Recommended Transition Plan for Estimating Calendar Year Exploitation Rates for Chinook Salmon Escapement Indicator Stocks Impacted by Mark-Selective Fisheries

Calendar Year Exploitation Rate Working Group

March 2023

Pacific Salmon Commission
Technical Report No. 50

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For

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List of Acronyms and Abbreviations

ADF&G	Alaska Department of Fish & Game
ASFEC	Ad-hoc Selective Fishery Evaluation Committee
CDFW	California Department of Fish and Wildlife
CIG	Chinook Interface Group
DFO	Fisheries and Oceans Canada
DGM	Data Generation Model
DIT	Double Index Tag Group
CRITFC	Columbia River Inter-Tribal Fish Commission
CTC	Chinook Technical Committee
CWT	Coded-Wire Tag
CYER	Calendar Year Exploitation Rate
CYER WG	CYER Working Group
ETD	Electronic Tag Detection
ISBM	Individual Stock-Based Management
MM	Mass Marking
MRE	Mark-Recognition Error
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish and Wildlife
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
SFEC	Selective Fisheries Evaluation Committee
SIT	Single Index Tag Group
URE	Unmarked-Retention Error
WDFW	Washington Department of Fish and Wildlife

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Executive Summary

Mark-selective fisheries (MSFs) for Chinook salmon have been increasingly implemented as a fishery management tool to promote increased fishery exploitation of hatchery-origin Chinook salmon relative to natural-origin fish. As currently practiced, this management tool relies upon marking hatchery-origin fish prior to release by clipping the adipose fin. In its most basic form, a MSF regulation requires the release of all unclipped Chinook salmon while allowing only the retention of clipped, hatchery-origin Chinook salmon greater than a minimum size.

The initiation of MSFs introduced challenges into the estimation of fishery exploitation rates on natural-origin Chinook salmon (ASFEC 1995; Expert Panel 2005). Since an objective of a MSF is to differentially exploit hatchery- and natural-origin salmon, the underlying assumption that a CWT indicator stock of hatchery-origin accurately represents fishery impacts on the escapement indicator stocks is no longer valid if the fish are impacted by MSFs.

The importance of addressing these estimation challenges was accentuated by the 2019 update to the Pacific Salmon Treaty (PST). The 2019 update establishes constraints on the impact of one or both Parties' individual stock-based management (ISBM) fisheries on certain naturally spawning escapement indicator stocks of Chinook salmon when a 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 calendar year exploitation rate (CYER) estimated from the associated CWT indicator stock with the ISBM limit (see PST, Annex IV, Chapter 3, paragraph 5 and Attachment I). However, compliance with a CYER limit is reliant on accurate estimation of a CYER which may be influenced by MSFs.

The Pacific Salmon Commission (PSC or Commission) recognized that a broad range of enhancements to existing programs might be necessary to implement the updated provisions of the PST. Accordingly, the PSC directed the Calendar Year Exploitation Rate Working Group (CYER WG) to work with the Chinook Interface Group (CIG) to develop a recommended transition plan:

> ***"<u>Develop MSF Transition Plan</u>. The transition plan could include short- and long-term methods to estimate CYERs on natural-origin Chinook salmon, and a time schedule for implementation of recommended changes to tagging, sampling, fishery monitoring, information management, and analytical methods."***

We provide the following recommendations to the PSC to effectively implement those changes.

Chapter 2. Evaluation of Estimation Methods

We evaluated seven alternative methods to estimate CYERs on unmarked Chinook salmon in MSFs. The methods can be categorized into two broad groups: 1) single index tag (SIT) methods use data from only clipped CWT tag groups; and 2) double index tag (DIT) methods use data from both a clipped and an unclipped CWT tag group.

Method	Description
SIT 0	Cohort reconstruction of the SIT group without any MSF adjustments
SIT 2	λ_a estimated at escapement and cohort reconstructed using a backwards cohort analysis
SIT 4	λ_a estimated at release and cohort reconstructed using a forward cohort analysis
SIT 7	The SIT method described in chapter 5 of the CTC's annual exploitation rate analysis report. Briefly, SIT 7 is the SIT 4 method with pre-terminal MSF fish survivors accruing to the terminal run.
DIT 0	Cohort reconstruction of the DIT group without any MSF adjustments
DIT 1	DIT with equal marine survival method to estimate preterminal mortality in pre-terminal MSF; uses SIT 2 for terminal MSF.
DIT 2	DIT with paired ratio method applied to pre-terminal and terminal MSF.

The performance of alternative estimators was evaluated using the Data Generation Model (DGM), a stochastic simulator previously developed to inform CTC analyses (Ding 2018). More than 20 fishery scenarios were simulated to evaluate the performance of estimators under different conditions. These scenarios included variation in the location of the MSF (preterminal or terminal fishery), intensity of the MSF (low or high), number of MSF (preterminal, terminal, or both), and the path of the tagged stock through the preterminal fisheries (single pool or "pipeline" (i.e. fish move through a series of fisheries)).

Our recommendations are primarily informed by the performance of the alternative estimators in the simulation scenarios. Additional considerations, though not expressly accounted for, include the logistics of implementation and anticipated cost.

Recommendation 2.1. Estimate CYERs using SIT 2 or SIT 4. These methods provided estimates of CYERs with minimal bias and the highest precision over the range of simulations evaluated. An additional advantage is that implementation can occur with the existing CWT indicator stock tagging and fishery monitoring programs, although tagging and sampling rates may need to be increased in some fisheries (Anderson and Reid 2020) to match the 20% sample rate used in the simulations. Since SIT 2 and SIT 4 had similar performance in the simulation, the CYER WG proposes to select one of the two methods for application to CWT indicator stocks after discussions with the CTC regarding the relative ease of implementing each method in the cohort analysis program among other factors.

