Risk tables
(and other ways to incorporate ecosystem considerations)

Approaches to incorporating habitat/ecosystem indicators into salmon harvest management

- Incorporate into risk tables
- Improve forecasting model
- Incorporate into harvest control rule

Risk table approach to incorporating ecosystem considerations (Dorn and Zador 2020)

	Assessment-related considerations	**Population dynamics considerations**	**Environmental/ecosystem considerations**
Level 1: Normal	Typical to moderately increased uncertainty; **minor unresolved issues in assessment**.	**Stock trends are typical** for the stock; recent recruitment is within normal range.	**No apparent environmental/ecosystem concerns**.
Level 2: Substantially increased concerns	**Substantially increased assessment uncertainty** or unresolved issues.	Stock trends are unusual; **abundance increasing or decreasing faster** than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals but the **pattern is not consistent across all indicators**.
Level 3: Major Concern	**Major problems with the stock assessment**; very poor fits to data; high level of uncertainty; strong retrospective bias.	**Stock trends are highly unusual**; very rapid changes in stock abundance, or highly atypical recruitment patterns.	**Multiple indicators showing consistent adverse signals** a) across the same trophic level, and/or b) up or down trophic levels (i.e., predators and prey of stock)
Level 4: Extreme concern	**Severe problems with the stock assessment**; severe retrospective bias. Assessment considered unreliable.	**Stock trends are unprecedented**. More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	**Extreme anomalies in multiple ecosystem indicators** that are highly likely to impact the stock. Potential for cascading effects on other ecosystem components.

EWG risk table adaptation for groundfish

	Environmental/ecosystem considerations	**Assessment data inputs**	**Assessment model fits and structural uncertainty**
Level 1: Favorable	Indicators not used in the stock assessment - show medium to high level of agreement - moderate to strong evidence supporting high species productivity	- Reliable catch reconstruction - Informative fishery-independent survey - Age & length composition data for landed fish and bycatch for key fleets across a range of years - Solid fits to data - Maturity data from samples collected across time and the model area - Species-specific fecundity in the CEE	- Most productivity parameters (recruitment, natural mortality, growth) estimated internally - Minimal evidence for temporally and/or spatially varying biology - Sensitivity model runs within the estimated parametric uncertainty - Sensitivities symmetric around base model - No long-term trends in recruitment - Parameters are well-estimated - Minimal evidence of retrospective bias
Level 2: Neutral	Majority of indicators - show no notable trends and/or - no apparent environmental and ecosystem concerns	- Historical catches with moderate uncertainty but reliable catches over the last 4+ decades - Age & length composition data covering landed catch for fleets with the majority of removals - Some gaps in time and/or for bycatch - Species-specific maturity - Fecundity based across species or regions	- Moderate fits to data - Multiple productivity parameters estimated internally - Weak-moderate evidence for temporally and/or spatially varying biology not captured by model - Weak-moderate long-term trends in recruitment not captured in the forecast - Most parameters are well-estimated - some possible evidence of retrospective bias
Level 3: Unfavorable	Majority of indicators show - medium to high level of agreement and - moderate to strong evidence supporting low species productivity	- Uncertain catch reconstructions both historically and more recently - Limited age composition data - Maturity and fecundity based on other species and/or regions	- Some problematic fits to data - most productivity parameters fixed or estimated externally - Recruitment deviations are estimable for some portion of the time series, but are only weakly informed by composition data - Evidence for temporally and/or spatially varying biology not captured by model - Long-term trends in recruitment not captured in the forecast - Difficulty estimating parameters - Evidence of retrospective bias

CCIEA (2024), H.1.a CCIEA Team Report 1

Application of risk tables to stock assessment process

CCIEA Report (2024), H.1.a CCIEA Team Report 1

- Risk table could inform estimate of
  - Sigma – level of scientific uncertainty (higher sigma ~ greater uncertainty -> lower catch levels)
  - P* – Council risk tolerance (higher P* ~ higher risk tolerance -> higher catch levels)
  - Both sigma and P*
  - Something else (e.g., allowable biological catch directly)

