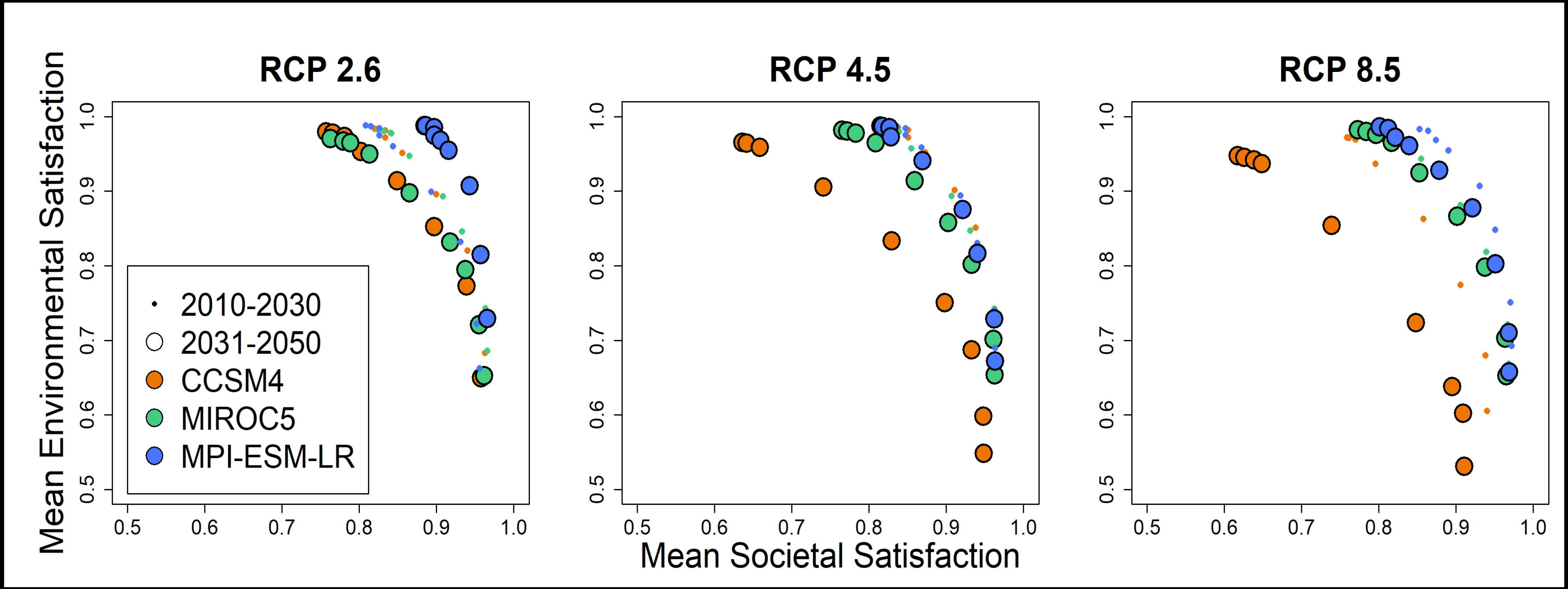



**Figure 2.** Optimal trade-off curves balancing RRB-wide satisfaction of societal and environmental water targets. Trade-off curves are calculated for two time periods – early century (2010-2030; small circles) and near future (2031-2050; large circles).

