FINAL

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ANCHOR QEA

Memorandum

To: Wells, Rocky Reach, and Rock Island HCP Hatchery Committees and Priest Rapids Coordinating Committee Hatchery Subcommittee

Document Date: January 18, 2023

From: Tracy Hillman, HCP Hatchery Committees Chairman and PRCC Hatchery Subcommittee Facilitator

cc: Larissa Rohrbach, Anchor QEA, LLC

Re: Final Minutes of the December 21, 2022, HCP Hatchery Committees and PRCC Hatchery Subcommittee Meetings

The Wells, Rocky Reach, and Rock Island Hydroelectric Projects Habitat Conservation Plan Hatchery Committees (HCP-HCs) and Priest Rapids Coordinating Committee's Hatchery Subcommittee (PRCC HSC) meetings were held virtually on Webex, on Wednesday, December 21, 2022, from 9:00 a.m. to 11:45 a.m. Attendees are listed in Attachment A to these meeting minutes.

Action Item Summary

Long-Term

Joint HCP-HCs and PRCC HSC

- Kirk Truscott will work with Confederated Tribes of the Colville Reservation staff to develop a model that addresses the probability of encountering natural-origin return (NOR) Okanogan River spring Chinook Salmon at Wells Dam (Item I-A). *(Note: This item is ongoing; expected completion date to be determined*.)
- Kirk Truscott will determine the number of scales that should be collected from spring Chinook Salmon at Wells Dam for elemental signature analysis to discern Okanogan River spring Chinook Salmon from Methow River spring Chinook Salmon (Item I-A). (*Note: This item is ongoing; completion depends on the outcome of the previous action item.)*
- Keely Murdoch and Mike Tonseth will obtain estimates of pre-spawn mortality from Andrew Murdoch to update the retrospective analysis for Wenatchee spring Chinook Salmon (Item I-A). *(Note: This item is ongoing; expected completion date to be determined.)*
- Members of the HCP-HCs and PRCC HSC will provide feedback to the Washington Department of Fish and Wildlife (WDFW)-revised version of questions on recalculation for Policy Committees (Item I-A). *(Note: This item is ongoing.)*

Near-Term (to be completed by next meeting)

Joint HCP-HCs and PRCC HSC

- Todd Pearsons and Catherine Willard will revise Grant and Chelan PUD's draft Statements of Agreement (SOAs) on Sockeye Salmon obligations for approval in an upcoming meeting (Item I-A). (*Note: This item is ongoing.*)
- Mike Tonseth will work with Matt Cooper to distribute an analysis showing feasibility of the Methow spring Chinook Salmon outplanting plan based on historical run size data and proportionate natural influence (PNI) targets (Item I-A). (*Note: This item is ongoing.*)
- Members of the HCP-HC and PRCC HSC will review materials provided by Kevin See (WDFW) on a proposed approach for updating and merging existing Wenatchee steelhead spawning escapement time-series data for further discussion in the January 18, 2023, meeting.

Decision Summary

- Douglas PUD's Wells program monitoring and evaluation (M&E) implementation plan was approved.
- Chelan PUD's M&E implementation plan was approved.

Agreements

- None

Review Items

- None

Finalized Documents

- Douglas PUD's Wells program M&E implementation plan, *Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2023*, was distributed following today's meeting.
- Chelan PUD's M&E implementation plan, *Chelan County PUD Hatchery Monitoring and Evaluation Implementation Plan 2023*, was distributed following today's meeting.

I. Welcome

A. Agenda, Approval of Past Minutes, Action Item Review

Tracy Hillman welcomed the HCP-HCs and PRCC HSC, reviewed the agenda, and asked for any additions or changes to the agenda. The agenda was approved without any changes.

Action items from the HCP-HCs and PRCC HSC meeting on November 16, 2022, were reviewed. *(Note: Italicized text below corresponds to action items from the previous meeting.)*

Long-Term

Joint HCP-HCs and PRCC HSC

- *Kirk Truscott will work with Confederated Tribes of the Colville Reservation staff to develop a model that addresses the probability of encountering NOR Okanogan River spring Chinook Salmon at Wells Dam (Item I-A). (Note: This item is ongoing; expected completion date to be determined.)*
- *Kirk Truscott will determine the number of scales that should be collected from spring Chinook Salmon at Wells Dam for elemental signature analysis to discern Okanogan River spring Chinook Salmon from Methow River spring Chinook Salmon (Item I-A). (Note: This item is ongoing; completion depends on the outcome of the previous action item.)*
- *Keely Murdoch and Mike Tonseth will obtain estimates of pre-spawn mortality from Andrew Murdoch to update the retrospective analysis for Wenatchee spring Chinook Salmon (Item I-A). (Note: This item is ongoing; a presentation will be given in early 2023.)*
  Tonseth said this item is ongoing.
- *Members of the HCP-HCs and PRCC HSC will provide feedback to the WDFW-revised version of questions on recalculation for Policy Committees prior to the next meeting (Item I-A). (Note: This item is ongoing.)*
  Keely Murdoch reviewed a set of revisions proposed by the Yakama Nation (YN) (Attachment B). The version including the YN edits was distributed for HCP-HC and PRCC HSC review following the meeting.

Near-Term (to be completed by next meeting)

Joint HCP-HCs and PRCC HSC

- *Todd Pearsons and Catherine Willard will revise Grant and Chelan PUD's draft SOAs on Sockeye Salmon obligations for approval in an upcoming meeting (Item I-A).*
  Pearsons said this item is ongoing.
- *Mike Tonseth will work with Matt Cooper to distribute an analysis showing feasibility of the Methow spring Chinook Salmon outplanting plan based on historical run size data and PNI targets (Item I-A).*
  Tonseth said this item is ongoing. Comments have been received from USFWS last week, and progress is being made.
- *HCP-HCs and PRCC HSC members will review the 2017 Methow spring Chinook Salmon outplanting plan and provide comments to Mike Tonseth by Friday, December 9, 2022 (Item II-A).*
  This item is complete.

- *Bill Gale will invite Greg Fraser to the January meeting to present on redd superimposition in the Entiat River (Item II-B).*
  This item is complete. Gale said he asked Fraser to provide a 30-minute presentation.
- *Larissa Rohrbach will share the Broodstock Collection Protocols using OneDrive for co-authoring (Item II-C).*
  This item is complete. Rohrbach shared a link to the Broodstock Collection Protocols with designated co-authors, and PUD representatives identified staff and contractors who should be given access.
- *Tracy Hillman will provide the timeline for the next reporting milestones for the HCP-HCs and PRCC HSC (Item I-A).*
  This item will be discussed in today's meeting.

PRCC HSC

- *Rod O'Connor will share Grant PUD's emergency release plan for the Carlton Acclimation Facility for review by the PRCC HSC (Item III-A).*
  This item is complete. Grant PUD's emergency release plan for the Carlton Acclimation Facility was distributed via email by Rohrbach on December 7, 2022.

II. Joint HCP-HC and PRCC HSC

A. 10-Year Comprehensive Reporting Milestones

Tracy Hillman shared the 2017 SOA that identifies the M&E Reporting Schedule for the PUDs' programs. This document was distributed by Larissa Rohrbach on November 21, 2022. Hillman reviewed the next steps in the process following the completion of the 10-Year Comprehensive Report, noting that the statistical report is scheduled to start in 2024 and is due in 2025.

B. Wenatchee Spring Chinook Salmon Life-Cycle Modeling

Tracy Hillman welcomed Mark Sorel (University of Washington and WDFW) to the meeting. Sorel summarized components of his PhD dissertation research related to work of the HCP-HCs and PRCC HSC. He gave a presentation entitled "Wenatchee Spring Chinook Population Modeling" (Attachment C). The following highlights were presented:

- The focus of the work was to develop a population dynamics model to test the consequences of various Wenatchee spring Chinook Salmon management decisions. The various data sources used to characterize the Wenatchee spring Chinook Salmon population were shown.

- It was hypothesized that in the Wenatchee Basin there might be a positive density-dependent relationship between the number of spawners and subyearling outmigrants. When the habitat reaches capacity in tributaries, a positive response of subyearlings leaving was observed, based on the abundance of fish emigrating past screw traps at the mouths of natal streams.
- Survival rates were estimated based on detections of PIT-tagged natural-origin juveniles emigrating from the Wenatchee Basin and returning in subsequent years. Groups that left the natal stream at a younger age tended to have better smolt-to-adult return rates, but greater numbers of those also returned as jacks.
- An integrated population model was built to include these different life-history strategies and hatchery management actions based on historical data. The model was then used to forecast the population 50 years into the future. Hatchery management decisions may not be the same in the future as they have been in the past. In the model, the future suite of hatchery management decisions was based on meeting the abundance-based PNI targets for the population.
- The result was that the future population was projected to be just under 200 female spawners for the three key tributary populations combined (Chiwawa River, Nason Creek, and White River). Based on past productivity data that the model was fit to, the Wenatchee spring Chinook Salmon population is not headed toward the recovery target of 2,000 natural returns total (1,000 females) in the next 50 years; although, it is not likely to head toward extinction either. Based on the model, all of the various juvenile life-history types would continue to contribute to adult returns.
- A workshop was convened earlier in the year to examine alternative habitat and hatchery management strategies. One of the major management strategies tested was a reduction of hatchery production by 50%, which would reduce the amount of hatchery broodstock collected, but also would reduce the juvenile hatchery production. Historical PIT-tag data were used to account for differences in survival across years. When ocean conditions are bad, fewer natural- and hatchery-origin fish would return, affecting the total number of fish that the hatchery programs can use.
- The outcomes of future potential habitat restoration and hatchery management actions were presented. The total increase with both natal tributary and downstream restoration was greater than the sum of the two, showing a synergistic effect. Based on the assumptions used in the model, this population would move in the right direction but would still not achieve recovery targets even with habitat restoration and continued hatchery production. There was not a large effect on natural production with a change in hatchery broodstock number; however, the reduction in hatchery broodstock did have a beneficial effect on PNI.
- Sorel concluded that this type of population model could be a powerful tool for assessing future management alternatives.

Tonseth asked if one of the strategies was to maintain the current level of hatchery production when projecting future numbers. Sorel said there was a function that calculated the number of smolts produced based on historical broodstock-to-smolt relationships from past HCP reports. Tonseth said the hatchery programs have a fixed target for smolt production; there are typically enough hatchery-origin returns (HOR) to achieve broodstock targets, and the composition of the broodstock between natural-origin returns (NOR) and HOR is typically adjusted to meet the conservation or safety-net elements of the program. Tonseth asked how easy it would be to model a static broodstock target but adjust the size of the conservation program (made up of NOR) and how that might affect estimates of proportion of hatchery-origin spawners or PNI. Reducing the number of NOR and increasing the number of HOR used in broodstock would allow more NOR to spawn on the spawning grounds. Sorel said it's likely that that type of adjustment in the model is possible depending on decisions of the model manager. Sorel said the broodstock target in the Hatchery Genetic Management Plan was used as the baseline and was reduced by 50% for his dissertation research. Sorel said it is interesting that reducing the hatchery broodstock number reduced the number of hatchery fish coming back and answered the question of whether there could be enough adult returns to meet hatchery targets.

Pearsons asked about optimization to understand thresholds where tradeoffs become evident, such as between PNI and demographic benefits of the size of the hatchery programs. Pearsons said 50% of the existing broodstock was modeled, but he is interested in seeing where those thresholds are, such as testing whether a 25% decrease or 75% decrease in hatchery production would show major changes in the program's ability to meet those targets. Pearsons suggested also striving to develop common currencies in outputs relative to adult abundance. Sorel agreed that PNI could feedback in the model; then PNI would not be reported as a separate metric but would influence the population abundance estimates.

Pearsons said that in the projections of the future, it looks like the population abundance was at a flat line for a number of years, and he found it interesting that the numbers would not achieve recovery but that the population would also not blink out, which is one of the major concerns with small populations. He asked if Sorel has any thoughts on why those populations would be sustained rather than blink out. Sorel said he does not know, but there appears to be some resilience at low abundances because of being relieved from density dependence. Hatchery production is also likely sustaining them. Sorel said it will be important to keep an eye on the quasi-extinction risk threshold when testing management decisions, like reducing hatchery production. Pearsons asked Sorel whether a complete reduction of hatchery programs would increase extinction risk. Sorel said he did not model that scenario.

Keely Murdoch said she is interested in understanding the survival rates associated with the different life-history trajectories; this is new information and really important. Murdoch said the outcome of the hatchery programs was not surprising, and that within the Committees she has expressed the idea that hatchery supplementation cannot bring this population to recovery because the hatchery program does not address the bottlenecks affecting survival of smolts from naturally spawning adults. It is disappointing that the results of the habitat and hatchery supplementation combined also do not achieve population recovery. Murdoch asked if there are any plans to add a hydroelectric project (hydro) component to this model. Sorel said he agrees with Murdoch's interpretation that habitat productivity appears to be limiting recovery. He said it could be possible to add hydro effects to the model, but he is not actively working on the model at this time. One of the challenges was to translate the management actions that are available to changes in survival. For habitat, the solution was to adjust survival by 10%, and then model the change in the population. It could be important and influential to make those adjustments for changes in hydro management. Hillman asked if the population model could be linked to the COMPASS model. Sorel said yes, the COMPASS model adjusts for management actions like spill and conditions like temperature and translates these into survival estimates. There are challenges to applying that model with data from the Upper Columbia Basin compared to the data available for the Snake River Basin, but perhaps it could be done.

Gale said historically, there has been a higher level of hatchery production, though not necessarily with the best management practices that we use now. Gale asked why an increase in hatchery production wasn't modeled. Sorel said his time constraints limited the number of strategies that were run.

Regarding extinction risk, Sorel said climate change should be considered in the future of this model to avoid planning for what was and to plan for the future. Some of these survival rates and productivity estimates might be reduced in the future because of climate change. Sorel said that work was included in his dissertation.

Tim Taylor asked if the short-term and long-term dynamics in response to the management decisions were different. Sorel said he modeled it out to 50 years but did not look at what would be expected in the shorter term.

Pearsons asked if Sorel, because he is now employed with WDFW, is going to continue to tinker with the model or hand it off to someone else. Pearsons said he is interested in Sorel's thoughts on whether this model could be used for sizing hatchery programs; there is some flexibility in numbers of fish allocated to conservation and safety-net programs. Sorel said he is now working on harvest and would like the model to be more user-friendly. He plans to package it up in an app for himself and potentially pass the model off to be usable by various entities and programs. Sorel said it could be refined to be used when needed further out in the future.

Pearsons asked how the estimated increase in survival with habitat restoration was informed (e.g., the 10% increase) and whether that increase could be improved upon with more restoration actions in the future. Sorel said that level was informed by conversations in the workshop with Committee members. It was a hypothesis: if there is a 10% benefit across three difference life stages in freshwater, what would the effect be at the population level? There are probably other practitioners who have a better sense for an estimate based on habitat capacity. Sorel said the natal stream survival estimates are multiplicative, so it's actually more than a 20% increase in overall survival.

Tom Kahler asked what future habitat scenario was used and if typical climate change expectations were included. Sorel said baseline habitat conditions were assumed at the time the model was fit to the data. There are environmental controls on some of the transitions in the life-cycle model; the trajectories showed today did not include climate change. Another analysis (not shown today) showed that upwelling and sea surface temperature have been trending in a bad direction for salmon and reduced population size but did not lead to population crashes. Kahler said the expectation is for lower summer flows in the Upper Columbia Basin. In the Methow Basin, there could continue to be issues with low winter flows and ice, similar to the Upper Thompson River and Fraser River, unless there will be a warming of winter conditions, but then the juveniles in Methow Basin streams could be subject to winter freshets. Sorel said that there were correlations between discharge or higher winter flows, and fish leaving at a younger age; that type of analysis establishes a relationship of assumed environmental conditions in the future.

Hillman thanked Sorel for presenting. Sorel said he will distribute this presentation and a copy of his dissertation after the meeting.

III. Wells HCP-HC

A. DECISION: Approval of Douglas PUD's 2023 Wells Implementation Plan

Douglas PUD's draft *Implementation of Comprehensive Monitoring and Evaluation of Wells Hatchery Complex Programs in 2023* was distributed on Tuesday, October 25. No substantive changes were made by Douglas PUD compared to previous years. Tom Kahler said no substantive comments and edits were received within the 30-day review period, and there is no change in what Douglas PUD is proposing to do. All members of the Wells HCP-HC approved the Douglas PUD's 2023 M&E implementation plan.

IV. RI/RR HCP-HC

A. DECISION: Approval of Chelan PUD's 2023 M&E Implementation Plan

Catherine Willard shared an updated 2023 M&E Implementation Plan that included continuing to conduct spawning ground surveys. Willard stated she appreciated the productive and informative conversations she had with various HC members regarding Chelan's proposal to modify the methodology used to generate steelhead spawner escapement estimates in the mainstem Wenatchee River. The concern of applying a static overwinter mortality rate that was estimated in 2015 and 2016 with a radio telemetry study to the escapement estimates seemed to be the main reason for not agreeing with the proposed methodology. Willard said Chelan PUD had included language in the previous version of the *Chelan County PUD Hatchery Monitoring and Evaluation*

Implementation Plan 2023 to utilize the Hatchery Evaluations Technical Team to develop a study plan to update estimates of Wenatchee steelhead overwinter mortality rates. Willard said in one-on-one conversations, some representatives shared concerns about approving an implementation plan without an actual study plan to update the overwinter mortality rate. Chelan appreciates the willingness of some representatives to want to continue looking for an agreed upon methodology that does not include spawning ground surveys; however, Chelan does not want to commit time or resources to this endeavor without some type of assurance from each entity that they would consider approving a methodology that does not include spawning ground surveys to estimate spawner escapement. Some representatives indicated they would never support an implementation plan that does not include steelhead spawner surveys in the mainstem Wenatchee River, regardless of what methodology was proposed, especially if it proposed by another entity other than WDFW. Chelan PUD is disappointed, the HCP is an adaptive management agreement that "provides for ongoing modification of management practices to respond to new information and scientific developments."

Willard showed the minor proposed changes to Chelan PUD's implementation plan in tracked changes which included on page 3 that Chelan PUD will be conducting spawning surveys in 2023 instead of WDFW and language that had already been agreed to for Grant PUD's plan regarding spawning surveys in Icicle Creek on page 29. Willard said she is open to allowing the typical 30-day review period (meaning approval would take place during the January meeting), but asked if the HC members would be able to approve today, given the changes were minor.

All members of the RI/RR HCP-HC approved the implementation plan.

B. Wenatchee Steelhead Spawner Abundance

Tracy Hillman displayed Tables 3.28a and 3.28b of the Annual Hatchery M&E Report, which show steelhead spawning escapements. Two separate time-series exist that up until now have not been successfully linked to show trends across a longer period of time. WDFW has been working on a model to crosswalk the two time-series based on the "old" method and the currently used "new" - method.

Kevin See joined the meeting to present a method for creating one continuous time-series going back to 1987. See thanked the Committee for providing time for him in today's meeting. He gave his presentation, entitled "Updating Time-Series of Wenatchee Steelhead Spawners" (Attachment D).

See described the currently used method (since 2011) for estimating steelhead spawner escapements to the Wenatchee Basin. Tributary spawner escapement is estimated with a mark-recapture model based on PIT-tag detections (Dam Adult Branch Occupancy Model), supported by past radiotelemetry work, which showed that steelhead tend to move into the tributaries in the spring and become spawners. Mainstem Wenatchee spawner escapement is estimated with redd surveys.

A comparison plot between the old method and new method showed that there are some similarities in the direction of the trends, but the new method is assumed to be more accurate and unbiased. The objective was to use a Multivariate Auto-Regressive State-Space (MARSS) model to extend the estimates based on the new method, back to the beginning of the old time-series. Based on model selection criteria, dam counts were supported for inclusion as co-variates in the model whereas smolt release numbers were not. The MARSS model was used to create a new updated and complete time-series for steelhead spawning escapement.

Murdoch asked, regarding Chelan PUD's M&E implementation plan that was just approved, which redd survey method Chelan PUD will use. Willard said that Chelan PUD will continue the field methods that have been done since 2014, which includes the two observer method.

See said this approach would initially be applied to Wenatchee steelhead. Next steps would include applying it to the other Upper Columbia River tributary basins. See said he would distribute this presentation to the HCP-HCs and PRCC HSC, and include a write-up about the MARSS framework, the various configurations tested, and the various time-series used.

Hillman thanked See for his presentation. Hillman said it's likely that Chelan and Grant PUDs annual report will be modified based on this work and spawning escapement estimates may be displayed in a single table; however, the HC members will first need to review and approve the cross-walk model and results.

V. Administration

A. Next Meetings

The next regular HCP-HCs and PRCC HSC meetings will be held virtually on Wednesday, January 18; Wednesday, February 15; and Wednesday, March 15, 2023. The HCP-HC and PRCC HSC agreed they would meet virtually from December through February.

VI. Attachments

Attachment A: List of Attendees
Attachment B: Yakama Nation's revisions to the "Questions for PRCC from the PRCC Hatchery Subcommittee" document
Attachment C: Mark Sorel's presentation, "Wenatchee Spring Chinook Population Modeling"
Attachment D: Kevin See's presentation, "Updating Time-Series of Wenatchee Steelhead Spawners"
Attachment E: Estimates of Wenatchee Steelhead Spawners, Spawn Years 1987-2021, Kevin See, December 23, 2022

Attachment A
List of Attendees

Name	Organization
Larissa Rohrbach°	Anchor QEA, LLC
Tracy Hillman°	BioAnalysts, Inc.
Scott Hopkins*°	Chelan PUD
Catherine Willard*°	Chelan PUD
Tom Kahler*°	Douglas PUD
John Rohrback°	Douglas PUD
Deanne Pavlik-Kunkel°	Grant PUD
Todd Pearsons‡°	Grant PUD
Tim Taylor°	Grant PUD
Brett Farman*‡°	National Marine Fisheries Service
Ben Goodman°	Washington Department of Fish and Wildlife
Mike Tonseth*‡°	Washington Department of Fish and Wildlife
Chad Jackson*‡°	Washington Department of Fish and Wildlife
Katy Shelby°	Washington Department of Fish and Wildlife
Kevin See°	Washington Department of Fish and Wildlife
Charlie Snow°	Washington Department of Fish and Wildlife
Keely Murdoch*‡	Yakama Nation
Mark Sorel°	University of Washington
Charles Frady°	U.S. Fish and Wildlife Service
Bill Gale*‡°	U.S. Fish and Wildlife Service

Notes:
* Denotes HCP-HCs member or alternate
‡ Denotes PRCC HSC member or alternate
° Joined by Webex

Attachment B

Yakama Nation's revisions to the "Questions for PRCC from the PRCC Hatchery Subcommittee" document

Questions for PRCC from the PRCC Hatchery Subcommittee

As described in the Priest Rapids Project Salmon and Steelhead Settlement Agreement (SSSA), every ten years, the PRCC Hatchery Subcommittee (PRCC HSC) is required to review production levels to determine if adjustments are necessary to achieve and maintain "No Net Impact" (NNI). Adjustments are made based on changes in average adult returns, adult-to-smolt survival rates, and smolt-to-adult survival rates (SARs) from the hatcheries relative to the survival rates used to establish the initial production levels that were based on the Biological Assessment and Management Plan (BAMP). The PRCC HSC is responsible for recommending adjustments in program levels and strategies considering the methodologies described in the BAMP and recommending modified implementation plans for Grant PUD funding. The last (which was the first) review of production levels (referred to as "Recalc") occurred in 2013. The PRCC HSC began the second Recalc process in early 2021.

As the PRCC HSC worked through the second Recalc process, it became clear that there were differences in interpretation of some of the language within the SSSA. These differences in interpretation greatly slowed the Recalc process, raised questions about initiating the dispute resolution process, and resulted in at least an additional six months of discussion and negotiations. In an effort to avoid disputes and help the PRCC HSC more easily calculate production numbers in a reasonable period of time, the PRCC HSC is asking the PRCC and/or the PRCC Policy Committee to provide responses to the following questions. Importantly, responses to these questions are intended to facilitate the next Recalc process, which will occur prior to 2033.

1. **What fish stocks and hatchery programs are subject to NNI calculations?**

   To avoid a future dispute, the PRCC HSC needs to know what stocks of Covered Species are included in the definition of NNI. For example, do the definitions include mitigation for upstream inundation production (e.g., mitigation for the production of summer Chinook and steelhead produced in Chelan and Douglas PUD-funded hatcheries to mitigate for inundation [loss] of spawning habitat created by the construction of Rock Island, Rocky Reach, and Wells dams), full mitigation for fish released from Chief Joseph Hatchery, and for future consideration, full mitigation for fish produced in blocked areas (e.g., upstream from Chief Joseph and Grand Coulee dams)? The following table identifies the hatchery programs and stocks that currently exist or may exist in the future. The PRCC HSC is asking the PRCC or PRCC Policy Committee to identify which stocks and hatchery programs are included in NNI Recalc.

Table 1. Listing of populations and/or hatchery programs by type, origin, and species/race that are subject to NNI. HO = hatchery origin.

<table>
<tr><th rowspan="2">Species/Race</th><th rowspan="2">Population or Program</th><th colspan="2">Covered under NNI</th></tr>
<tr><th>Yes</th><th>No</th></tr>
<tr><td rowspan="6">Spring Chinook</td><td>Blocked Area Natural Origin</td><td></td><td></td></tr>
<tr><td>Blocked Area Reintroduction (HO)</td><td></td><td></td></tr>
<tr><td>Okanogan Natural Origin</td><td></td><td></td></tr>
<tr><td>Methow Natural Origin</td><td></td><td></td></tr>
<tr><td>Entiat Natural Origin</td><td></td><td></td></tr>
<tr><td>Wenatchee Natural Origin</td><td></td><td></td></tr>
</table>

Commented [MT1]: Because a big part of this questions is directed at mitigating for inundation programs, a secondary question may be, are hatchery programs (or a portion thereof) initiated in the Blocked Area as part of reintroduction efforts considered inundation production? The same question could be raised for the BOR programs in the Methow (Winthrop), Entiat, and Wenatchee (Leavenworth) operated by the USFWS. At the end of the day, the BOR programs are mitigation for the blocked area but in what context; lost production as a result of pool inundation or extirpation of species/populations in the tributaries.

This might be a can of worms but I think perspectives may be important here - perhaps there is language for the BOR programs which may provide some clear(er) context.

Species/Race	Population or Program	Covered under NNI	
		Yes	No
	Okanogan Reintroduction (HO)		
	Chief Joseph Harvest (HO)		
	Methow NNI Conservation (HO)		
	Winthrop Safety Net (USFWS, HO)		
	Chiwawa NNI Conservation (HO)		
	Nason NNI Conservation (HO)		
	Nason NNI Safety Net (HO)		
	White River NNI Conservation (HO)		
	Leavenworth Harvest (USFWS, HO)		
Summer Chinook	Blocked Area Natural Origin		
	Blocked Area Reintroduction (HO)		
	Okanogan Natural Origin		
	Methow Natural Origin		
	Entiat Natural Origin		
	Wenatchee Natural Origin		
	Okanogan NNI Supplementation (HO)		
	Chief Joseph Harvest (HO)		
	Methow (Carlton) NNI Supplementation (HO)		
	Wells Inundation (HO)		
	Chelan Falls Inundation (HO)		
	Chelan Falls NNI Harvest (HO)		
	Entiat Harvest (USFWS, HO)		
	Wenatchee NNI Supplementation (HO)		
Fall Chinook	Priest Rapids Inundation (HO)		
	Priest Rapids Fry Conversion (HO)		
	Priest Rapids NNI (HO)		
Steelhead	Blocked Area Natural Origin		
	Blocked Area Reintroduction (HO)		
	Okanogan Natural Origin		
	Methow Natural Origin		
	Entiat Natural Origin		
	Wenatchee Natural Origin		
	Okanogan NNI Conservation (HO)		
	Winthrop Conservation (USFWS, HO)		
	Methow NNI Conservation (HO)		
	Wells Inundation (HO)		
	Rocky Reach Inundation (HO)		
	Wenatchee NNI Conservation (HO)		
Sockeye	Okanagan Natural Origin		
	Skaha Lake/Lake Okanagan Reintroduction (HO)		
	Blocked Area Natural Origin		

Species/Race	Population or Program	Covered under NNI	
		Yes	No
	Blocked Area Reintroduction (HO)		
	Wenatchee Natural Origin		
	Wenatchee NNI Supplementation (HO)		
Coho	Blocked Area Natural Origin		
	Blocked Area Reintroduction (HO)		
	Methow Natural Origin		
	Methow Reintroduction (HO)		
	Wenatchee Natural Origin		
	Wenatchee Reintroduction (HO)		

2. ~~What are the project effects that need to be mitigated?~~ Is hatchery mitigation intended to return fish to areas the mitigation is intended to supplement (in-kind in-place mitigation), or does the mitigation obligation end at the Project where juvenile mortality occurred?

