Stock status and biological and fishery consequences of alternative harvest and rebuilding actions for Yukon Chinook Salmon (*Oncorhynchus tshawytscha*)

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Illustration by Paul Vecsei

Outline

- Background context and request for science advice Terms of Reference
- Stock structure, biology, and distribution
- Stock status and trends (Stock Management Unit and Conservation Unit scales)
- Proposed Stock Management Unit reference points
- Anthropogenic, ecosystem, and climate factors affecting the stock
- Enhancement history and potential to contribute to rebuilding
- Habitat and potential to contribute to rebuilding
- Impact of alternative fishery management measures
- Key findings, knowledge gaps and areas of future work

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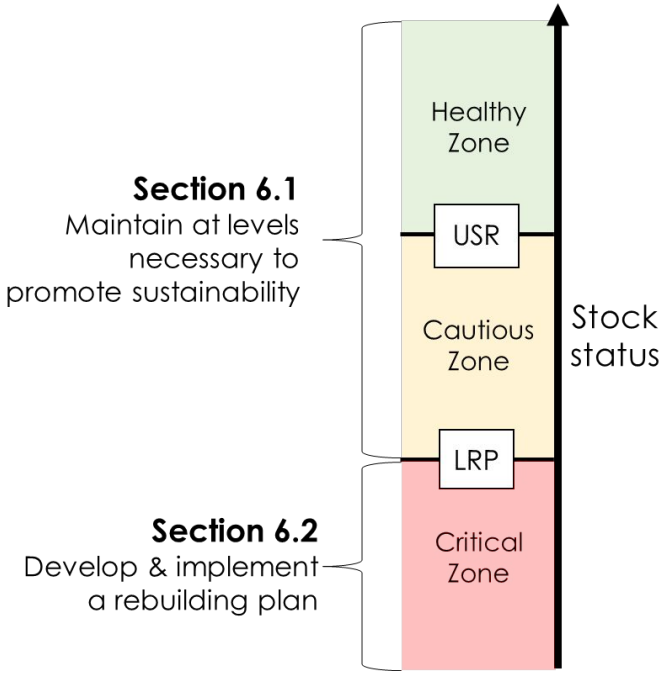
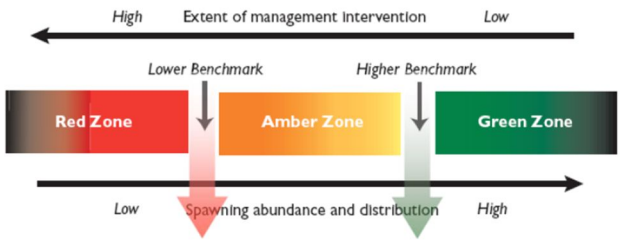
Background

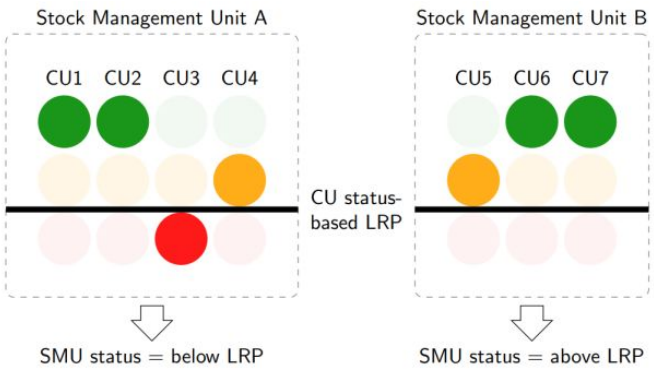
- Yukon Chinook will be prescribed by regulation as a "major fish stock" under section 6 (Fish Stocks provisions) of the *Fisheries Act*
- DFO is legally required to assess stock status, maintain the stock at levels necessary to promote sustainability, and develop and implement a Rebuilding Plan if the stock falls below its Limit Reference Point*



Background

- For Pacific salmon, LRPs under *Fisheries Act* should be ‘Conservation Unit status based’, where status is based on recent spawner abundance relative to biological benchmarks
- This recommendation is aligned with Canada’s Wild Salmon Policy objective of preserving biodiversity of salmon at the scale of Conservation Units





Holt *et al*. 2017. DFO Can. Sci. Advis. Sec.

Science advice Terms of Reference

1. describe current understanding of (a) **stock structure and distribution**, (b) stock, and component Conservation Unit, Wild Salmon Policy **biological status and trends**, and (c) anthropogenic, ecosystem, and climate **factors affecting the stock**;
2. describe potential **habitat and enhancement activities** that could contribute to stock rebuilding;
3. provide estimates of a **Limit Reference Point** and other **candidate reference points** (e.g., Upper Stock Reference and Removal Reference) for the stock;
4. provide quantitative estimates of the expected biological and fishery **consequences of current and alternative harvest management measures** that could contribute to stock rebuilding; and
5. identify key **knowledge gaps and areas requiring future work**

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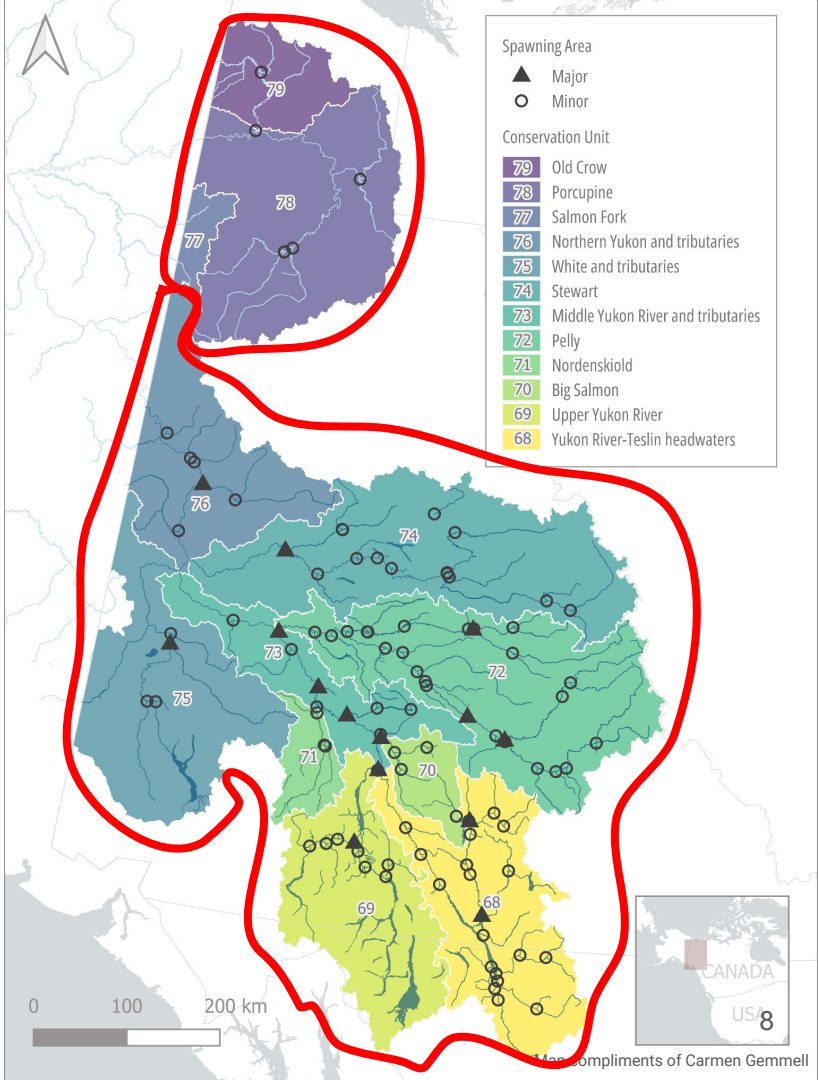
Stock structure and distribution

Spawning locations

Porcupine SMU
- CK-77: Salmon Fork
- CK-78: Porcupine
- CK-79: Old Crow

Yukon SMU
- CK-68: Yukon River-Teslin headwaters
- CK-69: Upper Yukon River
- CK-70: Big Salmon
- CK-71: Nordenskiold
- CK-72: Pelly
- CK-73: Middle Yukon River and tribs.
- CK-74: Stewart
- CK-75: White and tribs.
- CK-76: Northern Yukon River and tribs.



Map compliments of Carmen Gemmell

Brown *et al*. 2017. JFWM.

Stock structure and distribution

GSI baseline locations

Porcupine SMU
- CK-77: Salmon Fork
- CK-78: Porcupine
- CK-79: Old Crow

Yukon SMU
- CK-68: Yukon River-Teslin headwaters
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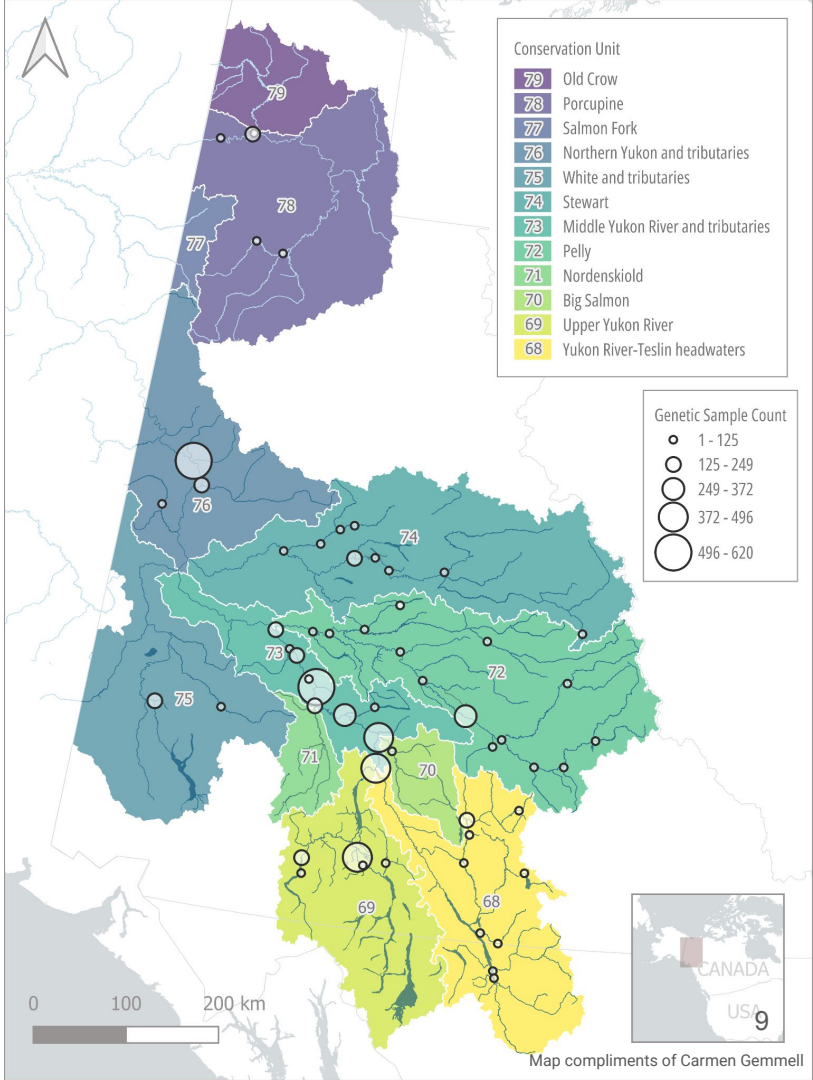
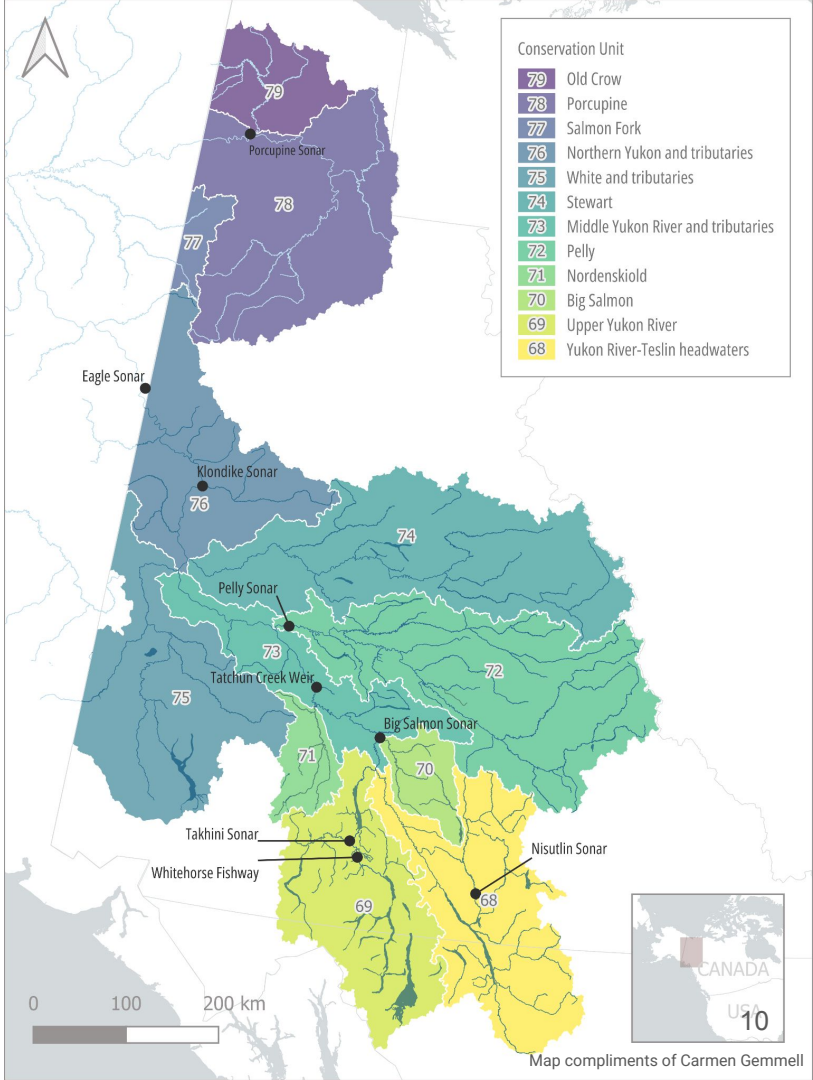


Map compliments of Carmen Gemmell

Stock assessment

- Current stock aggregate and SMU sonar assessments: Pilot, Eagle, Porcupine
- Current CU sonar assessments: Klondike, Pelly, Big Salmon, Tahkini, Nisutlin
- Numerous other tributary assessment (weirs, aerial or foot surveys) have occurred or are ongoing
- Nearly all assessment projects are run/co-run by Yukon First Nations
- CUs with no tributary assessments:
    - Salmon Fork
    - Nordenskiold
    - Stewart
    - White



