A Review of Indirect Methods Used in Estimation of Chinook Salmon Exploitation Rates and Recommendations for Improvement

Pacific Salmon Commission Calendar Year
Exploitation Rate Working Group

September 2021

Pacific Salmon Commission Technical Report No. 46

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List of Acronyms and Abbreviations

AABM	Aggregate Abundance-Based Management
ADF&G	Alaska Department of Fish & Game
CDFO	Fisheries and Oceans Canada
CRITFC	Columbia River Inter-Tribal Fish Commission
CTC	Chinook Technical Committee
CWT	Coded-Wire Tag
CWTIT	Coded-Wired Tag Implementation Team
CYER	Calendar Year Exploitation Rate
EIS	Escapement Indicator Stock
ER	Exploitation Rate
ERA	Exploitation Rate Analysis
ERIS	Exploitation Rate Indicator Stock
HR	Harvest Rate
ISBM	Individual Stock-Based Management
MRP	Mark Recovery Program
NEVI	Northeast Vancouver Island
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
NWVI	Northwest Vancouver Island
ODFW	Oregon Department of Fish and Wildlife
PFMC	Pacific Fishery Management Council
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fish Commission
RMIS	Regional Mark Information Systems
SFEC	Selective Fisheries Evaluation Committee
SWVI	Southwest Vancouver Island
TAM	Terminal Area Adjustments
TNF TERM S	North of Falcon Terminal Sport
TWAC FN	Terminal Washington Coast Freshwater Net
WA CST N	Washington Coastal Net
WDFW	Washington Department of Fish and Wildlife

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Executive Summary

In 2018 the Pacific Salmon Commission (Commission) requested the assistance of management entities in completing a Readiness Questionnaire to identify any gaps in coded-wire-tag (CWT) and associated fishery and stock assessment programs (Reid and Oatman 2018). The Commission subsequently tasked the Calendar Year Exploitation Rate Work Group (CYER WG) with identifying opportunities for collaboration to address the identified data gaps. A conclusion of the work group was that "multiple types of indirect methods are used or have been proposed to estimate CWT recoveries, but limited testing of assumptions has occurred, and bilateral guidance on the application of indirect methods is lacking" (CYER WG 2019a).

The work group issued four recommendations associated with this conclusion:

A. ***Proxy Methods.*** Task a workgroup with providing recommendations on the application of proxy methods and identifying priority fisheries for transition to direct estimation of CWT recoveries.

B. ***Review Terminal Area Adjustments***. Request that the Chinook Technical Committee (CTC) accelerate the completion of Appendix A, task 5 (documentation of methods used to adjust the CWT recoveries for the Robertson Creek, Quinsam River, Queets River, Salmon River, and Elk River CWT indicator stocks), recommend improvements, and identify any research necessary to verify assumptions.

C. ***Ensure Impacts Assessed in all Fisheries.*** Ensure that in each fishery in which a CWT indicator stock is caught that either estimated recoveries are reported, or a technically agreed indirect method is used to provide a best estimate of the CWT recoveries.

D. ***Puget Sound Freshwater Sport.*** Complete the analysis and document the results from the testing of indirect methods in Puget Sound freshwater sport fisheries funded through the Coded Wire Tag Improvement Program.

In October 2019, the Commission tasked the CYER WG to address these recommendations. Although indirect methods are used in both catch and escapement estimation, the CYER WG limited its work to fishery applications to align with the scope of the CYER WG recommendation. The conclusions and recommendations from this work are summarized here.

A. Proxy Methods

We requested that management entities identify fisheries throughout the Pacific Salmon Treaty area where proxy methods are implemented. Fisheries of greatest concern were identified through a risk assessment framework that included the number of indirectly estimated recoveries and a qualitative assessment of the potential bias in the indirect method applied.

> **Conclusion 3.1. Proxy methods are widely used to estimate CWT recoveries and have the potential to introduce a substantial bias into estimates of CYERs.**
>
> > ***Recommendation 3.1.1.*** *Encourage management entities to address the limitations in fishery and stock assessment programs that result in the application of proxy methods. Increasing the proportion of strata for which CWTs are directly estimated will decrease the amount to which these fisheries are influenced by bias due to reliance on proxy methods. For fisheries relying on proxy methods to estimate total catch, options include expanding*

coverage of established catch estimation surveys or use of new survey types (e.g., internet-based surveys). For fisheries relying on proxy sources of CWT composition information, CWT sampling surveys should be established where possible.

Recommendation 3.1.2. *Prioritize funding to initiate improved fishery and stock assessment programs where the use of the proxy methods poses the greatest risk to accurate estimation of CYERs. These fisheries include the Central Sport, North Georgia Strait Sport, Canadian Juan de Fuca Sport, South Georgia Strait Sport, and Lower Fraser River Net.*

Recommendation 3.1.3. Where resource or other constraints prevent the continuous application of direct methods, encourage management entities to conduct studies to assess the accuracy of the proxy method and apply any appropriate bias correction procedures.

We subjectively assessed each proxy method relative to the potential risk of introducing bias.

Conclusion 3.2. The risk of bias introduced by the application of a proxy method depends in part on the particular method applied. All methods were assessed as having a moderate or high level of risk of introducing bias.

Recommendation 3.2.1. *Where proxy methods must be applied because of resource constraints or unanticipated gaps in catch estimates or sampling, apply proxy methods that have the lowest risk of introducing bias. Selection of the appropriate proxy method will be context-specific. The two proxy methods that are generally likely to have the least risk of introducing bias are: 1) application of submission rates from an adjacent time or area; or 2) application of tag composition from an adjacent fishery or escapement stratum.*

Recommendation 3.2.2. *Support the continued development, testing, and evaluation of proxy methods by management entities and by the CTC. Options to evaluate proxy methods include field studies that implement and test alternative methods, assessment of proxy methods on a post-hoc basis (i.e., "What would have happened if we applied this proxy method?"), and simulation analyses.*

B. Review Terminal Area Adjustments

Attachment I of Chapter 3 identifies 11 escapement indicator stocks for which an adjustment of the terminal area harvest rate of the associated CWT indicator stock will be applied. The CYER WG (2019a) previously illustrated that terminal area adjustments can have a substantial effect on the estimated CYER in ISBM fisheries. Accordingly, the Commission directed the CTC and CYER WG to document existing terminal area adjustment methods, recommend any improvements, and identify monitoring and research to verify assumptions.

We reviewed existing CTC reports and concluded that improved documentation would increase the clarity and consistency of CTC analyses.

Conclusion 4.1. Improved documentation of the methods and data sources for terminal area adjustments would promote clarity of and consistency among CTC analyses.

Recommendation 4.1.1. *Include and document in annual CTC reports the terminal run and escapement estimates for each escapement indicator stock for which a terminal area adjustment is applied to the associated CWT indicator stock.*

We also found that fisheries and the escapement indicator stocks are continuing to evolve. With this evolution it will be important to continually review, modify as needed, and document the methods used for terminal area adjustments in order to accurately represent the terminal harvest rates on the escapement indicator stocks for which a terminal area adjustment occurs.

Conclusion 4.2. The continued evolution of fisheries and the escapement indicator stocks can make it challenging to ensure that fishery catch is appropriately accounted for in the harvest rates used in terminal area adjustments.

Recommendation 4.2.1. *The CTC should continue to annually report and review the terminal area management of each escapement indicator stock for which an adjustment is made, identify any changes needed in the methods to estimate the terminal harvest rate, and document these methods in one of the annual reports.*

We reviewed the terminal area adjustments used for each escapement indicator stock and identified several potential improvements. Careful selection and documentation of the specific fisheries included in the estimate of the terminal harvest rate is essential to prevent double- or under-counting - of fishery impacts.

Conclusion 4.3. Improvements in the methods used by the CTC (2019a) to adjust terminal area harvest rates may result in a more accurate representation of CYERs on several of the escapement indicator stocks.

Recommendation 4.3.1 *(Quillayute, Hoh, and Grays Harbor Fall Chinook). For the Washington coastal fall escapement indicator stocks, limit adjustments of CWT recoveries to the WA CST N, TWAC FN, TNF TERM S fisheries to reduce the potential of inadvertently introducing a negative bias into fishery impacts.*

Recommendation 4.3.2 *(Grays Harbor Fall Chinook). Use the terminal harvest rate for natural-origin fall Chinook, rather than the composite hatchery-natural harvest rate, to more accurately represent the terminal harvest rate on the Grays Harbor Fall Chinook escapement indicator stock.*

Recommendation 4.3.3 *(NWVI Natural Aggregate and SWVI Natural Aggregate).* Evaluate whether new information (see Luedke et al. 2019) on terminal area harvest rates could be used to improve the accuracy with which RBT adj reflects the terminal exploitation rate experienced by NWVI and SWVI escapement indicator stocks.

A complete accounting of catch and estimates of escapement that have low error are important to estimating the terminal harvest rate and monitoring the performance of the ISBM fisheries.

Conclusion 4.4. The run reconstructions typically used to estimate terminal harvest rates require escapement estimates that have low error. The CTC previously found that escapement estimates for five stocks for which a terminal adjustment is applied do not meet CTC standards.

Recommendation 4.4.1. *Prioritize the implementation of studies to verify or recalibrate the estimated escapement for the five escapement indicator stocks found by the CTC to not meet CTC standards (Grays Harbor Fall, Quillayute Fall, Hoh Fall, NWVI Natural Aggregate, and SWVI Aggregate).*

An important assumption when using estimates derived from the CWT indicator stocks~~,~~ is that they accurately represent the fishery impacts on the escapement indicator stocks. The CWT Expert Panel (Expert Panel 2005) previously recommended further review and testing of the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts.

Conclusion 4.5. The assumption that an adjusted CWT indicator stocks accurately represents exploitation rates on the associated escapement indicator stock may become more tenuous in instances where the CWT indicator stock is released in a different basin than the associated escapement indicator stock originates. That divergence occurs for 10 of the escapement indicator stocks for which a terminal area adjustment is identified in Attachment I.

Recommendation 4.5.1. *Conduct studies to test the assumption that the CWT indicator stocks accurately reflect exploitation rates on the escapement stocks and evaluate if a better CWT stock exists or could be developed. Prioritize the implementation of these studies for stocks such as the NWVI Natural Aggregate and Grays Harbor Fall where a significant difference exists between the geographic location of the escapement and associated CWT indicator stock (Figure 1).*

C. Ensure Impacts Assessed in all Fisheries

Management entities have long recognized the fundamental importance of estimating CWT recoveries in all fisheries. Our analysis reinforces the importance of those programs and illustrates the importance of applying indirect methods when lack of direct CWT sampling or catch estimation programs would prevent such estimates. Collaboratively working to address shortcomings in the CWT program will benefit both Parties and improve the CTC exploitation rate analysis and promote effective implementation of the ISBM provisions of Chapter 3.

