FISH PASSAGE CENTER

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MEMORANDUM

TO: Bill Tweit, WDFW
Tucker Jones, ODFW
Margaret Filardo, Citizen

Michele DeHart

FROM: Michele DeHart, FPC

DATE: December 4, 2020

SUBJECT: Technical review of Welch et al. (2020), titled, *A synthesis of the coast-wide decline in survival of West Coast Chinook Salmon (Onchorhynchus tshawytsha, Salmonidae).*

In response to your request, the Fish Passage Center (FPC) staff has reviewed the subject Welch et al. (2020) article published on October 30 in Fish and Fisheries. In January 2019, the FPC staff reviewed a manuscript that appears to be an earlier version of this article (FPC 2019). That manuscript was titled, *The coast-wide collapse in marine survival of west coast Chinook and Steelhead: slow moving catastrophe or deeper failure?* This 2018 manuscript was attached to David Welch's' comments on the Northwest Power and Conservation Council Draft Fish and Wildlife Program. The FPC review comments on the 2018 manuscript are posted on the FPC website and are available to the public. Although the 2018 Welch et al. manuscript was submitted for publication, it was not published.

The Welch et al. (2020) article was published in the journal Fish and Fisheries in October 2020. Fish and Fisheries describes its primary focus as presentation of syntheses or meta-analyses in which various research results in the primary literature are considered together. Further, the journal states "a paper in Fish and Fisheries ***must draw upon all key elements of the existing literature on a topic***." [emphasis added]. For a synthesis or meta-analysis to be considered reliable, it first requires and relies on a detailed understanding and acknowledgment of the details, assumptions, objectives and results of research generating the data bases utilized in order to assure that the data are comparable. Second, a synthesis or meta-analysis must draw upon all key elements of the existing literature on a topic. Welch et al. (2020) failed to meet these fundamental requirements of a synthesis or meta-analysis.

Welch et al. (2020) present data from a wide range of studies and management activities, comparing results from various west-coast rivers and conclude that Columbia River rebuilding targets may be unachievable and that Chinook salmon survival is driven primarily by broader oceanic factors, therefore the present management activities implemented in the freshwater environment are misdirected. Although the authors conclude that Chinook salmon survival is driven primarily by broad oceanic factors, the authors do not conduct any analyses of ocean conditions or their effects on survival.

Our overall conclusion of this review is that Welch et al. (2020) is technically flawed. Therefore, their contentions that Columbia River rebuilding targets may be unachievable, that broad oceanic factors are a primary driving force in Chinook salmon survival coast-wide, and that freshwater management and mitigation activities are misdirected are not supported by the considerable body of available scientific information. Quantitative analysis of their own selected data sets does not support their conclusions. Our primary conclusions are listed below, followed by detailed discussions of each point.

- The authors fail to meet the most important requirements of a synthesis or meta-analysis, which is clearly establishing that the data and results utilized are comparable. Failure to understand, acknowledge, and address assumptions, objectives, uncertainty, and details of the data that were used results in comparisons that are uninterpretable. Their approach results in an “apples to oranges” comparison at best, and a misrepresentation of the data utilized and erroneous conclusions at worst.
- The authors only report results that support their conclusions. They fail to report results of a significant body of analyses that actually evaluate the effects of oceanic and freshwater factors and the importance of these factors to Chinook salmon survival. The results of these analyses, which are ignored by the authors in their synthesis, conclude that freshwater factors are an important driver of survival for many Chinook salmon populations.
- There is no doubt that the ocean is important and affects numbers of returning adults. However, the number of smolts that enter the ocean is dependent on freshwater survival and management strategies that result in the highest freshwater survival possible, because not even the best ocean conditions can resurrect a dead fish.
- Wild spring Chinook stocks in the Columbia River Basin that experience less hydrosystem impacts (e.g., John Day River and Yakima River) have much higher survival than stocks that experience greater hydrosystem impacts (Snake River, upper Columbia River). These examples, which enter the ocean at the same location, clearly demonstrate the impacts of the freshwater environment on Chinook salmon survival.
- Historical and recent analyses indicate that freshwater management alternatives that include increases in spill levels and breaching the lower Snake River dams could achieve the NPCC regional SAR goals for Snake River spring-summer Chinook salmon.
- Quantitative analyses of the data sets collated by the authors in this study do not support their conclusions of a coast-wide decline of Chinook salmon survival, that broad oceanic factors are a primary driving force in coast-wide survival of Chinook salmon, or that the

  SARs of Snake River spring Chinook populations are higher than estimates reported from many other regions of the west coast lacking dams.
  - If Chinook salmon survival across the West Coast is determined in the ocean by common processes, we would expect that common year effects would explain a substantial portion of the variability in SARs. We found that common year effects explained only 14% of the variation in SARs, indicating little support for the claim that common ocean processes are a primary driver of Chinook salmon survival along the West Coast.
  - Of the 77 Chinook salmon stocks collated by Welch et al. (2020), 66.2% showed no significant temporal trend in SARs, 14.3% showed significant increases in SARs over time, and 19.5% showed significant decreases in SARs over time. Four of the stocks that showed significant declines over time were hatchery Snake River spring Chinook, wild Snake River spring Chinook, wild Snake River summer Chinook, and wild upper Columbia River summer Chinook
  - The majority of spring Chinook stocks collated by Welch et al. (2020) demonstrate significantly higher SARs than the Snake River stocks, particularly those hatchery and wild stocks from the southeast Alaska region that are not impacted by dams.
- The authors' comparison of PIT-tag data and CWT data is misleading and reflects the authors' lack of understanding of both types of data and their application.
- The authors have misrepresented Pacific Salmon Commission and Chinook Technical Committee (CTC) data sources. The CTC does not maintain a smolt-to-adult-return database, contrary to the authors' statements.
- The authors conflate fall Chinook and spring Chinook and misrepresent the Northwest Power and Conservation Council (NPCC) regional 4% average, 2% to 6% SAR goals. The authors ignore the fact that these two different races of Chinook salmon have different life histories and have a very different presence in ocean fisheries.
- The analytical techniques and underlying data used by the authors are inappropriate, misleading, and unreliable.
  - The sample sizes in these groups are concerningly unbalanced and small varying from 0 to 11 (Table 2) and from 3 to 49 (Table 3), despite the fact that these groups were visually weighted equally with uniform confidence estimates.
  - The replication process relied on unbalanced sample sizes between years which skew the expected draws within regions and weights SARs to years that are more heavily represented within the sampling distribution. For example, drawing at random from the 2010-2014 SAR distribution for the Snake River (N=46), a SAR value from ocean entry year 2012 would be 5.5 times more likely to be drawn than an SAR value from 2014.
  - The lack of any attempt to include or evaluate a year effect within the Welch et al. (2020) analysis significantly dilutes the level of insight we can obtain from the visual comparisons presented in their Figure 4.

The authors fail to meet the most important requirements of a synoptic approach, which is clearly establishing that the databases and results utilized are comparable. Failure to understand, acknowledge and address assumptions, objectives, uncertainty, and details of databases used results in an "apples to oranges" comparison at best and a misrepresentation of the data utilized and erroneous conclusions at worst.

