Estimating flow and nonflow management impacts on Rio Grande Silvery Minnow by integrating data, research, and expert opinion

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U.S. Department of the Interior
U.S. Geological Survey

Many thanks

- *In collaboration with Thomas P Archdeacon, Richard A. Valdez, Monika Hobbs, Michael D. Porter, Joel Lusk, Ashley Tanner, Eric J. Gonzales, Debbie Y Lee, and Grace M. Haggerty.*
- *Thanks to the New Mexico Interstate Stream Commission and the Albuquerque Bernalillo County Water Utility Authority who funded my involvement.*
- *Thanks also to Kate Mendoza, Dave Wegner, Steve Zipper, Rob Dudley and ASIR.*

Outline

- Motivation

- Model structure and data
  - Demographic processes
  - Observation processes

- Model results
  - Expert elicitation
  - Model evaluation
  - Biological inferences

- Assessing management effectiveness
  - Flow management
  - Nonflow management

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Why build a model?

- Predict outcomes of management and associated uncertainty.
- Evaluate multiple competing hypotheses.
- Determine monitoring, and research to reduce uncertainty / discriminate amongst competing hypotheses.

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Why build a model collaboratively?

- A group can develop and operationalize multiple competing hypotheses better (but maybe not quicker) than one person.

- Increase transparency and minimize unintended assumptions.

Why build an integrated model?

Lots of different data being collected

- CPE monitoring
- Rescue data
- River eyes data
- Meso-habitat availability surveys
- Flow vs. larval habitat availability studies
- Reproduction field studies
- Reproduction laboratory studies

Lots of ongoing management

- Spring flows
- River drying / Pumping
- Fish rescue
- Augmentation
- Restoration

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Model basics

- Three river segments and four age classes: Age 0, Age 1, Age 2+ and augmented fish.
- Key processes occur on April 1^{st}, July 1^{st} and November 1^{st}.
- Daily predictions are made between these dates based on drying, rescue, etc.
- Predictions are compared to monitoring and rescue data using daily discharge at either San Acacia or Angostura to adjust parts of the observation process.
- Four population abundance estimates by ASIR essential to make absolute instead of relative abundance estimates.

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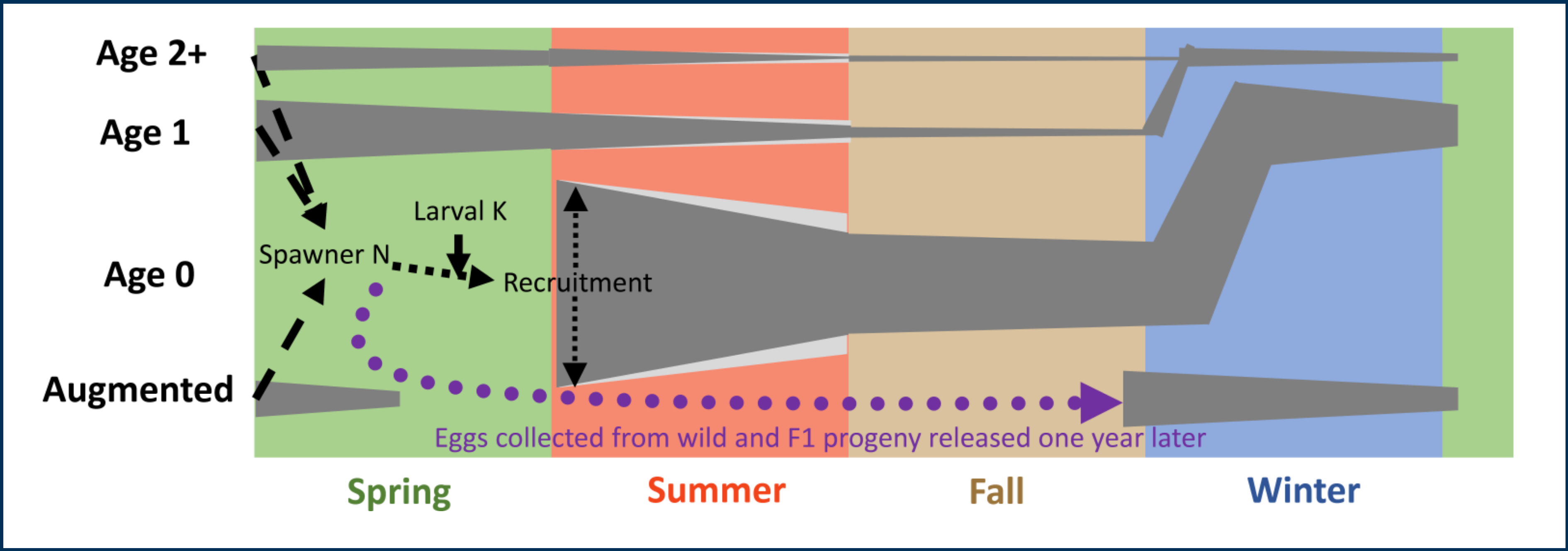
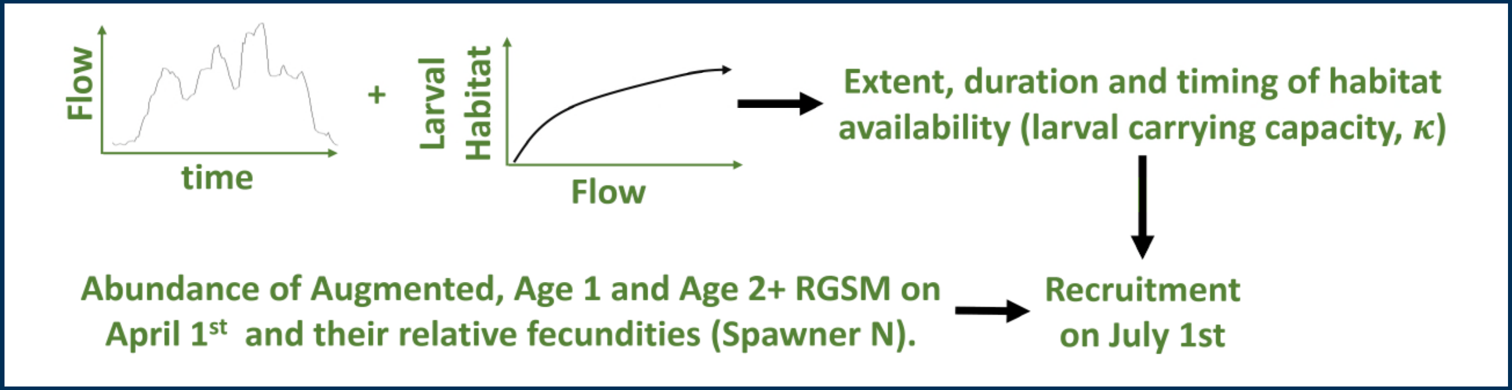
Population processes in the integrated model





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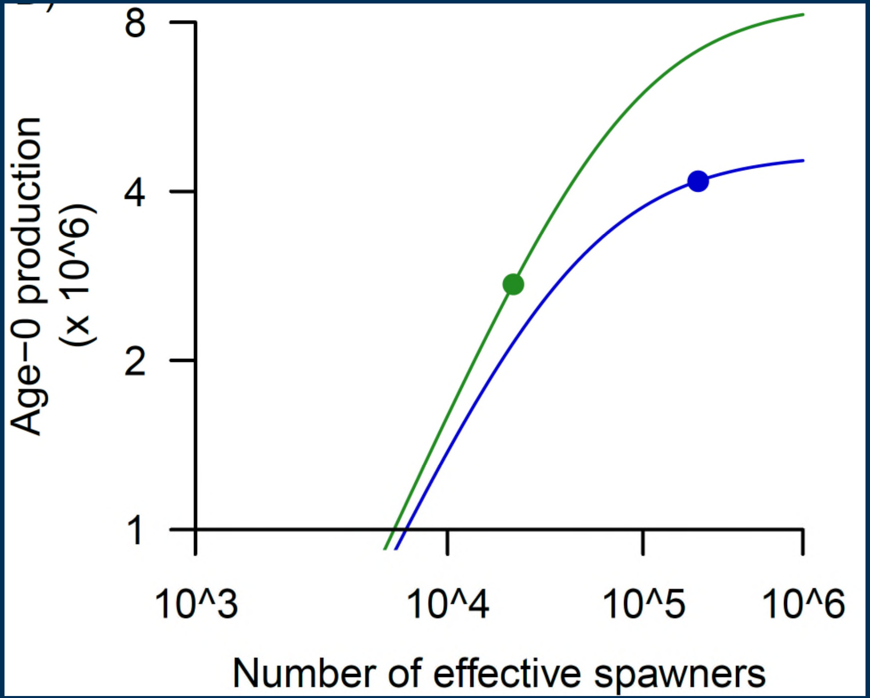
Predicting recruitment from spawner abundance and larval carrying capacity index

- Beverton-Holt (1957)
- Rio Grande Silvery Minnow limited by larval habitat availability
  - How is larval habitat availability related to discharge?
  - How long is habitat needed for larval development?
  - When is larval habitat needed?
  - What are cues for spawning?



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Expert elicitation Delphi process

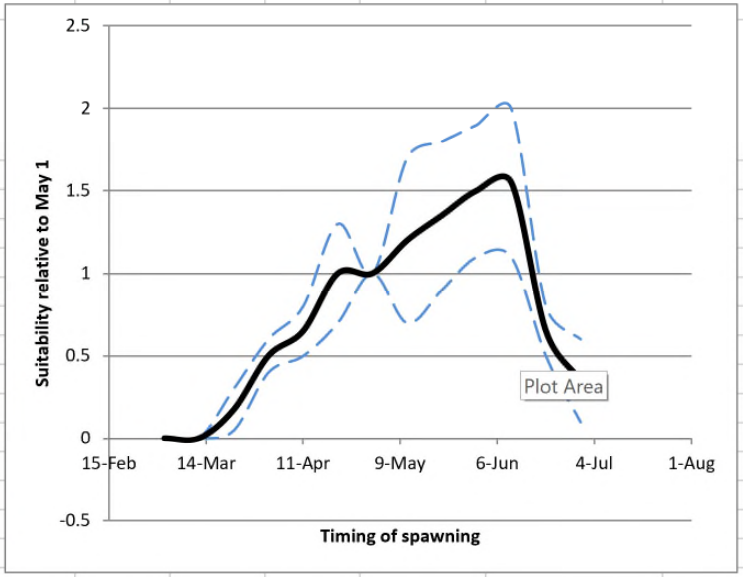
Description: It appears to be well agreed that RGSM are not strictly synchronous in their spawning, particularly in years when water (and thus larval habitat) are readily available. We are interested in quantifying the proportion of individuals that might be expected to lay eggs at different times throughout the spring and early summer when water (and any cue for spawning are not limiting). We choose as a reference, May 1st, and fix its values to 1 and then ask experts to quantify how much more, or less likely, an individual RGSM is to produce eggs on other days relative to May 1st. For example, a value of 1.5 indicates and individual would be 50% more likely to produce eggs relative to May 1st, whereas a value of 0.1 indicates an individual would only be 10% change as likely to produce eggs as on May 1st.

