# Evaluating Riparian and In-Stream Habitat Conditions as Predictors of Freshwater Mussel Occupancy

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# Acknowledgments

Mussel surveys: Mitchell (2023)

Model ideas/feedback/data: Cushway et al. (2024) / Harris et al. (2023), Dr. Todd Swannack, Dr. Astrid Schwalb (Texas State University), Dr. Jeff Hepinstall-Cymerman (University of Georgia)

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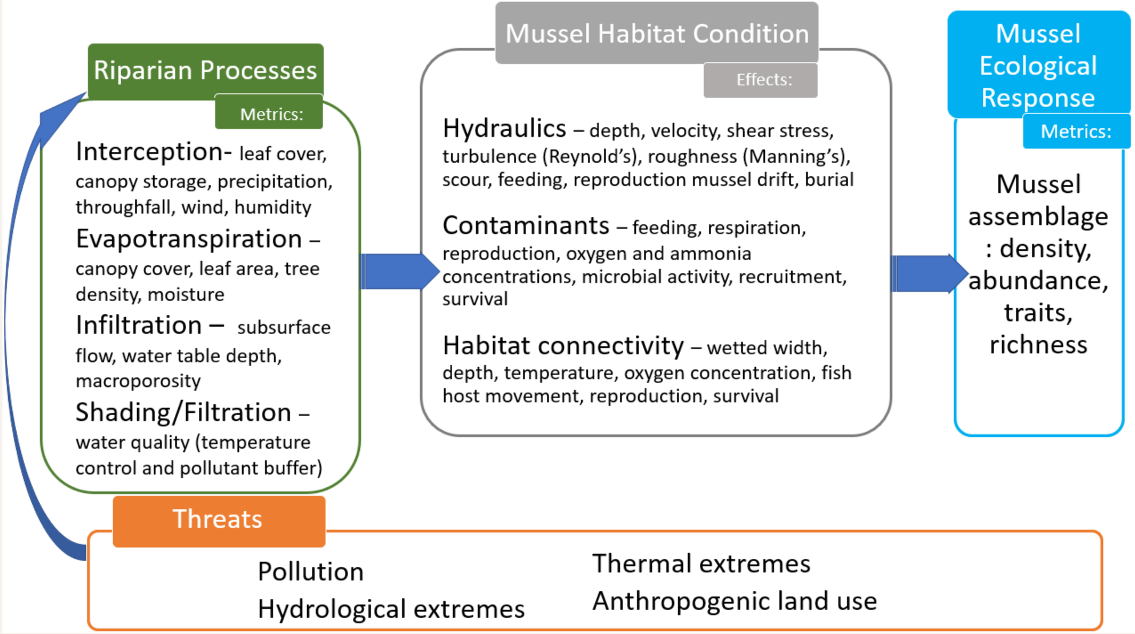
# Why This Study?

## Problem

- **Known-** Freshwater mussels are imperiled, mostly sessile organisms whose persistence depends on local flow, bed stability, dewatering risk, food delivery, host-fish movement, and thermal stress.
- **Missing link-** Riparian zones regulate shade, inputs, banks, and microclimate, but are not normally linked to mussel habitat condition.
- **Applied opportunity-** Habitat Suitability models can help translate statistical relationships intro habitat quality and restoration-priority maps (site selection).




*Hernandez-Abrams in Review*

# Hypotheses Tested

**H1.1** Riparian and in-stream features significantly influence mussel presence.

**H1.2** Combined riparian + hydraulic models outperform hydraulic only models.

**H2.1** Higher model-based suitability / occupancy probability is associated with riparian vegetation condition .

**H3.1** Low riparian condition in hydraulically suitable areas identifies candidate restoration reaches.

# Questions Associated to Hypotheses Tested

**H1.1**

**Do riparian and hydraulic features matter?**

Model screening →

Model coefficients + AICc support + Spearman rho

**H1.2**

**Do combined riparian + hydraulic models outperform single predictors?**

Strongest models combined →

Top models: Riparian + hydraulic, GLMs

**H2.1**

**Does occurrence probability rise with riparian vegetation?**

Model-averaged prediction curves →

Occupancy probability → SI/HSI

**H3.1**

**Where should restoration be prioritized?**

HSI + hydraulic/riparian matrix

Restoration priority zones

Key constraint: all hydraulic variable types were collinear ($|r| > 0.70$), so each combined model contains only one hydraulic covariate, plus one riparian covariate.