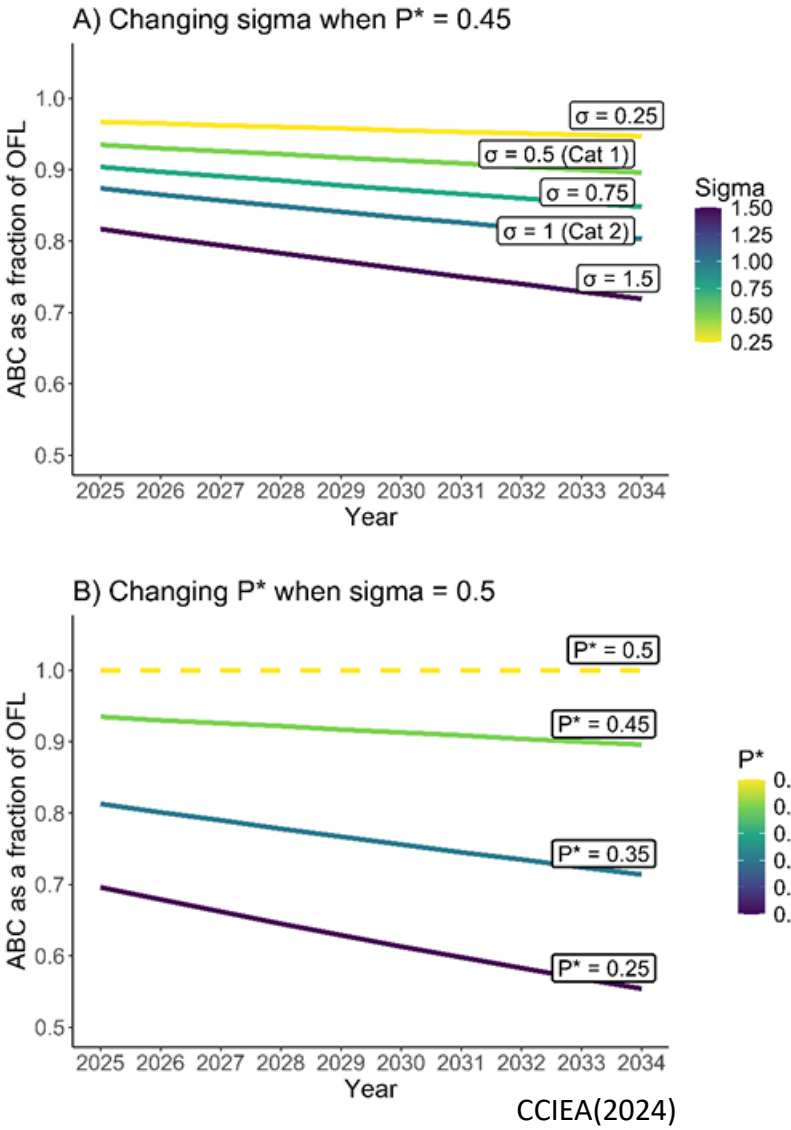
- Recommended using sigma, not P* because upper limit of P* has been fixed at 0.45 and therefore is less suitable to assign for favorable conditions

Draft SSC Review

- Supported revised risk table rubric

- Supported sigma approach, while noting "all pathways … be considered by the PFMC"

- Supported "nonformulaic" approach for using risk tables to set sigma or P*, while noting that a "defined methodology" would improve consistent application



CCIEA(2024)

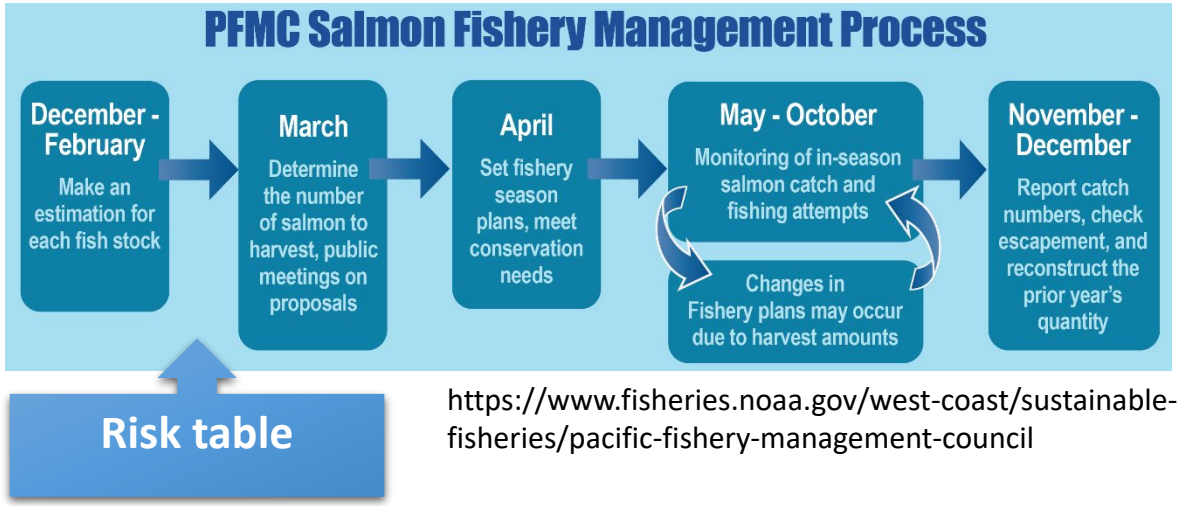
How would risk tables (or other pathways for incorporating ecosystem conditions) look for salmon?