Currently, the production objective to achieve NNI ~~mitigation~~ for natural-origin Covered Species is calculated by multiplying the juvenile mortality rate to the quotient of the run size at each project and release-to-adult survival (SAR) from the hatchery producing the mitigation in order to determine how many fish to release from that facility (Figure 1) ~~using SARs from tagged hatchery-origin fish and then applying those SARs to natural-origin adult returns (measured at each project)~~.

Figure 1. BAMP formula (page 10 in the Biological Assessment Management Plan)

Baseline returns (Table 2)		*Survival rate (Table 3)*		*NNI component*		*Hatchery production (Table 4)*
3,761 adults	÷	0.003 adults/smolt	x	0.07	≈	90,000 smolts

This calculation~~, which~~ is described in the BAMP for all salmon and steelhead passing through the project area and was used to calculate the initial production numbers in the Settlement Agreement and HCPs. The PRCC HSC has continued to use the BAMP formula to estimate the number of hatchery fish to release to replace natural origin smolts lost to juvenile project mortality (note: a different formula is currently being used to estimate mitigation for hatchery fish released upstream).~~, estimates the number of natural-origin smolts entering the project areas~~. The BAMP uses hatchery-origin fish tagged with CWTs to estimate SARs. In this case, all adult~~s~~ recoveries ~~detected~~ (i.e., on target spawning grounds, strays in non-target spawning areas, in fisheries downstream of the project, in fisheries upstream of the project, ~~and~~ in broodstock, and in hatchery surplus) are included in the SAR calculation.

Advantages: A large percentage of the hatchery fish are tagged (>95%) and therefore there is assumed to be no tagging bias, there is a long-term data set, and this approach was agreed to by parties to the BAMP. A CWT SAR represents the release to adult survival rate which includes of all the places a fish might have returned to.

Commented [k2]: I would not call this project effects. The project effect is **juvenile mortality** only and this is not in dispute by anyone. What is not clear is whether you are simply replacing the fish for its whole life (in-kind –in place, 1 smolt killed = 1 smolt replaced , or are you only replacing that smolt back to the dam – not in-kind in place if the replaced fish is not replaced to the areas it was intended to supplement. Or are we only replacing the fish only as far as the project (more like a Wells FH or a PRH).

Commented [MT3]: And to what point beyond the project area are project effects an agent of mortality?

Commented [MT4]: This is what is considered a "full lifecycle" SAR by some parties.

Disadvantages: Not all adult returns are recovered (this could under- or over-estimate the true SAR if there is uncertainty around the recovery rate)

A SAR calculated to the Project using PIT tags (see below) underestimates the

A SAR calculated to the Project using PIT tags (see below) underestimates the

A SAR calculated to the Project using PIT tags (see below) underestimates the

mitigation needed for in-kind in-place mitigation.

The PUDs offered an alternative method that uses hatchery-origin fish tagged with PIT tags to estimate SARs. In this case, adults detected at the projects (same locations where enumeration of natural-origin returns occur) are used to calculate SARs. This method calculates the number of smolts released to return the adults as far as the Project only. The PUDs assert they are not responsible for returning fish to the tributaries to which the hatchery programs are intend to supplement because of non-project related effects that may occur upstream of the project area (e.g. in tributaries).

Advantages: This approach matches adult enumeration sites with PIT-tag detection sites (thus, it is algebraically correct), it does not include agents of mortality upstream and independent of project effects, and it provides mature data sets within a short period of time (i.e., there is no long-term delay in reporting tag detections; thus, results from recent brood years are available). (Note: PIT tag SARs could be calculated to the tributaries with instream arrays instead of to the Project which would allow for the benefits of PIT tag data turnaround time while maintain an in-kind in-place mitigation calculation).

Disadvantages: A relatively small percentage of hatchery-origin fish are tagged (5,000-20,000 hatchery fish from each stock/program are PIT tagged annually), the percentage of hatchery-origin fish tagged may not be representative of the entire population of hatchery-origin fish released (only fish of a certain size are PIT tagged), and detections are made at the dams. Some signatories believe that measuring hatchery release-to adult survival only as far as each Project is fundamentally inconsistent it the concept of in-kind in-place mitigation intended to supplement spawning in key locations within the Upper Columbia. Measuring hatchery release-to-adult survival only as far as each Project results in unequal mitigation rates for each PUD, even when rearing those fish together at the same facility; each PUD would use a different release to adult survival rate for the same program (Methow spring Chinook example: Using PIT tags to project Grant PUD would release less fish, and Chelan and Douglas would release respectively more fish per juvenile lost to project mortality ; Using the CWT for the hatchery facility all PUDs would release the same number of Methow spring Chinook per fish lost to juvenile mortality)

Currently, there is a difference of opinion among members on whether SARs, which are used to calculate the number of natural-origin smolts entering the project area, which are used to determine how many smolts to release from a given hatchery to return the number of adults which would have returned to that area in the absence of juvenile project mortality should use the CWT based hatchery SAR as has been presented in the M&E report and used to calculate

Commented [k5]: This is not about Project Effects. The only 'project effect' that matters here is juvenile mortality. We are replacing smolts that are killed by juvenile project mortality with an equal number of smolts released from a hatchery. The deleted part of this sentence is confusing the issue. The question is are we replacing that fish for its whole life to all the places it would have wound up if it were not killed at the project, or are we only replacing that fish for its journey to the ocean and back to the project. These fish, if not killed, would have returned to spawning grounds, to hatcheries, to fisheries, and would have been lost to prespawn mortality, all that is part of the equation in figuring out how many fish are needed to be released. We are replacing them with an equal number of adults that would do the same thing they theoretically would have if not killed. The issue of adult survival rates and where we measure them (the project effects referred to here) applies ONLY for the 2% habitat mitigation and for calculating the 91% survival standard. The BAMP formula is simply an equation to get the right number of fish back to spawning grounds and hatcheries for in-kind in-place mitigation. Replacing fish only as far as the dam is not in-place in-kind mitigation and is only appropriate for hatchery programs such as Wells Fish Hatchery, Priest Rapids FH, and Chelan Falls where the production is released essentially at the Project. So the real question relates to whether this is in-kind-in-place mitigation or not.

Commented [MT6]: If I recall correctly, there was substantial discussion about the location for the point estimate as being to the project or through the project.

Commented [k7]: We need a better way to describe this, the only project effect that we are talking about is juvenile project mortality and how to calculate the right number of hatchery fish to release to replace a fish that was killed.

Commented [MT8]: I would say that another disadvantage is that it does not include/consider project related effects which may function as an agent of mortality beyond the project area.

Perhaps what the committees could work on is a list of what are considered agents of mortality, are they measurable (and where), and are they attributable to the project (an example of this may be recreational fisheries whereby there is post release (delayed) hooking related mortality and while the fishery occurred within the project area, is not attributable as a project effect. The inverse of this is a conservation fishery whereby the same post release (delayed) hooking mortality occurs but since it exists as an adult management action related to a hatchery program, it is an attributable project effect whether the fishery occurs within the project are or outside the project area (tributaries). I'm not taking a position on these but they may function as examples for consideration/discussion.

mitigation in the BAMP or an alternate measure of hatchery release-to-adult survival which would use an adult survival value to the Project only.

The full life cycle (CWT) SARs were used in the BAMP; however, the SSSA does not require the PRCC HSC to use the methods described in the BAMP. The SSSA states that the PRCC HSC needs to “consider” the methods described in the BAMP. To avoid a future dispute, the PRCC HSC would like to know the appropriate end point when measuring release-to-adult survival rates used to calculate the number of hatchery fish to release in order to replace NOR adults that would have returned in the absence of juvenile project mortality.

Commented [k9]: While the different SAR calculation do encompass different mortality rates as adults, I want to get way from the term project effects because the only project effect we are mitigating for here is juvenile project mortality and I think it confuses the issue. The question is to what point do we replace fish inclusive of their mortality regime. Is the mitigation intended to replace fish to the hatchery/spawning grounds/fisheries where they would have wound up if not lost to mortality, or is it intended to return fish to the project? It has nothing to do with why an adult fish might die, frankly I don’t think that matters.

Commented [TK10]: This parses the project effects into ones requiring mitigation, and ones not requiring mitigation. Is that’s the right question, if the answer to the question of what constitutes NNI is truly to make the project invisible? The hatchery compensation is intended to replace lost juveniles at the project with a quality smolt or emigrant, and the subsequent survival of that emigrant in its journey beyond the project is not the responsibility of the District beyond the extent of any measurable delayed effects attributable to project passage. Similarly, the survival of returning adults is not the responsibility of the District until the adults encounter the project, beyond which the District’s responsibility for subsequent survival extends only to delayed effects measurably attributable to project passage. Mitigation for adult passage-losses is not a component of the hatchery compensation, but is fulfilled by the Plan Species Accounts.

Commented [TK11]: I would clarify that the effects need to be measurably attributable to the project.

Attachment C
Mark Sorel's presentation "Wenatchee Spring Chinook Population Modeling"

Wenatchee Spring Chinook Population modeling

Mark Sorel

Washington Department of Fish and Wildlife, Columbia River Management Unit

University of Washington, School of Aquatic and Fishery Sciences

Hatchery Committee Meeting—21 December 2022

NOAA FISHERIES

WACFWRU

NORTHWEST Climate Adaptation Science Center

Aquatic and Fishery Sciences
University of Washington

Grant PUD

P.U.D. CHELAN COUNTY

Washington Department of Fish and Wildlife

Yakama Nation Fisheries

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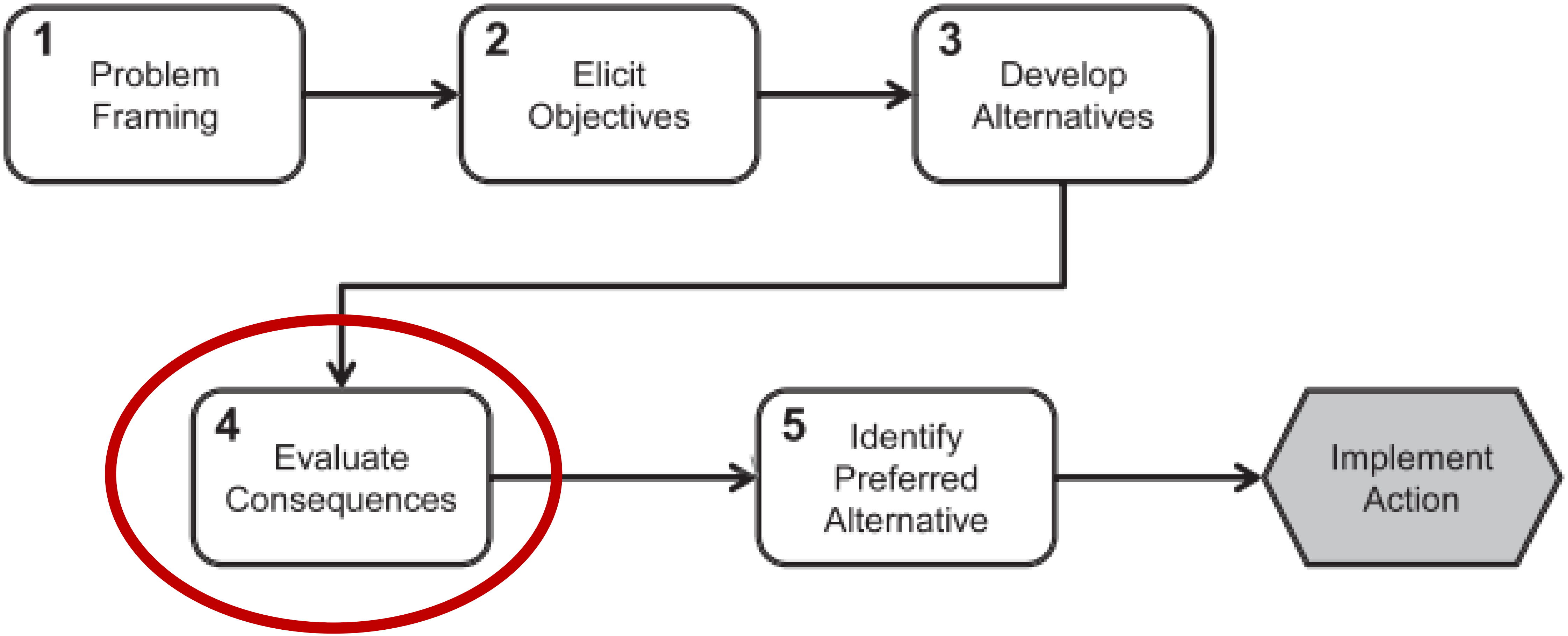
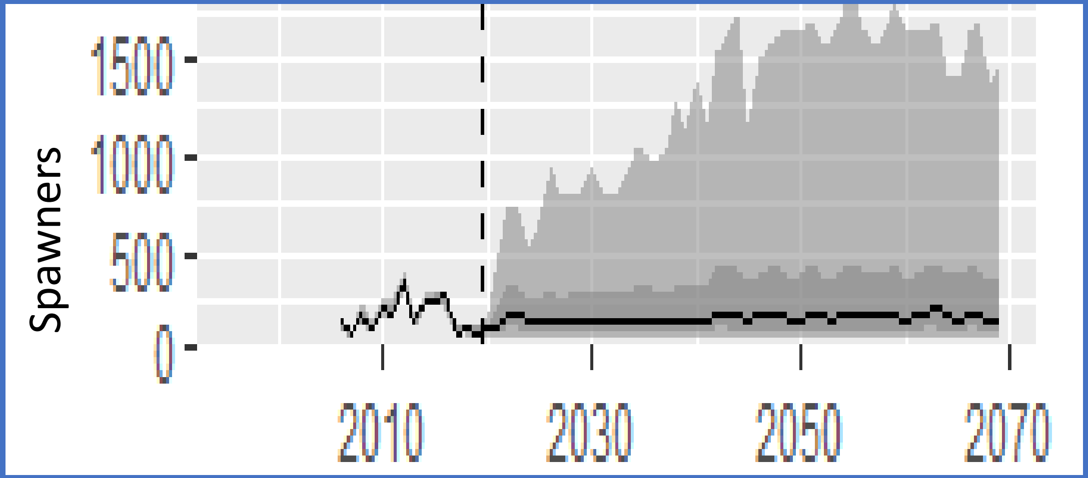
  - Todd Pearsons
  - Catherine Willard
  - Tracy Hillman
- Data
  - Washington Department of Fish and Wildlife
  - Yakama Nation Fisheries
  - Grant County PUD
  - Chelan County PUD
- Funders
  - NOAA Northwest Fisheries Science Center
  - Northwest Climate Adaptation Science Center
  - Washington Cooperative Fish and Wildlife Research Unit

Decision analysis



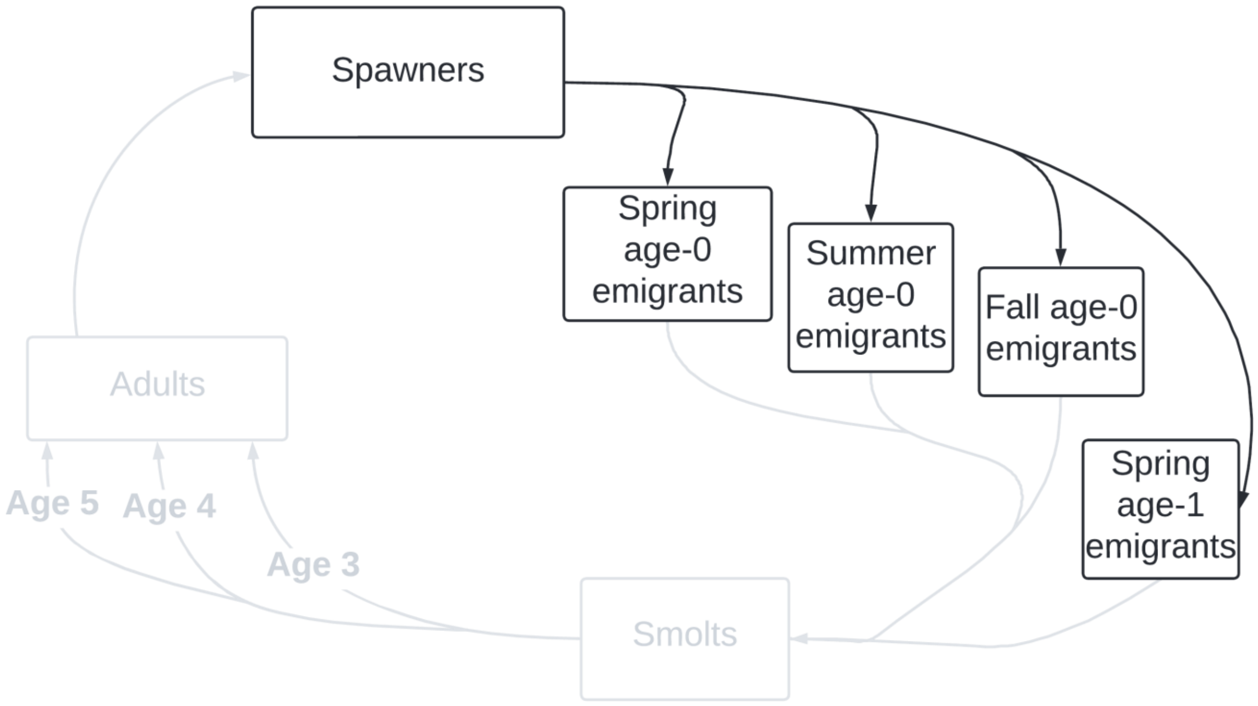
Runge 2011

Population models can be used to project populations under alternative management strategies or environmental scenarios



Chapters

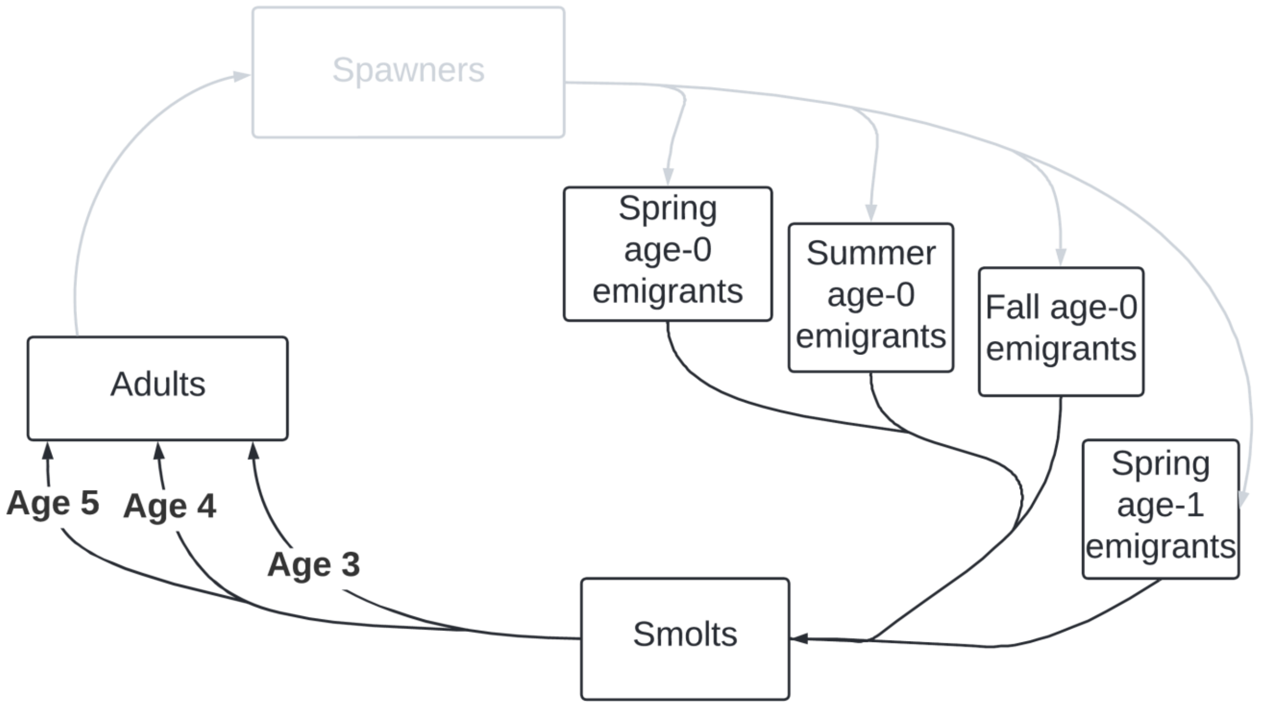
1) Juvenile production



Chapters

1) Juvenile production

2) Juvenile survival through adult return

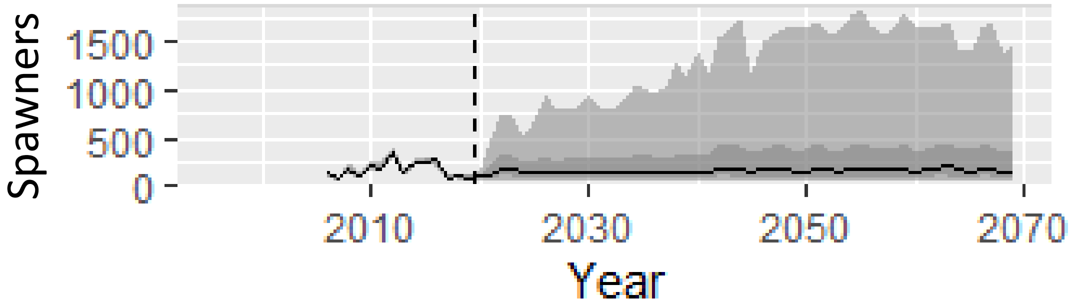


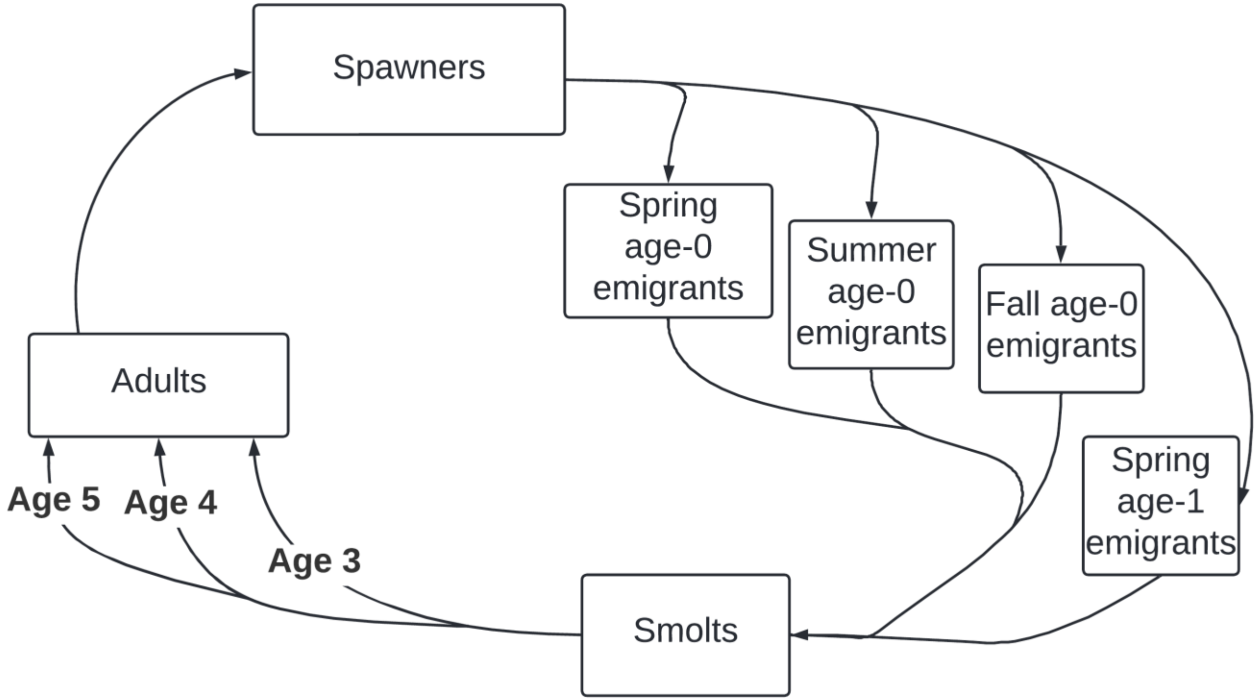
Chapters

1) Juvenile production

2) Juvenile survival through adult return

3) Population viability analysis





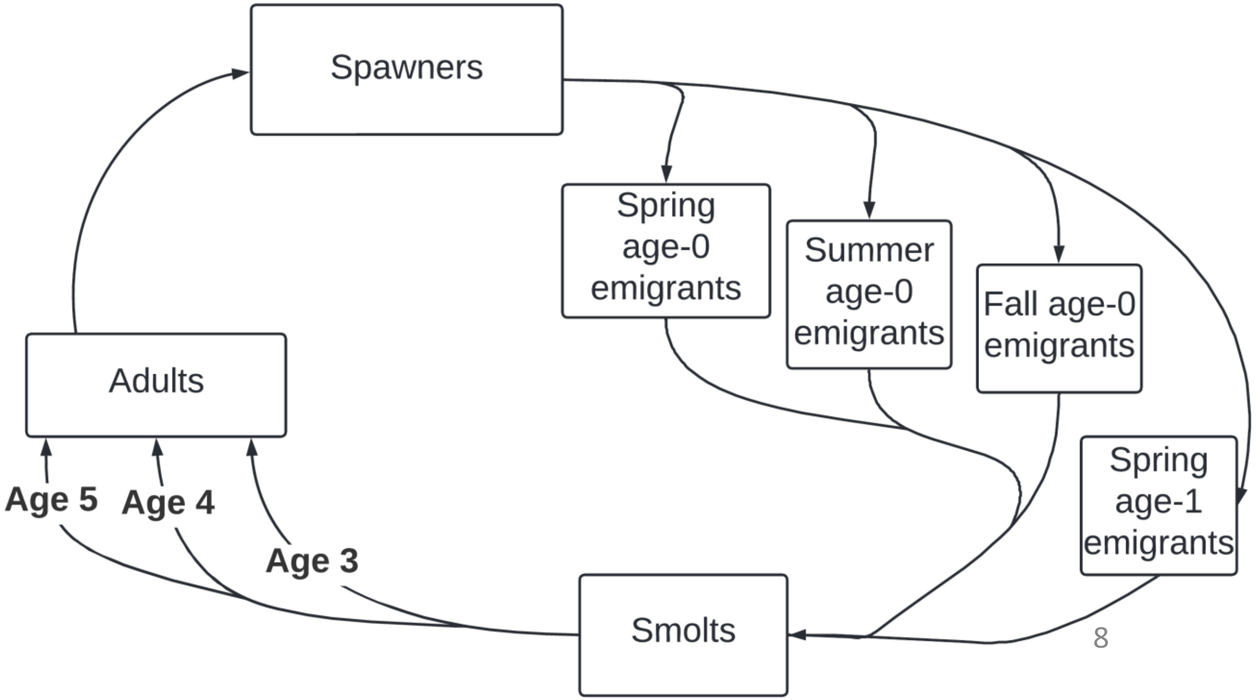
Chapters

1) Juvenile production

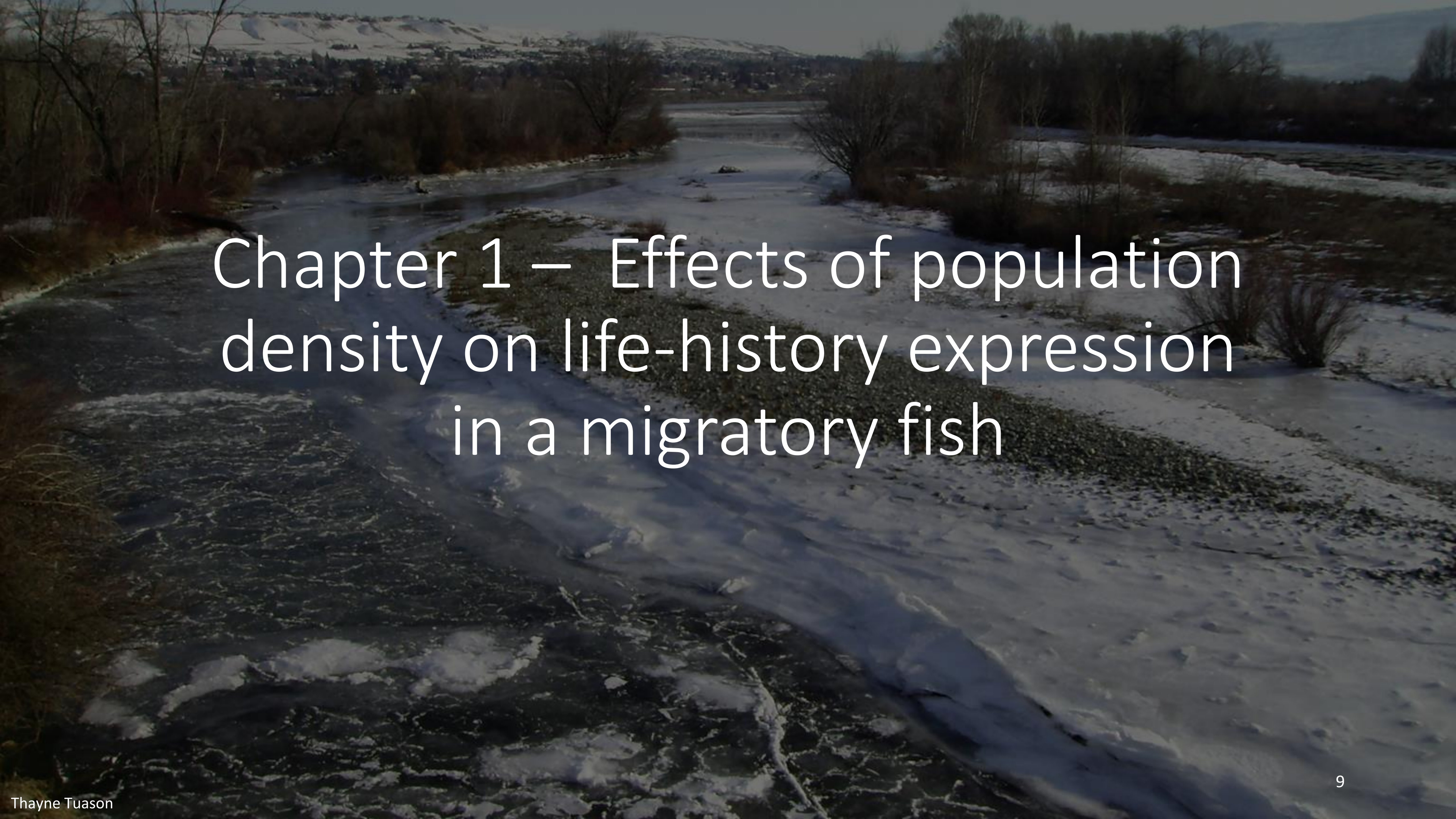
2) Juvenile survival through adult return