Recommendation 2.2*. *Ensure technical review. The CYER WG will complete a more detailed technical description of the alternative estimators, results, and evaluation methods by May 2023. The draft report should be provided to the CTC, SFEC, and independent scientists for a technical review. The CYER WG should address comments from those committees in the final report and inform the Commission by August 2023 if new analyses or considerations suggest modification of the recommendations of the Transition Plan.

Chapter 3. Fishery Monitoring and Tagging

While the simulations are invaluable in assessing the performance of the estimators, in practice challenges are likely to arise in the application of these estimators including 1) variations from the "basic" MSF, and 2) deviations from the assumptions of exploitation rate analysis.

Agencies are encouraged to undertake the following actions to address implementation challenges, improve the data used to estimate CYERs, and facilitate adaptive management.

> ***Recommendation 3.1***. ***Monitor releases and retention by clip status in MSFs***. Encourage management entities to monitor and report the number of Chinook salmon kept and released by clip status to improve estimates of CYERs. CTC recommendations regarding the types of information needed would provide agencies with useful guidance in developing or assessing fishery monitoring.

> ***Recommendation 3.2***. ***DIT indicator network***. Modify the existing DIT indicator network and consider adding stocks in new geographic areas that are impacted by MSFs to provide an ongoing assessment of the performance of SIT methods. The network would have a lower density of CWT indicator stock coverage than required by Chapter 3 of the PST but would facilitate an assessment of the escapement rates estimated by a SIT method relative to the empirical estimates provided by the marked and unmarked components of the DIT groups. This would not require fishery sampling of unclipped and tagged Chinook salmon. Consideration of DIT stocks for the network should be informed by the feasibility of implementation, the expected quality with which the marked and unmarked CWT escapement can be estimated, and the intensity and pattern (e.g., terminal versus preterminal) of the MSFs projected to be applied to the CWT indicator stock.

Chapter 4. PSC Implementation

As anticipated by the Commission, a broad range of enhancements to existing data management and reporting processes will be needed to implement the recommended methods to estimate CYERs, ensure a consistent and coordinated coastwide approach, and maximize the repeatability of future analyses.

> ***Recommendation 4.1. Update CTC cohort analysis (CTC task).*** The CTC cohort analysis computer program will need to be updated to incorporate the recommended method to estimate CYERs. This work should be initiated in 2023, with the target of conducting the 2024 exploitation rate analysis with the updated computer code.

> ***Recommendation 4.2. Review terminal fishery designations and fishery aggregation used in CTC cohort analysis (CTC task).*** The incorporation of methods to estimate CYERs in MSFs is a substantive change in the underlying framework of the CTC cohort analysis. Ensuring that the framework, including terminal fishery designations and level of fishery aggregation, remains appropriate will be important to successful implementation of the estimation methods. This work should be initiated in 2023 with a target of implementation for the 2024 exploitation rate analysis.

> ***Recommendation 4.3. Revise post-season information management process (SFEC task).*** Rather than the agency reporting of stock-specific mortalities in MSFs envisioned in the 2004 MOU, develop bilateral standards and reporting for MSF data and ensure that it is available to the CTC to conduct bilaterally agreed analyses. Any required changes to data sharing processes should be completed prior to submissions of post-season information for fisheries conducted in 2023.

Recommendation 4.4*. *Establish reporting protocols for MSF regulations and fishery data (Data Sharing Committee task). Task the Data Sharing Committee, working with the CTC and SFEC, with establishing reporting protocols and standards for MSF regulations and fishery data (catch and release by mark status) and ensure that this information is available for CTC analyses. WDFW has been awarded a U.S. grant to develop a regulation database that, at a minimum, provides an opportunity to advance bilateral discussions of the types of regulation data necessary to facilitate the CTC exploitation rate analysis. Any required changes to data sharing processes should be completed prior to submissions of post-season information for fisheries conducted in 2023.

Recommendation 4.5. Task CYER WG with coordinating implementation of Recommendations 4.1-4.4. With representatives from the CTC, SFEC, and Data Sharing Committee, the CYER WG is well positioned to share expertise and guide implementation of these recommendations.

Recommendation 4.6. Adaptively manage CYER estimation (CTC and management entities tasks). Provide for an ongoing assessment of the performance of MSF analytic methods, assess critical uncertainties, and modify estimation and monitoring to incorporate new finding. Priority actions include: 1) develop and test additional estimators; 2) assess the mortality rate of fish released in MSFs; and 3) where mark-recognition error (MRE) and unmarked-retention error (URE) values are relied upon to estimate exploitation rates in pure MSFs, periodically review MRE and URE rate estimates based on fishery monitoring. Note that the CYER WG (2021) previously recommended that management entities 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.

1.0 Introduction

Recoveries of coded-wire-tags (CWTs) from salmon fisheries and spawning escapements are used along the west coast of North America to assess fishery impacts on Chinook salmon (ASFEC 1995). These stock-specific estimates rely on sampling fish harvested in fisheries and spawners for CWTs that were implanted in juvenile fish prior to entry into marine waters. The recoveries of CWTs are subsequently used in deterministic cohort analyses (CTC 1988), catch at age models (e.g., Savereide and Quinn 2004), or in statistical models (e.g., Bernard and Clark 1996; Newman 1998; Shelton et al. 2019) to estimate the initial abundance, fishery-specific exploitation rates, total fishery exploitation rates, distribution, or other statistics for a group of juvenile fish that were tagged with a unique CWT.