# Data & Analytical Approach

*All data temporally aligned to July 2018 low-flow conditions (0.42 m³/s, ~15 cfs)*

## Mussel Surveys

- 200 sites at 100 m spacing
- 11 species recorded (Mitchell 2023; Cushway et al. 2024)

Primary response: Presence/absence

Richness rejected: logistic occupancy fit 110 AICc units better than Poisson richness

## Riparian covariates

- PlanetScope (high res 3m imagery) July 21, 2018
- 16 candidate metrics from wetted channel edge (NDVI, SAVI, Hi-NDVI, NLCD canopy X 25, 50, 100, 200 m buffers upstream of site)

## Hydraulic Model

- 2D HEC-RAS (Harris et al. 2023) calibrated to July 2018
- Low flow conditions *(0.42 m³/s, ~15 cfs)*
- 6 hydraulic variable types

All mutually collinear (|r| > 0.70)

## Information-Theoretic Model Selection Framework (Burnham & Anderson 2002)

**1 Riparian screen**
16 single-predictor models

→

**2 Hydraulic screen**
6 single-predictor models

→

**3 Combined set**
13 models: hydraulic-only, NDVI + hydraulic, NDVI-only

→

**4 Model averaging**
95% confidence set + variable importance

→

**5 HSI mapping**
Predicted occupancy probability → rescaled HSI + suitability classes → restoration priority

# Which riparian metric best predicts mussel presence?

*AICc screening of 16 single-predictor logistic occupancy models: 4 vegetation metrics × 4 riparian buffer widths*

## Ranked model evidence for riparian covariates

| Rank | Predictor | Buffer | AICc | ΔAICc | $w_i$ | ρ |
|---|---|---|---|---|---|---|
| **1** | **Hi-NDVI cover** | **25 m** | **265.31** | **0.00** | **0.74** | **+0.25** |
| 2 | Mean NDVI | 25 m | 267.68 | 2.38 | 0.23 | +0.23 |
| 3 | Mean SAVI | 25 m | 272.38 | 7.07 | 0.02 | +0.18 |
| 4 | Hi-NDVI cover | 50 m | 275.12 | 9.81 | 0.01 | +0.13 |
| 5 | Mean NDVI | 50 m | 277.31 | 12.00 | <0.01 | +0.09 |
| 6–16 | Remaining metrics / wider buffers | 50–200 m | ≥279.52 | ≥14.22 | <0.01 | weak |

*Hi-NDVI = high-reflectance NDVI composite; SAVI = soil-adjusted vegetation index;*
*AICc Akaike Information Criterion corrected for small sample size.*
$w_i$ = Akaike weight; ρ = Spearman correlation with mussel presence.
Null AICc = 278.78