It is important for experts to keep in mind:

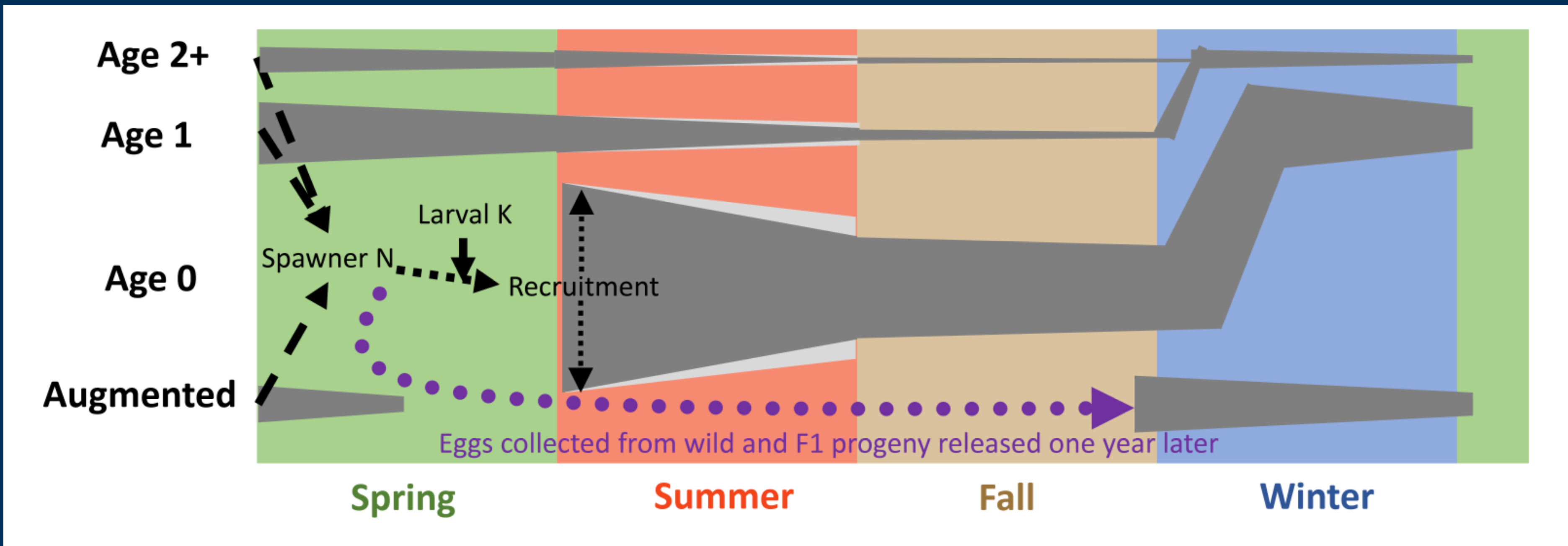
1)The function being estimated is based on when eggs are produced and may differ from back-calculated hatch dates if larval habitat availability (and thus survival) differs substantially.

2)We are focusing on the timing of egg-laying when cues are not limiting (i.e., in wet years).

Date	lower CI	upper CI	probability truth is within your lower and upper CI (not graphed)	best guess (mean)	upper CI > lower CI	95 >= CI >= 50	upper CI >= mean >=lower CI
2-Mar	0.001	0.002	95	0.0015	1	1	1
12-Mar	0.001	0.002	90	0.0015	1	1	1
22-Mar	0.05	0.3	80	0.175	1	1	1
1-Apr	0.4	0.6	75	0.5	1	1	1
11-Apr	0.5	0.8	75	0.65	1	1	1
21-Apr	0.7	1.3	75	1	1	1	1
1-May	1	1	NA	1			
11-May	0.7	1.7	75	1.2	1	1	1
21-May	0.9	1.8	80	1.35	1	1	1
31-May	1.1	1.9	80	1.5	1	1	1
10-Jun	1.1	2	80	1.55	1	1	1
20-Jun	0.5	0.8	80	0.65	1	1	1
30-Jun	0.1	0.6	80	0.35	1	1	1



Population processes in the integrated model



$$N^0_{d,y,r} = P_{r,y} \cdot e^{-(d-91)M^0_{r,y}} \cdot \left[\left(1-\delta_{d,y,r}\right) + \tau\left(\delta_{d,y,r} - \delta_{91,y,r}\right) + (1-\tau)r_0\left(\varphi_{d,y,r} - \varphi_{91,y,r}\right)\right]$$

- $P_{r,y} \cdot e^{-(d-91)M^0_{r,y}}$: Production as of July 1st (91 days after March 1st) and natural mortality
- $\left(1-\delta_{d,y,r}\right)$: Proportion of reach that has not dried
- $\tau\left(\delta_{d,y,r} - \delta_{91,y,r}\right)$: Proportion of age-0's exposed to drying after July 1st that moved to escape mortality - before July 1st, all age-0's exposed to drying are assumed to die
- $(1-\tau)r_0\left(\varphi_{d,y,r} - \varphi_{91,y,r}\right)$: Proportion of age-0's exposed to drying after July 1st that did not move, were rescued, and survived.

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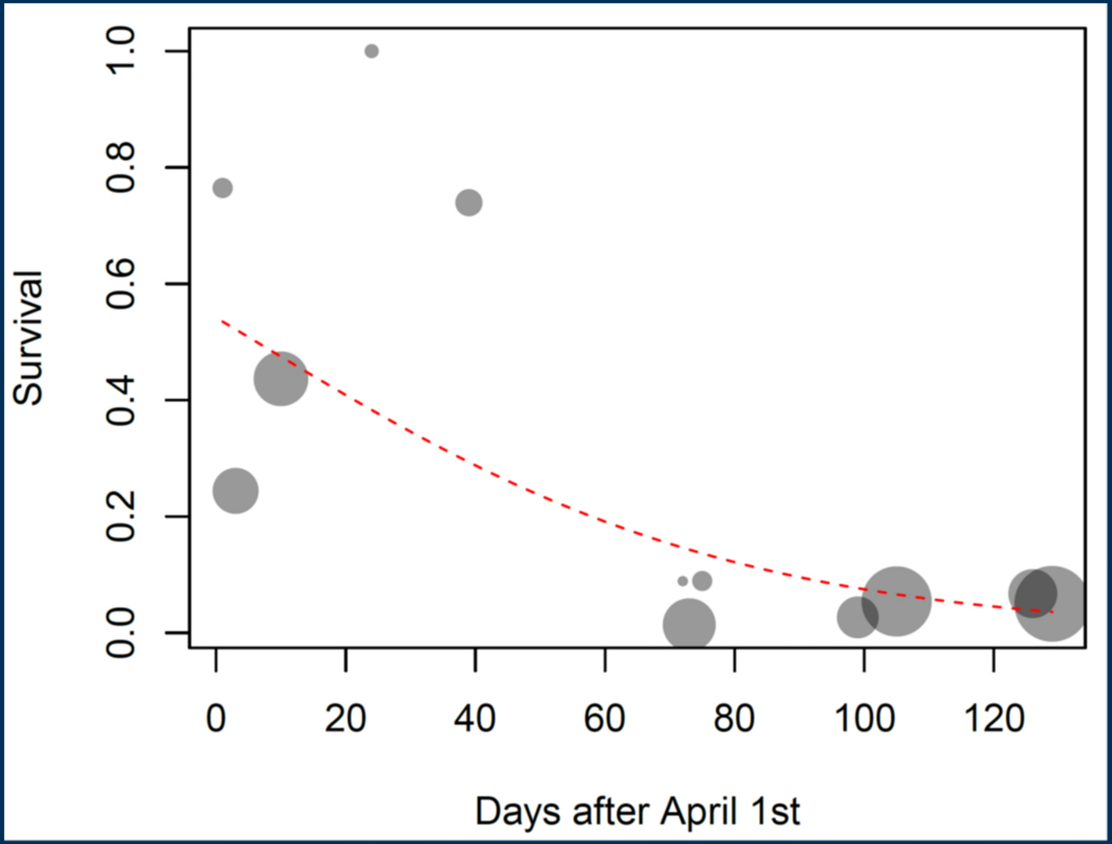
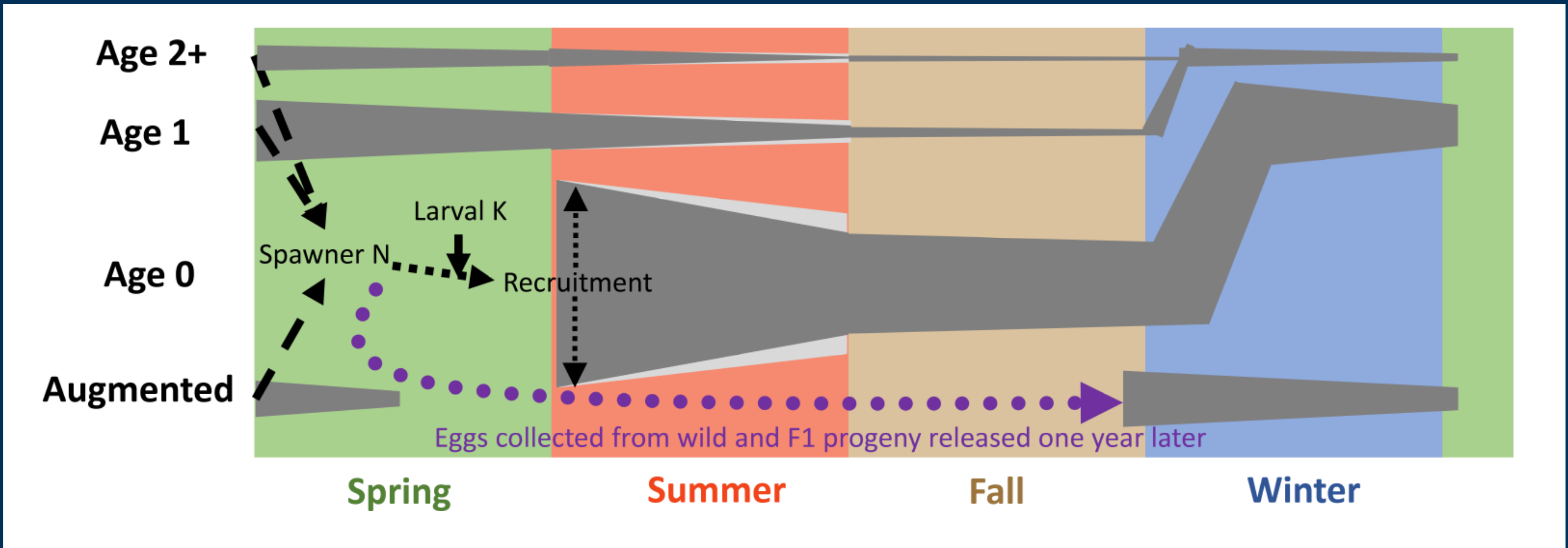
Survival of rescued fish



Based on Archdeacon et al., 2020

Population processes in the integrated model



Augmented fish subject to estimated stocking survival and modelled dispersal.

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Relationship between abundance and catch

- $C = p * f * \phi * N$
  - C – catch of a particular class.
  - N – abundance of same class in that river segment.
  - Φ – proportion of river segment population in site – affected by drying.
  - f – proportion of fish in the site sampled (affected by mesohabitats) – affected by effort and discharge.
  - P – probability of capturing fish given they were in the sampled portion of the site.