The aim and scope of the Journal, Fish and Fisheries, is to present synoptic papers and syntheses or meta-analyses of research in the primary literature. Further, the journal states "a paper in Fish and Fisheries ***must draw upon all key elements of the existing literature on a topic***." [emphasis added]. Acting against this requirement, Welch et al. (2020) omit key elements of the existing literature and results on the topic of freshwater and marine factors and their effects on survival of Chinook salmon. Some specific examples of Welch et al. (2020) omitting key elements of the existing literature include:

1.) Michel (2019) found that flow in the Sacramento River during outmigration was a strong predictor of SAR in all three of the Chinook salmon runs, while indices of ocean conditions had little influence on SARs. The study recommended that managers explore approaches to increase river flow during the outmigration season to benefit Central Valley Chinook salmon populations. These key elements of the results and recommendations, contradicting the notion that freshwater management and mitigation actions are misdirected, were not included in the Welch et al. (2020) synthesis.
2.) Raymond (1988) found that spring and summer Chinook salmon from the Snake River and upper Columbia River above Priest Rapids Dam declined as a result of hydroelectric development of the river. He concluded that the main cause for the decline was the mortality of juveniles migrating downstream through as many as nine dams and impoundments en route to the ocean. Welch et al. (2020) omit these key elements and results from their synthesis.
3.) Schaller and Petrosky (2007) found that Snake River stream-type Chinook salmon exhibited substantial delayed mortality despite recent improvements in oceanic and climatic conditions. They found that Snake River stream-type Chinook salmon populations continued to exhibit survival patterns similar to those of their downriver counterparts from the John Day River but survived only one-fourth to one-third as well. They suggested that a plausible explanation for this persistent pattern of delayed mortality for Snake River populations is that it is related to the construction and operation of the hydrosystem. These patterns of survival and these key elements and findings were omitted from the Welch et al. (2020) synthesis.
4.) Haeseker et al. (2012) found that the freshwater variables (the percentage of river flow spilled over out-migration dams and water transit time) were important for characterizing the variation in survival rates not only during freshwater out-migration but also during estuarine and marine residence. In support of the hydrosystem-related, delayed-mortality hypothesis, they found that freshwater and marine survival rates were correlated, indicating that a portion of the mortality expressed after leaving the hydrosystem is related to processes affected by downstream migration conditions.

They suggested that improvements in life-stage-specific and smolt-to-adult survival may be achievable across a range of marine conditions through increasing spill percentages and reducing water transit times during juvenile salmon out-migration. This paper, these patterns of survival, and these key elements and results were omitted from the Welch et al. (2020) synthesis.

5.) Schaller et al. (2014) found that Snake River stream-type Chinook salmon experience substantial delayed mortality in the marine environment as a result of their outmigration experience through the Federal Columbia River Power System (FCRPS). Spatial and temporal methods consistently indicated that Snake River salmon survived about one quarter as well as the reference populations from the John Day River. Temporal analysis indicated that a high percentage (76%) of Snake River juvenile salmon that survived the FCRPS subsequently died in the marine environment as a result of their outmigration experience. They also found that delayed hydrosystem mortality increases with the number of powerhouse passages and decreases with the speed of outmigration. They recommended that a promising conservation approach would be to increase managed spill levels at the dams during the spring migration period. This paper, these patterns of survival, and these key elements and results were omitted from the Welch et al. (2020) synthesis.

6.) The Columbia River Systems Operations – Environmental Impact Statement analyses projected increases in SARs associated with freshwater management strategies. USACE et al. (2020) modeled the effects of alternative hydrosystem management strategies and projected that SARs of Snake River spring Chinook salmon would average 4.2% under the management alternative of breaching the four lower Snake River dams and increasing spill levels at the lower Columbia River dams. These results indicate that the Columbia River rebuilding targets may be achievable. This study, and the key findings and results were omitted from the Welch et al. (2020) synthesis.

The authors comparison of PIT-tag data and CWT data is misleading and reflects the authors lack of understanding of both types of data and its application

The author's neglect to address and present the considerable uncertainty associated with CWT SAR estimates. In addition, the authors do not recognize the purpose or the management application of the PIT-tag SARs in the Columbia Basin. Because PIT tags are detected and recorded without the necessity of lethal sampling of the fish, which is required for CWT recoveries, PIT tags are detected multiple times at multiple life stages and provide more extensive life history data and more precise, estimates of SARs.

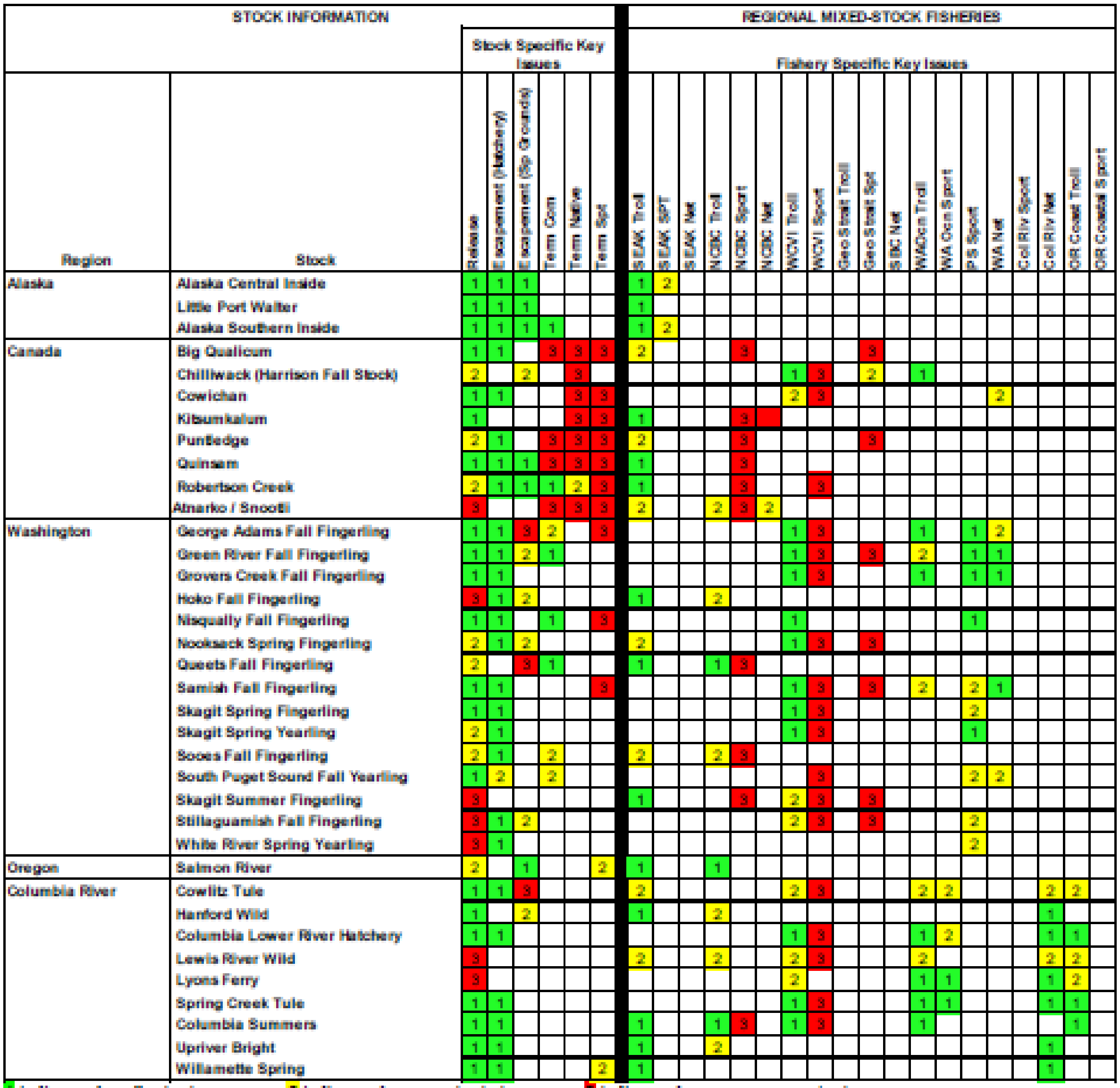
Welch et al. (2020) made no attempt to account for differences in quality and variability of CWT data that was collected over a 48-year time period and across 77 different stocks. They present CWT SARs for 77 stocks of from Southeast Alaska to Northern California. Of those, 49 stocks were attributed to PSC sources. Those PSC CWT tag groups spanned the years from 1972 to 2015 and differ greatly in quality (bias and precision) based on the ever-improving CWT marking and recapture that occurred over that time period (PSC 2015). Early data sets suffered from low release numbers, unequal recapture quality among many stocks, lack of terminal fishery monitoring, and a lack of suitable index stocks for many populations (PSC 2005). In addition, the CWT program had ever improving, but uneven, levels of recaptures and sampling of commercial, sport, and tribal harvest among stocks (PSC 2005, PSC 2015). For wild stocks, spawning ground sampling efforts, as well as stray enumeration, were uneven among the many different stocks. And yet, Welch et al. (2020) made no attempt to weight estimates by quality of data or provide any measure of variability that could be used to weight estimates with poorer precision. Treating all estimates equally in their analyses ignores the wide range of data quality that is inherent in a data set that spans 44 years and nearly 2,000 miles. Similarly, even among recently collected CWT data, there are recognized differences in levels of bias and variability based on differing commercial and sport fishery capture rates, stock release numbers, terminal capture, and spawning ground sampling, as well as effort levels in enumerating strays. Welch et al. (2020) treated these data as a monolith, when in fact efforts should have been made to either remove highly biased estimates or weight the data in a way that accounted for inherent variability in the estimates. Such a task would require detailed knowledge of the data collection, estimation methods, and sources of bias and variability.