## Importance weights

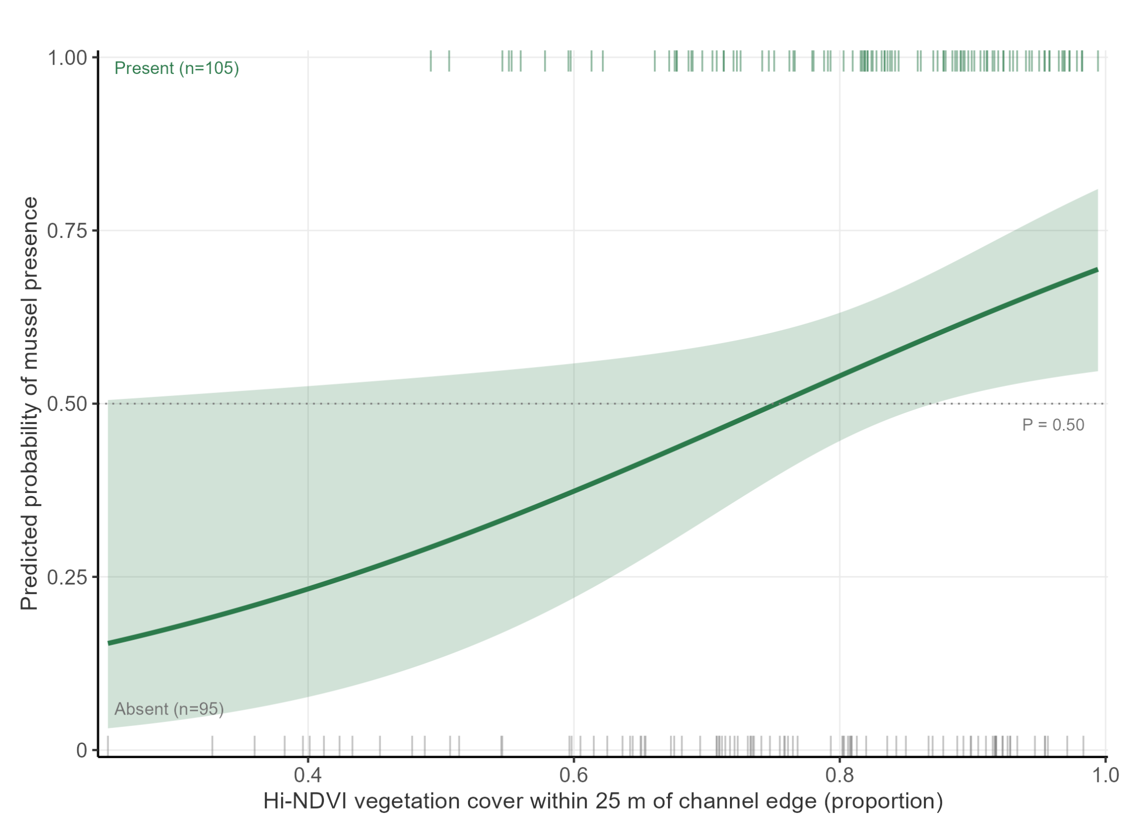
Summed Akaike weight ($\Sigma w_i$) shows which metric type or buffer width appears most often in well-supported models.

| Metric type | $\Sigma w_i$ | Rank |
|---|---|---|
| **Hi-NDVI cover** | **0.75** | **1** |
| Mean NDVI | 0.23 | 2 |
| Mean SAVI | 0.023 | 3 |
| NLCD canopy | 0.0015 | 4 |

| Buffer width | $\Sigma w_i$ | Rank |
|---|---|---|
| **25 m** | **0.99** | **1** |
| 50 m | 0.008 | 2 |
| 100 m | 0.002 | 3 |
| 200 m | 0.001 | 4 |

**Hi-NDVI cover within 25 m was carried forward as the riparian predictor.**
**Model support: $w_i$ = 0.74**
**Improvement vs. null: −13.5 AICc**
**Scale signal: 25 m: $\Sigma w_i$ = 0.99**
**Effect size: OR = 47.6**

# Mussel Presence Increases with Near-Channel Vegetation Cover




**At Hi-NDVI = 0.30**

## ~15%

predicted P(presence)
at low vegetation cover

**P = 0.50 crossed at**

## NDVI ≈ 0.78

sites below this threshold
more likely absent than present

**At Hi-NDVI = 1.00**

## ~70%

predicted P(presence)
at dense vegetation cover

**Rug pattern**

## Asymmetric

Present sites absent below
NDVI ≈ 0.50; absent sites
span full range

# Which hydraulic metric best predicts mussel presence?

*AICc screening of 6 single-predictor logistic occupancy models: one hydraulic variable type per model*

## Ranked model evidence for hydraulic metrics

| Rank | Predictor | AICc | ΔAICc | $w_i$ | ρ |
|---|---|---|---|---|---|
| **1** | **Depth max (m)** | **229.11** | **0.00** | **0.90** | **+0.54** |
| 2 | Froude median | 234.92 | 5.81 | 0.049 | −0.56 |
| 3 | Velocity median (m/s) | 234.97 | 5.86 | 0.048 | −0.54 |
| 4 | Top width (m) | 252.46 | 23.34 | <0.0001 | +0.36 |
| 5 | Shear stress median | 265.05 | 35.94 | ≈0 | −0.53 |
| 6 | Stream power median | 271.49 | 42.38 | ≈0 | −0.54 |

## Maximum pool depth was the best single hydraulic predictor

**Model support: $w_i$ = 0.90**
**Improvement vs. null: −49.7 AICc**
**Next best models: ΔAICc ≈ 5.8**

# Do combined riparian + hydraulic models outperform single predictors?

*Tested with a 13-model candidate set: 6 hydraulic-only + 6 NDVI + hydraulic + 1 riparian-only model*