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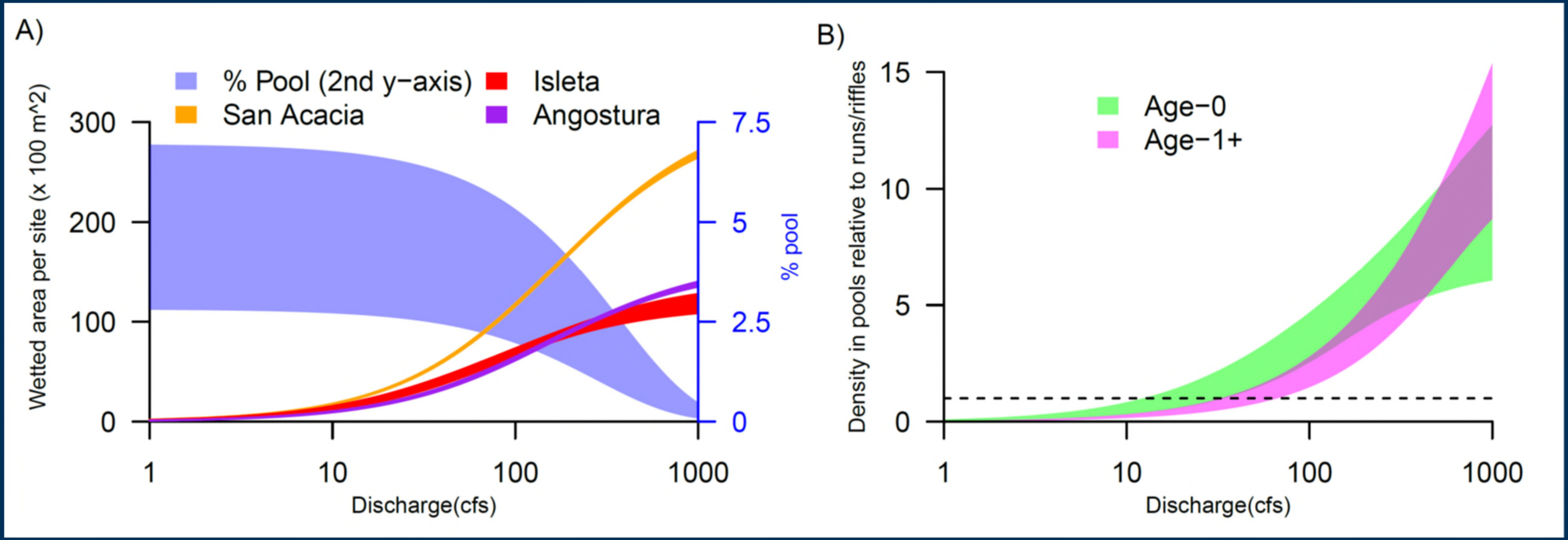
Discharge affects various processes relevant to translating abundance to catch



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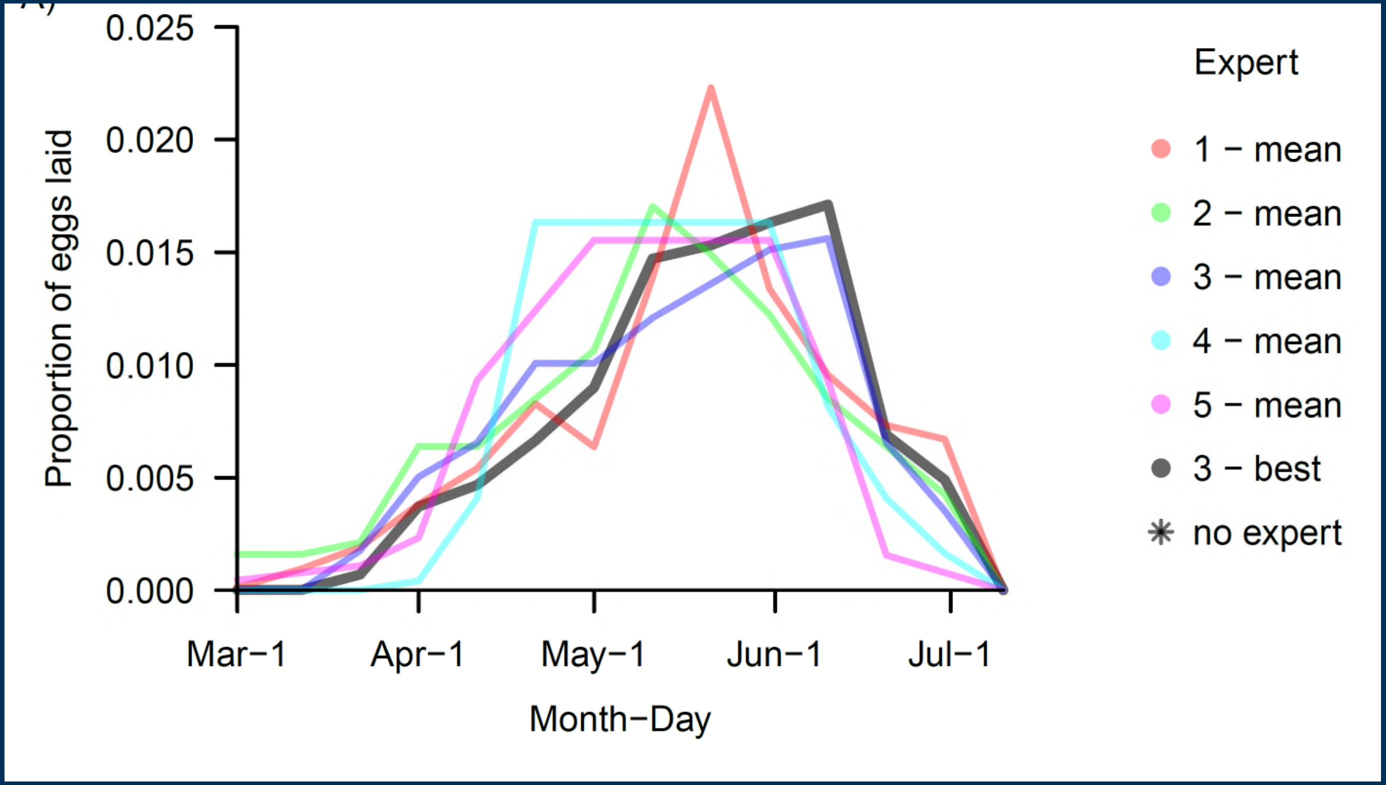
Broad agreement amongst experts regarding timing, but everybody's model performed better when timing shifted later in the season.



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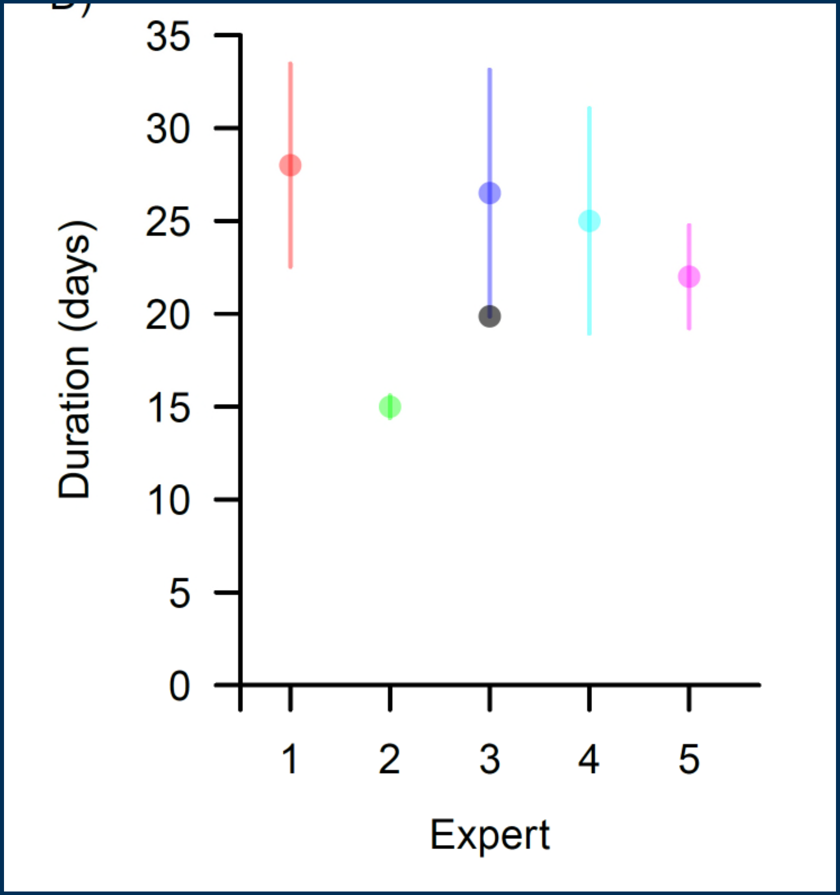
Very good agreement regarding the duration of inundation required per cohort (and everyone's best model converged to a common value around 20 days).



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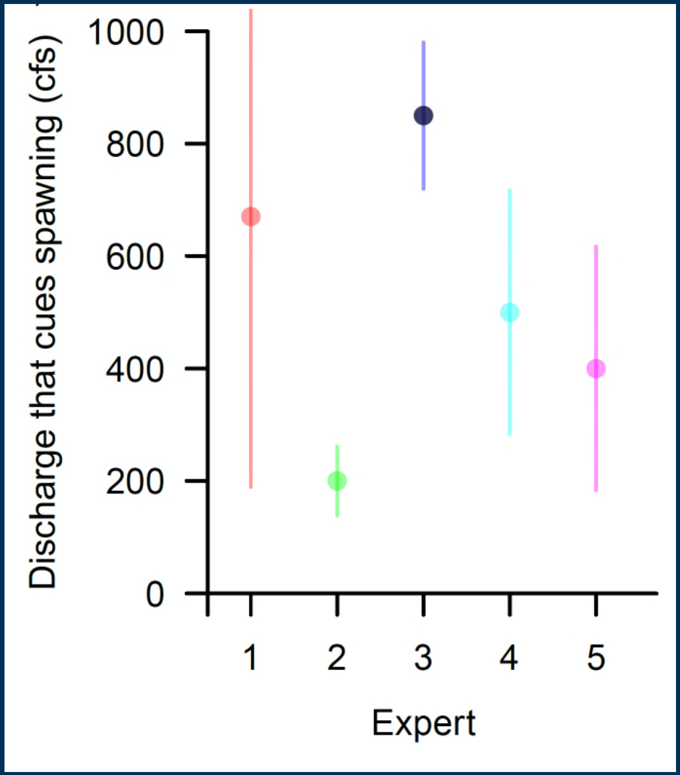
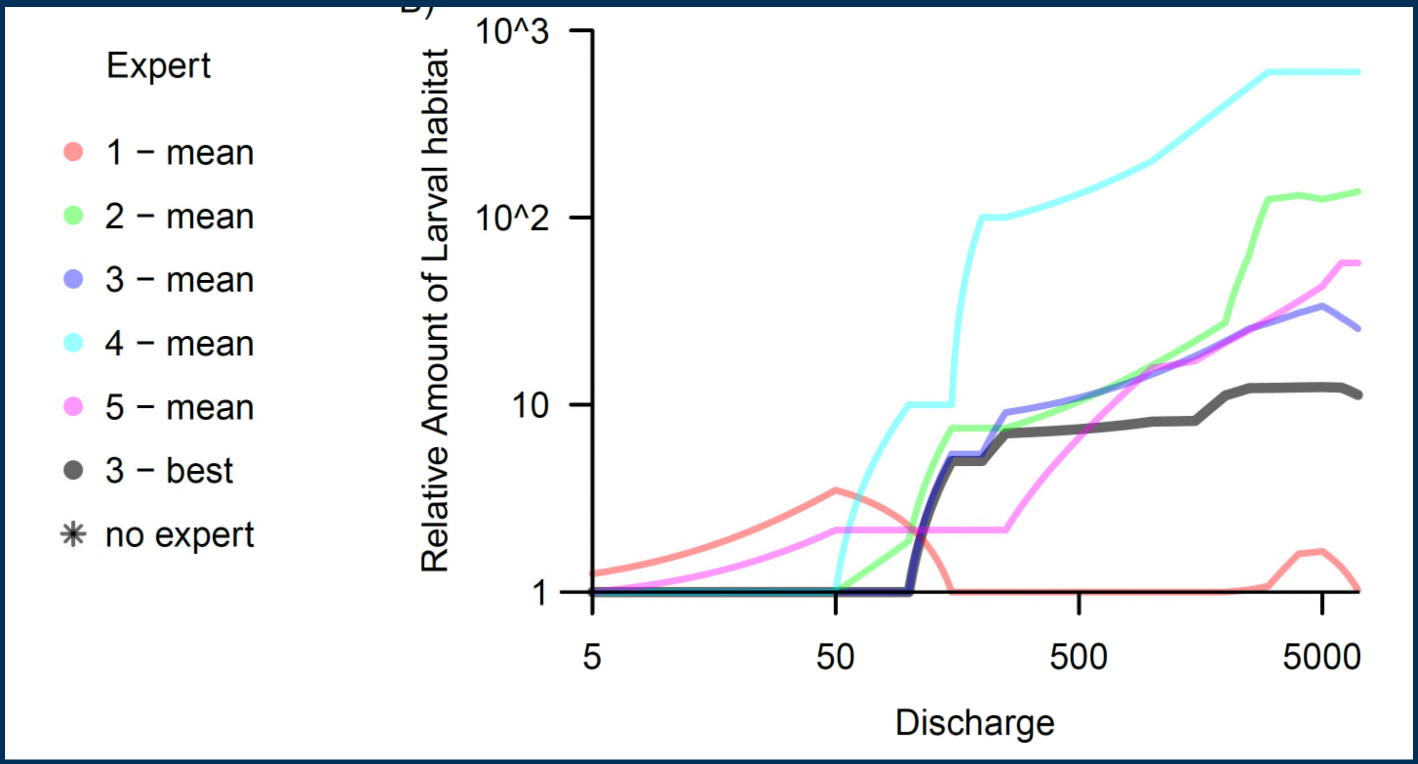
Some disagreement about the cue required for spawning, but model less sensitive to this parameter.