Conclusion 5.1. The lack of estimated CWT recoveries from a fishery (or escapement) where a CWT indicator stock was caught can affect the estimated CYER and perceived compliance with ISBM obligations.

Recommendation 5.1. *Encourage management entities to annually review fishery monitoring programs to maximize the number of fisheries for which CWT recoveries are directly estimated.*

Recommendation 5.2. *Encourage management entities responsible for estimating CWT recoveries to provide the estimated CWT recoveries for each fishery with landed catch using indirect methods if necessary. An example is the Puget Sound Freshwater Recreational analysis done by WDFW and presented to the CYER WG in February 2021 (K. Ryding pers. comm.).*

Recommendation 5.3. *Prior to conducting the annual exploitation rate analysis, the CTC should identify at the estimation level (i.e., the location, fishery gear, and time period strata for which CWT recoveries are estimated) the fisheries for which CWT recovery estimates are currently not provided. In consultation with CTC members familiar with these fisheries, summarize the identified situations and apply an indirect method in the annual exploitation rate analysis.*

1.0 Introduction

In 2018 the Pacific Salmon Commission (Commission) requested the assistance of management entities in completing a Readiness Questionnaire to identify any gaps in coded-wire-tag (CWT) and associated fishery and stock assessment programs (Reid and Oatman 2018). The responses provided by the management entities were generally encouraging and reflected an ongoing commitment to maintain and improve the coastwide CWT system. However, the questionnaire responses also raised concerns that there could be challenges to effectively implementing the Chinook Chapter of the Pacific Salmon Treaty (PST).

The Commission subsequently tasked the Calendar Year Exploitation Rate Work Group (CYER WG) with identifying opportunities for collaboration to address the identified data gaps. One of the initial tasks of the CYER WG was to recommend improvements to the CWT indicator stock tagging program and fishery sampling to increase the precision of estimates of CYERs. Since precision is affected by both the number of fish tagged and the fishery sampling rate, the CYER WG suggested that it was in the interest of both Party's to work collaboratively to improve the precision of estimates and reduce the likelihood that random error unnecessarily triggered the ISBM fishery review process described in paragraph 7(c) of Chapter 3. The Pacific Salmon Commission subsequently sent a letter to management entities stressing the importance of improving the coastwide CWT system by increasing the number of fish tagged for certain CWT indicator stocks and increasing sampling rates in some fisheries (Anderson and Reid 2020).

A second conclusion of the work group was that "multiple types of indirect methods are used or have been proposed to estimate CWT recoveries, but limited testing of assumptions has occurred, and bilateral guidance on the application of indirect methods is lacking" (CYER WG 2019a). The work group issued three recommendations associated with this conclusion:

A. ***Proxy Methods.*** Task a workgroup with providing recommendations on the application of proxy methods and identifying priority fisheries for transition to direct estimation of CWT recoveries.

B. ***Review Terminal Area Adjustments***. Request that the Chinook Technical Committee (CTC) accelerate the completion of Appendix A, task 5 (documentation of methods used to adjust the CWT recoveries for the Robertson Creek, Quinsam River, Queets River, Salmon River, and Elk River CWT indicator stocks), recommend improvements, and identify any research necessary to verify assumptions.

C. ***Ensure Impacts Assessed in all Fisheries.*** Ensure that in each fishery in which a CWT indicator stock is caught that either estimated recoveries are reported, or a technically agreed indirect method is used to provide a best estimate of the CWT recoveries.

In October 2019, the Commission tasked the CYER WG to address these recommendations. Although indirect methods are used in both catch and escapement estimation, the CYER WG decided to limit its work to fishery applications to align with the scope of the CYER WG recommendation.

2.0 Description of Indirect Methods

The CYER WG (2019b) defined an estimated CWT as originating from an indirect method if: a) the CWTs were estimated using a Category 3 method as defined in the Readiness Questionnaire (termed a Proxy method); or b) the CTC adjusts the estimated CWTs to account for a different pattern of fishery exploitation of the CWT indicator stock than the escapement indicator stock that it represents (termed a Terminal Adjustment Method or TAM).

The types of indirect methods discussed in this report are summarized in Table 1 and are described in the following sections.

Table 1 – Classification of indirect methods included in this report.

Indirect Method Type	Description	Acronym
Category 3 or Proxy	Fishery not adequately sampled	C-comp
	Fishery catch not known	C-pop
Terminal Adjustment Method	Fishery recoveries of CWT indicator stock do not accurately reflect natural stock it is intended to represent	TAM
Fisheries Lacking Estimates of CWTs	No proxy or adjustment method applied	

2.1 Category 3 or Proxy Methods

The Readiness Questionnaire defined three categories of estimated CWTs:

> Category 1 (fisher independent): CWT samples are obtained "directly" by creel surveyors or monitors (i.e., in First Nations fisheries).
>
> Category 2 (fisher dependent): CWT samples are obtained through voluntary submissions by fishers.
>
> Category 3 (other): CWT recoveries are projected from a proxy (a hatchery, other fishery, or other time period or area for that fishery) or other method not included in Category 1 or 2.

Category 3, or proxy methods, may be applied when the fishery was not adequately sampled for CWTs (termed Catch-composition or C-comp) or when the fishery catch is not known (termed Catch-population or C-pop). In the first case, C-comp, the fishery may not have been sampled, poor sampling may have resulted in few recoveries, sampling may have been conducted without a study design, or other anomalies may prevent the use of category 1 or 2 methods (e.g., when snout cuts are too small to reliably collect a CWT, or when there is a mismatch between the sample and catch data, such as more sample than catch or samples from only one gear-type). C-comp proxy methods may use CWT samples from fisheries sampled in nearby areas, times, or even previous years or, in the absence of CWT samples, potentially use genetic sampling data.

In the second case, C-pop, the fishery catch is not known and indirect estimates of one or more parameters involved in estimating total retained catch or total retained marked catch are needed. For

example, catch estimates have been produced by extrapolating parameters such as submission rate from nearby fisheries or previous time periods. In programs that rely on voluntary submission of heads, expansion of recovered tags requires an estimate of submission rate. In fisheries without submission rate information, estimates from nearby fisheries or other time periods may be used.

Proxy methods are vulnerable to bias because the characteristics of the fishery from which the information is borrowed may not be the same as the one to which it is applied. For example, using a C-comp sample from a fishery nearby risks biasing the estimates if the tag composition differs between the two fisheries. This report qualitatively evaluates proxy methods according to their perceived potential bias. This choice reflects how the Readiness Questionnaire phrased its questions about the use of proxy methods:

> If it is anticipated that a Category 3 method will be used in a fishery in 2019-2028, have potential sources of bias been considered, and studies or analyses been conducted to assess potential biases in the projected CWT recoveries?

We focused on bias but recognize that precision of catch and CWT estimates are important for the successful implementation of the PST (CYER WG 2019b).

When choosing sources for proxy information, there will often be a trade-off between choosing C-comp or C-pop sources that are assumed to be more accurate due to proximity (in time or space) versus sources from one or more locations with more precise estimates. For example, consider a hypothetical case in which proxy estimates of the head submission rate could be based on the catch estimate from spatially adjacent stratum (location A) or from the estimates from a distant stratum with a larger catch (location B). Further, assume that the types of anglers, availability of locations to deposit heads, or other factors are believed to result in a submission rate for location A that more closely matches the area for which a proxy estimate is needed. However, for location B, assume that the precision of the estimate of the submission rate is slightly greater because of a larger catch. Under the assumptions of this scenario, we would anticipate that using the submission rate from location A would have relatively high accuracy, but lower precision, because the submission rates would be expected to be similar to those in the stratum of interest (relatively accurate) but the submission rate would be estimated using a catch estimate from a stratum with lower precision. In contrast, we would anticipate that using the submission rate from location B would have lower accuracy but higher precision. Obviously, there would be many factors to consider when choosing between these options, but we expect that, in most cases, higher accuracy would be chosen even if there was a small loss in precision.

2.2 Terminal Adjustment Methods

Most CWT indicator stocks used to monitor the performance of ISBM fisheries are reared, tagged, and released from hatcheries. While it is generally assumed that these indicator stocks represent the fishery exploitation pattern in preterminal fisheries, at least prior to the initiation of mark-selective fisheries, the indicator stock or natural-origin stock(s) may be exposed to a different set of fisheries in their respective terminal areas. Under such circumstances, the CTC will often adjust the indicator stock's CWT recoveries to more accurately reflect the fishery impacts on the natural stock(s).

Attachment I of Chapter 3 of the PST identifies CWT indicator stocks for which adjustments in terminal area CWT recoveries are made to more accurately represent fishery impacts on the associated escapement indicator stock. The following stocks were identified:

- Robertson Creek representing the Northwest Vancouver Island (NWVI) Natural Aggregate and Southwest Vancouver Island (SWVI) Natural Aggregate escapement indicator stocks;
- Quinsam River representing the East Vancouver Island North escapement indicator stock
- Queets River Fall Fingerling representing the Grays Harbor Fall, Quillayute Fall, and Hoh Fall escapement indicator stocks;
- Salmon River representing the Nehalem, Siletz, and Siuslaw escapement indicator stocks; and
- Elk River representing the South Umpqua and Coquille escapement indicator stocks.

Terminal adjustment methods (TAM) rely on auxiliary information or assumptions of differing fishery harvest of indicator stocks relative to associated wild stocks to adjust the CWT recoveries.

2.3 Fisheries Lacking Estimates of CWTs

Neither a direct or an indirect estimate of CWT recoveries may be provided by a management entity for some time periods or gears where catch occurred. The magnitude of the bias in the estimated calendar year exploitation rate (CYER) for the fishery will depend on the proportion of the catch for which estimated CWT recoveries was not reported. Positive bias will also be introduced into the estimated CYERs for other fisheries because the total number of recoveries (the denominator of the CYER) will be too small (CYER WG 2019b). The potential effects of the absence of estimated recoveries are assessed for several fisheries in Section 5.0.

3.0 Proxy Methods

Proxy methods are vulnerable to bias because the characteristics of the fishery from which the information is borrowed may not be the same as the one to which it is applied.

3.1 Description

We used an approach similar to a risk assessment to rank fisheries by the amount of bias they were likely to impart on exploitation rate estimates due to reliance on indirect methods. Where risk assessment is based on the combined influence of categorical estimates of "consequence" and "likelihood", we used categorical measures of bias in the parameter estimate and of the size of the catch to which the indirectly estimated parameter estimate is applied (Table 2). As with many risk assessments, our approach relied on expert opinion to estimate the bias in the parameter estimate (C-pop or C-comp), as these biases are unknown. Experts were asked whether the bias was likely to be low, medium, or high, defined for consistency as less than 10%, 10-30%, and greater than 30%, respectively; note that our analysis treated biases of equal relative size the same whether they were positive or negative, so we did not ask experts to indicate direction. The relevant measure of size of catch in a fishery, for evaluating the influence of bias in indirect methods on exploitation rate (ER) estimates across CYER stocks (Appendix 1, Attachment 1) is the number of estimated CWTs from those stocks recovered in that fishery that were estimated using indirect methods. We adopted five categories of fishery size, to improve the resolution of the final rankings.

