Northwest **Power** and **Conservation** Council

April 1, 2025

MEMORANDUM

TO: **Council Members**

FROM: **Erik Merrill, Independent Science Manager, and Kris Homel, Biologist for Program Performance and ISAB Ex Officio Representative**

SUBJECT: **Independent Scientific Advisory Board (ISAB) Report, Challenges and Opportunities for Improved Estimation, Interpretation, and Use of Smolt-to-Adult Return (SAR) and Survival (SAS) Metrics for Salmon and Steelhead in the Columbia River Basin**

BACKGROUND:

Presenter: Tom Quinn, ISAB Chair

Summary: This presentation will describe key findings and recommendations from the ISAB's Report: Challenges and Opportunities for Improved Estimation, Interpretation, and Use of Smolt-to-Adult Return (SAR) and Survival (SAS) Metrics for Salmon and Steelhead in the Columbia River Basin (ISAB SAR and SAS Metrics Report). Estimates of salmon and steelhead smolt-to-adult survival and return are used in fisheries management and the assessment of hatcheries, habitat improvement projects, hydroelectric facility operations, and other activities. The estimates are also used to forecast future abundance and understand environmental processes affecting salmon. The ISAB seeks to heighten awareness of the variation underlying their estimation and the pitfalls related to their inconsistent or unclear application. Those who generate and use the estimates and manage data archives all contribute to their usability. The ISAB's report provides recommendations to improve the estimation, interpretation, documentation, and usability of SAR and SAS metrics in the Columbia River Basin.

Relevance: The 2014 Fish and Wildlife Program and ISAB Terms of Reference call for the ISAB to conduct reviews to ensure sound scientific methods are used in research related to the Columbia River Fish and Wildlife Program. This report evaluates fundamental fish survival metrics used to gauge progress of the Program.

Workplan: Scientific reviews are an integral part of the Fish and Wildlife Program's work plan.

Background:

This report reviews the estimation of smolt-to-adult survival (SAS) and smolt-to-adult return (SAR) for Columbia River Basin salmon, with a focus on terminology, methodology, data inputs, and other attributes affecting their use. SAS and SAR are related but different metrics to represent salmon smolt survival to adulthood and return for spawning. SAS is the estimated proportion of smolts leaving some specified location that survive to adulthood and are either taken in ocean or freshwater fisheries, stray, or return to a designated location in the river system (e.g., a hatchery or stream). SAR is the estimated proportion of smolts leaving a specified location that return to that or another designated location on their return as adults. The distinction between SAR and SAS, and the terms return and survival, should be clearly defined when used. Notably, salmon taken in ocean fisheries are considered to have survived for the purposes of estimating SAS, but they have not returned to their designated location in the river and thus do not count towards the SAR estimate. The use of SAR to estimate survival relies on the assumption of little or no ocean fishery interceptions.

The overall goal of this report is to promote the clear and consistent use of SAR and SAS. To that end, the ISAB: 1) reviews how SAR and SAS are commonly estimated and used for Columbia River Basin salmon, 2) discusses some of the key assumptions and limitations in their use, 3) presents some of the complexities associated with the apparently simple terms "smolt, adult, return, survival" and 4) makes recommendations to help practitioners and readers best use and understand these metrics. The ISAB's goal is neither to criticize past studies nor to discourage the use of these metrics. Rather, the ISAB seeks to heighten awareness of the variation underlying their estimation and the pitfalls related to their inconsistent or unclear application.

Estimating SAR and SAS requires designated locations where smolt and adult abundances are estimated. These locations are often different for the two estimators for a given stock and for different stocks, and the methods for estimating abundance depend on the mark and recapture methodology and sampling techniques. Consequently, for a single cohort of smolts, SAR and SAS estimates may be similar or very different, and the choice of which estimate to report, or to report both, can affect our understanding of a population's trend or the effects of management. Moreover, directly comparing SAR or SAS estimates that are produced with different tagging methods (e.g., coded wire tags [CWTs], passive integrated transponder [PIT]-tags, and parentage-based tagging), from different locations, representing stocks of different origins and life histories, or different definitions of smolts and adults can introduce unintended biases and can lead to erroneous conclusions. These metrics are available for public use, so comparisons are commonly made within and beyond the Columbia River Basin. Consequently, well-defined

terms, transparent methods, and consistent application are important for sound science and use in the management process.