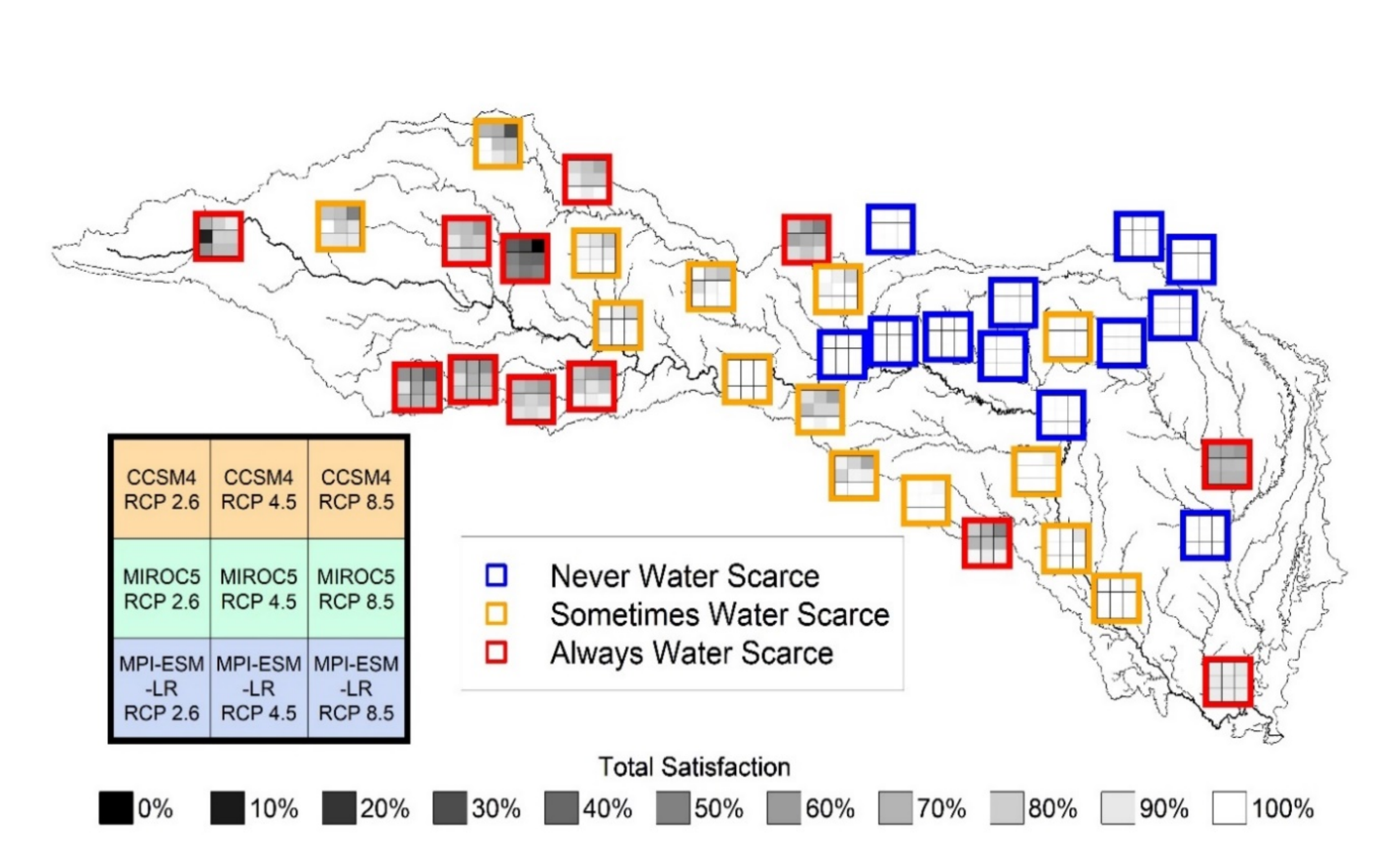
Fovargue et al. *in review*

# Planning for water sustainability under uncertainty

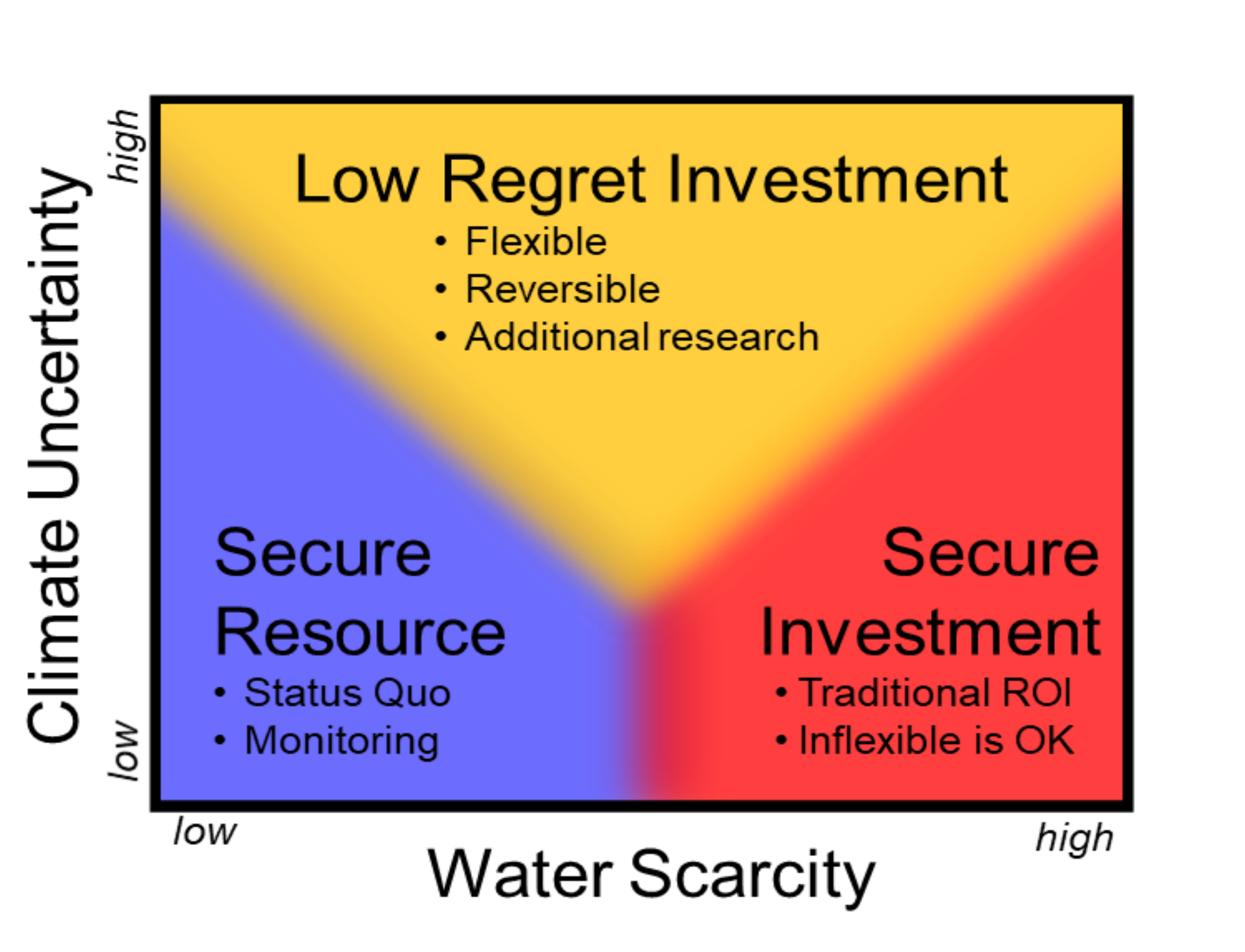
Water availability varies among climate scenarios. Can we identify locations where we are fairly certain of water scarcity, despite climate uncertainty?

Figure gives satisfaction of societal and environmental flow goals assuming basin-wide optimal reservoir management.