The Pacific Salmon Treaty (PST) defines the escapement indicator stocks used to monitor the escapement of naturally-spawning Chinook salmon relative to management objectives (see PSC 2022, Annex IV, Chapter 3, Attachment 1). Each escapement indicator stock is paired with a CWT indicator stock that is used to estimate fishery exploitation rates that, along with the number of spawners and environmental factors, may be affecting stock performance. Tagging of juvenile salmon for each CWT indicator stock typically occurs at hatcheries because the fish are easily accessible in that location and can be economically tagged. The adipose fin is also often clipped for fish that are tagged so that the fish can be visually identified when later sampled in fishery catches or as adults spawning in rivers or hatcheries.

A crucial assumption when using estimates derived from a CWT indicator stock originating from a hatchery is that it accurately represents the fishery impacts on the associated escapement indicator stock. Testing the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts is important to the implementation and interpretation of analyses (Expert Panel 2005; CYER WG 2021).

Mark-selective fisheries (MSFs) for Chinook salmon have been increasingly implemented as a fishery management tool to promote increased fishery exploitation of hatchery-origin Chinook salmon relative to natural-origin fish. As currently practiced, this management tool relies upon marking hatchery-origin fish prior to release by clipping the adipose fin. In its most basic form, a MSF regulation requires the release of all unclipped Chinook salmon while allowing only the retention of clipped, hatchery-origin Chinook salmon greater than a minimum size. Complexity may be added by regulations that allow for the retention of some unmarked fish and, in practice, retention of unmarked fish and release of marked fish occurs. Thus, information on regulations, or the number of fish kept and released by mark status, is necessary for the analysis.

The initiation of MSFs introduced challenges into the estimation of fishery exploitation rates on natural-origin Chinook salmon (ASFEC 1995; Expert Panel 2005). Since an objective of a MSF is to differentially exploit hatchery- and natural-origin salmon, the underlying assumption that a CWT indicator stock of hatchery-origin accurately represents fishery impacts on the escapement indicator stocks will not be valid if the fish are impacted by MSFs. Estimation of exploitation rates is also challenging because the mortality of unmarked fish that occurs after release is rarely observed. Mortality rates of released fish can be substantive with estimates in the range of 10% to 35% for commercial troll and recreational hook-and-line fisheries (STT 2000; CTC 2022a). For these reasons, the Expert Panel (2005) acknowledged that "MM {mass marking} and MSFs are likely to continue to develop in the near-term and that some loss of information from the CWT program will occur. The significance of the bias and uncertainty resulting from MSFs will vary depending on their complexity and intensity."

The importance of addressing these estimation challenges was accentuated by the 2019 update to the PST. The 2019 update establishes constraints on the impact of one or both Parties' individual stock-based management (ISBM) fisheries on certain naturally spawning escapement indicator stocks of Chinook salmon when a 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 calendar year exploitation rate (CYER) estimated from the associated CWT indicator stock with the ISBM limit (see PST, Annex IV, Chapter 3, paragraph 5 and Attachment I). However, compliance with a CYER limit is reliant on accurate estimation of a CYER which may be influenced by MSFs.

The Pacific Salmon Commission (PSC or Commission) recognized that a broad range of enhancements to existing programs might be necessary to implement the updated provisions of the PST. Implementing these enhancements without unexpected challenges and delays would require a well-developed transition plan that identified the required changes to long-established fishery monitoring practices, analytical methods of the Chinook Technical Committee (CTC), data organization, and the support roles of other PSC committees. Although the transition plan would require technical assessments, including the evaluation of alternative methods to estimate a CYER, it was also anticipated that policy consideration of implementation costs and logistics would be necessary.

Accordingly, the PSC directed the Calendar Year Exploitation Rate Working Group (CYER WG) to work with the Chinook Interface Group (CIG) to develop a recommended transition plan:

> ***"Develop MSF Transition Plan*. The transition plan could include short- and long-term methods to estimate CYERs on natural-origin Chinook salmon, and a time schedule for implementation of recommended changes to tagging, sampling, fishery monitoring, information management, and analytical methods."**

This document provides recommendations to the PSC to effectively implement those changes. Chapter 2 discusses and evaluates seven estimation methods for CYERs, Chapter 3 discusses complementary tagging and fishery monitoring actions recommended for implementation by management entities, while Chapter 4 recommends potential implementation roles of the CTC, Selective Fishery Evaluation Committee (SFEC), and Data Sharing Committee.

2.0 Evaluation of Estimation Methods

2.1 Single and Double Index Tag Groups

Numerous methods have been developed that rely on CWT recoveries to estimate fishery exploitation rates on unclipped fish that are impacted by MSFs (e.g., ASFEC 1995; SFEC 2002; Zhou 2004; Expert Panel 2005; Newman 2006; Yuen and Conrad 2011; Pyper et al. 2012; Conrad et al. 2013). The methods can be categorized into two broad groups: 1) single index tag (SIT) methods use data from only clipped CWT tag groups; and 2) double index tag (DIT) methods use data from both a clipped and an unclipped CWT tag group.

With SIT-based methods, all fish within a tag group receive both a CWT and an adipose fin clip. Fishery and spawner[1] sampling for the SIT group can be conducted either visually, based on the presence of a clipped adipose fin, or by using electronic tag detection (ETD) methods to identify fish that have been tagged with a CWT. Fishery exploitation rates on the associated unclipped escapement indicator stock are estimated by adjusting the recoveries of the clipped and tagged fish to account for the release of unclipped fish in MSFs. The adjustments rely on assumptions similar to the PSC Chinook Model and CTC cohort analysis including an assumed mortality rate for the fish that are released in the fishery.