## AICc ranking of the candidate set

| Rank | Model | Type | ΔAICc | $w_i$ | 95% set |
|---|---|---|---|---|---|
| **1** | **NDVI + Velocity** | **Combined** | **0.00** | **0.616** | **Yes** |
| **2** | **NDVI + Froude** | **Combined** | **1.99** | **0.228** | **Yes** |
| **3** | **NDVI + Depth** | **Combined** | **3.86** | **0.089** | **Yes** |
| **4** | **Depth** | **Hydraulic** | **4.70** | **0.059** | **Yes** |
| 5 | Froude | **Hydraulic** | 10.50 | 0.003 | |
| 6 | Velocity | **Hydraulic** | 10.55 | 0.003 | |
| 7 | NDVI + TopWidth | **Combined** | 11.48 | 0.002 | |
| 12 | NDVI | **Riparian** | 40.89 | ≈0 | |
| 13 | StreamPow | **Hydraulic** | 47.07 | ≈0 | |

**Combined models outperformed single-predictor models.**

**Top 3 models**

All 3 were combined models; ΔAICc = 0.0–3.9.

**Best single predictor**

Depth alone ranked 4th (ΔAICc = 4.70, $w_i$ = 0.059).

**Riparian alone**

NDVI-only ranked 12th (ΔAICc = 40.89, $w_i \approx 0$).

**95% confidence set**

4 models: NDVI+Velocity, NDVI+Froude, NDVI+Depth, and Depth; cumulative $w_i$ = 0.991.

# What does the top combined model tell us?

## Logistic regression coefficients for the *top-ranked combined model: NDVI + Velocity*

All predictors were standardized (z-scores).

| Parameter | β | SE | z | p | Odds ratio | 95% CI (OR) |
|---|---|---|---|---|---|---|
| Intercept | 0.0433 | 0.1679 | 0.258 | 0.797 | 1.044 | 0.752–1.451 |
| **Hi_NDVI_Mean_25m (std)** | **0.5918** | **0.1763** | **3.357** | **<0.001** | **1.807** | **1.279–2.553** |
| **Velocity_MEDIAN (std)** | **−1.1380** | **0.2056** | **−5.536** | **<0.001** | **0.321** | **0.214–0.480** |

**Model fit**

n = 200 | AICc = 224.414 | ΔAICc vs. null = −54.365
McFadden $R^2$ = 0.211 | Accuracy = 73.5% | Sensitivity = 66.0% | Specificity = 79.0%

