PREDICTING RECRUITMENT OF RIO GRANDE SILVERY MINNOW IN RESPONSE TO FLOODPLAIN RESTORATION

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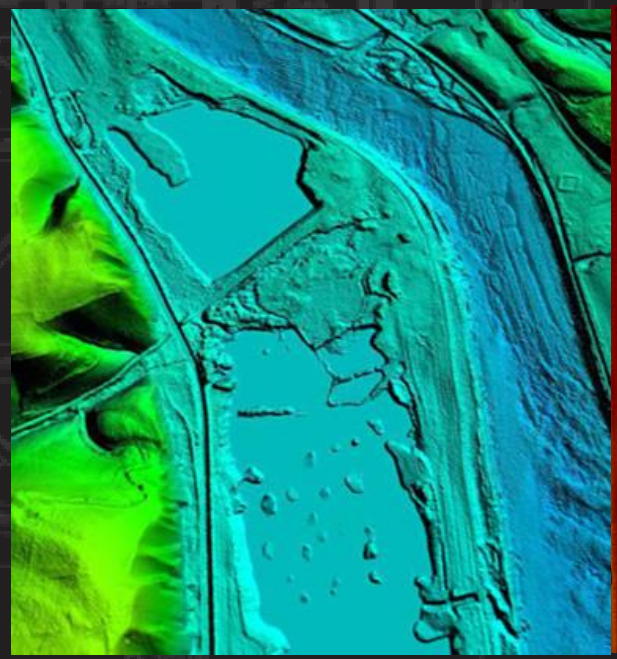
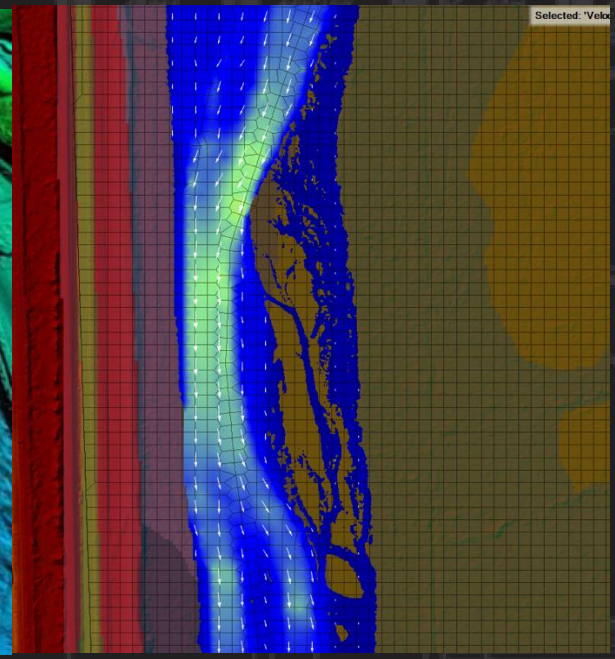
Environmental Laboratory

EMRRP Webinar December 2024





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OVERVIEW

- Introduction
  - Ecological models in the USACE
  - Rio Grande Silvery Minnow
- Analysis
  - Hydraulic analysis
  - Population model
- Silvery Minnow prediction tool
- Example scenarios
- Concluding remarks

ECOLOGICAL MODELING WITHIN USACE

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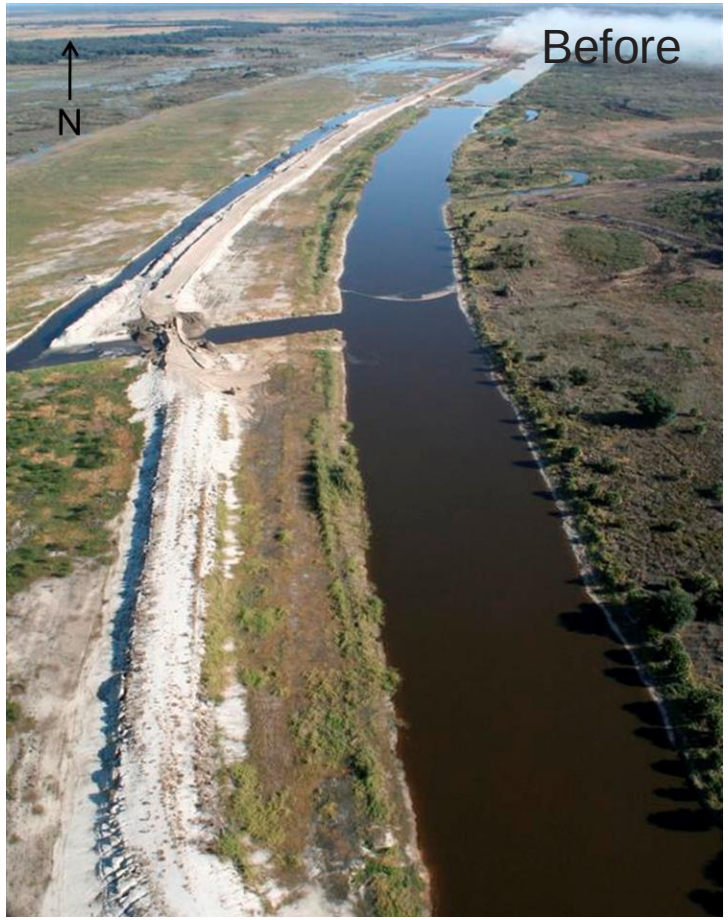
USACE RESTORATION RELIES ON ECOLOGICAL MODELS

- $400M/year on aquatic ecosystem restoration
- Habitat suitability index (HSI) models to predict effects on species/ecosystems
- Benefits
  - Simple to interpret and implement
  - Enable input from biologists/subject experts
- Shortcomings
  - Static/deterministic
  - Proxies for species, etc.
  - Narrow spatial/temporal scales
  - Not empirically derived



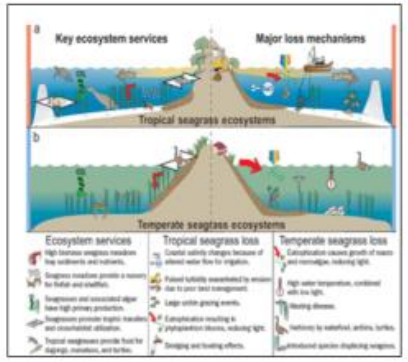
Kissimmee River, FL

ECOLOGICAL MODELS BROADLY

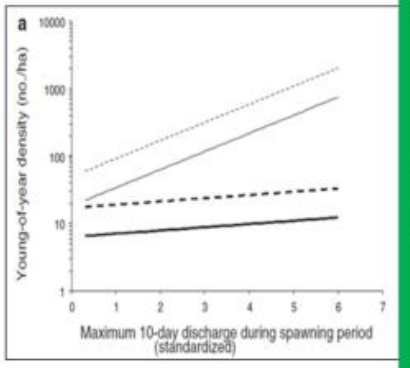
Approach

Outcome

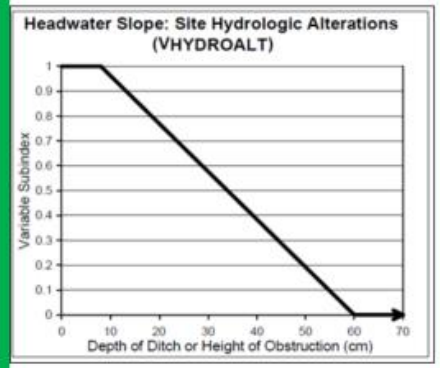
Conceptual



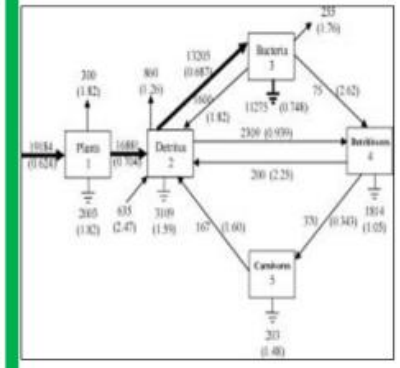
Statistical



Index-based



Mass Balance



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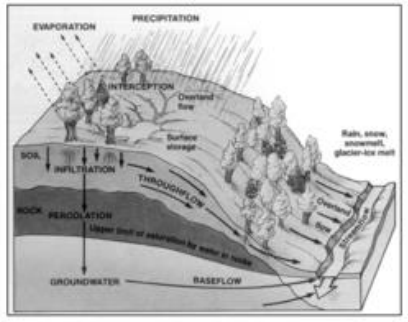
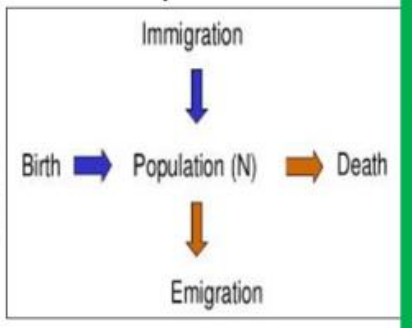
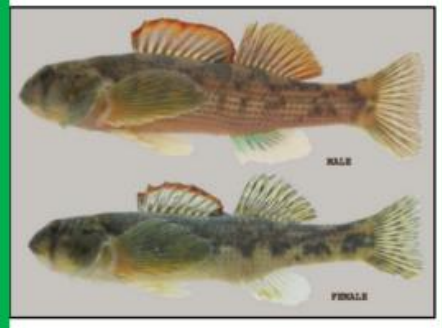
Physical



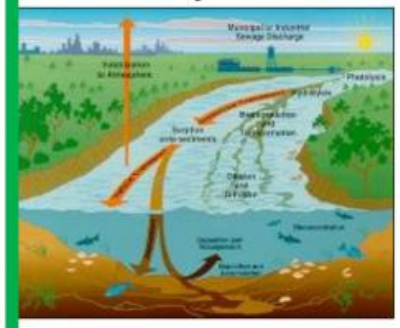
Population



Habitat



Ecosystem



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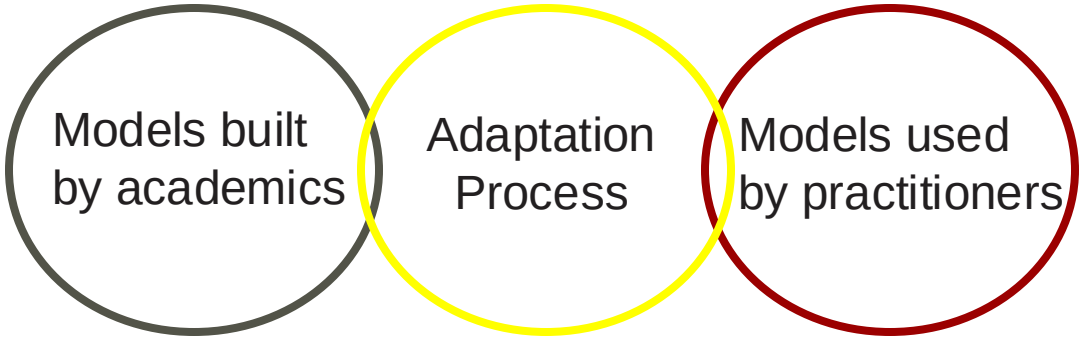
Can the USACE take advantage of these advancements?

EMERGING APPROACHES TO ECOLOGICAL MODELING

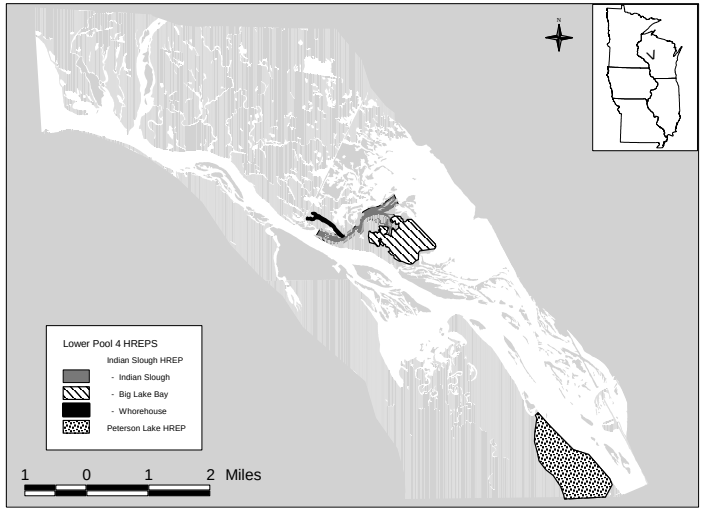
- Explore ways to bring additional modeling approaches into USACE projects
- Case studies can demonstrate the utility of approaches that complement status quo
- Complex models are built for many scenarios, but infrequently translated/adapted for practitioners



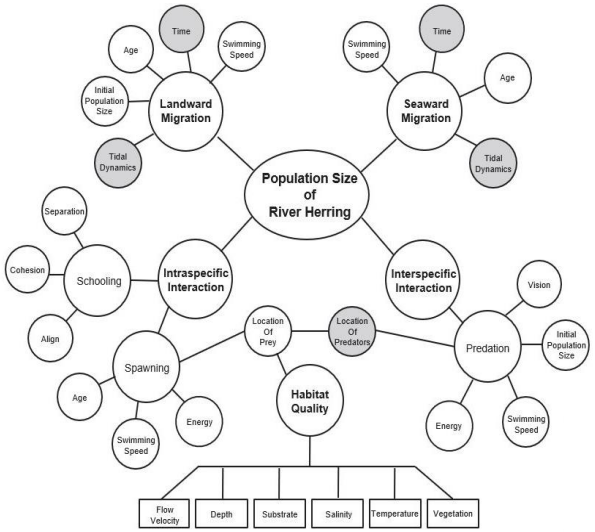
EMERGING APPROACHES CASE STUDIES

Rio Grande
Silvery Minnow
Population model

Upper Mississippi
Backwater Fish
Community Model



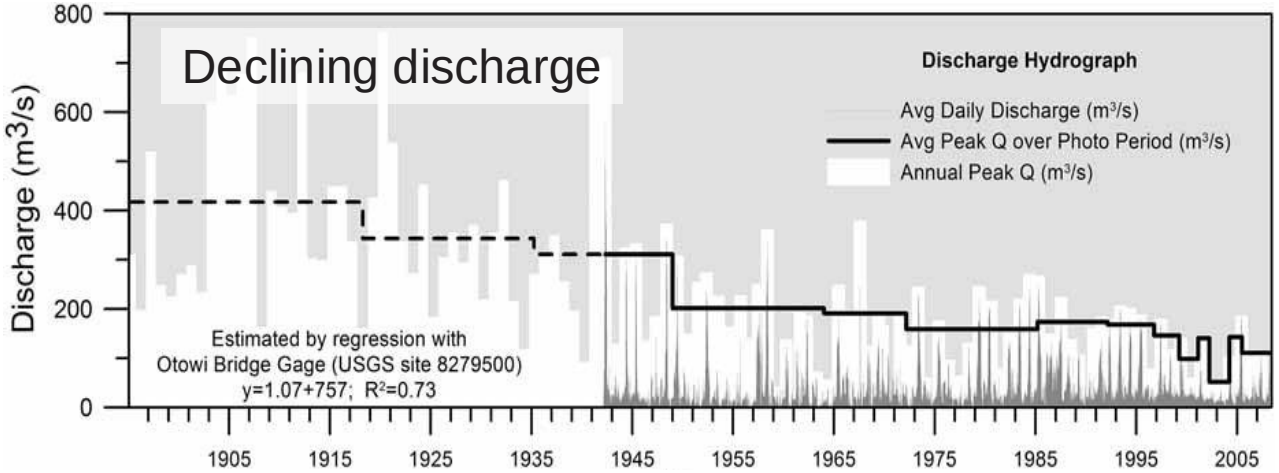
River Herring
Agent-based Model



ECOLOGICAL MODELS BEYOND DECISION-MAKING

- Communication
  - Internal
  - With collaborating entities and stakeholders
- Exploring dynamics of systems and interplay of ecosystem components
- Guiding post-project monitoring and assessment

MIDDLE RIO GRANDE



RIO GRANDE SILVERY MINNOW

- Listed as endangered in 1993
- Population bottlenecks:
  - Summer river drying: increased mortality
  - Low flows in spring coupled with floodplain disconnection: **decreased recruitment**
- Larger barriers to augmenting flow than restoration that reconnects floodplains