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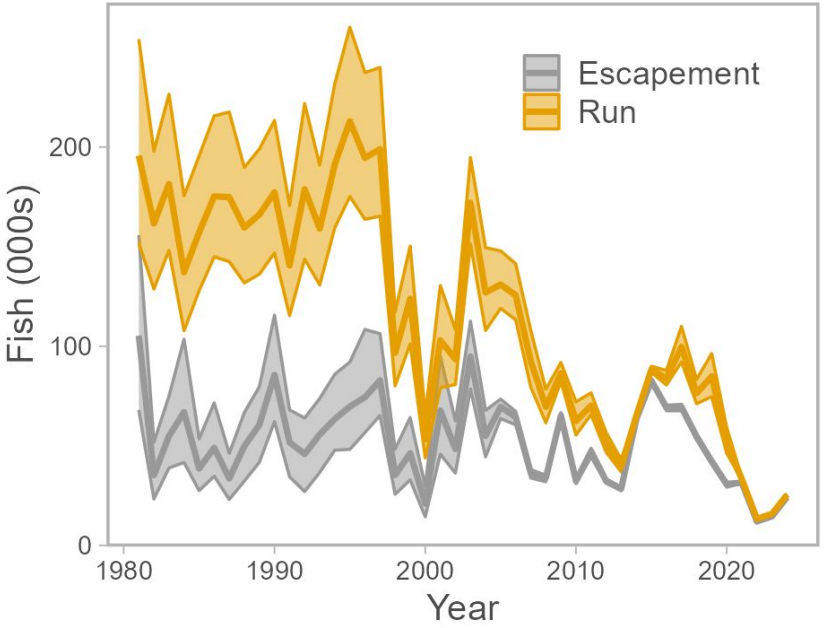
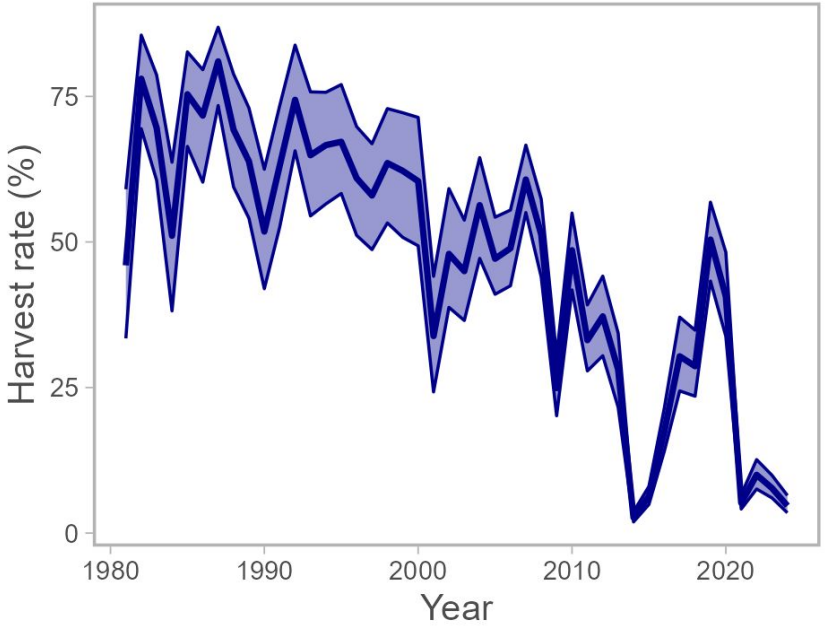
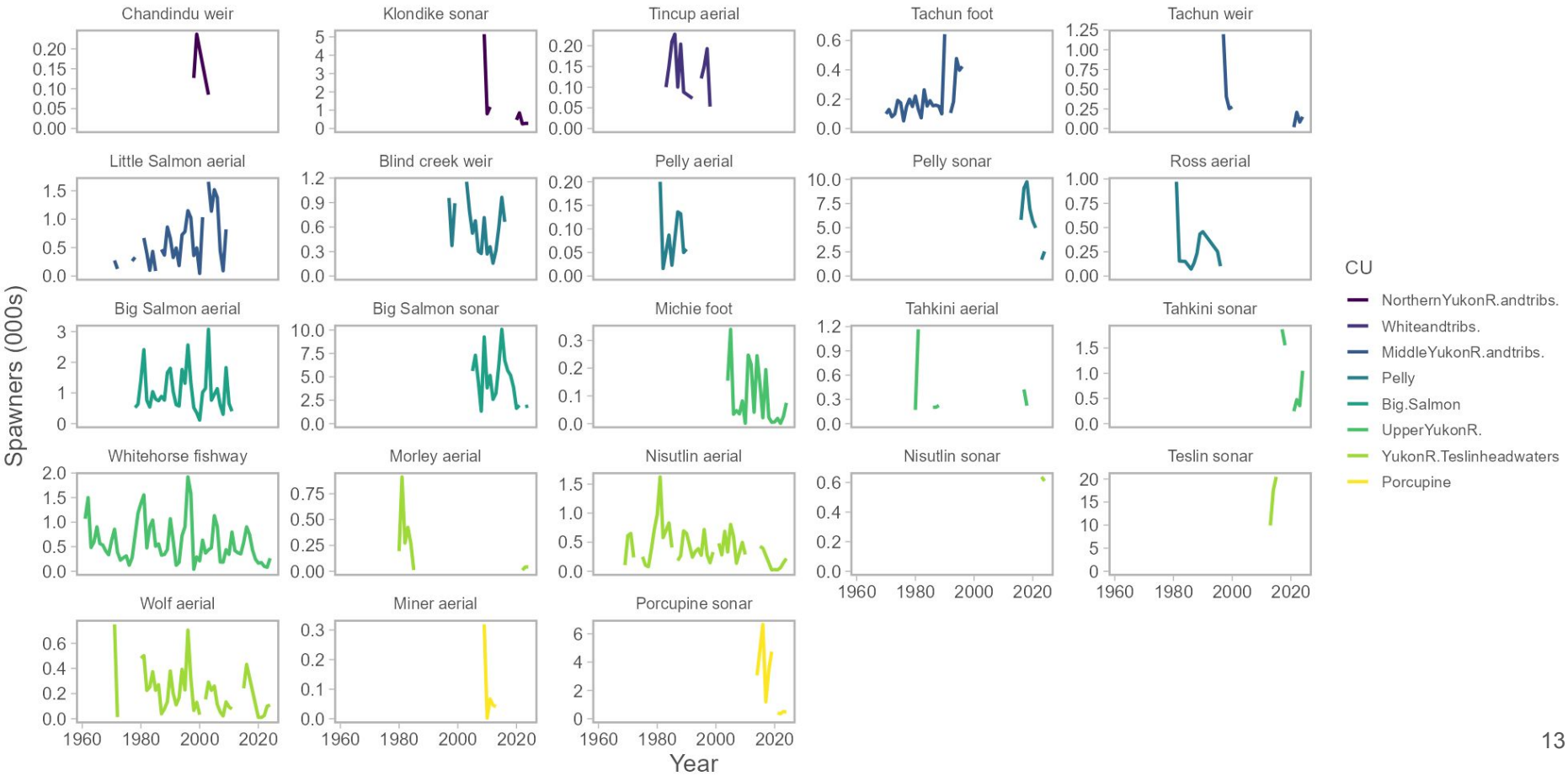
Aggregate spawners, returns and harvest rates over time



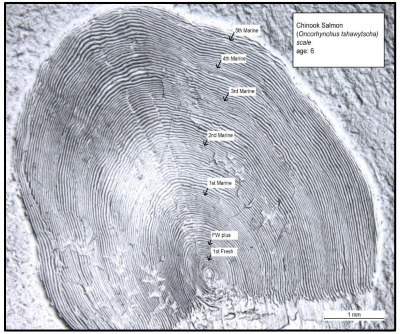


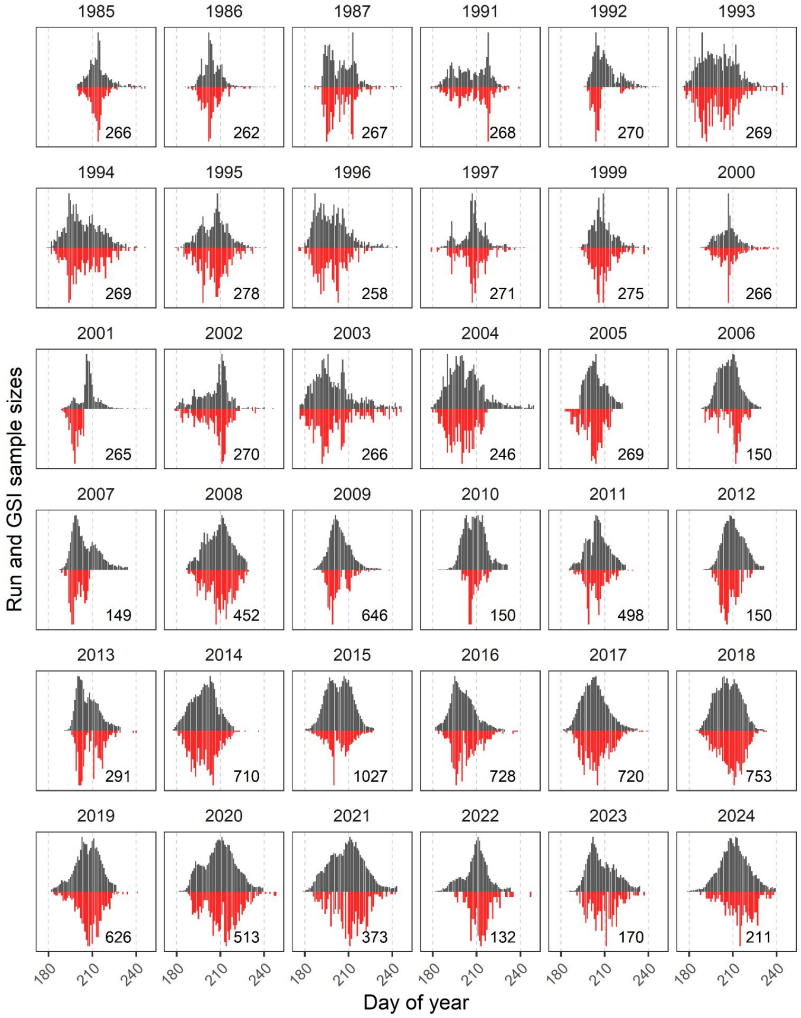
Updated through 2024 using model in Connors *et al*. 2022. DFO Can. Sci. Advis. Sec.

Tributary spawner abundance estimates



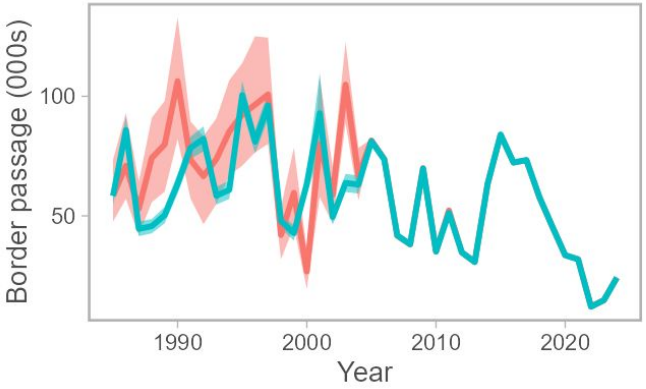
Genetics at border to reconstruct CUs



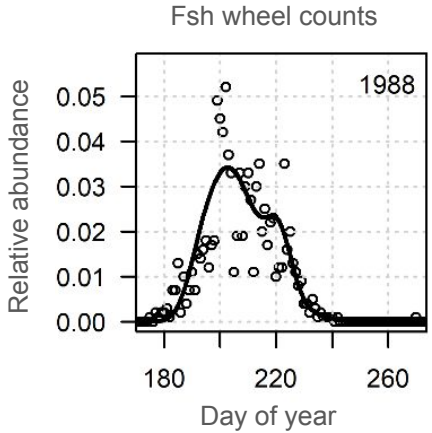


Update of approach in [Connors et al. 2022. Ecological Applications]

Conservation Unit border passage reconstruction model



Border passage estimates
Border passage model predictions



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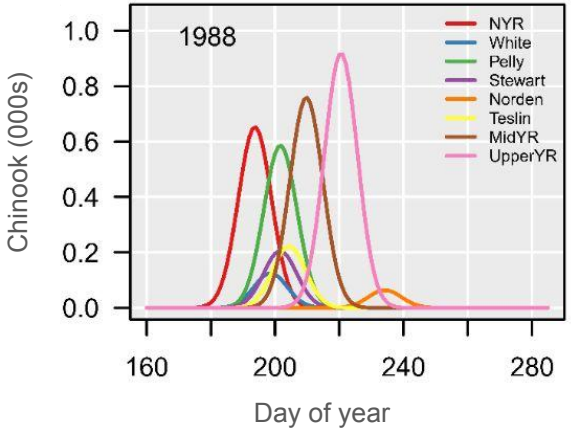