- CCIEA report did not examine this in detail and referred to methodology review of P* - based approach in Satterthwaite and Shelton (2023)

- Draft SSC review has several recommendations:
  - Similar risk table approach could be use if a buffer existed in preseason forecasts
  - Sigma approach doesn't work because forecast model uncertainty is not quantified
  - Improve documentation of salmon forecasts and start accounting for uncertainty
  - Revisit inclusion of environmental covariates (e.g., salmon stoplights) into forecasts
  - Environmental conditions might help determine year-specific escapement goals but "this path is less straightforward"

How would risk tables (or other pathways for incorporating ecosystem conditions) look for salmon?

- Risk table should be produced annually November-March
  - Could adjust uncertainty buffers if they existed
  - Could informally adjust escapement goals
- Risk table rubric
  - How should table be structured?



https://www.fisheries.noaa.gov/west-coast/sustainable-fisheries/pacific-fishery-management-council

Possible risk table rubric for SRFC

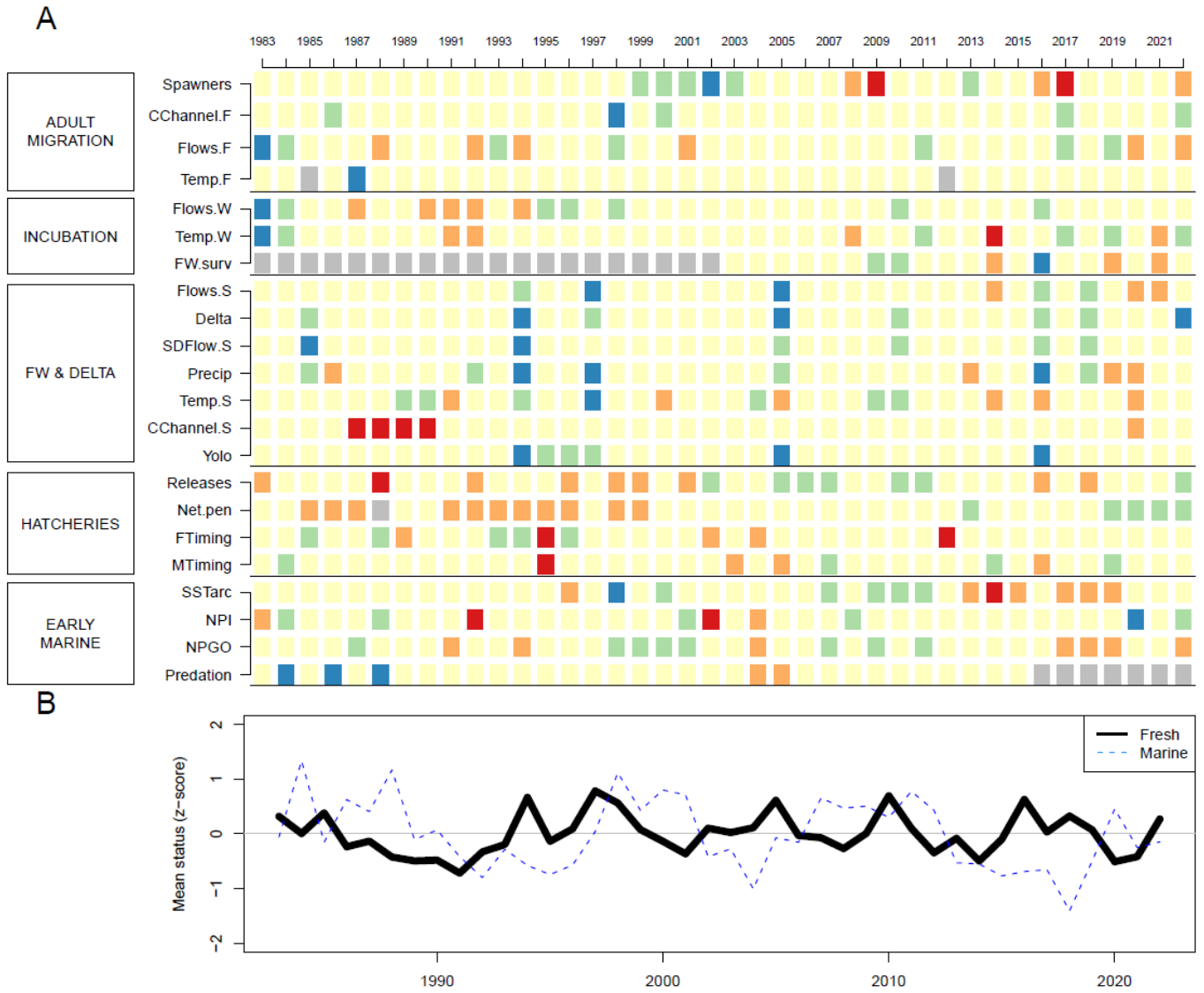
	Habitat Indicators	**Assessment data inputs for forecast, run reconstruction, and harvest models**	**Retrospective assessment of model performance**
Level 1: Favorable	Indicators - show medium-high level of agreement - are in the “green or blue” - are fully available for time series	- Reliable data on jack spawners across watershed - No gaps/problems estimating commercial, recreational, and in-river harvest - Full age structure data for current cohort	- Minimal evidence for spatially variable trends of spawners in return year - Hatcheries met broodstock goal in previous year - Forecast model under-predicted stock in previous 1-2 years - No overfishing in last two years
Level 2: Neutral	Indicators - are inconsistent - majority are in the “yellow” - are not fully available	- Reliable data on jack spawners with some gaps - Few gaps/problems estimating commercial, recreational, and in-river harvest - Partial age structure data for current cohort	- Some evidence for spatially variable trends of spawners in return year - Hatcheries mostly met broodstock goal in previous year - Minor under/over-prediction of forecast model in previous 1-2 years - No overfishing in previous year
Level 3: Unfavorable	Majority of indicators show - Show medium-high level of agreement - are in the “orange/red” - are “gappy”	- Data on jack spawners is spotty - Gaps/problems existed estimating commercial, recreational, and in-river harvest - Poor age structure data for current cohort	- Strong evidence for spatially variable trends of spawners in return year - Hatcheries did not meet broodstock goal in previous year - Forecast model over-predicted stock in previous 1-2 years - Overfishing in one of two previous years