3) Population viability analysis

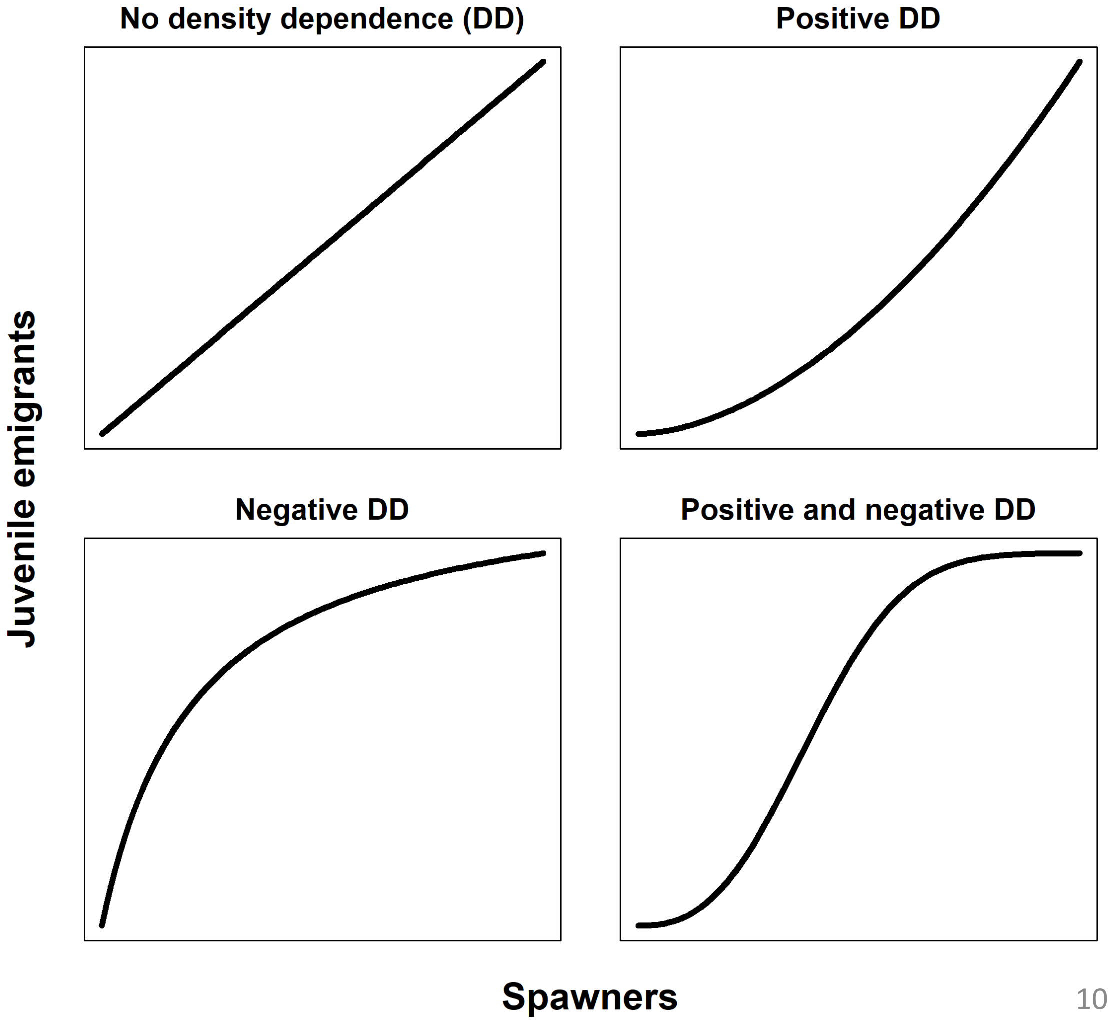
4) Management evaluation



Chapter 1 – Effects of population density on life-history expression in a migratory fish



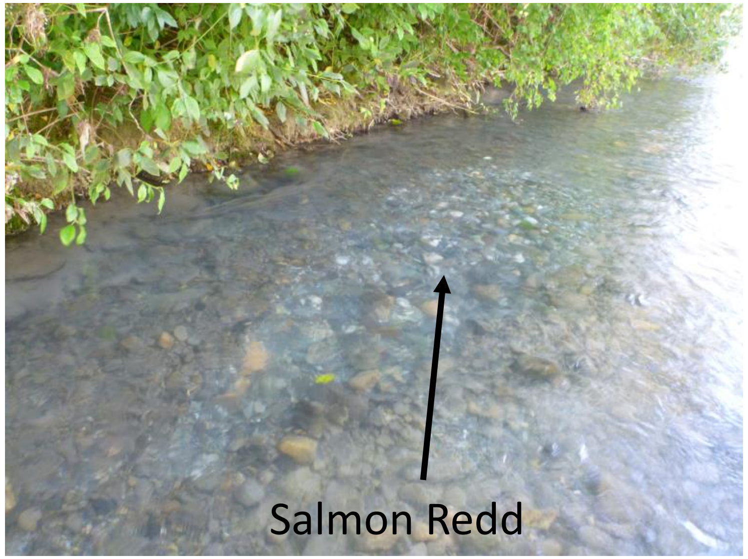
Hypothesis #1: Density affects relative production of alternative life-history pathways

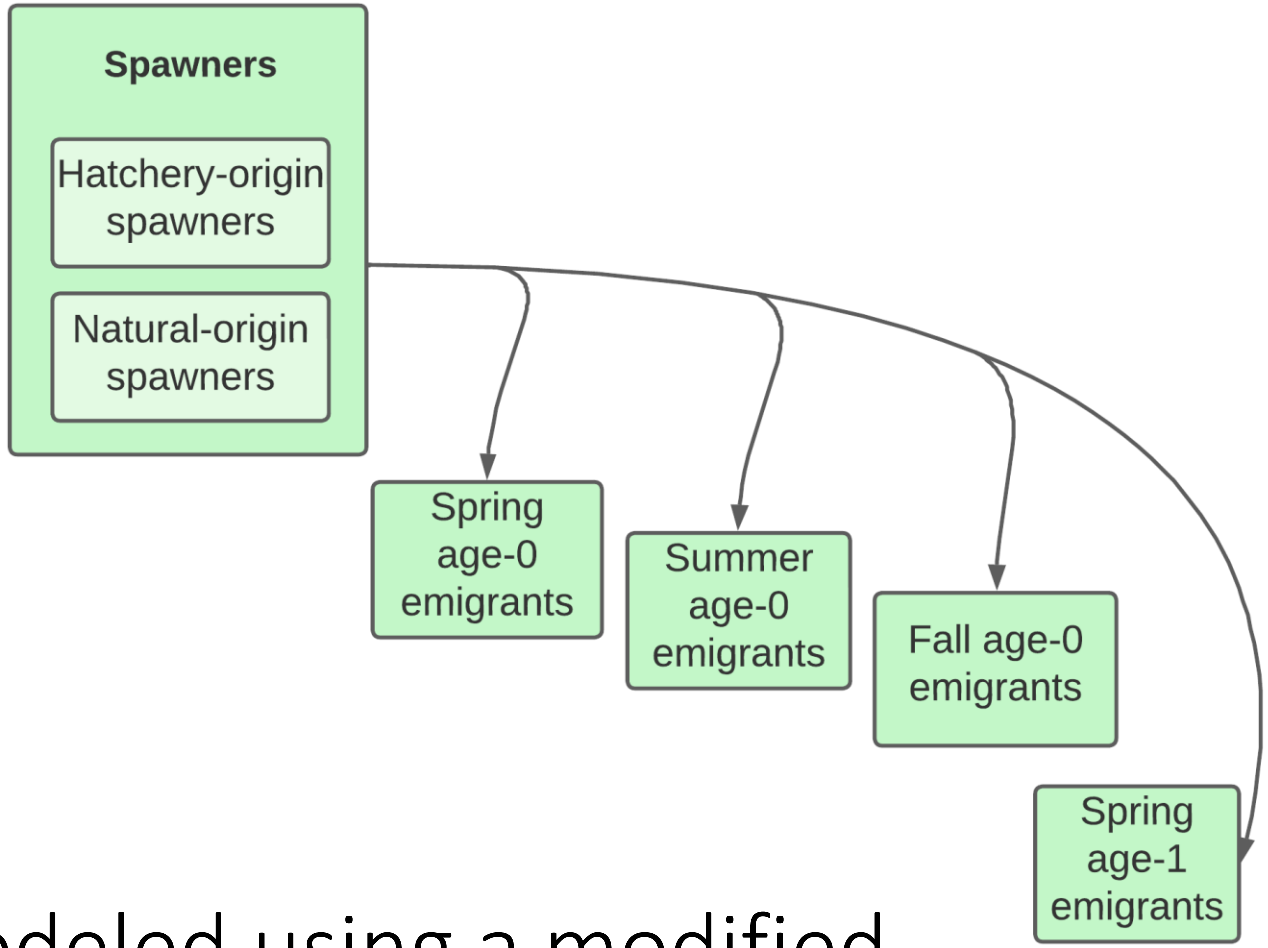


Data

Spawner abundance from redd (nest) surveys

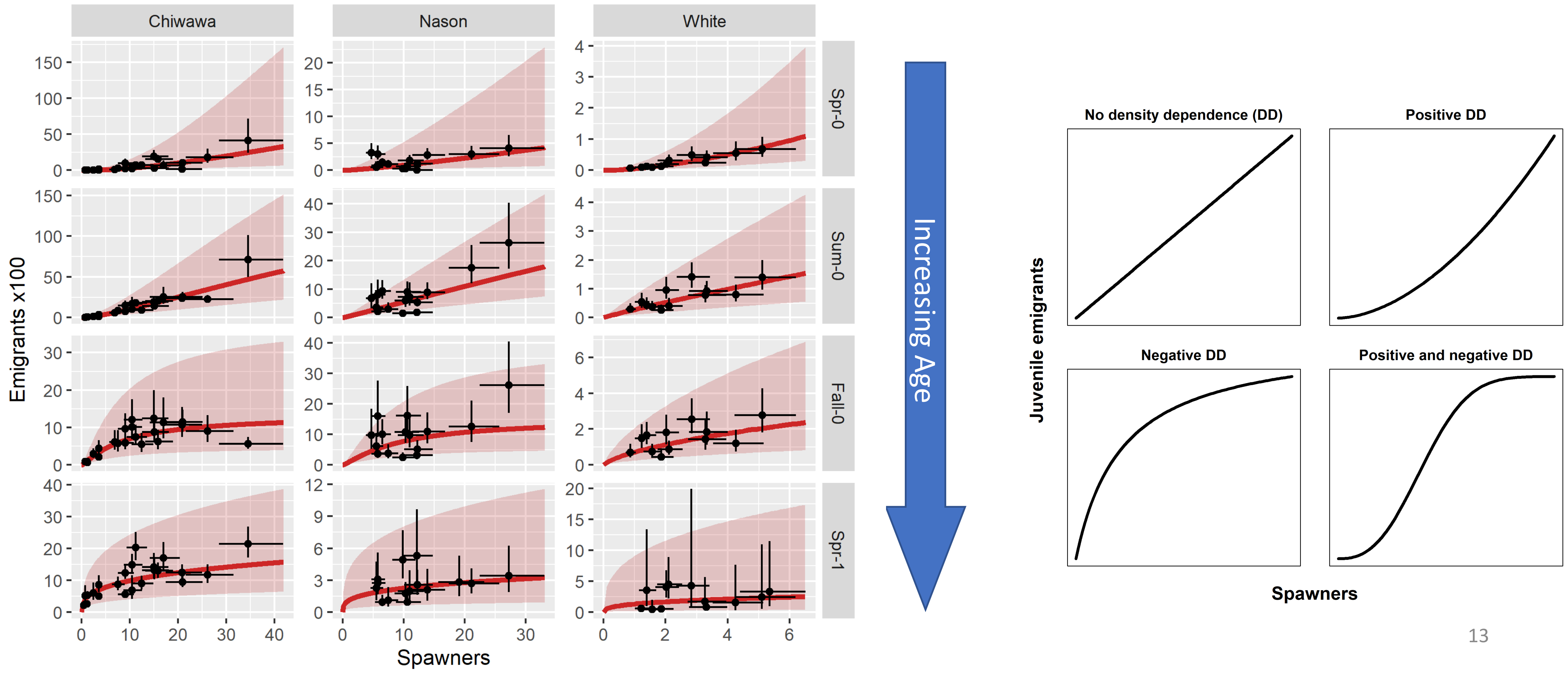
Juvenile abundance from downstream-migrant traps



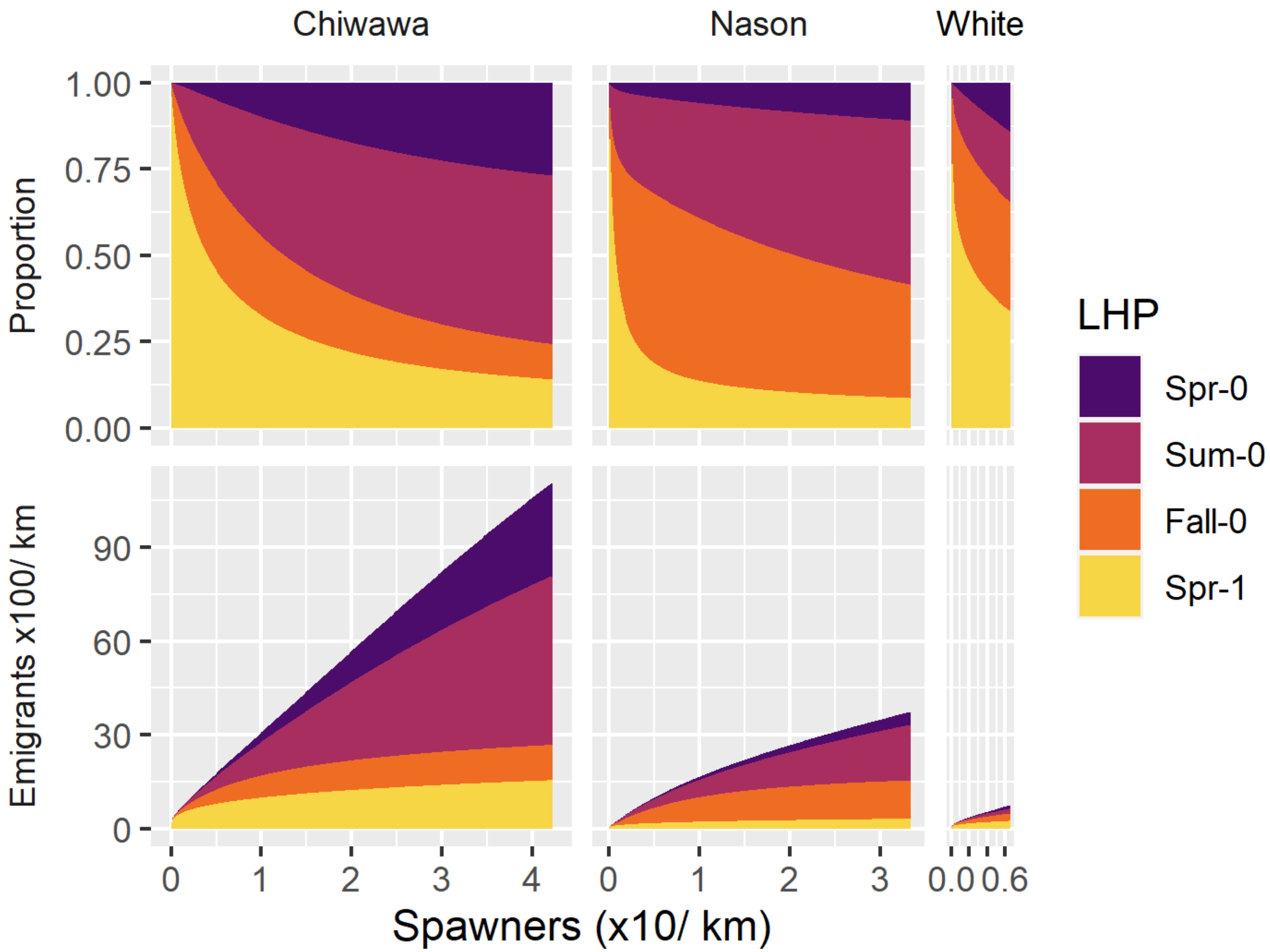


Juvenile abundance was modeled using a modified Beverton-Holt function of spawners

There was evidence of positive density dependence in younger-emigrating LHPs and negative density-dependence in older-emigrating LHPs



Younger emigrating life history pathways become more common with increasing spawners

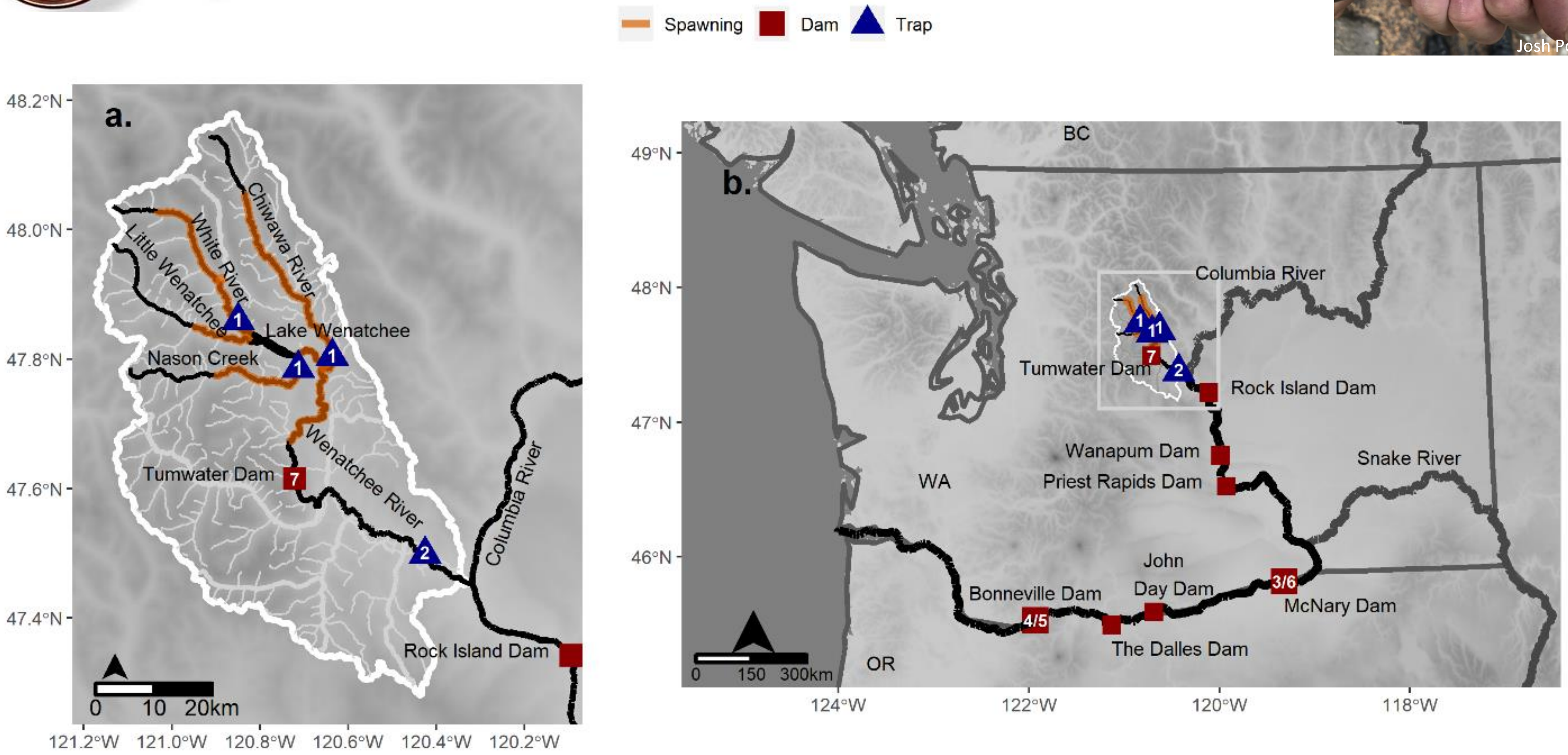


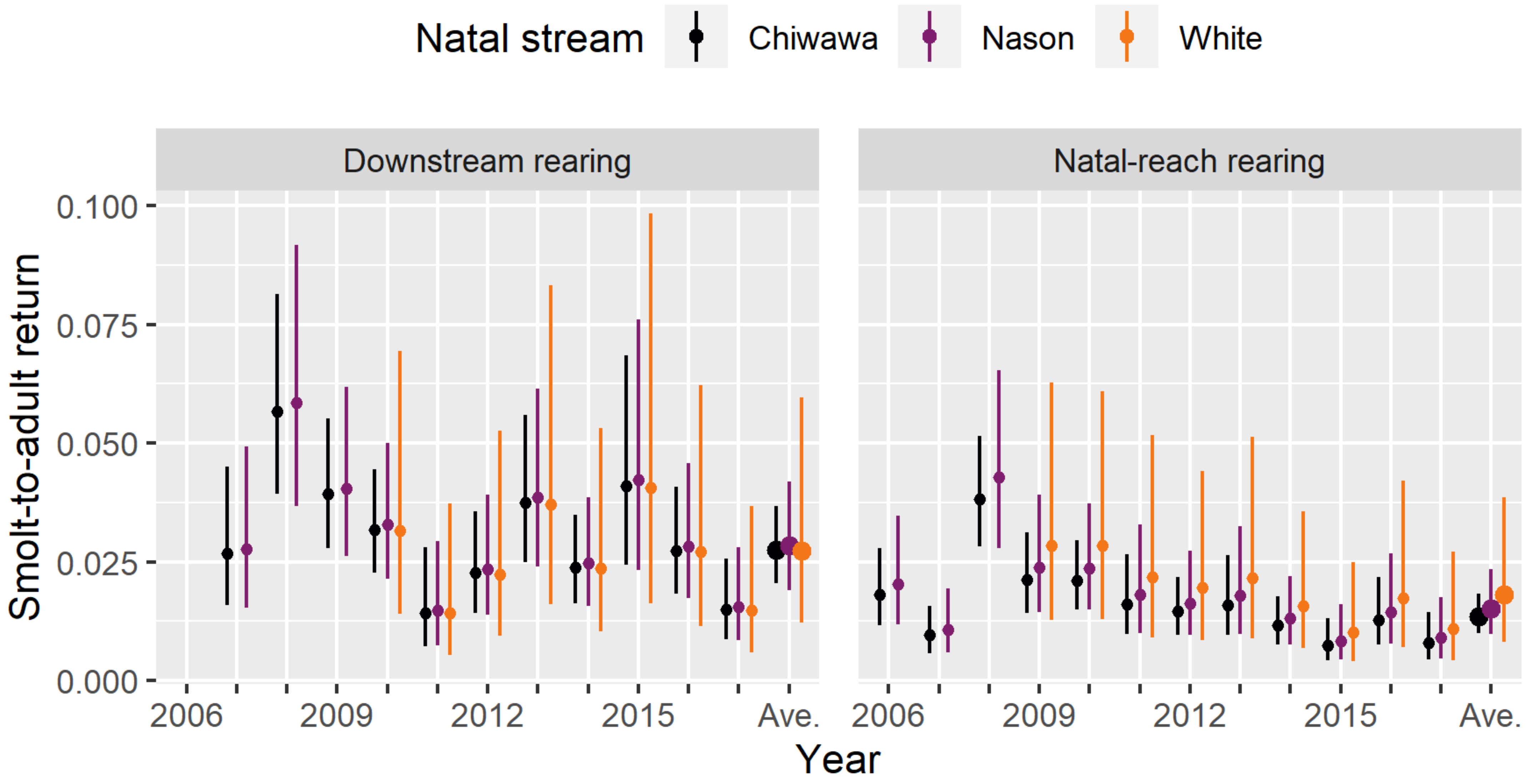

Thayne Tuason

Chapter 2 – Juvenile life history diversity is associated with lifetime demographic heterogeneity in a migratory fish

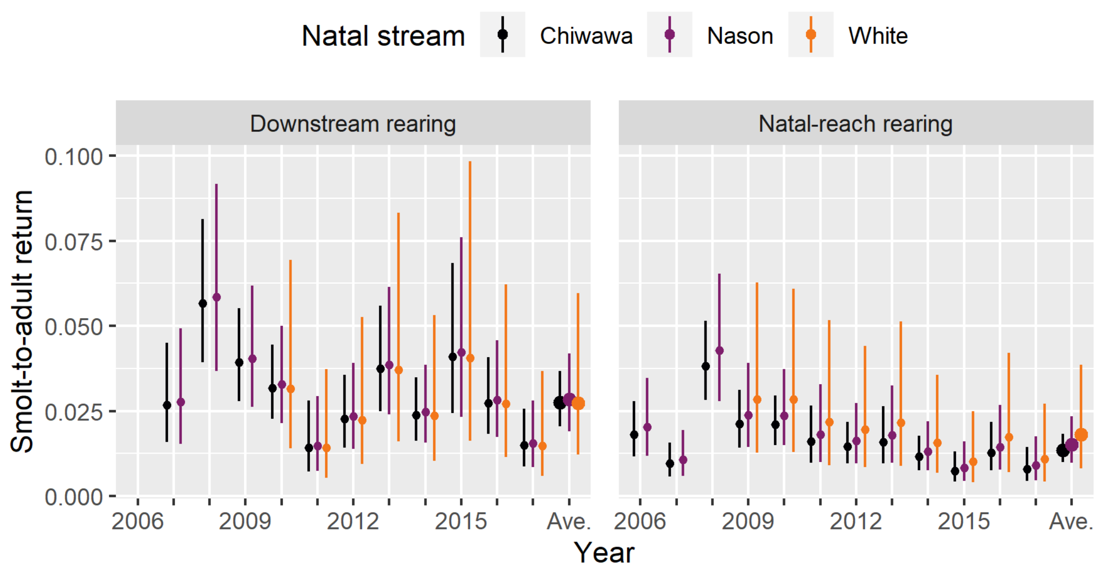

PIT tag
LIBERTY
IN GOD WE TRUST
2003

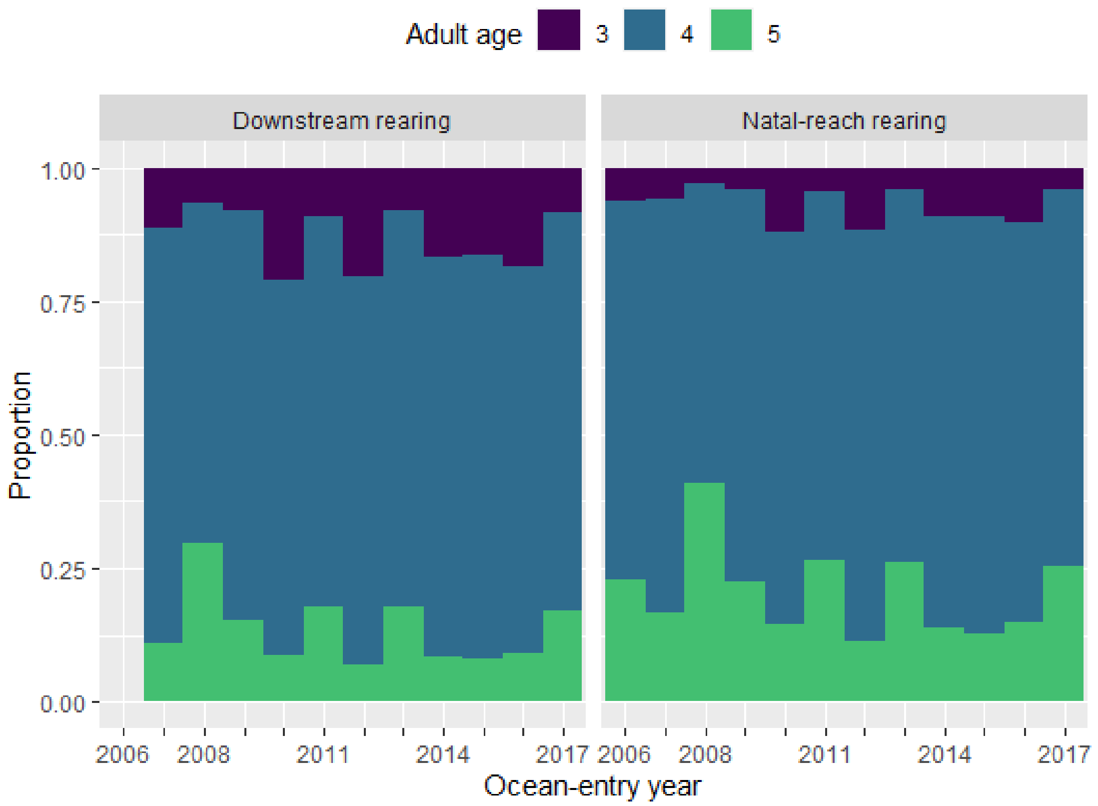

PIT tagging
Josh Poole


Spawning
Dam
Trap
a.
48.2°N
48.0°N
47.8°N
47.6°N
47.4°N
121.2°W
121.0°W
120.8°W
120.6°W
120.4°W
120.2°W
Chiwawa River
White River
Little Wenatchee
Lake Wenatchee
Nason Creek
Tumwater Dam
Wenatchee River
Columbia River
Rock Island Dam
0 10 20km
b.
BC
49°N
48°N
47°N
46°N
124°W
122°W
120°W
118°W
Columbia River
Tumwater Dam
Rock Island Dam
Wanapum Dam
Priest Rapids Dam
Snake River
WA
John Day Dam
Bonneville Dam
McNary Dam
The Dalles Dam
OR
0 150 300km