Recruitment = production of free-swimming, young-of-year fish

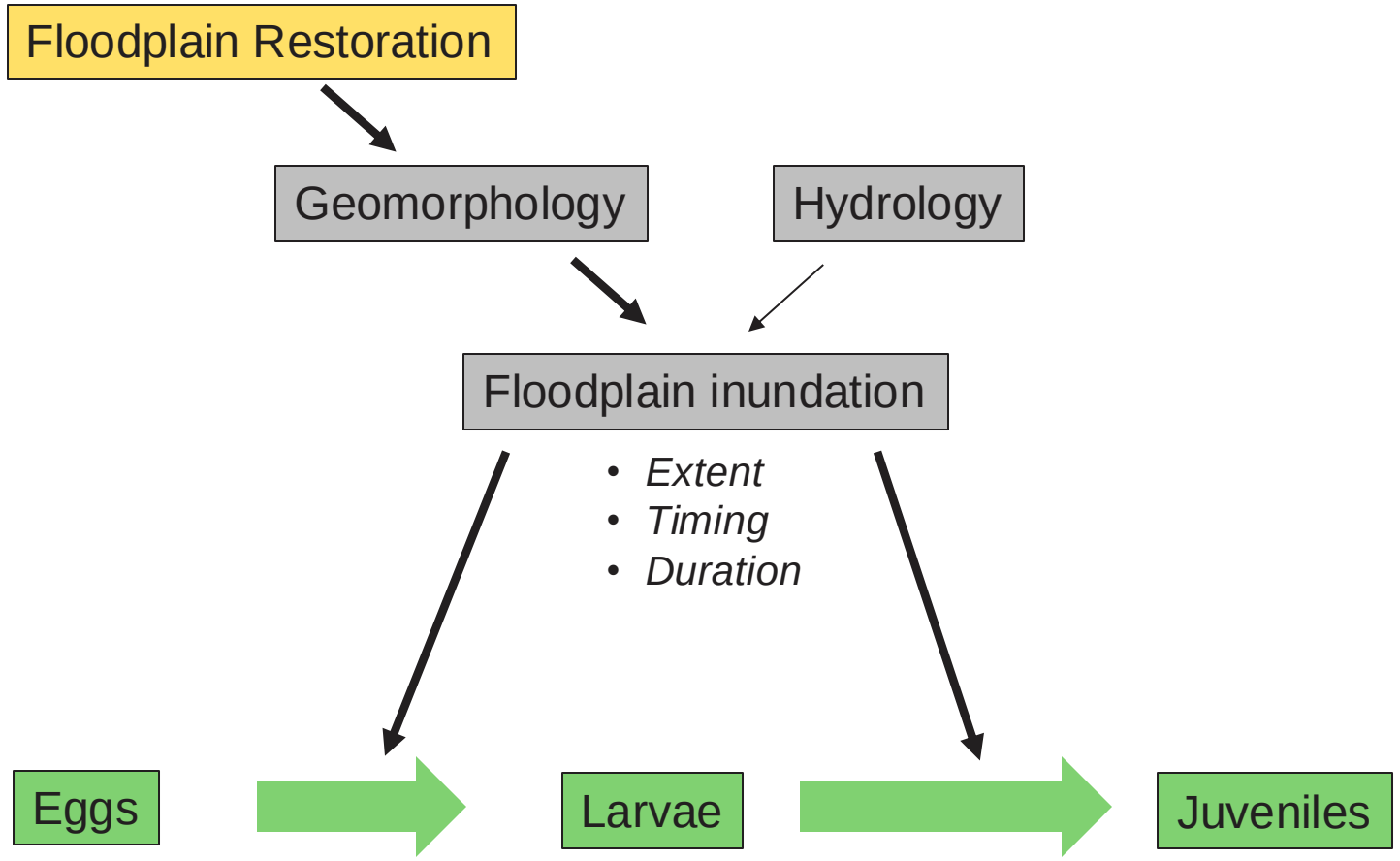
Valdez et al. 2019

RGSM FLOODPLAIN RECRUITMENT

USACE Intervention

Abiotic factors

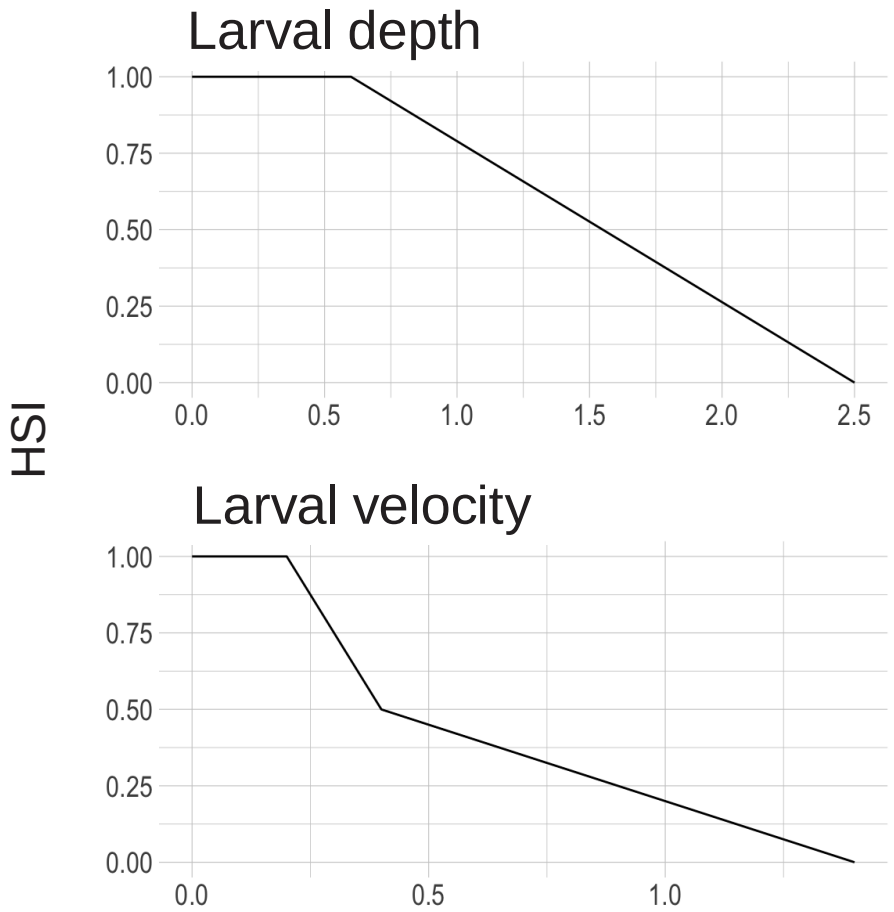
Recruitment life stages

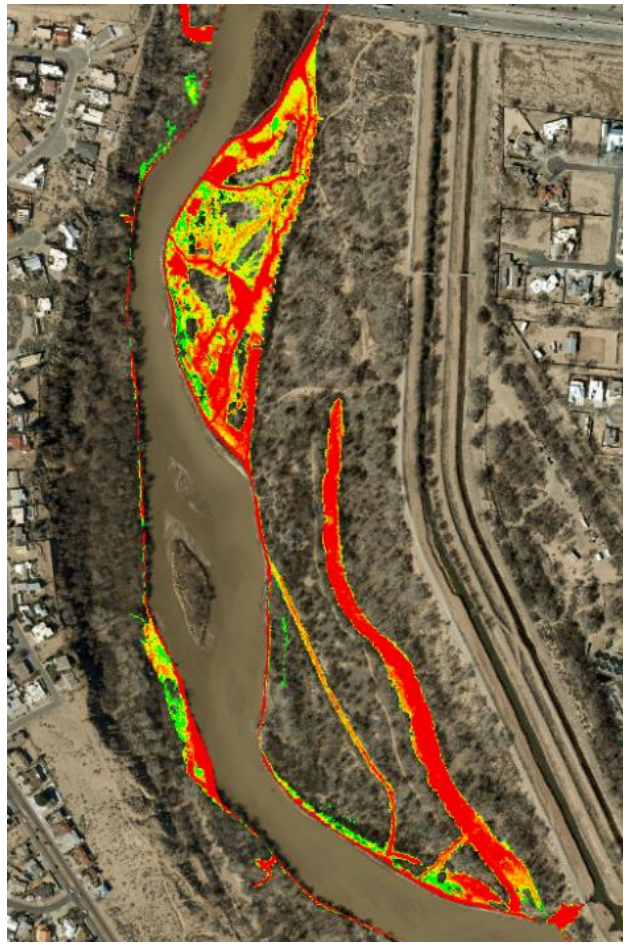


ECOLOGICAL ASSESSMENT

Question: How will floodplain restoration affect Rio Grande silvery minnow recruitment?

HSI Approach





ECOLOGICAL ASSESSMENT

Question: How will floodplain restoration affect Rio Grande silvery minnow recruitment?

Population modeling approach

- Pertains directly to our objective: more RGSM (i.e., the currency of managing ESA species)
- Enables variability among reaches/sites
- Allows for stochasticity and error estimation
- Enables apples-to-apples comparison with other mgmt. interventions (e.g., adding water)

OBJECTIVES

1. Use a population model to develop an empirical relationship between floodplain inundation and Rio Grande Silvery Minnow recruitment
2. Create tool that uses this relationship to estimate RGSM recruitment under different restoration scenarios

QUANTIFYING INUNDATION – RECRUITMENT RELATIONSHIP

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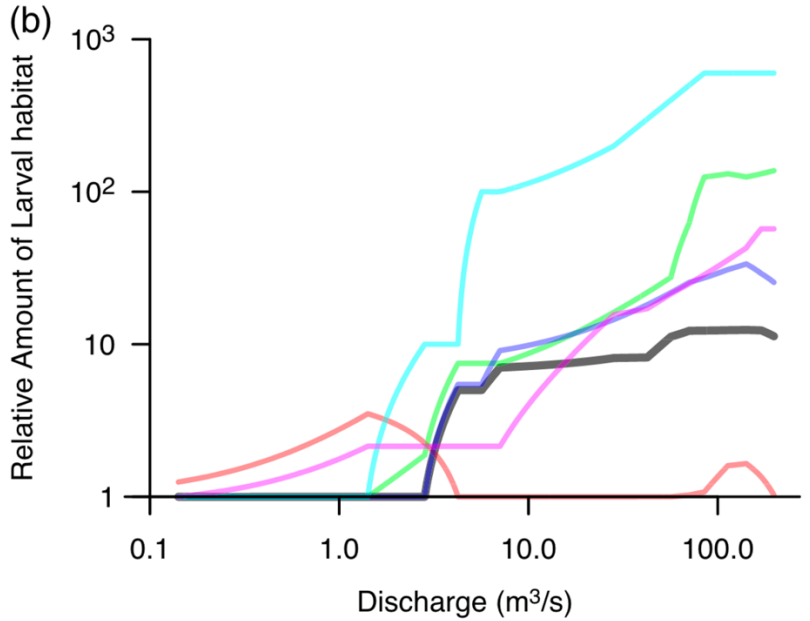
QUANTIFYING INUNDATION-RECRUITMENT RELATIONSHIP

- Bayesian integrated population model (Yackulic et al. 2022)
  - Generates estimates of RGSM recruitment at reach-scale (e.g., San Acacia) using many data sources
  - Main predictor is spring hydrograph and inundation expected to result from this

- Not able to use model to predict response as-is because inundated habitat is not absolute



Expert-elicited values

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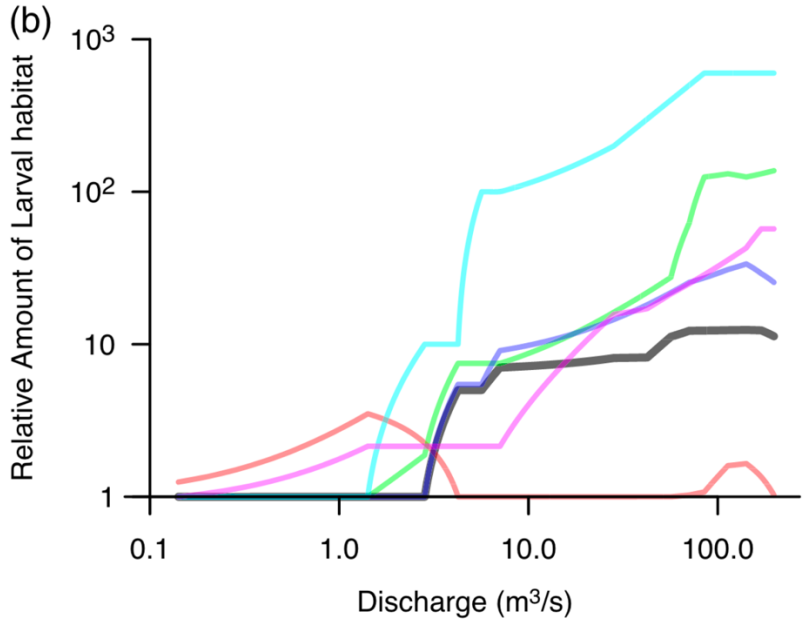
  - Main predictor is spring hydrograph and inundation expected to result from this

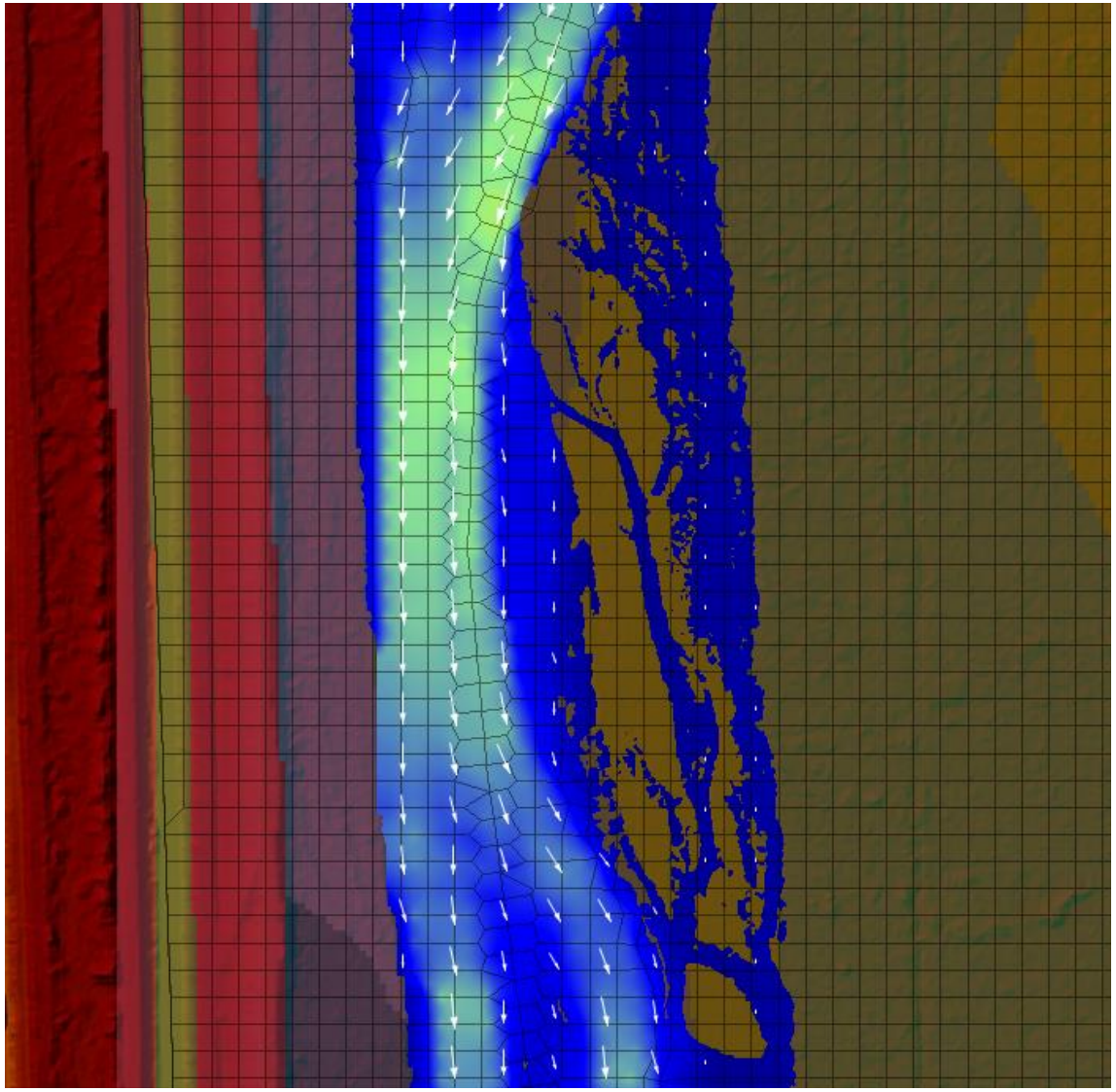
- Can we replace best guesses with actual modeled habitat?