Alternatively, with DIT-based methods, two groups are used. One group receives a unique CWT and an adipose fin clip, and a second group receives another unique CWT and is not clipped. Mortalities of the unclipped fish can be estimated from the difference in the return rate to spawning of the clipped and unclipped components of the DIT group or from recoveries of CWTs from unclipped fish in a paired, non-selective fishery.

Although a coastwide DIT program has been recommended on multiple occasions (ASFEC 1995; SFEC 2002), consistent implementation for coho and Chinook salmon has been lacking (SFEC 2016). The reasons for the inconsistent implementation include the following:

1) Tagging costs and logistics. SFEC (2016) reviewed the cost and logistical challenges associated with implementing a DIT program. Since a DIT program requires twice as many fish to be tagged, the cost of tagging is approximately double the cost of a SIT program. The increased size of the program can be logistically challenging as well. Sufficient broodstock or hatchery space may not be available and, particularly for subyearling Chinook salmon, doubling the number of fish to be tagged within the juvenile rearing period may not be feasible without a substantial increase in tagging capacity.
2) Concerns with ETD. SFEC (2022) observed that "ETD is not employed coastwide because of continuing reservations by some agencies regarding the cost, accuracy, and practical feasibility of incorporating this technology into their sampling programs. The Alaska Department of Fish and Game (ADFG), Canadian Department of Fisheries and Oceans (CDFO), Oregon Department of Fish and Wildlife (ODFW), and California Department of Fish and Wildlife (CDFW) all conduct visual sampling programs which will not recover the unclipped component of DIT programs required to assess impacts of MSFs."

[1] "Spawners is broadly defined to include sampling locations after all fishing has occurred, and includes fish at hatcheries, spawning in a river, or removed from the river at a weir or other structure.

3) Lack of bilateral agreement on estimation methods. Methods to estimate fishery exploitation rates from a DIT group for Chinook salmon have not been bilaterally developed or applied in the PSC CTC or SFEC (SFEC 2016; CTC 2022b). In part this reflects the lack of consistent and coordinated tagging and sampling protocols for DIT groups, but the absence of analysis of DIT groups further reinforces the lack of a perceived need to address the tagging and fishery sampling gaps.

The Expert Panel (2005) concluded the following regarding DIT-based methods:

> "Finding 5. We have serious methodological and sampling concerns regarding application of the DIT concept:
>
> > a. We have been unable to find convincing theoretical or empirical evidence that DIT approaches can generate precise, unbiased estimates of age-fishery-specific exploitation rates for natural stocks of chinook or coho salmon (represented by unmarked DIT release groups) in the presence of sub-stocks and multiple mark-selective ocean fisheries. Methods for analysis of DIT recovery data remain incompletely developed for: (a) complex mixtures of non-selective and mark-selective fisheries with varying exploitation rates and different catch-and-release mortality rates, and (b) the full age-structured setting required for chinook salmon.
> >
> > b. The potential utility of DIT is undermined by the reluctance of some agencies to recover CWTs for both marked and unmarked DIT groups. This reluctance can be attributed in part to the additional sampling burdens and costs associated with the use of the adipose fin clip both as a mass mark and as a visual indicator for the presence of a CWT."

A fundamental question for our work, therefore, was whether a DIT-based method was necessary to provide reliable estimates of CYERs for implementation of the Chinook chapter of the PST.

2.2 Evaluation Methods

A more detailed technical description of the alternative estimators, results, and evaluation methods will be provided in a forthcoming report by the CYER WG. The following overview is intended to provide sufficient detail to inform and support the recommendations provided in subsequent sections. The CYER WG will inform the Commission after the final technical report is completed if new analyses or considerations suggest modification of the recommendations of the Transition Plan.

The performance of alternative estimators was evaluated using the Data Generation Model (DGM), a stochastic simulator previously developed to inform CTC analyses (Ding 2018). Paragraph 5e of Chapter 3 directs the CTC to complete development of the DGM as a step towards evaluation of the CYER as a metric to monitor the performance of fisheries. The DGM stochastically simulates natural (unclipped) and hatchery (clipped or unclipped, tagged or untagged) production of Chinook salmon, natural processes such as mortality and maturation, fisheries, and sampling for CWTs over multiple time periods, fisheries, and years. A schematic depiction of the DGM fishery process is provided in **Figure *1***.

```
A fish is encountered...
  Flip a coin If the fish dies before being caught then
    Update population, go to next fish
  Else the fish is caught
    If the fish is smaller than the size limit then
      Flip a coin If the fish dies upon release then
        Update population, go to next fish
      Else the fish survives
        Go to next fish
    Else the fish is legal sized
      If the fishery is mark-selective fishery then
        If the fish has an adipose-fin then
          Flip a coin If the fish is accidentally retained then
            Update population, update catch, go to next fish
          Else the fish is released
            Flip a coin If the fish dies upon release then
              Update population, go to next fish
            Else the fish survives
              Go to next fish
        Else the fish does not have an adipose-fin and can be retained
          Update population, update catch, go to next fish
      Else the fishery is not mark-selective
        Update population, update catch, go to next fish
Next fish
```

Figure 1. Schematic depiction of the fishing process used by the DGM.

More than 20 fishery scenarios were simulated to evaluate the performance of estimators under different conditions. These scenarios included variation in the location of the MSF (preterminal or terminal fishery), intensity of the MSF (low or high), number of MSF (preterminal, terminal, or both), and the path of the tagged stock through the preterminal fisheries (single pool or “pipeline” (i.e. fish move through a series of fisheries)).