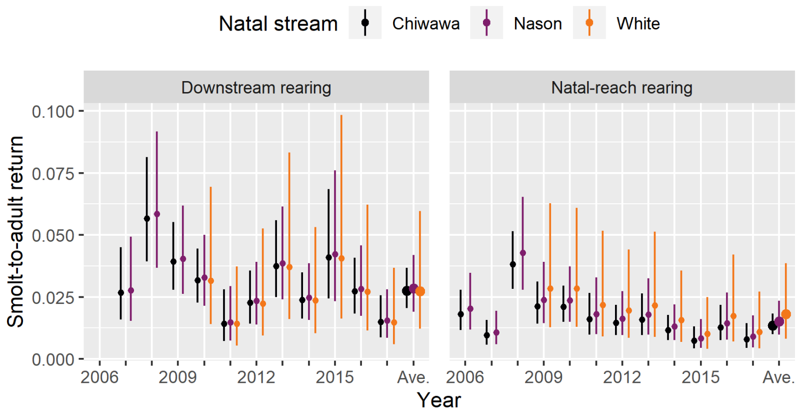
Natal stream
Chiwawa
Nason
White
Downstream rearing
Natal-reach rearing
0.100
0.075
0.050
0.025
0.000
Smolt-to-adult return
2006
2009
2012
2015
Ave.
Year

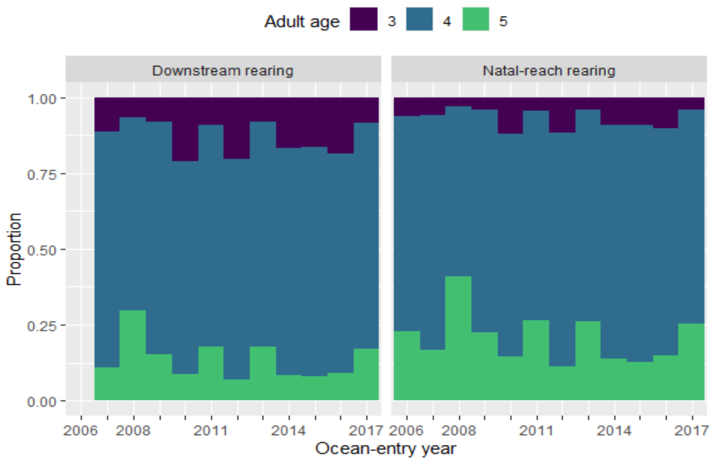

Natal stream
Chiwawa
Nason
White
Downstream rearing
Natal-reach rearing
Smolt-to-adult return
0.100
0.075
0.050
0.025
0.000
2006
2009
2012
2015
Ave.
Year

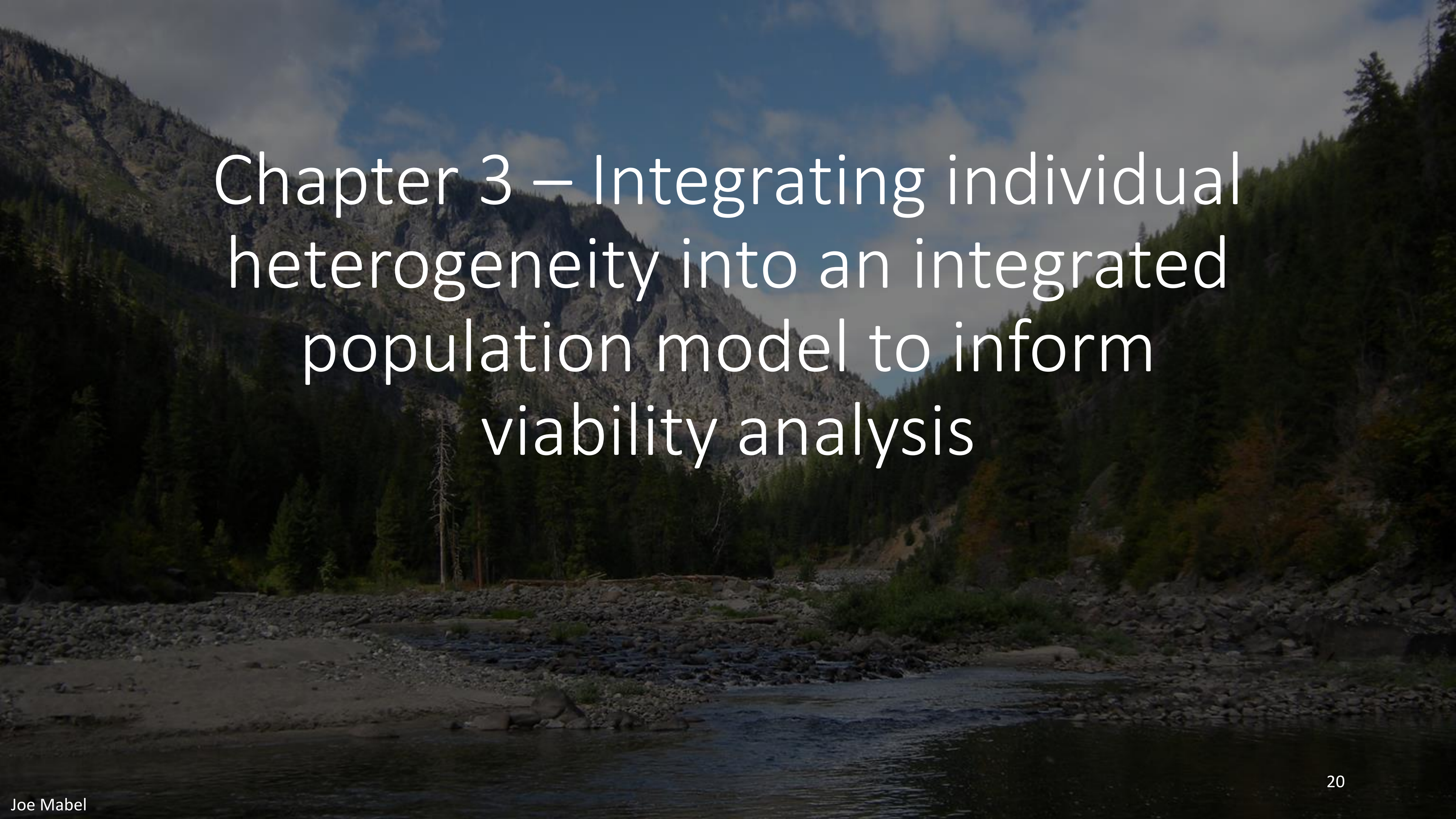

Adult age
3
4
5
Downstream rearing
Natal-reach rearing
Proportion
1.00
0.75
0.50
0.25
0.00
2006
2008
2011
2014
2017
Ocean-entry year

Chapter 2 conclusions

- Return rates and ages differed between life history pathways

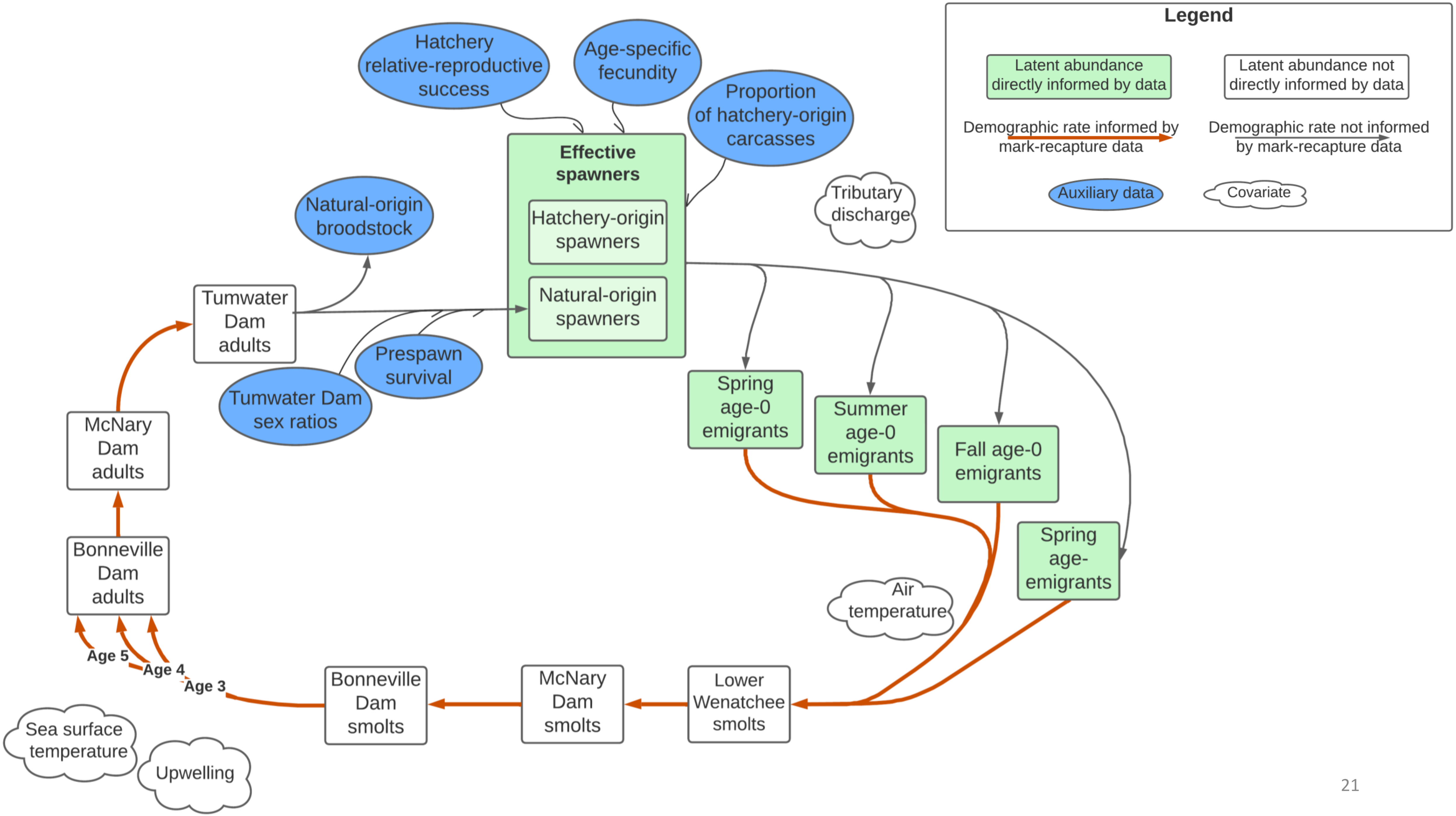






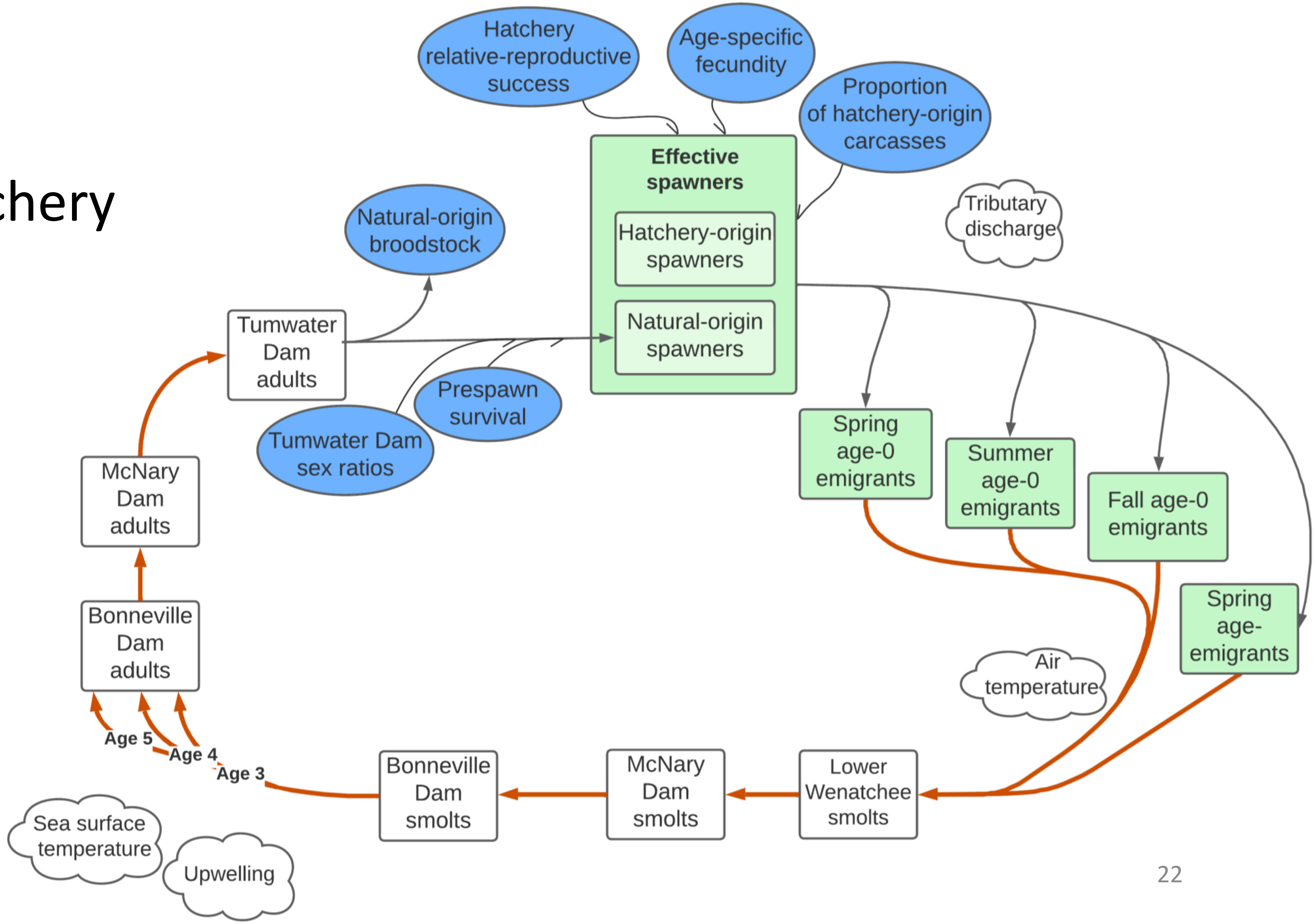
Chapter 3 – Integrating individual heterogeneity into an integrated population model to inform viability analysis

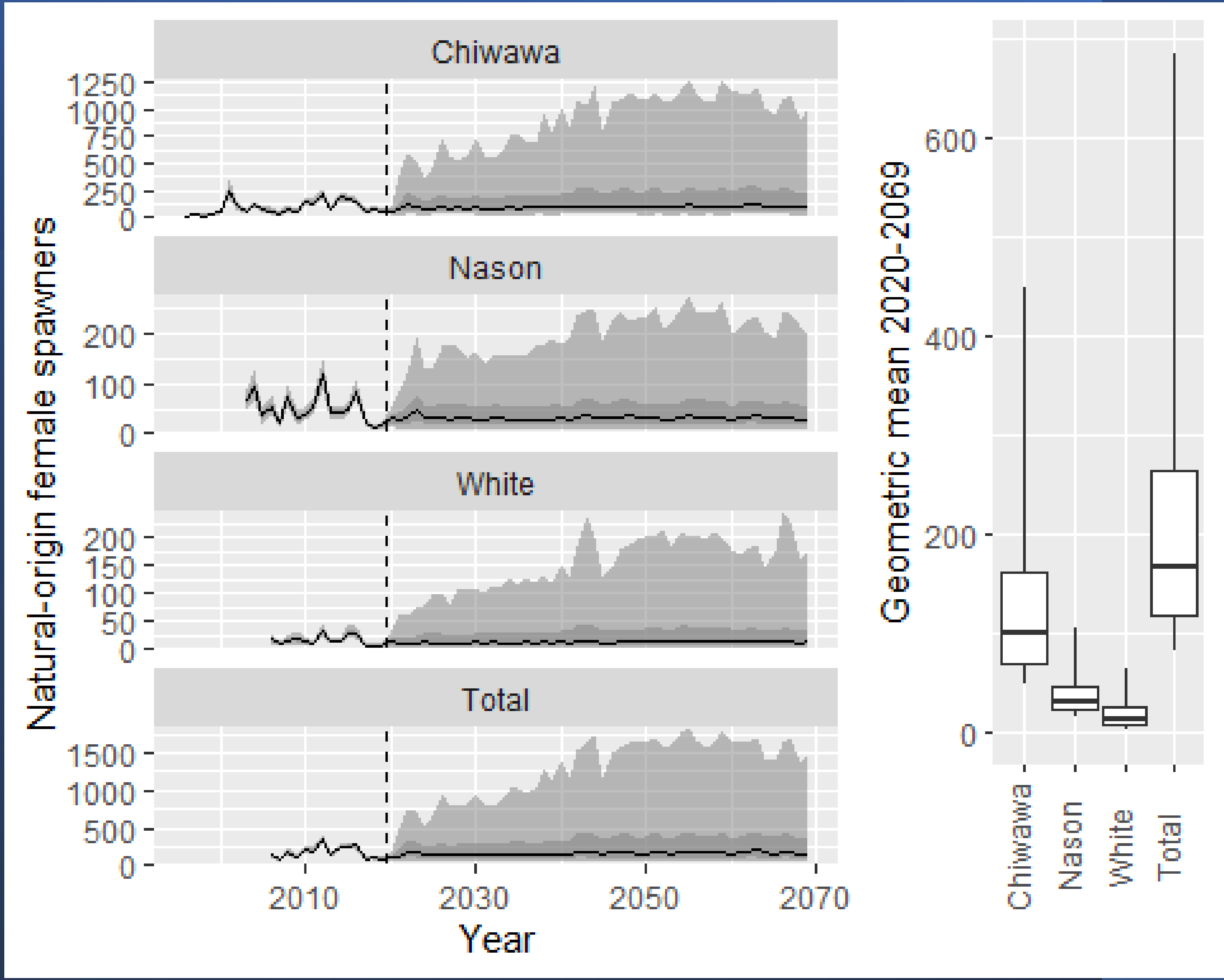
Joe Mabel

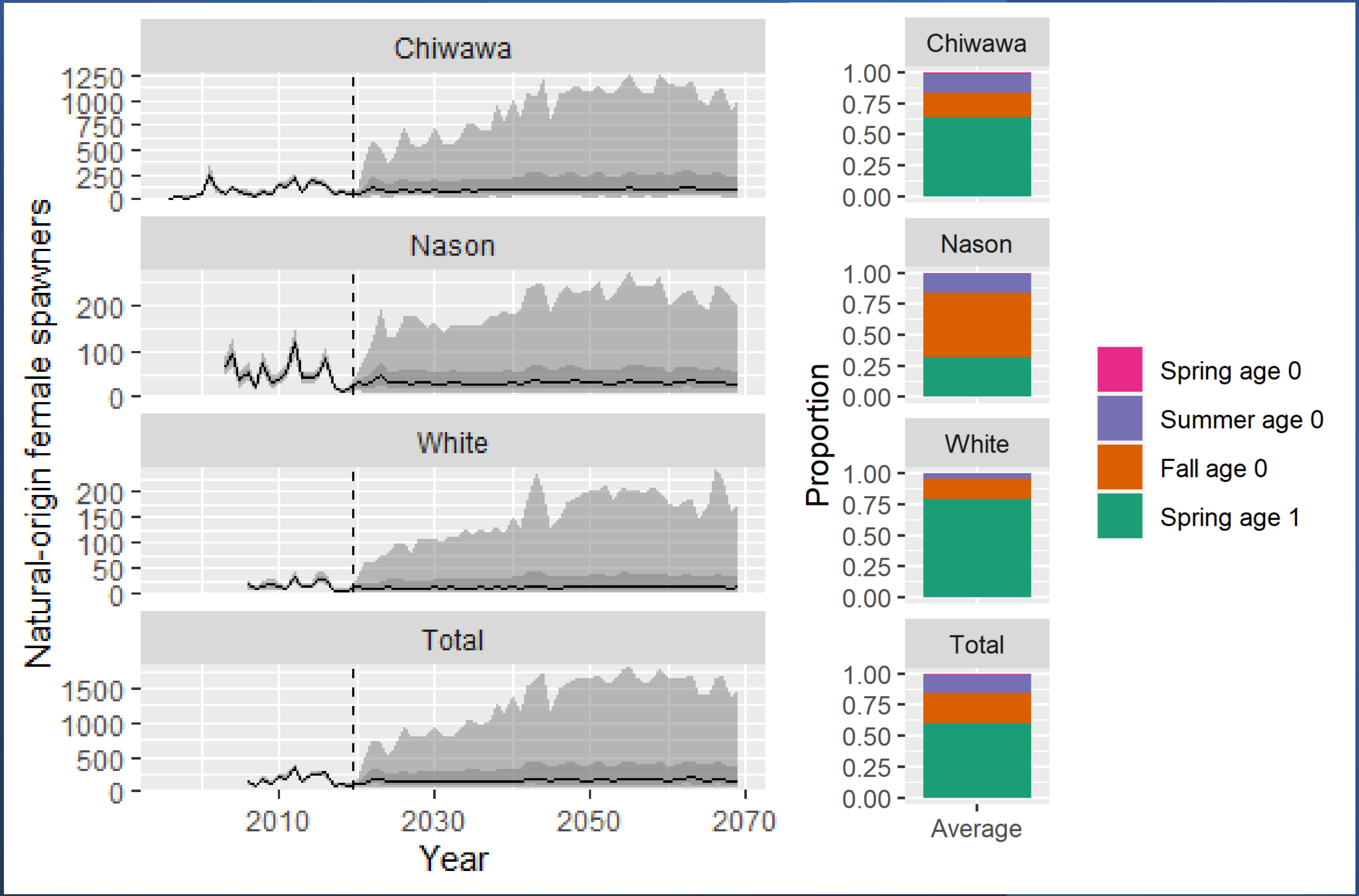

Legend
Latent abundance directly informed by data
Latent abundance not directly informed by data
Demographic rate informed by mark-recapture data
Demographic rate not informed by mark-recapture data
Auxiliary data
Covariate
Hatchery relative-reproductive success
Age-specific fecundity
Proportion of hatchery-origin carcasses
Effective spawners
Hatchery-origin spawners
Natural-origin spawners
Tributary discharge
Natural-origin broodstock
Tumwater Dam adults
Prespawn survival
Tumwater Dam sex ratios
Spring age-0 emigrants
Summer age-0 emigrants
Fall age-0 emigrants
Spring age- emigrants
Air temperature
McNary Dam adults
Bonneville Dam adults
Age 5
Age 4
Age 3
Bonneville Dam smolts
McNary Dam smolts
Lower Wenatchee smolts
Sea surface temperature
Upwelling

Projections and viability metrics

- 50-year projection
- Abundance-based hatchery management rules




Chiwawa
Nason
White
Total
Natural-origin female spawners
1250
1000
750
500
250
0
200
100
0
200
150
100
50
0
1500
1000
500
0
2010
2030
2050
2070
Year
Geometric mean 2020-2069
600
400
200
0
Chiwawa
Nason
White
Total



Chiwawa
Nason
White
Total
Natural-origin female spawners
1250
1000
750
500
250
0
200
100
150
50
1500
2010
2030
2050
2070
Year
Proportion
1.00
0.75
0.50
0.25
0.00
Average
Spring age 0
Summer age 0
Fall age 0
Spring age 1

Chapter 3 conclusions

Projected abundance was < recovery criteria

Multiple juvenile life history pathways contribute to adult returns

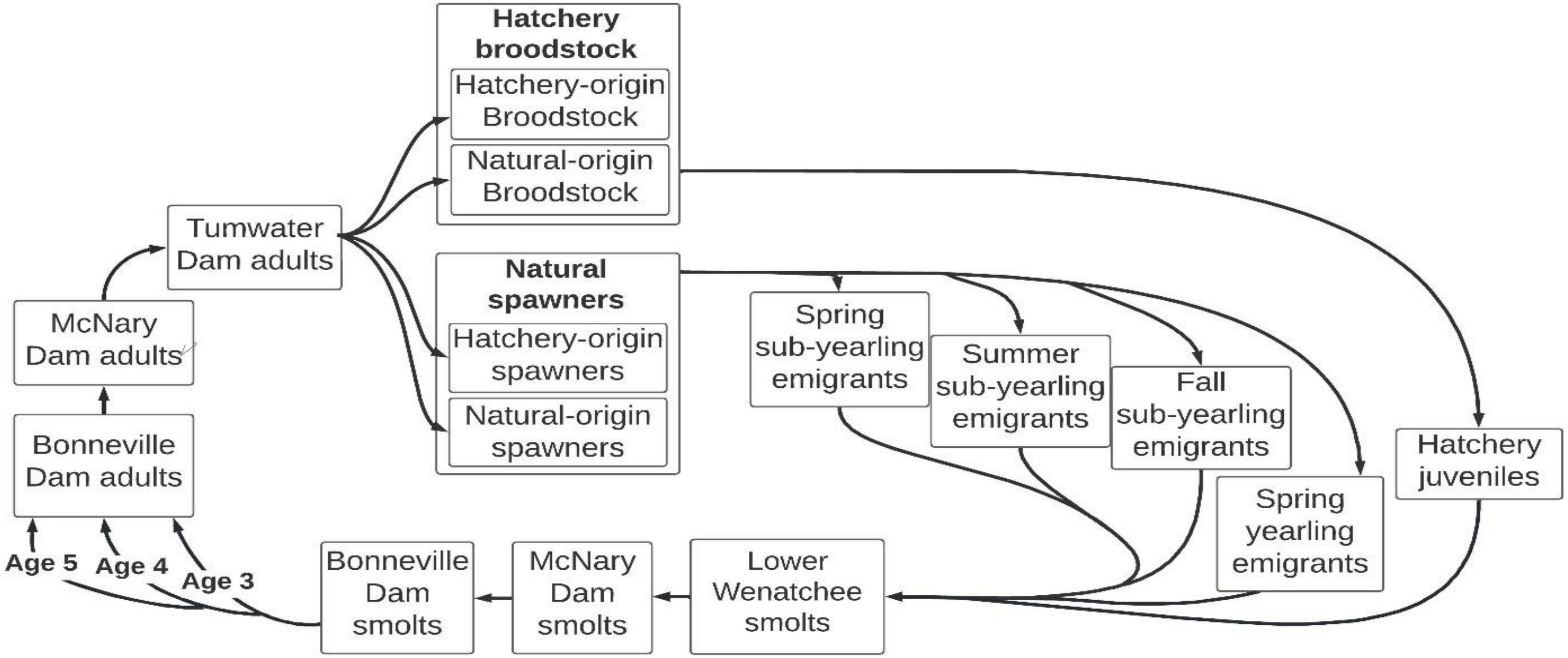
Chapter 4 – Informing salmon habitat restoration and hatchery management with management modeling