Also, disagreement regarding how larval habitat availability changed with discharge.



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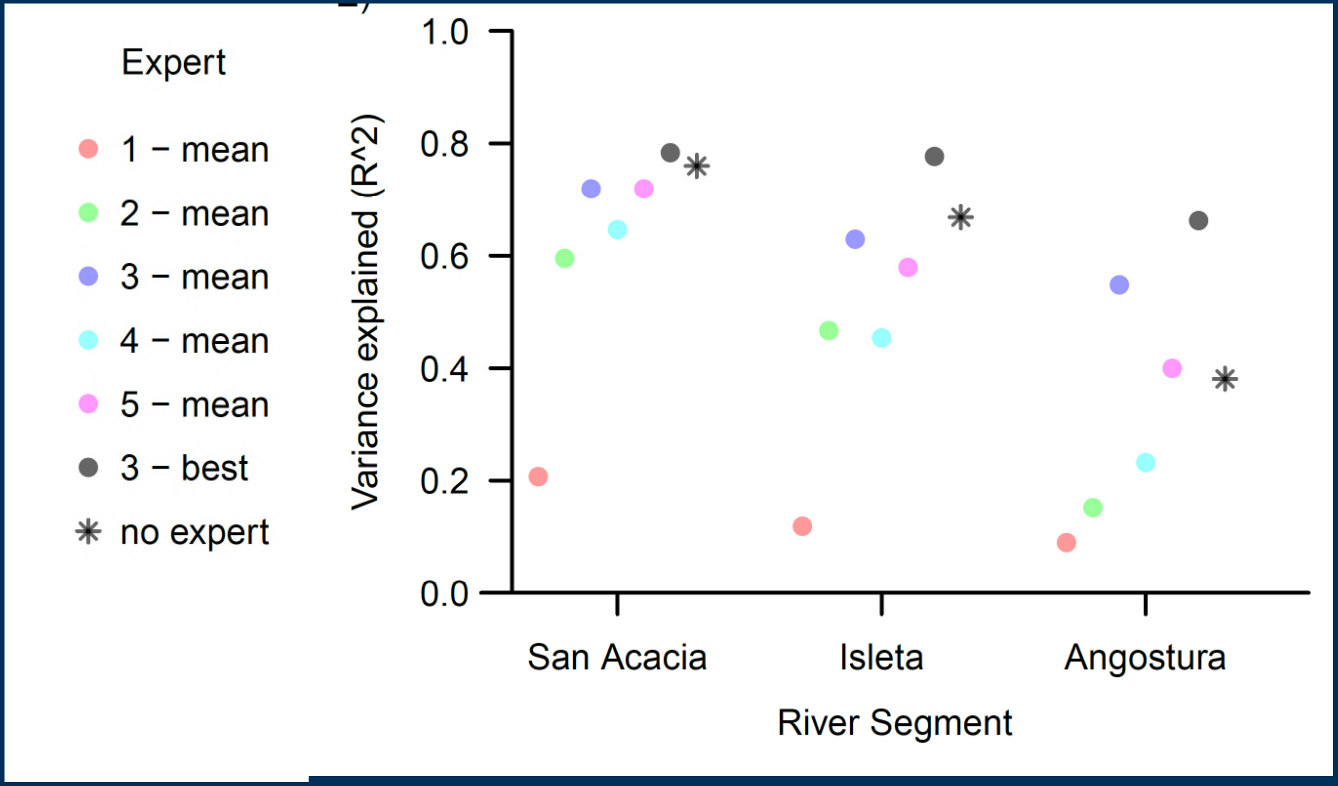
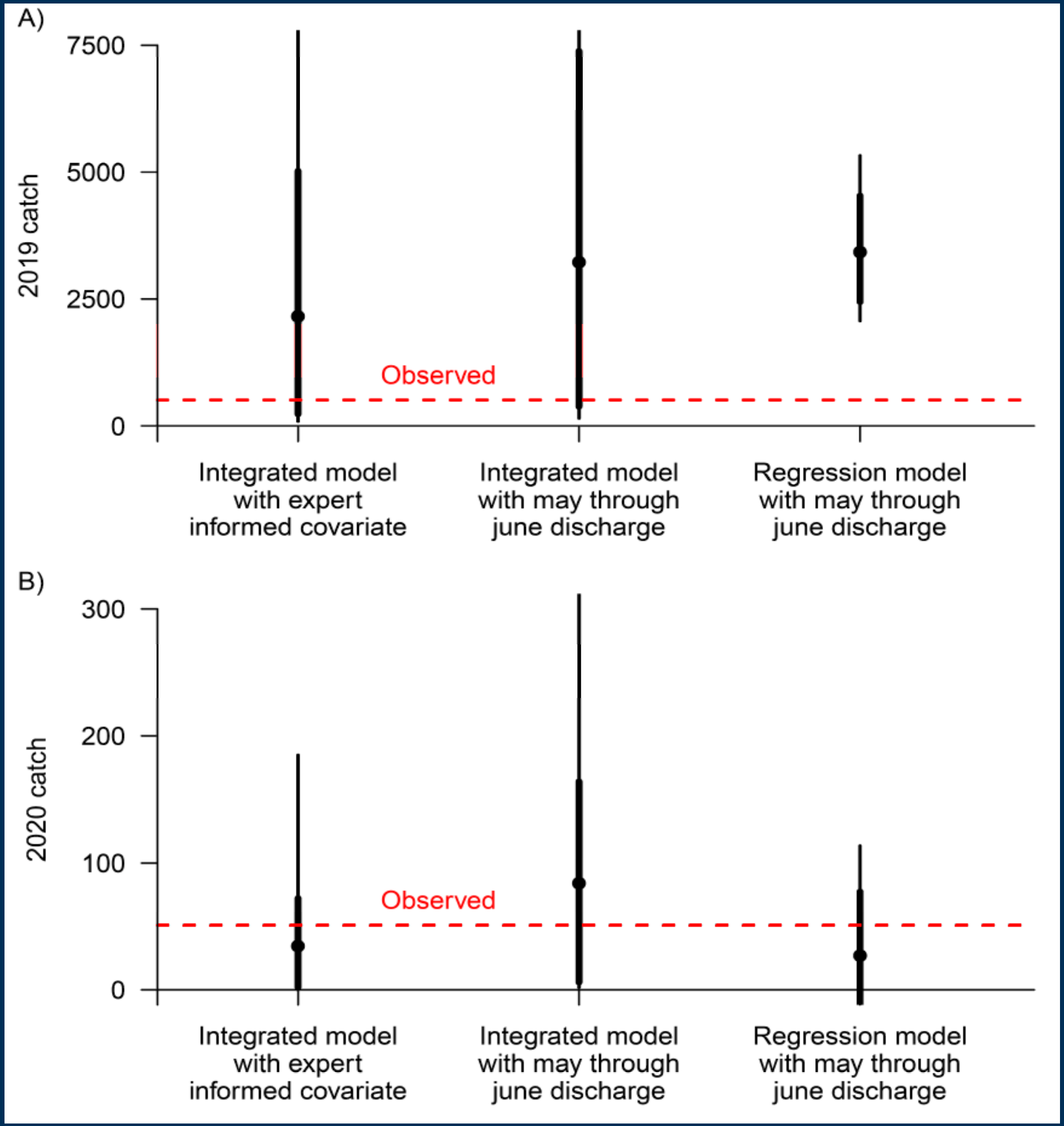
For each expert, we calculated nine sets of year and river segment specific larval carrying capacity indices based on their average answers to four questions and their uncertainty in these answers. We then identified the best performing set of answers.



Our goal is prediction, so after fitting model to data from 2002 – 2018, we tried predicting 2019 and 2020 October catch (and compared to two alternatives for reference).