**The top model included both riparian vegetation and velocity.**

**Hi-NDVI effect**

Positive and significant
$\beta = 0.592$, $p < 0.001$
OR = 1.81

**Velocity effect**

Negative and significant
$\beta = -1.138$, $p < 0.001$
OR = 0.32

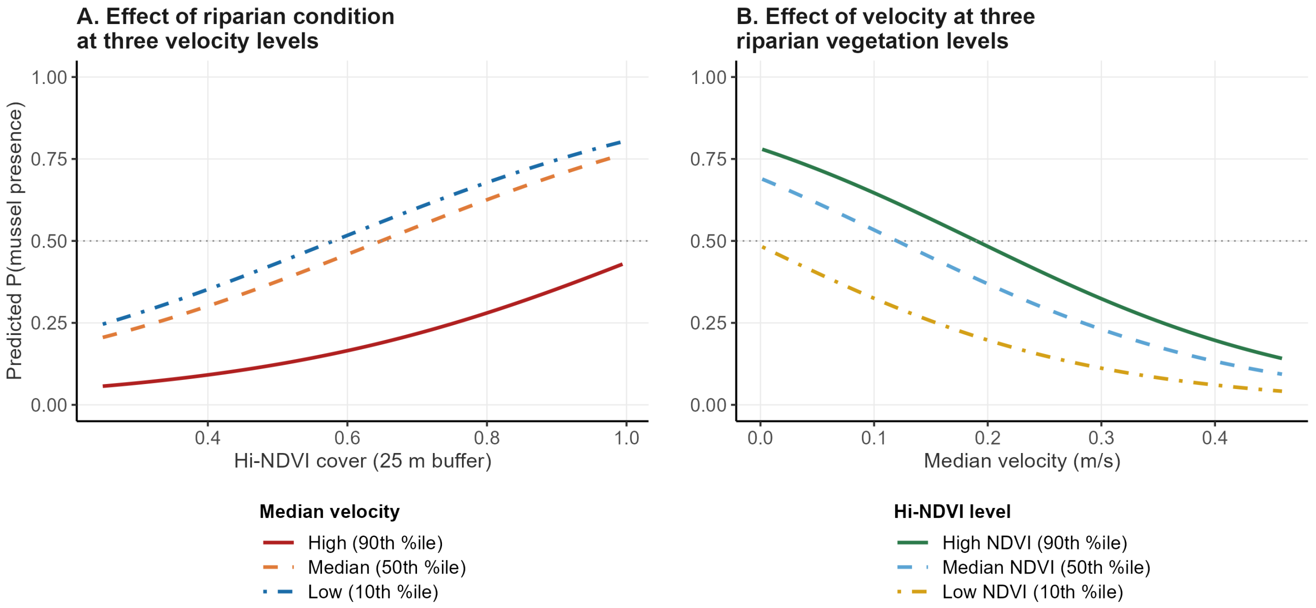
**Relative strength**

Velocity had the larger standardized effect size, suggesting hydraulics were the stronger local predictor.

**Occupancy increased with vegetation cover and decreased with higher velocity.**

Mussels were most likely where riparian vegetation was strong and local hydraulic conditions were relatively slow

# Riparian Condition and Velocity Jointly Determine Occupancy Probability




## Ecological context

Dense riparian cover helps, but cannot compensate for high velocity

At high velocity (90th %ile), P(presence) stays below 0.50 even at maximum NDVI

Low velocity sites benefit most from riparian restoration

*Note: velocity range reflects 15 cfs low-flow only — higher discharge scenarios untested*

# From Riparian-Instream Presence/Absence Model to Habitat Suitability Index

*H2.1 / H3.1 — Empirical HSI framework (Layzer & Madison 1995)*

1. **Best model coefficients**
   NDVI + Velocity
   $b_0$, β_NDVI, β_vel

2. **Logistic prediction**
   P (presence)
   per pixel

3. **Min-max rescaling**
   SI = (P − P_min)
   / (P_max − P_min)

4. **Suitability classes**
   Low / Moderate
   / High classification

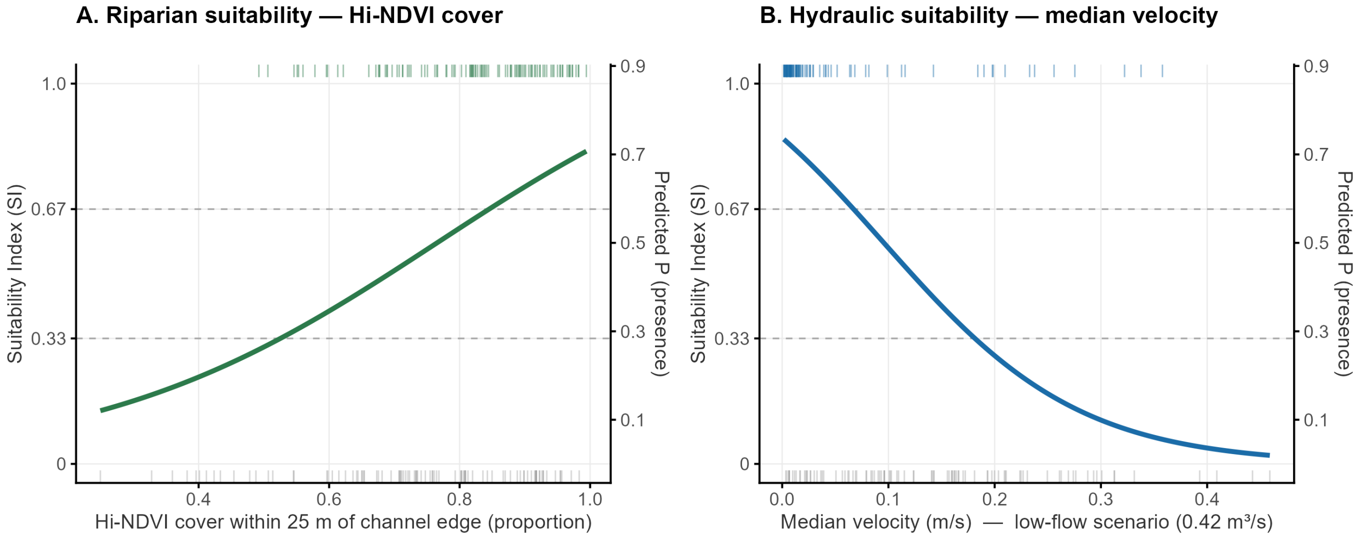
5. **Restoration priority map**
   Velocity × NDVI
   matrix