Expert-elicited values

MIDDLE RIO GRANDE 2-D HYDRAULIC MODEL

- Estimates floodplain inundation, depth, velocity at 7 discharge levels (700 - 7000 cfs)
- Depth/velocity data processed through HSI (Harris 2021) to calculate weighted-usable area (WUA)



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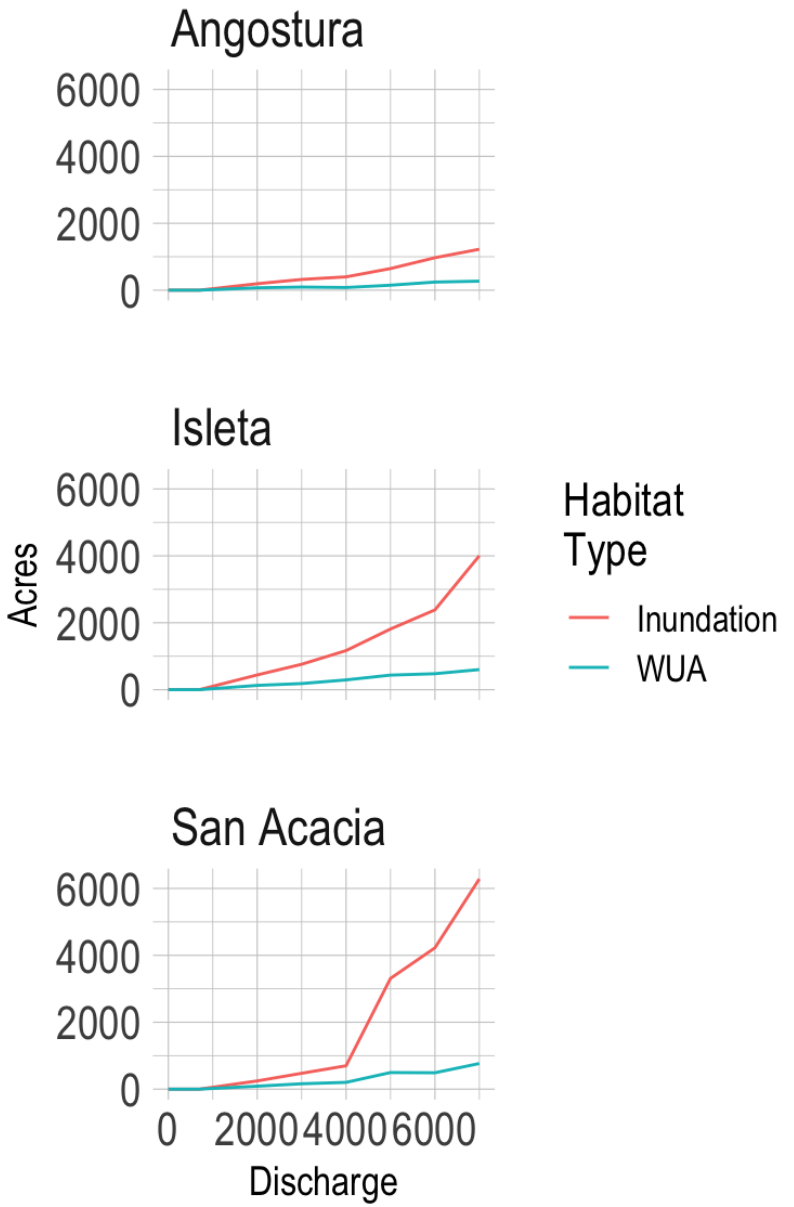
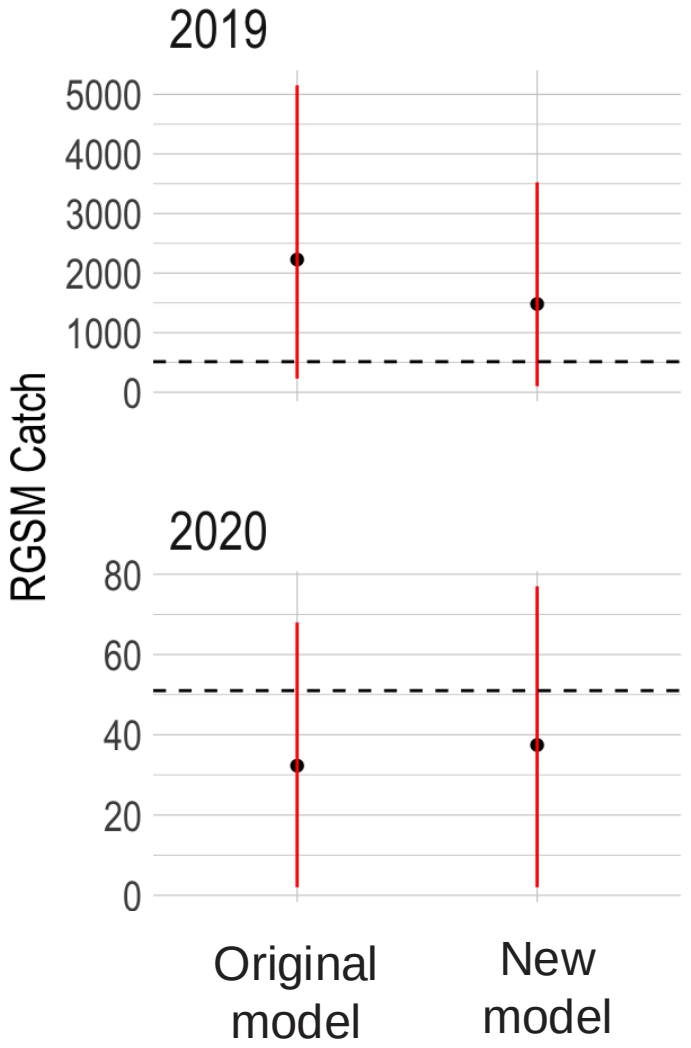


INTEGRATING HYDRAULIC AND POPULATION MODELS

- 2 ways of incorporating yearly inundation data into population model
  - Inundation flow metric
  - Larval Carrying Capacity Index covariate
- Validation by predicting actual RGSM catch in two out-of-sample years
- New model means that we can estimate populations produced under different hydrologic and restoration scenarios



PREDICTING MINNOW RESPONSE TO RESTORATION

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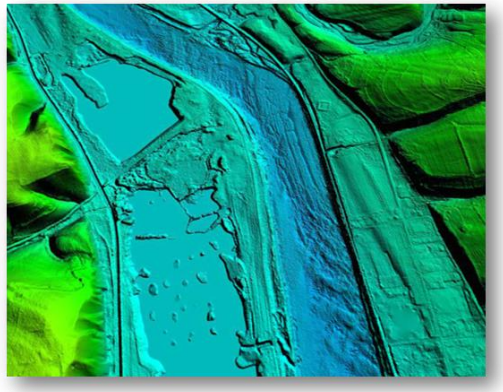
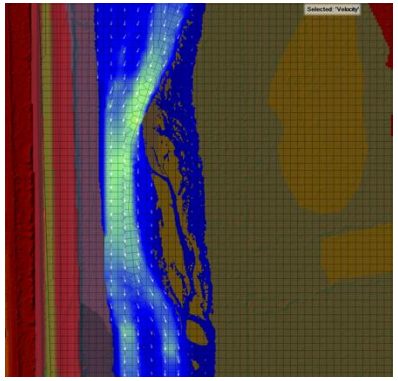
PREDICTING POPULATION RESPONSE TO RESTORATION

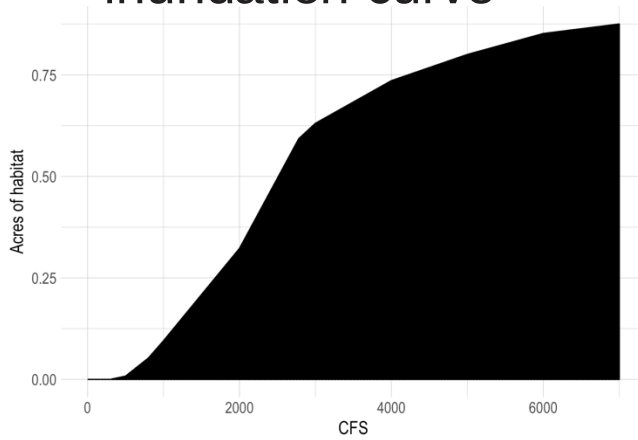
Topobathy



2-D HEC-RAS Model

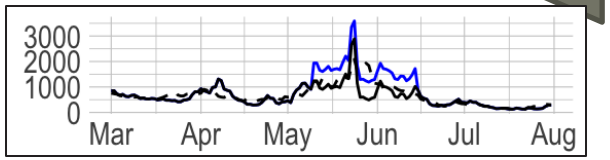


Site-specific flow-inundation curve



Hydraulic modeling

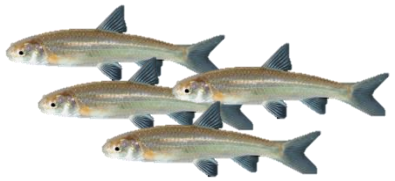
Hydrographs (USGS)



Inundation flow metrics

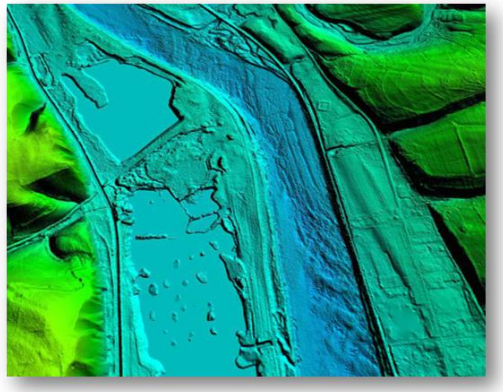
Population model

RGSM recruitment



PREDICTING POPULATION RESPONSE TO RESTORATION

Topobathy



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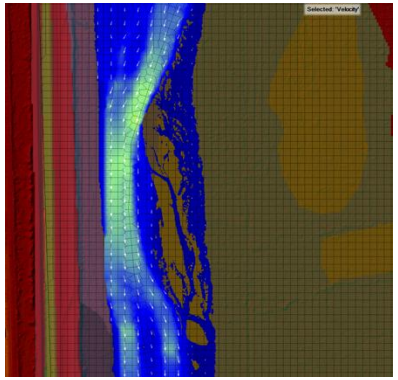

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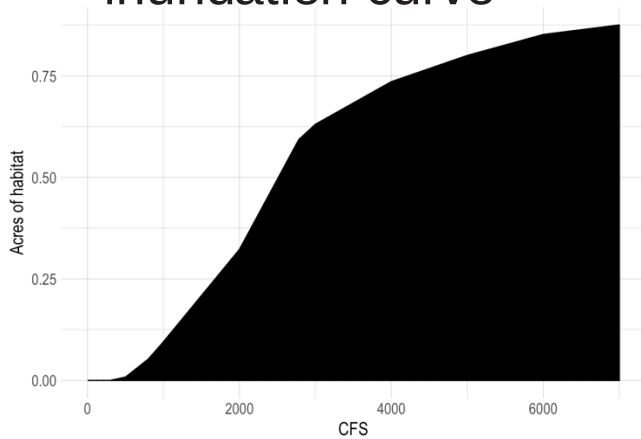
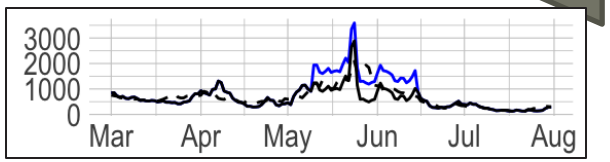


Hydrographs (USGS)



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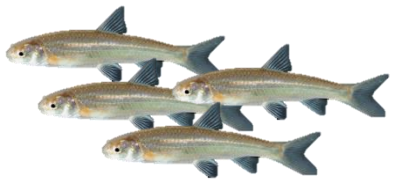


RGSM prediction tool

RGSM PREDICTION TOOL

User selects:
– Model variant (i.e., inundation covariate)

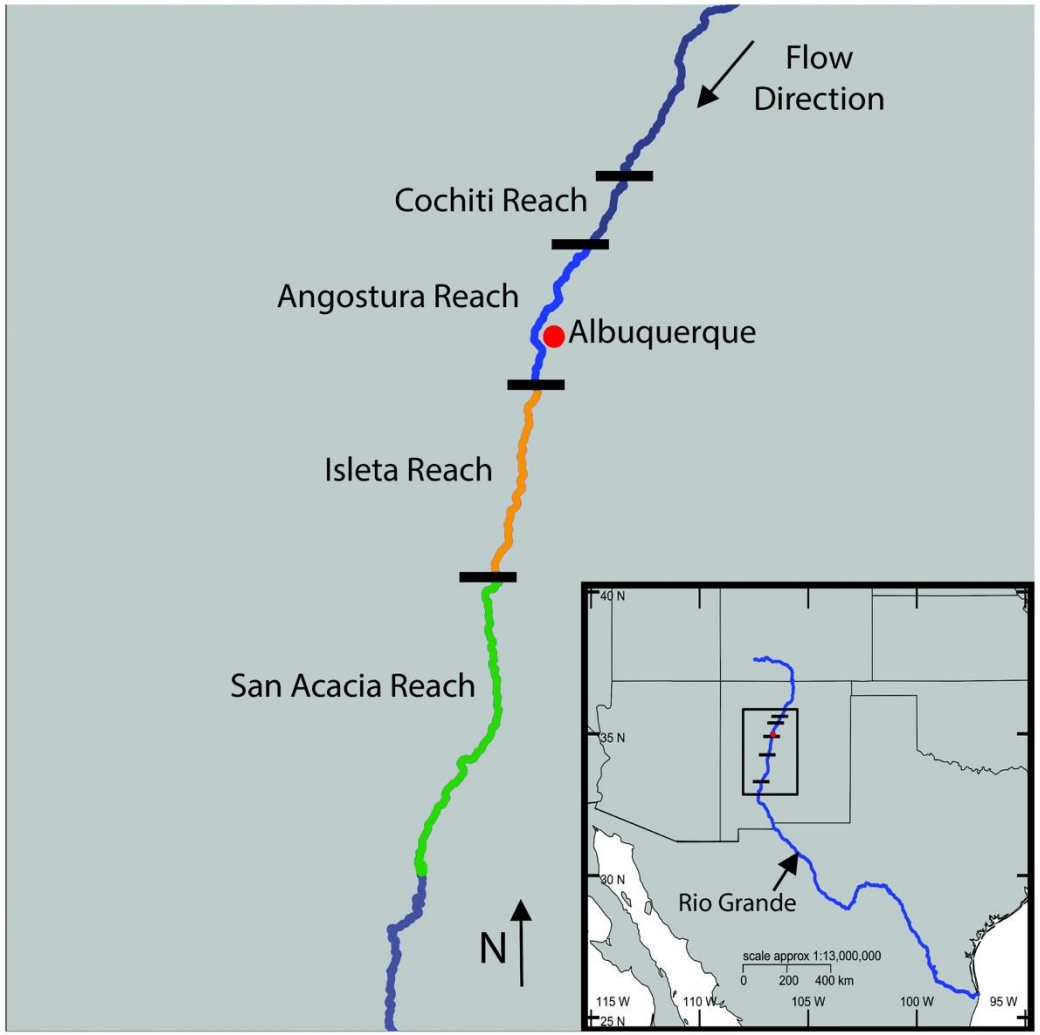
RGSM PREDICTION TOOL

User selects:

– Model variant (i.e., inundation covariate)