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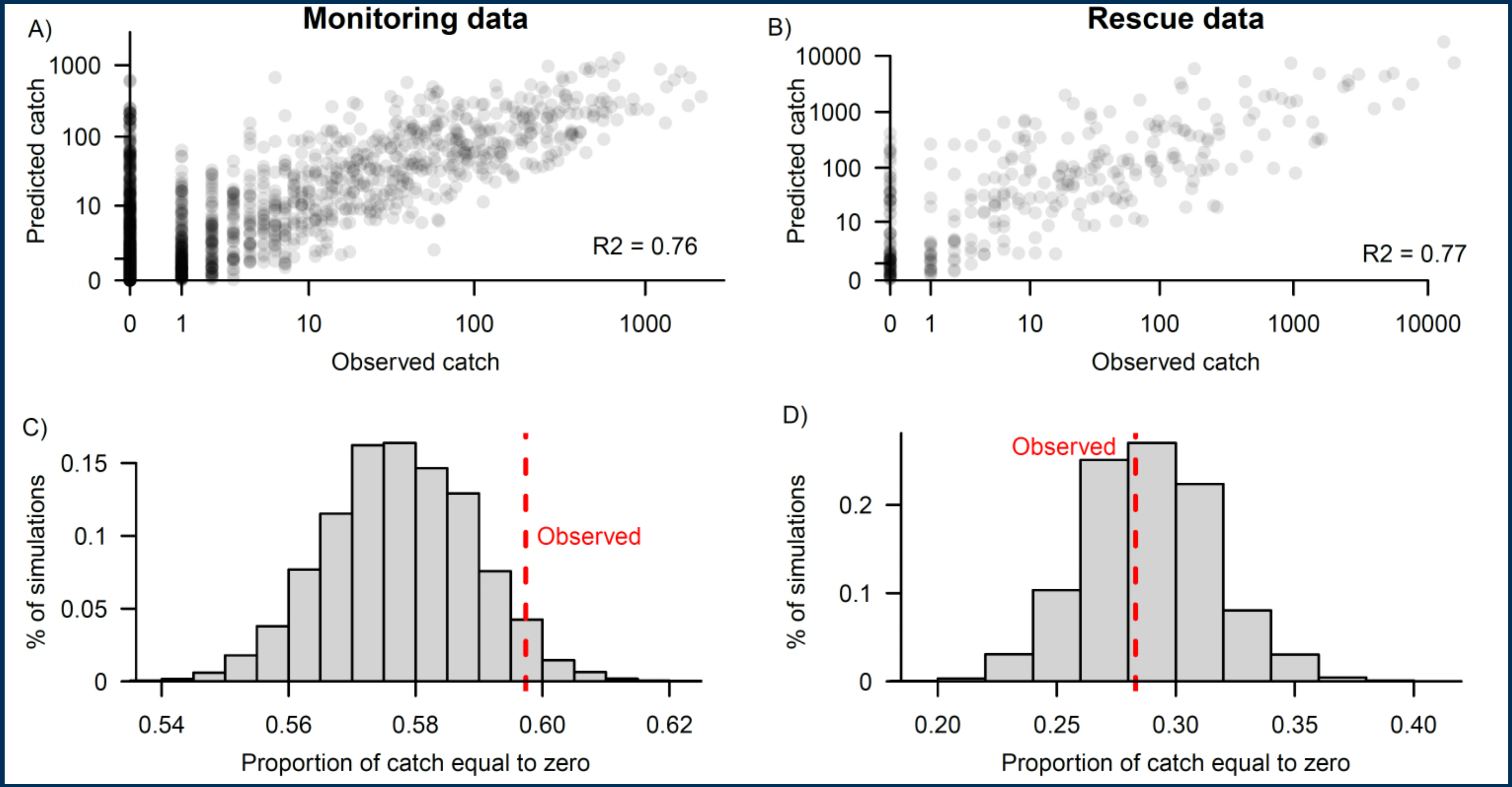
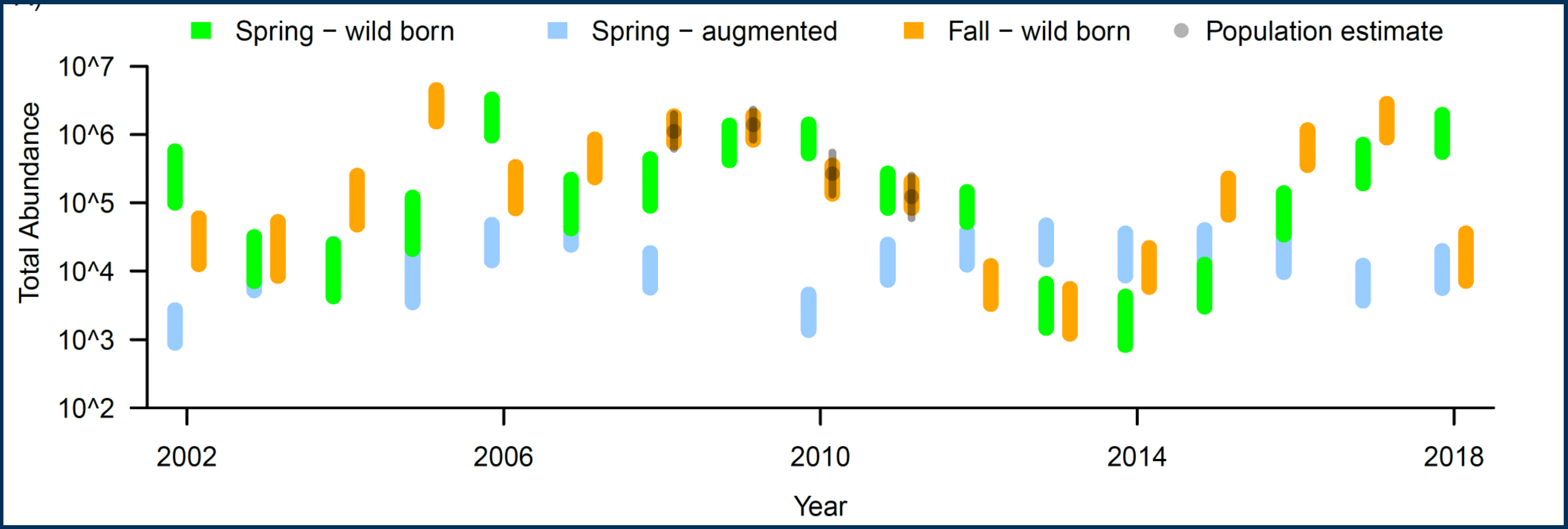
We also did a series of checks to make sure model was reproducing certain statistical properties of actual data (i.e., that it was fitting data well).



Not surprisingly, the model suggests substantial variation in minnow abundance over time.



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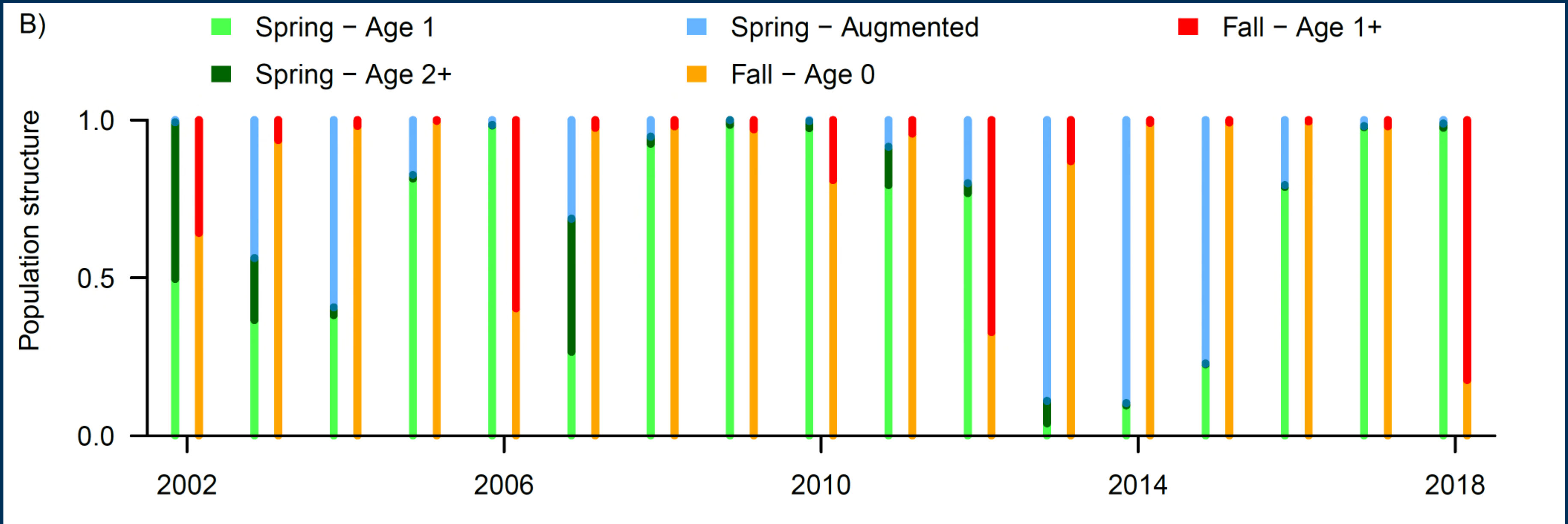
As well as substantial variation in population structure over time.



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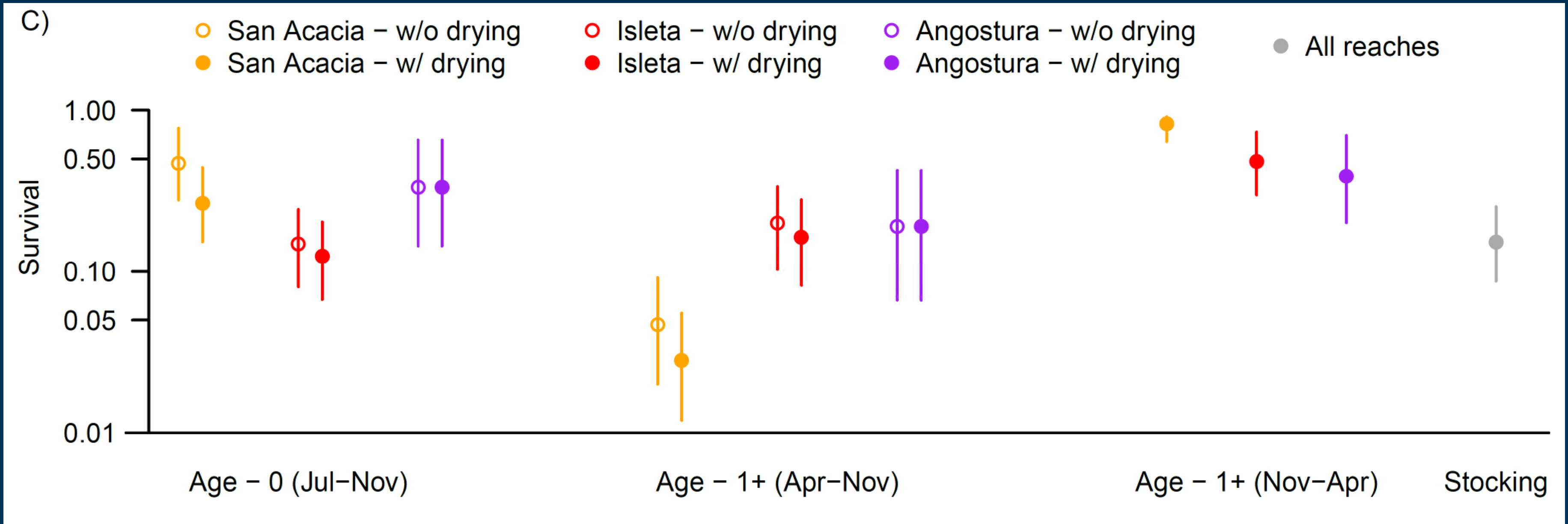
The model also suggests some interesting patterns in survival.