- Uncertainties of indicators *model*?
- Long list or key indicators?
- Other ecosystem attributes?

- Focus on forecast model?
- Additional demographic indicators not used in assessment models (e.g., outmigrant indices)?

- Additional retrospective analysis of demographic indicators not used in assessment models?

Existing habitat indicators as reported



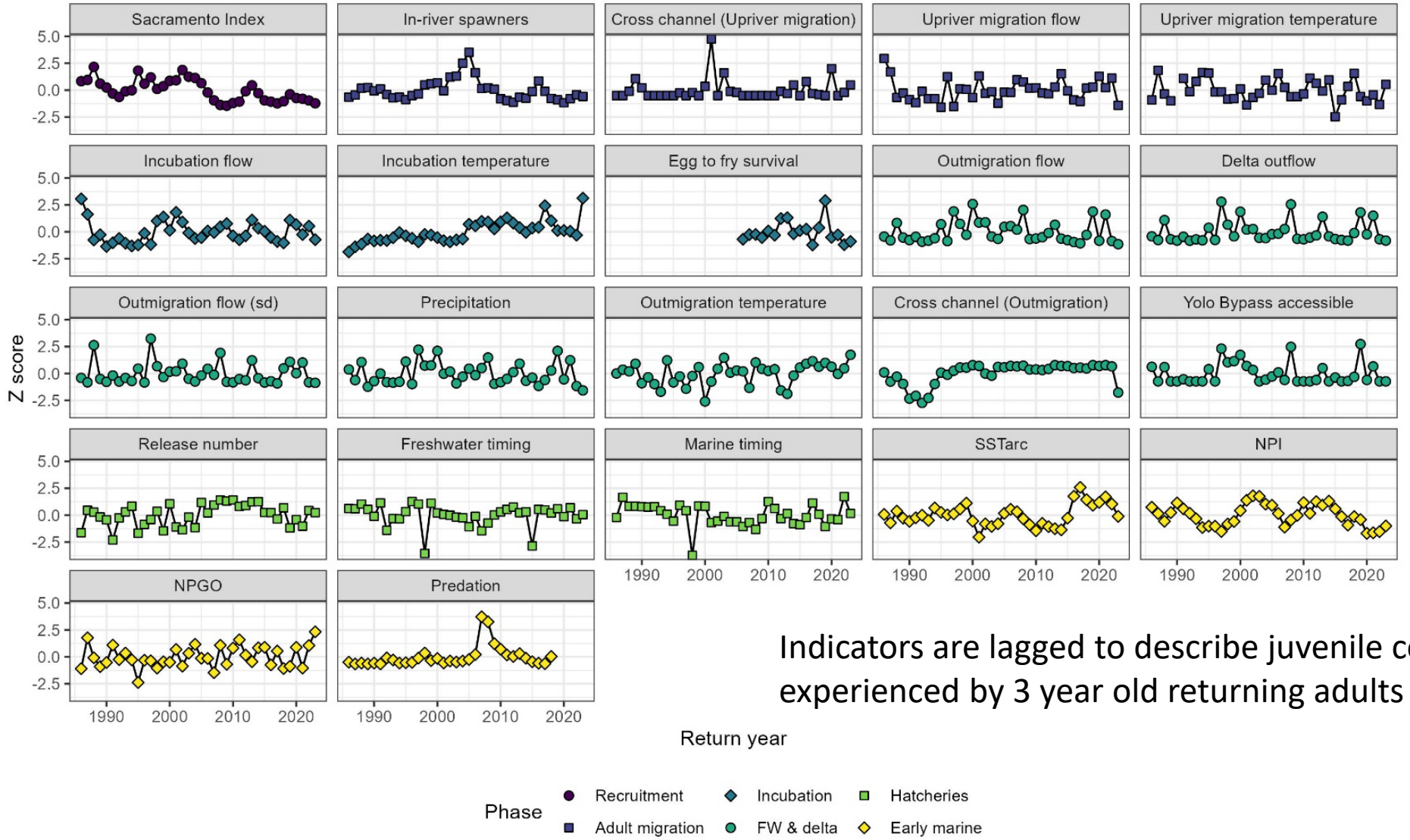
Approaches to incorporating habitat/ecosystem indicators into salmon harvest management

- Incorporate into risk tables
- Improve forecasting model
- Incorporate into harvest control rule

Improve forecasting model?