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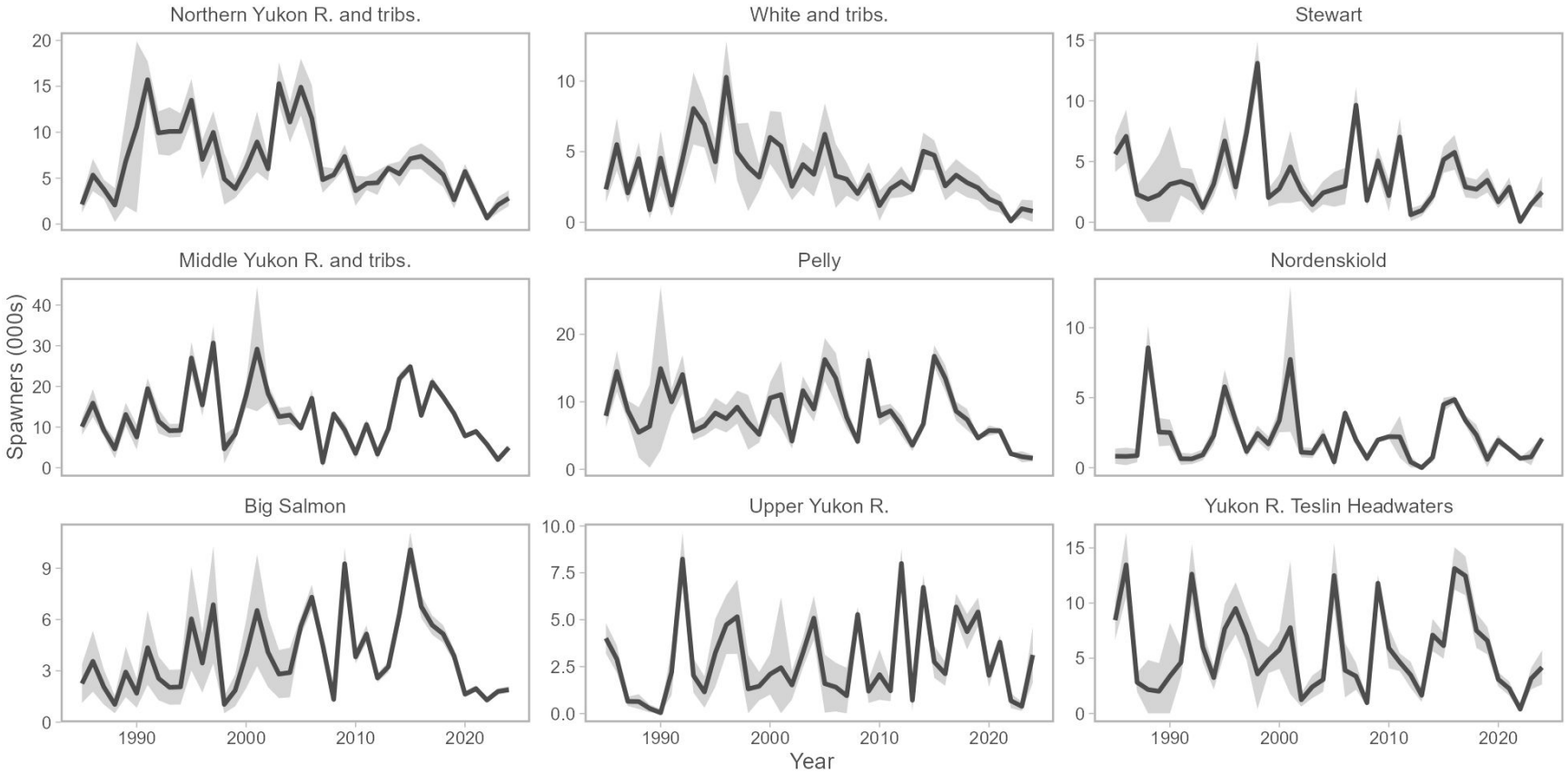
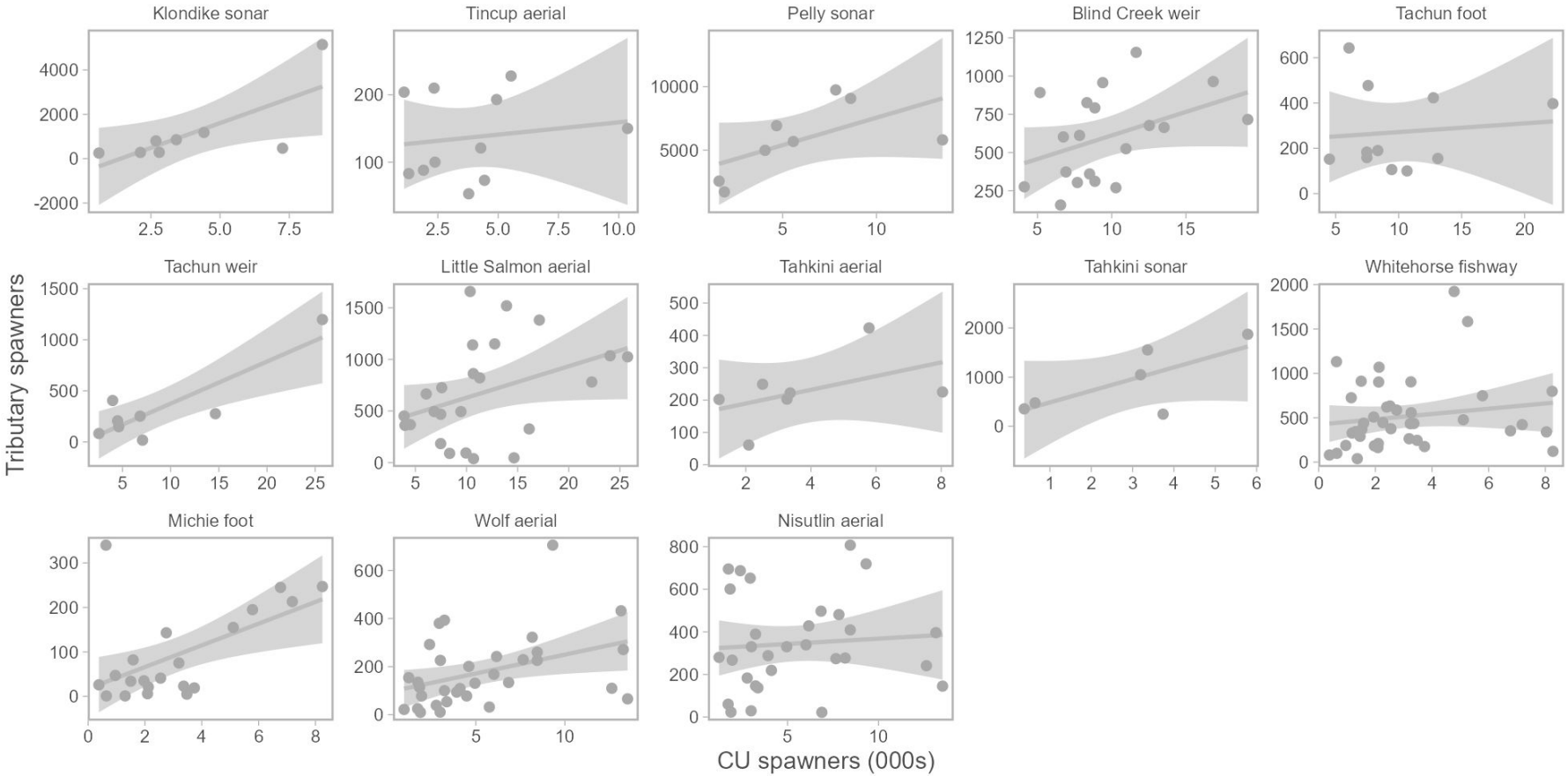
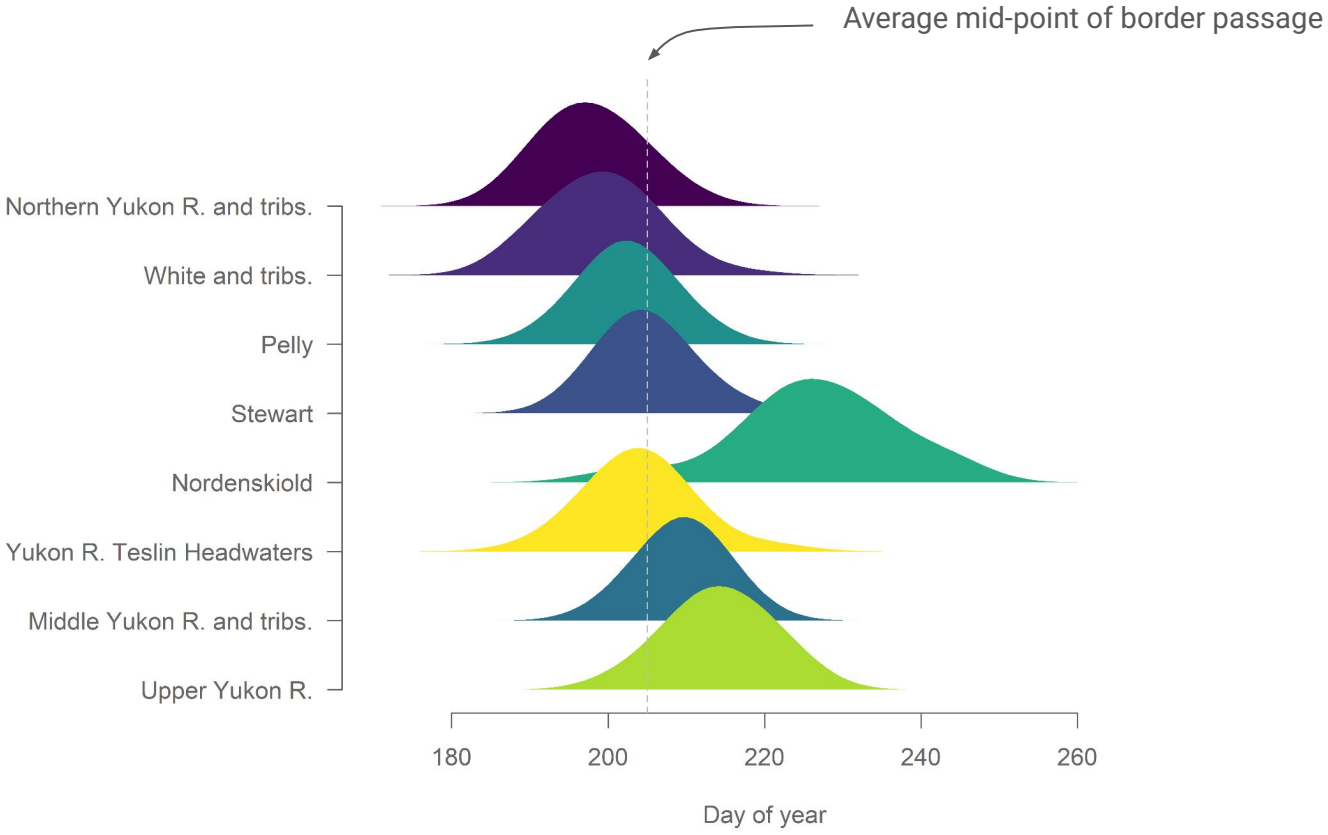
Conservation Unit spawner abundance reconstructions



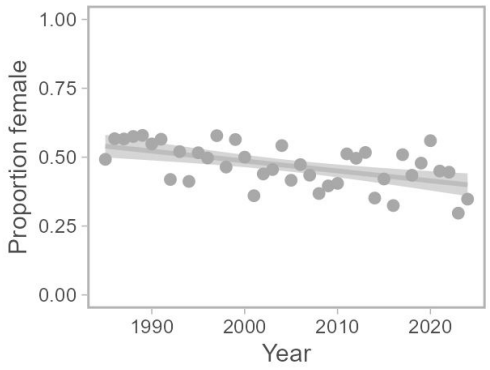
Tributary spawner abundance vs. CU reconstructions