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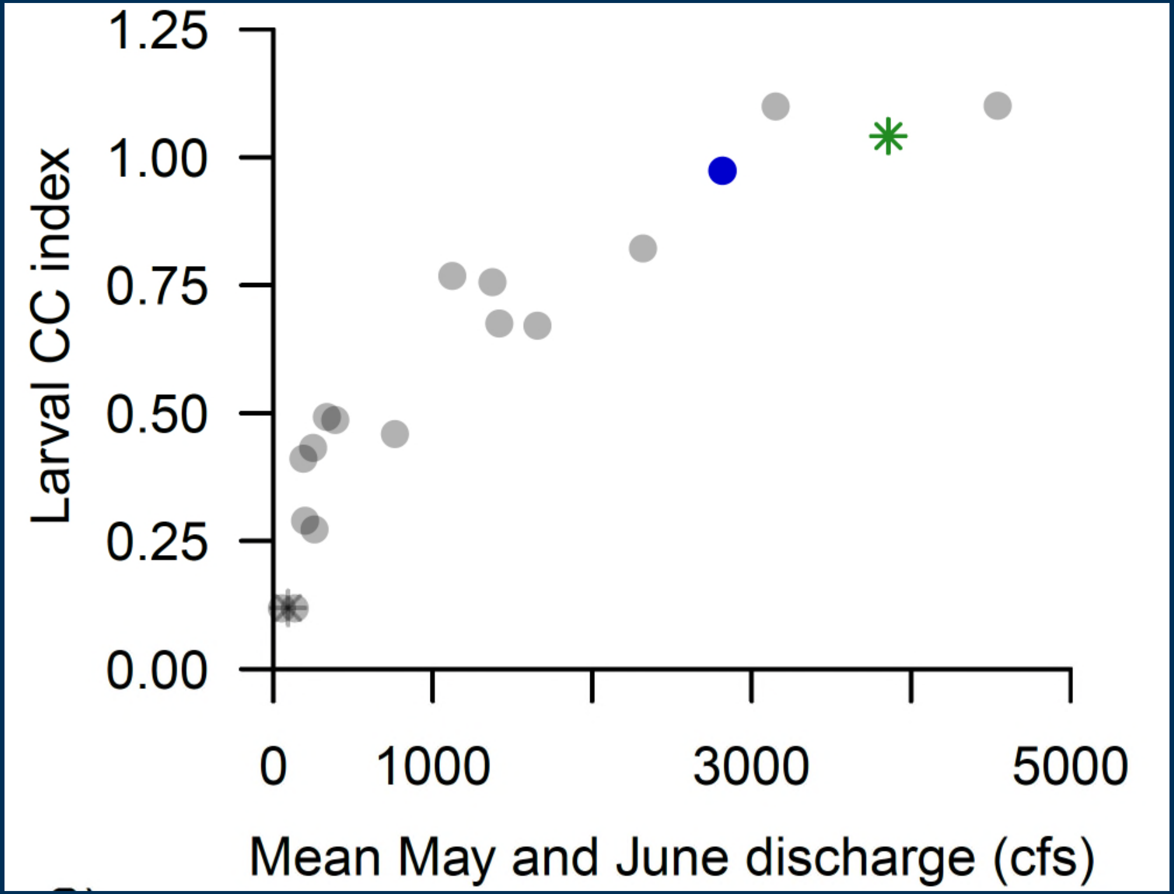
Generally, the larval carrying capacity index tracks mean May and June discharge (and other metrics), but with some important differences.



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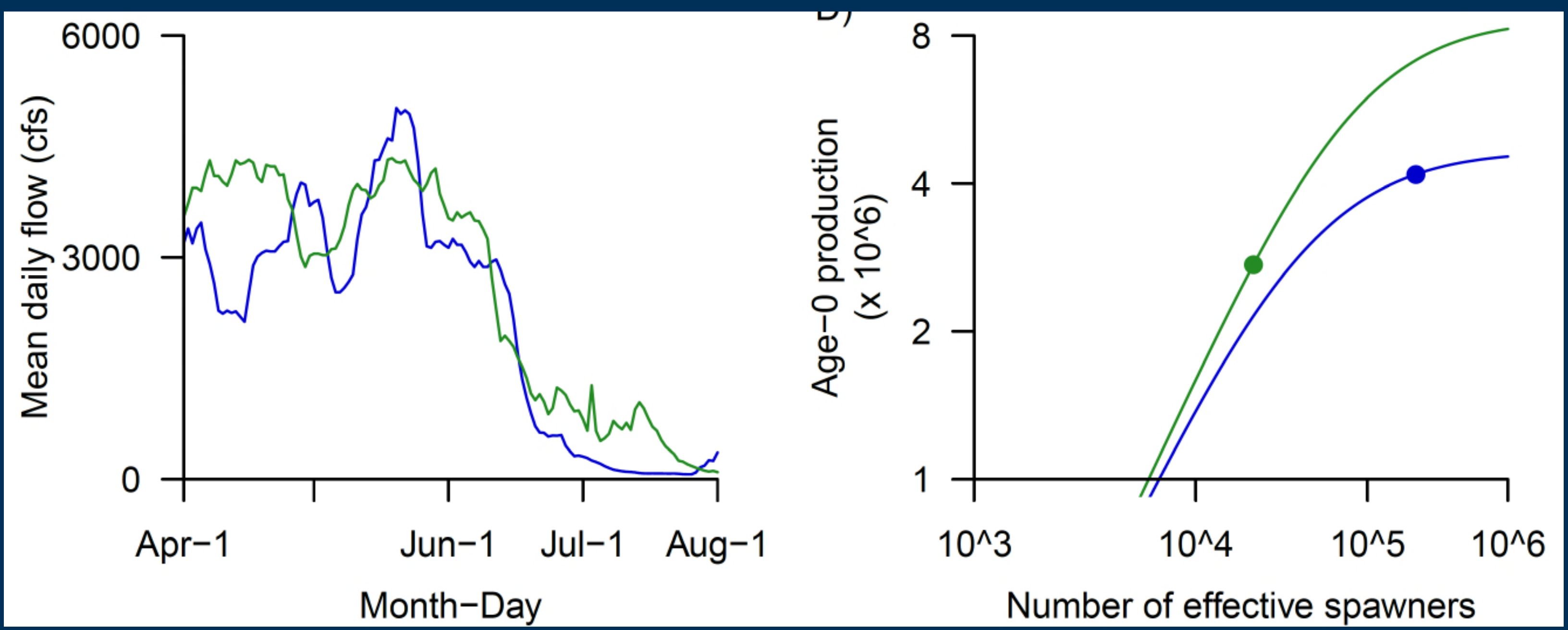
Age-0 production generally tracks the larval carrying capacity index, except in a few years were spawner abundance limits production.



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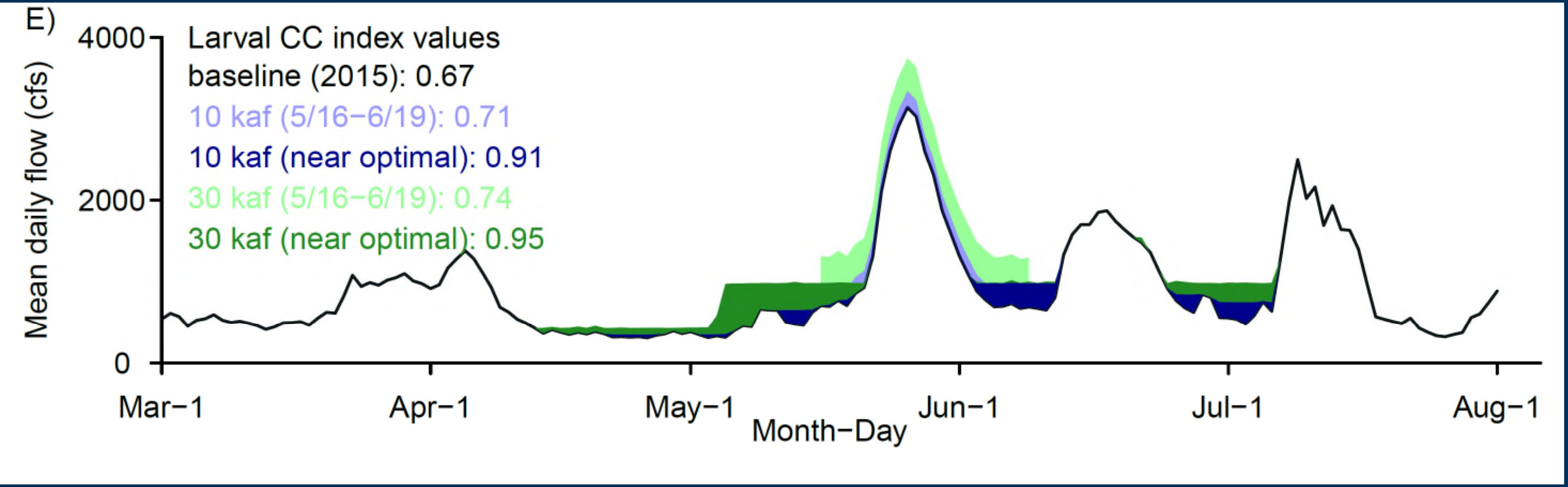
Part of the motivation for developing larval carrying capacity index was to be able to make more specific predictions about how changing a hydrograph should change age-0 production



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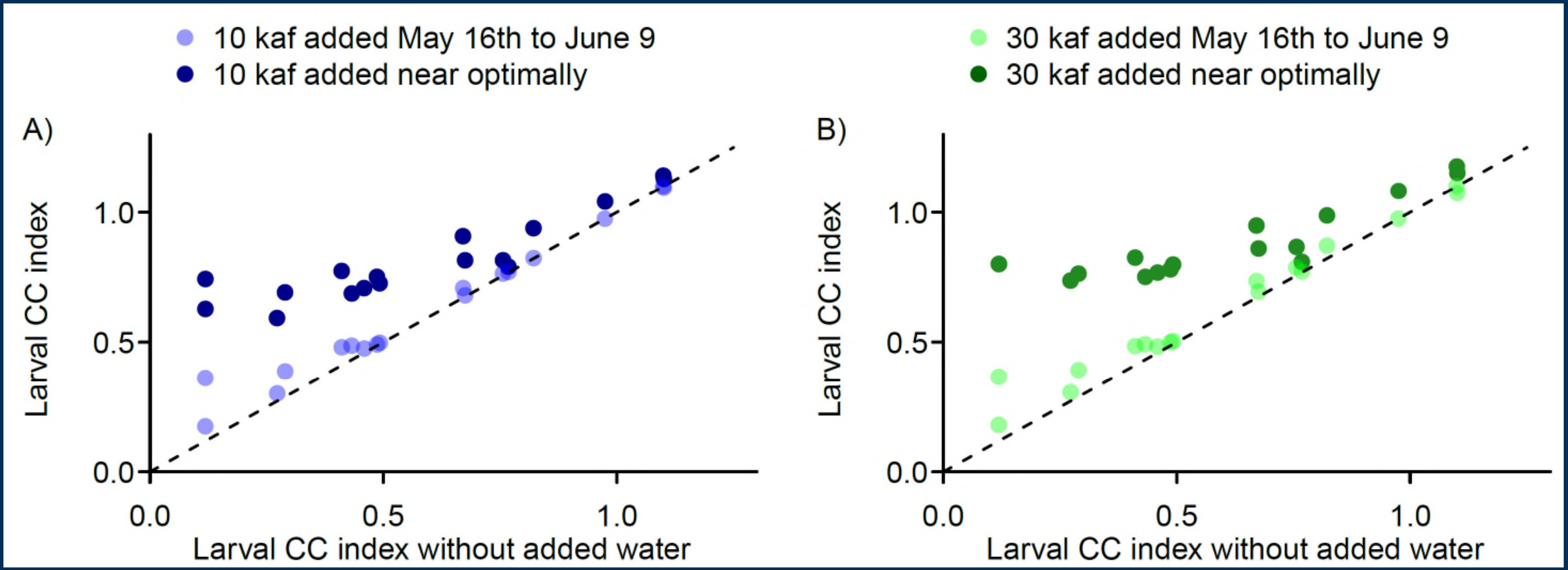
There is more potential to increase the larval carrying capacity when the base value of a hydrograph is low.

