Salmon Risk Management Framework

Presentation on [Satterthwaite and Shelton (2023)]

to PFMC, 9/19/26

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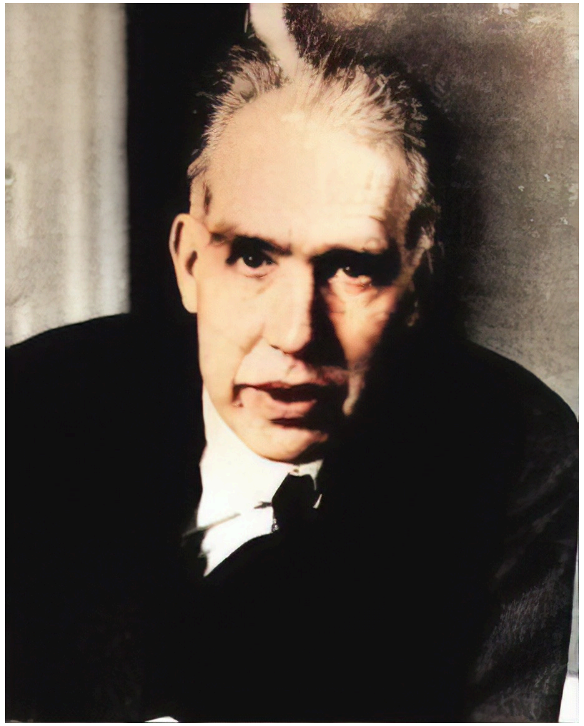

"Prediction is very difficult, especially if it's about the future."

- Danish proverb often attributed to Niels Bohr

https://commons.wikimedia.org/wiki/File:Niels_Henrik_David_Bohr_Physicist_1945.jpg

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Aspects of forecast performance

- Bias: on “average”, is there directional error?
  - This is a statistical concept, not implying intentional prejudice
    - Mean-unbiased: mean error = 0 fish
    - Median-unbiased: too high 50% of time, too low 50% of time

- Precision: repeatability of errors
  - How consistent are forecast errors across attempts at forecasting

Past salmon methodology reviews have used an alphabet soup of performance metrics

- Since 2013: APE, MAPE, RMSE, MSA, ME, MPE, MLAR, R^2, MAE, C, MASE, LPPD, PVE (and maybe more I missed)
- Some of these measure bias, some measure precision, some combine aspects of both

- "The SSC recommends work on reducing redundant metrics and identifying which metrics should be emphasized for particular forecasts based on management goals and the broader context for that stock."
  - (November 2023 Agenda Item D.3.a, Supplemental SSC Report I)

Proposal:
Track (maybe in Pre-I?) forecast performance with a common set of metrics.

- One metric of bias (C, median N_{post}/N_{pre} ratio)
  - *Could also serve as a risk-neutral bias correction (multiply forecast by C)*

- One metric of precision (σ, log scale standard deviation in ratio)
  - *And/or because it's hard to confidently identify bias in noisy forecasts…*
  - A metric of precision that assumes the forecast is unbiased (σ_0)
    - *Could be part of a precautionary buffering approach*

Salmon forecast performance for PFMC stocks

- See Table 1 of [Satterthwaite and Shelton (2023)]
- Conclusive evidence of bias is rare, but present for a few stocks, and moderate amounts of bias are impossible to confidently detect nor rule out
- Many Chinook forecasts have σ_0 near 0.5
- Coho forecasts σ_0 often somewhat higher
- Could/should we buffer against this level of uncertainty?

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[Article]

Retrospective Evaluation of Preseason Forecasting Models for Pink Salmon

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Abstract.—Models for making preseason forecasts of adult abundance are an important component of the management of many stocks of Pacific salmon *Oncorhynchus* spp. Reliable forecasts could increase both the profits from fisheries and the probability of achieving conservation and other management targets. However, the predictive performance of salmon forecasting models is generally poor, in part because of the high variability in salmon survival rates. To improve the accuracy of forecasts, we retrospectively evaluated the performance of eight preseason forecasting models for 43 stocks of pink salmon *O. gorbuscha* over a total of 783 stock-years. The results indicate that no single forecasting model was consistently the most accurate. Nevertheless, across the 43 stocks we found that two naïve time series models (i.e., those without explicitly modeled mechanisms) most frequently performed best based on mean raw error, mean absolute error, mean percent error, and root mean square error for forecasts of total adult recruits. In many cases, though, the best-performing model depended on the stock and performance measure used for ranking. In 21% of the stocks, a new multistock, mixed-effects stock–recruitment model that included early-summer sea surface temperature as an independent variable along with spawner abundance demonstrated the best performance based on root mean square error. The best-performing model for each pink salmon stock explained on average only 20% of the observed variation in recruitment. Owing to the uncertainty in forecasts, a strong precautionary approach should be taken to achieve conservation and management targets for pink salmon on the West Coast of North America.