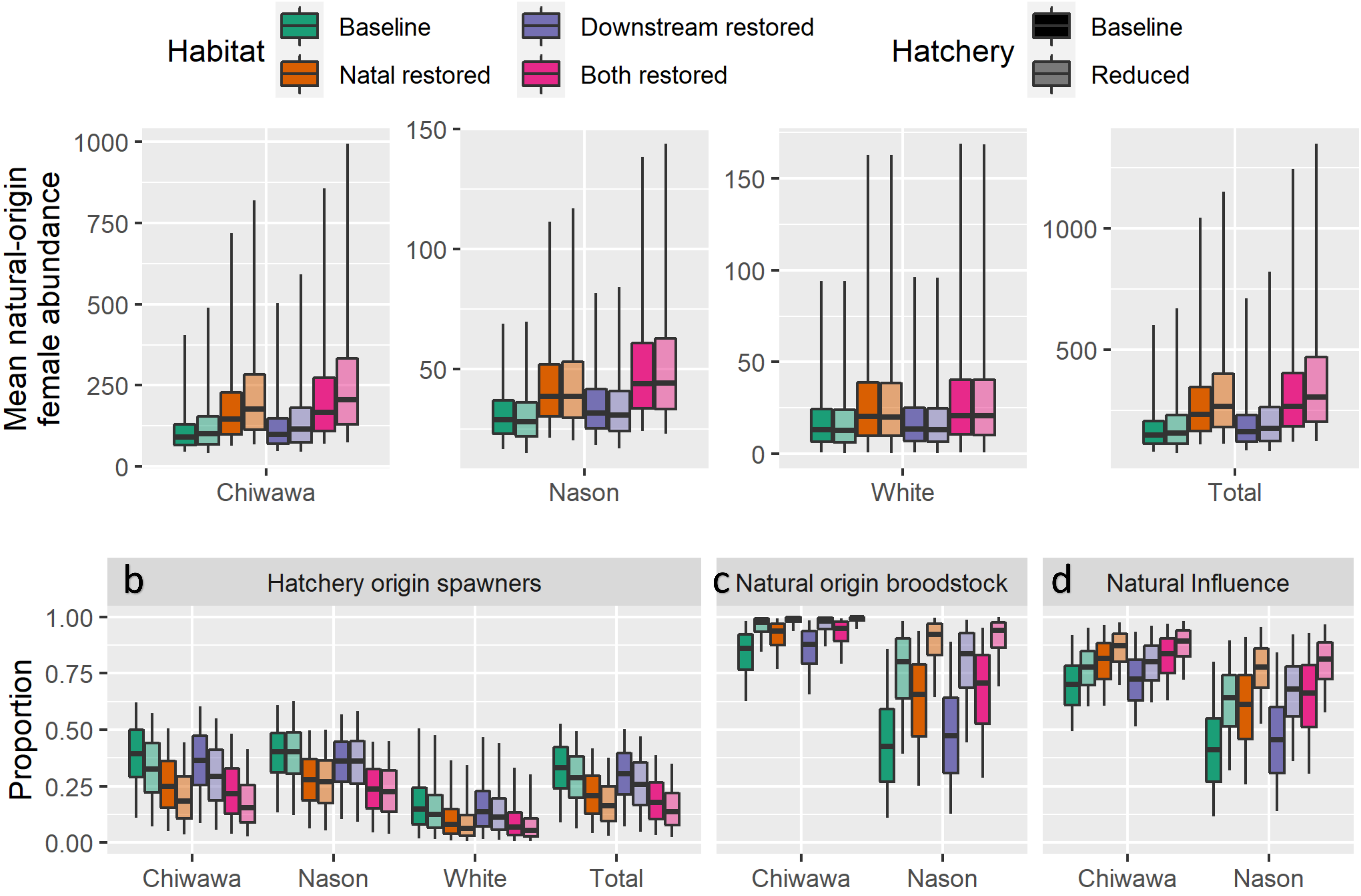
Alternative management strategies

Strategy	Habitat	Hatchery
1	Baseline	Baseline
2	Baseline	Reduced
3	Natal	Baseline
4	Natal	Reduced
5	Downstream	Baseline
6	Downstream	Reduced
7	Both	Baseline
8	Both	Reduced

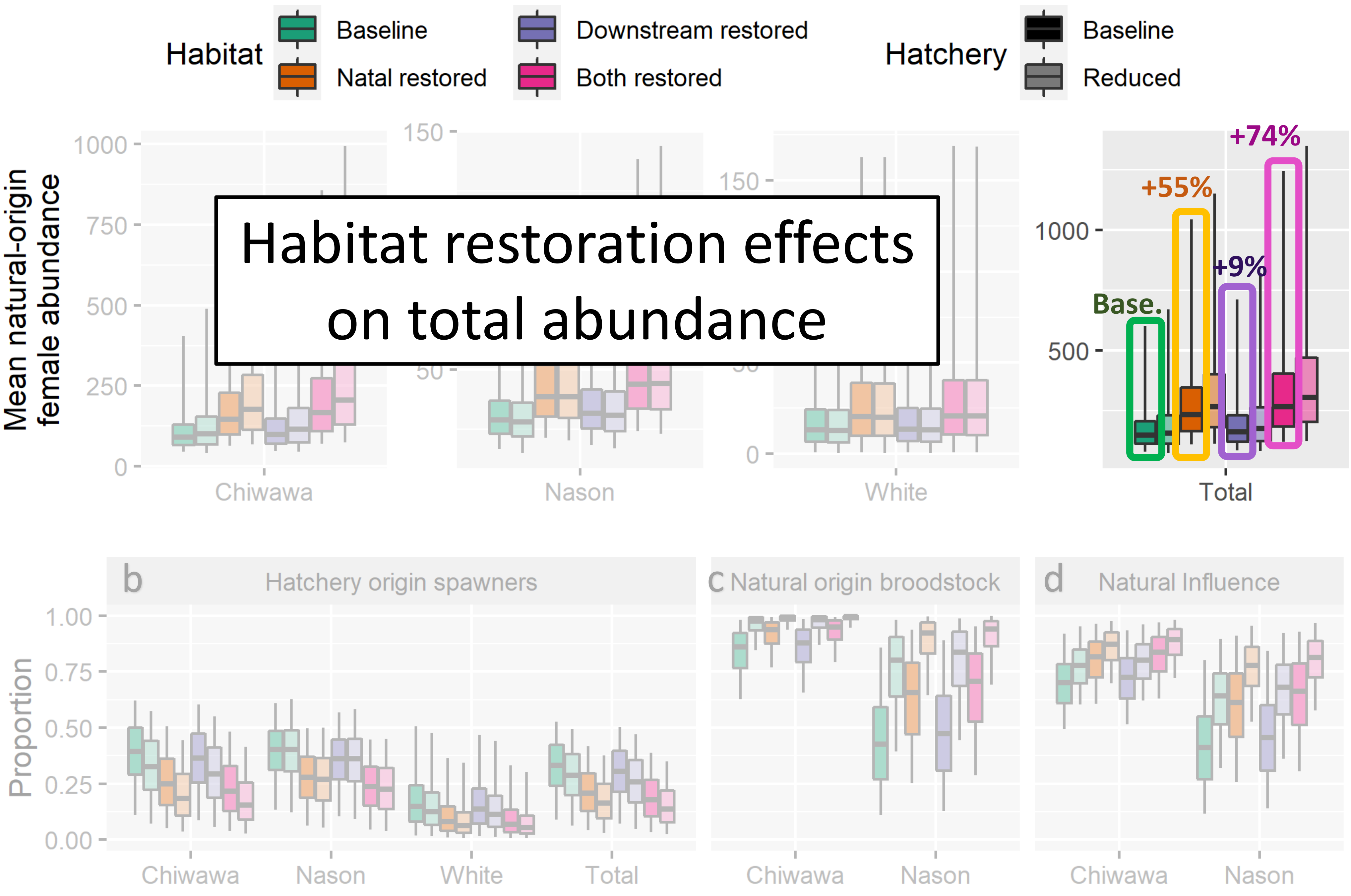
Projections and viability metrics

- Viability metrics
  - Geometric-mean abundance
  - Proportionate natural influence (PNI) = pNOB/(pNOB+pHOS)
    - pNOB = proportion of natural-origin broodstock
    - pHOS = proportion of hatchery-origin spawners

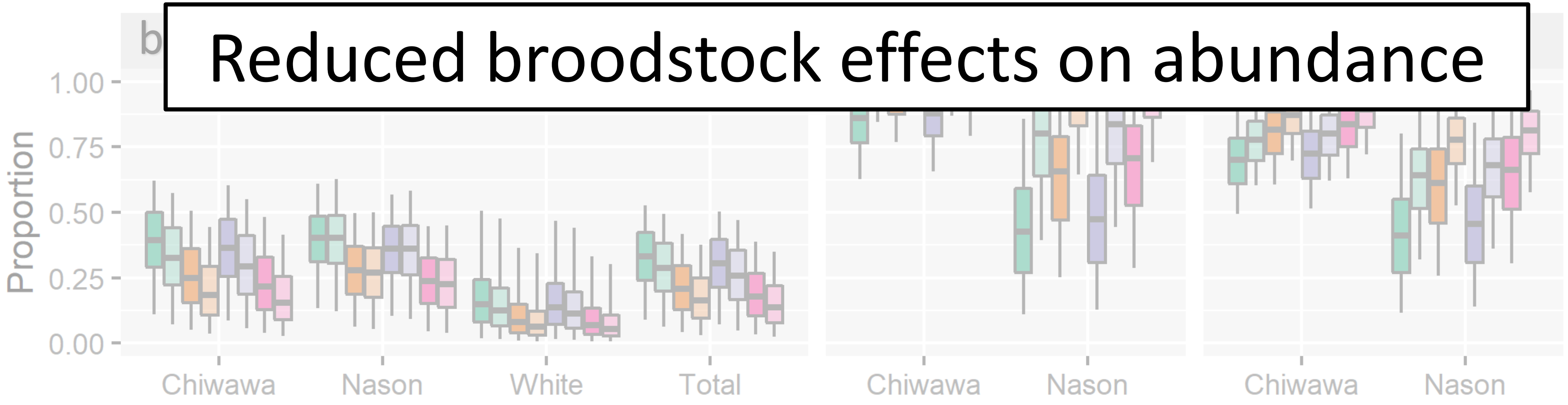


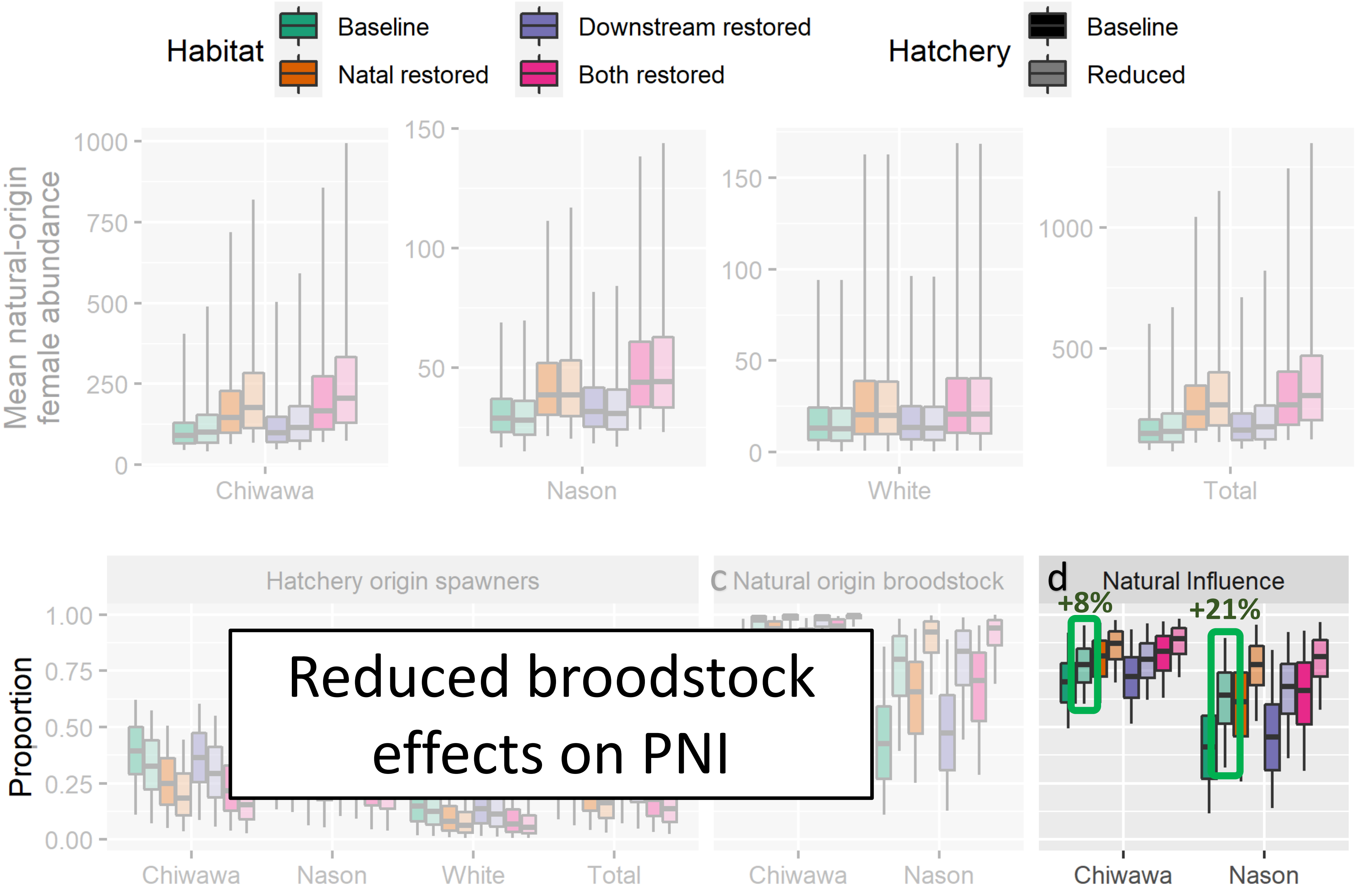

Habitat
Baseline
Natal restored
Downstream restored
Both restored
Hatchery
Baseline
Reduced
Mean natural-origin female abundance
1000
750
500
250
0
Chiwawa
150
100
50
Nason
150
100
50
0
White
1000
500
Total
b
Hatchery origin spawners
c Natural origin broodstock
d
Natural Influence
Proportion
1.00
0.75
0.50
0.25
0.00
Chiwawa
Nason
White
Total
Chiwawa
Nason
Chiwawa
Nason

Habitat restoration effects on total abundance



Reduced broodstock effects on abundance

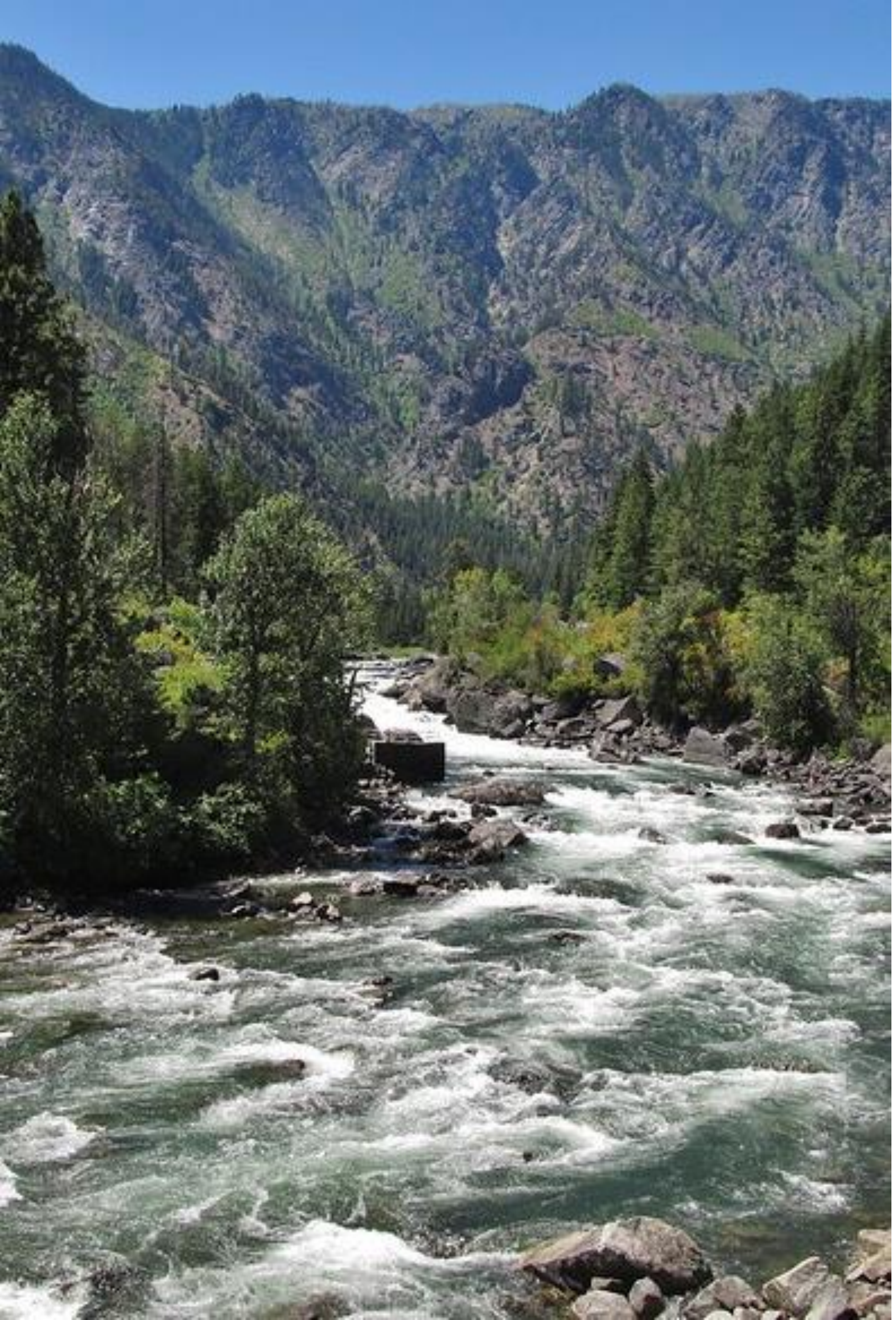




Reduced broodstock effects on PNI

Chapter 4 conclusions

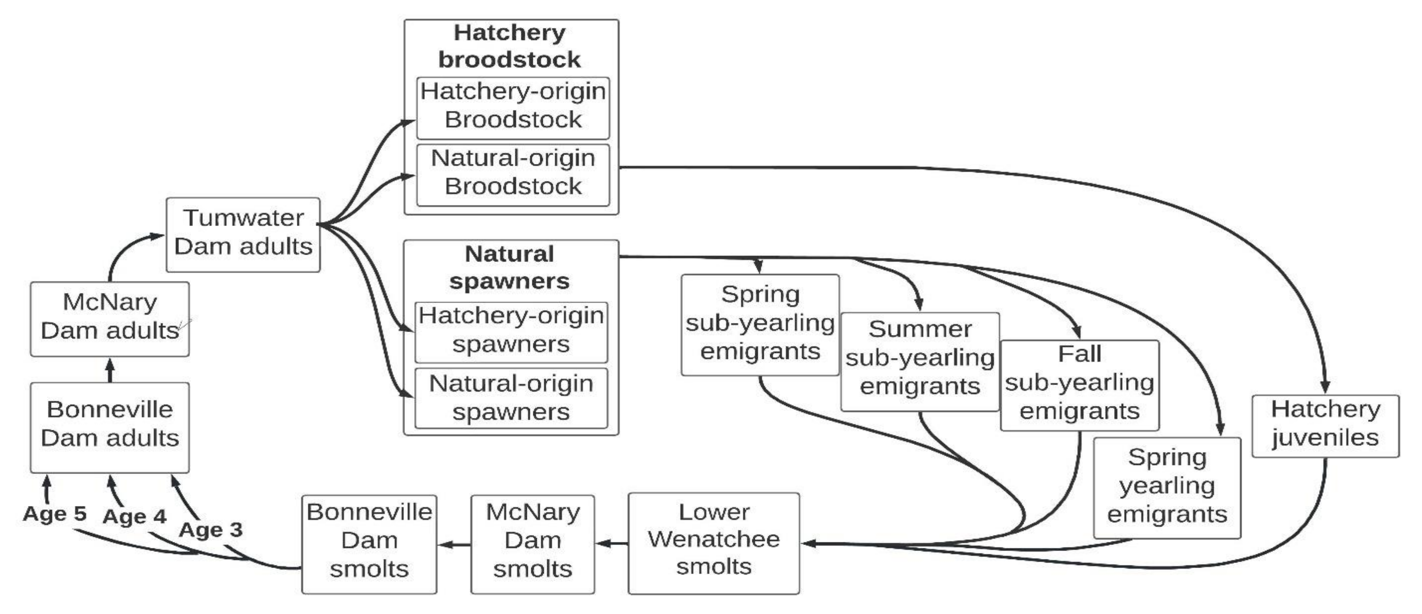
- Natal stream restoration may increase abundance > downstream restoration
- Smaller hatchery program sizes may benefit population
- Population models are a powerful tool for assessing management alternatives



Overall conclusions

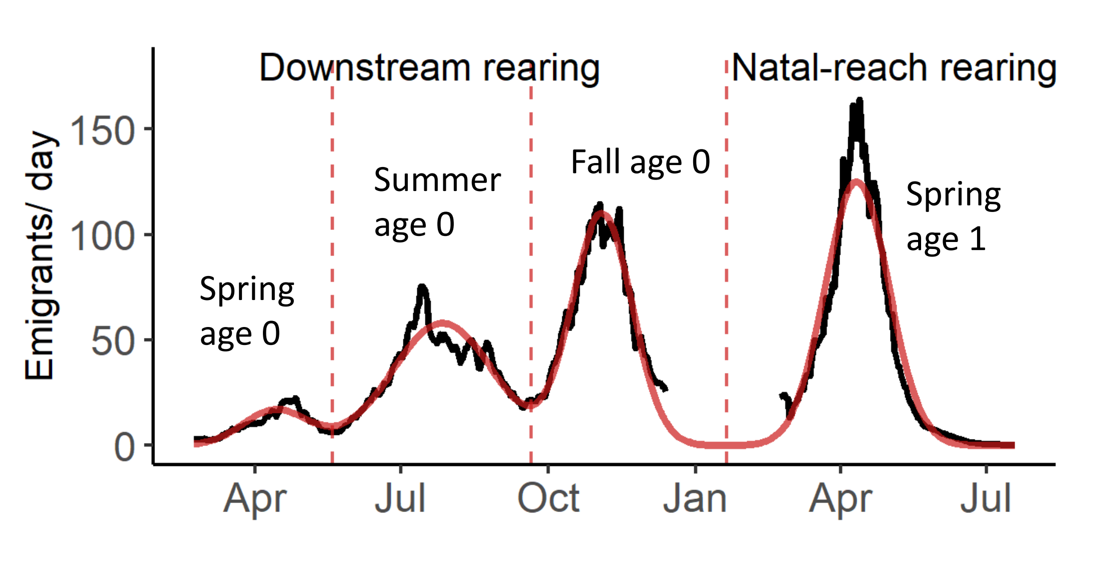
- Relative production of alternative life histories is affected by density
- Fish exhibiting different juvenile life histories differ in lifetime demographic rates
- Management modeling can help identify optimal strategies

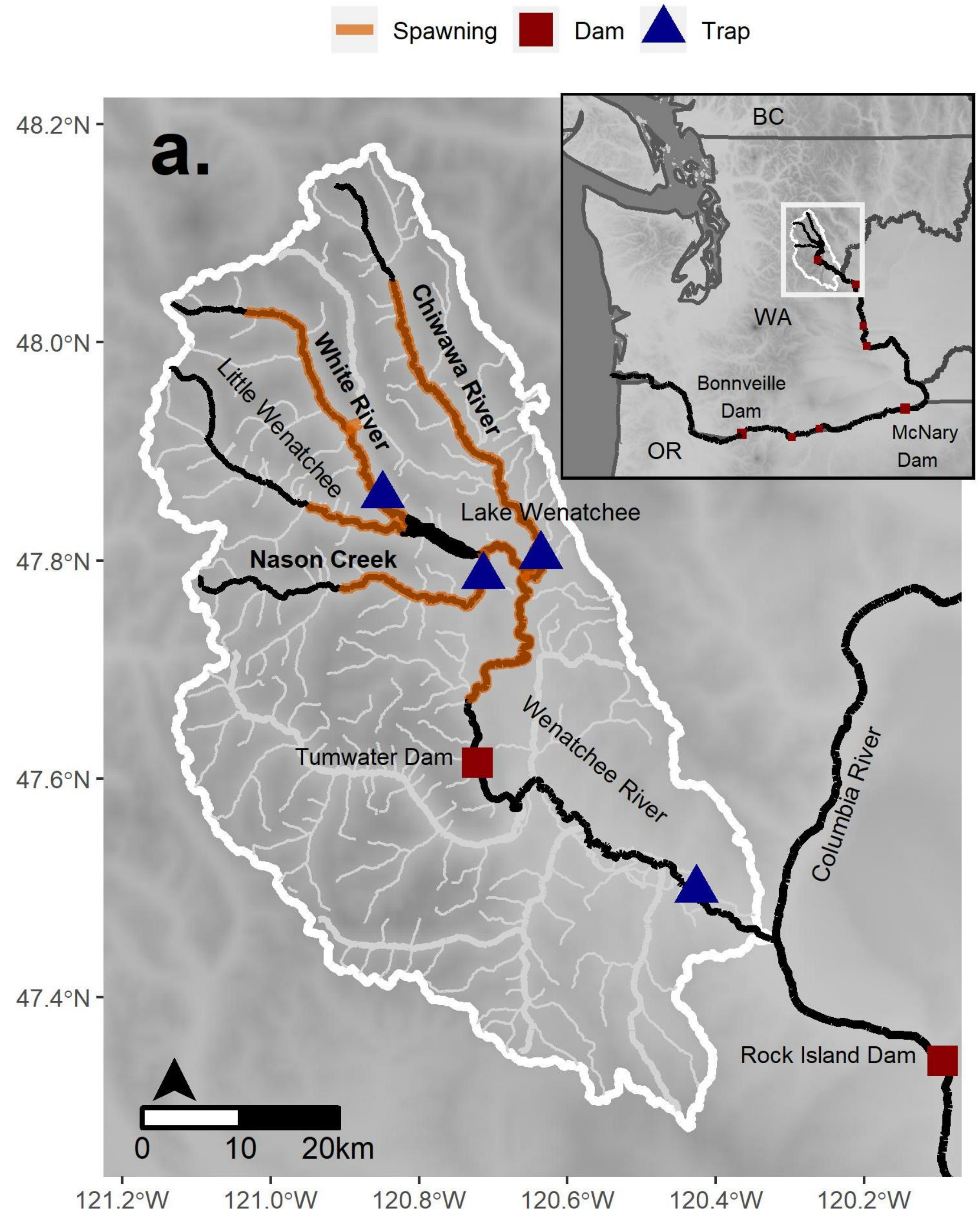
Questions?