**Key constraint:** All hydraulic variables were mutually collinear ($|r| > 0.70$). Each model contains only one hydraulic covariate paired with Hi-NDVI. The NDVI + Velocity model ($\Delta AICc = 0.00$, $w_i = 0.62$) was carried forward for spatial prediction. Predictions are conditioned on the low-flow scenario (0.42 $m^3/s$, ~15 cfs, July 2018) and should not be extrapolated to higher discharge conditions.

# Empirical Suitability Index (SI) Curves

*Derived from the best-supported logistic model; SI = linear rescaling of P(presence) to 0–1*

**Empirical suitability index (SI) curves derived from the best-supported logistic model**




### Riparian SI (Panel A)

Positive trend - suitability rises continuously with Hi-NDVI cover. SI = 0.67 threshold not reached within observed range when velocity is at mean → NDVI alone is necessary but not sufficient.

### Hydraulic SI (Panel B)

Steep negative decline - SI crosses Low to Moderate boundary (0.33) at only ~0.20 m/s. High velocity rapidly dominates and overrides riparian benefits.

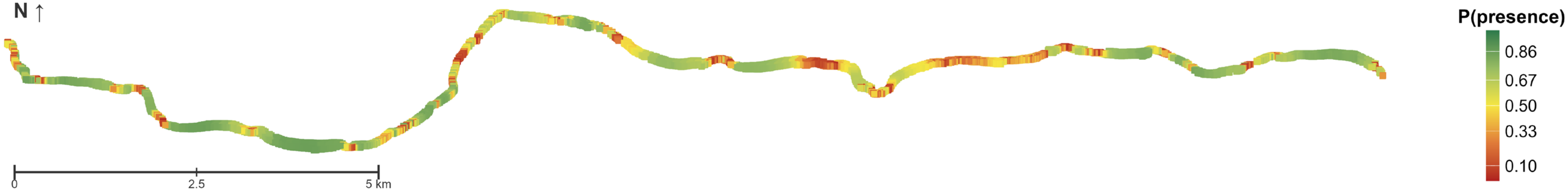
### Class boundaries

Dashed lines at SI = 0.33 and 0.67 correspond to P = 0.33 and P = 0.67 — points where presence is twice as unlikely, or twice as likely, as absence.

# Predicted P (Mussel Presence)

*H2.1 — Continuous probability surface from best model (NDVI + Velocity) | Low-flow scenario (0.42 m³/s, July 2018) | Reach length ~20 km*

**A. Predicted P (mussel presence) — Upper San Saba River**




**0.620**

Mean P(presence) across wetted area

**74.2%**

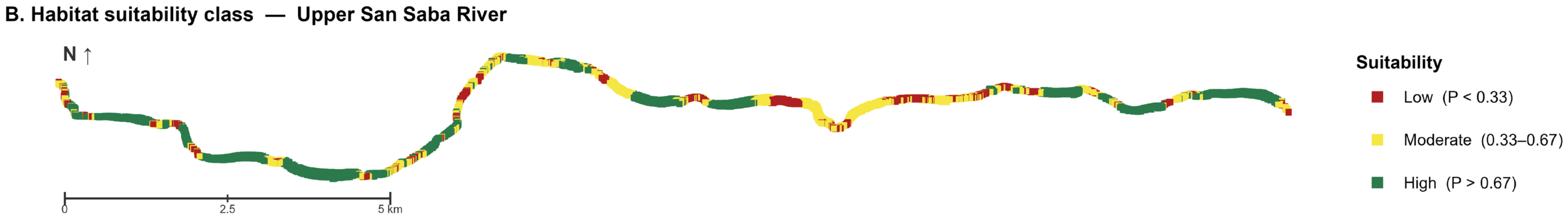
Wetted area with P > 0.50

**0.000–0.860**

Predicted probability range

# Habitat Suitability Classification — Upper San Saba River

*H2.1 — Low / Moderate / High classes from P(presence) thresholds | Low-flow scenario (0.42 m³/s, July 2018)*




### HIGH suitability

***P > 0.67***

**57.6%** of wetted area

Dominates the reach - dense riparian cover + slow pools.