This report does not advocate specific ways of estimating and interpreting salmon return and survival, but the ISAB provides examples of the use of SAR and SAS in the region that illustrate some of the issues the ISAB has identified. The ISAB also considers some of the complexities in estimating mortality from fishing and natural causes at sea. Apportioning mortality to different years and life stages has frustrated fisheries scientists for decades. Mortality during the early marine phase may determine the success of the cohort, but it is very difficult to estimate with any confidence. In the Columbia River Basin, this early marine phase has special importance because it is more plausibly linked to the delayed effects of smolt exposure to the hydrosystem during seaward migration than is mortality that occurs years later.

SAR and SAS estimates are essential to salmon conservation and management efforts in the Columbia River Basin and the broader science and management communities. Those who generate and use the estimates and manage data archives all contribute to their usability. The ISAB makes the following summary recommendations to improve the estimation, interpretation, documentation, and usability of SAR and SAS metrics in the Columbia River Basin:

1. Provide clear study objectives and describe the application for studies using SAR and SAS.
2. Clearly define and consistently use the terms SAR, SAS, smolt, adult, return, and survival.
3. Describe how SAR and SAS are estimated and how time-series data are analyzed.
4. Report PIT-tag detections for SAR components (downstream, ocean, upriver) where applicable.
5. Maintain the integrity of long-term SAR and SAS datasets by comparing results of different marking and analytical methods, developing robust conversions where appropriate, and reporting CWT-based SAS estimates for representative stocks throughout the basin.
6. Augment SAR reporting in publicly accessible databases to include SAS.
7. Where appropriate for the application, adjust SAR and SAS estimates to a common age at maturity and provide the rationale and methods for adjustments.
8. Use SAR and SAS metrics from surrogate populations with caution and explain how well the surrogate represents the population of interest.

More info: The report is available online (link).

ISAB SAR and SAS Metrics Report

Challenges and Opportunities for Improved Estimation, Interpretation, and Use of Smolt-to-Adult Return (SAR) and Survival (SAS) Metrics for Salmon and Steelhead in the Columbia River Basin

ISAB Report 2025-1 April 1, 2025

ISAB INDEPENDENT SCIENTIFIC ADVISORY BOARD

Presentation to Northwest Power & Conservation Council
April 9, 2025

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- **Courtney Carothers, Ph.D.,** University of Alaska, Fairbanks, Alaska
- **Patrick Connolly, Ph.D.,** US Geological Survey (Emeritus), Cook Lab, Washington
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- **Michael Young, Ph.D.,** US Forest Service (Emeritus), Rocky Mountain Research Station, Missoula, Montana

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ISAB Ex Officios and Manager

- **Kris Homel, Ph.D.,** Northwest Power and Conservation Council, Portland, Oregon
- **Michael Ford, Ph.D.,** Northwest Fisheries Science Center, Seattle, Washington
- **Robert Lessard, Ph.D.,** Columbia River Inter-Tribal Fish Commission, Portland, Oregon
- **Erik Merrill, J.D.,** Northwest Power and Conservation Council, Portland, Oregon

External review – a novel but beneficial review step

Columbia Basin scientists who provided comments:

- Jay Hesse and Bill Young – Nez Perce Tribe
- Pete McHugh, Stuart Ellis, Tom Lorz, and Tommy Garrison – Columbia River Inter-Tribal Fish Commission
- Tim Copeland, Jonathan Ebel, and Brian Leth – Idaho Department of Fish and Game
- Andrew Murdoch and Brandon Chasco – Washington Department of Fish and Wildlife
- Adam Storch, Ian Tattam, and Joseph Feldhaus – Oregon Department of Fish and Wildlife
- Rod Engle and Steve Haeseker – US Fish and Wildlife Service
- Steven G. Smith – NOAA Northwest Fisheries Science Center