Table 2 – The assessment scheme used to rank fisheries by the extent to which reliance on proxy indirect methods impart bias on exploitation rates. Numbers in the grid rank the amount of bias in exploitation rate estimates resulting from reliance on indirect methods. Cells with the same values show different combinations of fishery size and bias level that were treated as having the same level of concern.

Average annual estimated CYER stock tags (# tags)		Bias in proxy method*			
		Direct 0%	Low <10%	Moderate 10-30%	High >30%
None	0	0	0	0	0
Very Small	<10 tags	0	1	1	2
Small	10-30 tags	0	1	2	3
Medium	30-50 tags	0	2	3	4
Medium-High	50-80	0	3	4	5
High	>80 tags	0	4	5	6

* Bias per tag; absolute value.

We developed a questionnaire (Appendix 1) for regional experts to provide the necessary data for evaluating fisheries using this assessment scheme. Respondents for all agencies other than Fisheries and Oceans Canada (CDFO) indicated that there were no proxy methods involved in estimating CWT recoveries in fisheries. For CDFO, where a variety of indirect methods are relied upon, there was a need to incorporate the CDFO Mark Recovery Program (MRP) database information on which tag recoveries were estimated using direct methods and which were estimated using indirect methods. Further, for

those estimates relying on indirect methods, there was a need to describe which type of indirect methods were used, since different methods would be subject to different levels of bias. Adding this information to the MRP database, for all recoveries in sport and First Nations (FN) fisheries (commercial recovery estimates do not rely on indirect methods) from 2009 through 2019, was a major undertaking completed by CDFO staff in support of this assessment. With that information added, we were able to query the number of estimated CYER (or PST Attachment I stocks) CWT recoveries, by fishery, stock, and estimation method for the 2009-2019 period.

Separating the results by estimation method was important because some fisheries rely on more than one indirect method in different periods or areas. In such cases, we calculated a weighted average rank value. The weight assigned to each method was determined by the product of the 'midpoint' of the bias range for that method and the annual average estimated number of CWT recoveries estimated using that method. Midpoint values for low, medium, and high bias ranges were 5%, 20% and 40%, respectively; although the high bias range was greater than 30%, we used the midpoint value 40% based on the opinion that the probability of a given level of bias decreases as bias level increases.

The MRP query provided the number of estimated tag recoveries estimated using indirect methods by stock. However, we ranked fisheries based on the total number of CYER stock tags, regardless of stock. This approach meant that a mixed stock fishery and a single stock fishery, both of which relied on indirect methods subject to the same bias, to estimate a similar total number of recoveries, would be ranked equally, even though the contribution to bias in the stock specific ERs would be spread across the various stocks encountered in the mixed stock fishery, but focused (and individually much larger) in the single stock fishery.

3.2 Results

A range of proxy methods are used by Canada to estimate recoveries in Canadian fisheries. These methods were organized into eight categories (Table 3). A panel of experts familiar with the methods determined the level of bias inherent in each method, either moderate or high (none could be determined to have a low level of bias (<10%) without further information). Methods 1-4 are all variations on the same approach, proxy estimates of the rate at which fishers in the subject stratum submitted heads to Canada's voluntary head submission program. The variations represent a range from only adjacent strata being used for the submission rate estimate, to estimates from previous years being used to estimate submission rates in subject stratum. While the degree of bias likely increases from method 1-4, methods 2-4 were all classified as high for the assessment scheme.

Table 3 – The types of indirect methods used to estimate CWT recoveries in Canadian fisheries, including the parameter type they provide a proxy value for, descriptions of the method and the major potential sources of bias, and the level of potential bias determined by expert opinion.

Method Number	Indirect Method	Parameter	Method Description	Bias concerns	Potential Bias
1	Single Adjacent Strata	C-pop	A submission rate from an adjacent month or area is used to expand recoveries in the subject stratum.	Potential bias from differing head depot availability, lodge and guide participation, and fisher composition (local vs tourist). Bias ranked moderate because of reliance on adjacent stratum.	Moderate
2	Multi Strata Average	C-pop	A submission rate average based on multiple strata in the same region (e.g., WCVI), possibly over more than one period, is used to expand recoveries in the subject stratum.	Potential bias from differing head depot availability, lodge and guide participation, and fisher composition (local vs tourist). Bias ranked high because of reliance on multiple, potentially less similar, strata.	High
3	Coastwide Average	C-pop	An average submission rate from all Pacific Fishery Management Areas over May-Sept period.	Potential bias from differing head depot availability, lodge and guide participation, and fisher composition (local vs tourist). Bias ranked high because of reliance on multiple, potentially less similar, strata.	High
4	Interannual Average	C-pop	Submission rates or marked catch rates from previous years are used to estimate the recoveries in the subject stratum.	Potential bias from interannual variation in fisher behavior, lodge and guide participation, and fisher composition (local vs tourist).	High
5	Indirect Mark Rate	C-pop	Marked kept catch estimated as the product of a direct total kept catch and a mark rate estimate from adjacent strata.	Potential bias from the variation in mark rates over time and space.	High

Method Number	Indirect Method	Parameter	Method Description	Bias concerns	Potential Bias
6	Assumed Value	C-pop	Submission rates in recreational fisheries are capped at 50% and are assumed to be 25% for strata without marked catch estimates in the South Coast during the May through September period.	Potential bias because these assumed values are based on no actual sample information. Bias is expected to be very high.	High
7	Terminal Tag Composition	C-comp	Tag composition from another catch or escapement population is used to estimate C-comp in the subject stratum.	Potential bias from differences in tag composition between the sampled catch or escapement population and the subject population. Bias is ranked moderate because sample populations are selected due to their expected similarity.	Moderate
8	Terminal Tag Composition and/or Marked Catch	C-comp & C-pop	Tag composition from another catch or escapement population is used to estimate C-comp in the subject stratum. Indirect methods are also involved in estimating marked catch.	Potential bias from differences in tag composition and in mark rates, between the sampled and subject populations. Bias ranked high because of the potential combined impacts of both C-pop and C-comp indirect methods.	High

The 10 fisheries ranked the highest according to the assessment scheme are provided in Table 4; Appendix 2 presents the same information for all fisheries assessed. Seven of the 10 highest ranked fisheries are Canadian sport fisheries. These fisheries relied strictly on C-pop methods since all fisheries were directly sampled for tag composition through the voluntary head submission program. Further, these C-pop methods are required for strata that lack a direct estimate of marked catch. The one exception is capping the submission rate at 50% (method 6) when strata have directly estimated marked catch estimates that, given the number of heads submitted, lead to estimated submission rates higher than 50%. Three net fisheries are also in the 10 fisheries of highest concern. These fisheries all rely on indirect C-comp methods due to lack of direct CWT sampling. Two of them, Lower Fraser Freshwater Net and Georgia Strait Freshwater Net, also rely on C-pop methods, requiring direct catch estimation to address.

Table 4 – The ten CTC fisheries with the highest level of concern about biasing exploitation rate estimates due to the indirect methods involved in estimating CWT recoveries. Also provided are the row and column bins into which the fishery fits in the assessment scheme (Table 2), the index numbers of the indirect method(s) used for estimating recoveries in a particular fishery (Table 3), and the number of stocks encountered at least once in the fishery from 2009 to 2019.

CTC Fishery	Indirectly Estimated Recoveries	Level of Bias	Rank Level of Concern	Estimation Methods Used*	Number of CYER Stocks Impacted
Central Sport	High	High	6	1,2,3,4	20
North Georgia Strait Sport	High	High	6	1,2,4,6	10
Canadian Juan De Fuca Sport	High	High	6	2,5	9
South Georgia Strait Sport	High	High	6	2,4,6	7
Lower Fraser Freshwater Net	High	High	6	5,7,8	4
North AABM Sport (Haida Gwaii)	High	Moderate	5	1,2,3,6	23
North ISBM Sport	Medium-High	High	5	1,2,3,	18
WCVI AABM Sport	Medium-High	High	5	1,2,6	14
Central Freshwater Net	High	Moderate	5	7	1
Georgia Strait Freshwater Net	Medium-High	High	5	8	1

*see Table 3 for description of estimation methods

Note: AABM = Aggregate abundance-based management; ISBM = individual stock-based management.

3.3 Conclusions and Recommendations

The use of proxy methods to estimate CWT recoveries can introduce bias into the estimated CYER for a fishery where the method is applied. Any bias that is introduced will also affect the estimated CYER for other fisheries due to the inclusion of estimated recoveries in the denominator of the CYER.

We requested that management entities identify fisheries throughout the Pacific Salmon Treaty area where proxy methods are implemented. Fisheries of greatest concern were identified through a risk

assessment framework that included the number of indirectly estimated recoveries and a qualitative assessment of the potential bias in the indirect method applied.

Conclusion 3.1. Proxy methods are widely used to estimate CWT recoveries and have the potential to introduce a substantial bias into estimates of CYERs.

Recommendation 3.1.1. *Encourage management entities to address the limitations in fishery and stock assessment programs that result in the application of proxy methods. Increasing the proportion of strata for which CWTs are directly estimated will decrease the amount to which these fisheries are influenced by bias due to reliance on proxy methods. For fisheries relying on proxy methods to estimate total catch, options include expanding coverage of established catch estimation surveys or use of new survey types (e.g., internet-based surveys). For fisheries relying on proxy sources of CWT composition information, CWT sampling surveys should be established where possible.*

Recommendation 3.1.2. *Prioritize funding to initiate improved fishery and stock assessment programs where the use of the proxy methods poses the greatest risk to accurate estimation of CYERs. These fisheries include the Central Sport, North Georgia Strait Sport, Canadian Juan de Fuca Sport, South Georgia Strait Sport, and Lower Fraser River Net.*

Recommendation 3.1.3. Where resource or other constraints prevent the continuous application of direct methods, encourage management entities to conduct studies to assess the accuracy of the proxy method and apply any appropriate bias correction procedures.

We subjectively assessed each proxy method relative to the potential risk of introducing bias.

Conclusion 3.2. The risk of bias introduced by the application of a proxy method depends in part on the particular method applied. All methods were assessed as having a moderate or high level of risk of introducing bias.