Hatchery broodstock
Hatchery-origin Broodstock
Natural-origin Broodstock
Tumwater Dam adults
McNary Dam adults
Bonneville Dam adults
Natural spawners
Hatchery-origin spawners
Natural-origin spawners
Spring sub-yearling emigrants
Summer sub-yearling emigrants
Fall sub-yearling emigrants
Spring yearling emigrants
Hatchery juveniles
Age 5
Age 4
Age 3
Bonneville Dam smolts
McNary Dam smolts
Lower Wenatchee smolts


Habitat
Baseline
Natal restored
Downstream restored
Both restored
Hatchery
Baseline
Reduced
Mean natural-origin female abundance
+11%
-4%
0%
+6%
Chiwawa
Nason
White
Total
0
250
500
750
1000
50
100
150

Wenatchee River spring Chinook salmon





Attachment D
Kevin See's presentation, "Updating Time-Series of Wenatchee Steelhead Spawners

Updating Time-Series of Wenatchee Steelhead Spawners

Kevin See
Hatchery Committee
December 21, 2022

Washington Department of FISH and WILDLIFE

Acknowledgements

CCPUD has funded the Wenatchee River spawning ground surveys since 2000

BPA funded the development of the redd observer error model

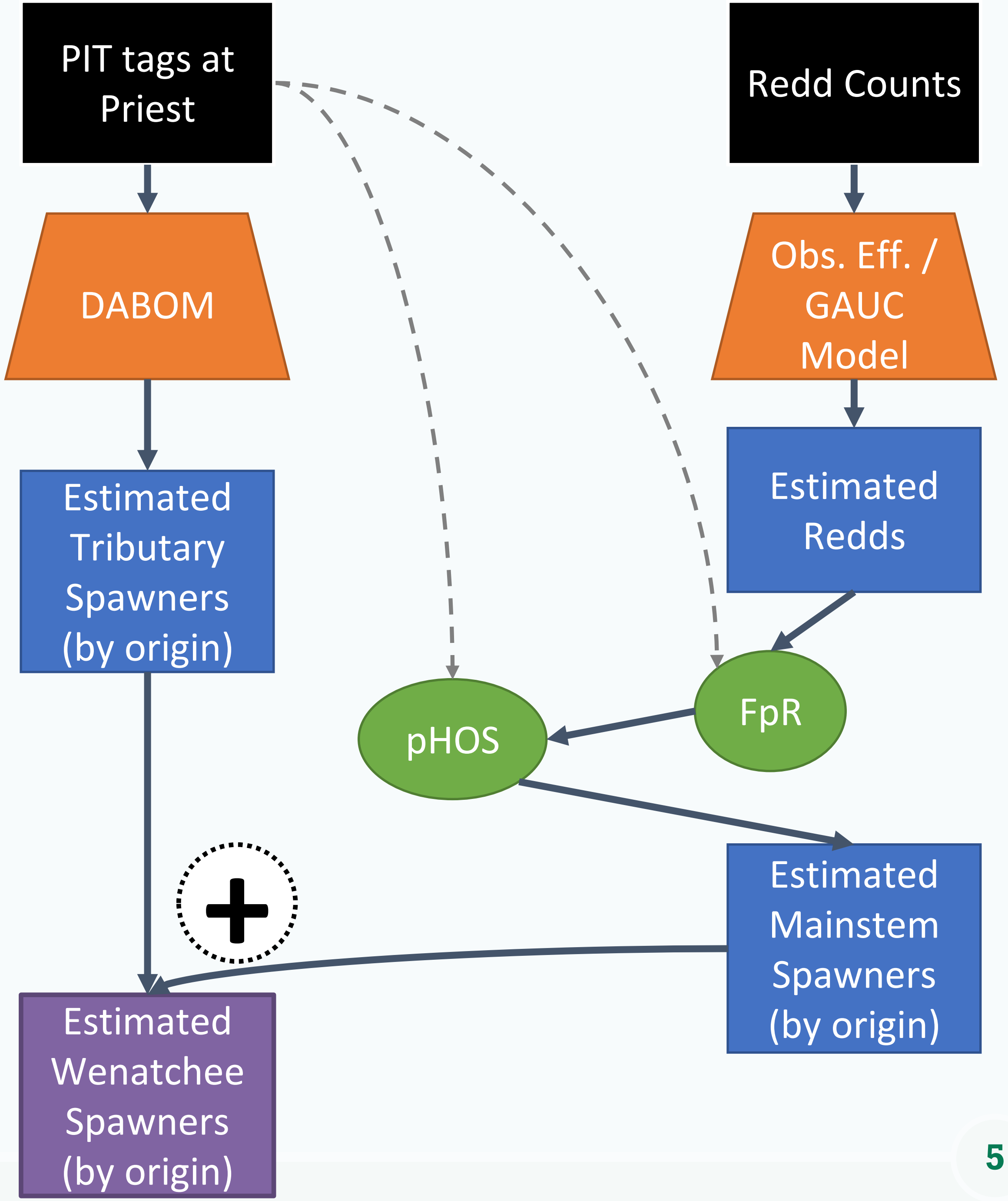
WDFW funded the general analysis of this recent work (1987-2013)

Outline

- Overview of current methods
- Comparison with older method
- Extend current time-series backwards
- Questions/Discussion

Current Methods

Current Method (2011-present)



Observer Efficiency Model (Murdoch et al. 2018)

$$Net\ Error_i = \frac{C_i}{V_i}$$

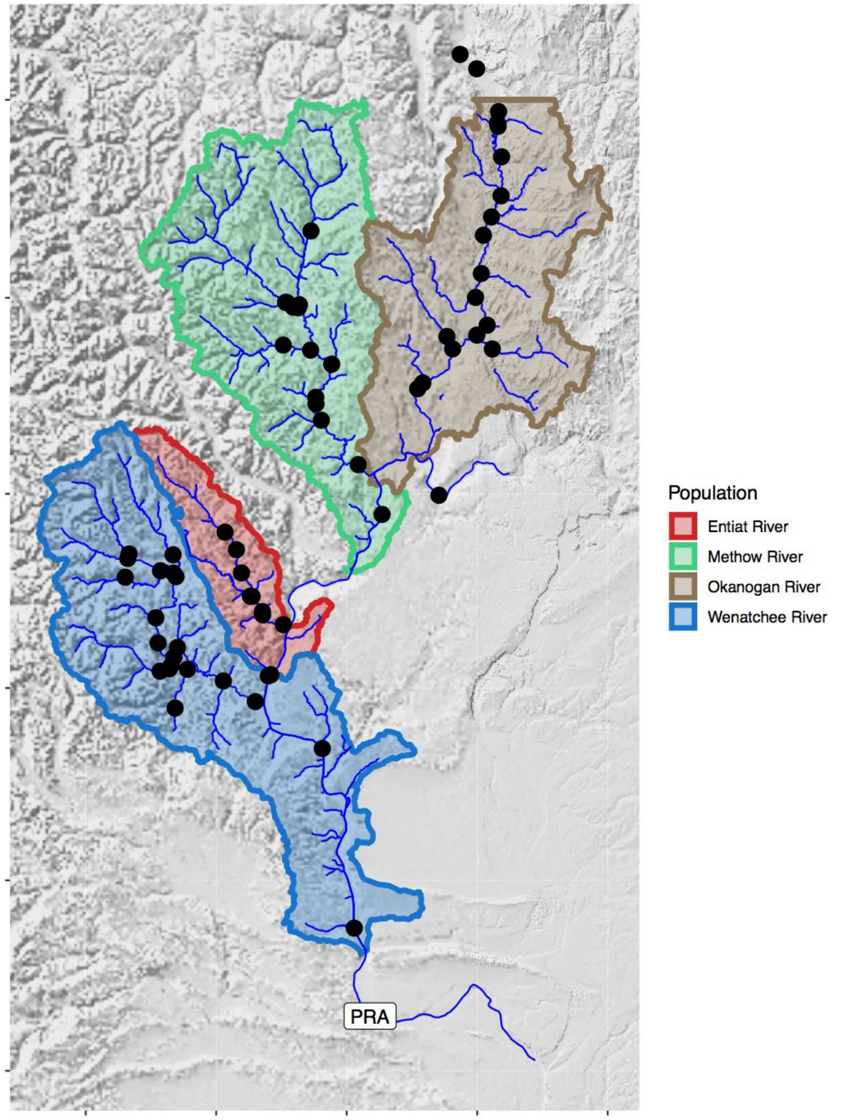
Two Observer:

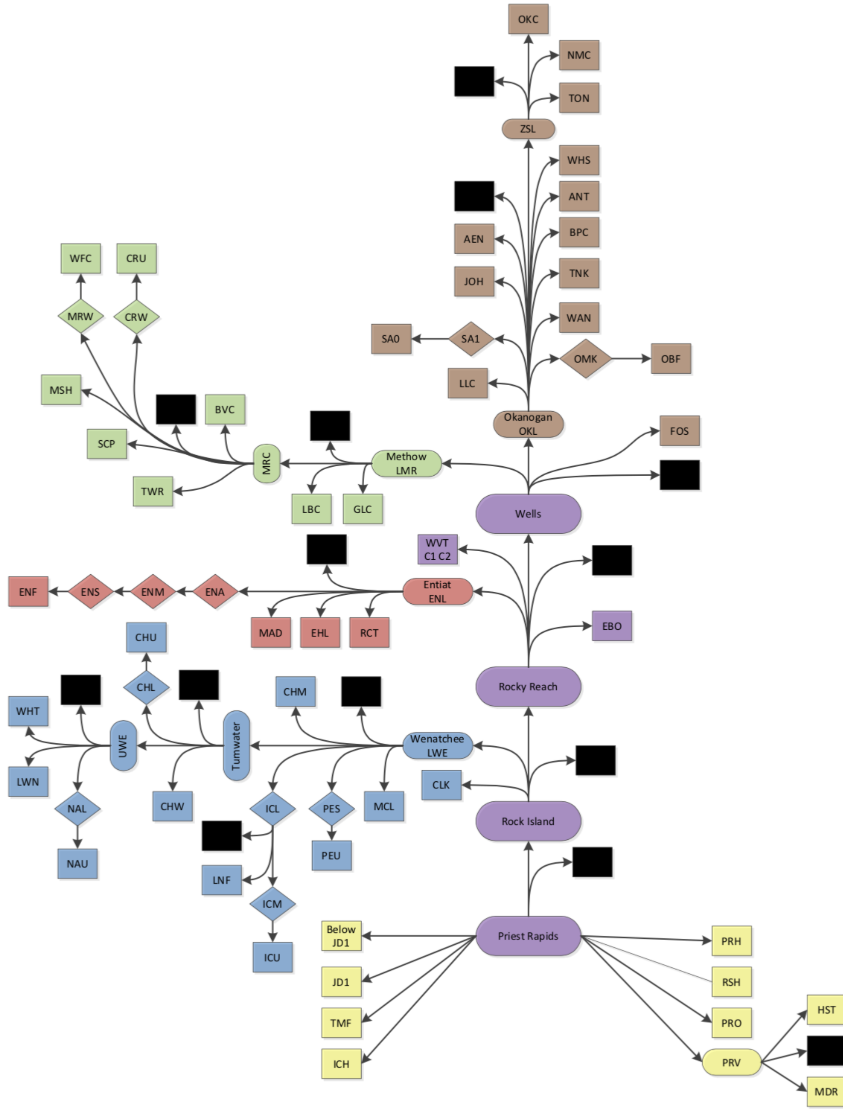
- Observed redd density (**+**)
- CV of Thalweg Depth (**-**)
- Discharge (**+**)
- Experience (**+**)

One Observer:

- Observed redd density (**+**)
- CV of Thalweg Depth (**+**)
- Depth (**-**)

Dam Adult Branch Occupancy Model (DABOM)





“New” Time-Series By Area and Time Period

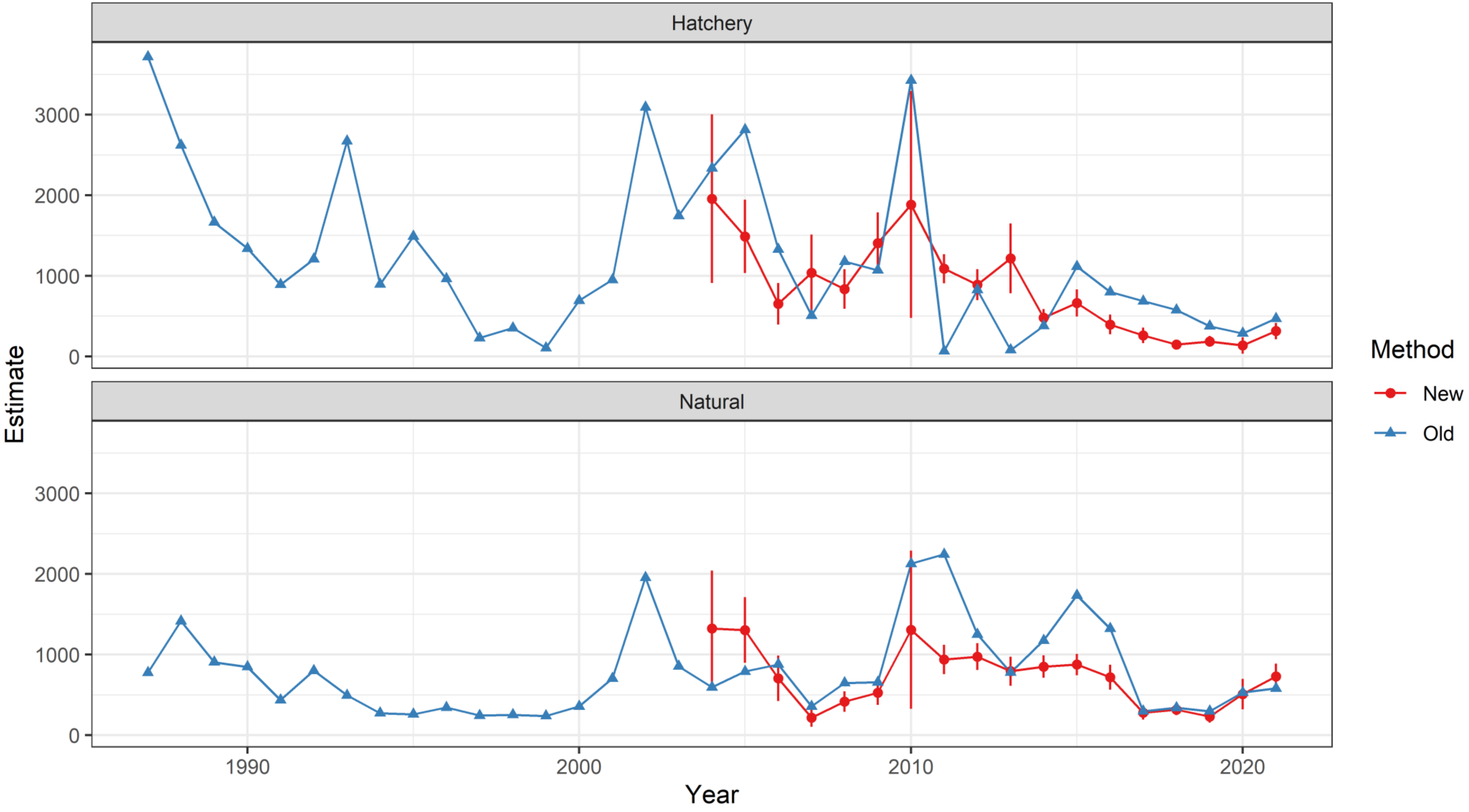
Years	Mainstem Wenatchee	Chiwaukum, Chumstick and Misson	Other Tributaries
2014 – 2022	2 Observer Net Error Model	DABOM	DABOM
2011 – 2013	1 Observer Net Error Model	DABOM	DABOM
2004 – 2010	1 Observer Net Error Model	Expansion	1 Observer Net Error Model

Comparison with Older Method

“Older Method”

- Uses dam counts (PRD, RI, RR and Wells)
  - Accounted for broodstock, direct and indirect harvest
- 2- year RT study (English et. 1999 and 2001)
  - Excluded overshoot fallbacks
  - Constant proportion by origin for each population
- All potential spawners were assigned to a population
  - Applied 10% overwinter mortality to get spawners

Comparison Plot



Extend Current Time-Series Backwards

Multivariate Auto-Regressive State-Space Model

$$x_t = x_{t-1} + \boldsymbol{C}c_t + w_t, \text{ where } w_t \sim MVN(0, \boldsymbol{Q})$$

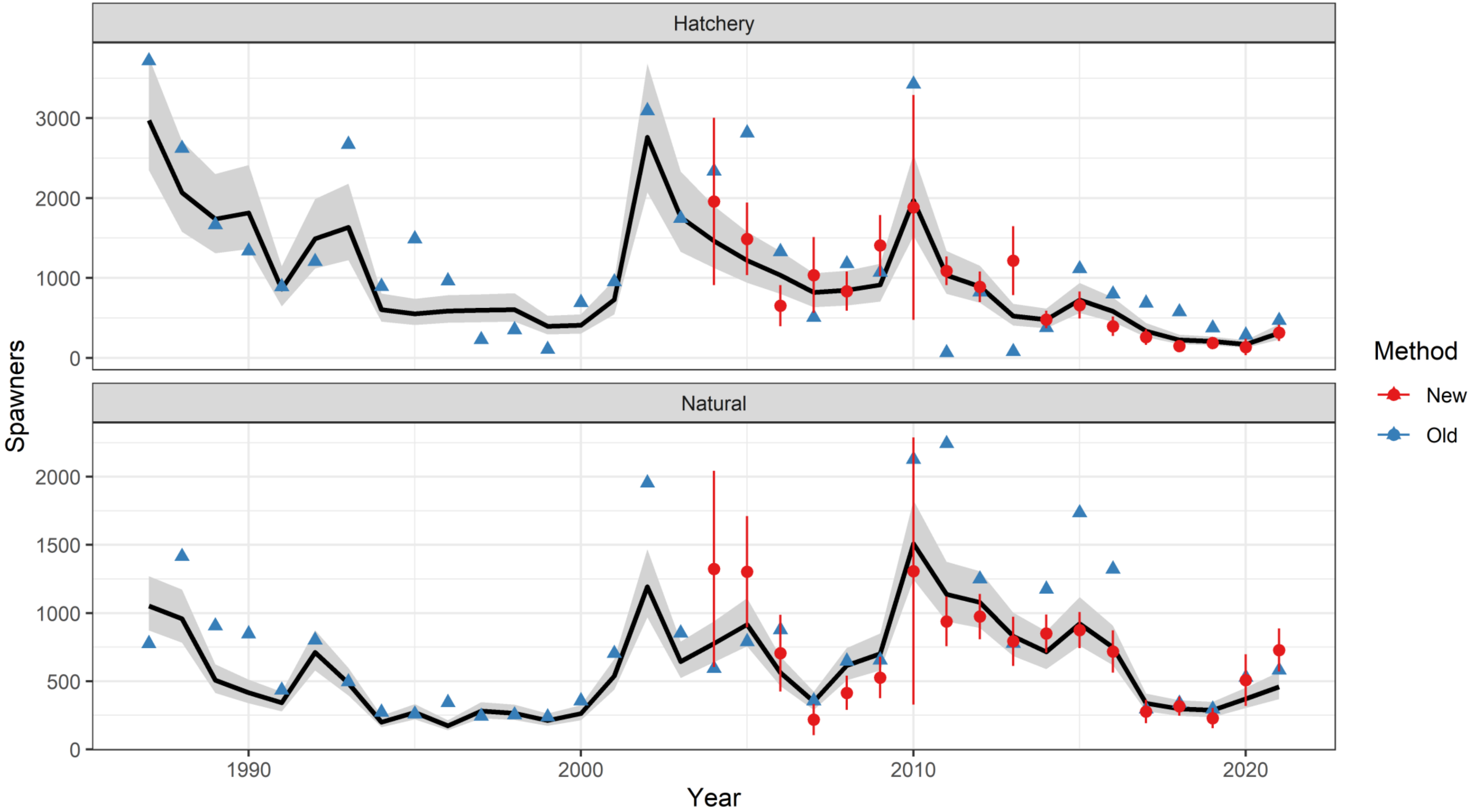
$$y_t = \boldsymbol{Z}x_t + a + v_t, \text{ where } v_t \sim MVN(0, \boldsymbol{R})$$

- States include:
  - Wenatchee natural- and hatchery-origin spawners
  - Dam counts at Bonneville, McNary, Prosser, Rock Island and Ice Harbor
- Observations include new and old time-series of both natural- and hatchery-origin spawners
- Set *a* to assume new time-series is unbiased for each origin
- Allowed ***Q*** to estimate covariance between various states
- Fixed elements of ***R*** to be equal to estimated uncertainty from new time-series.
- Tested using a weighted average of smolt releases as a covariate (c_t)
  - Was not supported by model selection (AICc)

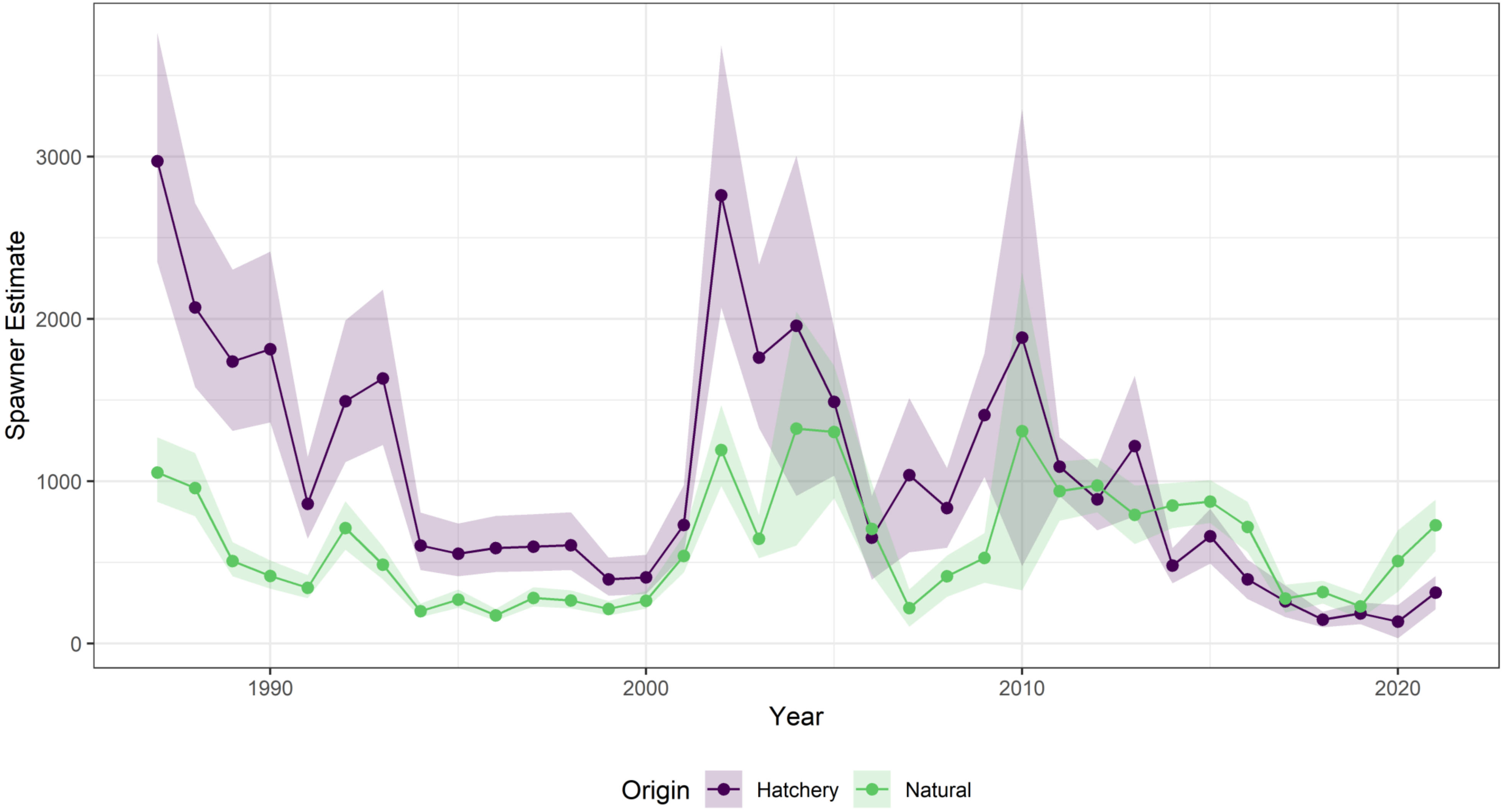
MARSS Benefits

- Estimates any consistent bias
- Utilizes multiple time-series
  - Correlated year-to-year variability
  - Shared ocean conditions
- Allows known observation errors to be fixed
- Compare various model configurations

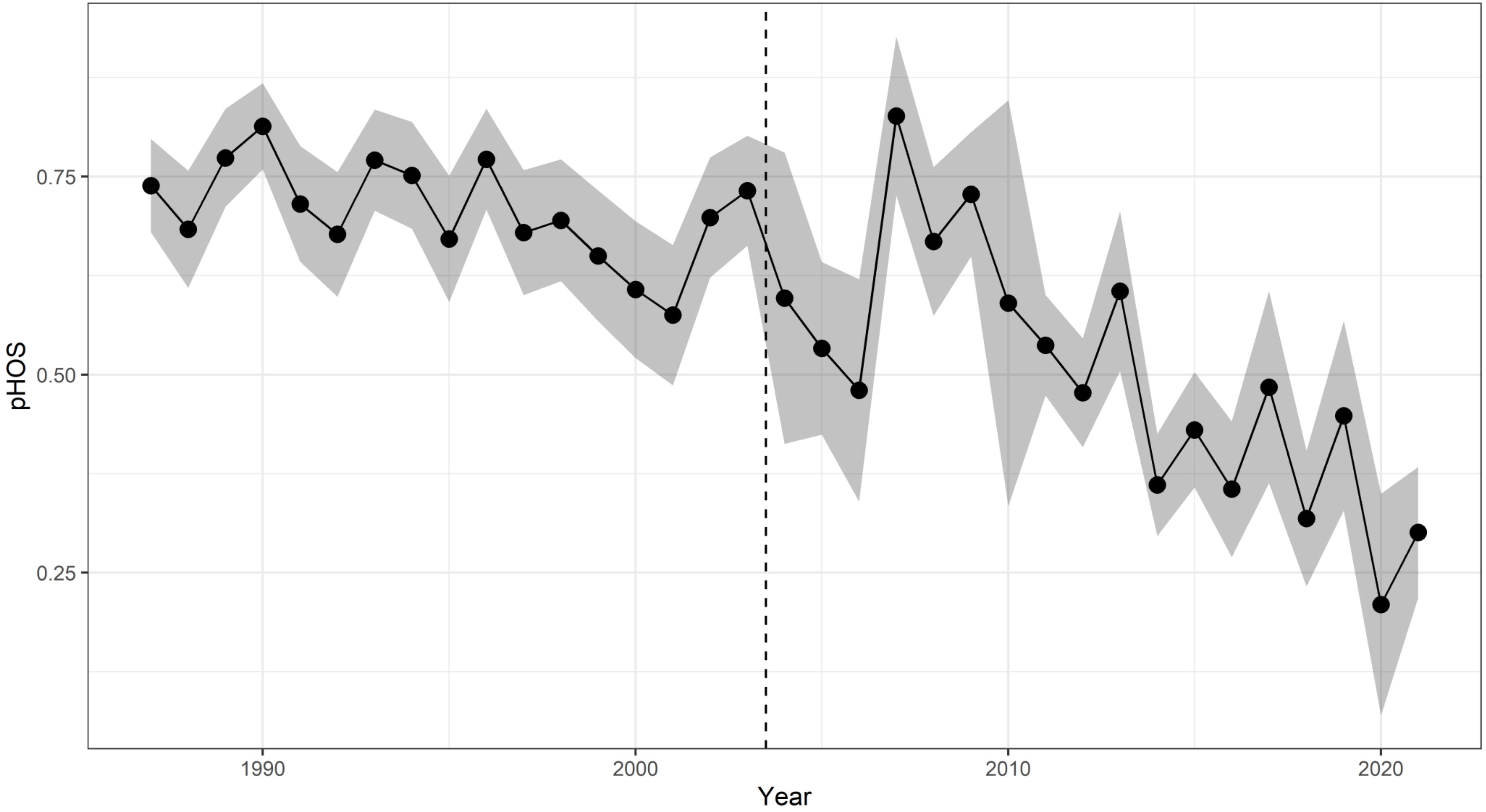
MARSS Estimates



Updated Complete Time-Series

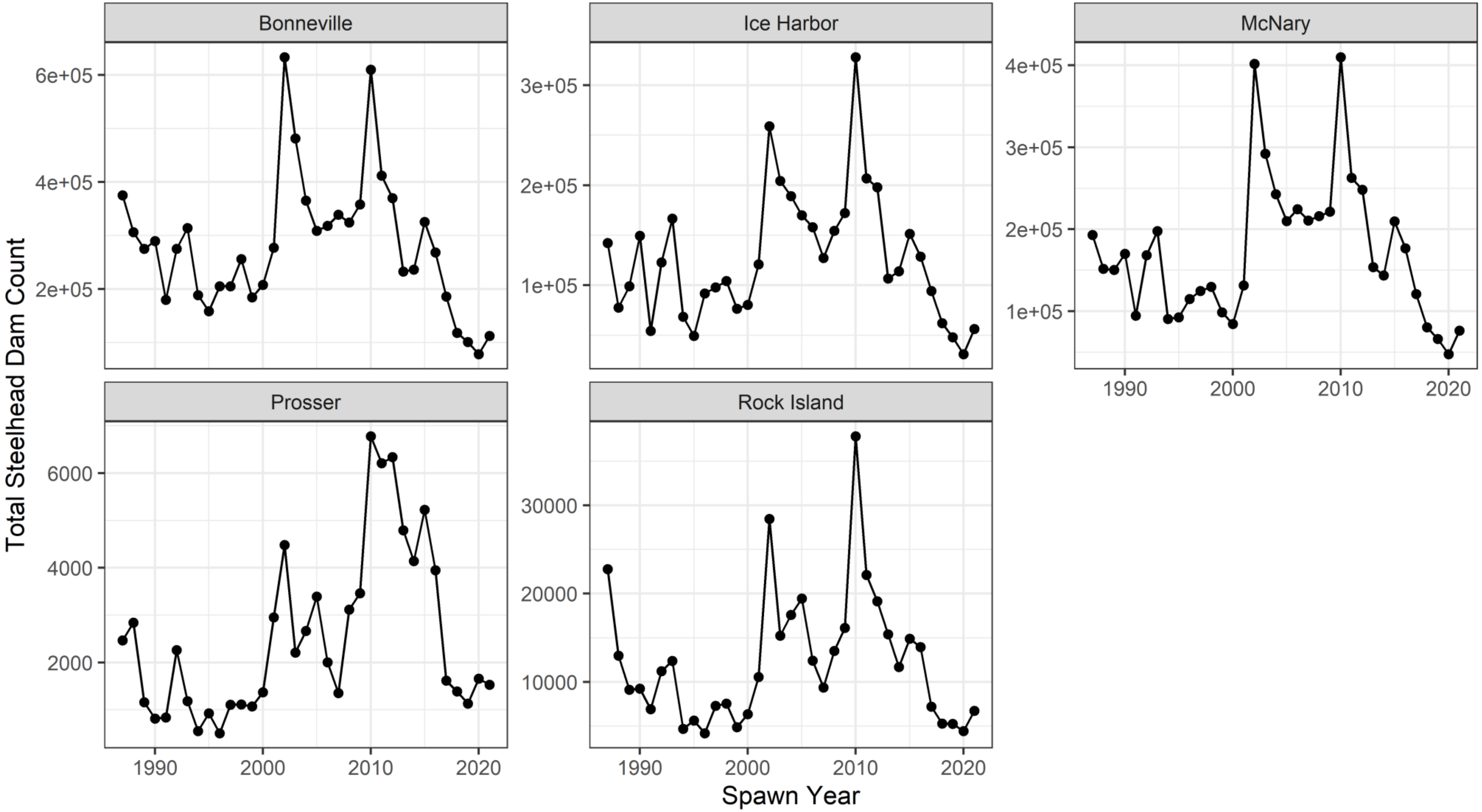


Proportion of Hatchery Origin Spawners (pHOS)