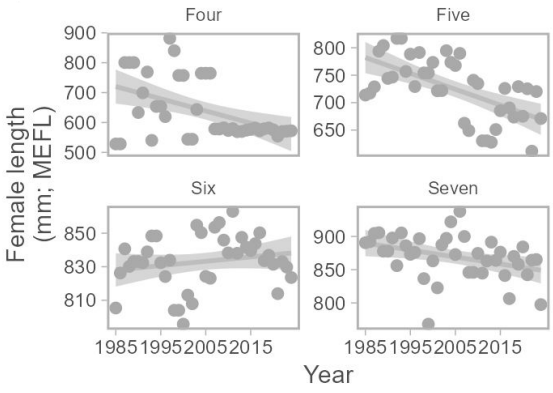


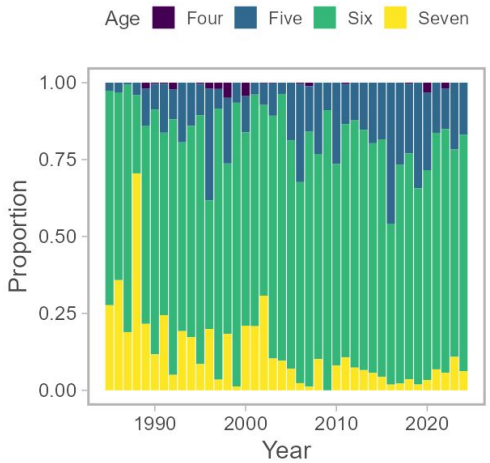
Conservation Unit run-timing

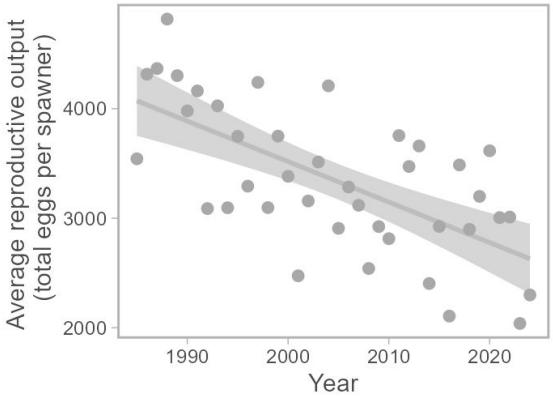


Escapement quality over time

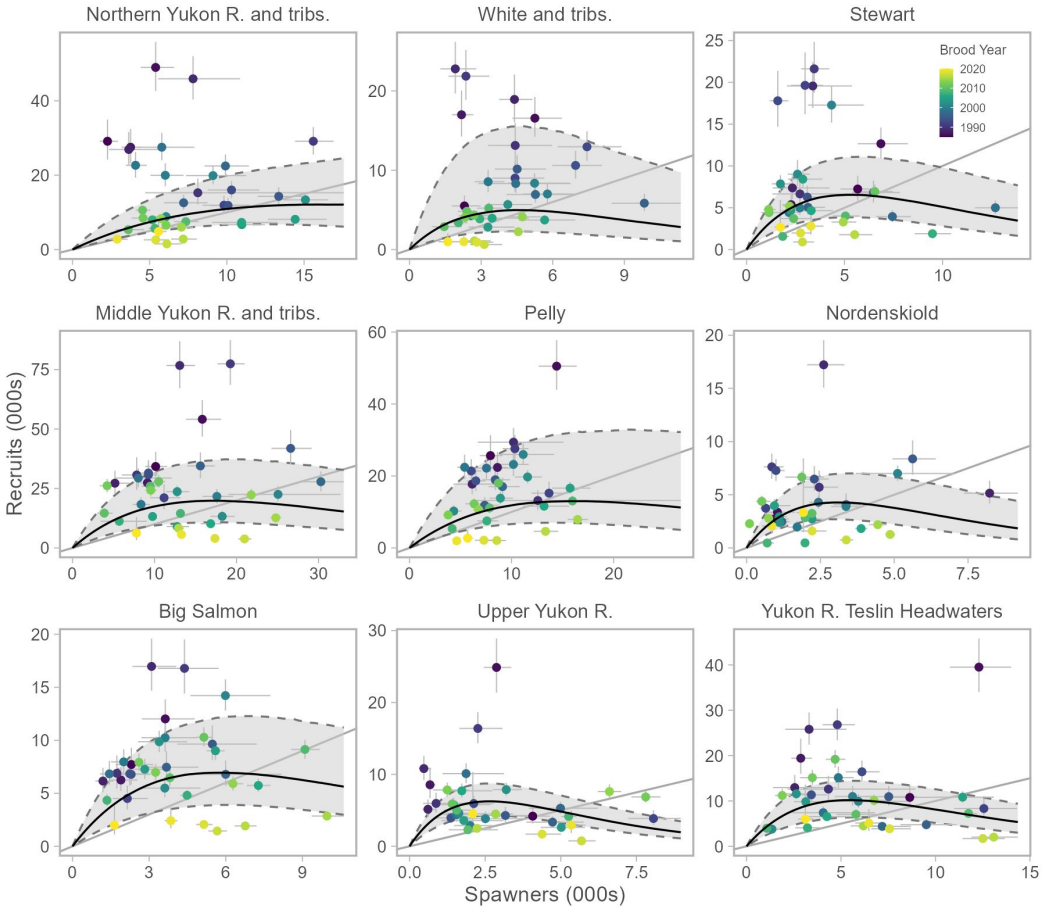




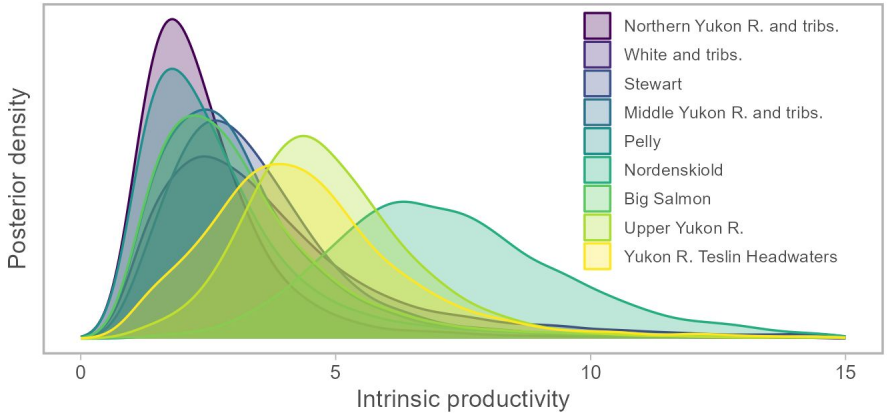


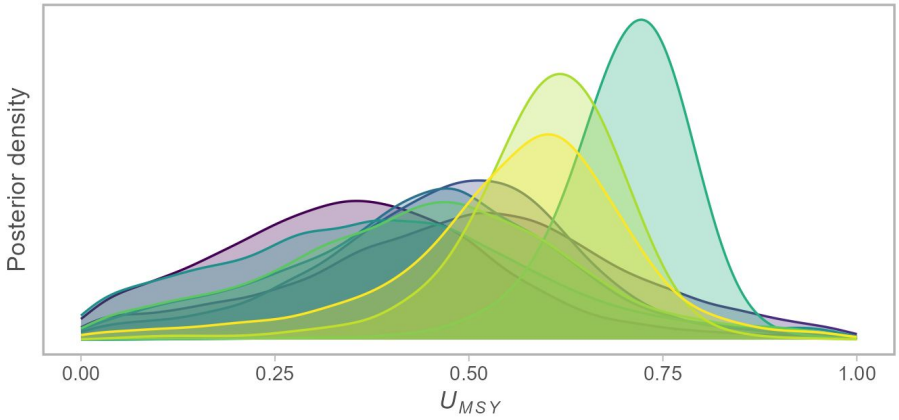


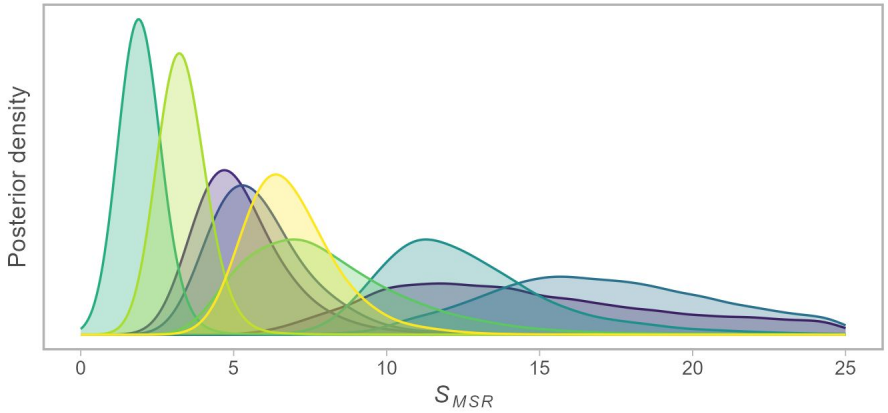
Spawner-recruitment relationships



CU population parameters

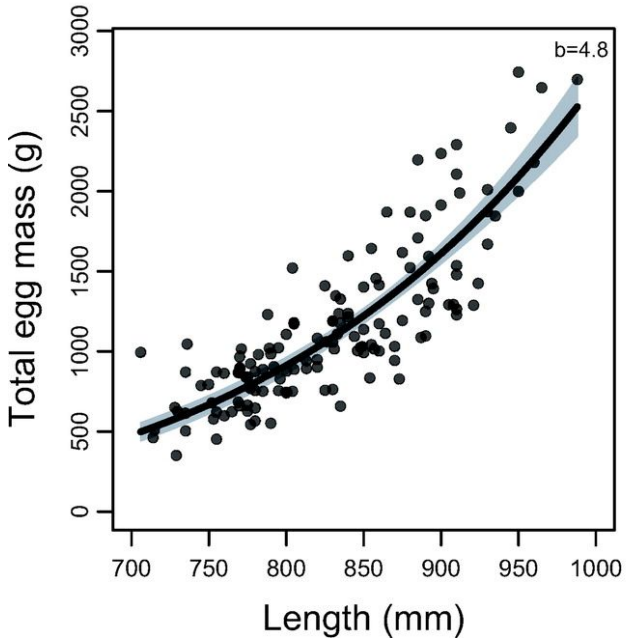






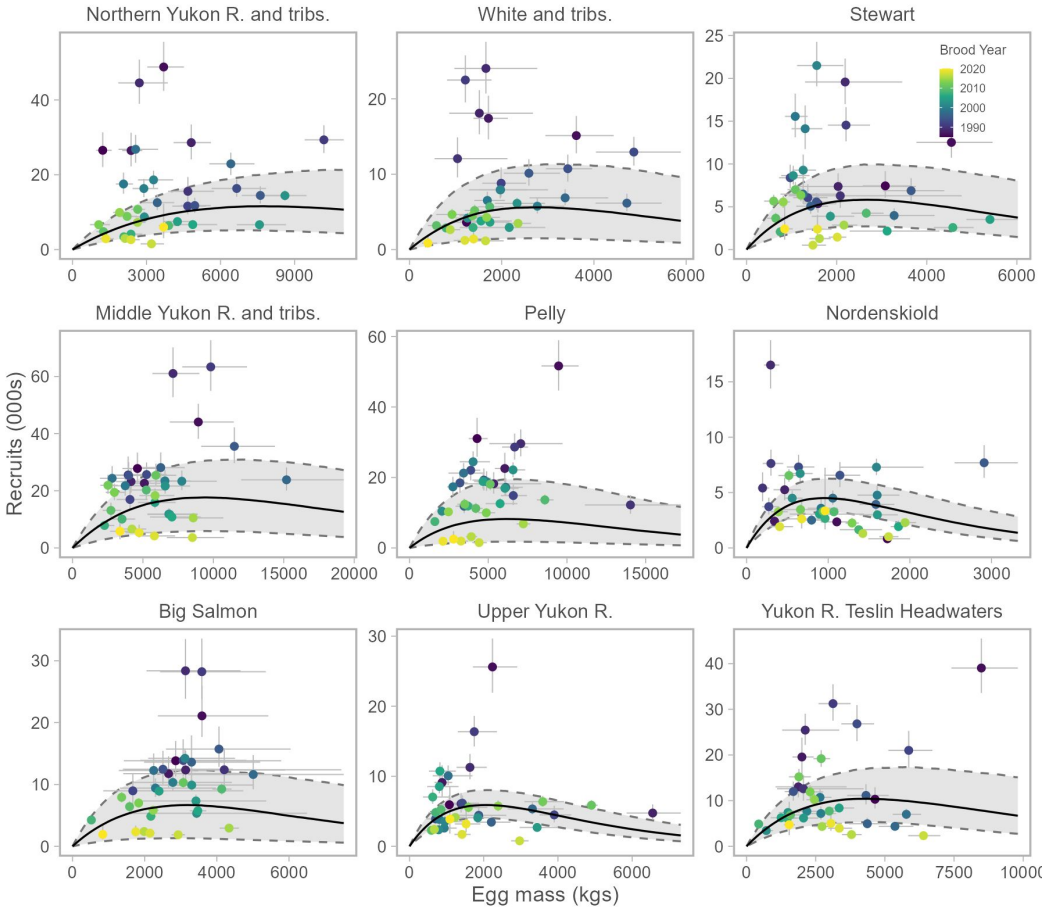
Accounting for demographic change

- Larger (older) females produce more, larger, eggs
- Failing to account for demographic change can underestimate spawners needed to maximize long term sustainable yield or returns (Staton et al. 2021; Connors et al. 2022).
- Simulation analyses suggest that accounting for demographic change in fishery management (via reference points) can reduce conservation risks relative to not taking demographic change into account (Ohlberger et al. 2025).