Recommendation 3.2.1. *Where proxy methods must be applied because of resource constraints or unanticipated gaps in catch estimates or sampling, apply proxy methods that have the lowest risk of introducing bias. Selection of the appropriate proxy method will be context-specific. The two proxy methods that are generally likely to have the least risk of introducing bias are: 1) application of submission rates from an adjacent time or area; or 2) application of tag composition from an adjacent fishery or escapement stratum.*

Recommendation 3.2.2. *Support the continued development, testing, and evaluation of proxy methods by management entities and by the CTC. Options to evaluate proxy methods include field studies that implement and test alternative methods, assessment of proxy methods on a post-hoc basis (i.e., "What would have happened if we applied this proxy method?"), and simulation analyses.*

4.0 Terminal Adjustment Methods

The PST establishes a constraint on the impact of one or both Parties' individual stock-based management (ISBM) fisheries on certain naturally spawning escapement indicator stocks when the stock is not meeting an agreed biologically-based escapement goal or when an agreed goal is lacking. In a year when an ISBM limit is in place for an escapement indicator stock, compliance is assessed by comparing the estimated CYER for the associated CWT indicator stock with the ISBM limit (see PST Chapter 3, paragraph 5 and Attachment I).

A fundamental assumption of this assessment, termed the *gorilla assumption* (Expert Panel 2005) or the *indicator stock assumption*, is that the vulnerability to and distribution amongst fisheries of each CWT indicator stock is similar to that of the associated escapement indicator stock. Although the CWT Expert Panel found that there appeared to be some empirical support for this assumption, it also recommended further review and testing of the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts.

The CTC (2019a) has recognized that a violation of this assumption may occur in terminal areas when differences in the return location, run timing, or other factors result in a different harvest rate on the CWT indicator stock than the associated escapement indicator stock. In each of these cases the terminal area CWT recoveries of the CWT indicator stock may need to be adjusted to more accurately reflect the harvest rate on the associated escapement indicator stock. This is accomplished by switching out the actual recoveries and switching in pseudo recoveries of terminal harvest and escapement that align with the harvest rate on the escapement indicator stock.

Attachment I of Chapter 3 identifies five CWT indicator stocks for which an adjustment in the terminal area harvest rate occurs: Robertson Creek, Quinsam River, Queets River, Salmon River, and Elk River. Since these adjustments in the harvest rates can have a substantial effect on the estimated CYER (CYER WG 2019b), the Commission directed the CTC and CYER WG to:

1) document the methods used to adjust the CWT recoveries for these CWT indicator stocks;
2) recommend improvements; and
3) identify any research to verify assumptions.

For these five stocks, we: 1) describe the general methodology for adjusting terminal area harvest rates; b) describe, review, and recommend the terminal fisheries for each pair of CWT and escapement indicator stocks; c) review the stock-specific methods to switch-in the terminal area harvest and escapement; and d) identify priorities for research and monitoring.

4.1 General Methodology for Adjustment of Terminal Area Harvest Rates

We define a terminal harvest rate (HR) as the fraction of mature fish removed through terminal fisheries, or $HR = \frac{T}{T+E}$, where *T* is terminal harvest and *E* is escapement. This definition addresses terminal fishery impacts only, and does not address pre-spawn mortality, inter-dam loss, or differences in natural mortality. Most CWT-based stock assessments assume the CWT indicator stock (also referred to as exploitation rate indicator stock, or ERIS) and escapement indicator stock (EIS) experience the same terminal harvest rate, or $HR_{ERIS} = HR_{EIS}$, where HR_{ERIS} is the terminal harvest rate of the ERIS

and HR_{EIS} is the terminal harvest rate of the EIS. If $HR_{ERIS} \neq HR_{EIS}$ then the equal terminal harvest rate assumption is not true, and an adjustment must be made to accurately reflect the terminal harvest rate on the escapement indicator stock.

Let $\widehat{ERIS}$ be defined as the adjusted ERIS and $HR_{\widehat{ERIS}}$ be defined as this stock's adjusted terminal harvest rate (i.e., an "Adj" CWT indicator stock in Attachment I of the 2019 PST):

$$HR_{\widehat{ERIS}} = \frac{T_{\widehat{ERIS}}}{T_{\widehat{ERIS}} + E_{\widehat{ERIS}}} \tag{1}$$

where $T_{\widehat{ERIS}}$ and $E_{\widehat{ERIS}}$ are the adjusted terminal harvest and escapement that yield $HR_{\widehat{ERIS}} = HR_{EIS}$. Subscripts for year and age are not shown in order to simplify presentation, and because age-specific harvest rates are often unavailable. Equations for $T_{\widehat{ERIS}}$ and $E_{\widehat{ERIS}}$ are:

$$E_{\widehat{ERIS}} = (T_{ERIS} + E_{ERIS})(1 - HR_{EIS}) \tag{2}$$

and

$$T_{\widehat{ERIS}} = (T_{ERIS} + E_{ERIS})HR_{EIS} \tag{3}$$

where Equations 2 and 3 are derived by solving the system of equations: (1) $HR_{\widehat{ERIS}} = HR_{EIS}$ and (2) $E_{\widehat{ERIS}} + T_{\widehat{ERIS}} = E_{ERIS} + T_{ERIS}$. Equations 2 and 3 can be extended to multiple fisheries as follows:

$$E_{\widehat{ERIS}} = \left(E_{ERIS} + \sum_{\mathrm{i}} T_{ERIS,i}\right)\left(1 - \sum_{i} HR_{EIS,i}\right) \tag{4}$$

and

$$T_{\widehat{ERIS}} = \left(E_{ERIS} + \sum_{\mathrm{i}} T_{ERIS,i}\right)\sum_{i} HR_{EIS,i} \tag{5}$$

where *i* are the terminal fisheries being adjusted. Modifications of Equation 5 may be necessary for complex terminal fisheries that include estimates of sequential terminal harvest rates. We will refer to these fisheries, which are specific to each CWT and escapement indicator stock pair, as the terminal adjustment fisheries (TAFs).

4.2 Description and Review of Switch-Out Fisheries

Application of the general methodology described in Section 4.1 requires identification of the switch-out fisheries for each CWT and escapement indicator stock pair. We documented the switch-out fisheries previously used by the CTC (Table 5) based on a review of CTC reports (CTC 2019a; 2019b), CTC computer programs and associated input files, and discussions with CTC members.

We reviewed the fisheries that are currently switched-out and recommended potential modifications based upon the following considerations:

1) Does the switched-out fishery predominantly impact maturing Chinook salmon?

2) What quantitative or qualitative information supports a conclusion that a differential harvest rate occurs on the CWT and associated escapement indicator stock in the switched-out fishery? The types of information considered included estimates of differential harvest rates on the CWT and escapement indicator stocks provided by management entities, and qualitative information regarding the location of fisheries and the likely migration path of the CWT and escapement indicator stocks.
3) Are there adequate and appropriate data to replace CWT harvest rates? This is discussed further in Section 4.4.

After review, it was apparent that no changes to switched-out fisheries were required except for Queets River. The QUE CWT indicator stock is used to represent the terminal area harvest rates on the Grays Harbor Fall, Quillayute Fall, and Hoh escapement indicator stocks. Previously, 14 fisheries were switched out; after a review of CWT recoveries and a discussion of likely migratory patterns, we concluded that there was no evidence to suggest that a fall Chinook salmon originating from the Queets River would be impacted differently than a Grays Harbor, Quillayute, or Hoh stock in fisheries 1-11. Regardless, since the number of CWT recoveries in these 10 terminal fisheries in Puget Sound, the Columbia River, and Oregon has been small, there is likely to be minimal impact on the CTC analysis.

Table 5 – Escapement indicator stock, associated coded wire tag (CWT) indicator stock, fisheries that were being switched out prior to Calendar Year Exploitation Rate Work Group review, and recommended switch-out fisheries. Fishery full names can be found in Attachment 1 of Appendix 1.

Escapement Indicator Stock Name	CWT Indicator Stock	Switch-out Fisheries	
		CTC (2019a)	Recommendation
Northwest Vancouver Island (NWVI) Natural Aggregate	Robertson Creek Fall (RBT Adj)	TWCVI TERM N, TWCVI TERM S, TWCVI FS	No change
Southwest Vancouver Island (SWVI) Natural Aggregate	Robertson Creek Fall (RBT Adj)		
East Vancouver Island North	Quinsam River Fall (QUI Adj)	TJNST TERM S, TGS FS	No change
Grays Harbor Fall	Queets River Fall (QUE Adj)	TOR TERM T, TPGSDN TERM N, TPGSDO TERM N, WA CST N, TCOL R N, TPS FN, TWAC FN, TNF TERM S, TSF TERM S, TPGSDN TERM S, TPGSDO TERM S, TCOL R S, TPS FS, TSF TERM FS	WA CST N, TWAC FN, TNF TERM S
Quillayute Fall	Queets River Fall (QUE Adj)		
Hoh Fall	Queets River Fall (QUE Adj)		

Escapement Indicator Stock Name	CWT Indicator Stock	Switch-out Fisheries	
		CTC (2019a)	Recommendation
Nehalem	Salmon River (SRH Adj)	TSF TERM FS	No change
Siletz	Salmon River (SRH Adj)		
Siuslaw	Salmon River (SRH Adj)		
South Umpqua	Elk River (ELK Adj)	TOR TERM T, TSF TERM FS	No change
Coquille	Elk River (ELK Adj)		

4.3 Description and Review of Switch-In Fisheries

When there are terminal fisheries impacts on an escapement indicator stock that are not accounted for after the switch-out, the terminal adjustment method requires an external estimate of the harvest rate of the escapement indicator stock (HR_{EIS}). The external estimates are typically provided by management entities and derived from a run reconstruction, genetic stock identification, or tagging studies. Careful selection and documentation of the specific fisheries included in the estimate of HR_{EIS} is essential to prevent double- or under-counting of fishery impacts.

Our documentation of the current HR_{EIS} and recommendations for improvements are provided below for each CWT-escapement indicator stock pair.

4.3.1 Northwest Vancouver Island (NWVI) Natural Aggregate & Southwest Vancouver Island (SWVI) Natural Aggregate (RBT Adj)

The CTC (2016) described the terminal area adjustment for the Robertson Creek (RBT) CWT indicator stock as:

> *"Unadjusted and adjusted mortality estimates are given for the RBT CWT indicator to bound the likely range of ISBM (and other) fishery impacts applicable to the escapement indicator stocks comprising the aggregate. The adjusted estimates were obtained by subtracting the terminal fishery CWT estimates specific to RBT from the ISBM fishery total and adding them to the escapement. Recalculation of the percentage distribution of mortality results in some adjustment to each category."*

However, the ISBM indices calculated in the performance review report (CTC 2016) did not include any switch-ins. The adjustments were included for the first time in the most recent exploitation rate analysis (CTC in prep).

Recent West Coast Vancouver Island (WCVI) terminal fishery assessments provide estimates of the catch of natural-origin stocks for a number of terminal fisheries along the WCVI (Luedke et al. 2019), however the analysis was not conducted at the scale of the Southwest Vancouver Island (SWVI) and Northwest Vancouver Island (NWVI) EIS. We recommend evaluating whether these estimates could be used to

improve the accuracy with which RBT adj reflects the terminal exploitation rate experienced by NWVI and SWVI EIS.

Table 6 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the Northwest Vancouver Island (NWVI) Natural Aggregate escapement indicator stock and recommended improvements.