– Location of restoration

- "Reach" specific parameters



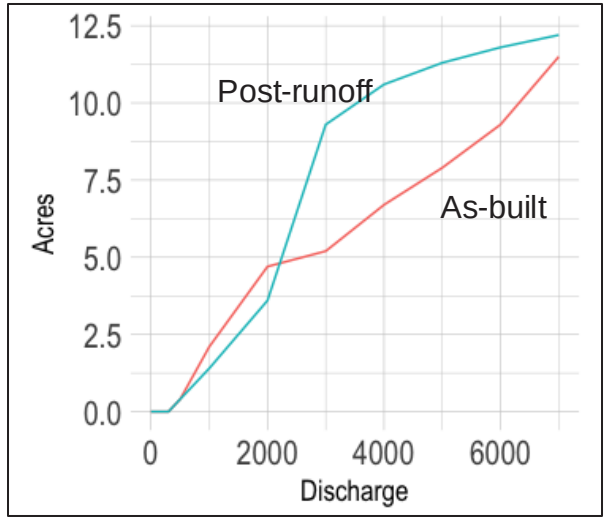
RGSM PREDICTION TOOL

User selects:

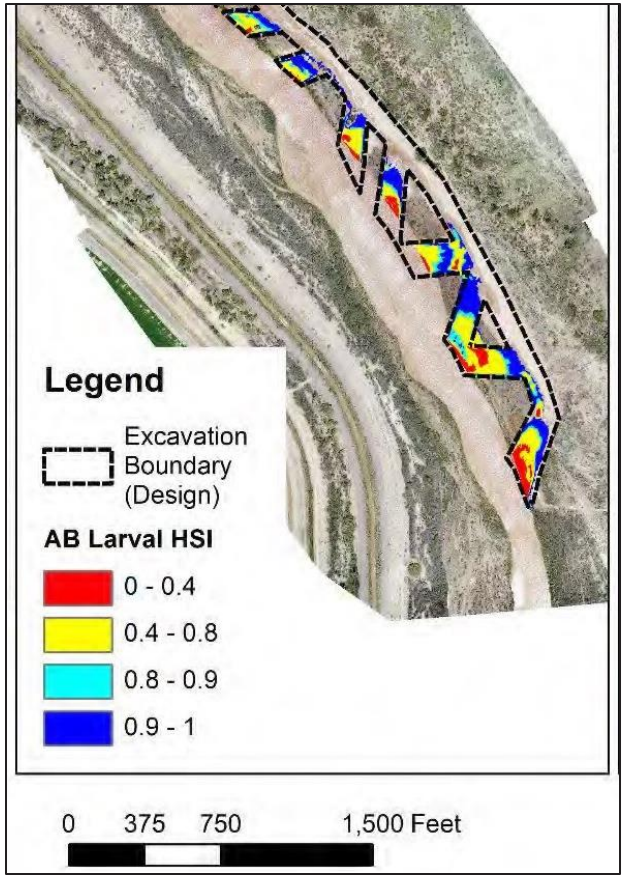
– Model variant (i.e., inundation covariate)

– Location of restoration
  - "Reach" specific parameters

– Size and scope of restoration
  - Flow-inundation curve at site(s)
  - Type of restoration (e.g., embayment vs. backwater…)



RM 93 embayment restoration



Harris 2021

RGSM PREDICTION TOOL

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– Size and scope of restoration
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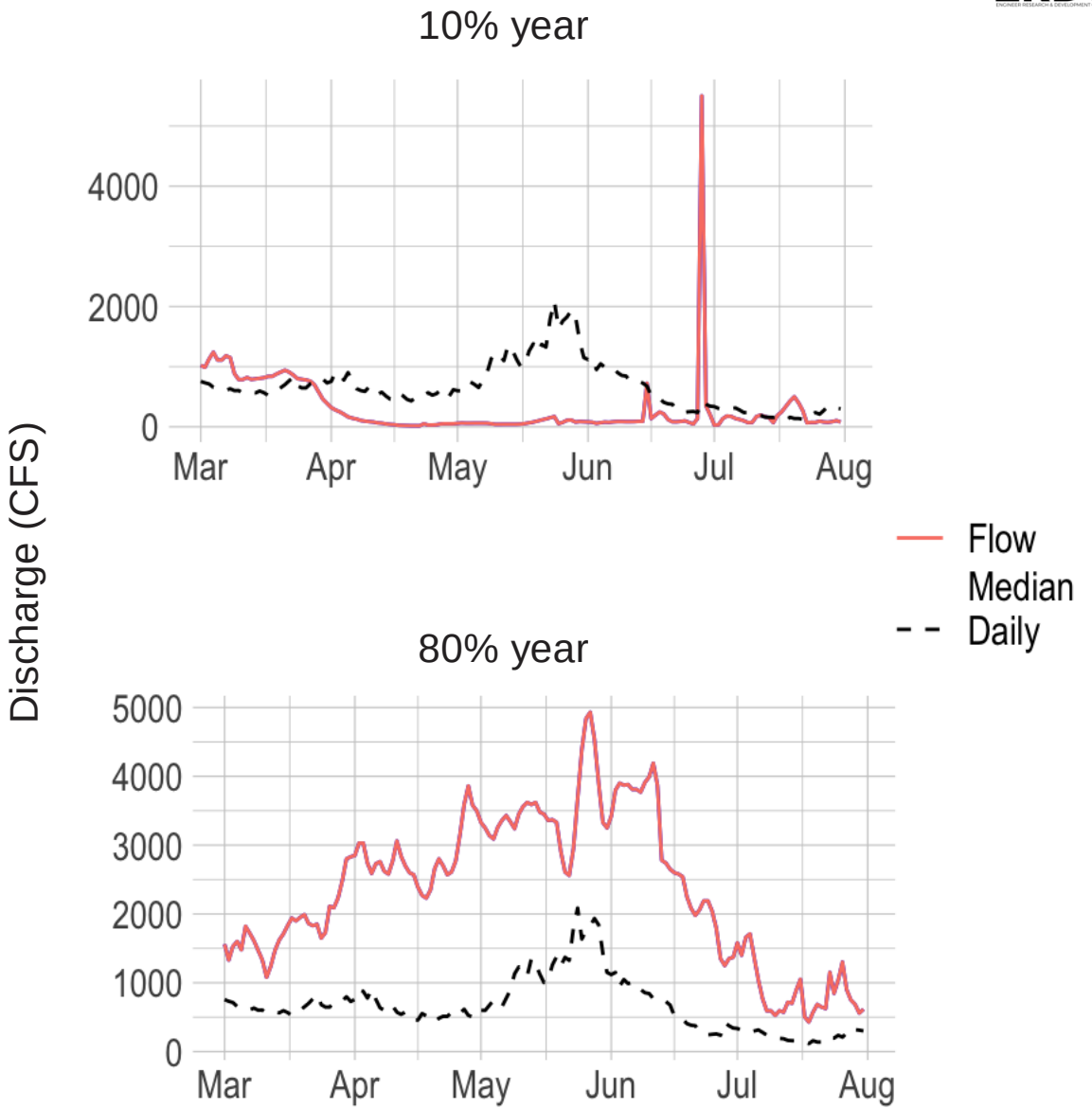
  - Type of restoration (e.g., embayment vs. backwater…)

– Flow conditions (either specific years or quantiles)



EXAMPLE SCENARIOS

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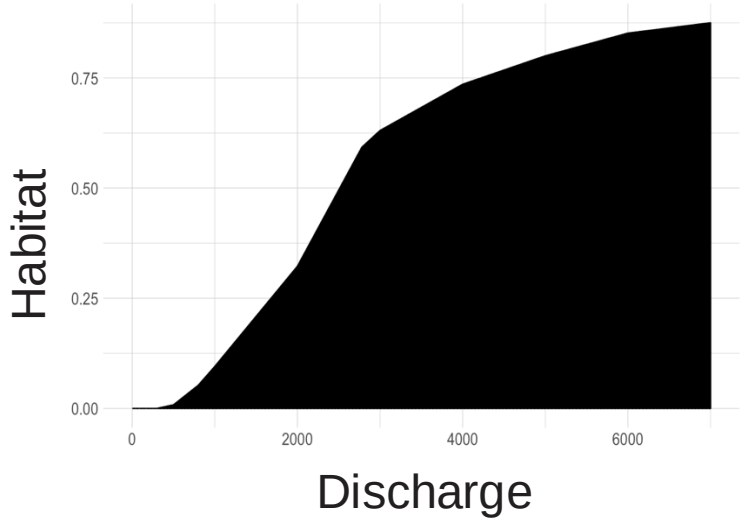
These are preliminary demonstration scenarios and do not reflect district project planning

RESTORATION VS. FLOW AUGMENTATION

200 acres of restoration in San Acacia vs. 3 flow augmentation scenarios

– Restoration effect can be tweaked by size of restoration and flow-inundation curve
– Augmentation values (0.5k, 5k, 50k ac-ft) represents different acquisition scenarios; flow augmented for 25-days in spring

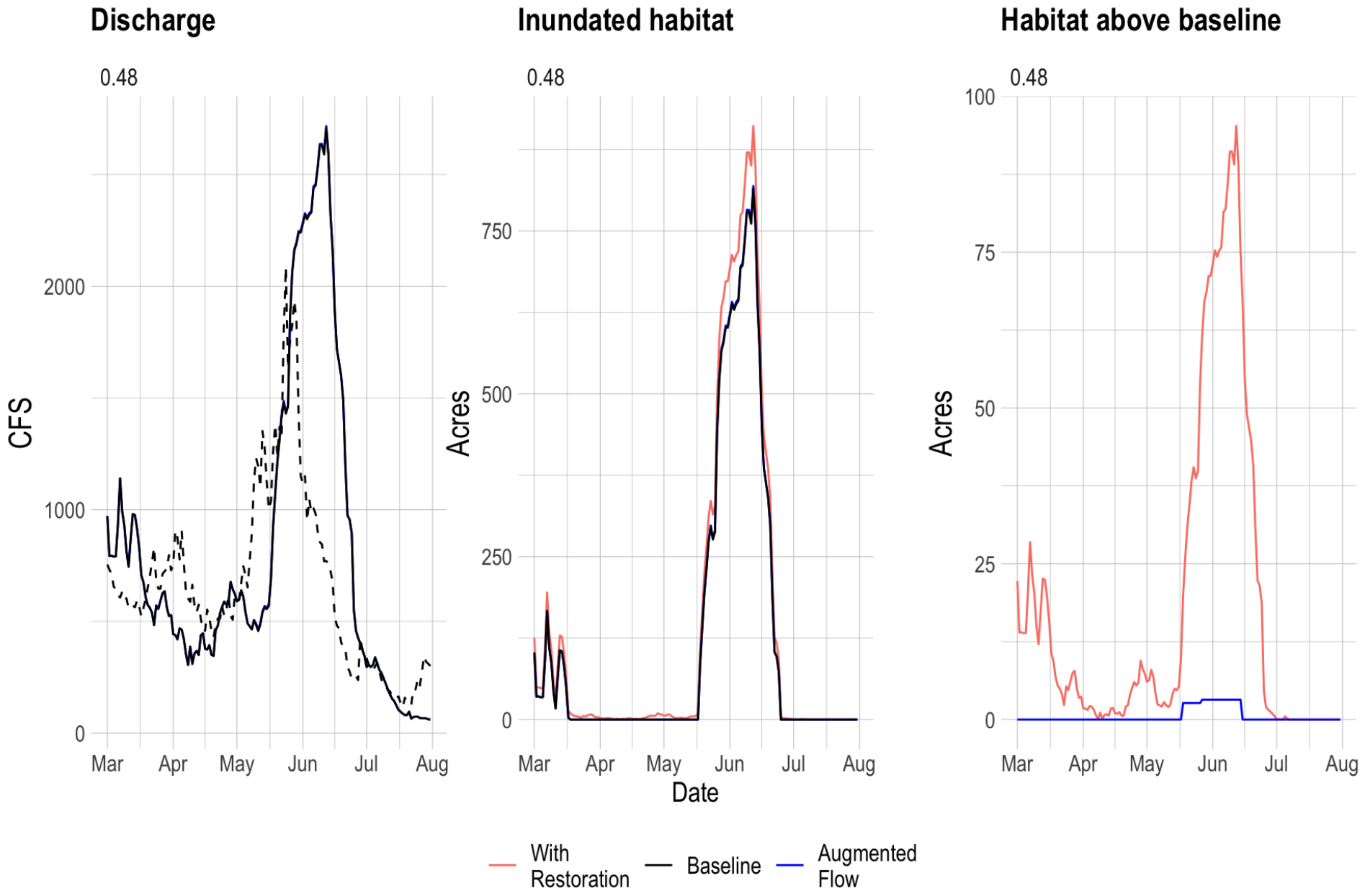
Model enables apples-to-apples comparisons:
augmentation and restoration both translated into # RGSM produced



Floodplain restoration (200 acres) vs. augmented flow (500 acre-ft)

San Acacia

48% flow year



Floodplain restoration (200 acres) vs. augmented flow (5,000 acre-ft)

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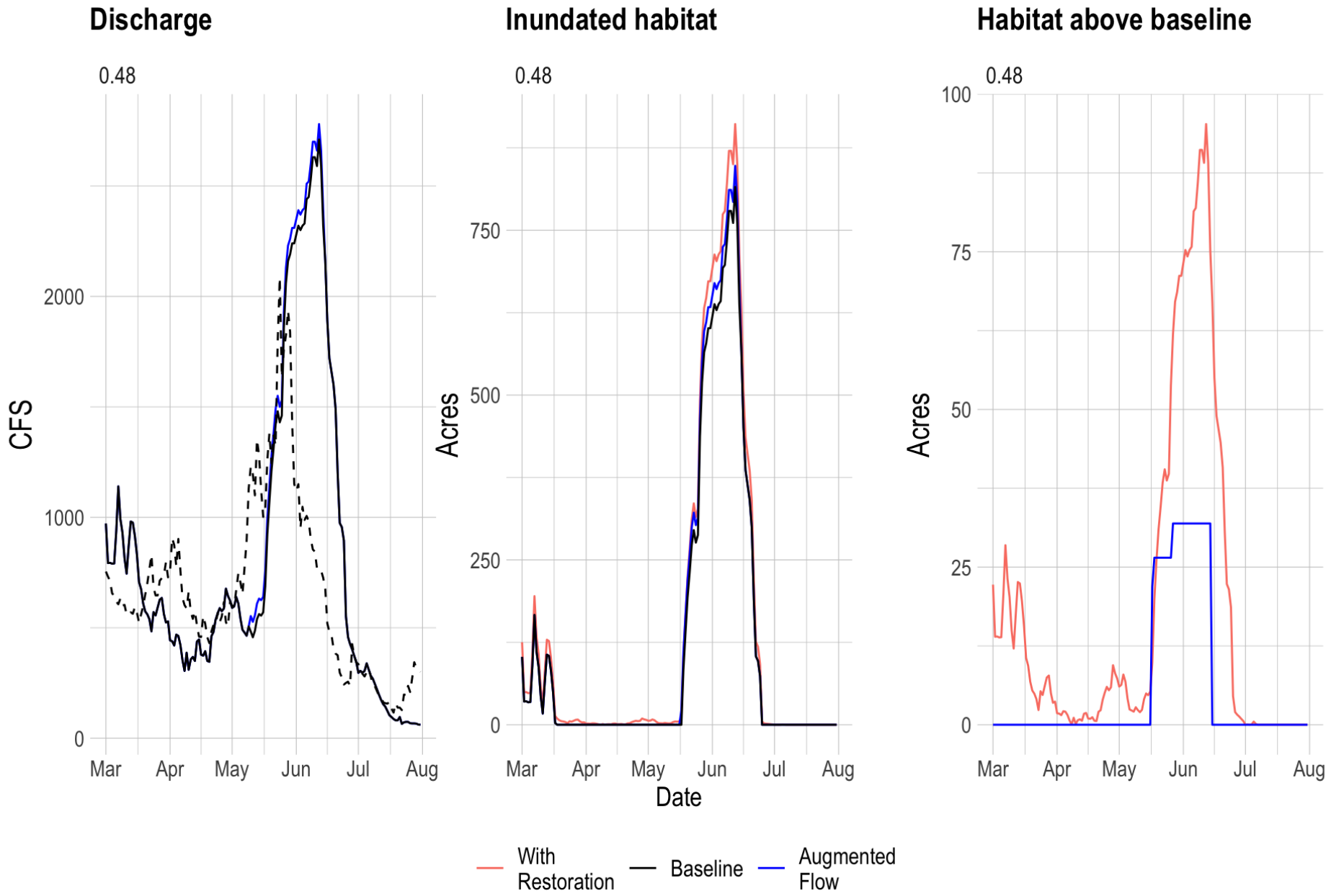
48% flow year



Floodplain restoration (200 acres) vs. augmented flow (50,000 acre-ft)