The PSC undertook a large-scale review of the CWT data collection system beginning in 2004 (PSC 2005). That review led to a wide range of improvements to data collection for many stocks and that were found to require varying levels of improvements across managed stocks to ensure data accuracy and precision required for each stock (PSC 2008). For example, while many stocks had adequate release numbers, some were identified that required greater release numbers due to declining harvest rates. Monitoring of the impacts of improvements has been ongoing, with a great majority of stocks meeting most release and capture targets in more recent years since 2009 (PSC 2015). But those improvements do show that more recent data are likely more reliable than past data and would consequently lead to improved accuracy and lower variability in stock related harvest metrics. At the same time, the review pointed out that not all stocks are meeting the same number of goals for capture rates, so that even now, accuracy and variability in stock-related indices would differ among stocks.

Below we display figures from the PSC (2015) review of the CWT program that show the number of stocks that are meeting PSC Chinook Technical workgroup criteria release numbers and sampling in fisheries. Green squares indicate meeting all criteria in those categories, while yellow and red indicate one or more criteria are not met (respectively). Meeting those targets assures robust estimates of exploitation rates. Our use of these plots is not to be critical of the CWT program, rather to show that there was variability in the levels at which stocks were being monitored. And, that variability would impact the error on estimates of escapement, and presumably it would apply to metrics used by Welch et al. (2020) (i.e. point estimates of SAR). Comparing Figure 1 and 2 shows that, after 2009, a much higher portion of criteria for all the stocks shown were being met. These figures show that, for individual stocks, variability in survival estimates changes through time, and that among stocks, those meeting more criteria would likely have lower variability in key statistics.

The PSC in their CWT review (PSC 2008) demonstrated the importance of meeting these criteria in reducing variability around exploitation estimates, but they also considered the impacts of missing some key sampling data on the accuracy of estimates. They identified sources of possible bias, such as unsampled catches, voluntary recovery of tags in some recreational fisheries, inaccuracy in spawning estimation, and incomplete coverage of indicator stocks (especially for coho stocks). Below are some of the problems identified that could lead to biases as well as increased variability.