Fovargue et al. *in review*



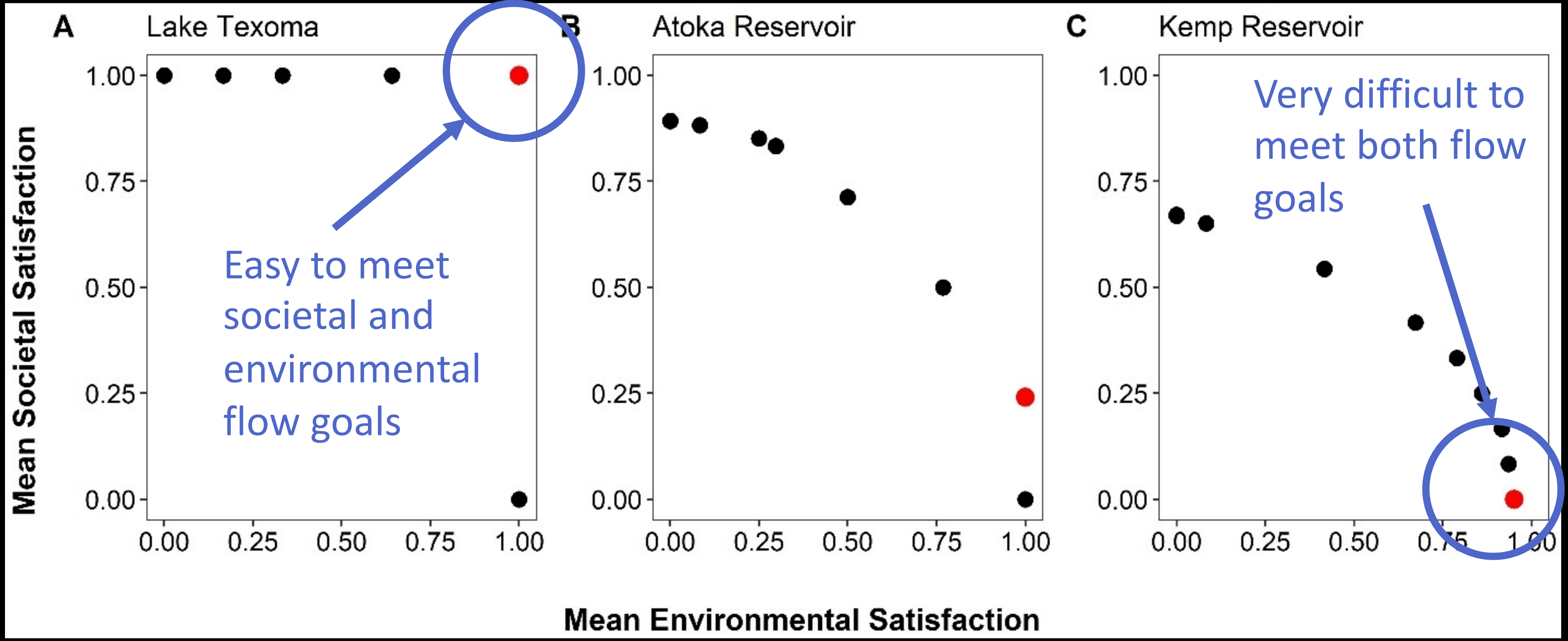
# Planning for water sustainability under climate uncertainty




Fovargue et al. *in review*

Can joint consideration of water scarcity and climate uncertainty guide investments in water sustainability?