- Winship et al. (2015): No “compelling evidence for stable…environmental variables”
- Other environmental variables that Winship et al. (2015) did not examine?
- What about habitat indicators?
- Other forecasting approaches independent of sibling model?

Existing habitat indicators



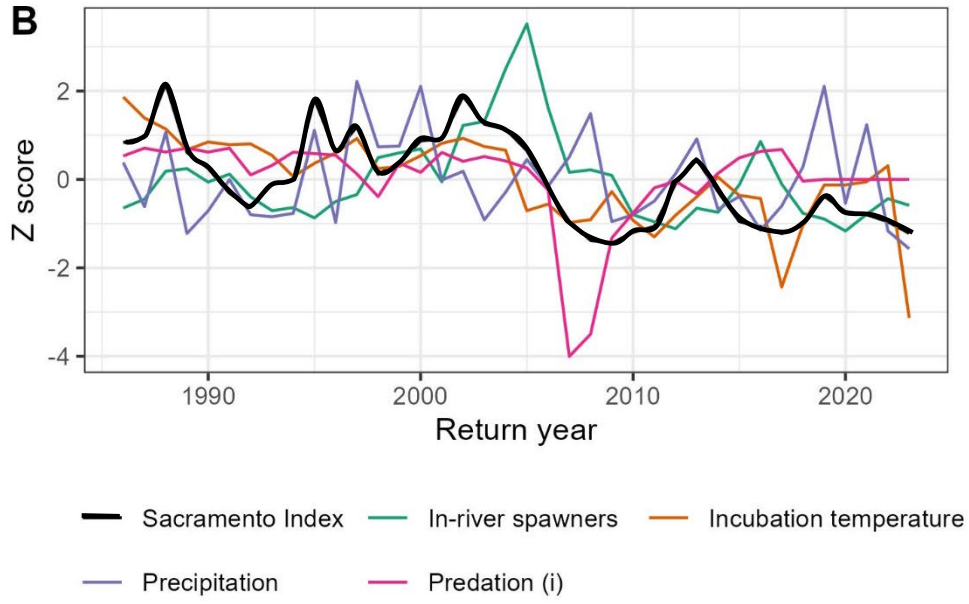
Indicators are lagged to describe juvenile conditions experienced by 3 year old returning adults

Improve forecasting model?

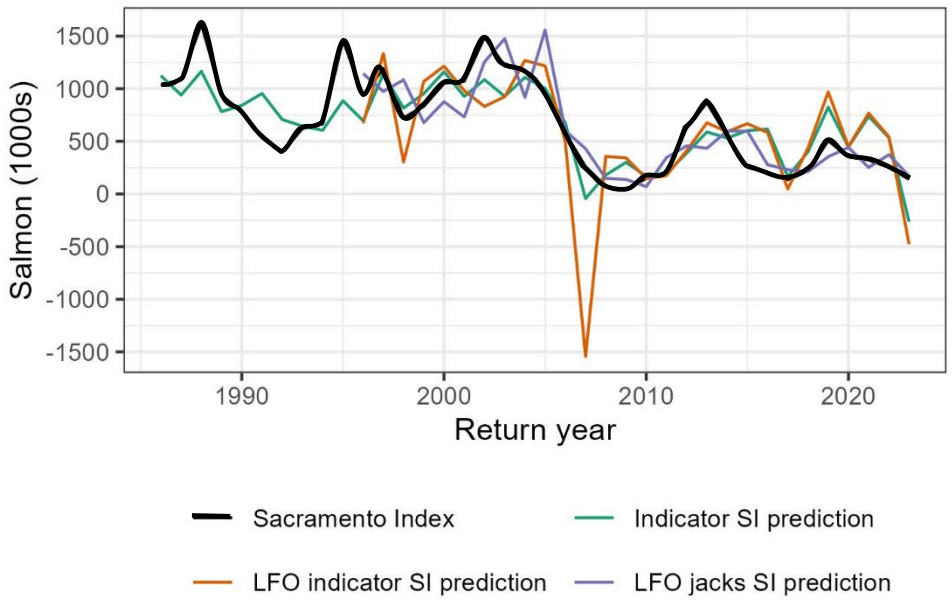
- Winship et al. (2015): No “compelling evidence for stable…environmental variables”
- Other environmental variables after 1st ocean year that Winship et al. (2015) did not examine?
- Habitat indicators are not likely candidates because they compete for variance with jacks.
- Other forecasting approaches independent of sibling model?