Adding water near optimally outperforms adding water uniformly between mid-May and early June.



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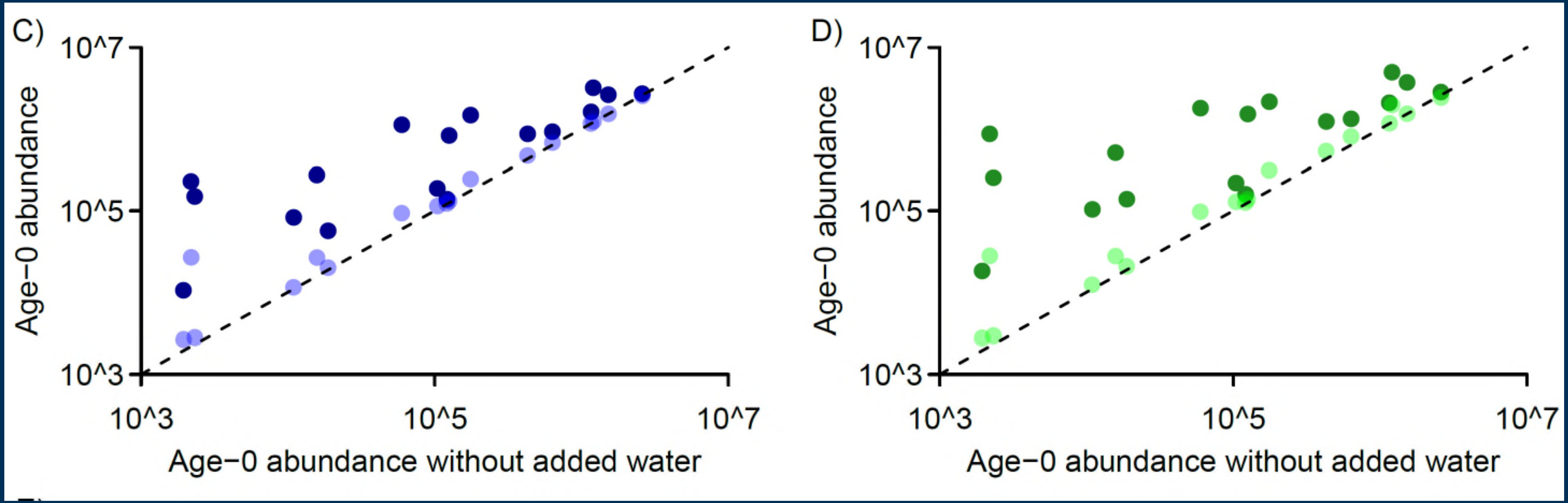
In most years, these increases in the larval carrying capacity index are expected to translate to greater age-0 production.



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Assessing various actions – key assumptions

- **Augmentation – predict difference in fall abundance if augmentation had <u>not</u> occurred.**
- **Restoration – use expert elicitation and assume 10% of shoreline was restored.**
- **Flow supplementation – predict additional recruitment if 10 kaf had been added near optimally.**
- **Rescue – predict difference in fall abundance if rescue had <u>not</u> occurred.**
- **Reduced drying – drying in each river segment reduced by up to 10% of the river segment length.**

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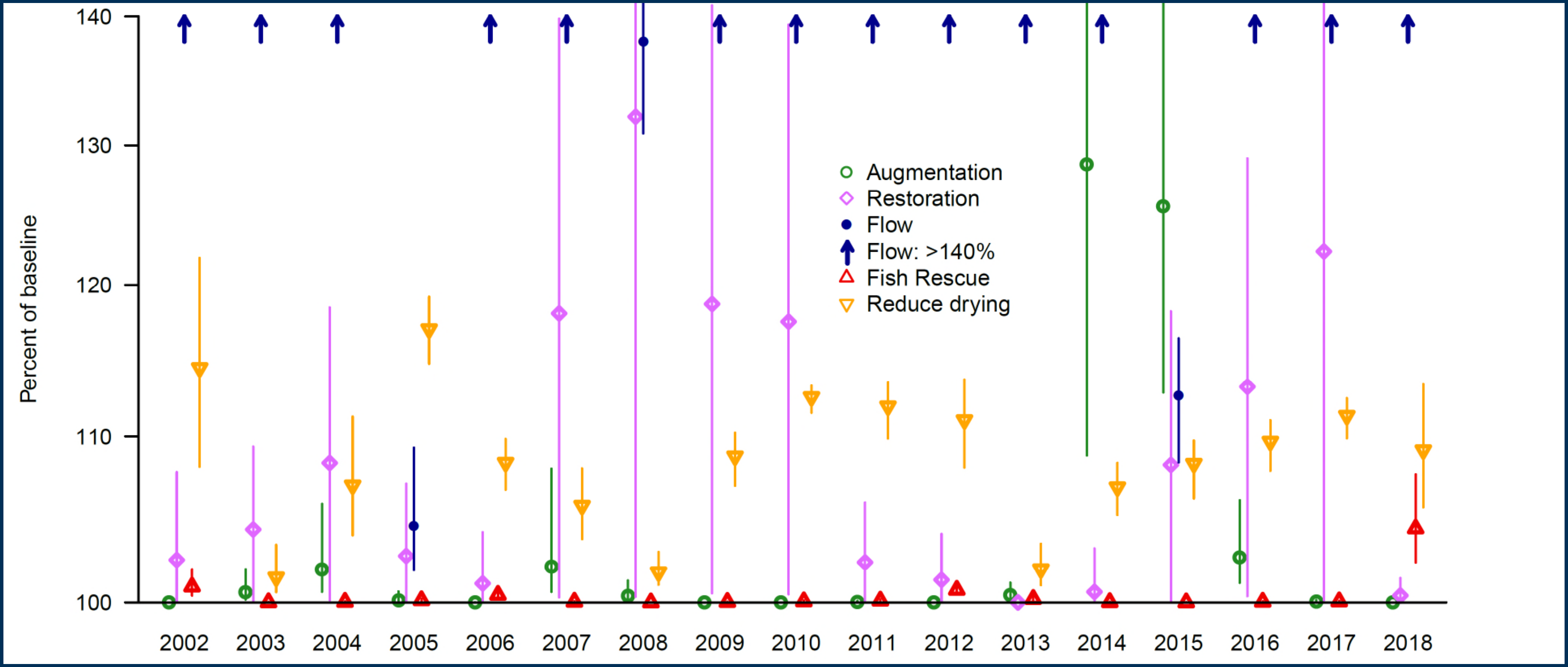
Flow often, but not always most effective.



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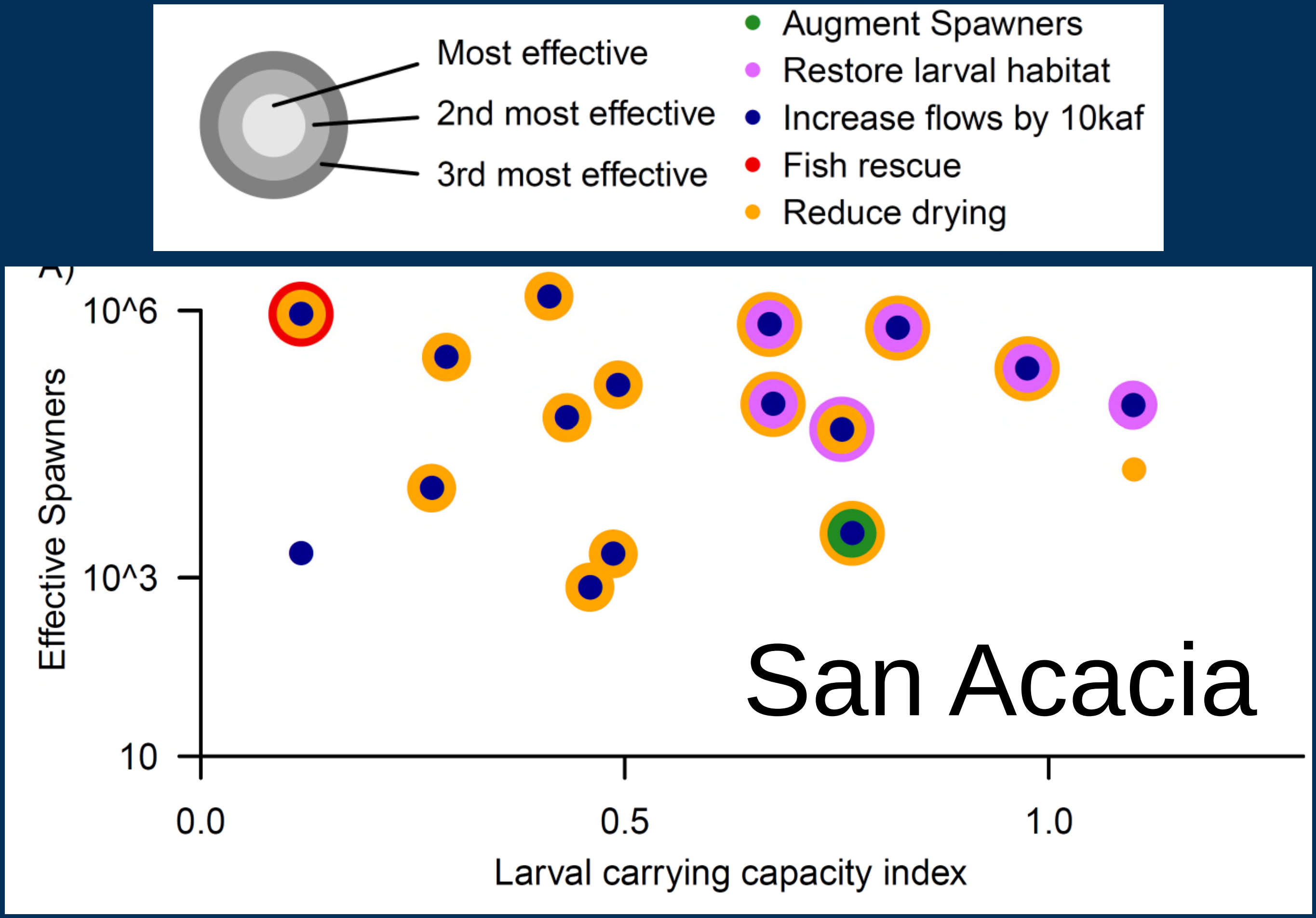
Also, effectiveness of different actions varies by river segment