Switch-In Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
No terminal fishery impacts included	Evaluate if new information (Luedke et al. 2019) can be used to improve accuracy of estimated terminal harvest rate	Not Applicable	TBD based on review

Table 7 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the Southwest Vancouver Island (SWVI) Natural Aggregate escapement indicator stock and recommended improvements.

Switch-In Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
No terminal fishery impacts included	Evaluate if new information (Luedke et al. 2019) can be used to improve accuracy of estimated terminal harvest rate	Not Applicable	TBD based on review

4.3.2 East Vancouver Island North (QUI Adj)

The CTC (2020) states:

> "*Under the 2019 PST Agreement, two escapement indicators are identified within the Upper Strait of Georgia. Phillips River fall Chinook is an enhanced escapement indicator for the mainland inlets area, and a yet to be determined system will represent the North East Vancouver Island (NEVI) area. Work is ongoing to identify the most suitable escapement indicator for the NEVI area, which is not reported on this year.*"

We recommend that when an escapement indicator stock is identified for the NEVI, that the CTC compare the likely migratory paths of the selected escapement indicator stock and the Quinsam CWT indicator stock and identify what, if any, terminal area adjustments are needed.

4.3.3 Grays Harbor Fall (QUE Adj)

The terminal harvest rate for the Grays Harbor Fall escapement indicator stock reported by the CTC (2019b) includes all net and sport fisheries in the Grays Harbor basin. The reported harvest rate is a composite of the rates on natural- and hatchery-origin Chinook salmon because the stock origin of the catches was not distinguished in the source data obtained from the Pacific Fishery Management Council (PFMC).

No changes are recommended in the fisheries included in the estimate of HR_{EIS}. However, we recommend using the estimates of the natural-origin terminal run and spawners in the run reconstruction maintained by the co-managers to estimate the harvest rate.

Table 8 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the Grays Harbor Fall escapement indicator stock and recommended improvements.

Switch-In Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
Sport: Marine Area 2-2 and all tributaries to Grays Harbor Non-Indian Gillnet: Marine Areas 2A-2D Treaty Indian Gillnet: Marine Area 2A-2D and tributaries to Grays Harbor Chehalis Tribal Gillnet: Tributaries to Grays Harbor	No Change	PFMC (2018), Table B-25	Co-manager Run Reconstruction

4.3.4 Quillayute Fall and Hoh Fall (QUE Adj)

The terminal harvest rate for the Quillayute Fall and Hoh Fall escapement indicator stocks reported by the CTC (2019a) includes the net, sport, and Ceremonial and Subsistence fisheries in each river. Although the estimates of terminal run and escapement were obtained from PFMC reports, the same estimates are generally used by the CTC.

No changes are recommended in the fisheries included in the estimate of HR_{EIS}. We recommend using the estimates of the natural-origin terminal run and spawners reported by the CTC in the annual catch and escapement report (e.g., CTC (2020) Table B-8) to estimate the harvest rate in the future to ensure that a consistent set of data is used across all CTC analyses.

Table 9 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the Quillayute Fall and Hoh Fall escapement indicator stock and recommended improvements.

Switch-in Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
Sport: Mainstem and tributaries in each river basin Treaty Indian Gillnet: Mainstem and tributaries in each river basin Treaty Indian Ceremonial & Subsistence: Mainstem and tributaries in each river basin	No Change	PFMC (2018), Tables B-33 and B-36	CTC (2020), Table B-8

4.3.5 Nehalem, Siletz, and Siuslaw (SRH Adj)

A sport fishery generally occurs in each of these rivers and the catch in the sport fishery is included in the harvest rate used by the CTC (2019a). No changes are recommended in the fisheries included in the estimate of HR_{EIS}. We recommend using the estimates of the natural-origin terminal run and spawners reported by the CTC in the annual catch and escapement report (e.g., CTC (2020) Table B-11) to estimate the harvest rate in the future to ensure that a consistent set of data is used across all CTC analyses.

Table 10 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the Nehalem, Siletz, and Siuslaw escapement indicator stocks and recommended improvements.

Switch-in Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
Sport: Mainstem and tributaries in each river basin.	No Change	CTC unpublished data.	CTC (2020), Table B-11

4.3.6 South Umpqua and Coquille (ELK Adj)

The CTC has not previously reported the impact of ISBM fisheries on these stocks. A sport fishery occurs in these rivers when returns are sufficiently large. Estimates of the natural-origin terminal run and spawners for the Coquille River are reported by the CTC in the annual catch and escapement report (e.g., CTC (2020) Table B-11) and are recommended as a source of information to estimate the terminal harvest rate. The CTC currently does not report a terminal run for the South Umpqua. Inclusion of that information in future reports would facilitate the estimation of the terminal harvest rate for that river.

Table 11 – Description of switch-in fisheries included in the current $\boldsymbol{HR_{EIS}}$ for the South Umpqua and Coquille and recommended improvements.

Switch-in Fisheries		Data Source	
CTC (2019a)	**Recommended**	**CTC (2019a)**	**Recommended**
Not included in analysis.	Sport: Mainstem and tributaries in each river basin.	Not available	CTC (2020), Table B-11

4.4 Monitoring and Research

We previously discussed the *gorilla assumption* that each CWT indicator stock accurately measures the fishery impacts on the associated escapement indicator stock. That assumption may become more tenuous in instances where the CWT indicator stock is not released in the basin from which the associated escapement indicator stock originates. That divergence occurs for 10 of the escapement indicator stocks for which a terminal area adjustment is identified in Attachment I.

The Parties recognized the importance of the assumption of representation during the development of the 2019 Readiness Questionnaire. The questionnaire included the question “Has a paired tagging study been conducted to assess the similarity of the fishery exploitation rates and distribution between the CWT and escapement indicator stocks?” With the exception of the Siuslaw-Salmon River pair, no studies

to test those assumptions were reported to have been completed for the 10 escapement indicator stocks where the CWT indicator stock occurs in another basin. We encourage the implementation of these studies, particularly for the NWVI Natural Aggregate and Grays Harbor Fall stocks where a significant difference exists between the geographic location of the escapement and associated CWT indicator stock (Figure 1).

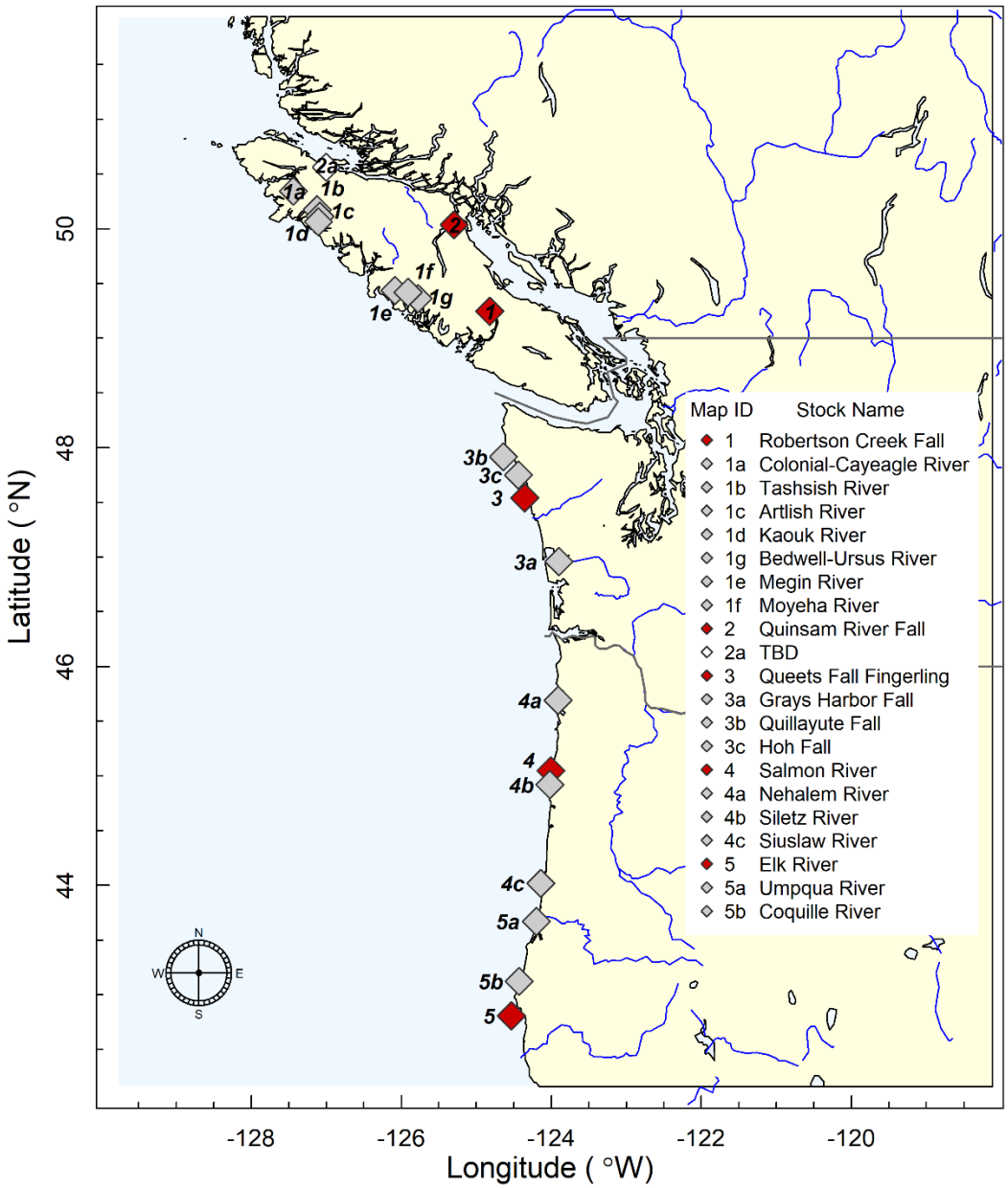

Figure 1 – Map of CWT indicator stocks (red) and their associated escapement indicator stocks (grey), discussed in this review.

The application of a terminal area adjustment requires an estimate of the terminal area harvest rate for the switch-in fisheries. While this rate could be estimated in multiple ways, in practice all of the CWT indicator stocks for which a terminal area adjustment is made rely on a terminal area reconstruction based on catch and escapement. Consequently, a complete accounting of local and non-local catch by fishery type and escapement that have low error are important to estimating the terminal harvest rate and monitoring the performance of the ISBM fisheries. It would be valuable for the CTC to consider these assessment needs during the development of recommendations to the Commission regarding the minimum assessment program required to effectively implement the Chinook Chapter (see paragraph Chapter 3, paragraph 2(b)(v)).

The CTC (2016) previously evaluated escapement estimation methods relative to CTC assessment standards. Five of the stocks for which terminal area adjustments are made were judged to rely on escapement estimation methods that did not meet CTC data standards (Table 12). Verifying or improving these escapement estimates would improve confidence in, and potentially the accuracy of, estimates of CYERs.