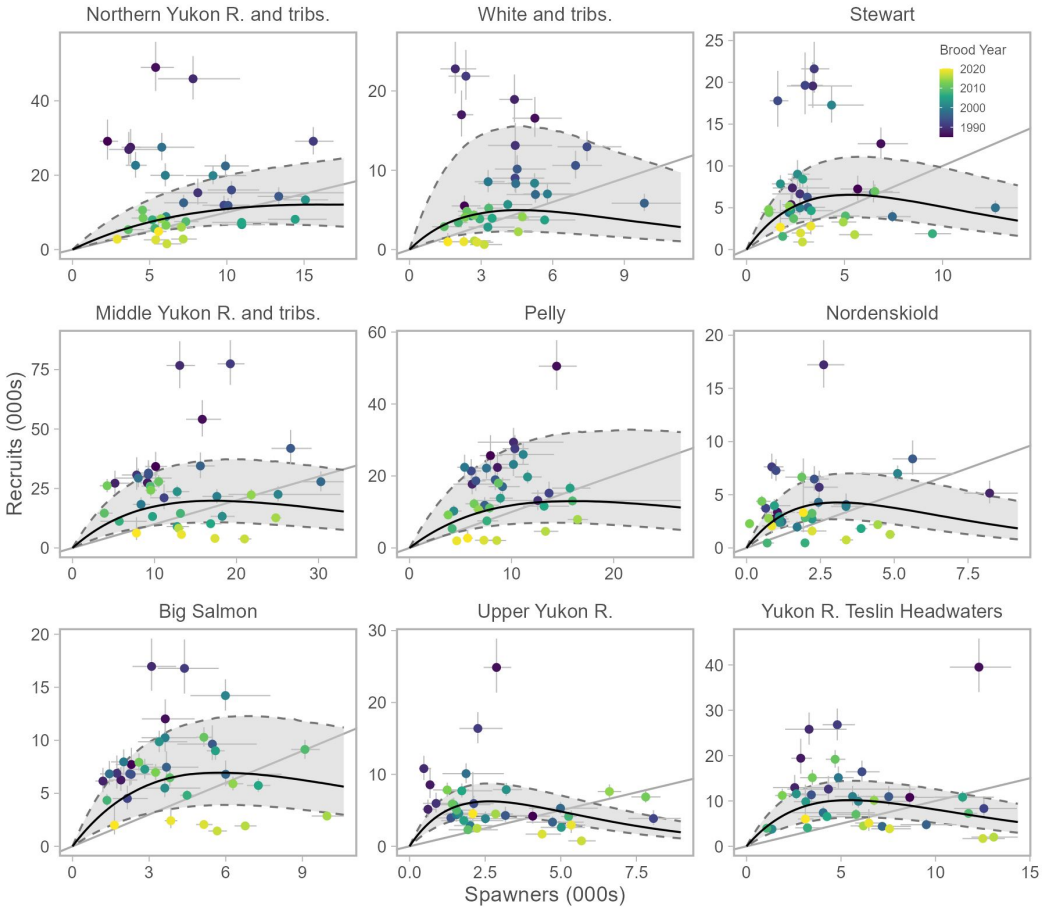


Ohlberger *et al.* 2020. CJFAS

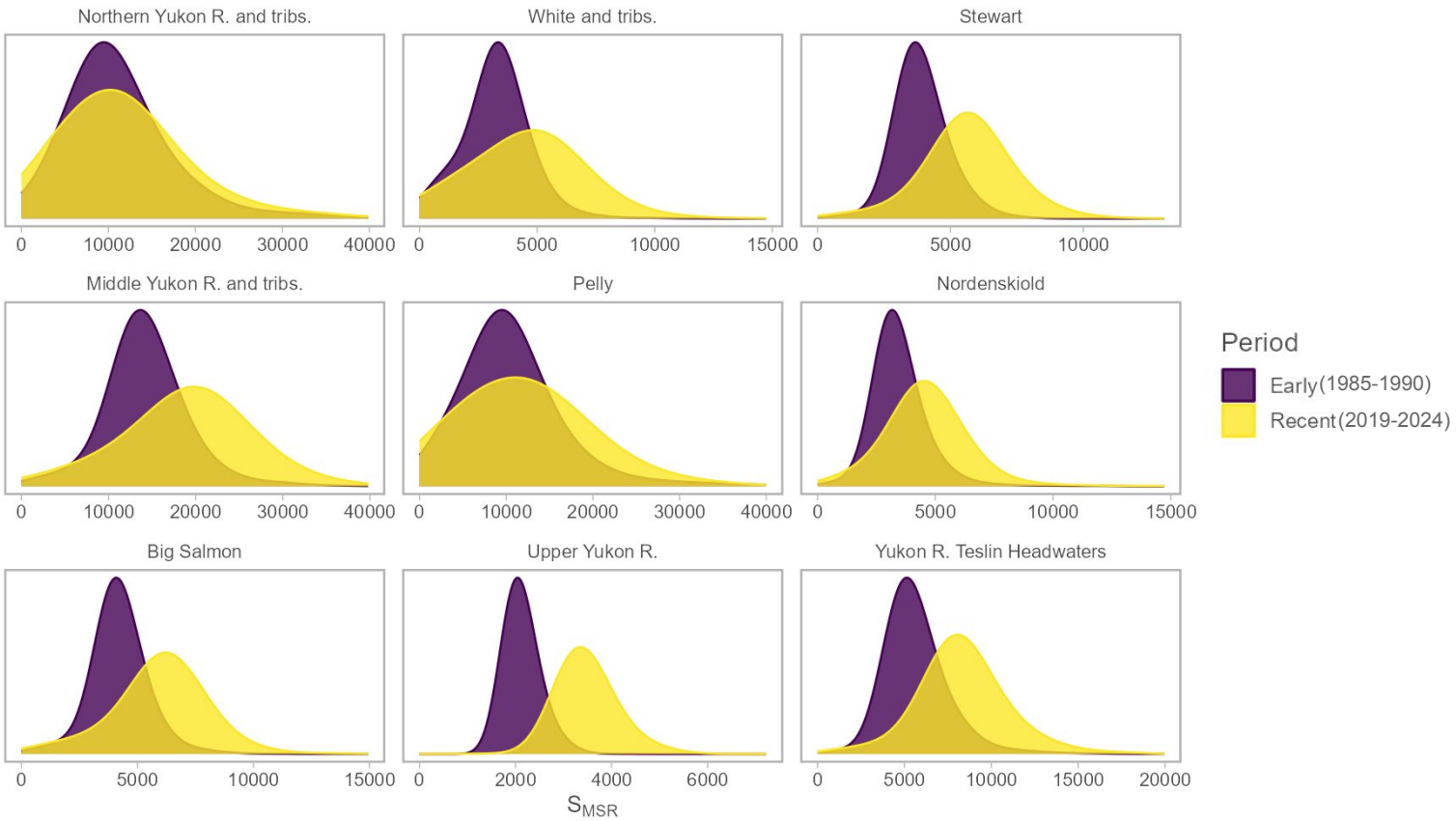
Egg mass - recruitment relationships



Spawner-recruitment relationships



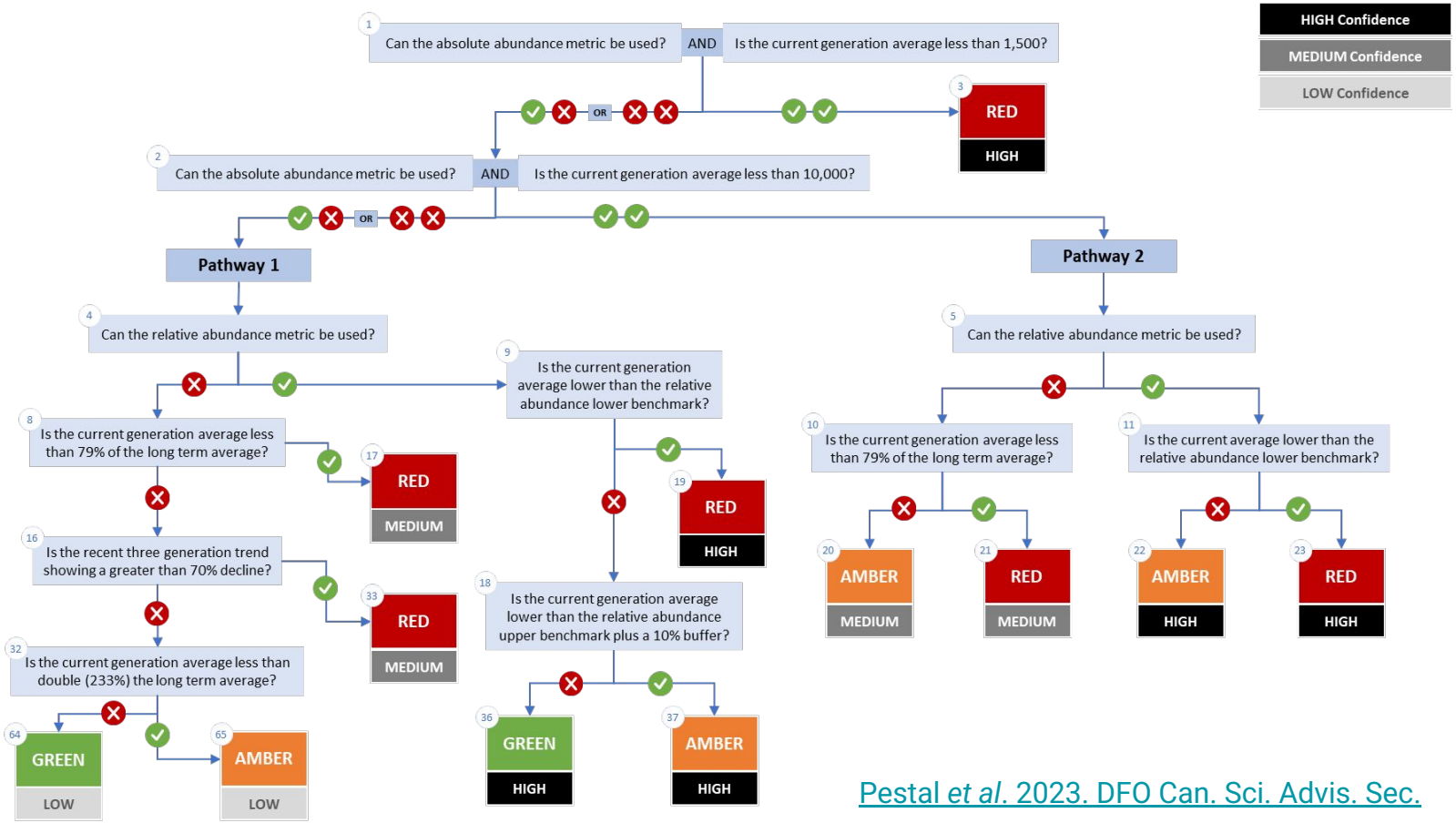
Accounting for demographics affects CU reference points



Proposed Conservation Unit biological benchmarks

Benchmark	Definition	Proposed value	Rationale
Lower Biological Benchmark	Spawner abundances below which CU is expected to have high risk of irreversible harm and which aligns with a COSEWIC assessment of "endangered"	20% S_{MSR}	• less sensitive to imprecise estimates of intrinsic productivity than MSY based benchmarks like S_{GEN} and 80%S_{MSY} • aligned with proposed use of S_{MSR} based reference points at SMU scale • proposed as proxy for upper and lower biological benchmarks (Holt et al. 2009) • precedent for use in other systems (e.g., Okanagan sockeye)
Upper Biological Benchmark	Spawner abundances associated with low risk of irreversible harm delineatinating *amber* and *green* Wild Salmon Policy status zones	40% S_{MSR}	
Rebuilding Target	Spawner abundances associated with a "healthy" state that meets socio-ecological objectives and resilient in the face of rapid and unpredictable environmental change	S_{MSR} (based on egg mass model and recent demographic characteristics)	• reference points linked to stock size greater than those associated with MSY, and that take demographics into account, have been argued to be more consistent with indigenous and ecosystem based principles (Reid et al. 2022; Frid et al 2023)

CU status based on Wild Salmon Policy rapid status assessments



Pestal *et al*. 2023. DFO Can. Sci. Advis. Sec.

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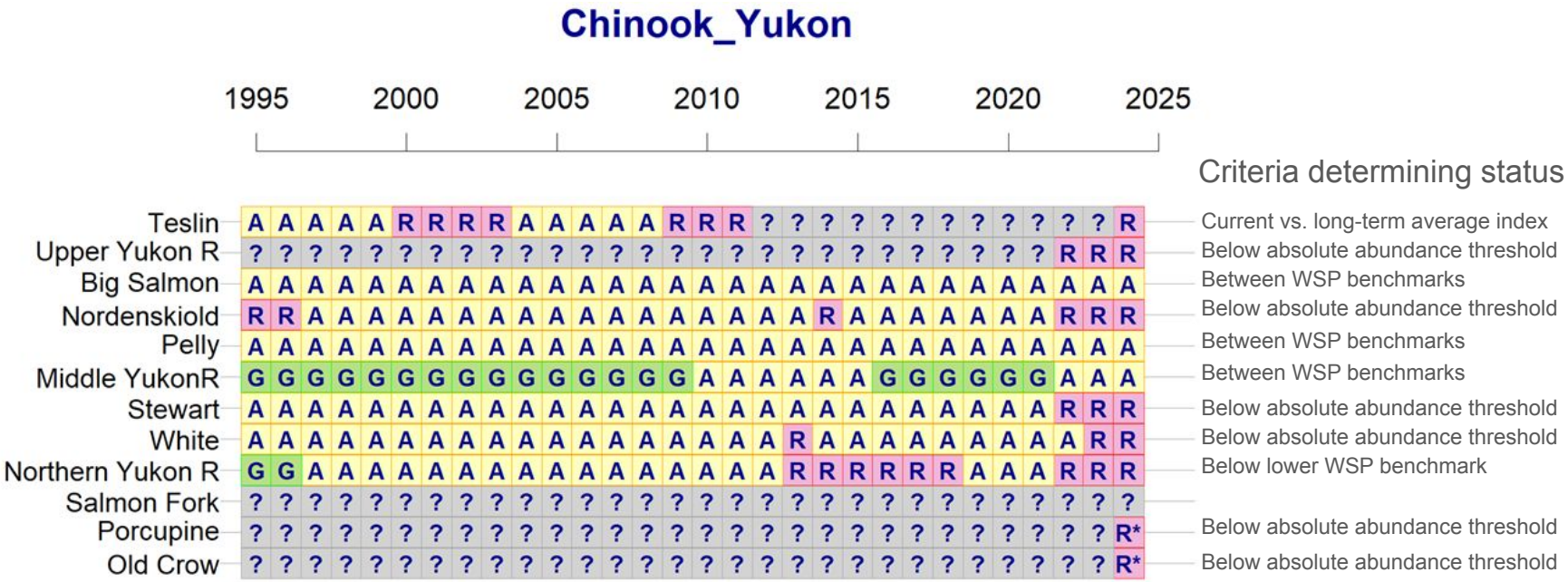

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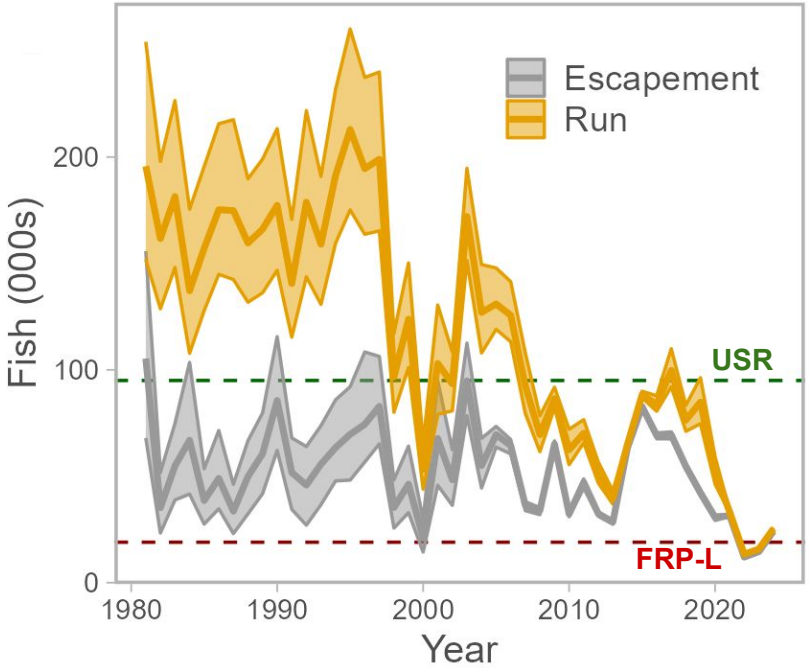
Yukon Chinook Stock Management Unit reference points

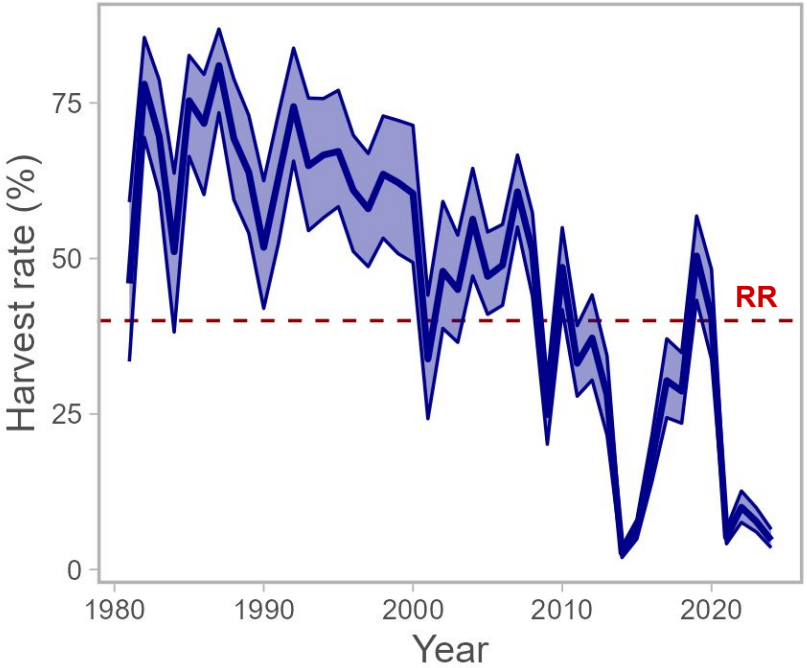
Reference point	Definition	Proposed value	Rationale
Limit Reference Point (LRP)	Point below which serious harm may occur to the stock and where there may also be impacts to the ecosystem, associated species, and/or a long-term loss of fishing opportunities	one or more component CUs in Wild Salmon Policy Red status zone	• required under Fish Stock Provision of *Fisheries Act* • reflects requirement for salmon LRPs to be aligned with Canada's Wild Salmon Policy objective of preserving biodiversity of salmon at the scale of CUs (Holt et al. 2023)
Upper Stock Reference Point (USR)	threshold to prevent stock from dropping below the LRP, and as a target related to biological and/or socio-economic considerations	95,000 spawners S_{MSR} (based on egg mass model and recent demographic characteristics; Connors et al. 2022)	• required under Fish Stock Provision of *Fisheries Act* • reference points linked to stock size greater than those associated with MSY, and that take demographics into account, have been argued to be more aligned with indigenous and ecosystem based principles (Reid et al. 2022; Frid et al 2023) • consistent with use of S_{MSR} as border passage target under current Yukon River 7-year agreement

Yukon Chinook Stock Management Unit reference points

Reference point	Definition	Proposed value	Rationale
Maximum Removal Reference (RR)	The maximum acceptable harvest rate the SMU can be subject to	40% Harvest rate associated with MSY (U_{MSY}) for the least productive CU in the SMU	● federal and international fishery policy typically set maximum fishery removals to be less than or equal to those associated with U_{MSY} ● required under Fish Stock Provision of *Fisheries Act* ● propose this value be from least productive CU to align with Wild Salmon Policy objective aimed at taking biodiversity at the scale of CUs into account
Fishery reference point - lower	Aggregate SMU spawner abundance below which fishery removals should be limited to the maximum extent possible	19,000 20% of S_{MSR} (based on egg mass model and recent demographic characteristics; Connors et al. 2022)	● not required under Fish Stock Provision of *Fisheries Act* but helpful for informing management since assessment and fishery decisions are often abundance based and so can be operationalized (compared to the CU-status based LRP) ● this value is close to the lowest spawner abundances, and harvest rates, on record and management interventions to reduce fishing impacts to lowest possible level