# How feasible might it be to meet environmental flow targets below each reservoir?

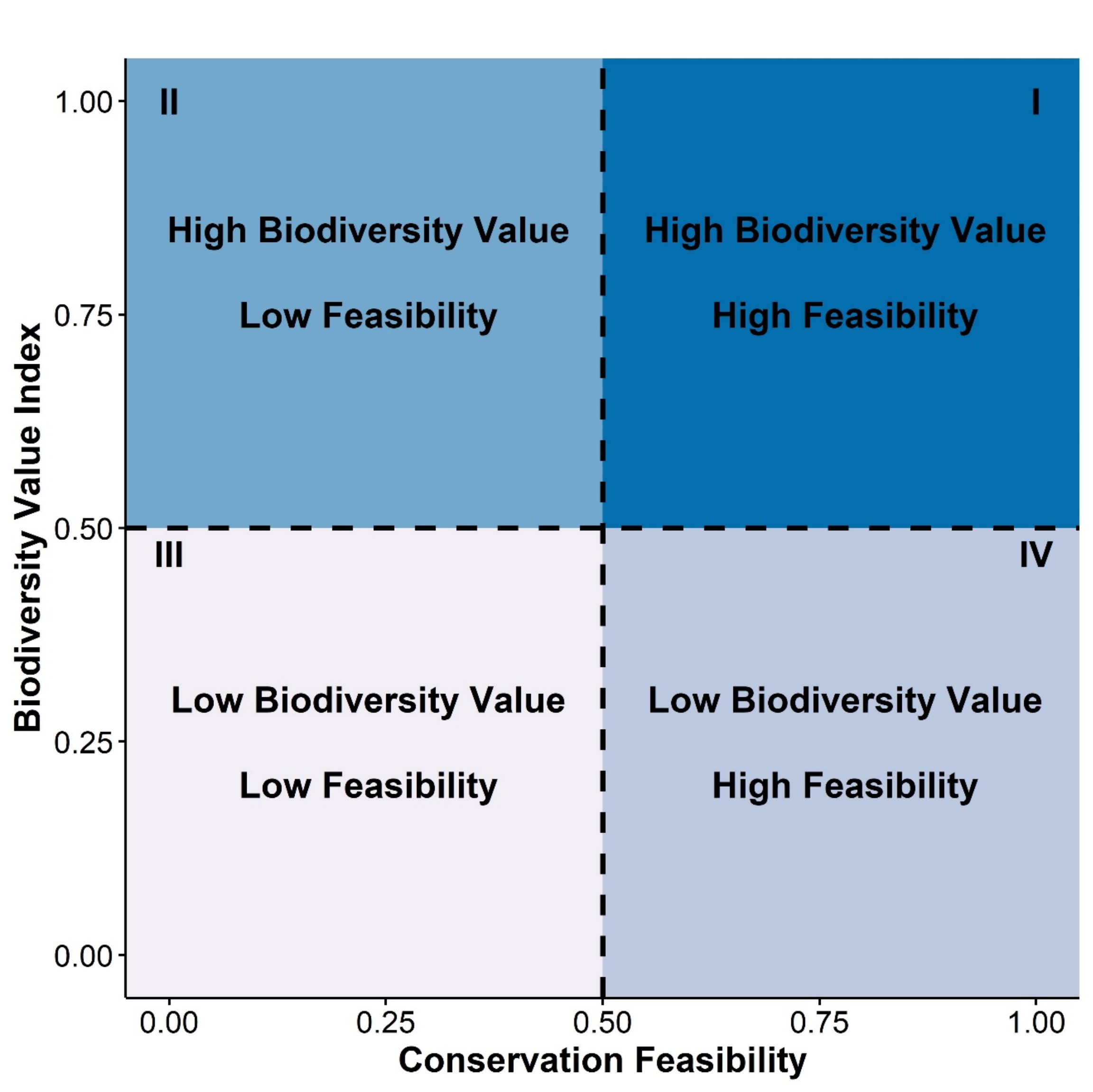



Assuming reservoir management that optimizes basin-wide water satisfaction, what is the highest possible societal satisfaction when environmental flow goals are fully met?

Wineland et al. *in review*

Both conservation feasibility and biodiversity value (i.e., species' presence) vary among climate scenarios.