Today's presentation goals:

1. Explain why survival and return estimates matter
2. Define smolt to adult survival and return
3. Explain the nature of the problem
4. Describe issues related to:
   a) Definitions: smolt, adult, survive, return
   b) Marking methods: CWT, PIT-tag, PBT
   c) Calculations
5. *Stay out of the weeds*
6. ***Urge clarity and consistency***

Smolt to adult survival and return estimates are central to Columbia River Basin management and science

1. Monitoring status and trends of hatchery and natural origin runs
2. Evaluating hatchery practices: smolt size, growth patterns, release date, on-site vs. off-site location, etc.
3. Assessing hydrosystem operations: flow, dam passage alternatives, etc.
4. Assessing transportation practices (barge, truck, in-river migration)
5. Managing fisheries: US-Canada treaty, obligations to tribal groups and other allocation issues, etc.
6. Studying salmon survival and conditions at sea to forecast future runs
7. And more…

From the ISAB report:

1) The 2020 Addendum to the 2014 Fish and Wildlife Program defines biological objective S2 as ***"contribute to achieving a smolt-to-adult return ratio (SAR) in the 2-6 percent range (minimum 2 percent; average 4 percent) for listed Snake River and upper Columbia salmon and steelhead, as well as for non-listed populations."***

2) The Comparative Survival Study annually estimates ***SARs for many salmon population in relation to the 2-6% SAR objective***.

3) The Lower Snake River Compensation Plan generates SAR and SAS metrics and ***has developed SAR and SAS goals specific to hatchery programs***.

Definitions:

"Based on common but not universal usage, we define

SAR as the proportion of smolts that survive all natural and fishery mortality between designated locations on their seaward and return migrations.

In contrast, we define

SAS as the proportion of smolts that survive to adulthood: those that return to a reference location ***plus* those that are caught in ocean and river fisheries or stray and never arrive at the reference location."**

Short version:

Smolts out to adults back.

Smolts out to adults back ***plus ocean catch***.

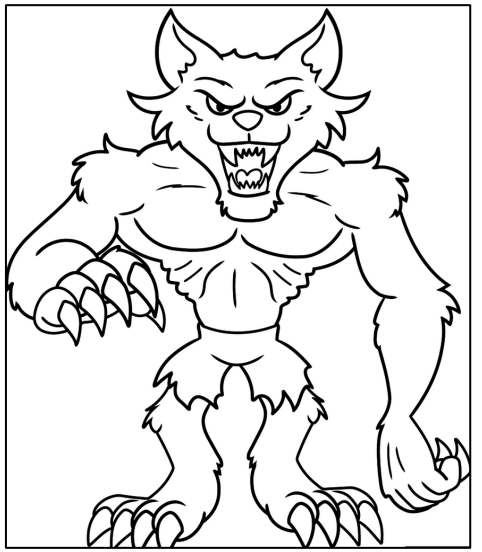
Hendry et al. (2014)

The baby:

Smolt to adult survival (SAS) and return (SAR) are critical metrics for Columbia River Basin salmon science, management, and policy.

We need them.

The werewolf:



SAS and SAR are ***different but related,*** and they can be estimated using ***different marking techniques***, beginning and ending at ***different locations***, with many ***different assumptions, calculations, and other attributes***.

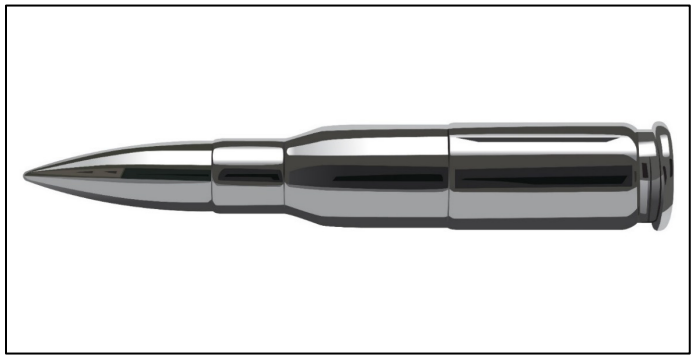
The key terms (***smolt, adult, survival*** and ***return***) are surprisingly difficult to determine and even to define.