Model performance

SI vs “key indicators” (those in most models)



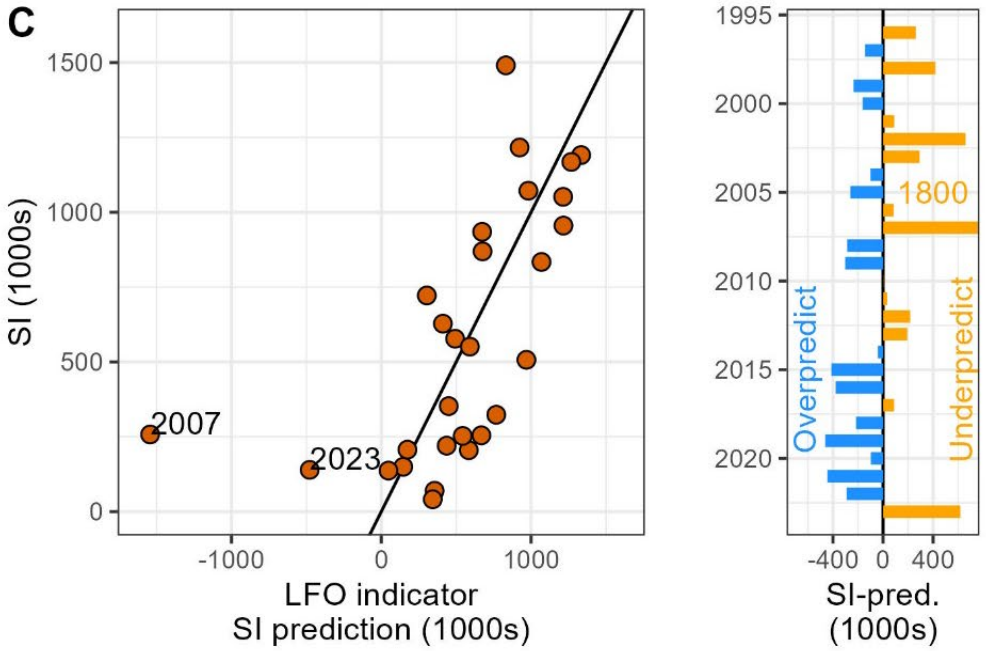
Prediction for jacks or key indicator suite



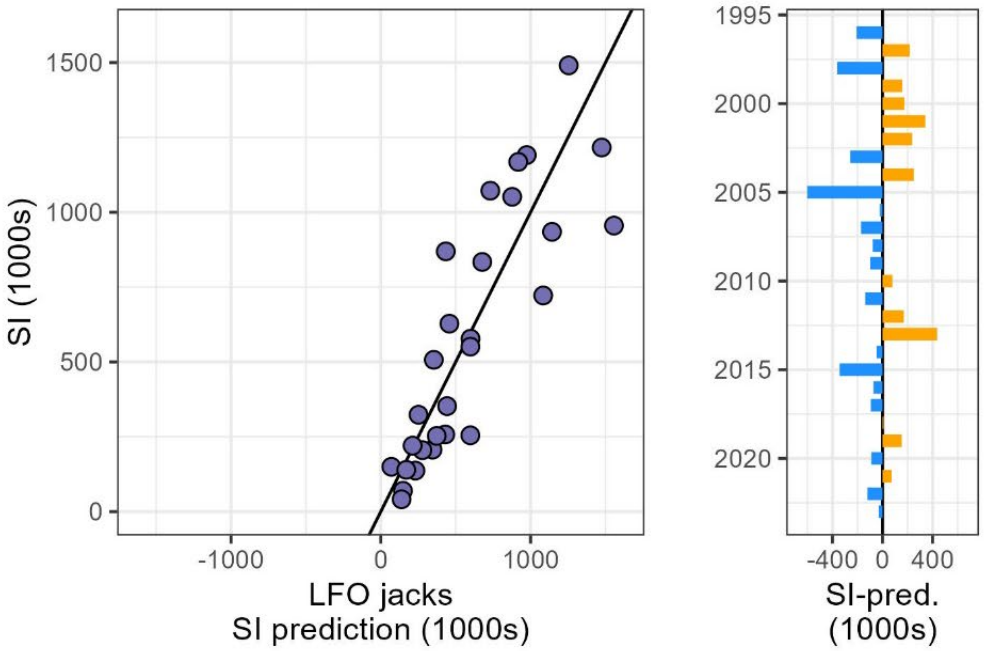
- Indicator SI prediction: model predictions as informed by data from all years
- Leave future out (LFO) indicator SI prediction: true predictions made one year in advance using the years of data before the prediction
- LFO jack-based SI prediction: true predictions using jacks, also one year out as above