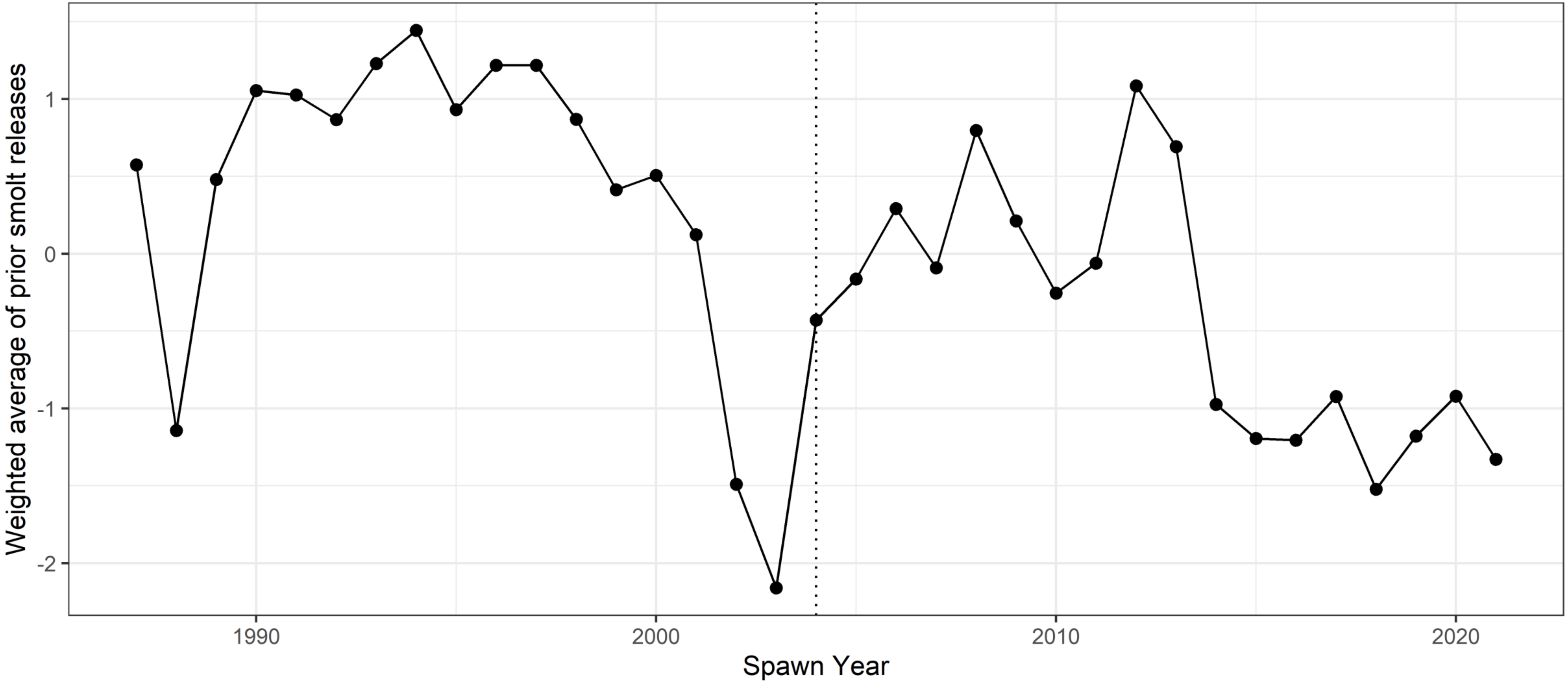


Questions?

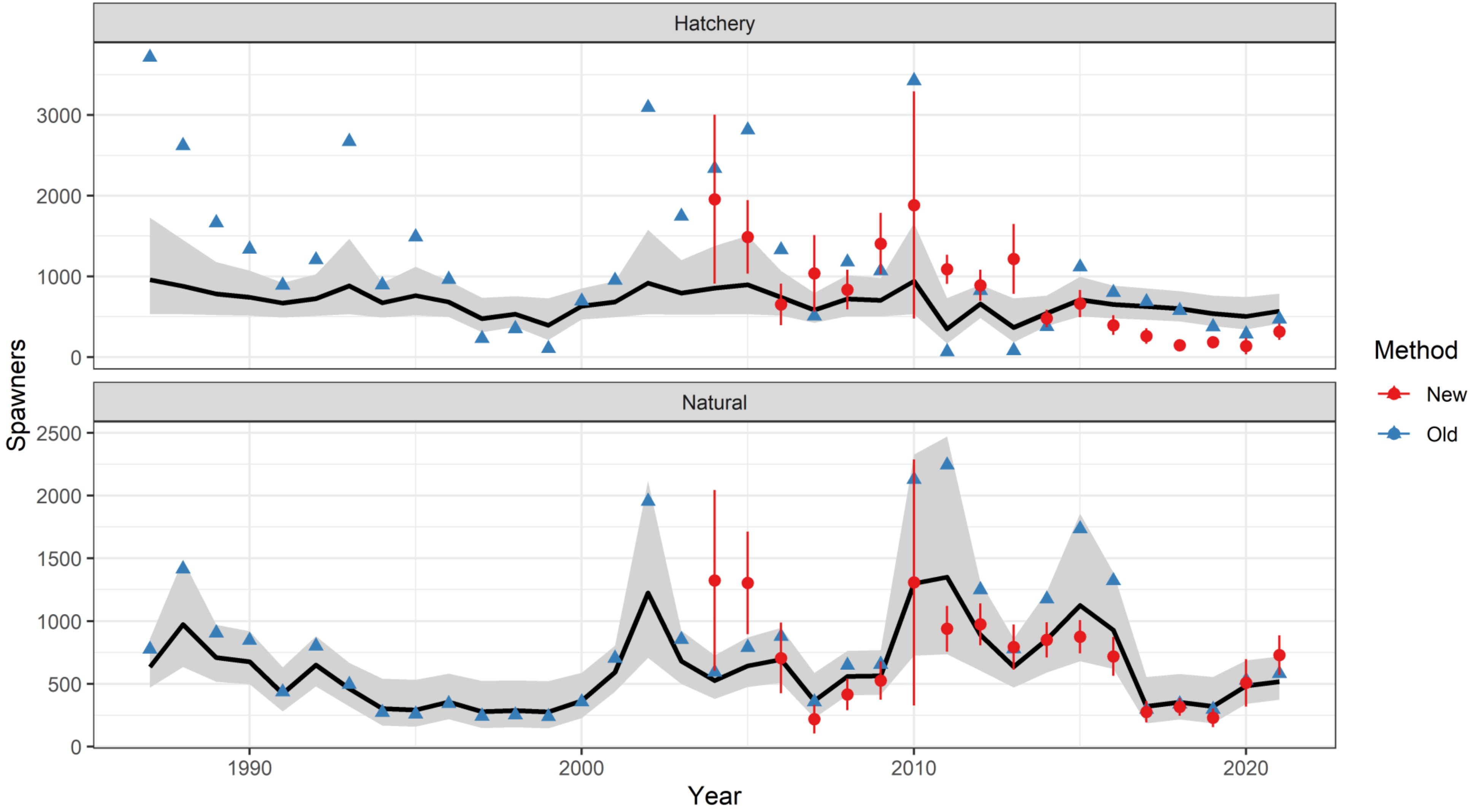
Columbia River Dam Counts



Hatchery Smolt Releases



Log-Log Linear Model Fit



Attachment E

Estimates of Wenatchee Steelhead Spawners, Spawn Years 1987-2021, Kevin See, December 23, 2022

Estimates of Wenatchee Steelhead Spawners

Spawn Years 1987-2021

Kevin See[1,*]

December 23, 2022

Contents

[1] Washington Department of Fish & Wildlife

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1 Goal

The current method of estimating spawners in the Wenatchee subbasin involves using a PIT-tag based escapement model (DABOM) to estimate tributary spawners (Waterhouse et al. 2020) and adjust the observed redd counts in the mainstem Wenatchee from two observers with a redd observer error model (Murdoch et al. 2018). These adjusted redd counts are combined with redd counts in tributaries below the PIT tag arrays. The PIT tags observed moving into the mainstem (or the tributaries) are used to calculate a fish / redd estimate (males/females + 1 (Murdoch et al. 2009)) and the proportion of hatchery fish on the spawning grounds (pHOS), both of which are used to translate estimates of redds into estimates of hatchery and natural origin spawners. This method has been utilized from spawn year 2014 until the present.

From 2011-2013, the exact same methods were used, except redd counts were adjusted for observer error estimated using the one-observer net error model from Murdoch et al. (2018), because redd surveys in the Wenatchee during that time used a one-observer methodology.

From 2004-2010, estimates of spawners come mainly from redd surveys, which are adjusted using the one-observer net error model from Murdoch et al. (2018). Estimates of fish / redd and pHOS come from fish sampled at Dryden dam. There were three tributaries (Mission, Chumstick and Chiwaukum) that were not part of the redd sampling frame. However, when PIT tag arrays were placed in those tributaries after 2011, some steelhead spawning was observed. Therefore, for 2004-2010, we estimated hatchery and natural origin spawners by the mean proportion of overall Wenatchee spawners in those tributaries from 2011 on.

This results in a complete time series from 2004-2021 of estimates of hatchery and natural origin spawners, with associated standard errors. We believe these estimates to be unbiased, based on Murdoch et al. (2018) and Waterhouse et al. (2020).

There is another time series of estimates, from 1987 - 2021, using older methods based on dam counts at the mainstem dams on the Upper Columbia. The goal of this work is to establish a relationship between the two time-series, and use that relationship to "adjust" the older time-series, from 1987-2003, to better match the more recent time-series.

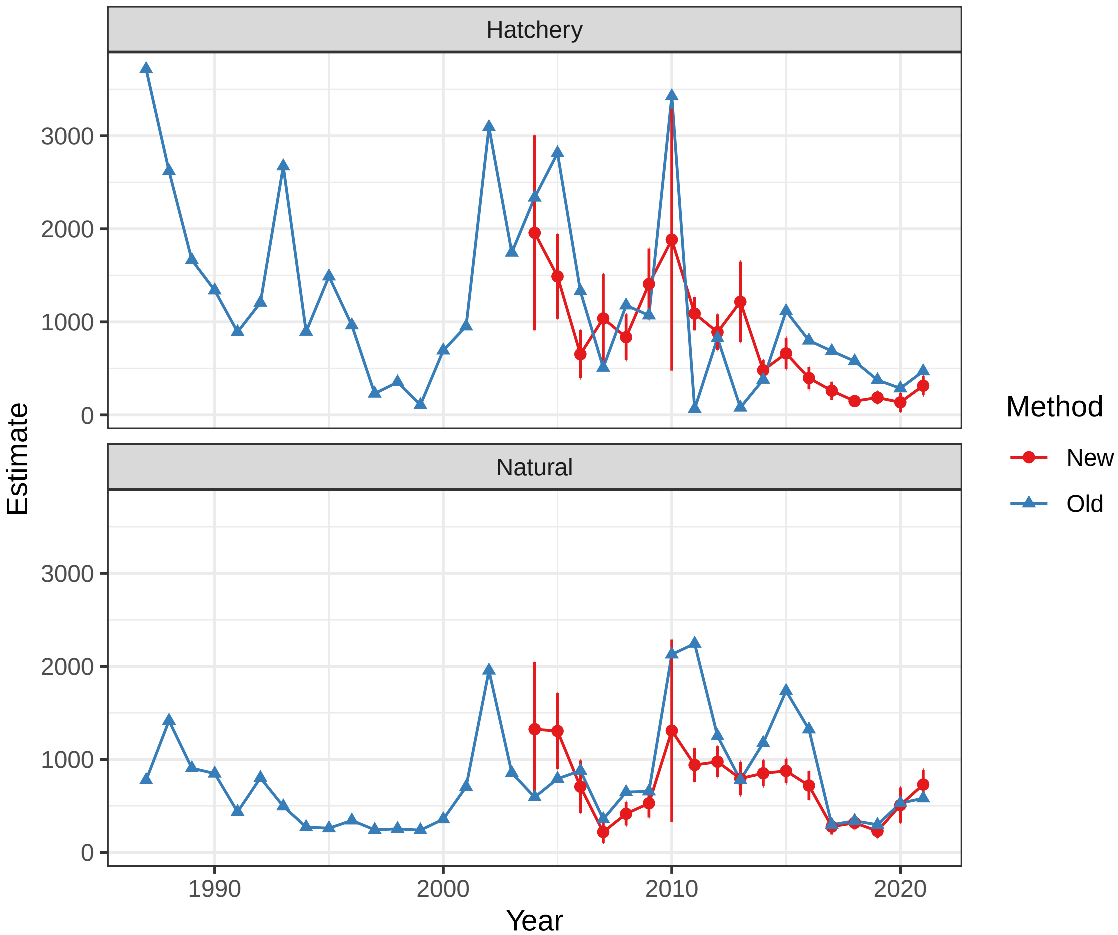

Figure 1: Time-series of hatchery and natural origin spawners in the Wenatchee, colored by what method was used. Error bars represent 95% confidence intervals where available.

2 Methods and Results

2.1 Linear Model

Treat each year as independent, and fit a linear model that includes interactions with origin for both the intercept and slope, with the new estimates as the independent variable and old estimates as the dependent variable. We also tested a log-log linear regression, which involved taking the natural logarithm of each time-series before fitting a linear regression.

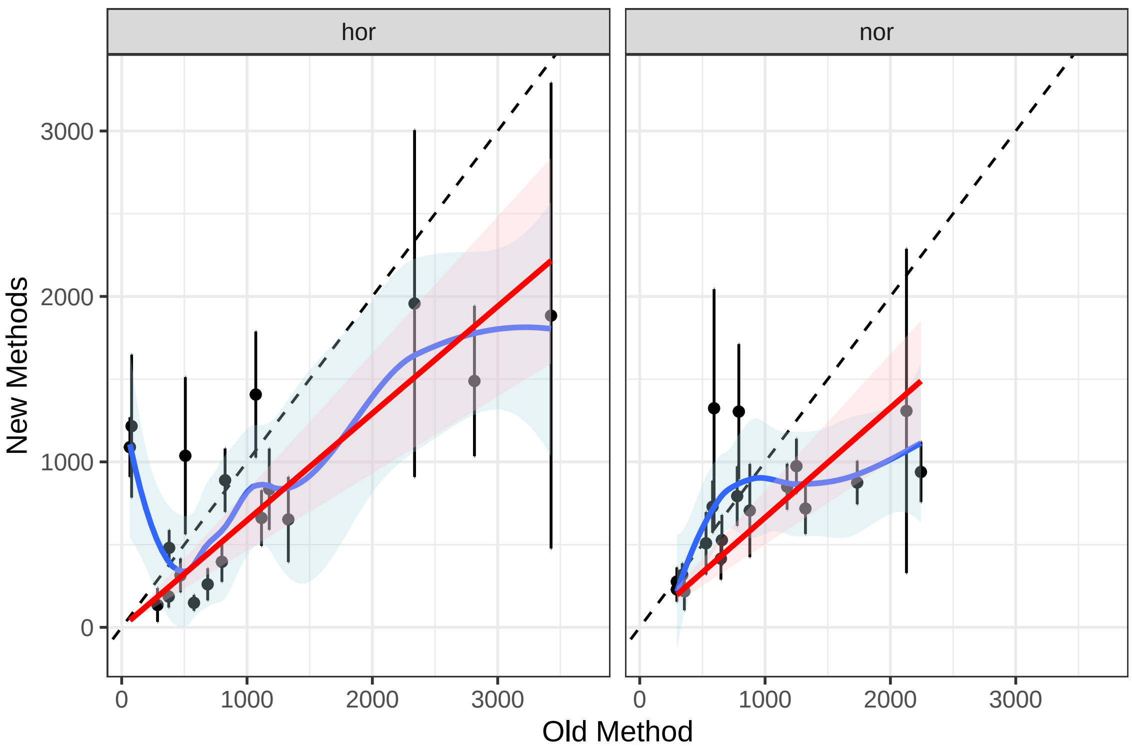

Figure 2: Scatterplots of hatchery and natural origin spawners in the Wenatachee, as estimated by the old method (x-axis) and new methods (y-axis). The blue line is a loess fit, and the red line shows a linear fit forced through the origin.

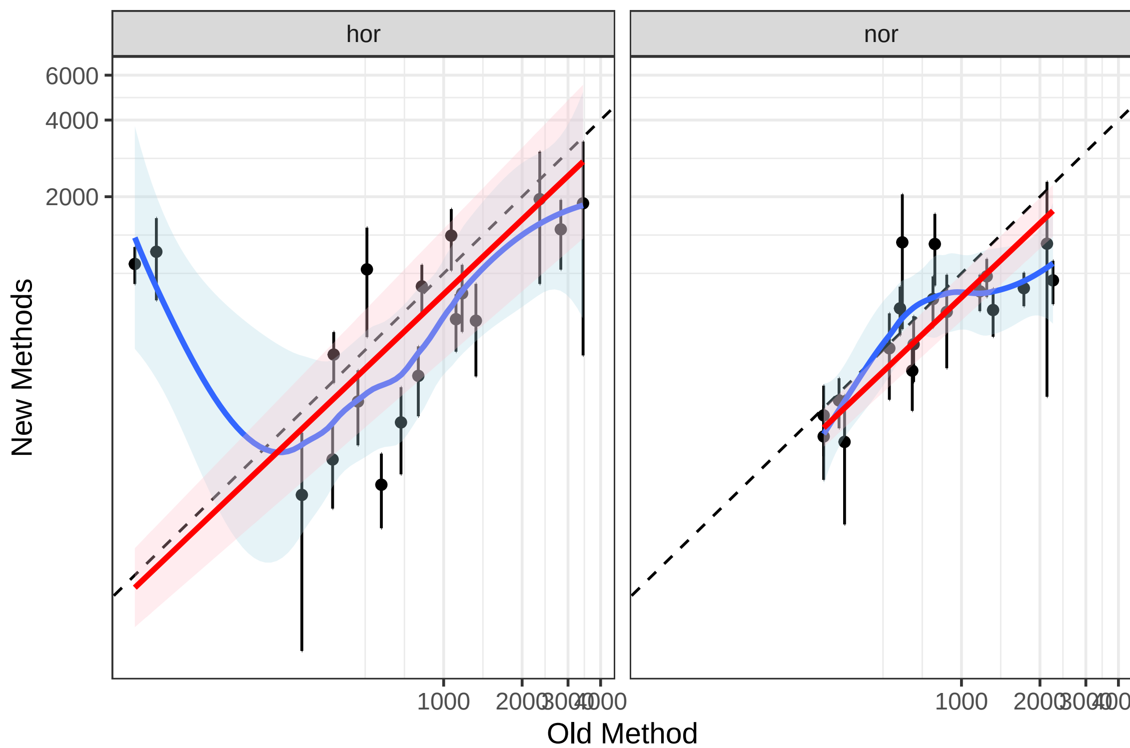

Figure 3: Log-log scatterplots of hatchery and natural origin spawners in the Wenatachee, as estimated by the old method (x-axis) and new methods (y-axis). The blue line is a loess fit, and the red line shows a linear fit forced through the origin.

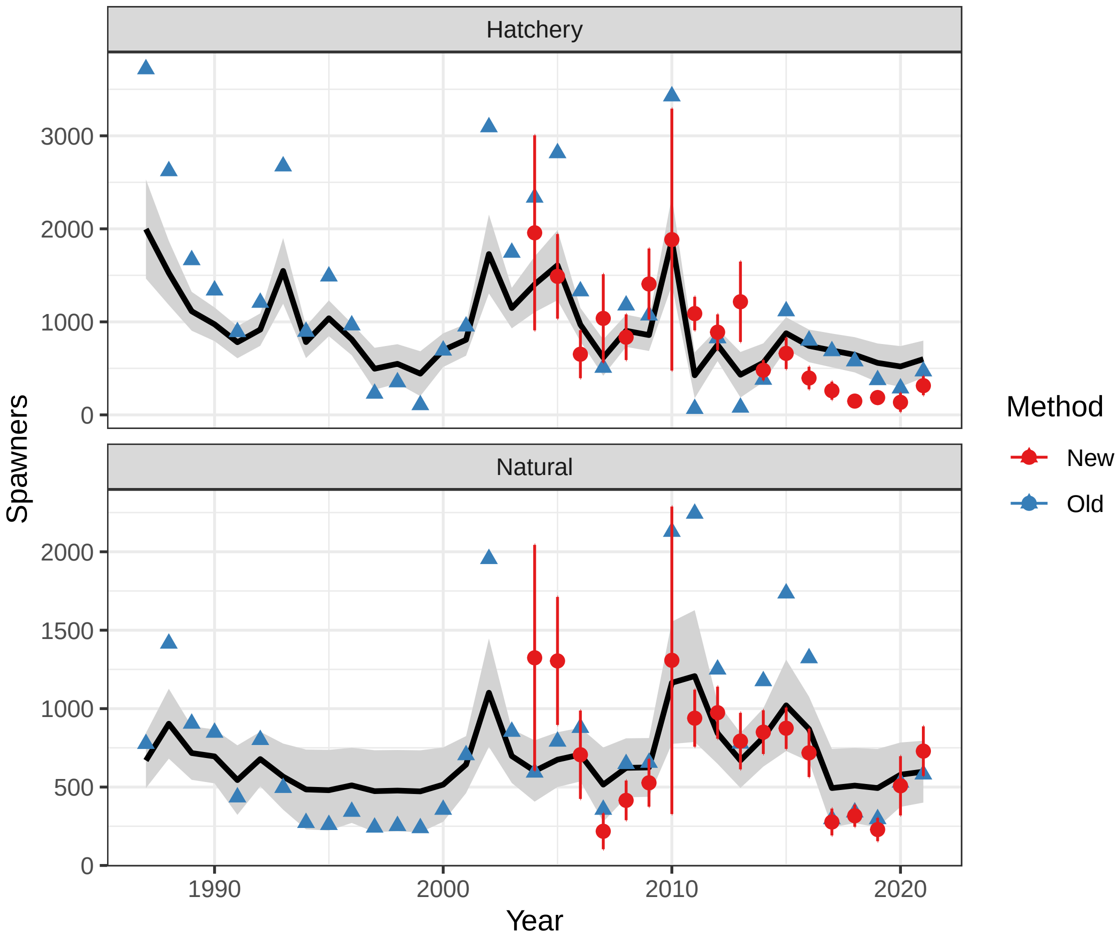

Figure 4: Black lines show linear regression estimates with the 95% confidence intervals depicted as grey ribbons. Blue triangles depict estimates from the old time-series, while red points and 95% confidence intervals are from the new time-series.

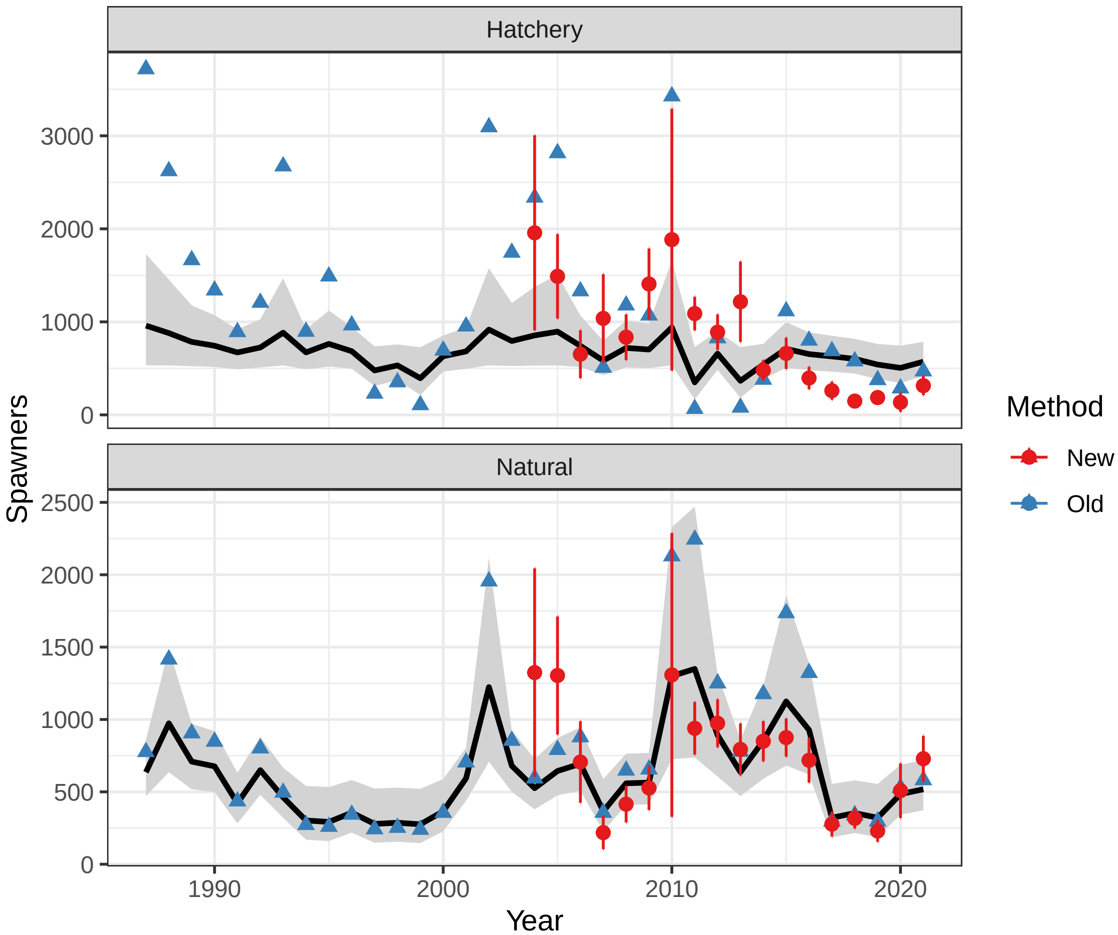

Figure 5: Black lines show log-log linear regression estimates with the 95% confidence intervals depicted as grey ribbons. Blue triangles depict estimates from the old time-series, while red points and 95% confidence intervals are from the new time-series.

2.1.1 Linear Modeling Results

Neither a linear nor a log-log linear model fit the data very well (Figures 2 and 3). A linear fit to these scatter plots would imply a consistent bias (either additive or multiplicative). The lack of such an obvious fit implies the relationship between the two time-series is more complicated. Both appeared to underestimate abundance during years when the older method predicted high numbers steelhead spawners (Figures 4 and 5).

2.2 MARSS

Fit a multivariate auto-regressive state-space (MARSS) model (Holmes et al. 2012, 2021) to the two time-series, ensuring that the only offset of the true states is for the old time-series and that the observation error of the new time-series is informed by mean standard error from the new time-series.

A MARSS model is of the form:

$$\begin{aligned}\mathbf{x}_t &= \mathbf{B}\mathbf{x}_{t-1} + \mathbf{u} + \mathbf{C}_t\mathbf{c}_t + \mathbf{w}_t, \text{where } \mathbf{w}_t \sim MVN(0, \mathbf{Q}) \\ \mathbf{y}_t &= \mathbf{Z}\mathbf{x}_t + \mathbf{a} + \mathbf{D}_t\mathbf{d}_t + \mathbf{v}_t, \text{where } \mathbf{v}_t \sim MVN(0, \mathbf{R})\end{aligned}$$

where $\mathbf{x}_t$ represents the true state at time t, which change as a correlated random walk through time. The $\mathbf{u}$ term represents average drift or trend through time. Meanwhile, $\mathbf{y}_t$ represent the observations of those true states, $\mathbf{x}_t$. Which state each element of $\mathbf{y}_t$ is an observation of is determined by the $\mathbf{Z}$ matrix, while $\mathbf{a}$ represents a fixed offset between different elements of $\mathbf{y}$. $\mathbf{C}_t$ and $\mathbf{D}_t$ are possible parameters that show how inputs $\mathbf{c}_t$ and $\mathbf{d}_t$ influence the states ($\mathbf{x}_t$) or observations ($\mathbf{y}_t$); in other words they are covariates. Finally $\mathbf{Q}$ is the process error variance, while $\mathbf{R}$ is the observation error covariance matrix. This framework works best in log-space, so we log-transformed $\mathbf{y}_t$. Further details of MARSS models can be found in the MARSS user guide.