Table 12 – Summary of escapement estimation methods and consistency with CTC data standards (CTC 2013).

Red shading indicates the indicator stock does not meet CTC data standards, green shading indicates stock does meet CTC data standards, and yellow shading indicates some of the data standards are met.

Escapement Indicator Stock	Consistency with CTC Data Standards	Escapement Estimation Methods
NWVI Natural Aggregate		Foot and swim surveys, area under the curve
SWVI Natural Aggregate		Foot and swim surveys, area under the curve
Grays Harbor Fall		Redd counts in index areas and supplemental surveys
Quillayute Fall		Redd counts in index areas and supplemental surveys
Hoh Fall		Redd counts in index areas and supplemental surveys
Nehalem		Expanded live and dead counts, mark-recapture estimates from 2000-2013
Siletz		Expanded dead counts, mark-recapture estimates from 2005-2013
Siuslaw		Expanded live and dead counts, mark-recapture estimates from 2001-2006, 2014
South Umpqua		Expanded live and dead counts, mark-recapture estimates from 1998-2004
Coquille		Expanded live and dead counts, mark-recapture estimates from 2001-2004

4.5 Conclusions and Recommendations

The 2019-2028 provisions of the PST include new obligations for the management of Chinook salmon in ISBM fisheries. Limits are specified on CYERs in one or both Parties' ISBM fisheries on certain naturally spawning escapement indicator stocks when the stock is not meeting an agreed biologically-based escapement goal or when an agreed goal is lacking. The CYERs are to be estimated by assessing the fishery impacts on the CWT indicator stock associated with each escapement indicator stock.

Attachment I of Chapter 3 identifies 11 escapement indicator stocks for which an adjustment of the terminal area harvest rate of the associated CWT indicator stock will be applied. The CYER WG (2019a) previously illustrated that terminal area adjustments can have a substantial effect on the estimated CYER in ISBM fisheries. Accordingly, the Commission directed the CTC and CYER WG to document existing terminal area adjustment methods, recommend any improvements, and identify monitoring and research to verify assumptions.

We reviewed existing CTC reports and concluded that improved documentation would increase the clarity and consistency of CTC analyses.

> **Conclusion 4.1. Improved documentation of the methods and data sources for terminal area adjustments would promote clarity of and consistency among CTC analyses.**
>
> > ***Recommendation 4.1.1.*** *Include and document in annual CTC reports the terminal run and escapement estimates for each escapement indicator stock for which a terminal area adjustment is applied to the associated CWT indicator stock.*

We also found that fisheries and the escapement indicator stocks are continuing to evolve. With this evolution it will be important to continually review, modify as needed, and document the methods used for terminal area adjustments in order to accurately represent the terminal harvest rates on the escapement indicator stocks for which a terminal area adjustment occurs.

> **Conclusion 4.2. The continued evolution of fisheries and the escapement indicator stocks can make it challenging to ensure that fishery catch is appropriately accounted for in the harvest rates used in terminal area adjustments.**
>
> > ***Recommendation 4.2.1.*** *The CTC should continue to annually report and review the terminal area management of each escapement indicator stock for which an adjustment is made, identify any changes needed in the methods to estimate the terminal harvest rate, and document these methods in one of the annual reports.*

We reviewed the terminal area adjustments used for each escapement indicator stock and identified several potential improvements. Careful selection and documentation of the specific fisheries included in the estimate of the terminal harvest rate is essential to prevent double- or under-counting - of fishery impacts.

> **Conclusion 4.3. Improvements in the methods used by the CTC (2019a) to adjust terminal area harvest rates may result in a more accurate representation of CYERs on several of the escapement indicator stocks.**
>
> > ***Recommendation 4.3.1*** *(Quillayute, Hoh, and Grays Harbor Fall Chinook). For the Washington coastal fall escapement indicator stocks, limit adjustments of CWT recoveries to*

the WA CST N, TWAC FN, TNF TERM S fisheries to reduce the potential of inadvertently introducing a negative bias into fishery impacts.

Recommendation 4.3.2 *(Grays Harbor Fall Chinook). Use the terminal harvest rate for natural-origin fall Chinook, rather than the composite hatchery-natural harvest rate, to more accurately represent the terminal harvest rate on the Grays Harbor Fall Chinook escapement indicator stock.*

Recommendation 4.3.3 *(NWVI Natural Aggregate and SWVI Natural Aggregate).* Evaluate whether new information (see Luedke et al. 2019) on terminal area harvest rates could be used to improve the accuracy with which RBT adj reflects the terminal exploitation rate experienced by NWVI and SWVI escapement indicator stocks.

A complete accounting of catch and estimates of escapement that have low error are important to estimating the terminal harvest rate and monitoring the performance of the ISBM fisheries.

Conclusion 4.4. The run reconstructions typically used to estimate terminal harvest rates require escapement estimates that have low error. The CTC previously found that escapement estimates for five stocks for which a terminal adjustment is applied do not meet CTC standards.

Recommendation 4.4.1. *Prioritize the implementation of studies to verify or recalibrate the estimated escapement for the five escapement indicator stocks found by the CTC to not meet CTC standards (Grays Harbor Fall, Quillayute Fall, Hoh Fall, NWVI Natural Aggregate, and SWVI Aggregate).*

An important assumption when using estimates derived from the CWT indicator stocks~~,~~ is that they accurately represent the fishery impacts on the escapement indicator stocks. The CWT Expert Panel (Expert Panel 2005) previously recommended further review and testing of the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts.

Conclusion 4.5. The assumption that an adjusted CWT indicator stocks accurately represents exploitation rates on the associated escapement indicator stock may become more tenuous in instances where the CWT indicator stock is released in a different basin than the associated escapement indicator stock originates. That divergence occurs for 10 of the escapement indicator stocks for which a terminal area adjustment is identified in Attachment I.

Recommendation 4.5.1. *Conduct studies to test the assumption that the CWT indicator stocks accurately reflect exploitation rates on the escapement stocks and evaluate if a better CWT stock exists or could be developed. Prioritize the implementation of these studies for stocks such as the NWVI Natural Aggregate and Grays Harbor Fall where a significant difference exists between the geographic location of the escapement and associated CWT indicator stock (Figure 1).*

5.0 Fisheries Lacking Estimates of CWTs

The CYER WG (2019b) reviewed the results from the Readiness Questionnaire, identified a number of fisheries in the U.S. and Canada for which CWT recoveries were not estimated, and conducted heuristic simulations to illustrate the effects of failing to report CWT recoveries where, in fact, fishery catch occurred. Due to the interdependence amongst fisheries and escapement of CYER estimates, a failure to estimate recoveries in fisheries where the CWT indicator stock is present will result in an overestimate of the CYER in all other sampled fisheries. Failure to adequately report CWT impacts in an ISBM fishery, for example, will reduce the perceived CYER in that fishery and potentially increase the estimated CYER in the other Party's ISBM fishery. Perhaps not as immediately evident, failure to report CWT impacts in an Aggregate Abundance Based Management (AABM) fishery can also affect the perceived compliance of a Party with the ISBM obligations of Chapter 3.

We chose two of the fisheries identified by the CYER WG (2019b) (U.S. North of Falcon Troll and Snohomish Freshwater Sport) to further illustrate the effects of not sampling fisheries for CWTs and not applying an indirect method to fill this gap.

5.1 Description

Fishery catches for each time period, fishery, and location stratum were compiled using the Catch/Sample queries available through the Regional Mark Information System (RMIS; PSMFC 2012) using the parameter values listed in Table 13. An unsampled stratum was defined to occur when the sample type was category 1 (i.e., fishery with known catch) but for which no fish were reported as sampled.

Table 13 – Parameters for RMIS queries for the catch years 2009-2019 and species 1 (Chinook).

Query	Fishery Gear	Reporting Agency	Catch Location
U.S. North of Falcon Troll	10 - 18	NMFS, NMFSNWR, NWIFC, ODFW, QDNR, QUIL, USFWS, WDFW	All WA catch locations
Snohomish Sport	40 - 48	Not Specified	All Snohomish River Basin catch locations

Preliminary, rough approximations of the CWTs that would have occurred had the fishery stratum been sampled were obtained by adjusting the estimated recoveries in the CTC distribution analysis (Appendix C, CTC 2019) by the application of indirect methods. Different indirect methods were used for the U.S. North of Falcon Troll and Snohomish River Basin Sport fisheries.

U.S. North of Falcon Troll Fishery: The estimated CWT recoveries in strata that were sampled were obtained from the distribution analysis by multiplying the total landed catch recoveries by the percentage of recoveries in the North of Falcon Troll fishery for each year from 2009 to the most recent year of reported recoveries. The CWT recoveries that would have occurred in the unsampled strata (termed a pseudo recovery) were predicted by multiplying the estimated recoveries by p/(1-p) where p is the proportion of catch that was not sampled. The landed catch CYER that would have occurred had the fishery been sampled was predicted by dividing the

corrected catch (estimated landed catch recoveries + pseudo recoveries) by the corrected total recoveries (total landed catch recoveries + pseudo recoveries).

Snohomish River Basin Sport Fishery: The Snohomish River Basin sport fishery allows only the retention of adipose fin-clipped Chinook salmon. The Skykomish Fingerling indicator stock is released from the Wallace Hatchery in the Snohomish River basin and is likely to be impacted by this fishery. The estimated CWT recoveries in strata that were sampled were obtained from the distribution analysis by multiplying the total landed catch recoveries by the percentage of recoveries in the Terminal Fishery-Southern US-S column of the CTC analysis for each year from 2009 to 2017 (CTC 2019b). The CWT recoveries that would have occurred in the unsampled strata were predicted by multiplying the unsampled catch by the proportion of the spawners at the Wallace Hatchery comprised of the indicator stock CWT groups in each year. A reported catch CYER was predicted by dividing the corrected catch (estimated landed catch recoveries + pseudo recoveries) by the corrected total recoveries (total landed catch recoveries + pseudo recoveries).

Assumptions of the method include the following:

1) Adipose fin-clipped Chinook salmon are correctly identified at the Wallace Hatchery; and
2) Marked and tagged fish are caught in the sport fishery in the same proportion as they occur at the Wallace Hatchery.

5.2 Results

5.2.1 U.S. North of Falcon Troll Fishery

An average of 10% (range of 4% - 18%) of the catch in Washington components of the U.S. North of Falcon Troll fishery was not sampled for CWTs from 2009-2019 (Table 14). The catch that was not sampled for CWTs varies by year, fishery, time, and area, but some general patterns are evident. In Table 15, for example, it is evident that the fishery gear 15 in Area 2 has consistently not been sampled. That was previously noted in the 2019 U.S. Response to the Readiness Questionnaire (CYER WG 2019b). Temporal trends in the lack of sampling are also evident, with the percentage of the catch that was sampled greatest from May through September (roughly time periods 19-40) (Table 16).