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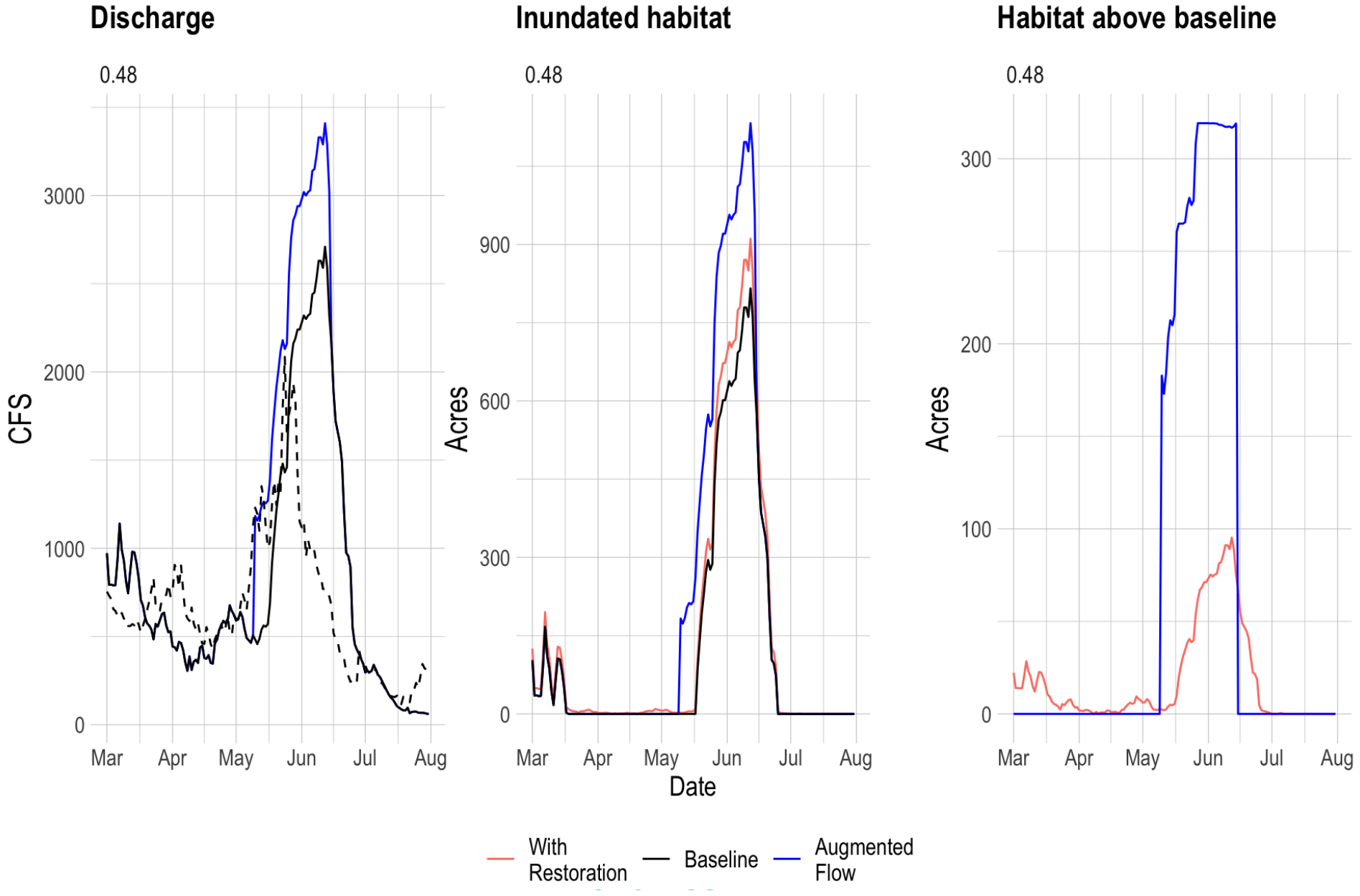
48% flow year



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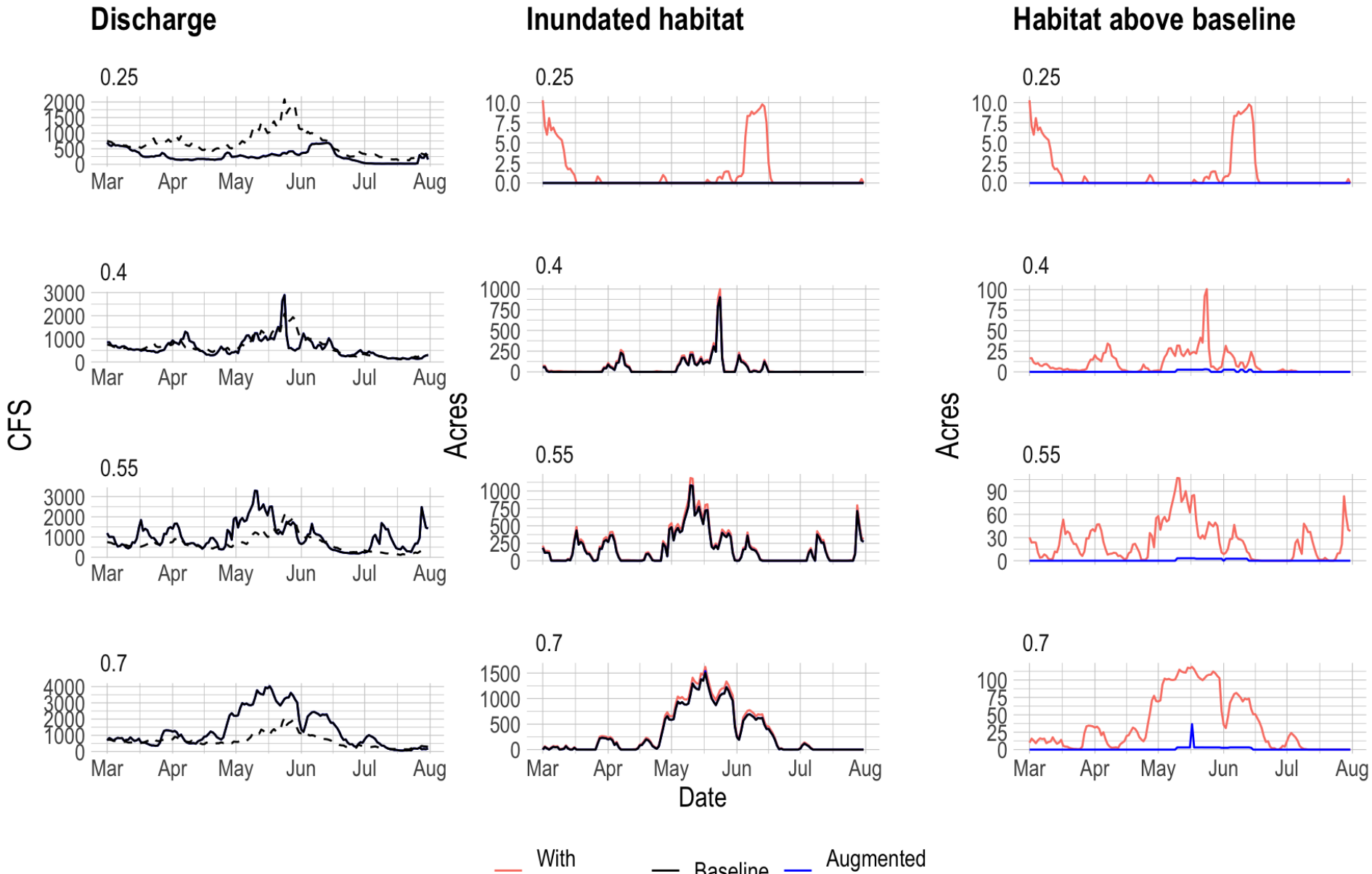
San Acacia

4 years (25-70% flow volume)



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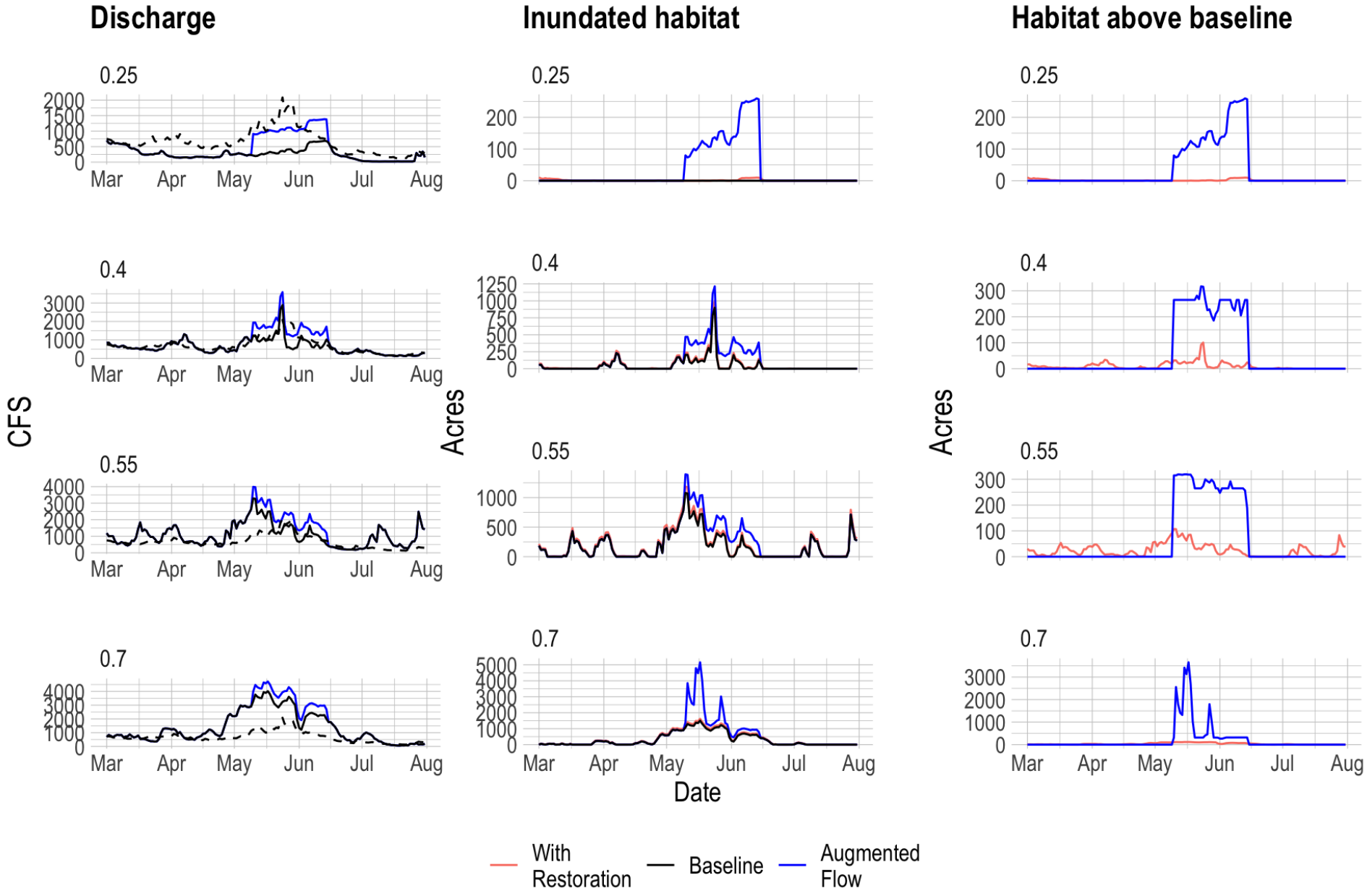
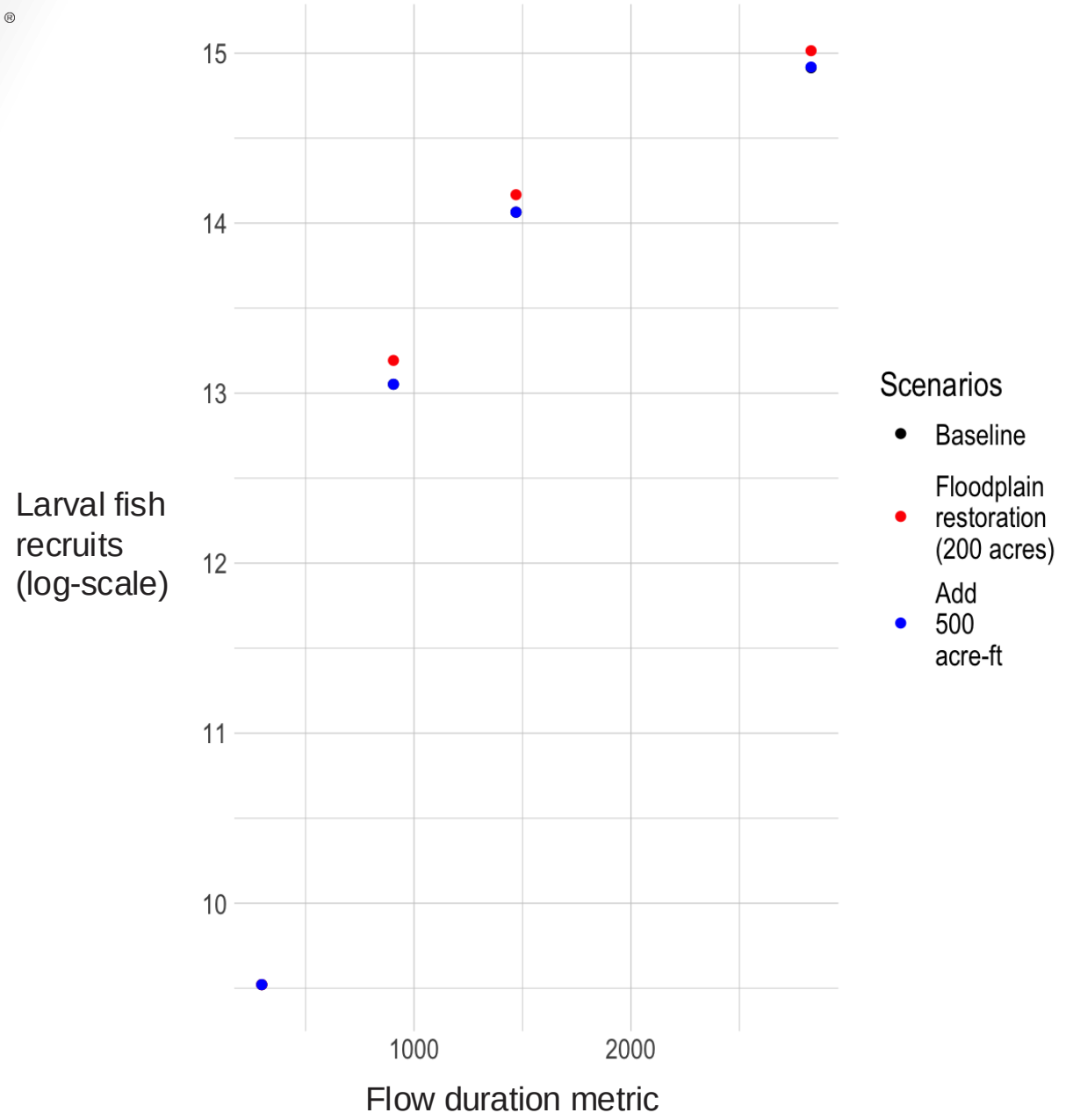