Yukon Chinook Stock Management Unit status





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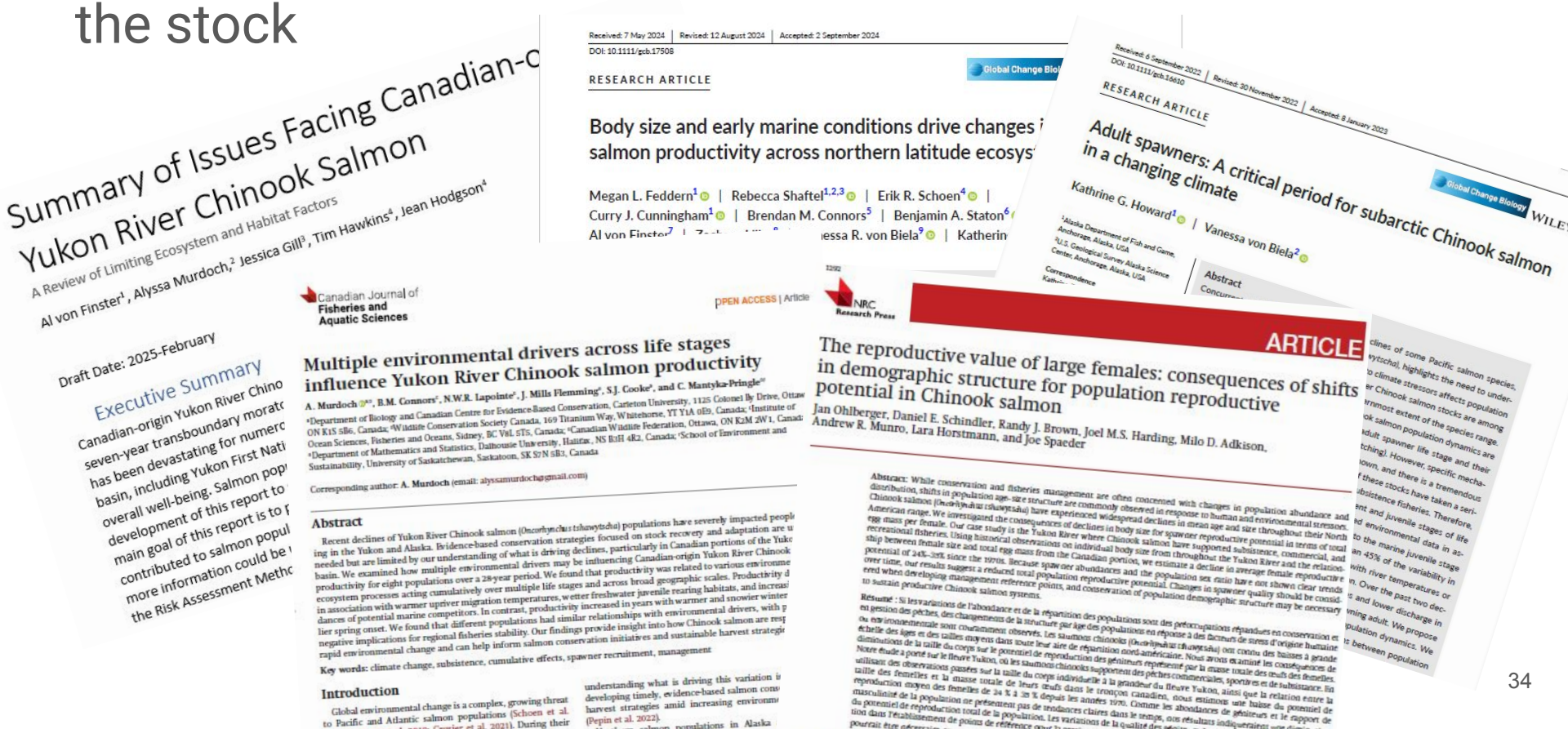
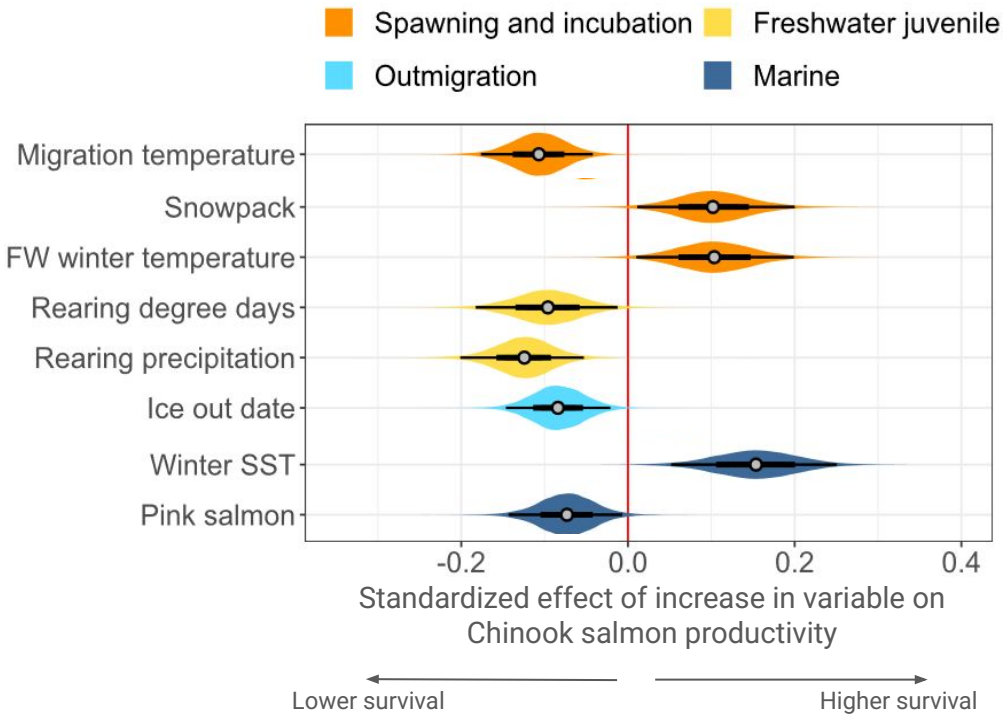
Anthropogenic, ecosystem, and climate factors affecting the stock



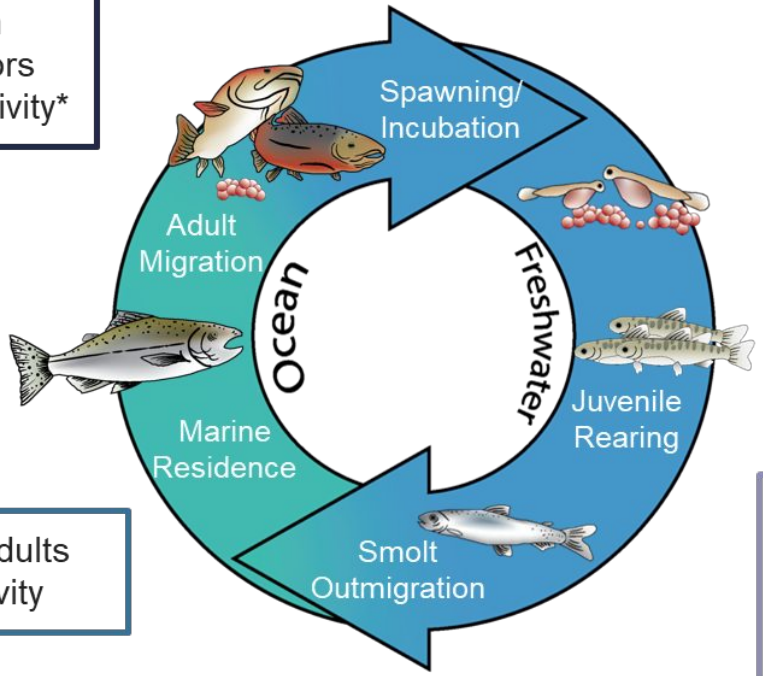
Anthropogenic, ecosystem, and climate factors affecting the stock



Murdoch et al. 2023. CJFAS

Anthropogenic, ecosystem, and climate factors affecting the stock

Warm water in migration corridors decreases productivity*



Smaller spawning adults decrease productivity

Productivity decreases with colder winters and warmer summers during the first year at sea

Feddern et al. 2024. GCB

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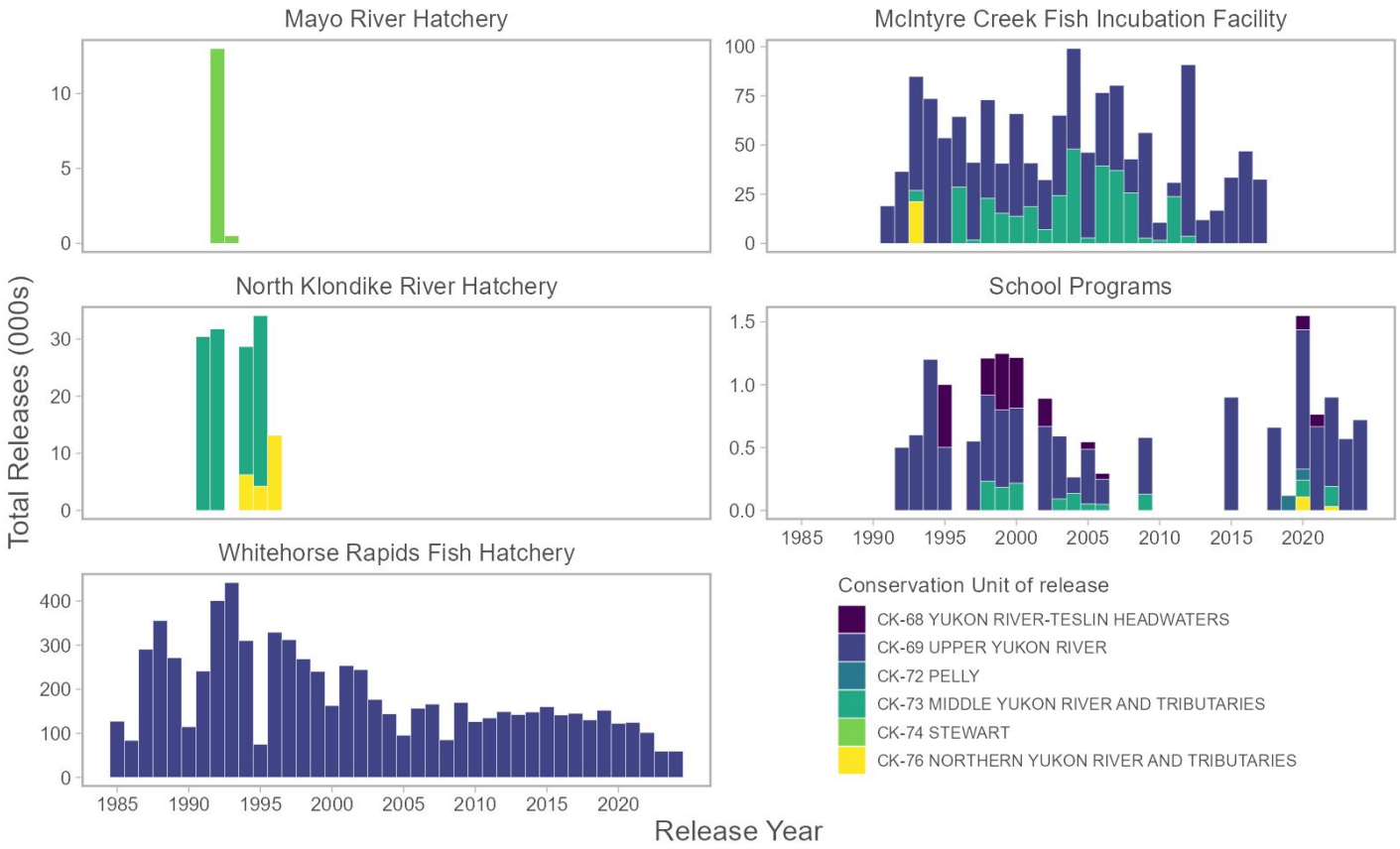
There is a long history of (very modest) enhancement



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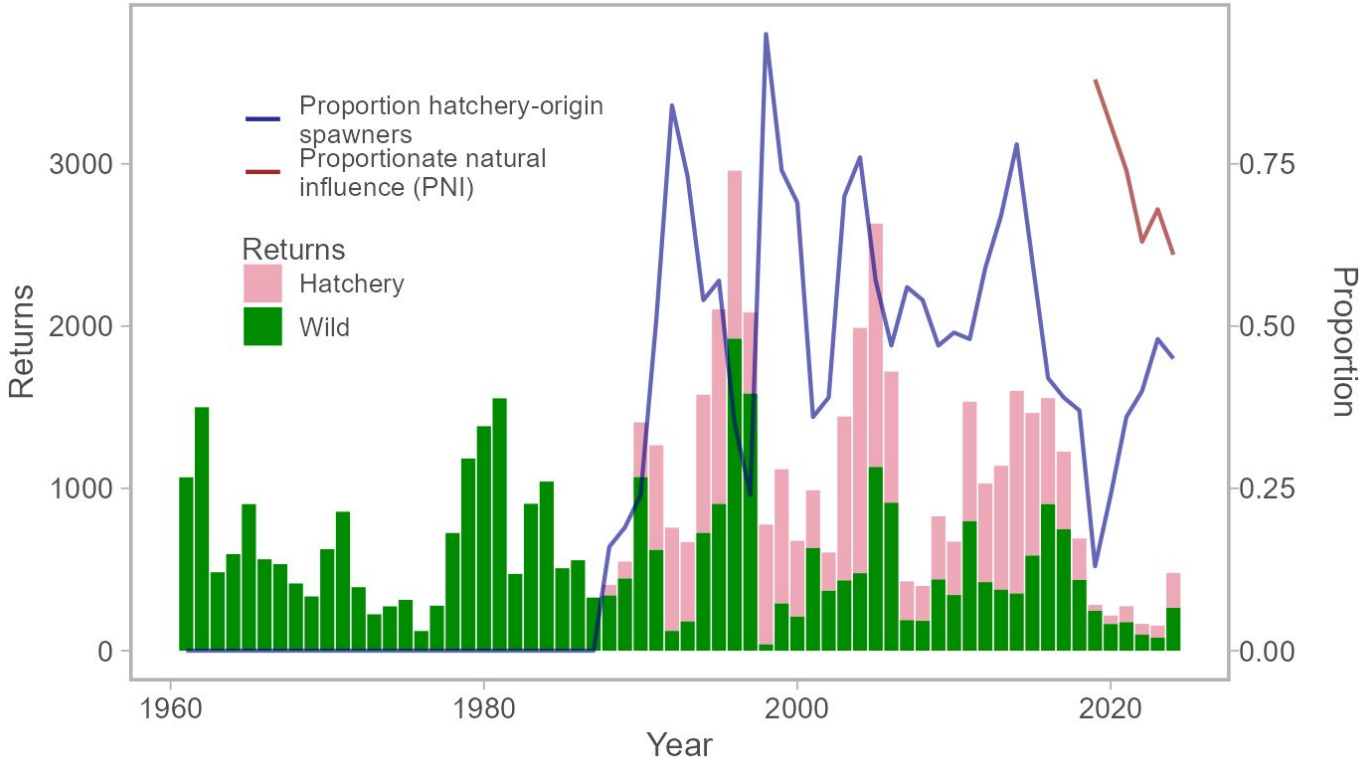

Potential for enhancement to contribute to rebuilding

- General agreement enhancement for restoration might help support rebuilding efforts
- More research and work needed to determine where enhancement could be effective, how best to use enhancement, and on what populations
  - Identify threats and whether enhancement could mitigate them
  - Assess likelihood of recovering a self-sustaining wild population to inform enhancement goals, approach, and possible outcomes.
  - Design enhancement plan that is based on spawner recovery goals and corresponding recovery phases and triggers.