Each simulation was repeated 250 times. The estimated CWT recoveries from the simulations were used as input to a cohort analysis program developed to compute CYERs using alternative estimators. The bias and variability of the alternative estimators were then assessed by comparing the true values known from each run of the DGM and the estimated values from the cohort analysis.

Estimation methods that relied on either SIT or DIT tag groups were developed and tested through an iterative approach across the range of fishery scenarios. Beginning with estimation methods drawn from previous reports and publications, the performance of the estimators was evaluated, limitations diagnosed, improvements identified, and the performance of the new estimators evaluated. Although time consuming and challenging, this iterative process resulted in the development of estimators that differed substantially, and performed better, than the estimators that had been previously developed.

A variety of programs and workbooks were also developed as needed to assess why, or why not, an estimator worked under a specific set of conditions. These programs and workbooks were invaluable in diagnosing what conditions were creating errors in the estimated CYERs.

2.3 Performance of Alternative Estimators

Our results and conclusions are drawn from the variety of scenarios that were simulated. However, for simplicity of presentation, we have illustrated the results using a single scenario chosen because it presents some of the most complex fisheries and stock migrations simulated. In this scenario, there is both a preterminal and terminal MSF and both MSFs are operating at the higher simulated intensity. The tagged stock moves through the preterminal fisheries sequentially, with preterminal non-selective fisheries occurring before and after the preterminal MSF. The simulated CWTs in the fishery catch are sampled at a 20% sample rate.

Seven alternative estimators were evaluated (**Table 1**). The performance of each estimator for the MSF preterminal fishery is illustrated in **Figure 2** and summarized below.

Table 1. Description of alternative methods to estimate exploitation rates on unmarked Chinook salmon in the presence of the mark-selective fisheries. λ_a is the ratio of unmarked to marked fish. All methods assume that marked and unmarked Chinook salmon have the same migratory pattern and maturation rates.

Method	Description
SIT 0	Cohort reconstruction of the SIT group without any MSF adjustments
SIT 2	λ_a estimated at escapement and cohort reconstructed using a backwards cohort analysis
SIT 4	λ_a estimated at release and cohort reconstructed using a forward cohort analysis
SIT 7	The SIT method described in chapter 5 of the CTC's annual exploitation rate analysis report. Briefly, SIT 7 is the SIT 4 method with pre-terminal MSF fish survivors accruing to the terminal run.
DIT 0	Cohort reconstruction of the DIT group without any MSF adjustments
DIT 1	DIT with equal marine survival method to estimate preterminal mortality in pre-terminal MSF; uses SIT 2 for terminal MSF.
DIT 2	DIT with paired ratio method applied to pre-terminal and terminal MSF.