Those who generate and report the metrics grasp these distinctions, but their different methods and mandates ***compromise standardization*** and can bring ***confusion and miscommunication***.

Trying to get out of the weeds.

And there are a lot of weeds!

The silver bullet:



We make specific recommendations, but some key ones are:

1. Define terms ***clearly*** and use them ***consistently***.

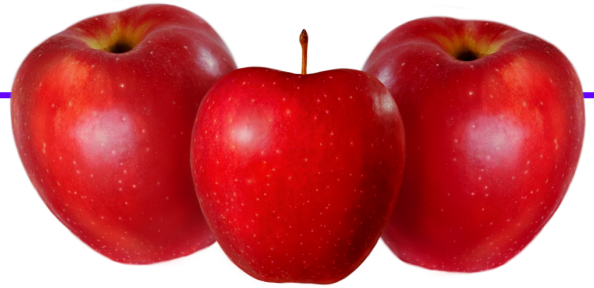
2. Distinguish losses of smolts in the river, salmon at sea, and adults back up to their designated return locations.

3. Annually report SAS from CWT for a set of representative stocks and report both SAR and SAS when possible.

Clear terms are essential

Metrics

Smolt to adult → survival
Smolt to adult → return

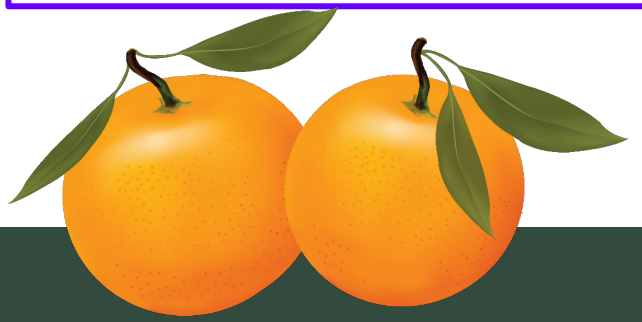


Marking approaches

Coded wire tag

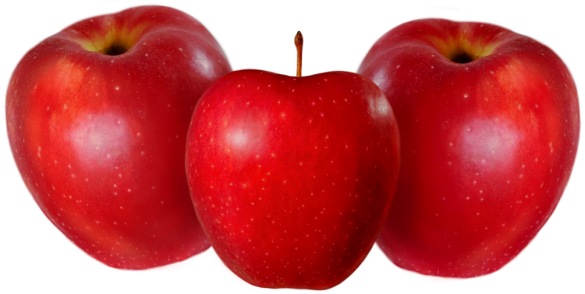
PIT-tag

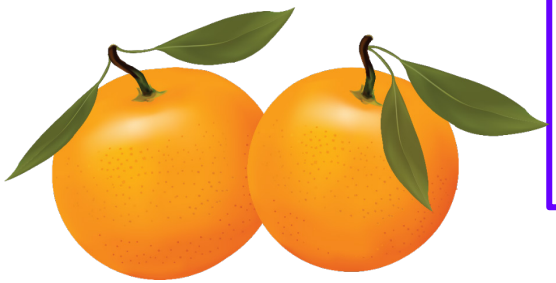
Parentage-based tagging (PBT)



SAR and SAS

Estimates may be very different or quite similar. They are not interchangeable, and neither is "marine survival" in most cases.





Marking approaches

CWT are usually associated with SAS.

PIT-tag are usually associated with SAR.

But there are many combinations of methods; PBT is increasingly used.

Each marking method has assets and drawbacks:

1. CWT:
   a) primarily applied in hatcheries
   b) group, not individual data
   c) widely sampled in fisheries
   d) lethal sampling (one and done!)