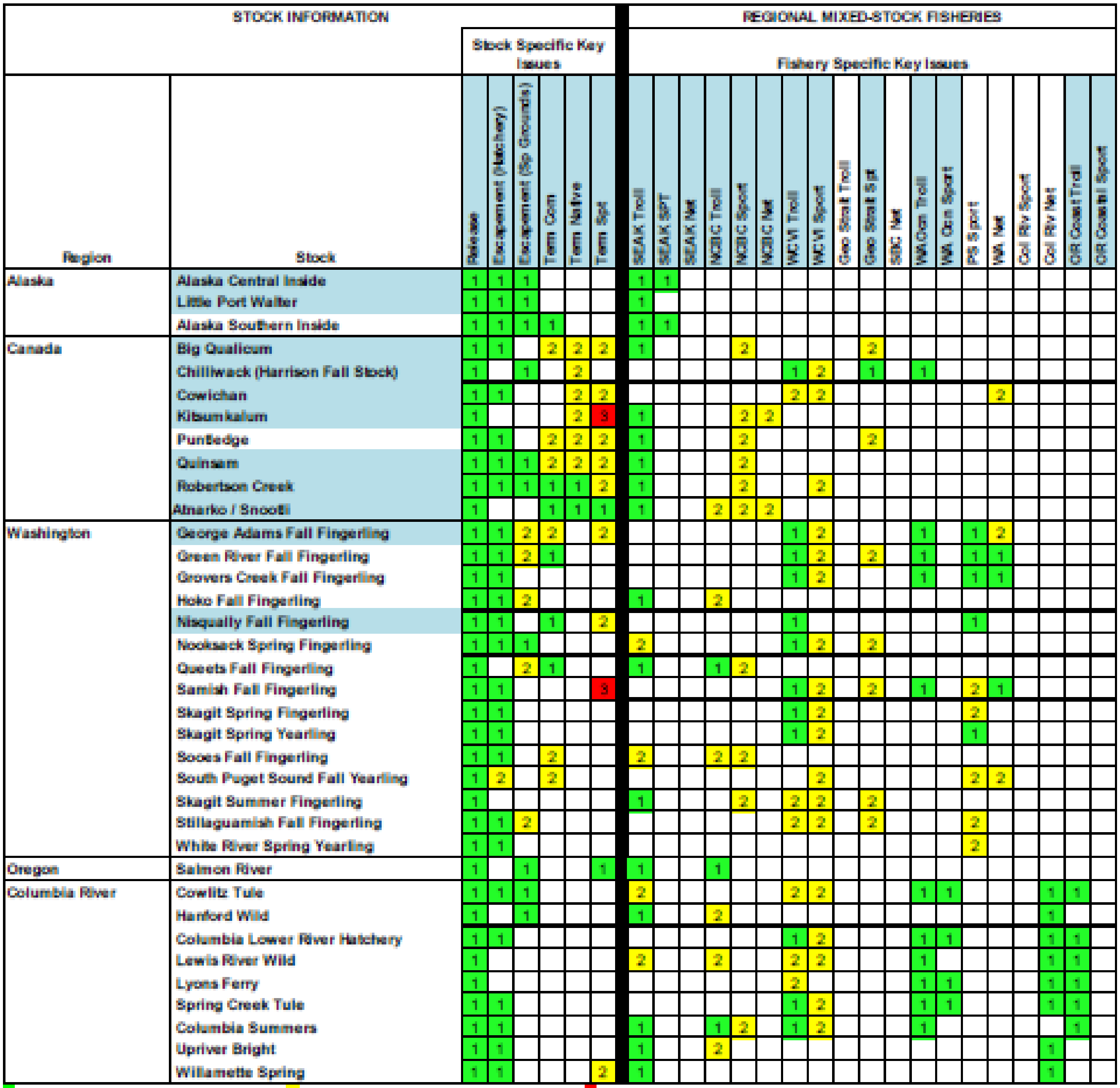
1.) Low or no sampling on spawning grounds. Low sampling rates reduce precision in estimates of tagged escapements and cohort size. No sampling underestimates cohort size causing survival to be biased low and exploitation rates (ERs) to be biased high, increasing uncertainty or adding bias to estimates of fishery ERs.
2.) Uncertainty in pre-terminal fishery impacts results when sample rates are low and few CWTs are recovered. Stocks may by missed resulting in imprecise or zero estimates of harvest and ER. This results in an inability to achieve adequate fishery resolution (lack of or insufficient tag recoveries) and imprecise estimates of ERs (low number of tag recoveries).
3.) Where the pre-terminal harvest being sampled is not known with certainty, the sample expansion is also uncertain, i.e., estimated. For example, in commercial fisheries, catches are sometimes estimated using average weights; in sport fisheries, catches are estimated through creel census programs or punch card systems. Reduced precision of the estimate of tagged fish in the harvest and of estimates of cohort size and ERs. Bias in estimates of total harvest leads to biased sample expansions. Consequently, the estimate of tagged fish will be biased, introducing bias in estimates of cohort size and ERs.
4.) All fishery or escapement locations where tagged fish are present are not sampled. Estimates of tagged fish are missing for unsampled fishery or escapement strata. Therefore, estimates of cohort size and ERs are biased, generally overestimated, or zero.



STOCK INFORMATION								REGIONAL MIXED-STOCK FISHERIES																		
		Stock Specific Key Issues						Fishery Specific Key Issues																		
Region	Stock	Release	Escapement (Hatchery)	Escapement (Sp Grounds)	Term Com	Term Native	Term Spt	SEAK Troll	SEAK SPT	SEAK Net	NCBC Troll	NCBC Sport	NCBC Net	WCVI Troll	WCVI Sport	Geo Strait Troll	Geo Strait Spt	SBC Net	WAOcn Troll	WA Ocn Sport	PS Sport	WA Net	Col Riv Sport	Col Riv Net	OR Coast Troll	OR Coastal Sport
Alaska	Alaska Central Inside	1	1	1				1	2																	
	Little Port Walter	1	1	1				1																		
	Alaska Southern Inside	1	1	1	1			1	2																	
Canada	Big Qualicum	1	1		3	3	3	2				3					3									
	Chilliwack (Harrison Fall Stock)	2		2		3								1	3		2		1							
	Cowichan	1	1			3	3							2	3							2				
	Kitsumkalum	1				3	3	1				3	🟥													
	Puntledge	2	1		3	3	3	2				3					3									
	Quinsam	1	1	1	3	3	3	1				3														
	Robertson Creek	2	1	1	1	2	3	1				3			3											
	Atnarko / Snootli	3			3	3	3	2			2	3	2													
Washington	George Adams Fall Fingerling	1	1	3	2		3							1	3				1		1	2				
	Green River Fall Fingerling	1	1	2	1									1	3		3		2		1	1				
	Grovers Creek Fall Fingerling	1	1											1	3				1		1	1				
	Hoko Fall Fingerling	3	1	2				1			2															
	Nisqually Fall Fingerling	1	1		1		3							1							1					
	Nooksack Spring Fingerling	2	1	2				2						1	3		3									
	Queets Fall Fingerling	2		3	1			1			1	3														
	Samish Fall Fingerling	1	1				3							1	3		3		2		2	1				
	Skagit Spring Fingerling	1	1											1	3						2					
	Skagit Spring Yearling	2	1											1	3						1					
	Soos Fall Fingerling	2	1		2			2			2	3														
	South Puget Sound Fall Yearling	1	2		2										3						2	2				
	Skagit Summer Fingerling	3						1				3		2	3		3									
	Stillaguamish Fall Fingerling	3	1	2										2	3		3				2					
	White River Spring Yearling	3	1																		2					
Oregon	Salmon River	2		1			2	1			1															
Columbia River	Cowlitz Tule	1	1	3				2						2	3				2	2				2	2	
	Hanford Wild	1		2				1			2													1		
	Columbia Lower River Hatchery	1	1											1	3				1	2				1	1	
	Lewis River Wild	3						2			2			2	3				2					2	2	
	Lyons Ferry	3												2					1	1				1	2	
	Spring Creek Tule	1	1											1	3				1	1				1	1	
	Columbia Summers	1	1					1			1	3		1	3				1						1	
	Upriver Bright	1	1					1			2													1		
	Willamette Spring	1	1				2	1																1		

1 indicates that all criteria were met; 2 indicates that one criteria is not met; 3 indicates that two or more criteria are not met

Figure 1. Figure 3.1 from PSC 2015 showing evaluation of release and sampling criteria for Chinook salmon.



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Region	Stock	Release	Escapement (Hatchery)	Escapement (Sp Grounds)	Term Com	Term Native	Term Spt	SEAK Troll	SEAK SPT	SEAK Net	NCBC Troll	NCBC Sport	NCBC Net	WCVI Troll	WCVI Sport	Geo Strait Troll	Geo Strait Spt	SBC Net	WA/Ocn Troll	WA Ocn Sport	PS Sport	WA Net	Col Riv Sport	Col Riv Net	OR Coast Troll	OR Coastal Sport
Alaska	Alaska Central Inside	1	1	1				1	1																	
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	Kitsumkalum	1				2	3	1				2	2													
	Puntledge	1	1		2	2	2	1				2					2									
	Quinsam	1	1	1	2	2	2	1				2														
	Robertson Creek	1	1	1	1	1	2	1				2			2											
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	Skagit Spring Yearling	1	1											1	2						1					
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	White River Spring Yearling	1	1																		2					
Oregon	Salmon River	1		1			1	1			1															
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	Hanford Wild	1		1				1			2													1		
	Columbia Lower River Hatchery	1	1											1	2				1	1				1	1	
	Lewis River Wild	1						2			2			2	2				1					1	1	
	Lyons Ferry	1												2					1	1				1	1	
	Spring Creek Tule	1	1											1	2				1	1				1	1	
	Columbia Summers	1	1					1			1	2		1	2				1						1	
	Upriver Bright	1	1					1			2													1		
	Willamette Spring	1	1				2	1																1		

1 indicates that all criteria were met; 2 indicates that one criteria is not met; 3 indicates that two or more criteria are not met

Figure 2. Figure 3.2 from PSC 2015 showing evaluation of release and sampling criteria for Chinook salmon for years 2009 and later, indicating improvements relative to Figure 1 (above).