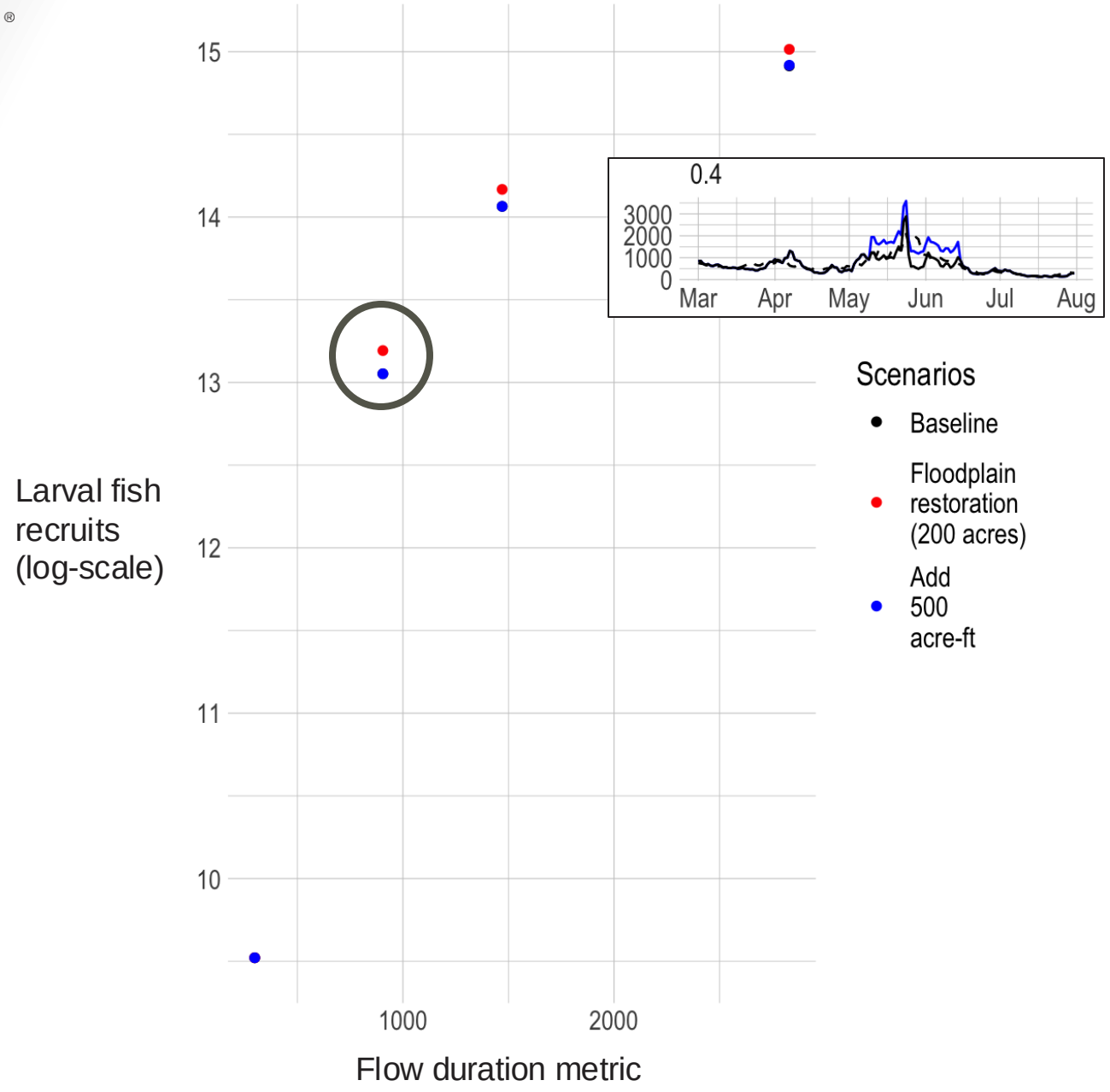
RGSM RECRUITMENT: RESTORATION (200 AC) VS. AUGMENTED FLOW (500 AC-FT)

SAN ACACIA REACH, 25 – 70% FLOW YEARS

RGSM RECRUITMENT: RESTORATION (200 AC) VS. AUGMENTED FLOW (500 AC-FT)



RGSM RECRUITMENT: RESTORATION (200 AC) VS. AUGMENTED FLOW (500 AC-FT)



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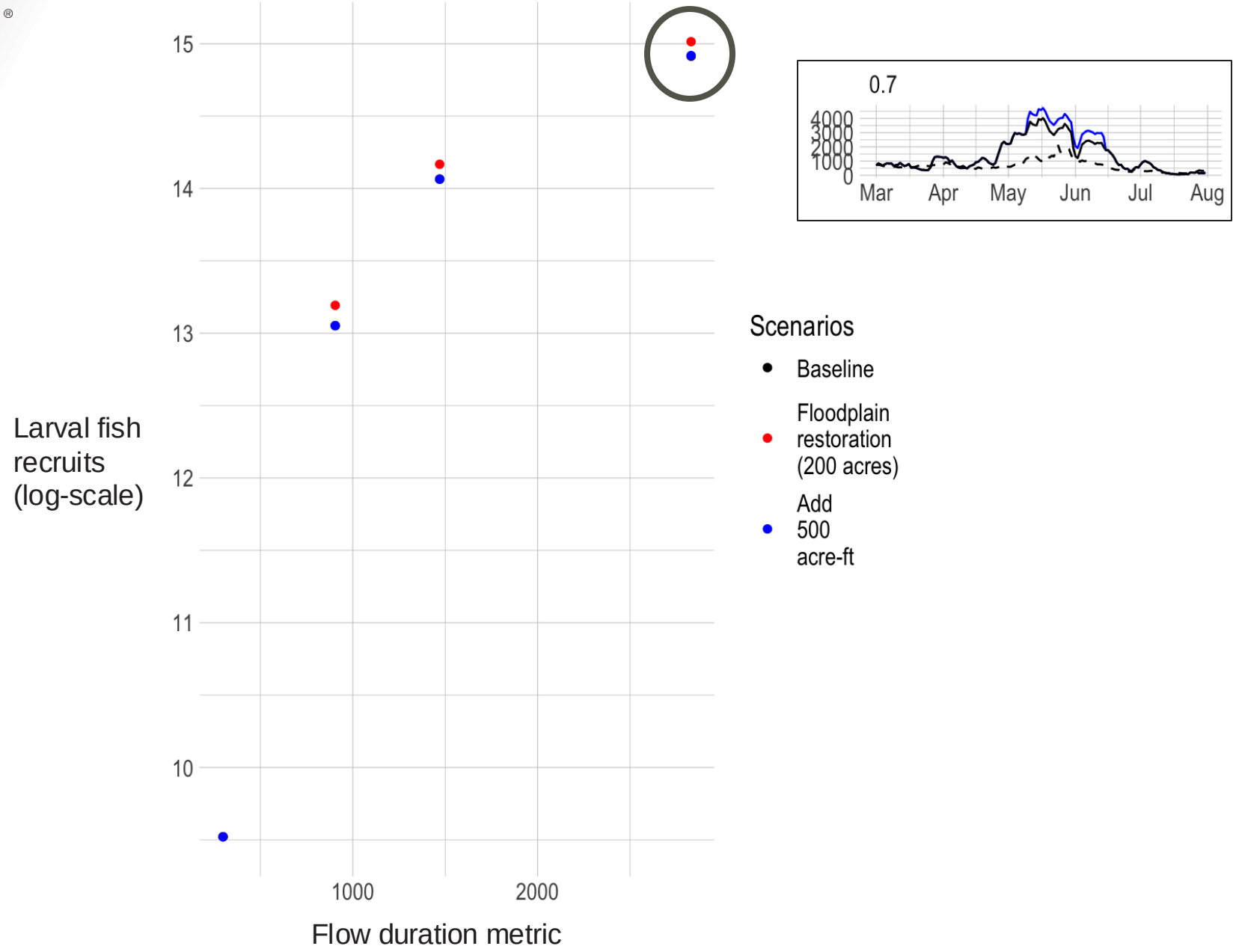

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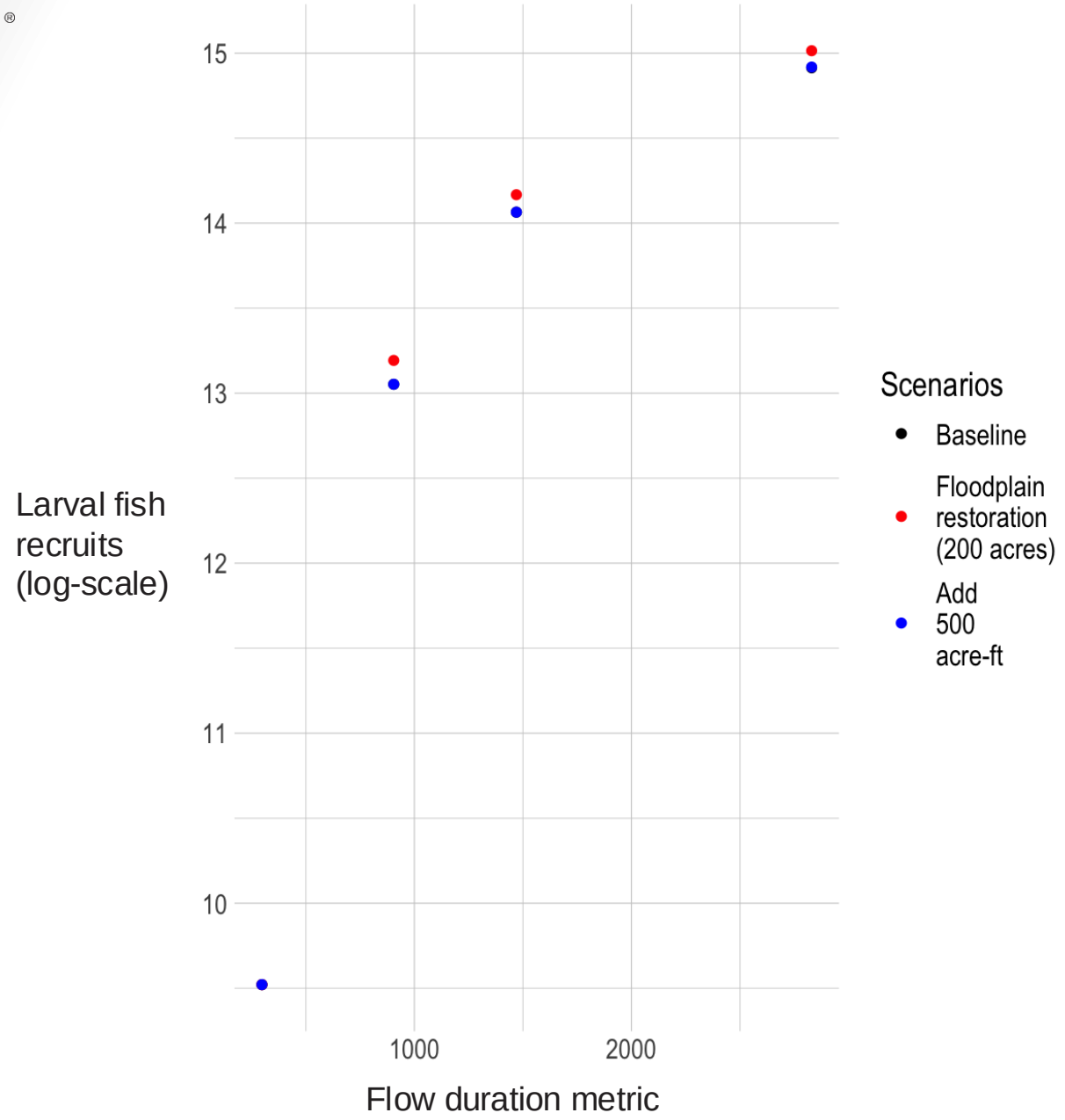

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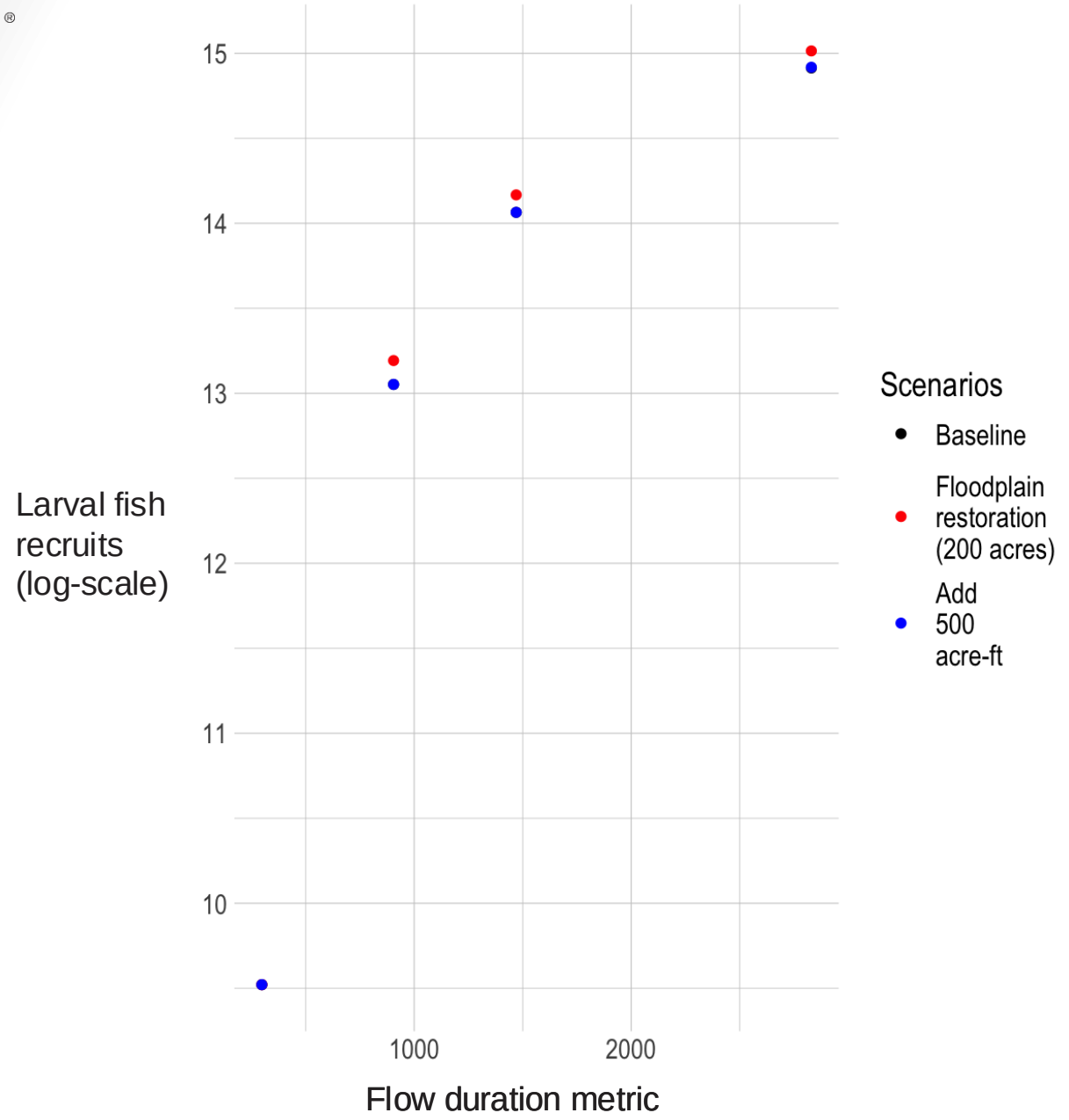