Table 14 – Sampled and unsampled catch by year in the U.S. North of Falcon Troll fishery from 2009-2019.

Catch Year	Sampled Strata		Unsampled Strata	
	Sample	Catch	Catch	Percent
2009	14,802	26,651	1,532	5%
2010	30,765	73,636	6,380	8%
2011	23,281	55,106	7,435	12%
2012	32,216	84,744	9,701	10%
2013	36,337	82,824	11,192	12%
2014	38,321	85,923	19,232	18%

Catch Year	Sampled Strata		Unsampled Strata	
	Sample	Catch	Catch	Percent
2015	54,524	112,504	7,204	6%
2016	19,360	36,790	4,210	10%
2017	32,703	56,600	2,474	4%
2018	26,565	46,164	2,856	6%
2019	22,788	40,387	2,458	6%
Average	**30,151**	**63,757**	**6,789**	**10%**

Table 15 – Sampled and unsampled catch by fishery gear-location strata in the U.S. North of Falcon Troll fishery from 2009-2019 for strata with an estimated catch.

Fishery Gear and Location	Sampled Strata		Unsampled Strata	
	Sample	Catch	Catch	Percent
10 Area 1	8,919	15,872	4,834	23%
10 Area 2	87,201	177,666	3,158	2%
10 Area 3	41,092	83,415	9,950	11%
10 Area 4	28,460	52,776	4,968	9%
15 Area 4, 4B, 5	23,153	41,553	2,380	5%
15 Area 4, 4B	16,450	24,405	917	4%
15 Area 4A	0	0	243	100%
15 Area 4B	14,239	41,902	9,040	18%
15 Area 2	0	0	13,586	100%
15 Area 3	21,493	51,720	14,265	22%
15 Area 4	88,303	206,235	6,152	3%
15 Area 5	2,352	5,785	3,329	37%
15 Area 6	0	0	743	100%
15 Area 6C	0	0	1,106	100%
15 Area 6D	0	0	3	100%
Average	**22,111**	**46,755**	**4,978**	**10%**

Table 16 – Sampled and unsampled catch by statistical week in the U.S. North of Falcon Troll fishery from 2009-2019 for strata with an estimated catch.

Statistical Week	Average Catch	Sampled Strata		Unsampled Strata	
		Sample	Catch	Catch	Percent
1	47	0	0	283	100%
2	87	25	223	644	74%
3	105	131	651	397	38%
4	126	63	525	608	54%
5	198	271	876	907	51%
6	122	222	891	333	27%
7	115	183	611	543	47%
8	196	1,135	1,655	497	23%
9	135	425	1,047	440	30%

Statistical Week	Average Catch	Sampled Strata		Unsampled Strata	
		Sample	Catch	Catch	Percent
10	137	386	1,081	287	21%
11	74	179	430	235	35%
12	46	132	232	180	44%
13	89	83	363	531	59%
14	130	109	527	902	63%
15	148	241	606	1,018	63%
16	105	223	456	589	56%
18	804	1,996	3,804	3,430	47%
19	2,381	11,852	22,813	3,374	13%
20	3,672	18,415	33,771	6,622	16%
21	3,866	21,678	40,274	2,253	5%
22	3,821	19,798	34,839	7,193	17%
23	3,723	19,933	37,924	3,033	7%
24	5,921	29,099	63,336	1,800	3%
25	5,779	27,393	60,062	3,505	6%
26	4,960	25,058	52,393	2,162	4%
27	4,545	19,288	45,327	4,666	9%
28	3,482	15,461	32,528	5,769	15%
29	4,540	25,973	46,987	2,957	6%
30	5,247	24,796	55,024	2,696	5%
31	3,429	15,409	35,769	1,947	5%
32	3,207	13,175	32,551	2,726	8%
33	2,849	12,295	28,814	2,520	8%
34	2,246	9,253	22,877	1,831	7%
35	1,801	8,648	17,611	2,203	11%
36	1,300	4,832	12,623	1,673	12%
37	824	2,487	8,289	771	9%
38	325	601	2,554	1,022	29%
39	109	322	485	384	44%
40	16	0	0	65	100%
44	7	0	0	37	100%
45	15	7	48	104	68%
46	23	0	0	114	100%
47	13	10	13	66	84%
48	37	0	0	256	100%
49	19	17	78	109	58%
50	35	34	188	164	47%
51	51	0	0	408	100%
52	41	24	173	194	53%
53	21	0	0	211	100%
54	1	0	0	15	100%
Average	**1,419**	**6,633**	**14,027**	**1,493**	**10%**

Recoveries of CWT for sampled fisheries, areas, and times indicate that 18 CWT indicator stocks may be present in unsampled strata of the U.S. North of Falcon Troll fishery (Table 17). Adjustment for unsampled strata resulted in an increase of 0 to 0.01 in the average landed catch CYER.

Table 17 – Average annual estimated recoveries, pseudo recoveries for unsampled strata, and approximate landed catch CYER for CWT Indicator Stocks with estimated recoveries in the U.S. North of Falcon Troll fishery from 2009 to the most recent year of recoveries.

CWT Indicator Stock	Average Estimated Recoveries	Average Pseudo Recoveries	Landed Catch CYER	
			Before Adjustment	After Adjustment
Robertson Creek Hatchery	1.0	0.1	0.00	0.00
Cowichan	27.4	3.3	0.01	0.01
Nicola	16.8	1.8	0.02	0.02
Lower Shuswap	25.4	3.2	0.01	0.01
Harrison	85.5	8.8	0.04	0.04
Nooksack Spring Fingerling	16.1	1.8	0.02	0.02
Skagit Spring Fingerling	3.7	0.3	0.00	0.00
Stillaguamish	8.7	1.0	0.01	0.02
Skykomish	9.7	1.0	0.01	0.02
Hoko	8.1	0.8	0.01	0.01
Queets	7.0	0.8	0.00	0.00
Upriver Bright	89.0	11.6	0.01	0.01
Hanford	14.7	1.8	0.01	0.01
Lewis River Wild	4.8	0.7	0.02	0.02
Cowlitz Fall Hatchery	21.6	2.2	0.04	0.04
Columbia Summer	249.2	26.3	0.04	0.04
Salmon River Hatchery	91.1	10.8	0.01	0.02
Elk	136.8	17.2	0.03	0.04

5.2.2 Snohomish River Basin Sport Fishery

An average of 77% (range of 0% - 100%) of the catch in the Snohomish River Basin Sport fishery was not sampled for CWTs from 2009-2018 (Table 18). More than 75% of the catch was sampled for CWTs in 2010-2012 in conjunction with the bilateral CWT Improvement Program (CWTIT 2015). The average CYER for 2009-2017 for reported catch in the Snohomish River Basin Sport fishery increased from 0.02 to 0.07, and the landed catch CYER increased by up to 0.11 (occurred in 2013), after application of an adjustment to account for unsampled catch.

Table 18 – Sampled and unsampled catch by year in the Snohomish River Basin sport fishery from 2009-2018.

Catch Year	Sampled Strata		Unsampled Strata	
	Sample	Catch	Catch	Percent
2009	0	0	185	100%
2010	70	218	12	5%
2011	172	288	0	0%
2012	97	526	137	21%
2013	0	0	754	100%
2014	0	0	272	100%
2015	0	0	188	100%
2016	0	0	686	100%
2017	0	0	716	100%
2018	0	0	527	100%
Average	34	103	348	77%

Table 19 – Total estimated CWTs, pseudo recoveries for unsampled strata, and approximate landed catch CYER for the Skykomish Fingerling CWT indicator stock from 2009 through 2017.

Catch Year	Total Estimated CWTs	Snohomish River Basin Sport			Landed Catch CYER	
		% of Total	Estimated CWTs	Pseudo CWTs	Base	Adjusted
2009	327	0.00%	0.0	31.8	0.00	0.09
2010	386	3.37%	13.0	1.5	0.03	0.04
2011	448	9.15%	41.0	0.0	0.09	0.09
2012	971	1.34%	13.0	14.3	0.01	0.03
2013	594	0.00%	0.0	75.7	0.00	0.11
2014	429	0.00%	0.0	22.5	0.00	0.05
2015	482	0.00%	0.0	21.6	0.00	0.04
2016	1,329	0.00%	0.0	106.8	0.00	0.07
2017	1,284	0.00%	0.0	106.8	0.00	0.08
Average					0.02	0.07

5.3 Conclusions and Recommendations

The Readiness Questionnaire identified a number of fisheries in the U.S. and Canada for which CWT recoveries are not estimated (CYER WG 2019b). Both the U.S. and Canada are reviewing the fisheries for which sampling may not have occurred or a catch estimate is not available, which may result in additional fisheries being identified in the list in Appendix 1 (CYER WG 2019b). The CYER WG (2019b) noted when fisheries are not sampled and an indirect method is not applied to fill this gap, the lack of estimated CWTs can adversely affect the estimates of CYERs in a Party's ISBM fisheries, even if the CWT indicator stock originated from the other Party. Our analyses were intended to illustrate and further

explore this topic, and we recognize that management entities or the CTC will likely improve the indirect methods that we applied to the U.S. North of Falcon Troll fishery and the Snohomish River Basin sport fishery.

Not surprisingly, the examples we provided illustrate the effect of a lack of estimated CWTs will vary depending on the location of the fishery and the percentage of the catch that is not sampled. In the U.S. North of Falcon Troll fishery, from 2009-2019, CWT recoveries an average of 10% of the catch were not estimated. Although our preliminary assessment indicated that the largest increase in the average landed catch CYER was 0.01 (Table 17), the CYERs for at least 18 stocks may have been affected. In the Snohomish River Basin sport fishery, although the catch not sampled averaged less than 500 fish, our preliminary analysis resulted in an increase in the landed catch CYER of up to 0.11 (Table 19) because the fishery was directed at the hatchery returns associated with the Skykomish Fingerling CWT indicator stock.

Management entities have long recognized the fundamental importance of estimating CWT recoveries in all fisheries. Our analysis reinforces the importance of those programs and illustrates the importance of applying indirect methods when lack of direct CWT sampling or catch estimation programs would prevent such estimates. Collaboratively working to address shortcomings in the CWT program will benefit both Parties and improve the CTC exploitation rate analysis and promote effective implementation of the ISBM provisions of Chapter 3.

Conclusion 5.1. The lack of estimated CWT recoveries from a fishery (or escapement) where a CWT indicator stock was caught can affect the estimated CYER and perceived compliance with ISBM obligations.