The authors have misrepresented Pacific Salmon Commission and Chinook Technical Committee (CTC) data sources. The CTC does not maintain a smolt-to-adult-return database, contrary to the authors statements.

The authors state that the CWT SAR data source was from the Pacific Salmon Commission (PSC) Chinook Technical Team (CTC). However, consultation with the PSC CTC chairperson revealed that the CTC does not compute SARs in any of their analyses and no such database exists. CTC does not maintain a database of smolt-to-adult return rates based on CWT data. The attribution of the CWT SARs to the CTC is not accurate. Furthermore, the CTC chairperson advised that the authors assigned incorrect smolt-ages for three stocks (NSF, SKF and SQP). The CTC expressed serious concerns with how the CTC data were characterized in the Welch et al. (2020) paper. The CTC uses and maintains various data sources that contain the information necessary to calculate the SARs calculated in Welch et al 2020, as they are defined in the paper, but they were not developed for this purpose. According to the CTC chair, no current CTC members were afforded the opportunity to review Welch et al.'s 2020 manuscript prior to publication.

Welch et al. (2020) define the smolt to adult return rate (SAR) as "the threefold product of freshwater smolt survival during downstream migration multiplied by the marine survival experienced over two to three years in the ocean and multiplied by adult freshwater survival during the upstream migration to the final census point." It is important to recognize that this definition of the SAR includes the combined impacts of freshwater and marine survival factors, and does not separate the effects of the two environments. Therefore, the characterization that SARs only reflect marine processes is a mischaracterization. The CWT recovery data used by the Pacific Salmon Commission (PSC) Chinook Technical Committee (CTC) are not compatible with this definition of SARs and the CTC does not use their CWT recovery data to calculate SARs. CWT recoveries in ocean fisheries overestimate survival to adult return because these data represent harvest mortality (not survival to adult return in terminal areas) and the natural mortality that occurs in the marine environment prior to adult return in freshwater is not incorporated. CWT recoveries in freshwater also likely underestimate survival to adult return because straying and enumeration of hatchery fish on spawning grounds is often incomplete.

The authors conflate fall Chinook and spring Chinook and misrepresent the Northwest Power and Conservation Council regional 2% to 6% SAR goals. The authors ignore the fact that these two different races of Chinook salmon have different life histories and have a very different presence in ocean fisheries.

While Welch et al (2020) referenced early work by Marmorek et al. (1998) regarding the 2-6% SAR goal they failed to take into account multiple years of analyses on Snake River populations published in CSS reports such as Chapter 5 of McCann et al. (2018). In those reports, the CSS demonstrates the applicability of those SAR targets to the Snake River wild spring/summer Chinook and steelhead. The SAR goal applies to populations in a very specific life segment and takes into account population productivity in spawning areas. A SAR target appropriate for Snake River spring summer Chinook salmon, measured through a very specific life phase, was not developed for, and is not appropriately applied to, CWT populations up and down the Pacific Coast. It is extremely difficult to match the exact life stage and mortality that populations would have occurred prior to entry into that life stage and subsequent to it. Mortality prior to the upper dam and terminal fisheries are different throughout the various river systems.

The CSS and others do not consider the 2-6% SAR goal appropriate for fall Chinook due to known impacts of high ocean harvest. And yet, Welch el al. (2020) use those targets for fall Chinook as if they are applicable. This shows a willingness to make sweeping generalizations without carefully considering the available information within an individual basin. Welch et al. (2020) make assumptions about SAR goals and then make conclusions based on a lack of information. For example, they state in their discussion section regarding the importance of ocean harvest "Unfortunately, what went unrecognized was the effect on the many Columbia River studies based on PIT tags." However, the CSS, recognizing the importance of ocean harvest for fall Chinook salmon, does not consider the 2-6% SAR goal appropriate for fall Chinook. This lack of understanding of CSS PIT-tag analyses makes these broad concluding statements nonsensical.

The authors have carefully selected data and analyses in an attempt to support their conclusions. They fail to include a significant body of analyses that actually include ocean conditions, and fresh water conditions and the importance of these variables in resulting survival of chinook salmon. These analyses which are ignored by the authors, conclude that the fresh water life stage environment affects survival to adult.

Important studies on the effects of environmental factors on freshwater survival, ocean survival, and SARs were ignored (Haeseker et al. 2012, McCann et al. 2018, Michel et al. 2015, Cordoleani et al. 2018, Michel 2019). The paper provides no quantitative analysis to refute the results of Haeseker et al. (2012) or McCann et al. (2018) on the importance of environmental factors for explaining patterns in freshwater survival, ocean survival, and SARs. The authors fail to recognize the documented correlations between freshwater and marine survival (Haeseker et al. 2012) or the associations between freshwater environmental conditions and marine survival and SARs (Petrosky and Schaller 2010, Haeseker et al. 2012, Schaller et al. 2014, Michel 2019).

Comparisons of SARs are conducted across different populations, with different freshwater environments, with different ocean entry locations and associated marine growth and survival conditions, experiencing different harvest levels, that were calculated in different ways and that have different assumptions. Welch et al. (2020) made no attempts to account-for or control-for the numerous environmental factors and management factors that influence smolt-to-adult survival. Visual inspection of the plots and fitted loess curves presented in Figure 2 of Welch et al. (2020) is used to assess temporal patterns in smolt-to-adult survival (SAR). For the CW tag-based SARs, important considerations of temporal patterns in fisheries effort, harvest, and efforts to recover tags in tributaries, spawning grounds, or at hatcheries are not addressed. There have been long-term declines in harvest in many of the ocean and tributary fisheries along the West Coast of North America, and these changes may have influenced the likelihood that CW tags were recovered and entered into the PSC or Regional Mark Information System (RMIS) databases. There have been changes in fisheries management to shift to mark-selective fisheries, which would influence the recovery rates of adipose-clipped fish (hatchery-reared) compared to adipose-intact fish (wild stocks and some hatchery stocks). There have also been changes to hatchery rearing practices over time such that many hatcheries have transitioned to only releasing adipose-clipped smolts, while some hatcheries release a combination of adipose-clipped and adipose-intact smolts, and others release only adipose-intact smolts. Several of the stocks listed in Table S1 that rely on CW tags for calculating SARs are wild stocks. As a result, some form of sampling program would be required to determine the number of tagged adults returning to tributaries to obtain a valid estimate of the number of returning adults. In addition, adipose-intact adults in mark-selective fisheries would not be sampled and would therefore not be listed as fishery recoveries in the PSC or RMIS databases. Hatcheries may or may not sample for CW tags depending on the objectives of the hatchery.