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Habitat and potential to contribute to rebuilding

- YK Salmon habitats generally intact, but rapid climate driven changes: permafrost thawing and slumping, landslides, fires
- Local projects focusing on identifying overwintering habitat, watershed and habitat protection, targeted monitoring of habitat change, addressing barriers to passage, and conservation of cold-water refugia
- Restoration efforts should target habitats hypothesized to be bottlenecks to survival, and preserve and protect heterogeneous and dynamic habitat landscapes

Yukon Geological Survey 2024

Huey O'Leary-Baikie

Yukon Fireline, 2020

Michie Creek 2022- KDFN

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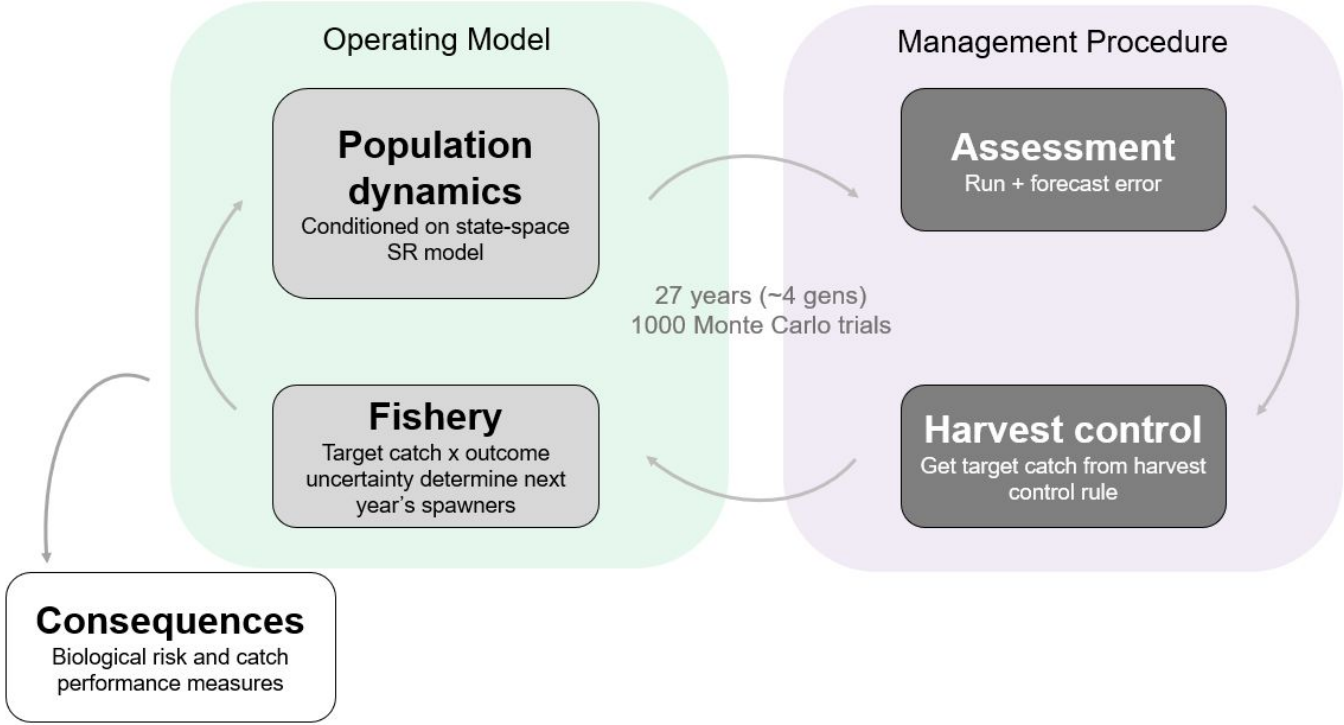
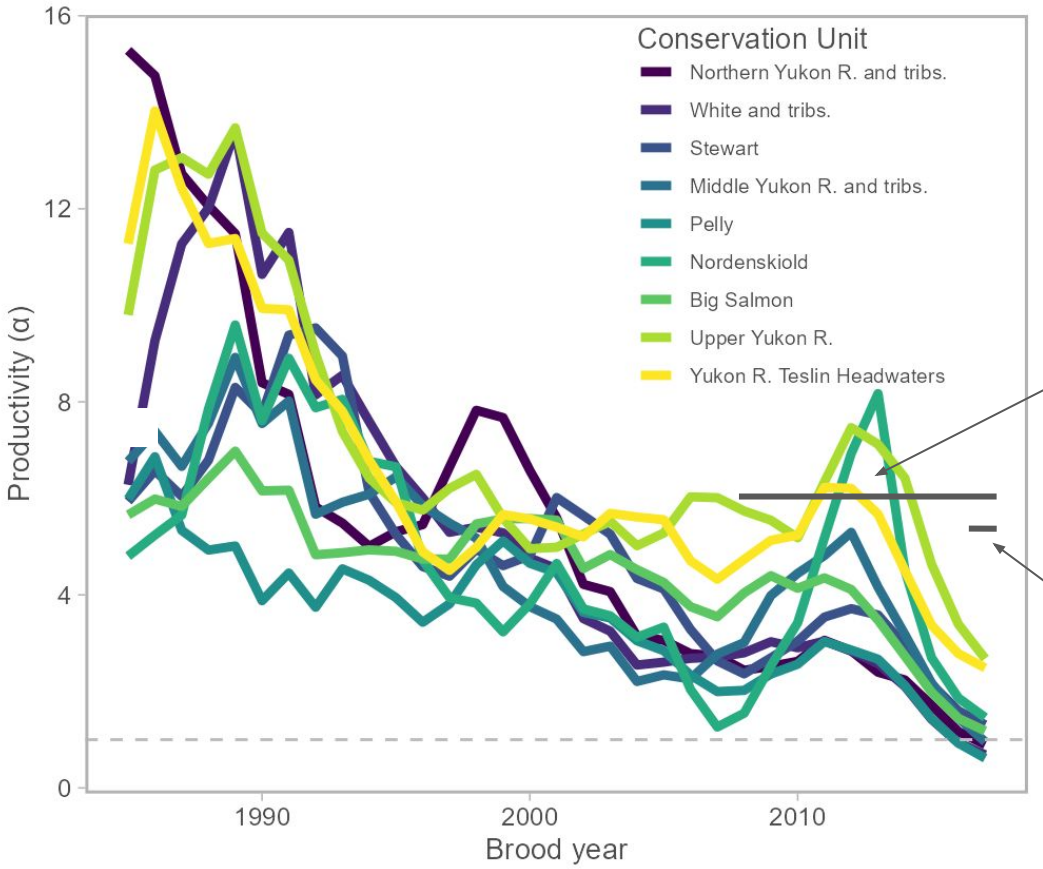
Quantitative estimates of the expected biological and fishery consequences of current and alternative harvest management measures that could contribute to stock rebuilding



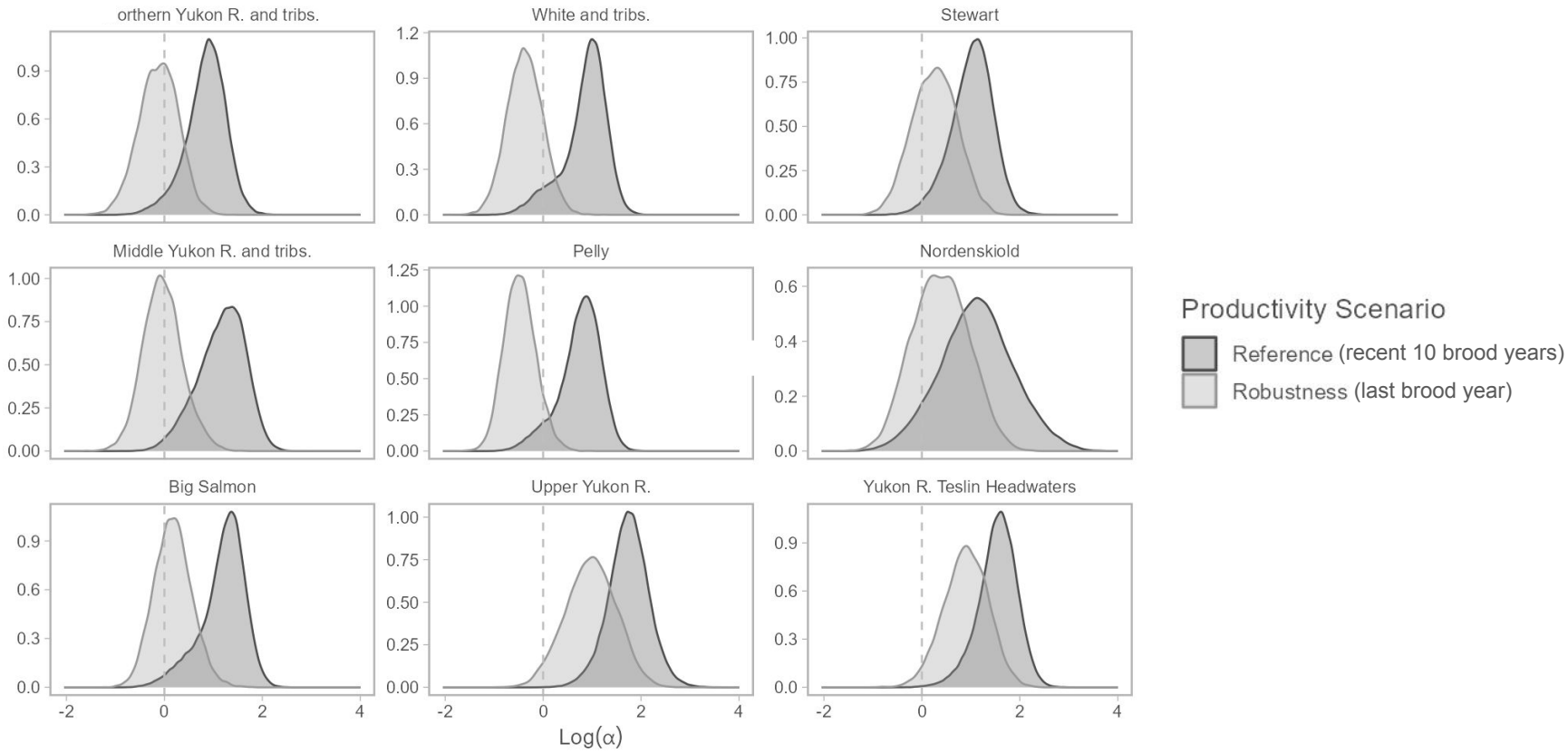
Operating Model population dynamics scenarios



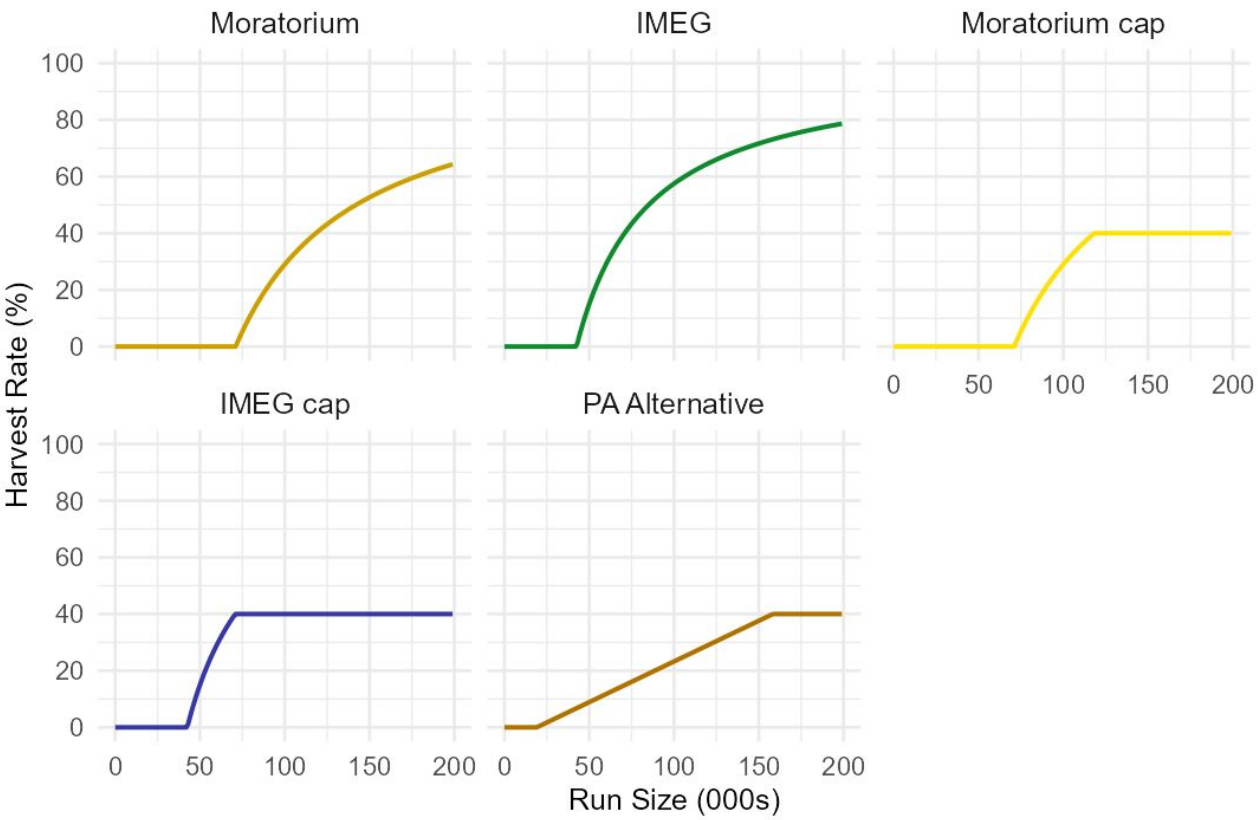
Reference scenario (last 10 brood years)

Robustness scenario (last brood year)