### MODERATE suitability

***0.33 ≤ P ≤ 0.67***

**27.8%** of wetted area

Transition zones between hydraulic pools and riffles; lateral channel margins.

### LOW suitability

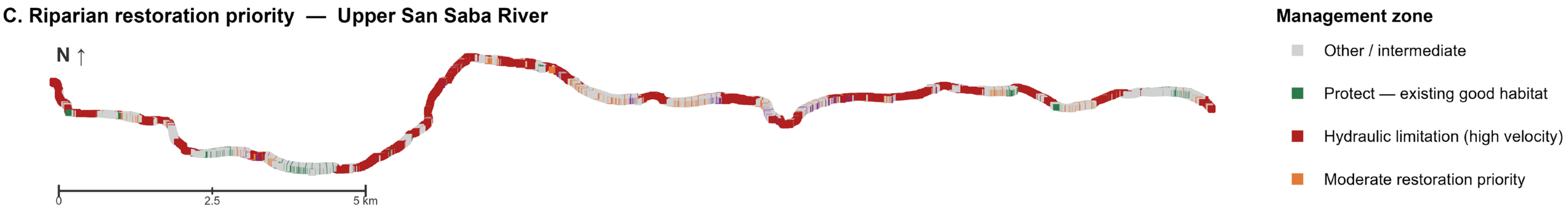
***P < 0.33***

**14.6%** of wetted area

High-velocity constrictions; reach sections with reduced NDVI.

# Riparian Restoration Priority

*J velocity × Hi-NDVI tertile classification*




### HIGH Restoration

**0.6% of wetted area**

Low vel + low NDVI = highest ecological leverage

### Moderate Restoration

**2.5% of wetted area**

Partial constraint in one dimension

### Hydraulic Limitation

**33.0% of wetted area**

High velocity - riparian alone cannot compensate

### Protect Existing

**1.5% of wetted area**

Low vel + high NDVI = conserve

### Other / Intermediate

**62.4% of wetted area**

Middle tertiles — neither priority

# Conclusions

**H1.1 ✓**

**Both riparian vegetation and velocity significantly predict mussel presence**

*OR = 1.81 (NDVI) · OR = 0.32 (velocity) · both $p < 0.001$*

**H1.2 ✓**

**Combined riparian + hydraulic models outperformed all single-predictor models**

*Top 3 models all combined · NDVI-only ranked 12th ($\Delta$AICc = 40.9)*

**H2.1 ✓**

**Occupancy probability rises with Hi-NDVI cover and falls steeply with velocity**

*P crosses 0.50 at NDVI ≈ 0.78 · 57.6% of reach is High suitability · mean P = 0.62*

**H3.1 ✓**

**Riparian condition identifies restoration targets, but hydraulics is higher influence**

*High priority = 0.6% of reach · Hydraulic limitation dominates = 33.0% of reach*

# Limitations

*Necessary caveats for interpreting results*

01

## Single discharge scenario

All results conditioned on 0.42 $m^3/s$ (July 2018) - predictions do not apply at higher flows

02

## One-time riparian snapshot

PlanetScope imagery and surveys from July 2018 only - seasonal and inter-annual variation not captured

03

## Presence/absence only

11 species recorded but HSI does not discriminate among them - species-specific models needed

04

## Correlation, not causation

Model predicts where habitat is currently favorable, does not prove riparian restoration will increase occupancy

# Future Directions

*Next steps to strengthen and extend the HSI framework*

### Multi-flow HSI

Run HSI at multiple discharges
using existing HEC-RAS model

### Include other mussel-relevant covariates

Temperature model?
Shade covariates, if possible

### Spatio- Temporal replication

Repeat surveys + imagery
to test inter-annual stability

### Species-specific models

Separate HSI per species
for ESA consultation support?

### Model transfer

Apply to lower San Saba River?

# Thank You

Questions? Suggestions?