All of these factors have the potential to influence the apparent CW tag-based SARs presented in Welch et al.'s (2020) Figures 2 and 3. Because these confounding issues were not taken into account, it is not possible to determine whether changes over time for the CW tag-based SARs are due to a true reduction in survival or some other factor(s). For the PIT tag-based SARs, there are important differences between stocks in terms of the locations for enumerating smolts and adults, differences across stocks as to whether jacks were or were not included, and differences in the number of stocks that are available for estimating SARs over time that complicate comparisons among stocks. These issues aside, there is no evidence among the PIT tag-based data indicating a recent "collapse" in SARs of subyearling or yearling Chinook salmon from the Columbia River Basin, contradicting the title of Welch et al. (2020). The PIT tag-based data from the Columbia River Basin indeed indicate that the Snake and Upper Columbia populations that pass through 7-8 dams have persistently low SARs while the Mid-Columbia populations that pass through 3-4 dams have SARs that are much higher and are meeting or close-to-meeting regional survival goals (McCann et al. 2018, Schaller et al. 2014). Important research and management questions include evaluating the environmental and management factors that are influencing these patterns of survival, which has been a focus of research and monitoring within the Columbia River Basin (Petrosky and Schaller 2010, Haeseker et al. 2012, Schaller et al. 2014, McCann et al. 2018). Unfortunately, Welch et al. (2020) do not contribute answers to these questions and provides no analyses to examine freshwater or marine factors associated with these patterns of survival within the Columbia River Basin or elsewhere.

Quantitative analyses of the data sets collated by the authors in this study do not support their conclusions of a coast-wide decline of Chinook salmon survival, that broad oceanic factors are a primary driving force in coast-wide survival of Chinook salmon, or that the SARs of Snake River spring Chinook populations are higher than estimates reported from many other regions of the west coast lacking dams.

Little evidence that broad oceanic factors are a primary driving force in coast-wide survival of Chinook salmon

Welch et al. (2020) claim, "most of the salmon conservation problem is determined in the ocean by common processes," but did not conduct an analysis to test this claim. To evaluate the level of support in the CWT data for this claim, we fit an analysis of variance model with stock and year effects to the collated SAR data used in the Welch et al (2020) paper. We first log-transformed the SAR data collated by Welch et al. (2020) to meet the normality assumption of analysis of variance. If Chinook salmon survival across the West Coast is determined in the ocean by common processes, we would expect that common year effects would explain a substantial portion of the variability in SARs. We found that common year effects explained only 14% of the variation in SARs, indicating little support for the claim that common ocean processes are a primary driver of Chinook salmon survival along the West Coast. Stock effects explained 35% of the variation in SARs, indicating that stock-specific factors explained more than twice the amount of variation in SARs compared to common year effects. Most of the variation in SARs (51%) was unexplained after accounting for stock and common year effects. Thus, the CWT data collated by Welch et al. (2020) provide little support for the claim that "most of the salmon conservation problem is determined in the ocean by common processes".

No evidence of a coast-wide decline in Chinook salmon survival

Welch et al. (2020) claim "most regions of west coast North America with CWT time series extending back prior to the 1978 regime shift show an approximate threefold decrease in SARs for hatchery populations" and that "overall, Chinook salmon survival (SAR) has decreased by roughly the same amount everywhere along the west coast of North America," but did not conduct a quantitative analysis to test these claims. To evaluate the level of support in the CWT data for this claim, we fit linear trend (regression) models of the CWT SAR data versus smolt outmigration year for each stock. We first log-transformed the SAR data collated by Welch et al. (2020) to meet the normality assumption of regression analysis. We tested whether the estimated slope coefficient for the effect of time was significantly different from zero ($p < 0.05$). Of the 77 Chinook salmon stocks collated by Welch et al. (2020), 51 stocks (66.2%) showed no significant temporal trend in SARs. Eleven stocks (14.3%) showed significant increases in SARs over time and 15 stocks (19.5%) showed significant decreases in SARs over time. Four of the stocks that showed significant declines over time were hatchery Snake River spring Chinook, wild Snake River spring Chinook, wild Snake River summer Chinook, and wild upper Columbia River summer Chinook (Figure 3, data from Raymond 1988). These stocks declined during the period of dam construction and operation, and Raymond (1988) attributed these declines to the construction and operation of the dams (Figure 3). Most of the time series for the other Columbia River Basin stocks began after the completion of the hydrosystem and therefore could not measure the effects of dam construction and operation. Thus, the SAR data collated by Welch et al. (2020) are not consistent with, and do not support, their claims. The majority of stocks showed no significant temporal trends over time, and a similar, lower proportion of stocks showed increasing trends over time and decreasing trends over time. Four of the 15 stocks that indicated declines over time were from the Columbia River Basin and coincided with dam construction and operation, illustrating the detrimental impacts of the dams on Chinook salmon survival in the Basin.