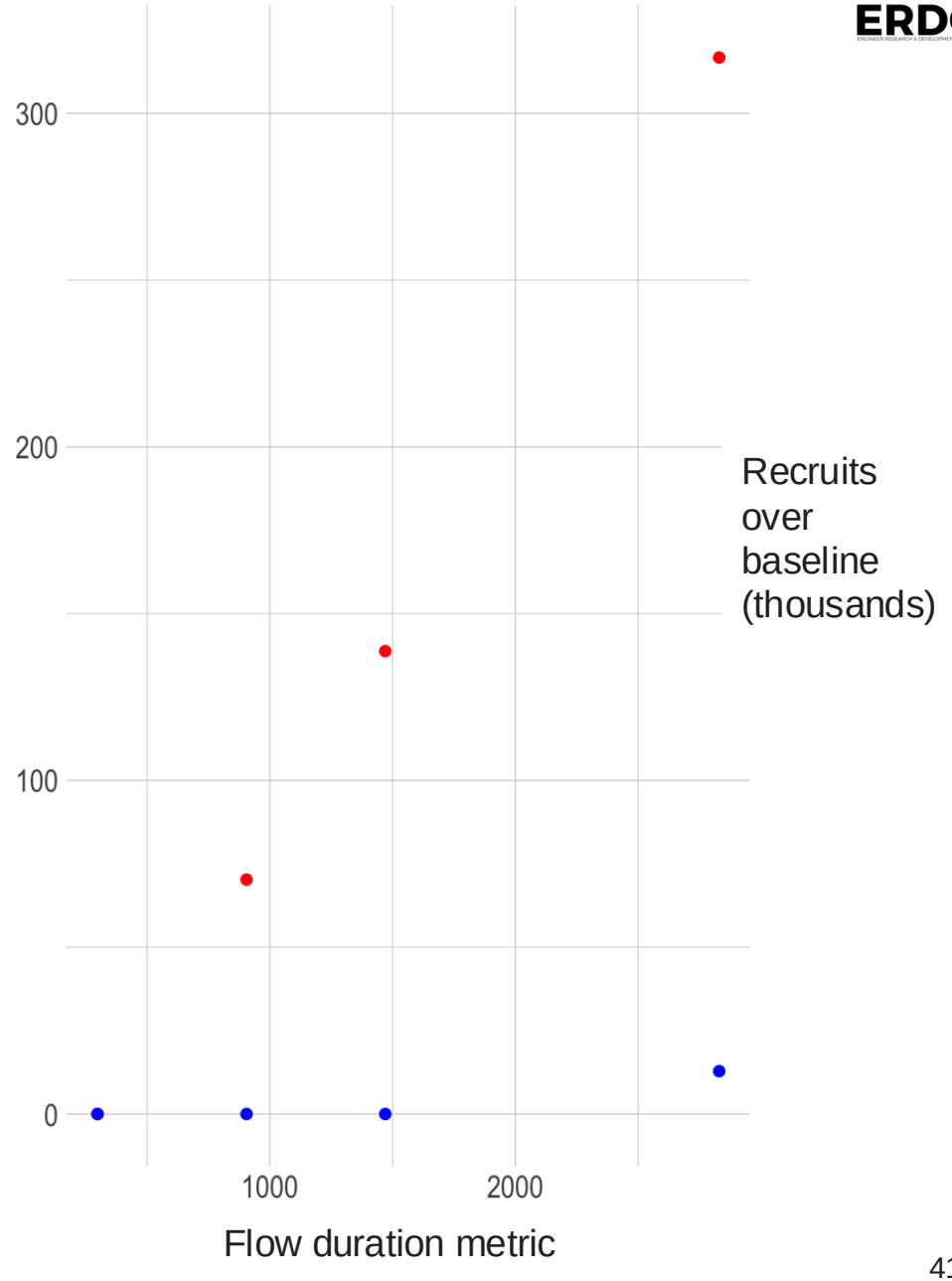

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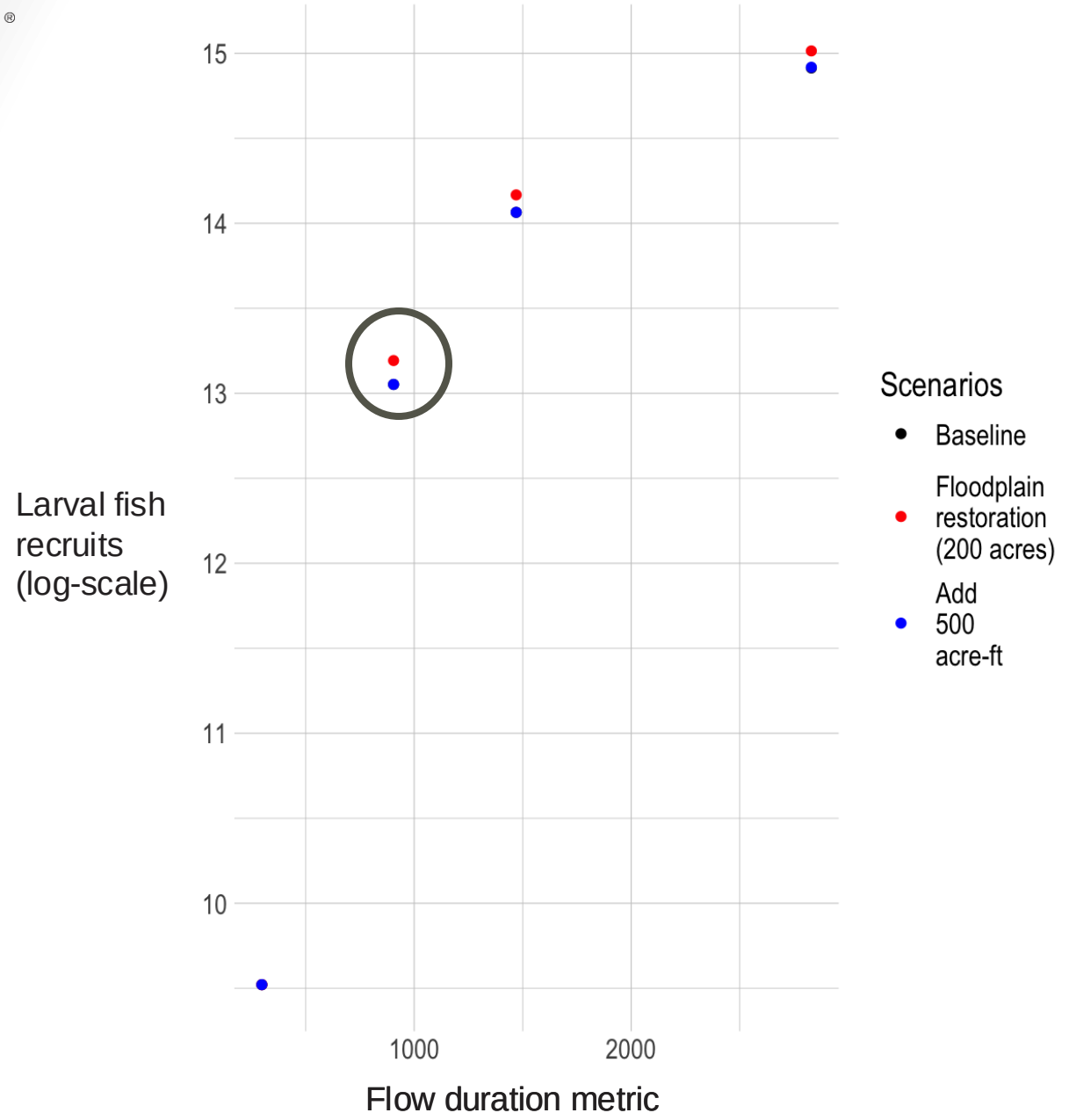

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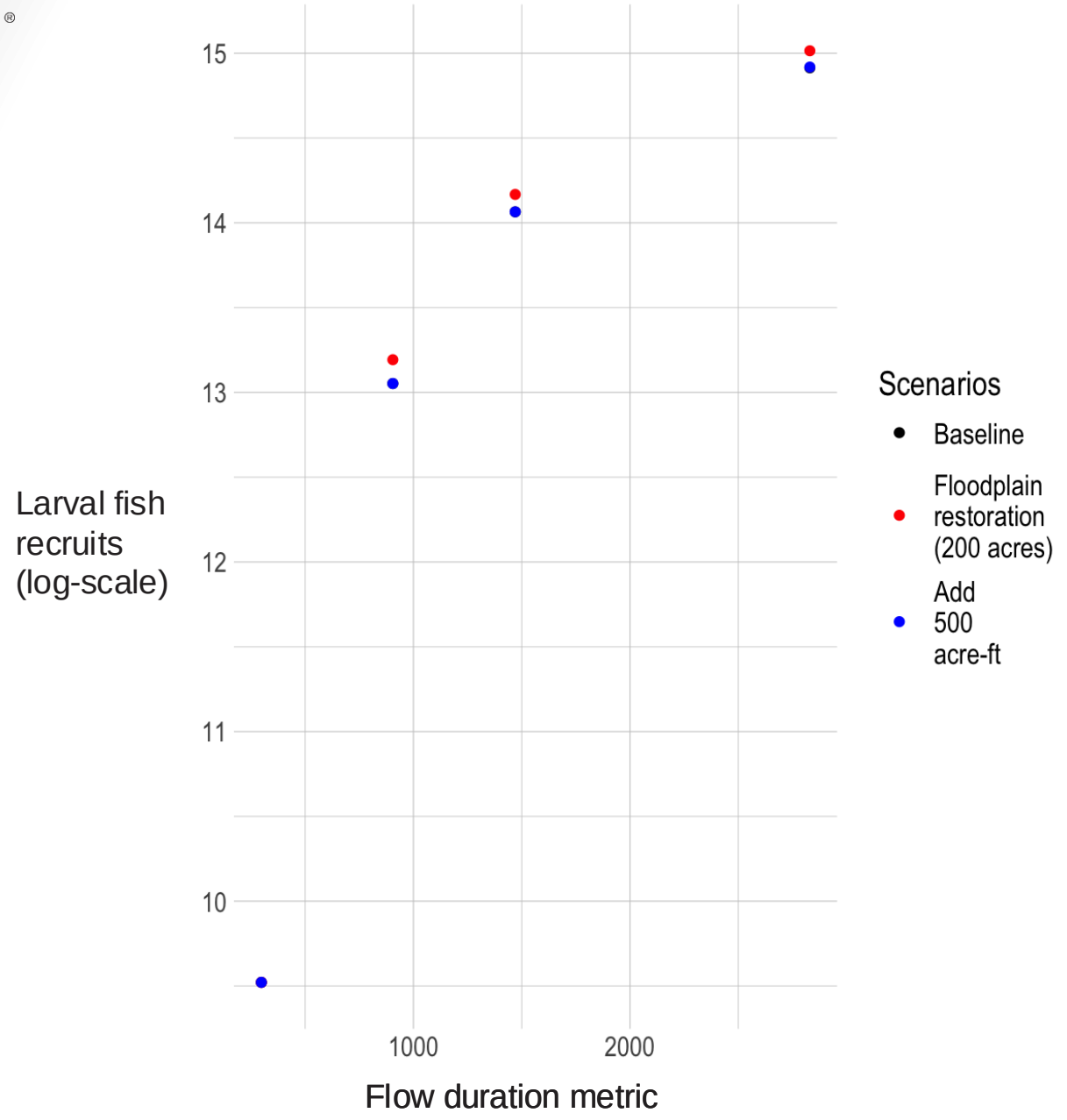
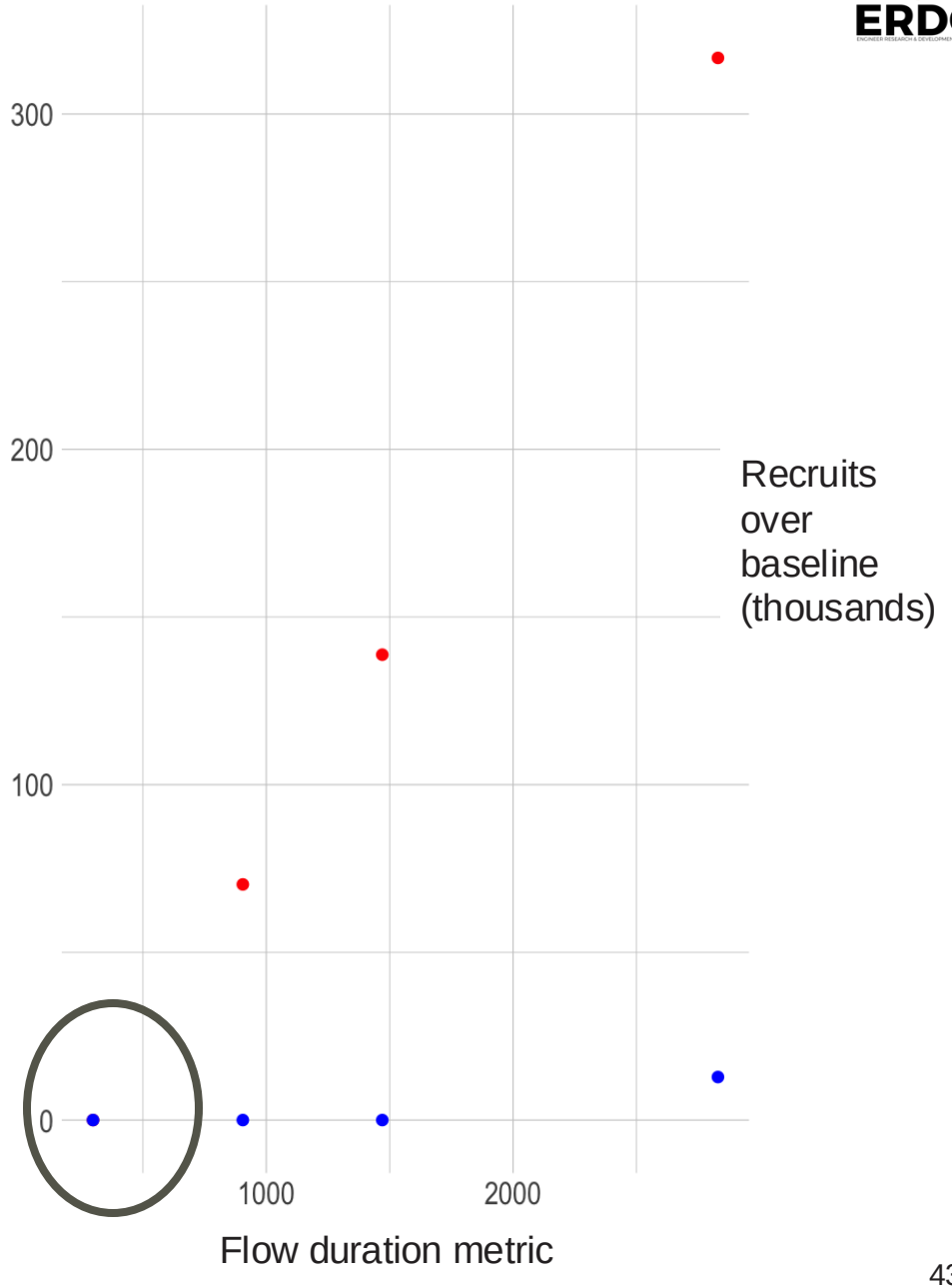
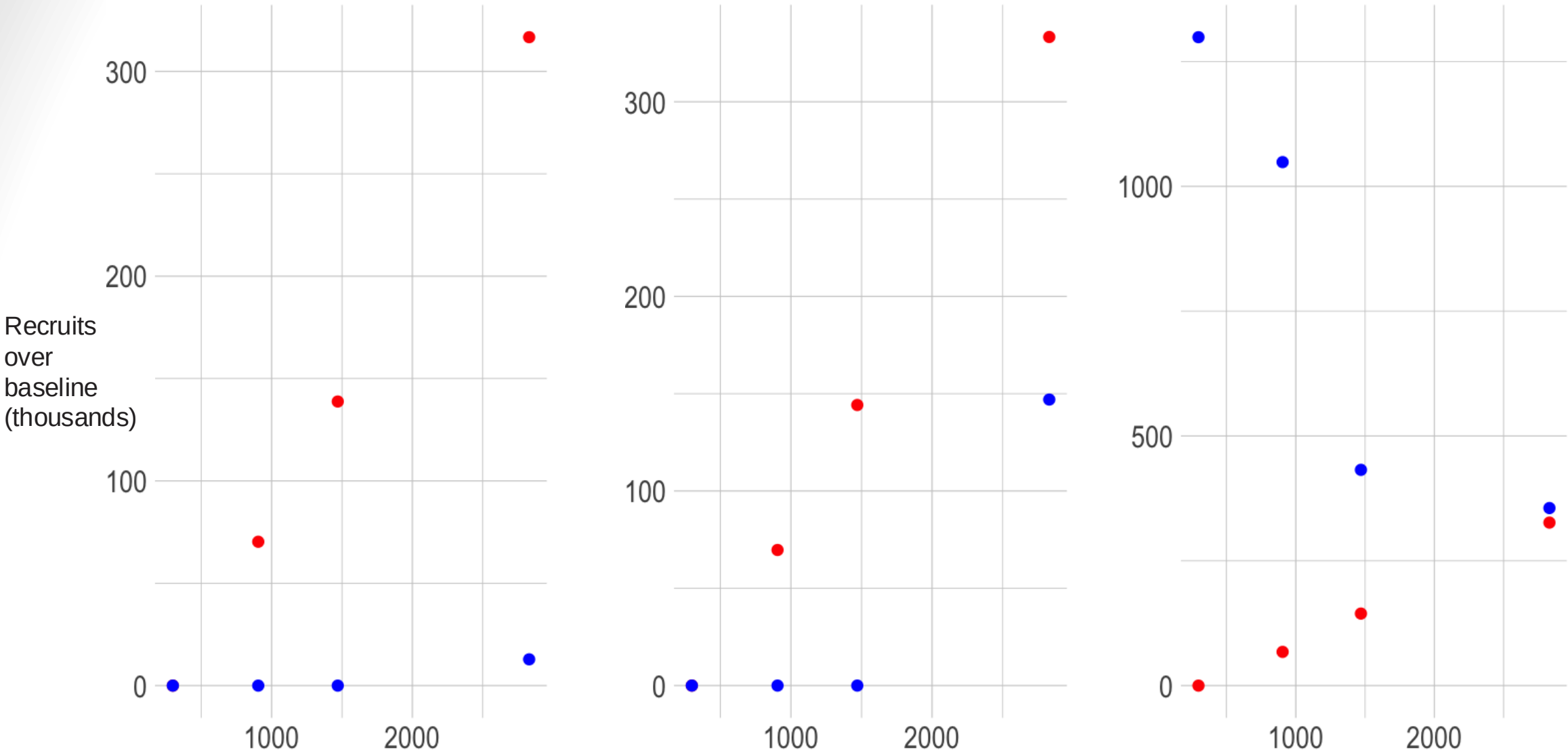