- We set $\mathbf{y}_{1,t}$ and $\mathbf{y}_{3,t}$ to be the estimates of hatchery and wild spawners using the most updated methods, while $\mathbf{y}_{2,t}$ and $\mathbf{y}_{4,t}$ are the vector of estimates of hatchery and wild spawners using the older method.
- We fixed the first and third element of $\mathbf{a}$ to be 0, to ensure there was no offset between the updated estimates and the MARSS model states (The second and fourth element of $\mathbf{a}$ was estimated, as the average multiplicative offset between the older time-series and the true states).
- We set $\mathbf{B}$ to be the identity matrix
- We tested setting $\mathbf{u}$ to 0, the equivalent of a random walk model, and allowing it be estimated, the equivalent of a random walk with drift or trend model.
- The other element we wanted to feed *a priori* into the MARSS framework was the observation error variance, based on the estimated standard errors in the updated estimates. Because the model is set in log-space, we transformed the estimated standard errors by calculating the coefficient of variation, adding 1, logging that value and then calculating the square root. We then took the mean of the log-space standard errors before squaring it. These two values for hatchery and wild observation error were set as the first and third term along the diagonal of the $\mathbf{R}$ matrix, while the off-diagonals were set to 0 and the observation variance of the older methods was left for the MARSS model to estimate.
- Because hatchery and natural origin returns may be correlated to other dam counts, we compiled time-series of counts from several other Columbia River dams: Bonneville, Ice Harbor, McNary, Prosser and Rock Island dams. These were treated as separate states in the MARSS framework, each with a single observation. For all dams, counts were summed from June 1 the year prior to May 31 of that spawn year. These counts are plotted in Figure 6.

Table 1: AICc values for all models.

Model Num.	Description	n Params	LogLik	AICc	delta AICc
3	Q unconstrained, no covariates	44	-20.1	145.0	0.0
6	Q unconstrained, smolt covariate	45	-20.1	147.8	2.8
9	Q unconstrained, no covariates, U unequal	51	-13.1	151.3	6.3
12	Q unconstrained, smolt covariate, U unequal	52	-12.9	154.0	9.0
2	Q mostly independent, no covariates	24	-181.7	416.2	271.2
5	Q mostly independent, smolt covariate	25	-181.7	418.5	273.5
1	Q diag and unequal, no covariates	23	-186.7	423.6	278.6
8	Q mostly independent, no covariates, U unequal	31	-177.1	424.1	279.1
4	Q diag and unequal, smolt covariate	24	-186.5	425.7	280.7
11	Q mostly independent, smolt covariate, U unequal	32	-176.8	426.2	281.2
7	Q diag and unequal, no covariates, U unequal	30	-184.8	437.1	292.1
10	Q diag and unequal, smolt covariate, U unequal	31	-184.8	439.6	294.6

- We also compiled one more possible input, hatchery releases of smolts. We hypothesized that the hatchery release numbers from previous years might inform the predicted returns of adults. We used the weighted average of salt age 1 and salt age 2 releases, weighted 70% towards salt age 1 and 30% towards salt age 2 based on average age composition data. Salt age 1 fish returned 2 years after their release, while salt age 2 fish returned after 3 years. This time-series extended back to 1987 and was normalized to have a mean of zero and standard deviation of one. This was treated as a possible covariate for the estimated state of hatchery spawners. This time series is shown in Figure 7.

- We tested several configurations of this model:

  1. Treated all states (Wenatchee hatchery and wild spawners, and other dam counts) as independent, by setting the off-diagonal terms of **Q** to 0. (`Q = "diagonal and unequal`)
  2. Similar to (1), but allowed for the process errors of Wenatchee hatchery and wild spawners to co-vary by estimating a single off-diagonal element of **Q**.
  3. Allowed the process errors to co-vary across all states, and estimated their covariance as the off-diagonal term of **Q**. (`Q = "unconstrained`)
  4. Same as (1), but included a covariate of hatchery smolt releases to inform hatchery returns.
  5. Same as (2), but included a covariate of hatchery smolt releases to inform hatchery returns.
  6. Same as (3), but included a covariate of hatchery smolt releases to inform hatchery returns. 7-12. Same as above, but included a possible trend (`U = "unequal"`).

Models 1, 2, 4 and 5 essentially ignore the dam counts when it comes to fitting and predicting for the Wenatchee states. Models 1 and 4 treat hatchery and wild spawners as independent time-series which is the equivalent of fitting separate models for wild and hatchery spawners.

- All models were compared with AICc.

- All models were fit using the `MARSS` package in R.

2.2.1 MARSS Results

The results (Table 1) show the third model to be best supported by the data. This model allows for correlated process errors between hatchery and natural spawners and various dam counts. The second best model by AICc was model 6, which was identical to model 3 but also included a covariate of previous smolt releases to help predict hatchery spawners.

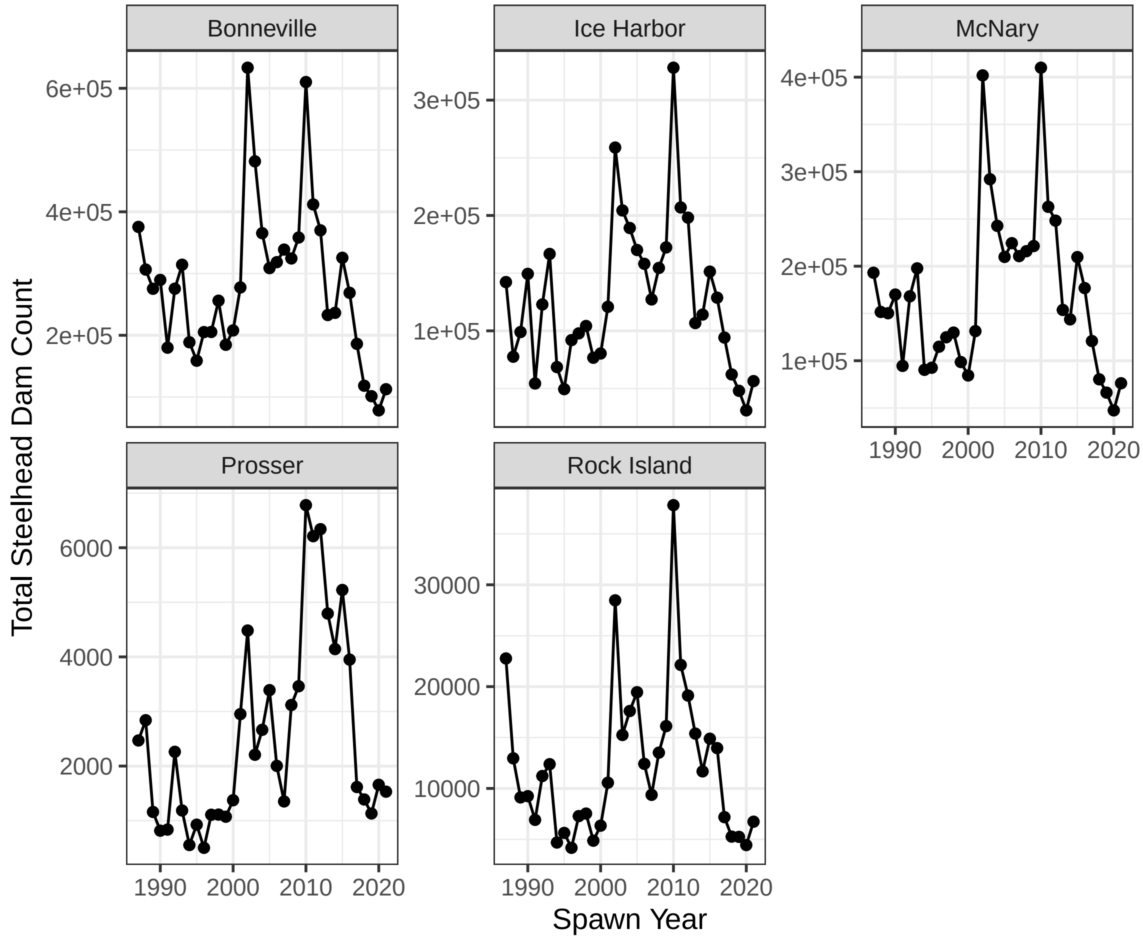

Figure 6: Time-series of counts from various Columbia River dams, from June 1 the year prior to May 31 of that spawn year.

Table 2: Estimates of Q matrix from model 3, showing variance and co-variance estimates.

	Wen. Hatch	Wen. Wild	BON	IHR	MCN	PRO	RIS
Wen. Hatch	0.222	0.157	0.136	0.159	0.162	0.118	0.167
Wen. Wild	0.157	0.202	0.089	0.098	0.104	0.198	0.167
BON	0.136	0.089	0.096	0.114	0.113	0.073	0.106
IHR	0.159	0.098	0.114	0.137	0.136	0.077	0.122
MCN	0.162	0.104	0.113	0.136	0.135	0.081	0.125
PRO	0.118	0.198	0.073	0.077	0.081	0.217	0.157
RIS	0.167	0.167	0.106	0.122	0.125	0.157	0.157

Table 3: Estimates of selected parameters from the best model.

term	estimate	std.error	conf.low	conf.up
A.a_old_hor	0.043	0.189	-0.328	0.413
A.a_old_nor	0.211	0.110	-0.005	0.427
R.r_old_hor	0.606	0.151	0.310	0.902
R.r_old_nor	0.089	0.025	0.040	0.139

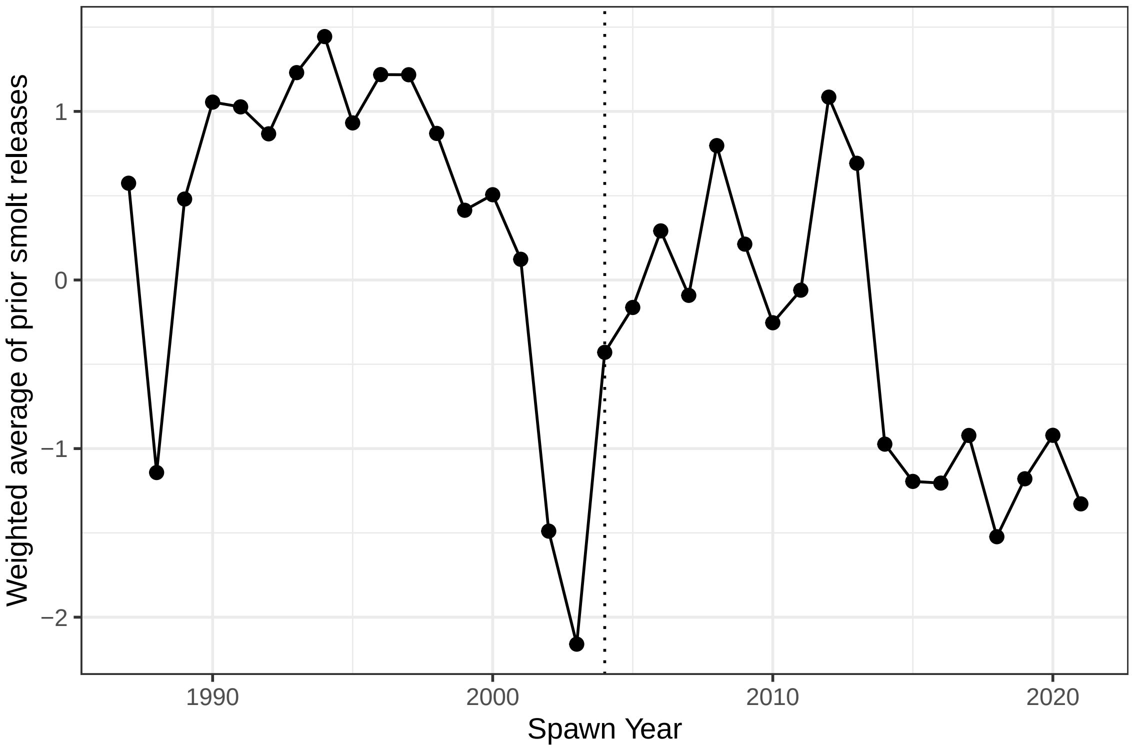

Figure 7: Time-series of normalized weighted average of smolt releases prior to the spawn year (x-axis). Dotted line shows when the new time-series begins.

Table 2 shows the estimates of the process error covariance matrix, **Q**. Table 3 shows other parameter estimates from the selected model.

Figure 8 compares the predictions of hatchery spawners from a model that does not use smolt releases as a covariate and one that does, although both have unconstrained **Q** matrices. (models 2 and 4). Predictions are greater for the model with a smolt release covariate, but only in the earlier years.

3 Conclusions

The MARSS framework appear to fit the data better than the linear regression for several reasons, so we chose to use that. First, there does not appear to be a consistent additive or multiplicative bias between the two time-series. Second, a MARSS model is explicitly a time-series model, which is appropriate for this comparison. Finally, the MARSS framework allowed us to test a variety of model structures, including bringing in other time-series and covariates. AICc supported a model that included several time-series of various dam counts, with correlated process errors (true year-to-year variability), including a positive correlation between hatchery and natural origin spawners. This positive correlation could reflect the impacts of shared ocean conditions. There was slightly less support for the same model that also included a covariate of weighted average of previous smolt releases to for the hatchery returns (but not natural origin returns). Because the coefficient of that covariate was negative, with confidence intervals that overlapped 0, and because including smolt releases had very little effect on spawner estimates (Figure 8), we decided against using that model and chose the one with the lowest AICc score.

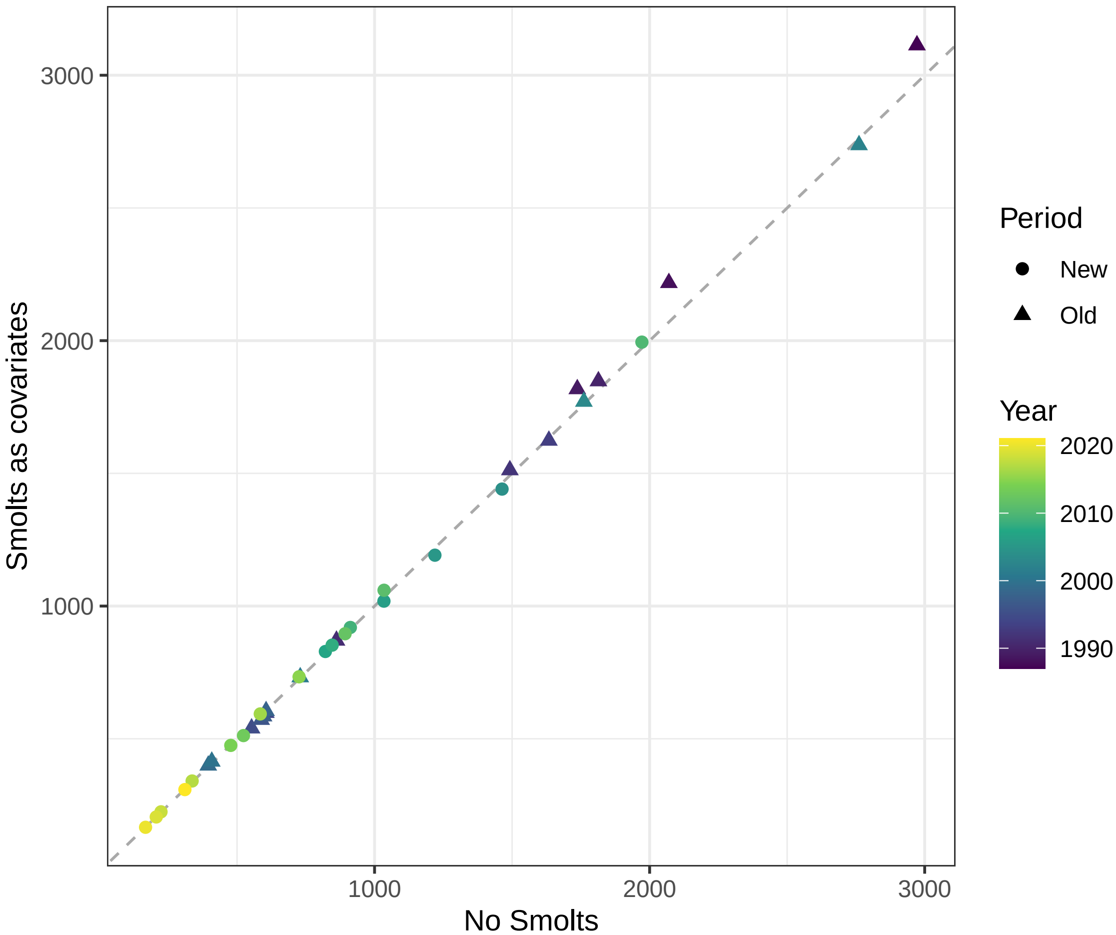

Figure 8: Comparison of predicted states of hatchery spawners for a model with no smolt release covariate (x-axis) and one that includes that covariate (y-axis). The period refers to whether the new time-series estimates exist.

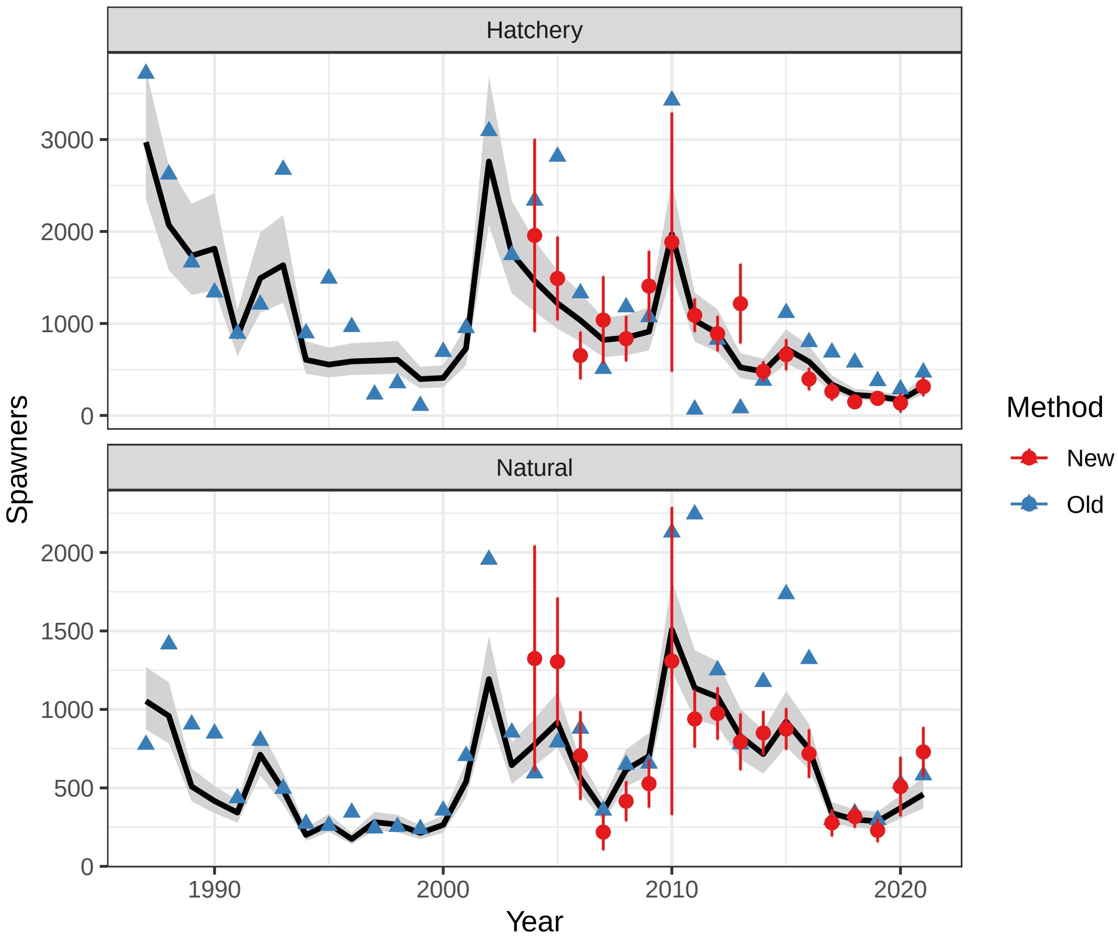

Figure 9: Estimates of spawners through the years, faceted by origin. Predicted spawners is the black line with 95% confidence interval in gray. Blue triangles depict estimates from the old time-series, while red points and 95% confidence intervals are from the new time-series.

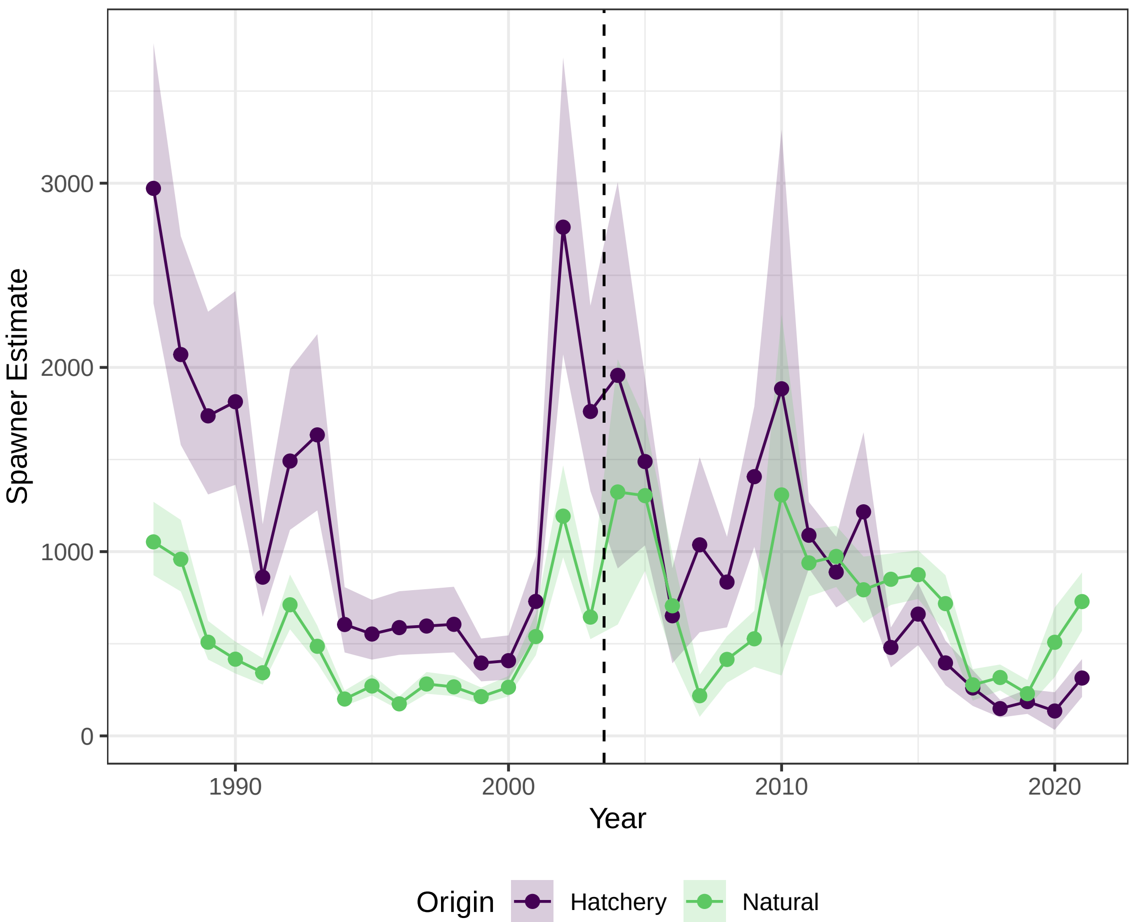

Figure 10: Updated estimates of spawners through the years, colored by origin, showing point estimates and 95% confidence intervals. Dashed vertical line differentiates older and newer time-series.

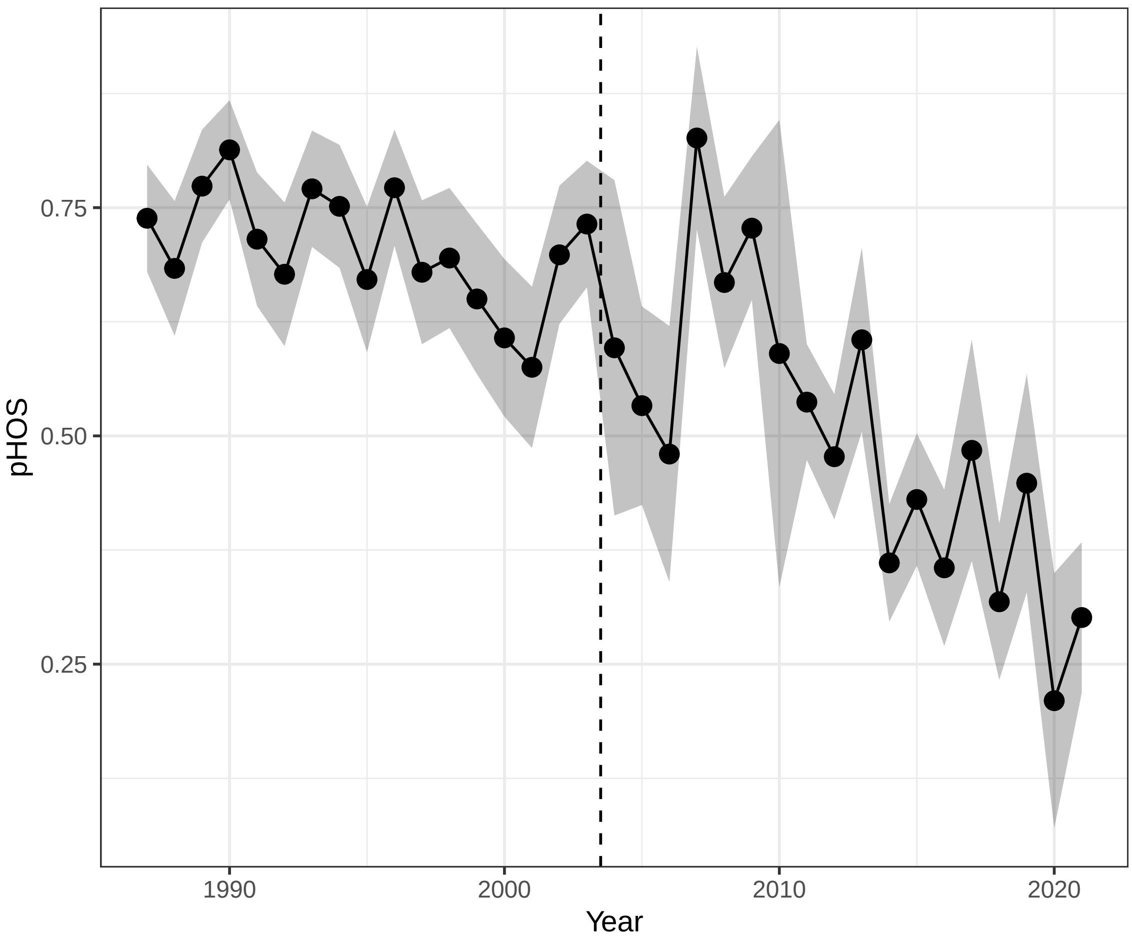

Figure 11: Estimates of pHOS based on the updated time-series, showing 95% confidence intervals. Dashed vertical line differentiates older and newer time-series.

References

Holmes, E. E., E. J. Ward, M. D. Scheuerell, and K. Wills. 2021. MARSS: Multivariate autoregressive state-space modeling.

Holmes, E. E., E. J. Ward, and K. Wills. 2012. MARSS: Multivariate autoregressive state-space models for analyzing time-series data. The R Journal 4(1):30.

Murdoch, A. R., C. J. Herring, C. H. Frady, K. See, and C. E. Jordan. 2018. Estimating observer error and steelhead redd abundance using a modified Gaussian area-under-the-curve framework. Canadian Journal of Fisheries and Aquatic Sciences 75(12):2149–2158.

Murdoch, A. R., T. N. Pearsons, and T. W. Maitland. 2009. The Number of Redds Constructed per Female Spring Chinook Salmon in the Wenatchee River Basin. North American Journal of Fisheries Management 29(2):441–446.

Waterhouse, L., J. White, K. See, A. Murdoch, and B. X. Semmens. 2020. A Bayesian nested patch occupancy model to estimate steelhead movement and abundance. Ecological Applications 30(8).