Each marking method has assets and drawbacks:

1. CWT: primarily in hatcheries, group data sampled in fisheries, but lethal
2. PIT:
   a) hatchery and wild fish
   b) data on individual fish when tagged
   c) not widely sampled in fisheries
   d) multiple “hands off” detections

Each marking method has assets and drawbacks:

1. CWT: primarily in hatcheries, group data sampled in fisheries, but lethal
2. PIT: hatchery and wild fish, data on individuals little fishery data, multiple detections
3. PBT:
   a) primarily in hatcheries
   b) families identified but no individual data
   c) not widely sampled in fisheries
   d) “hands on” but not lethal sampling

Clear use of terms is essential

1) What is a smolt?

2) What is an adult?

3) What does it mean to survive?

4) What does it mean to return?

1. What is a smolt?

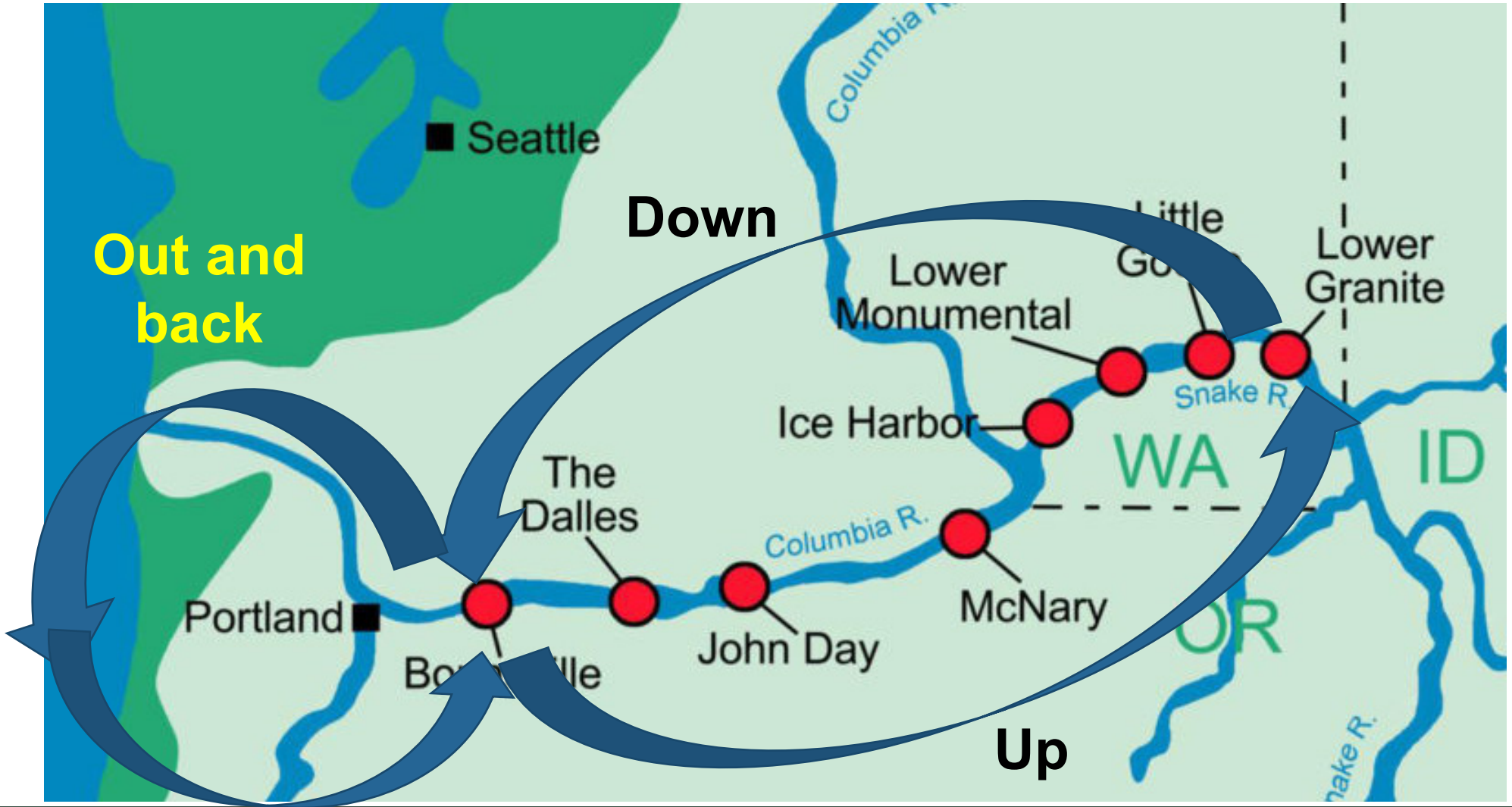
Fish may be released from a hatchery or marked in a stream and not migrate, or they might migrate at different times of the year, at different paces, and enter the estuary at different sizes and seasons.