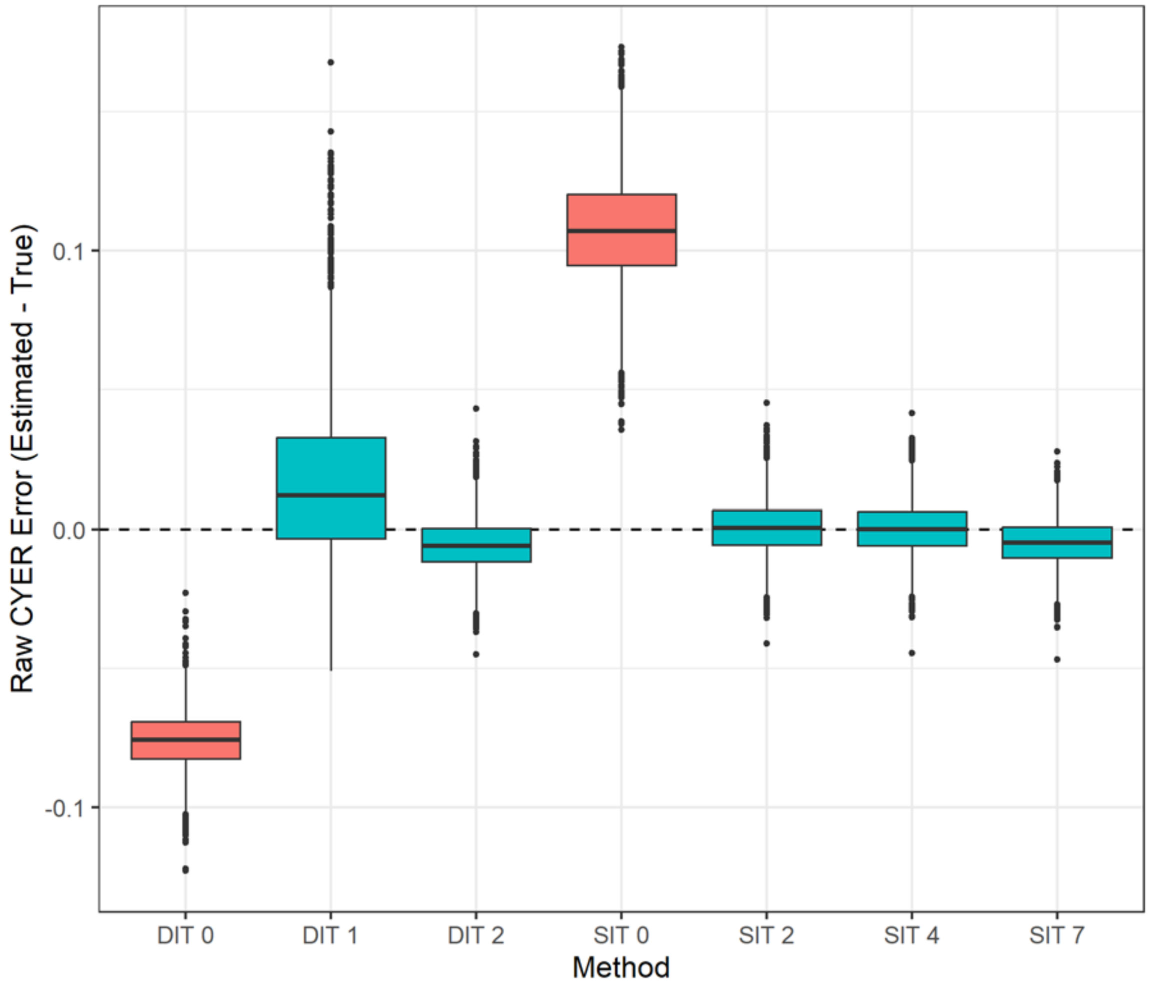

Figure 2. Comparison of performance of estimators for a scenario with high intensity MSF in both a terminal and preterminal fishery (DGM_M2P_M2_20). Estimated CYERs are for the preterminal MSF.

2.3.1 DIT 0 and SIT 0

These estimators bracket the magnitude of the bias in the estimated CYER that would occur absent accounting for the differential mortality rates exerted by the MSFs. With DIT 0, only the CWT recoveries of unclipped fish are used to estimate the CYER. Since in this simulation scenario all unmarked fish are released in the MSFs (i.e., there is no unmarked recognition error), but mortality of some of those fish subsequently occurs, DIT 0 has a substantial negative bias. Conversely, with SIT 0, the exploitation rates of unmarked and marked fish are assumed equal, resulting in a positive bias in the estimated CYER for the unclipped fish.

> ***Conclusion***. Failure to account for the differential effects of MSFs on clipped and unclipped Chinook salmon can result in a substantive bias in the estimated CYERs for an unclipped escapement indicator stock.

2.3.2 DIT 1

The MSF mortality is estimated from the difference in mortalities for the two DIT groups with mortality allocated to a specific MSF based upon recoveries of tagged and clipped fish (variation of Equal Marine Survival method of SFEC (2002) and Appendix A method of Expert Panel (2005)). In this scenario DIT 1 has a positive bias and the greatest variability of the estimators evaluated. The variability likely results from subtracting one random variable from a second random variable (the difference in the mortality of the two DIT groups), with variation in both random variables contributing to the variability in the estimated CYER. SFEC (2002) also found high variability in the estimated mortalities of unclipped fish in a MSF for DIT 1 relative to DIT 2.

> ***Conclusion.*** Similar to SFEC (2002) and Expert Panel (2005), DIT 1 did not perform as well as the other methods in estimating the CYERs in the simulation scenarios.

2.3.3 DIT 2

The MSF fishery mortalities are estimated using information from an adjacent, non-selective fishery (variation of the Paired Fishery method of SFEC 2002). DIT 2 has a slight negative bias in the simulation with variability similar to SIT 2, SIT 4, and SIT 7.

SFEC (2002) concluded that “reasonable estimates” could be obtained from this estimator if unbiased estimates of the release mortality rate and the ratio of unmarked to marked and tagged (λ) fish from the non-selective fishery were available.

In practice, that could be challenging. SFEC (2002) observed that the paired non-selective fishery should either: 1) “operate concurrently in the same area as the mark-selective fishery so that both fisheries exploit a single pool of fish”; or 2) “operate immediately before the conduct of the mark-selective fishery and not “upstream” of migration pathways where fish with different λ’s can be expected to enter the area where the mark-selective fishery operates”. SFEC also noted that “CWT recoveries from sampling the non-selective fishery must be sufficient to provide a reliable estimate of λ.”

> ***Conclusion***. DIT 2 may provide unbiased estimates of CYERs for unclipped escapement indicator stocks under some conditions. However, absent the implementation of an intensive, paired test fishery for each MSF, in practice those conditions are likely to be rarely achieved as mark selective and non-selective fisheries with the same gear generally do not operate simultaneously in the same area. Coastwide implementation of DIT 2 would also require a substantial new investment in tagging and fishery monitoring programs.

2.3.4 SIT 2 and SIT 4

The SIT 2 estimation method begins with the number of spawners and works backward in time to reconstruct the cohort and estimate the fishery mortalities of unclipped fish. Mortalities of unmarked fish in MSFs are estimated from an assumed release mortality rate (as in CTC analyses of the mortality resulting from legal and sublegal releases) and the CWT recoveries from the tagged and clipped fish (variation on mark ratio at return methods). SIT 2 had little bias and variability similar to DIT 2, SIT 4, and SIT 7.

The SIT 4 estimation method begins with the cohort size estimated for the tagged and clipped fish and moves forward in time to project the cohort and estimate the fishery mortalities of unclipped fish. Mortalities in MSFs are estimated from an assumed release mortality rate and the CWT recoveries from the tagged and clipped fish (variation on mark ratio at release methods). SIT 4 had little bias and variability similar to DIT 2, SIT 2, and SIT 7.

Conclusion. SIT 2 and SIT 4 provided estimates of CYERs for the scenarios that had little bias and with variability that was similar to DIT 2 and SIT 7. Implementation of SIT 2 or SIT 4 would not necessitate new coastwide tagging or fishery sampling programs, but some fisheries may be sampled at less than the 20% rate applied in the simulations (Anderson and Reid 2020).

2.3.5 SIT 7

The SIT 7 estimation is similar to SIT 4 except that unclipped fish that are released in a preterminal MSF, and do not subsequently die, and do not become available to subsequent preterminal fisheries (similar to method described in Section 5.2.2 of CTC (2022b)). SIT 7 has a slight negative bias in the estimated CYER for the unclipped escapement indicator stock. Variability was similar to DIT 2, SIT 2, and SIT 4.