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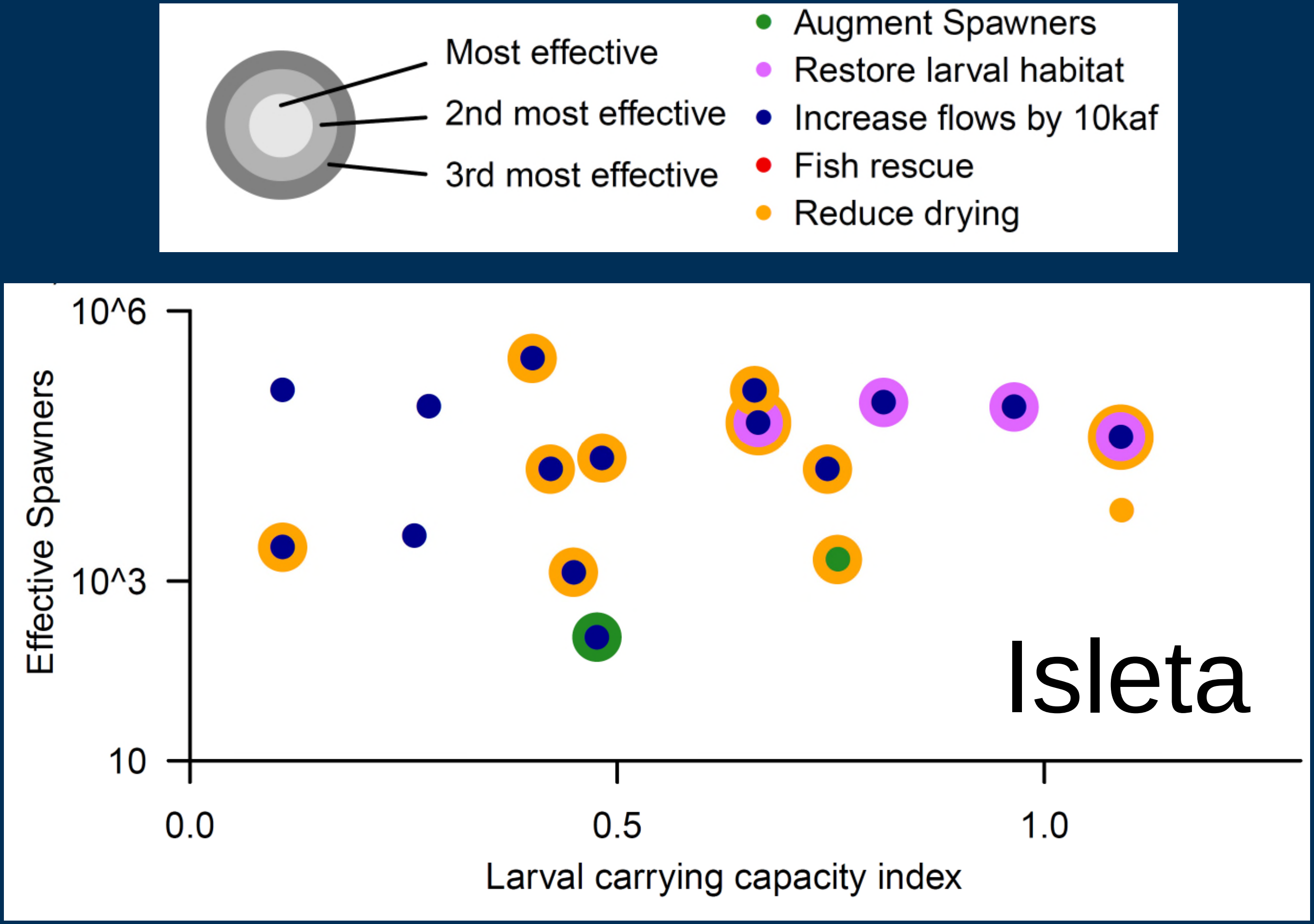

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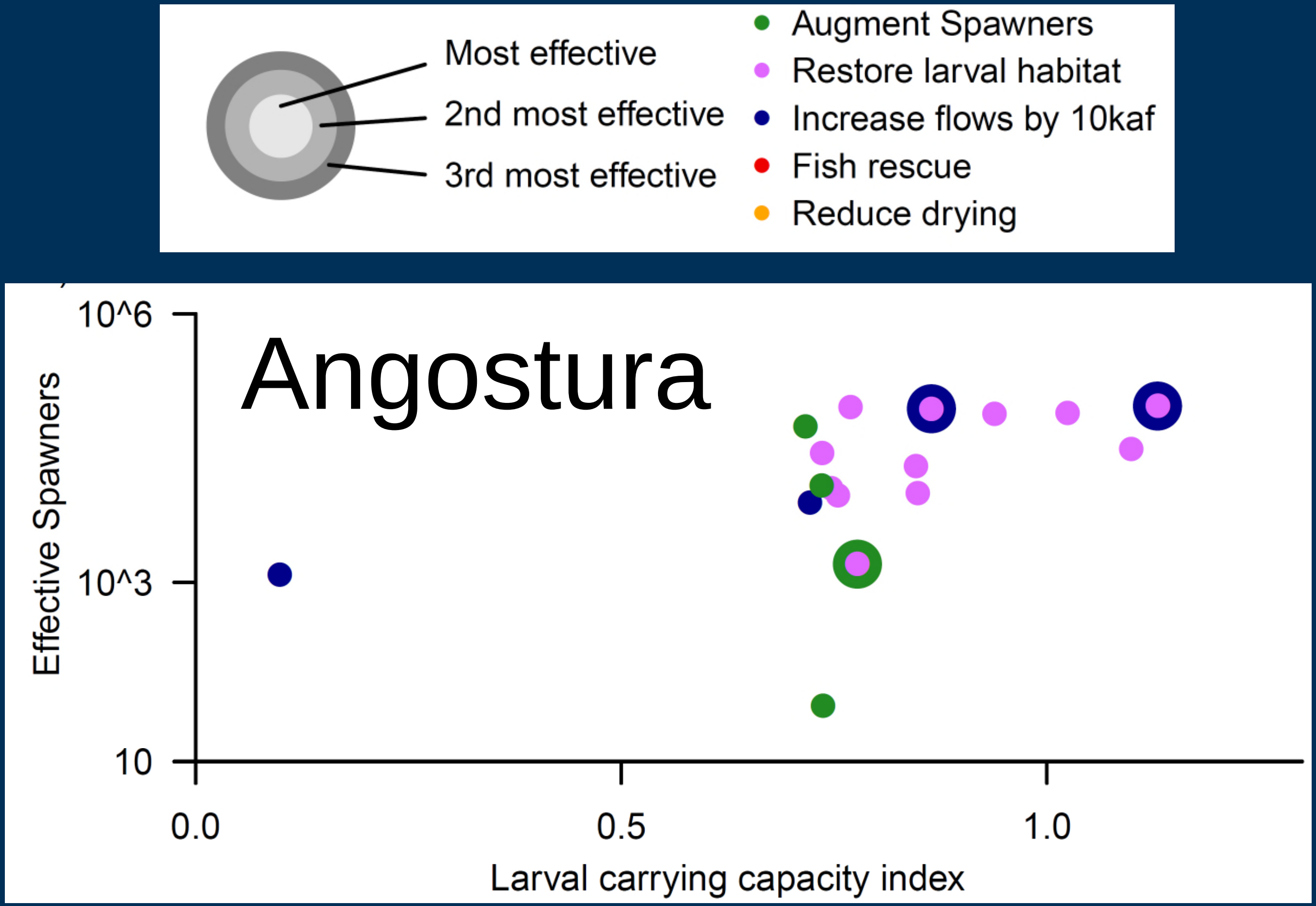

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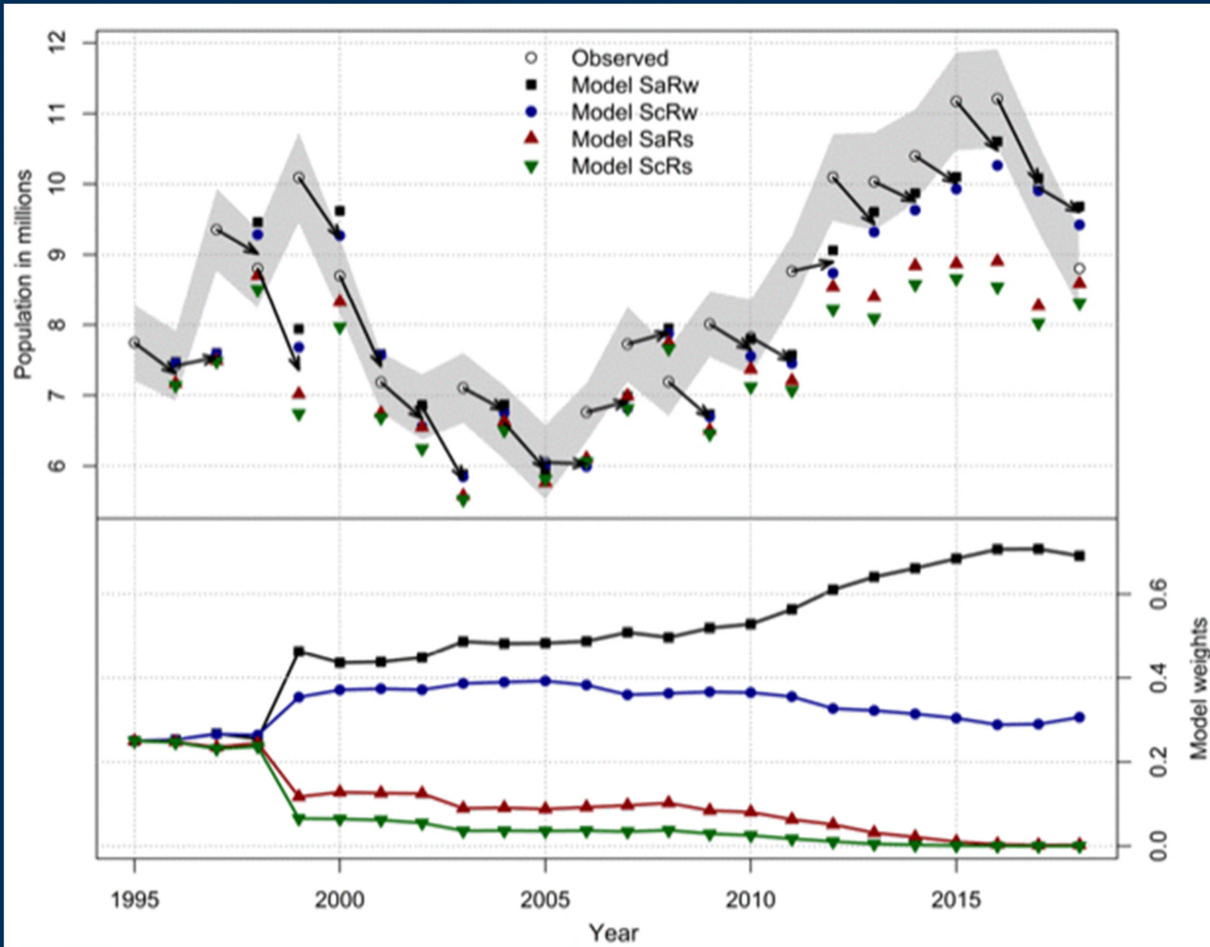
Implications for future research & monitoring

- **Model provides framework for generating testable hypotheses for adaptive management.**
- **Additional abundance estimates would be helpful for model precision.**
- **Intensive mark-recapture at sites could provide more direct estimates of survival.**
- **Model framework that can be updated as new information becomes available.**



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Nichols et al., 2019

Take home messages I

- Working collaboratively, we developed a model framework that integrates various sources of information, provides new insights and predicts as well, or better, than existing approaches.

- Framework could be updated & improved as new information becomes available (e.g., fish rescue survival information was integrated as it became available).

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Take home messages II

- In a few years, Rio Grande Silvery Minnow are spawner limited, but in most years, they are limited by larval habitat.
- At modelled management strengths, adding water near optimally would have been predicted to be the most effective overall action in 15 of 17 years, BUT
  - Under certain conditions (e.g., low spawner abundance or extremely dry conditions) other actions may be more effective.
  - Effectiveness varies by river segment.
  - We did not consider synergies among management actions.

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Thanks for your attention

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Questions?