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[Article]

Retrospective Evaluation of Preseason Forecasting Models for Sockeye and Chum Salmon

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Abstract.—Using comprehensive data sets for chum salmon *Oncorhynchus keta* (40 stocks) and sockeye salmon *O. nerka* (37 stocks) throughout their North American ranges, we compared the retrospective performance of 11 models in preseason forecasting of adult abundance. Chum and sockeye salmon have more complicated age structures than pink salmon *O. gorbuscha*, which we investigated previously (Haeseker et al. 2005), and this complexity presents new challenges as well as opportunities for forecasting. We extended our previous work to include two new forecasting models that make use of leading indicators: either the survival rate of earlier-maturing pink salmon from the same brood year (Ricker pink salmon index model) or the abundance of earlier-maturing siblings (hybrid sibling model, a new version of the standard sibling model). No single forecasting model was consistently the best for either chum or sockeye salmon, but the hybrid sibling model frequently performed best based on mean absolute error, mean percent error, and root mean square error. As was observed for pink salmon, several naïve models (i.e., simple time series models without explicitly modeled mechanisms) also performed well, as did forecast averaging models composed of two models with the least-correlated forecasting errors. In general, model ranking depended on the particular stock and performance measure used. However, even the top-ranked model for each stock explained on average only 21% of the observed interannual variation in chum salmon recruitment and only 36% of the variation in sockeye salmon recruitment. Although improvements may be possible for some stocks in specific circumstances, a major breakthrough in general forecasting ability seems unlikely given the breadth of stocks and models examined to date. Therefore, better in-season updates and adjustments to fishing regulations and a cautious approach to opening and closing fisheries should remain high priorities.

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Potential buffering approach:
Science step: Estimate C and σ (or σ_0)
Policy step: Choose P* (probability of over-forecast)

- 0.50 – “risk neutral”
- 0.45 – used most of the time for ABCs for groundfish and CPS
- 0.40 – used in cases of heightened concern for groundfish and CPS
- 0.35 – has been among alternatives analyzed for groundfish in certain cases, but not used to date (J. DeVore pers. comm.)
- 0.25 – used in some ICES Atlantic salmon frameworks

Might a “risk table” type approach inform year-specific P*?
And/or current status, etc.?

SRFC case study:
Retrospective evaluation of potential buffers

- For 2014 (“current” forecast method adopted) – 2021 (last year with postseason estimates at time of analysis),
  - What actually happened in terms of
    - forecast
    - allowable ER from control rule
    - anticipated ER factoring in Council guidance and mixed-stock constraints
    - ER achieved, reflecting implementation error
    - Escapement achieved
    - SRFC harvest achieved
    - Status determinations (overfished / rebuilding / rebuilt / NA)
  - What could have happened for all of these, if:
    - Bias correction was applied, with no precautionary buffer
    - Apply a precautionary buffer, but assume unbiased forecasts
    - Apply a combination of bias correction and buffer
    - Accounted for implementation error, guidance, and mixed stock constraints, but not the potential recruitment increase from higher escapement

Satterthwaite and Shelton (2023)

Table 3
Management outcomes for 2014–202~~0~~1 based on management actually implemented, as well as modified outcomes expected based on alternative scenarios for applying a bias correction and/or uncertainty buffer.

Scenario	Mean ann. SRFC harvest	Years overfished
Status quo	197,313	3
Bias adjustment only, P * =0.5	186,469	2
Bias adjustment, P * =0.45 buffer	179,193	1
Bias adjustment, P * =0.40 buffer	170,790	1
Bias adjustment, P * =0.33 buffer	156,871	0
Bias adjustment, P * =0.25 buffer	143,060	0
Bias adjustment, P * =0.10 buffer	116,909	0
Assume unbiased, P * =0.45 buffer	193,336	2
Assume unbiased, P * =0.40 buffer	187,306	2
Assume unbiased, P * =0.33 buffer	175,637	1
Assume unbiased, P * =0.25 buffer	157,860	0
Assume unbiased, P * =0.10 buffer	127,638	0

Satterthwaite and Shelton (2023)

Post-paper: What about 2022?

- 2022 preseason forecast was 396,458 resulting in control rule yielding a 69.2% allowable ER.
- Council issued guidance to target escapement of at least 180,000, leading to a 54.6% allowable ER.
- Pre-III expected ER was 49.9%, suggesting mixed-stock constraints predominated.
- Postseason estimate of ER was 75.5% (1.51x implementation error), yielding 61,862 escapement given the postseason SI of 252,951.
- A bias correction and P*=0.40 would have yielded a buffered forecast of 312,205.
- Applying guidance to target 180,000 escapement to buffered forecast would lead to a 42.3% allowable ER *(but did this guidance reflect a true desire for a higher escapement goal or just concern about the forecast?).*
- Assuming the same level of implementation error, potential outcome under buffered scenario would be an escapement of 91,013.

Post-paper: What about 2023-2025

- 2023 and 2024 hard to model given fishery closure. Maybe that closure could have been avoided if 2022 had not been quite so bad, and/or a more formal method for coping with model error was in place?

- 2025 hard to model given new approach to in-season management. But 2025 Pre-III projected escapement 21% higher than minimum objective, suggesting an ~80% buffer multiplier could have been accommodated for SRFC without changing plans.

Challenges to implementing this approach

- Forecast methodologies change over time, C & σ estimates may be dated
- Hard to confidently ascertain bias with imprecision and limited sample sizes
- Uncertainty in postseason abundance estimates not currently accounted for
- Changes in control rules or reference points may change consequences of forecast error
- Implementation (harvest model) error rather than abundance forecast error may be (or may have been) the more consequential error
    - Why not try to address both?
    - For South Of Falcon, move to in-season management may raise importance of forecast error relative to the historical importance of implementation error

What could this approach do for you?

- Reporting C and σ: Provide context on forecast performance, potentially prioritize reviews, guidance for expectation management.
- Implementing bias correction: Expectation of less biased forecasts in cases where bias confidently estimated to be present, and therefore more likely that management advice will meet the intent of control rules etc.
- Implementing buffers: Reduced probability of under-escapement, reduced risk of overfished status, faster rebuilding, potential for greater future yields.

- A quantitative, transparent, and repeatable way of translating concern (or lack thereof) over forecast performance into management advice.