Conclusion. SIT 7 resulted in biased estimates for the CYER for the simulations for a MSF in a preterminal fishery. The method is likely to perform best in instances when there are no fisheries that occur after the MSF and before spawning.

2.4 Summary of Recommendations

Our recommendations are primarily informed by the performance of the alternative estimators in the simulation scenarios. Additional considerations, though not expressly accounted for, include the logistics of implementation and anticipated cost.

Recommendation 2.1. Estimate CYERs using SIT 2 or SIT 4. These methods provided estimates of CYERs with minimal bias and the highest precision over the range of simulations evaluated. An additional advantage is that implementation can occur with the existing CWT indicator stock tagging and fishery monitoring programs, although tagging and sampling rates may need to be increased in some fisheries (Anderson and Reid 2020) to match the 20% sample rate used in the simulations. Since SIT 2 and SIT 4 had similar performance in the simulation, the CYER WG proposes to select one of the two methods for application to CWT indicator stocks after discussions with the CTC regarding the relative ease of implementing each method in the cohort analysis program among other factors.

Recommendation 2.2. Ensure technical review. The CYER WG will complete a more detailed technical description of the alternative estimators, results, and evaluation methods by May 2023. The draft report should be provided to the CTC, SFEC, and independent scientists for a technical review. The CYER WG should address comments from those committees in the final report and inform the Commission by August 2023 if new analyses or considerations suggest modification of the recommendations of the Transition Plan.

3.0 Fishery Monitoring and Tagging

While the simulations are invaluable in assessing the performance of the estimators, in practice challenges are likely to arise in the application of these estimators. These include: 1) variations from the "basic" MSF discussed in Chapter 1; and 2) deviations from the assumptions associated with the use of SIT methods.

3.1 Allowing for Variation from Ideal MSF

The most basic or "pure" MSF regulation requires the release of all unclipped Chinook salmon while allowing only the retention of clipped, hatchery-origin Chinook salmon greater than a minimum size. Complexity in estimating CYERs may be added by the following factors:

1) Fishery regulations and sampling programs may not be completely spatially or temporally aligned. There may be instances when the fishery sampling program operates at a coarser geographic or temporal scale than the regulations for the MSF. For example, CWT recoveries may be estimated for a two-week period, but a MSF was implemented only in the second week of the sample period. In this case, if the analysis assumed that the MSF occurred for the entire two-week period, the fishery catch will include both clipped and unclipped fish and the estimated CYERs for the unclipped escapement indicator stock will have a negative bias.
2) Fishery regulations for a MSF may allow retention of some unclipped fish. SFEC (2022) provides the following description for mixed bag fisheries: "Regulations to implement MSFs for recreational fisheries have become more complex, making analyses to estimate impacts challenging in a number of ways. We continue to be concerned about monitoring, sampling, and estimation methods keeping pace with increases in regulation complexity. Different types of mixed-bag regulations continue to be proposed by Canada, Washington, and Oregon for recreational fisheries. A mixed-bag fishery is one where an angler may retain different proportions of clipped or unclipped fish, and often may include jacks as well as adults in their daily bag limits. There are no reliable methods for estimating impacts on marked and unmarked fish under mixed-bag regulations."
3) Fishers may release marked fish that can be legally retained or retain unmarked fish in a MSF. Marked recognition error (MRE) and unmarked retention error (URE) are observed in fisheries (Garber and Kloempken 2017) and failure to incorporate this information can result in biased estimates of the mortality of marked and unmarked fish in MSFs (Lawson and Sampson 1996).

These implementation challenges may be addressed, at least in part, by encouraging management entities to implement or maintain fishery monitoring programs that estimate the kept and released catch by mark status. The CYER WG has developed methods ("mixed fishery adjustment" or MFA) to adjust the CWT recoveries using this fishery monitoring information that can reduce the bias of the estimated CYERs for the escapement indicator stocks. Alternatively, for pure MSFs, methods based on assumed rates of URE and MRE could be applied.

3.2 Protecting Against Bias in the Implemented MSF Method

The results and conclusions in Chapter 2 depend on several assumptions, including unbiased estimates of marked CWT recoveries, proportion non-vulnerable, release and drop-off mortality rates, and fisheries that can be categorized as purely preterminal or terminal. Given that mortality of unmarked fish in MSFs will largely be due to release mortality, the release mortality rate in particular takes on heightened importance. Release mortality rates are affected by a broad range of factors, including the characteristics of the fishery (e.g., gear, fishing method, duration of capture), environment (e.g., water temperature, dissolved oxygen, hydrology), and fish captured (e.g., size, condition, sex, maturity) (see CTC (2022a) for a recent review). In the cohort analysis used by the CTC the release mortality rates are likely to be chosen from a study with conditions that are believed to best match those in the MSF.

The SIT methods and DIT 2 will be sensitive to an error in the assumed release mortality rate used in the cohort analysis. SFEC (2002) found, for example, that a linear relationship existed between the magnitude of the bias in estimated mortalities and the bias in the release mortality rate used in the Paired Fishery method (i.e., a release mortality rate that was 33% too large resulted in an estimated mortality of unclipped fish that was also 33% too large). This concern is also present in the current CTC cohort analysis for fisheries that have a minimum size limit or for which release of Chinook salmon is required. The use of CYERs, rather than mortalities, and indexing to the 2009-2015 base period may reduce the magnitude of bias in the CYERs if the release mortality rates remain relatively stable through time.