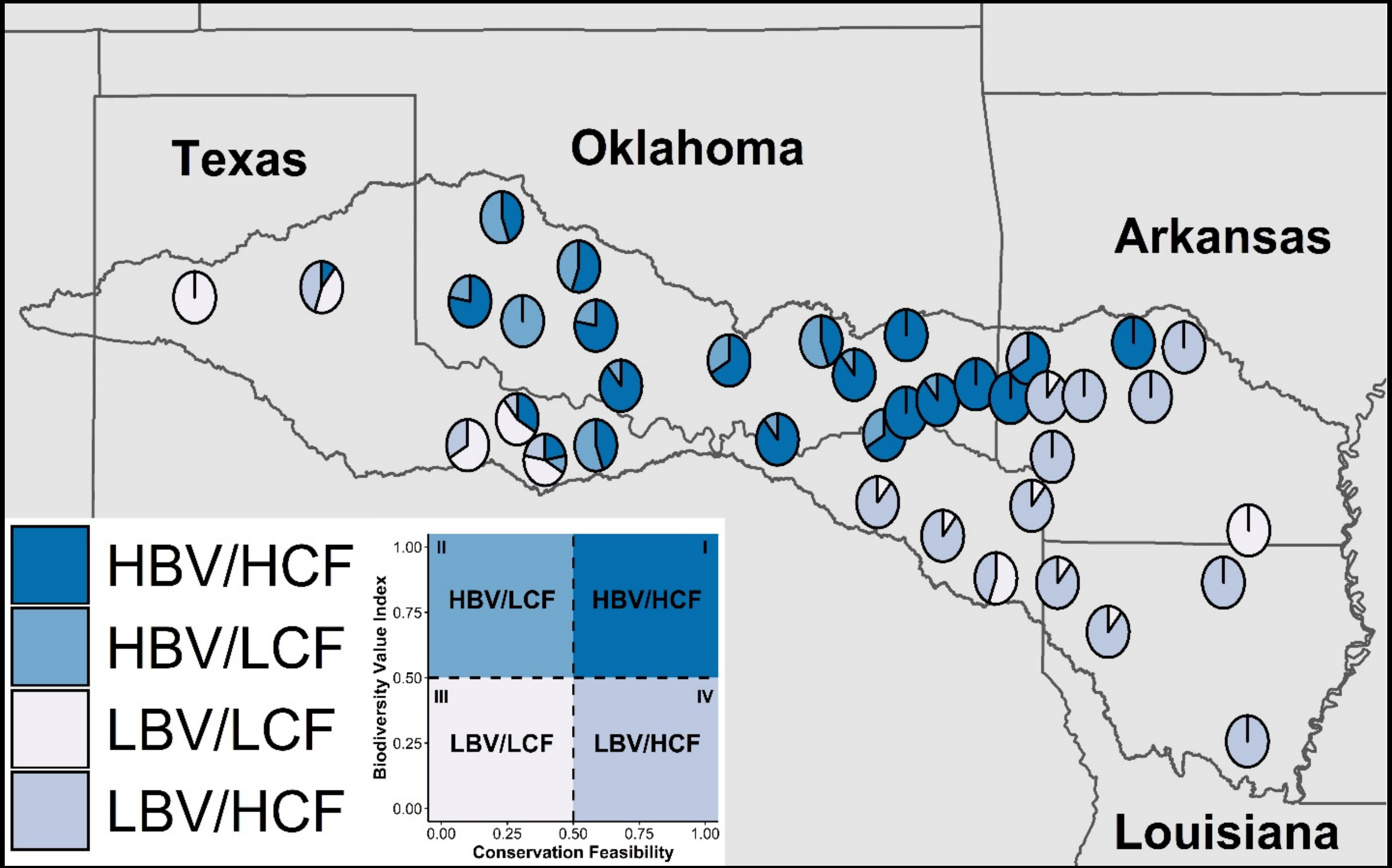
Can we identify locations that remain feasible and high biodiversity value across climate scenarios?




Conceptual framework from Wineland et al. *in review*

Some river reaches do indeed have high conservation feasibility and high biodiversity value across all nine climate scenarios.

Can this type of analysis help to identify locations for considering instream flow targets?




Pie charts give number of climate scenarios (out of nine) in which river reaches downstream of reach reservoir fall into each feasibiligy/biodiversity category.

Wineland et al. *in review*

# Conclusions and future work

- Distributions of many fish species will contract, but outcomes vary among species and among climate scenarios

- Spatial planning tools can help to prioritize water conservation efforts in space and time

- Central question: How can we plan for water sustainability under climate uncertainty?

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