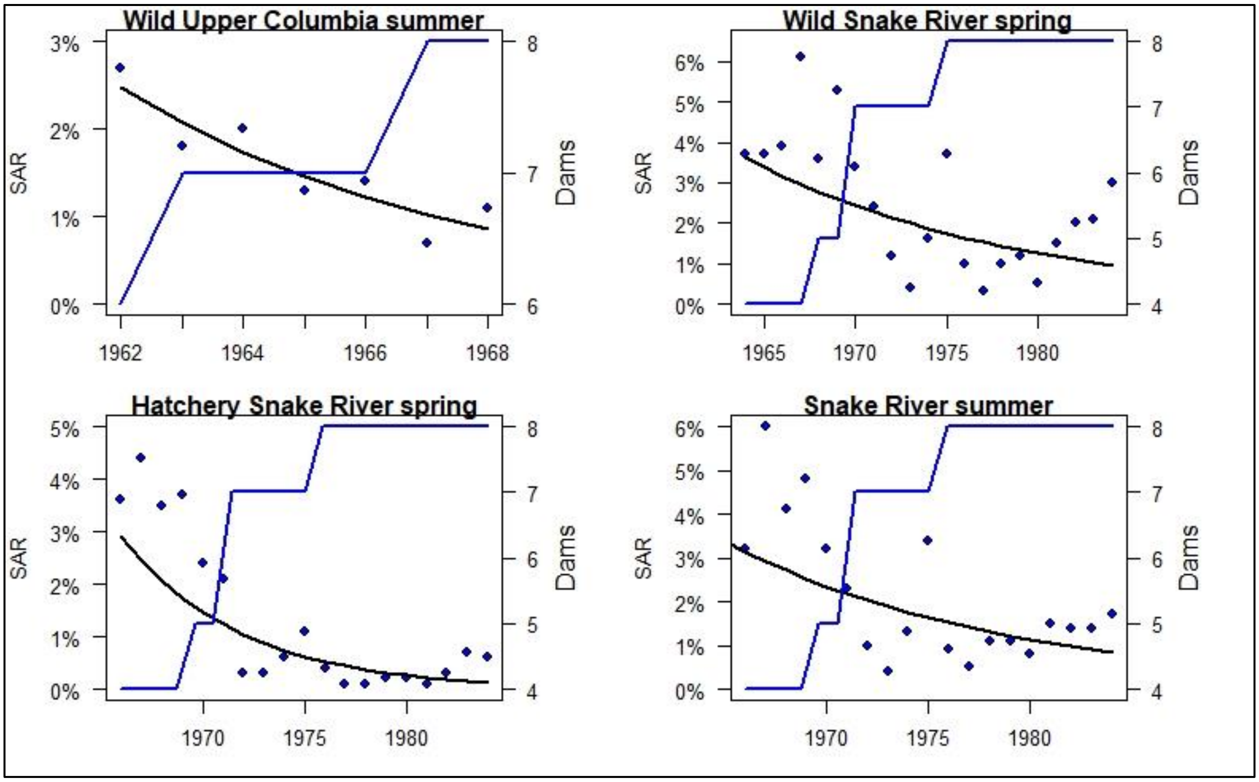

Figure 3. SARs for Upper Columbia summer Chinook, wild Snake River spring Chinook, hatchery Snake River spring Chinook, and Snake River summer Chinook (points) and fitted regression trend lines that indicated a significant decline in SARs over time. Blue lines represent the number of dams in place during each smolt outmigration year.

No evidence that the SARs of Snake River spring Chinook populations are higher than estimates reported from many other regions of the west coast lacking dams.

Welch et al. (2020) claim that "the SARs of Snake River populations, often singled out as exemplars of poor survival, are unexceptional and in fact higher than estimates reported from many other regions of the west coast lacking dams." To quantitatively assess their claim, we compared the Welch et al. (2020) SARs for yearling spring Chinook from other regions to those from the Snake River, aligning the data by smolt out-migration years. For each pair of stocks, we calculated the SAR ratio:

$$SAR\ ratio_{i,j,y} = \frac{SAR_{i,y}}{SAR_{j,y}}$$

where $SAR_{i,y}$ is the SAR from one of the *i* stocks in other regions in smolt out-migration year *y* and $SAR_{j,y}$ is the SAR from one of the *j* stocks in the Snake River in smolt out-migration year *y*. Values of the SAR ratio above 1 indicate higher SARs for the other stocks compared to the Snake River stocks and values near 1 indicate similar SARs. Under the claim of Welch et al. (2020), we would expect that the SAR ratios would be near or below 1. We applied t-tests to assess whether the means of the ratios were significantly different from 1. To meet the normality requirement of the tests, we first applied a log-transformation to the SAR ratios and equivalently tested whether the mean of the log-transformed ratios was equal to 0 for each stock pair.

We found that the SARs for yearling spring Chinook salmon from most other regions and stocks were substantially higher than the Snake River stocks (Table 1). SARs from the Alaska hatchery stocks averaged 6.7 times those of the Snake River stocks and the SARs for wild stocks from Alaska averaged 2.5 to 4.4 times those of the Snake River stocks. In Puget Sound, the SARs for the Skagit hatchery stock averaged 2.4 times those of the Snake River stocks and the SARs for the Nooksack hatchery stock averaged 1.2 times the Snake River stocks. In the Strait of Georgia, the SARs for the Nicola hatchery stock averaged 1.5 times those of the Snake River stocks. In the lower Columbia River, the SARs of the Willamette hatchery stock averaged 2.3 times those of the Snake River stocks. Only the White River hatchery and the Dome hatchery stocks displayed SAR ratios that averaged less than 1. The majority of spring Chinook stocks collated by Welch et al. (2020) demonstrate significantly higher SARs than the Snake River stocks, particularly those hatchery and wild stocks from the southeast Alaska region that are not impacted by dams. These data show that their claim that "the SARs of Snake River populations, often singled out as exemplars of poor survival, are unexceptional and in fact higher than estimates reported from many other regions of the west coast lacking dams" is demonstrably false for spring Chinook salmon.

Table 1. Mean SAR ratios for yearling spring Chinook salmon stocks from the southeast Alaska (SEAK), Puget Sound (PS), Strait of Georgia (SOG), and the lower Columbia River (LCOL) regions for hatchery (H) and wild (W) stocks collated by Welch et al. (2020). Snake River stocks are listed in the far-left column. Bolded values indicate that the ratios were significantly greater than 1 ($p < 0.05$) and the average of the ratios across Snake River stocks is presented at the bottom of each column. Blank cells represent combinations where there was insufficient data to calculate the SAR ratios.

Snake River Stock	**SEAK Alaska (H)**	**SEAK Chilkat (W)**	**SEAK Stikine (W)**	**SEAK Taku (W)**	**SEAK Unuk (W)**	**PS Skagit (H)**	**PS Nooksack (H)**	**PS White (H)**	**SOG Nicola (H)**	**SOG Dome (H)**	**LCOL Willamette (H)**
Snake (H) Raymond	**19.3**			**5.1**							**5.4**
Snake (W) Raymond	**3.3**			0.9							0.9
Catherine Creek (H)	**5.1**	**2.5**	**2.9**	**3.9**	**2.2**	**2.4**		0.9	1.1		**1.6**
Imnaha (H)	**4.8**	1.5	1.5	**4.1**	**2.4**	1.4	0.9	0.5	1.4	0.9	**1.8**
Lookinglass (H)	**2.8**	1.3	1.9	2.0	1.3	1.7		0.6	0.9		1.0
Lostine (H)	**2.5**	1.4	1.6	**2.2**	1.2	1.2		0.5	0.6	**0.2**	0.9
Tucannon (H)	**11.3**	**6.3**	**6.3**	**13.2**	**5.7**	**4.9**	1.5	1.7	**4.1**	**2.1**	**5.0**
Grande Ronde (H)	**4.6**	**2.3**	**2.6**	**3.5**	1.9	**2.4**		0.9	1.0	0.4	1.5
Average:	6.7	2.5	2.8	4.4	2.5	2.4	1.2	0.9	1.5	0.9	2.3

There is no doubt that the ocean is important and affects numbers of returning adults. However, the number of smolts that enter the ocean is dependent on freshwater survival and management strategies that result in the highest freshwater survival, because not even the best ocean conditions can resurrect a dead fish.