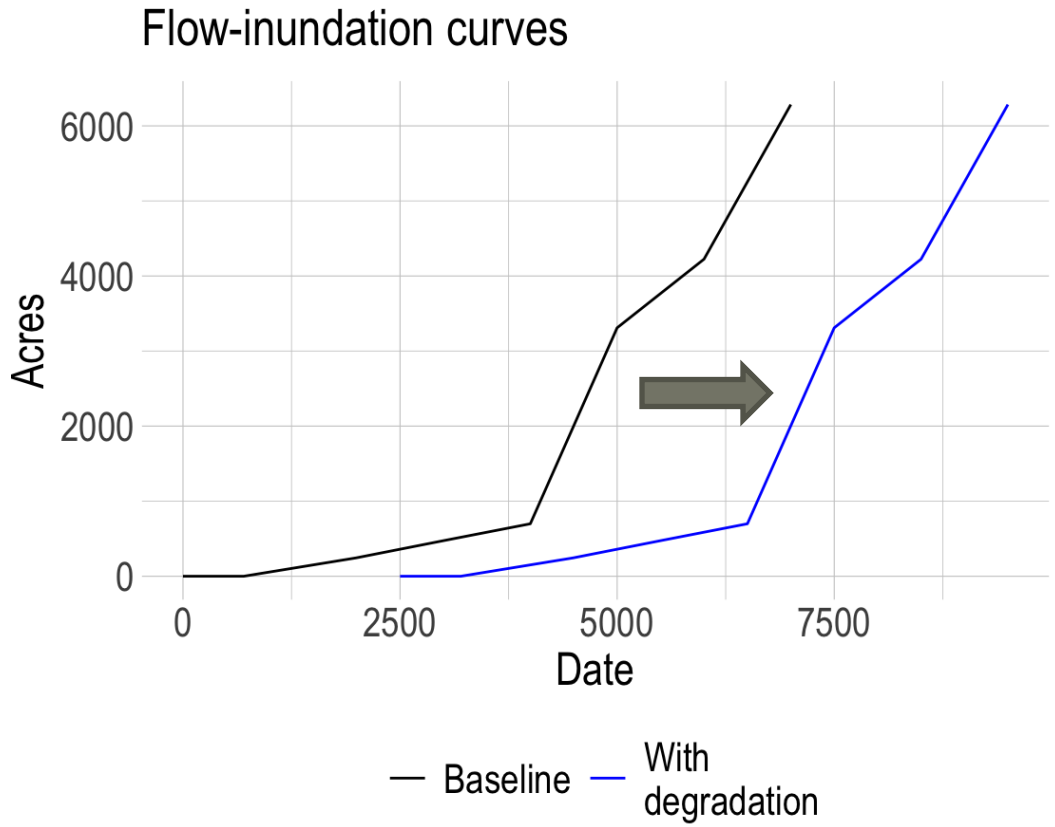



500 ac-ft
5,000 ac-ft
50,000 ac-ft
Recruits over baseline (thousands)
300
200
100
0
1000
2000
500
Flow duration metric

TOOL EXTENSIONS

Future without project

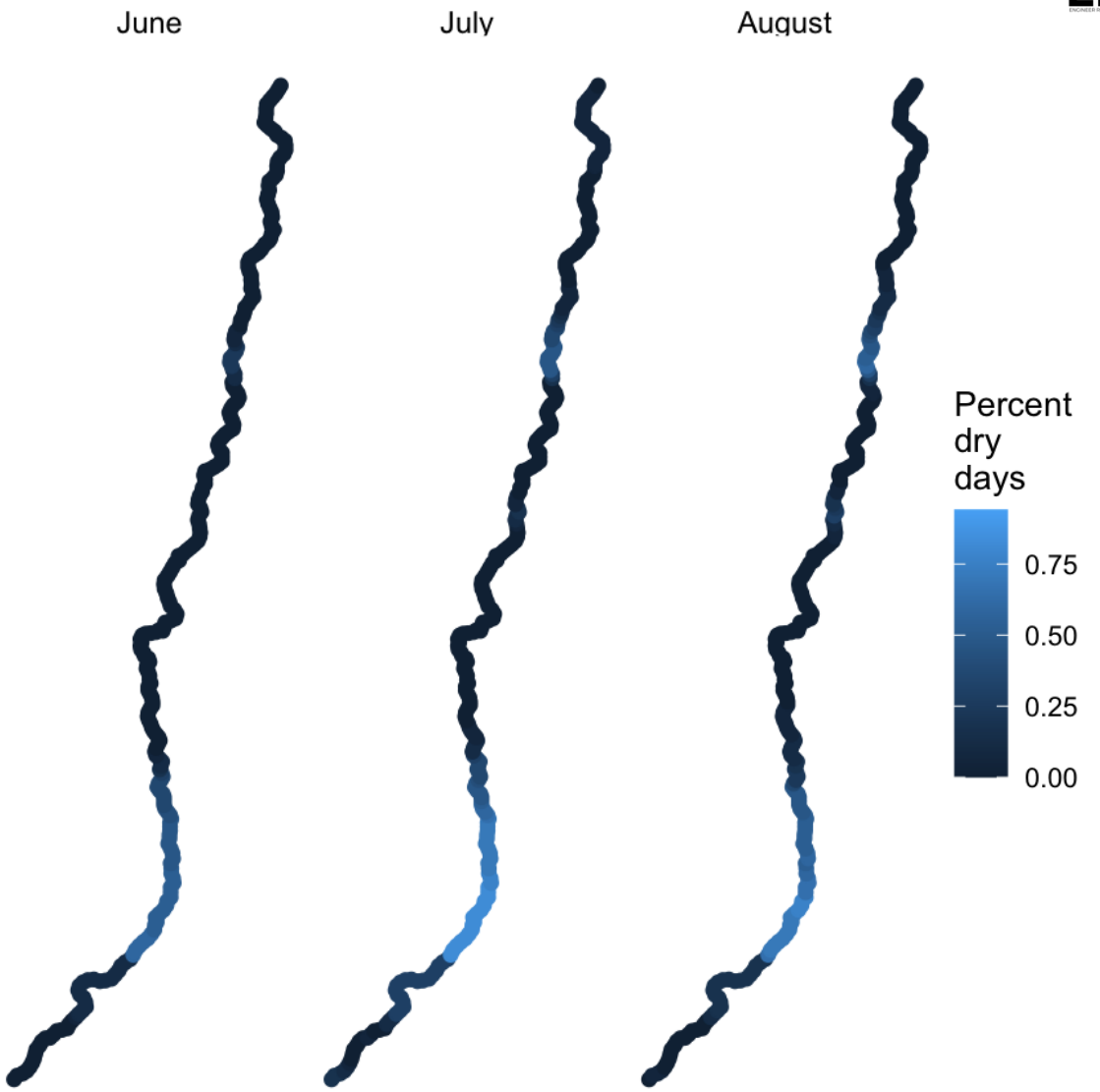
- With and without continued channel incision
- Continued degradation would shift overall flow-inundation curve
- Inundation then occurs only in high-flow years



TOOL EXTENSIONS

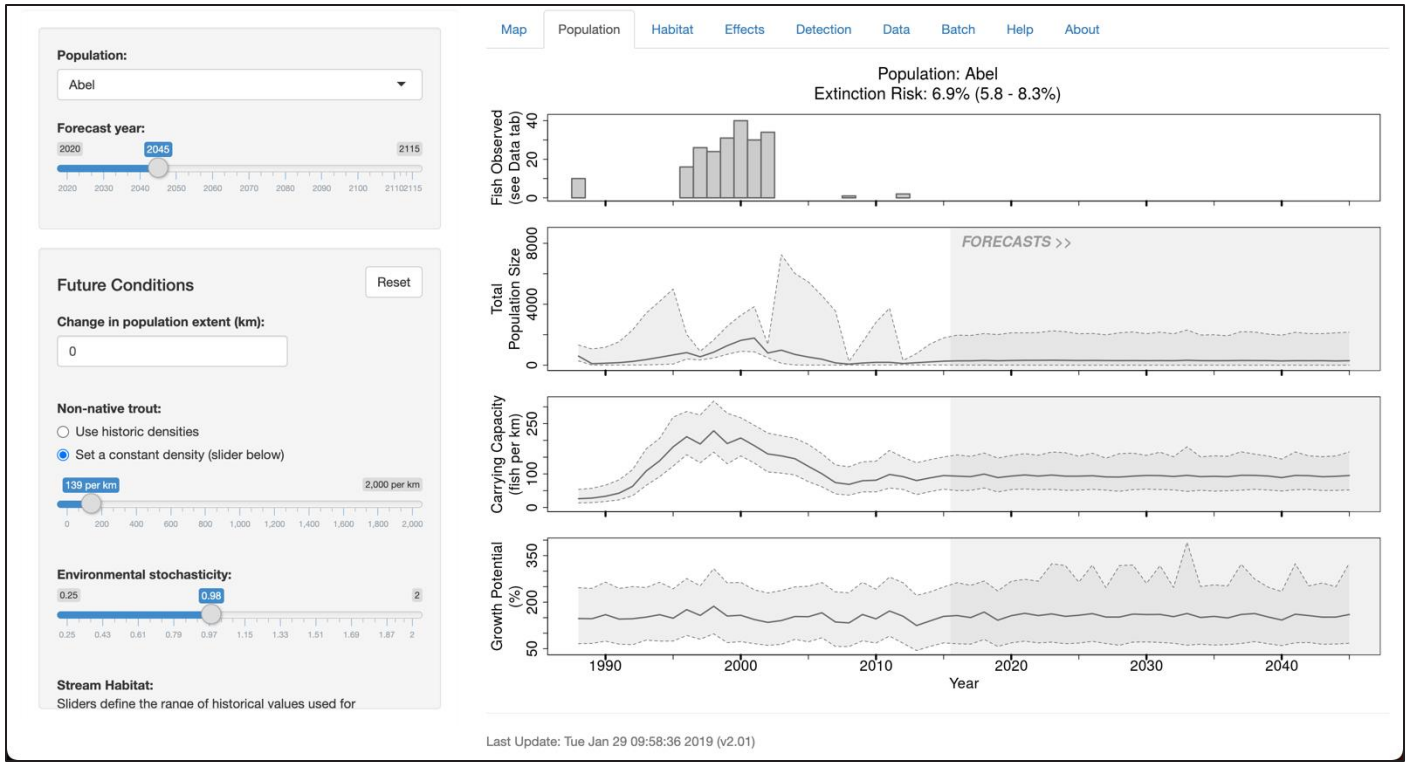
Include summer drying data

- Recruitment estimates can be multiplied by likelihood of drying
- Estimates could be calculated for specific time-periods or spatial increments



NEXT STEPS

- Further collaboration with District to adapt tool to their needs
- Package into ShinyApp or other tool that can be used by district personnel
- Work to incorporate full lifespan of restoration feature



Lahontan Cutthroat Trout ShinyApp

Leasure et al. 2018

CONCLUDING REMARKS

US Army Corps of Engineers®

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ENGINEER RESEARCH & DEVELOPMENT CENTER

ZOOMING OUT

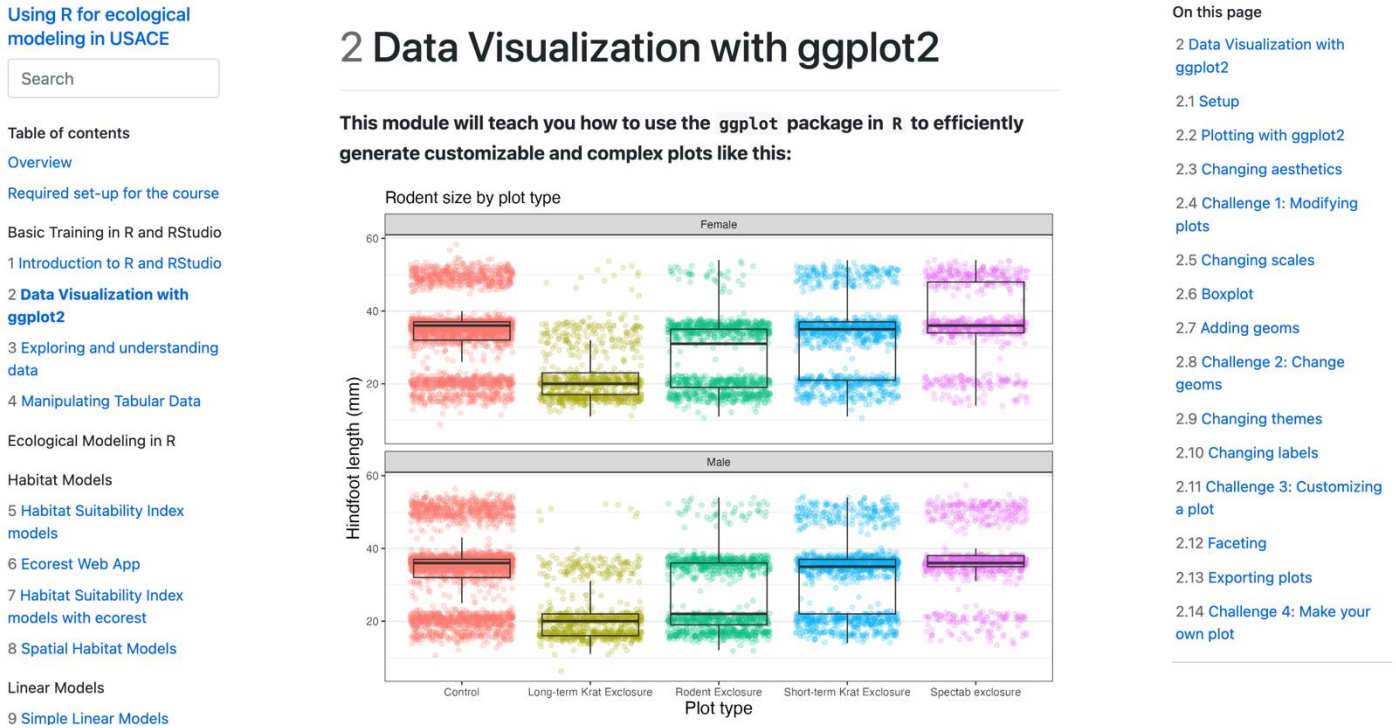
Use Cases that Models Can Inform	Habitat Model (what do we "get" now?)	Population Model (What could we "get"?)
Site prioritization	Sites that maximize habitat; strictly consider site-scale features	Population metrics incorporate exogenous features
Site-scale alternatives analysis	Tools that are directly responsive to typical engineering design parameters (velocity/depth)	Can utilize same site-scale info, but pop. parameters may vary based on other features (e.g., reach location)
Communication about restoration outcomes	Communication hinges on using a proxy for the underlying resource	Communication focuses on the resource of interest itself (fish)
Predictions that can be evaluated through monitoring	Models only validated indirectly through fish abundance and area correlations	Models can be directly validated by field data
Tracking benefits of many projects within system	Cannot capture "scaling up" because the models only assume patch-scale benefits	Captures synergies between flow, restoration, and other forms of mgmt

ZOOMING OUT

- Parallel projects
  - **Ecological modeling Tech Report in review**

ZOOMING OUT

- Parallel projects
  - Ecological modeling Tech Report in review
  - **Training modules on using R for ecological modeling**



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- Mick Porter, USACE
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- Water Research Integrating Socio-ecological and Engineered Systems (WRISES) Team

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