"Put simply, not all fish moving downstream are smolts, not all fish released as smolts move downstream, and fish do not all move downstream in the same manner."

It is very far from a tributary to Lower Granite Dam, to Bonneville Dam, the estuary, and out to sea. Where does the “smolt” start?

It is equally far from sea back to the tributary.

Counting locations vary greatly and determine which losses are included.



2. What is an adult?

What about this one, caught in the winter in Puget Sound?

Clearly an adult, right?

Mature male Chinook salmon

Age 1 (mini-jack)

Age 2 (jack)

Age 3

Age 4

Naturally spawned male parr

These sexually mature fish are not equivalent.

We need to know which are counted as “adults.”

2. What is an adult?

Analysis of survival and return may benefit from adjustment to a common age at maturity so natural and hatchery origin fish can be compared and we can assess trends over time.

Why?

Each year that salmon are at sea, they risk death. Fish that return early in life have higher apparent but not actual survival compared to fish maturing a year or two later.

A hatchery might give a false sense of success if it returns younger fish than the natural population. Adjusting to a common age facilitates comparisons.

Origin and sex	Age 3	Age 4	Age 5
Hatchery-origin males	60	32	8
Natural-origin males	15	63	22
Hatchery-origin females	0	72	28
Natural-origin females	0	39	61

All adults, but are they equivalent?

Age composition (%) of mature Imnaha River spring Chinook salmon from brood years 1982 – 1986 (Carmichael and Messmer 1995).

3. What does it mean to survive to adulthood?

For fisheries management, salmon that are large enough to “recruit to fisheries” are considered adults, though they might not mature and spawn that year.

For management purposes and analysis of factors affecting survival at sea, salmon are adjusted to a common age based on assumed natural mortality rates.

Some assume 20% mortality per year, others* assume that mortality rate declines as fish age (e.g., 40%, 30%, 20% and then 10%).

* Pacific Salmon Commission - Chinook Technical Committee Exploitation Rate Analysis

3. What does it mean to survive?

Salmon are said to have “survived” if they are ***caught in fisheries at sea and or in the river, or recovered at hatcheries and spawning grounds.***

Marine fisheries are routinely sampled for CWT, but rarely for PIT-tags and PBT so those methods ***do not fully assess survival***.

4. What does it mean to return?

In the Columbia River Basin, salmon are said to have “returned” if they are ***detected at some specified location*** (e.g., Lower Granite Dam). ***Fish caught below that point are not distinguished from natural mortalities.***

Andrew Dittman

When might survival and return be similar, and when might they differ?

If smolts are marked and counted at the same place (e.g., a hatchery), released together at similar date and size, and not exposed to fisheries at sea, survival and return are essentially the same.

But if many are ***lost to fisheries, they count as survivors but not as returns***, so the two metrics will report different values.

Some stocks exploited at sea and others are not. This is critical.

5 Million Fish by 2025

2014 Program – What?

Increase total adult salmon and steelhead ***runs*** of Columbia River origin to a 10-year rolling average of ***5 million*** annually by 2025, emphasizing increased abundance of populations originating above Bonneville Dam

2020 Addendum – How?

• Harvest in the ocean and river below Bonneville Dam ***(implies survival)***
• The number of fish spawning below Bonneville Dam ***(implies return?)***
• The number of adult salmon of all species counted at Bonneville Dam ***(implies return?)***

The world of SAR and SAS is a very weedy place. The ISAB report explores the weeds, but the key is to ***define terms clearly and use them consistently*** as appropriate for the task at hand.

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for the Northwest Power and Conservation Council,
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and National Marine Fisheries Service