Model performance

True predictions using key indicators

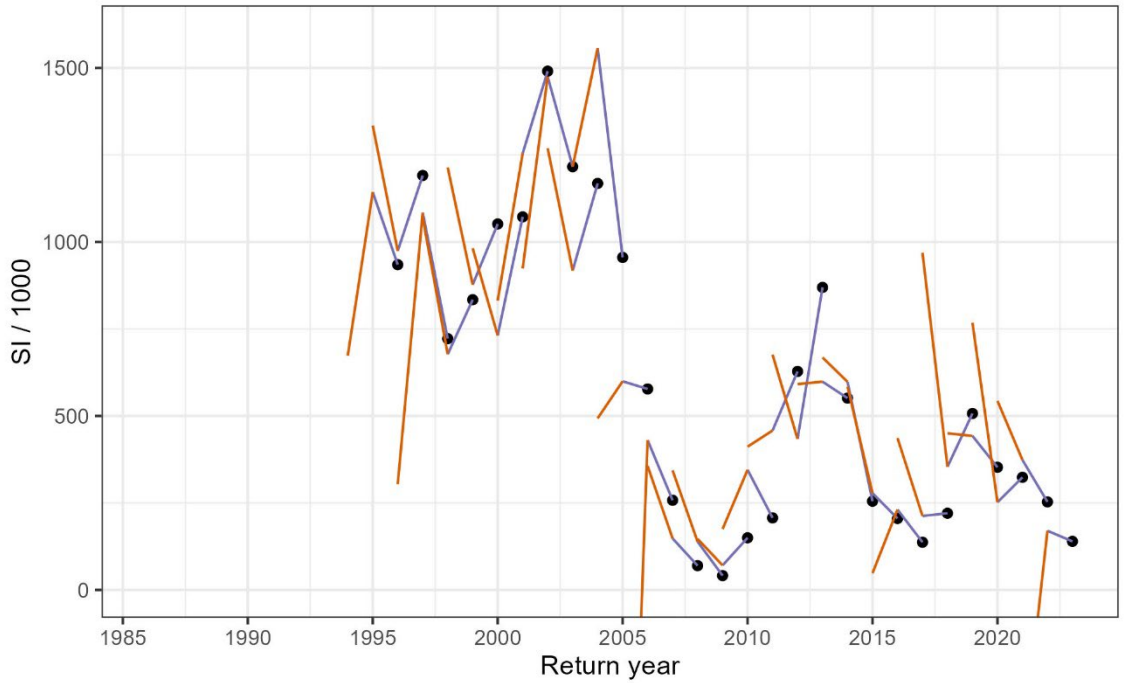


True predictions using jacks



- Preliminarily, jack models are still better than key indicator model
- However, indicators can make prediction <u>two years in advance</u>

Using indicator and jacks-based models together



Indicators -> Jacks prediction (2 -> 1 years out)
Jacks prediction -> Actual SI (1 -> 0 years out)
- Actual SI

- Indicator models could provide initial predictions 2 years out, followed up by current method of jack-based predictions one year out.

- Performance of ensemble forecasts could be examined

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Oregon Coho harvest control rule

Multi-model inference, suite of climate indicators

Forecast marine survival

FW production relative to capacity of parent spawners

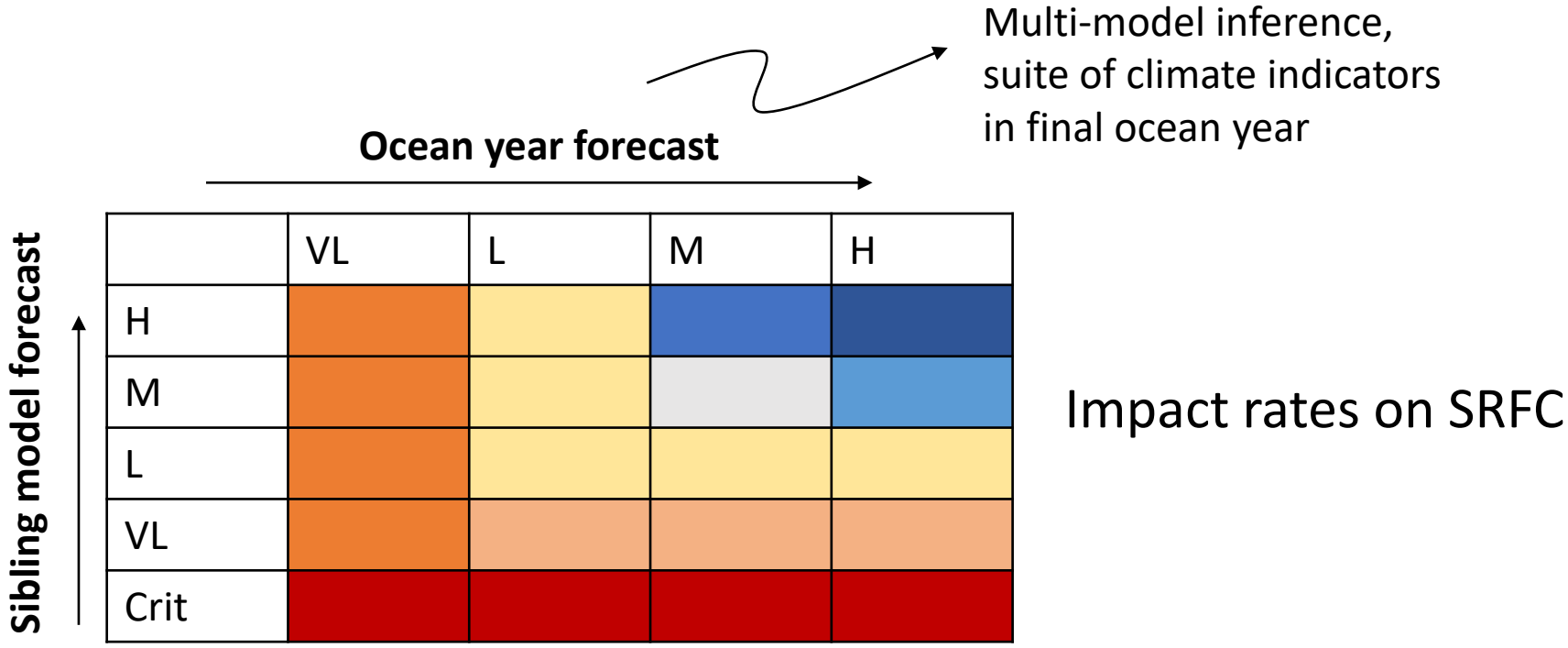
	VL	L	M	H
H	≤ 10%	≤ 15%	≤ 30%	≤ 35%
M	≤ 10%	≤ 15%	≤ 20%	≤ 25%
L	≤ 10%	≤ 15%	≤ 15%	≤ 15%
VL	≤ 10%	≤ 13%	≤ 13%	≤ 13%
Crit	≤ 5 %	≤ 5 %	≤ 5 %	≤ 5 %