Ocean productivity is recognized as an important factor affecting SARs. Downward trends in SARs could indicate increased harvest or decreased ocean productivity or both. If it is due to poorer ocean conditions, it only increases the need for maximizing freshwater survival. The Pacific Salmon Commission (PSC) recognized this in their recent review of habitat effects on salmon survival (PSC 2012). They stated

> *"There is no question that productive freshwater and estuarine habitats help sustain populations during periods of adverse marine conditions, by maximizing the number of smolts produced per spawner. Therefore, populations from healthy*

> *and productive watersheds and estuaries that produce higher numbers of smolts per spawner would be expected to experience smaller declines during poor ocean conditions, and recover at a faster rate if and when ocean conditions improve."*

Welch et al. (2020) concludes that all Pacific salmon stocks are declining and that any effort to improve freshwater survival is useless. However, there are examples, within the populations he evaluates, of freshwater habitat improvements leading to population level improvements. One example is from Canada (Cowichan River) where fine sediments were removed, and populations improved. The Cowichan River stock of Chinook have shown improved escapement (significantly above escapement goals) in the past 4 years (2015 to 2019). According to a PSC report (PSC 2020) "A large scale habitat restoration project conducted in 2006 at Stoltz Bluff significantly reduced fine sediment inputs to the lower 25 km. Considerable focus has also been put on water management in recent years." The Cowichan River is but one example where emphasis on watershed improvements have led to increased escapement, directly contradicting the premise of Welch et al (2020). Multiple studies have demonstrated the impacts of dam passage and operations in the Columbia River Basin on subsequent ocean survival and SARs (Budy et al. 2002, Haeseker et al. 2012, Schaller and Petrosky 2007).

The analytical techniques and underlying data used by the authors are inappropriate, misleading, and unreliable

The conclusions that Welch et al. (2020) make about salmon productivity are far reaching, in direct contrast to the broad body of literature showing that freshwater and early ocean experience explains large amounts of variability in survival rates (Petrosky and Schaller 2010, Michel 2019, McCann et al 2019, Petrosky et. al. 2020). With such immoderate and outlying conclusions, it is incumbent upon the authors to support them with equally robust and compelling evidence. Welch et al (2020) clearly do not provide such evidence. One striking example is that of Figure 4 (Welch et al. 2020) which displays the results of a simulation intended to compare survival rates of salmon populations from California to Alaska. However, we found major errors and omissions in the underlying methodology, data, and subsequent conclusions reached therein.

As previously discussed, there are significant and substantial differences between how SARs using CWTs are calculated between hatchery programs, basins, and agencies. As such, there is a considerable degree of uncertainty surrounding each estimate that renders comparisons across such a large geographical range and disparate methodologies incomprehensible. After examining the code Welch et al. (2020) used for this analysis, it became clear that all associated uncertainty in these estimates was completely overlooked and omitted. Drawing any kind of conclusions based on such highly uncertain estimates renders any conclusions of this paper exceptionally tenuous.

Even under the problematic assumptions that the CWT SAR values collated by Welch et al. (2020) were broadly comparable and that the uncertainties inherent in each estimate were accounted for, the methodology used to replicate and compare these datasets is highly flawed. Welch et al. (2020) use a five-year time series to compare SARs between regions, stating:

> *"We chose this time period because there was a consistent number of populations contributing to each regional grouping used in the comparison period (2014 being the last year with essentially complete data available for all populations) … Limiting the samples to this period ensured the data were current and removed the potential variability due to differing lengths of the time series."* – Welch et al. (2020) page 5

However, when we examined the data and code used for their comparison of observations, it becomes immediately clear that truncating the time frame does nothing to lessen variability, contrary to statements by the authors. Not only are the time series unequal between regions, (e.g., CA and WAC only have SAR estimates for 2010-2012), but the number of population SAR estimates also varies between years within regions (Table 2) and between region - smolt age - rearing group comparisons (Table 3). The sample sizes in these groups are concerningly unbalanced and small varying from 0 to 11 in Table 2 and from 3 to 49 in Table 3, despite the fact that these groups were visually weighted equally with uniform confidence estimates. It is worthwhile to note that replication methods, such as those used in this paper often lose reliability with very small sample sizes (Chernick 2008).

Table 2. Number of yearling and subyearling SAR estimates by year and region examined in Welch et al (2020)

	CA	LCOL	MCOL	NCBC	ORC	PS	SEAK	SNAK	SOG	UCOL	WAC	WCVI
2010	3	4	8	2	2	11	5	11	11	3	2	1
2011	3	4	8	2	2	11	5	11	11	3	2	1
2012	3	4	8	2	2	11	5	11	11	3	2	1
2013	0	4	8	2	2	10	5	11	11	3	0	1
2014	0	0	5	2	0	3	5	2	10	2	0	1

Table 3. Number of observations per region-smolt age-rearing group comparisons used in Figure 4 used in Welch et al. 2020

Obs.	Region	SmoltAge	Rear	count
1	CA	Subyearling	H	6
2	CA	Yearling	H	3
3	LCOL	Subyearling	H	8
4	LCOL	Subyearling	W	4
5	LCOL	Yearling	H	4
6	MCOL	Subyearling	H	13
7	MCOL	Subyearling	W	4
8	MCOL	Yearling	H	20
9	NCBC	Subyearling	H	5
10	NCBC	Yearling	H	5
11	ORC	Subyearling	H	8
12	PS	Subyearling	H	38
13	PS	Yearling	H	8
14	SEAK	Yearling	H	5
15	SEAK	Yearling	W	20
16	SNAK	Subyearling	H	16
17	SNAK	Yearling	H	25
18	SNAK	Yearling	W	5
19	SOG	Subyearling	H	49
20	SOG	Yearling	H	5
21	UCOL	Subyearling	H	4
22	UCOL	Yearling	H	10
23	WAC	Subyearling	H	6
24	WCVI	Subyearling	H	5

Within the random sampling methodology used by Welch et al. (2020), there was also no attempt to control for any type of year effect:

> "*We pooled all data in the 2010–2014 ocean entry period across all populations in a region and then resampled the pooled data with replacement N = 10,000 times, each time drawing a sample of the same size as the original pooled data*." – Welch et al. (2020) page 5

In their replication process, all estimates were drawn at random within each region, smolt age, and rearing group, then those values from the 2010-2014 period were normalized against the median value of the Snake River data for comparison. Therefore, in some regions these medians represent only median conditions for three years, while in others they represent median conditions for five. The unbalanced sample size between years also skews the expected draws within regions, weighting SAR to years that are more heavily represented within the sampling distribution. For example, drawing at random from the 2010-2014 SAR distribution for the Snake River (N=46), a SAR value from ocean entry year 2012 would be 5.5 times more likely to be drawn than an SAR value from 2014. Due to the sometimes large interannual variability in SARs, this would heavily skew the resulting estimates, especially considering Snake River Chinook SARs were relatively poor in 2014 (McCann et al. 2019).

Similarly, the lack of any attempt to include or evaluate a year effect within the Welch et al. (2020) analysis significantly dilutes the level of insight we can obtain from the visual comparisons presented in Figure 4 of Welch et al. (2020). The authors' single biggest contention is that marine conditions are primarily responsible for the variability in SARs both within and between regions. However, due to the unbalanced nature of the data used in their simulation, those conditions would be overrepresented in some years and groups and underrepresented in others, purely as a function of their analytical design. Without controlling for individual year effects in their simulation, the confounding nature of their primary contention biases their own results and subsequent conclusions.

Finally, the authors make no attempt to quantitatively link marine conditions to the variability in observed survival rates, nor any attempt to decouple freshwater and marine contributions from overall SARs. With such a truncated time series, it is likely this may not have been possible. However, with such broad and novel conclusions that contradict the large body of evidence in the published literature on this topic, it is surprising that no attempt at defining a quantitative link between marine conditions and SARs across regions was made. Its lack thereof should inform how credible we consider the resulting conclusions.

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