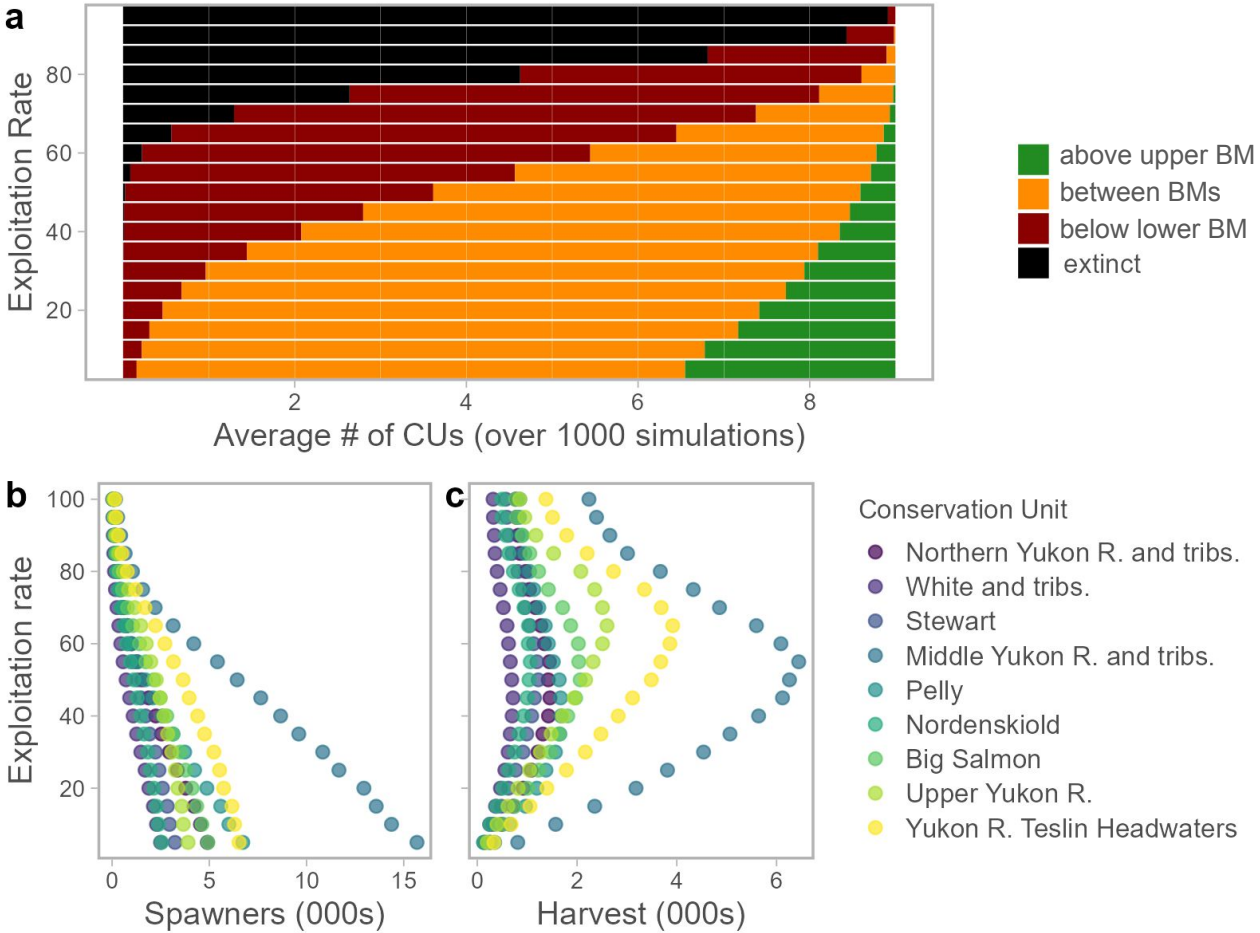
Operating Model population dynamics scenarios



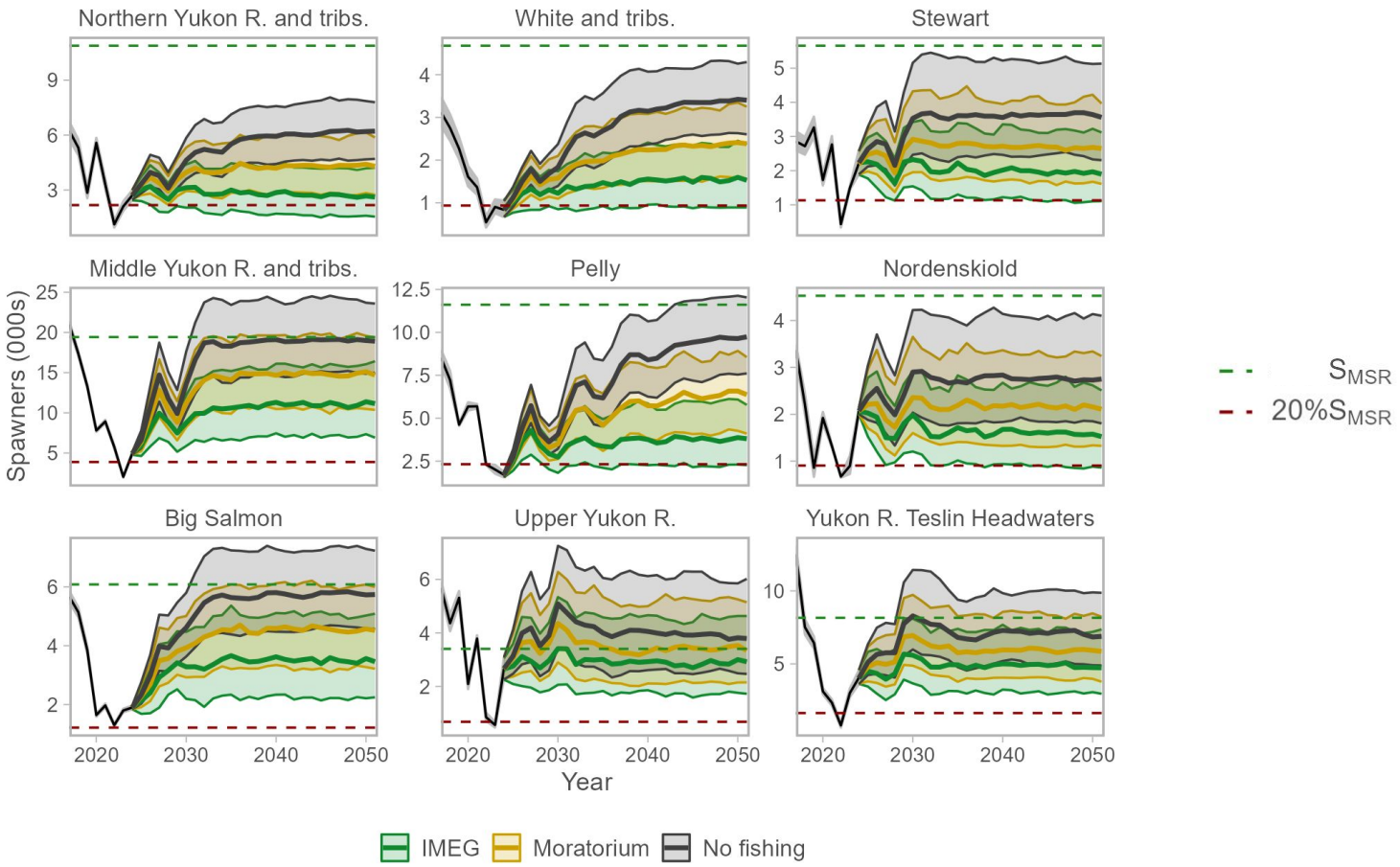
Harvest control rules



Fishery risk and tradeoffs



Projections under base case (reference) OM scenario



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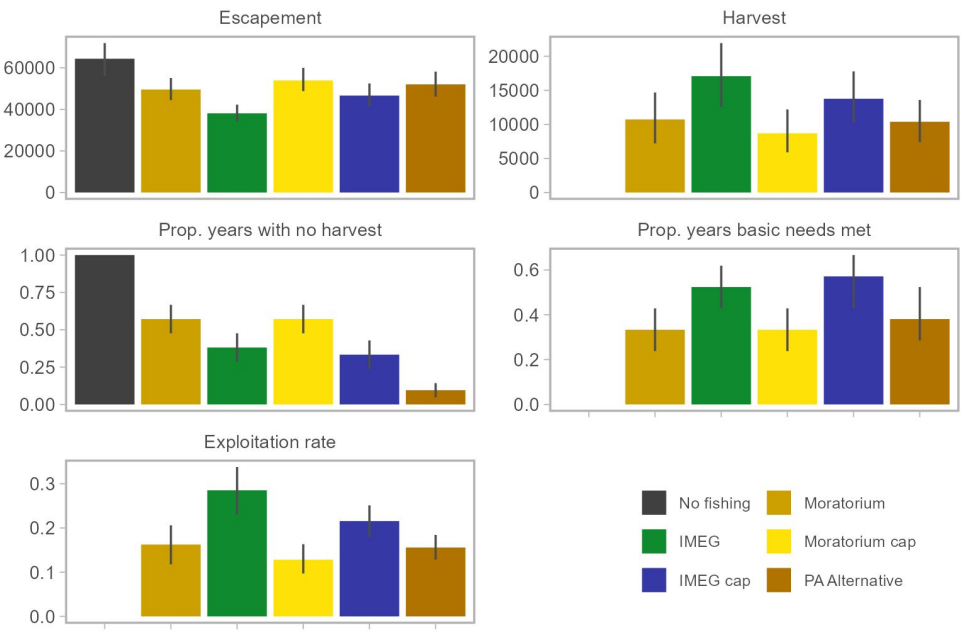
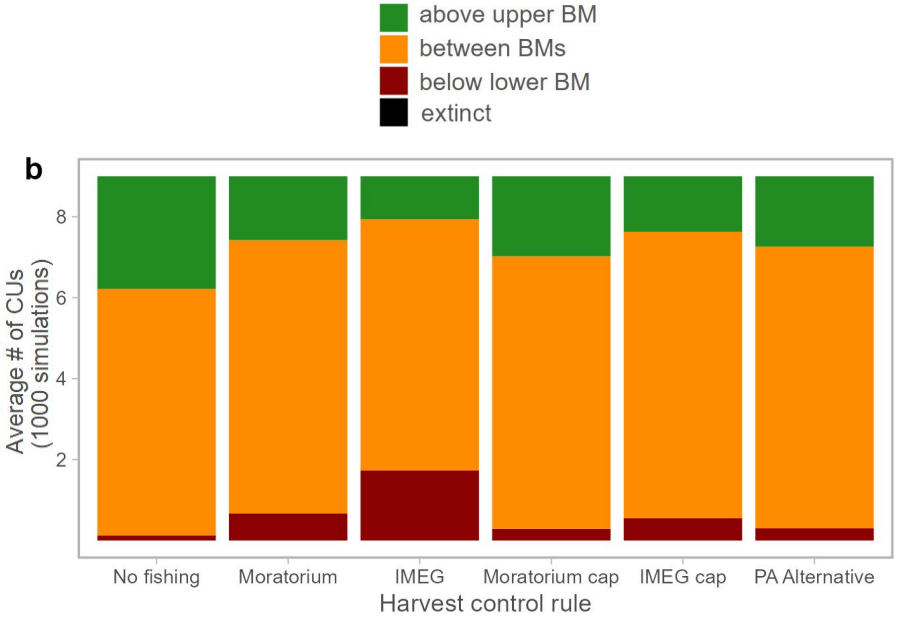
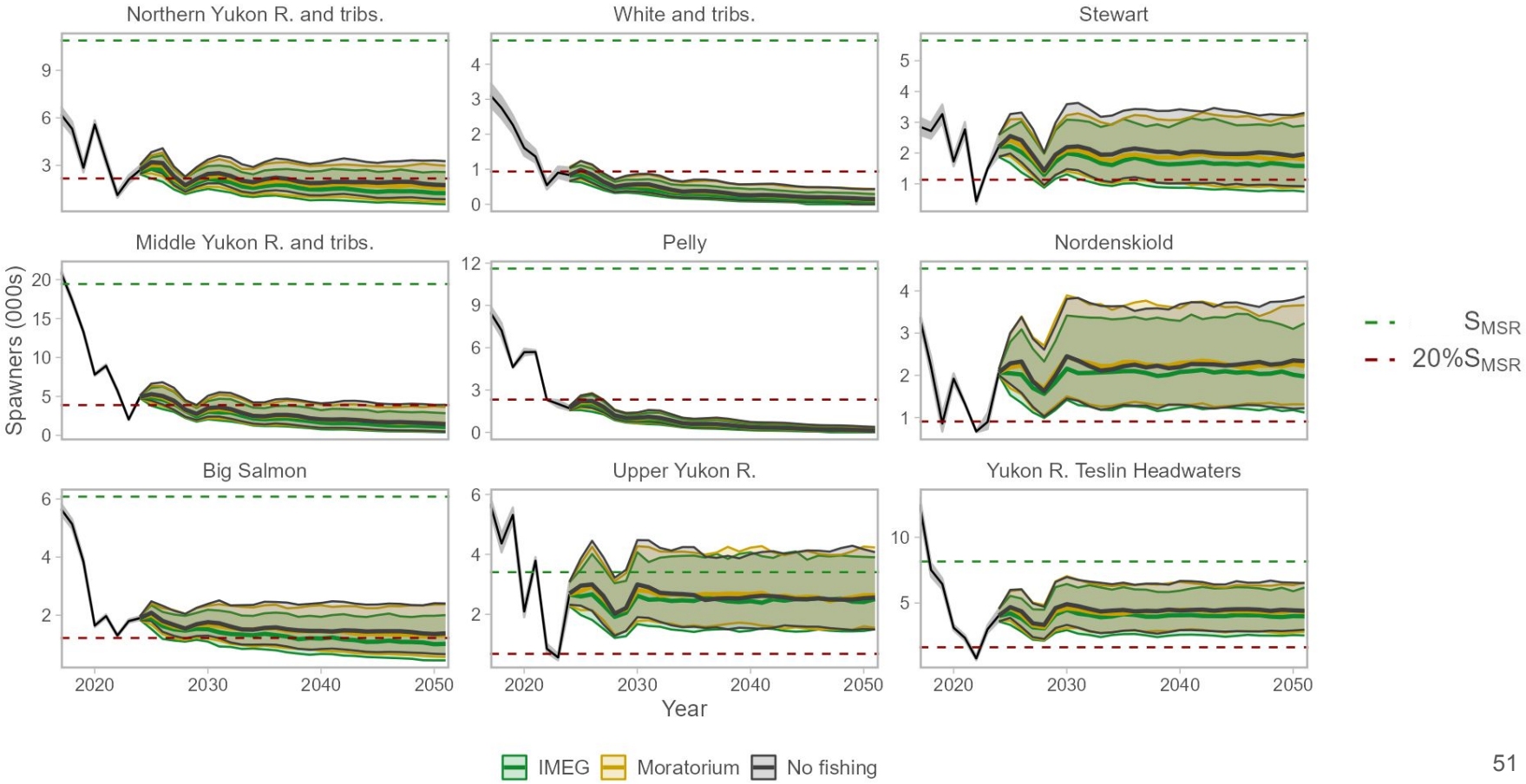




Projections under worst case (robustness) operating model scenario



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Key assumptions and areas of future work

Key assumptions

- Aggregate age composition is representative
- CUs are equally vulnerable to harvest
- No migration mortality in Canada
- Future productivity is similar to last decade

Future work

- Increase tributary assessment
- Account for migration mortality
- Re-examine CU delineations
- Develop Porcupine SMU reference points
- Explore incorporating juvenile assessment information from Bering Sea
- Update environment/ecosystem impact analyses

Take home messages

- Porcupine SMU below its CU-status based Limit Reference Point: two of three CUs assessed as *Red* status under Wild Salmon Policy
- Yukon SMU below its CU-status based Limit Reference Point: six of nine CUs assessed as *Red* status
- Returns to Yukon SMU have declined ~87% over the past four decades culminating in five of the lowest returns on record
- Aggregate spawner abundances over the most recent generation averaged ~25,000 which is well below proposed Upper Stock Reference point of 95,000 spawners
- Reproductive output per spawner has declined ~35% from late 1980s to early 2020s, coincident with ~ 60% decline in productivity
- Current “seven year agreement”, which severely limits harvest, likely gives stock best chance to slowly rebuild in the face of uncertain environmental conditions and depressed productivity

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- Dan Greenberg for analytical advice
- Luc Glover and Marina Milligan for input on assessment projects
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