Impact rates on Oregon coho

[exact VL and crit levels may be incorrect]

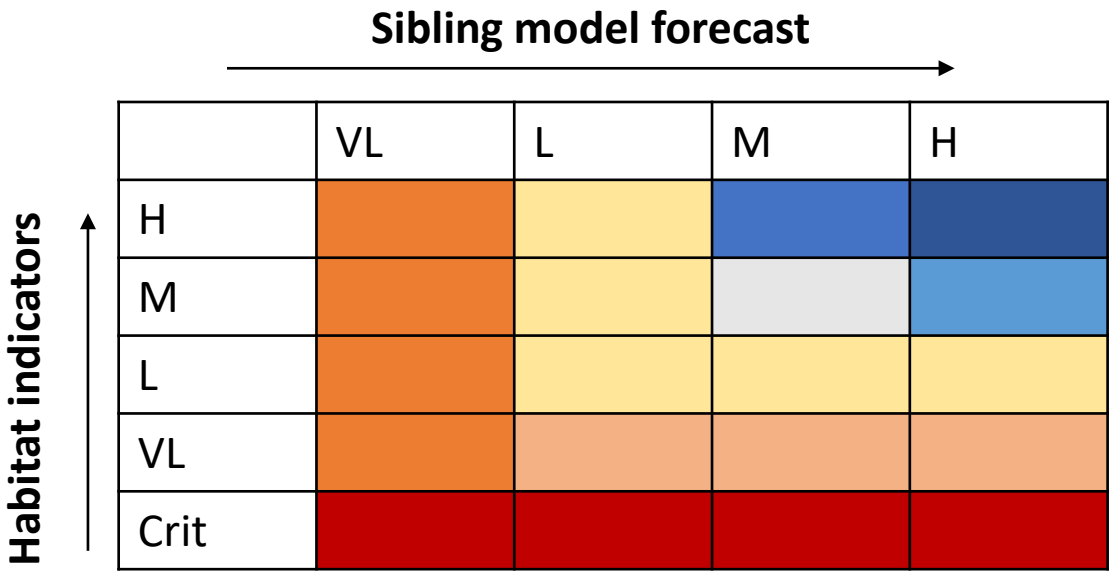
Inference from spawner and smolt monitoring

Possible SRFC harvest control matrix adaptations



Possible SRFC harvest control matrix adaptations

Re-evaluate additional
marine indicators
Multi-model inference?



Impact rates on SRFC

Inference from habitat indicators model
Could be multi-model inference

Also could do the two-year advance forecast (e.g., might be more aggressive if two year forecast showed high abundance)

Pros and cons of harvest matrix approach

Pros

- FW/marine phases of demography nicely captured
- Alternately, could independently integrate predictions of two independent models
- Given absence of sigma/P* estimation for salmon, harvest matrix could be more effective for ecosystem-informed harvests than informal application of risk table

Cons

- Creates zones where small changes in forecast can have large effects
- Following sibling model, there's not much extra variation to explain in final ocean year
- Following sibling + habitat indicators models, why not just use multi-model inference instead of a matrix?
- There is currently a lot of interest and momentum in risk table approach