Recommendation 5.1. *Encourage management entities to annually review fishery monitoring programs to maximize the number of fisheries for which CWT recoveries are directly estimated.*

Recommendation 5.2. *Encourage management entities responsible for estimating CWT recoveries to provide the estimated CWT recoveries for each fishery with landed catch using indirect methods if necessary. An example is the Puget Sound Freshwater Recreational analysis done by WDFW and presented to the CYER WG in February 2021 (K. Ryding pers. comm.).*

Recommendation 5.3. *Prior to conducting the annual exploitation rate analysis, the CTC should identify at the estimation level (i.e., the location, fishery gear, and time period strata for which CWT recoveries are estimated) the fisheries for which CWT recovery estimates are currently not provided. In consultation with CTC members familiar with these fisheries, summarize the identified situations and apply an indirect method in the annual exploitation rate analysis.*

6.0 References

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7.0 Appendices

Appendix 1—Indirect Fishery Questionnaire sent to agencies.

Indirect Methods Fishery Questionnaire

ERA Fishery Name (from list attached):

Agency Reviewers:

Contact Email:

1. Briefly describe the indirect method(s) used in each ERA fishery (Attachment 1) and whether it's a c-pop (estimate of total catch or sample rate), c-comp (estimate of tag composition), or both.

2. Describe when and where (temporal-spatio-gear) in the fishery the indirect method is used or CWT estimates are lacking.

3. Provide the 2009-2019 (or most recent year available) average estimated retained catch of CYER tags* retained in the fishery, by stock and total, separately for tags estimated by direct methods and by indirect methods. Please provide as an excel file (see Attachment 2 – WCVI AABM sport example below).

4a. Using consensus of subject matter experts (e.g., a Delphi approach), describe how biased the agency considers the indirect method (low (<10%) | medium (10-30%) | high (>30%). Note, question 4 a and b relate to how biased the estimation method is on a per tag basis, regardless of how many tags (or how 'big' the fishery is) the method is applied to.

4b. Provide the rationale used to reach this conclusion, and illustrate both confidence and concern as it applies to those estimates being produced.

5. If CWT estimates are not available for past years, describe why the fishery is expected to exploit a CWT Indicator Stock, your best assessment of the typical annual (from 2009-2019, or most recent year available) total retained catch in the fishery, and the percentage of the retained catch expected to contain a CYER tag (of any stock) (supporting an estimate comparable to those provided in question 3).

6. For any fishery identified in the response to question 5, Provide the best assessment of the typical annual (from 2009-2019, or most recent year available) kept CYER tags per stock **and** the exploitation rate for the stocks impacted by the fishery.

*CYER tags are defined as: Estimated coded wire tags from Attachment I stocks with CYER limits.

Attachment 1—List of Fisheries to be reviewed for indirect methods

PSC Fishery #	Acronym	PSC Fishery
1	AK W/S T	Alaska Winter/Spring Troll
2	AK JNO T	Alaska June Outside Troll
3	AK JNI T	Alaska June Inside Troll
4	AK JLO T	Alaska July Outside Troll
5	AK JLI T	Alaska July Inside Troll
6	AK FALL T	Alaska Fall Troll
7	TAK TERM T	Alaska Terminal Troll
8	NORTH T	North Troll
9	CENTRL T	Central Troll
10	WCVI F/W T	WCVI Fall/Winter Troll
11	WCVI SPR T	WCVI Spring Troll
12	WCVI SUM T	WCVI Summer Troll
13	N FALCON T	US North of Falcon Troll
14	S FALCON T	US South of Falcon Troll
15	TOR TERM T	Oregon Terminal Troll
16	GEO ST T	Georgia Strait Troll
17	ALASKA N	Alaska Net
18	NORTH N	North BC Net
19	TNBC TERM N	North BC Terminal Net
20	CENTRL N	Central BC Net
21	TCBC TERM N	Central BC Terminal Net
22	TWCVI TERM N	Terminal WCVI
23	WCVI N	WCVI Net
24	GEO ST N	Georgia Strait Net
25	PGSDN N	Puget Sound North Net
26	TPGSDN TERM N	Puget Sound North Terminal Net
27	US JF N	US Juan De Fuca Net
28	PGSDO N	Puget Sound Other Net
29	TPGSDO TERM N	Puget Sound Other Terminal Net
30	WA CST N	Washington Coastal Net
31	TCOL R N	Columbia River Terminal Net
32	TAK TERM N	Alaska Terminal Net

PSC Fishery #	Acronym	PSC Fishery
33	TBR TERM N	US Transboundary River Terminal Net
34	TNORTH FN	North BC Terminal Freshwater Net
35	TCENTRAL FN	Central BC Terminal Freshwater Net
36	TGEO ST FN	Georgia Strait Terminal Freshwater Net
37	TFRAS FN	Fraser Terminal Freshwater Net
38	TPS FN	Puget Sound Terminal Freshwater Net
39	TWAC FN	Washington Coastal Terminal Freshwater Net
40	JNST N	Johnstone Strait Net
41	BC JF N	BC Juan De Fuca Net
42	FRASER N	Fraser Net
43	TFRASER TERM N	Fraser Terminal Net
44	ALASKA S	Alaska Sport
45	CBC S	Central BC Sport
46	TCBC TERM S	Central BC Terminal Sport
47	NBC AABM S	North BC AABM Sport
48	NBC ISBM S	North BC ISBM Sport
49	TNBC TERM S	North BC Terminal Sport
50	WCVI AABM S	WCVI AABM Sport
51	WCVI ISBM S	WCVI ISBM Sport
52	TWCVI TERM S	WCVI Terminal Sport
53	N FALCON S	US North of Falcon Sport
54	TNF TERM S	US North of Falcon Terminal Sport
55	S FALCON S	US South of Falcon Sport
56	TSF TERM S	US South of Falcon Terminal Sport
57	PGSDN S	Puget Sound North Sport
58	TPGSDN TERM S	Puget Sound North Terminal Sport
59	PGSDO S	Puget Sound Other Sport
60	TPGSDO TERM S	Puget Sound Other Terminal Sport
61	JNST S	Johnstone Strait Sport
62	TJNST TERM S	Johnstone Strait Terminal Sport
63	GEO ST S	Georgia Strait Sport
64	TGEO ST TERM S	Georgia Strait Terminal Sport
65	BC JF S	BC Juan De Fuca Sport

PSC Fishery #	Acronym	PSC Fishery
66	TBC JF TERM S	BC Juan De Fuca Terminal Sport
67	TCOL R S	Columbia River Terminal Sport
68	TAK TERM S	Alaska Terminal Sport
69	TBR TERM S	Transboundary River Terminal Sport
70	TNORTH FS	North BC Terminal Freshwater Sport
71	TCENTRAL FS	Central BC Terminal Freshwater Sport
72	TWCVI FS	WCVI Terminal Freshwater Sport
73	TFRASER FS	Fraser Terminal Freshwater Sport
74	TGS FS	Georgia Strait Terminal Freshwater Sport
75	TPS FS	Puget Sound Terminal Freshwater Sport
76	TSF TERM FS	US South of Falcon Terminal Freshwater Sport
77	TCAN TBR N	Canadian Transboundary River Net
78	XCA ESC STRAY	Canadian Escapement Strays
79	XUS ESC STRAY	US Escapement Strays
80	ESCAPEMENT	Escapement

Appendix 2—Final ranks of Canadian fisheries under the risk assessment schema.

Fishery	Tag Bin[1]	Bias Level[1]	Rank Score	Fishery Method[2]	Number of CYER Stocks Impacted
Central Sport	High	High	6	2,4,5,6	20
North Georgia Strait Sport	High	High	6	1,4,5,6	10
Canadian Juan De Fuca Sport	High	High	6	3,5	9
South Georgia Strait Sport	High	High	6	1,4,5	7
Lower Fraser Freshwater Net	High	High	6	3,7,8	4
North AABM Sport (QCI)	High	Moderate	5	1,2,5,6	23
North ISBM Sport	Medium-High	High	5	2,5,6	18
WCVI AABM Sport	Medium-High	High	5	1,5,6	14
Central Freshwater Net	High	Moderate	5	7	1
Georgia Strait Freshwater Net	Medium-High	High	5	8	1
Fraser Freshwater Sport	Medium	High	4	2,3,5,6,7	4
Central Freshwater Sport	Medium-High	Moderate	4	2,7	1
Johnstone Strait Sport	Small	High	3	1,2,5,6	11
North Georgia Strait Terminal Sport	Small	High	3	1,4,5,6	4
North Freshwater Sport	Small	High	3	2	2
BC Stikine Freshwater Sport	Medium	Moderate	3	7	1
WCVI ISBM Sport	Very Small	High	2	1,5	8
Johnstone Strait Terminal Sport	Very Small	High	2	1,2,5,6	3
South Georgia Strait Terminal Sport	Very Small	High	2	1,4,5	3
North Spring Troll	Very Small	High	2	9	2
North Summer Troll	Very Small	High	2	9	2
Upper Fraser Freshwater Net	Small	Moderate	2	3,7	2
BC Taku Freshwater Sport	Small	Moderate	2	7	1
Central Terminal Net	Very Small	High	2	8	1
Central Terminal Sport	Very Small	High	2	2,4,5	1
North Georgia Strait Freshwater Sport	Very Small	High	2	2	1
North Terminal Net	Very Small	High	2	9	1
North Terminal Sport	Very Small	High	2	2,5	1
WCVI Freshwater Sport	Very Small	High	2	2	1
WCVI Terminal Sport	Very Small	High	2	1	1
Southwest WCVI Terminal Net	Very Small	Moderate	1	7	1
BC Stikine Freshwater Net	None	Moderate	0	Direct	Direct
BC Taku Freshwater Net	None	Moderate	0	Direct	Direct
Canadian Juan De Fuca Net	None	Moderate	0	Direct	Direct
Canadian Juan De Fuca Terminal Sport	None	Moderate	0	Direct	Direct
Central Net	None	Moderate	0	Direct	Direct
Fraser Net	None	Moderate	0	Direct	Direct
Fraser Terminal Net	None	Moderate	0	Direct	Direct

Fishery	Tag Bin[1]	Bias Level[1]	Rank Score	Fishery Method[2]	Number of Stocks Impacted
Johnstone Strait Net	None	Moderate	0	Direct	Direct
North Fall Troll	None	Moderate	0	Direct	Direct
North Net	None	Moderate	0	Direct	Direct
Northwest Vancouver Island Fall Troll	None	Moderate	0	Direct	Direct
Northwest Vancouver Island Spring Troll	None	Moderate	0	Direct	Direct
Northwest Vancouver Island Summer Troll	None	Moderate	0	Direct	Direct
Northwest Vancouver Island Winter Troll	None	Moderate	0	Direct	Direct
Northwest WCVI Terminal Net	None	Moderate	0	Direct	Direct
Southwest Vancouver Island Fall Troll	None	Moderate	0	Direct	Direct
Southwest Vancouver Island Spring Troll	None	Moderate	0	Direct	Direct
Southwest Vancouver Island Summer Troll	None	Moderate	0	Direct	Direct
Southwest Vancouver Island Winter Troll	None	Moderate	0	Direct	Direct
Southwest WCVI Net	None	Moderate	0	Direct	Direct

[1] See Table 2 for reference to tag bin and bias level score matrix.

[2] See Table 3 for reference to numerical fishery reference.