The authors extend their thanks for the thorough and thoughtful review of this manuscript.

## Response to General Comments, by paragraph:

1. The authors extend their thanks for the thorough and thoughtful review of this manuscript.
2. We have revised the text such that the abstract and practitioner points convey the same information. We have also added text in the introduction summarizing the large body of literature on Functional Flows. (see also response to Detailed Comments, Pg 4 line 40)
3. In the methodology,
   1. We have added detail and justification for the chosen fish population metrics.
   2. We have added a collinearity screening analysis to address correlation between flow metrics.
   3. We have included additional statistical methods (namely, predicting two different ecological units using MARSS and lasso) in supplementary material and added justification for the selected statistical method.
   4. We have added more information in the introduction addressing other studies and their findings on salmon flow requirements.
   5. In the discussion, we have added text analyzing our salmon flow requirement findings in the context of the rest of the literature on this topic.
4. The authors appreciate these comments and believe addressing them will meaningfully improve the robustness and clarity of the manuscript.

## Response to Detailed Comments:

Abstract: We have added a sentence clarifying which hydrologic metrics were found to be most important in the predictive model.

Practitioner Points: We have added a sentence as specified here.

Introduction:

* Pg 4 line 40: in the introduction, we have added citations to the following pieces of functional flows development:
  + Foundational work on natural flow regimes (Poff et al 97) and ecological responses to altered flow regimes (Poff and Zimmerman 2010)
  + Indicators of Hydrologic Alteration (Richter 1996)
  + Ecological Limits of Hydrologic Alteration (Poff et al 2010)
  + Functional Flows Approach (Yarnell et al. 2010; Grantham et al. 2020)
  + California Environmental Flows Framework (Patterson et al 2020; Stein et al 2021)
  + Added these citations: Yarnell et al. 2015; Grantham et al. 2020; Stein et al. 2021
* Pg 5 line 33:
  + We have added citations to the IHA metrics and ELOHA approaches and cited the three papers alluded to in the comment (Richter et al. 2016, Poff et al. 2010, McManamay et al 2013).
  + The exclusion of the Functional Flows literature is an oversight that we are happy to correct (see response to comment on Pg 4 line 40).
  + Needs further discussion:
    - Comment*: “On page 6, there is a discussion of what an ideal framework would be to translate relationships between flow and ecological response to water management actions and decisions. This is specifically what the Functional Flows approach and the related CA Eflows Framework describe and do”*
    - Manuscript: “*An ideal framework for supporting decision-making would involve two key steps, firstly connecting land and water management actions to flow changes, and secondly connecting flow changes to ecological responses*”
    - In my current understanding, the functional flows metric addresses neither of these steps. Can you help me understand what you mean here?
      * It does not predict flow changes due to management actions (at least not in the same way as a physically-based hydrologic model, which is our baseline expectation)
      * It does not predict quantitative ecological changes due to flow changes; rather it quantifies the flow phenomena known to affect the ecosystem.
    - Is this understanding incorrect?
  + At the end of the first section of the introduction we have added questions that currently persist that this study will address.

Methods

* Pg 7:
  + We have included fish sampling locations on the site map and clarified references to reports describing the fish sampling and monitoring of multiple life stages over the past two decades, and we have added the primary monitoring locations to the study map.
  + We have indicated reaches that typically become dewatered in a dry year on the study map.
  + We have moved and shortened the history of management text as suggested and/or moved this text to a supplement.
* Section 2.2.2: We have added text highlighting that coho over-summer in streams and that this places constraints on habitat suitable for rearing.
* Section 2.2.4:
  + We have added text highlighting that coho spawning is also influenced by which reaches have continuous summer flow.
  + [88 metrics]
  + …
* Section 3.4: We have improved the analysis by screening the hydrologic predictors for collinearity (R greater than 0.7) and selecting a subset predictors to represent hydrologic conditions in all seasons while minimizing redundancy in the predictor data.
* Section 3.5: This section on the ecological response selection was combined with the section describing ecological monitoring data (Section 3.2).
* Section 3.6
  + We have included text explaining why MARSS or Random Forest modeling was not used / why other methods were not used.
  + We have condensed the methods as recommended.
* Sect 3.6.2: We have added text explaining that the years that end up being excluded depend on the set of functional flows included in the lasso model (i.e., if Fall Pulse magnitude is selected, the years in which no Fall Pulse is recorded are excluded).
* Sect 3.7: [clarifying text – lambda was only included in the minimization equation, not in the predictive HB model. Also lambda not selected as 0]

Results

* Section 4.1, Fig 6: Some metrics with no major changes over time were included (i.e. wet season median baseflow) to provide some context that while dramatic changes are occurring in the flow regime, some quantifiable phenomena are remaining the same over time. We have ensured the names of these metrics are the same as in the literature and ceff.ucdavis.edu.
* Section 4.2: Agreed, the flow-ecology relationships are very multifaceted, and thus better reflected by multi-parameter statistics. [the order of influence of those metrics is typically related to the strength of individual correlation coefficients - check.] We therefore included this first-pass analysis to identify a set of most-important flow metrics based solely on single-variable correlations.
  + [another recommendation to use the method of screening your predictors for correlation before plugging them into your model. Explain that lasso does the screening for us?]
  + It’s true, including multiple life stages could make it more robust. Should we consider it?
* Pg ? lines 47-51
* Pg 33, line 9-10
* Next paragraph
* Tables 5 and 6
* Sect 4.4.1
* Sect 4.4.2
* Sect 4.4.3

Discussion

* Sect 5.1
* Sect 5.2
* Sect 5.3
* Sect 5.4
* Sect 5.5

Conclusions

* Hypotheses to be explored
* Pg 44 line 12-13
* First sentence, last paragraph

Discussion parts

I think we have a fundamental difference of approach or objective. It seems like you are super focused on predicting extinction risk.

Should we try to predict multiple life stages? Or just this one overall success metric?

Baruch 2024 paper

* Excluded 12 metrics that did not occur each year. Recalculated fall pulse to include it.
* Excluded 4 metrics highly correlated with other metrics. (Which did you keep?)
* Final set included 9 flow metrics.
* Trying to understand MARSS:
  + “leverages temporal autocorrelation”
  + “quantify abiotic drivers of population dynamics”
  + Which are “underlying ‘state’ processes”
  + “while accounting for observation error”
  + Multiple observations/sites of the same population – multiple monitoring locations?
  + Can handle gaps in the response variables. Cool.
  + Covariates, however, must be continuous.
  + Matrix math
    - What is x\_t?
    - Z matrix is site-specific observations? What is the data structure?
    - One flow metric per model as an environmental covariate
  + Abundance data logtransformed.
* Then, used the best model for each flow metric (selected with AICc).
  + Each flow metric has a coefficient for each species?
  + Used these coefficients, and future simulated managed flows? To predict species extinction risk under future new flow management.

MARSS

* MARSS has clearly been developed by these cool eco statisticians in Seattle. But the focus for this body of work for the past 20 years (https://atsa-es.github.io/) really seems to be predicting extinctions or quasi-extinctions, which is how it’s used in Baruch 2024. We were approaching this from the opposite direction: Which flows are correlated with salmon success? In your estimation is there any validity in that approach?

Alignment of functional flows to life stage

* For sure, the alignment to different life stages needs more explanation.
* Can we think through how best to illuminate that?
* Baruch 2024 uses the Patterson 2020 algorithms to calculate functional flows. So did we! We just had an expanded number because we calculated, for example, the wet season duration for both the egg stage and the juvenile wintering stage.
* This alignment makes this application super bespoke to the 2 species of concern.

Potential other statistical methods

* Our initial objective: automatically perform predictor selection, while dealing with high-dimensional data with lots of collinearity
  + Subsequent research may suggest that, depending on the severity of the collinearity, lasso may not be able to handle it
* Lasso or Ridge Regression
* Principal Component Regression (avoids collinearity entirely by making all components orthogonal)
* MARSS – does it perform predictor selection (identify the most important flow metrics)? How interpretable is it?
* Boosted regression trees
* Random forest – black box. Worse for interpretation

Buckets of review response tasks

Lit review

Adding detail/clarifying text

Statistical analysis tasks

Needs further discussion

Discussion Notes 1/16/2025

1. Distinct objectives: quasi-extinction forecasts vs. single-species single-metric forecast
   1. MARSS
      1. Albert Rui at Berkeley uses this method, Ethan worked with him. MARSS is upgraded random forest. You can throw all kinds of stuff at it. Will take some correlation into account.
      2. Ranking of importance of different variables
      3. Can be hard to interpret the degree of importance, or if it would change if the flow changes
      4. Random forest will give you those rankings, but it’s a bit of black box
      5. MARSS turning into extinction probability is more interpretable
   2. I don’t understand MARSS. I think we would be overfitting.
      1. You should talk to Ethan and Albert before you throw it out the window. Is it ok for your dataset. I can facilitate that meeting
      2. Modeling: MARSS does not take multiple life stages into account. Data goes into it is one observation per year. 10-15 years of fish datasets in Arizona in Ethan’s dissertation. Takes the changes over time into account. (I also do not understand the math.) Can handle the fish cohort lags into account.
      3. What trying to get out of it: quasi-extinction forecast vs single-species
         1. Can’t have one fish function, that’s impossible
         2. A couple metrics supporting fish growth
      4. What’s a hydrologic benefit funcnion
         1. The fundamental saying that flow will give you X number of fish is just wrong/misleading.
         2. To imply that you will get this many fish with this flow will set
2. Merits of accounting for collinearity: pre-screening vs. automated predictor selection
3. Statistical method rationale (LASSO and MARSS) and other options (Principal Component Regression; boosted regression trees, random forest)
4. Gauge reliability
   1. 50 cfs at FJ could be no French Creek connectivity or full connectivity
5. A gajillion metrics.
   1. Connectivity timing
   2. How important is the timing? Water year day. Continuous number. Looking for dates that correlate
   3. Why not separate it into onset of the wet season?
   4. What is the timing of 100% watershed reconnection
   5. What is the timing of 50% watershed reconnection
      1. Then you define the variable. You define the variable of, the 100% is typically connected at 200 cfs

Action items

~~Simplify connectivity timing metrics per discussion~~

~~Recalculate the metrics to confirm~~

~~Correlation analysis pre-screening~~

Chat with folks about MARSS and response variables

Reframe hydrologic benefit function: conditions that support salmonid rearing

Questions for Sarah

* What’s the citation for the Flashy calculator?