However, with the uncertainty in release mortality rates and other factors, and the sensitivity of the SIT methods and DIT 2 to the assumed release mortality values, it will be useful to empirically monitor for bias in the assumed parameter values. This could be achieved by establishing a network of DIT stocks and comparing the estimated difference (from a SIT method or DIT 2) in contribution rates to spawning with the actual difference observed for a DIT group.

3.3 Summary of Recommendations

Agencies are encouraged to undertake the following actions to improve the data used to estimate CYERs and facilitate adaptive management.

Recommendation 3.1. ***Monitor releases and retention by clip status in MSFs***. Encourage management entities to monitor and report the number of Chinook salmon kept and released by clip status to improve estimates of CYERs. CTC recommendations regarding the types of information needed would provide agencies with useful guidance in developing or assessing fishery monitoring.

Recommendation 3.2. ***DIT indicator network***. Modify the existing DIT indicator network and consider adding stocks in new geographic areas that are impacted by MSFs to provide an ongoing assessment of the performance of SIT methods. The network would have a lower density of CWT indicator stock coverage than required by Chapter 3 of the PST but would facilitate an assessment of the escapement rates estimated by a SIT method relative to the empirical estimates provided by the marked and unmarked components of the DIT groups. This would not require fishery sampling of unclipped and tagged Chinook salmon. Consideration of DIT stocks for the network, should be informed by the feasibility of implementation, the expected quality with which the marked and unmarked CWT escapement can be estimated, and the intensity and pattern (e.g., terminal versus preterminal) of the MSFs projected to be applied to the CWT indicator stock.

4.0 PSC Implementation

4.1 Chinook Technical Committee

The CTC has been assigned the task of assessing the performance of ISBM fisheries relative to PST obligations:

> "actual ISBM fishery performance relative to the obligations set out in this paragraph shall be evaluated by the CTC and reported annually to the Commission. Because the performance analysis is dependent on recovery of CWT, the CTC shall provide the evaluation for ISBM fisheries on a post-season basis;" (Annex IV, Chapter 3, paragraph 5e)

Incorporating the recommended methods for estimating CYERs in MSFs into the annual exploitation rate analysis would require the following actions:

1) Update cohort analysis. The computer program used for the cohort analysis would need to be modified to incorporate the proposed methods to estimate CYERs. Although the recent update of the cohort analysis program to the R programming language should simplify this task, substantial time will be required to complete the programming and error checking. After discussion with CTC members, we anticipate that this task could be completed for use in the exploitation rate analysis in 2024.
2) Link cohort analysis to regulation database. The CTC has applied a method similar to SIT 7 to a select set of CWT groups from the Fraser River. The task has been laborious, at least in part due to the lack of a regulations database that could be linked to CWT recoveries and enable computer processing of the CWT recoveries. Although this "hand" processing can be maintained as an interim approach, development of a regulation database linked to the cohort analysis program will be essential to minimize the potential for errors and maximize repeatability. After discussion with the U.S. projects leads, and members of the CTC, we anticipate that this task could be completed for used in the exploitation rate analysis in 2024. This topic is discussed further in Section 4.3.
3) Review terminal fishery designations and fishery aggregation used in cohort analysis. The CTC currently designates fisheries as "preterminal" or "terminal". Once a fish is allocated to the terminal run, its disposition will be either mortality in a fishery, a pre-spawning mortality, or a spawner. Reviewing the terminal fishery designations in the context of MSFs will be valuable to ensure that any "savings" from a terminal MSF are not inadvertently passed to the subsequent age rather than to spawning escapement. In addition, the current CTC fishery aggregates should be reviewed as finer stratification may be needed to implement the MSF methods discussed in Chapter 2. However, as with the current CTC exploitation rate analysis, there will be trade-offs between aggregating fisheries versus conducting analyses at a finer resolution with the concomitant CWT sparsity. After discussion with CTC members, we anticipate that this task could be completed for use in the exploitation rate analysis in 2024.

4.2 Selective Fishery Evaluation Committee

The SFEC has an established role in requesting post-season reports from agencies specific to MSFs. The 2004 Policy Statement and Terms of Reference for SFEC defines a number of agency reporting requirements including the following two postseason reports:

"Agencies shall report results of MSFs conducted during a season in the annual post-season report provided, using a format specified by the SFEC."

"Not later than November 30 of the year following conduct of MSFs. Agencies are to report fishery and stock-age-specific estimates of mortalities for unmarked fish impacted by MSFs to the PSC technical committees."

For the first report, SFEC has an established spreadsheet-based reporting format that includes kept and released catch estimates, by mark status, further broken out by size category (legal, sub-legal, super legal) for each MSF regulation. Few reports have been received, perhaps due in part to the lack of agreed estimation methods, and there is currently no database storage of reports that are submitted.

For the estimates specified in the second report, rather than the agency-based estimates envisioned in the 2004 Memorandum, improved transparency and consistency in estimation methods for Chinook salmon would be facilitated by the CTC conducting the analyses using bilaterally agreed databases. The CTC's exploitation rate analysis already relies upon bilaterally agreed CWT reporting protocols and database, but similar protocols and a database are lacking for MSF regulations and the catch and releases of marked and unmarked Chinook salmon in MSFs. The potential role of the CTC, SFEC, and Data Sharing Committee in developing those databases is discussed in the following section.

4.3 Data Sharing Committee

As discussed in previous sections, consistent, accurate, and efficient estimation of CYERs will be promoted by standardized data reporting protocols and the development of bilateral databases. Securing the assistance of the Data Sharing Committee, working with the CTC and SFEC, to develop protocols and recommend new or modified databases could yield substantial improvements relative to the current data systems,

SFEC (2022) recommended the creation of "a database housing regulations" as no bilateral database of regulations currently exists. There are multiple approaches to advancing the development of a regulation database that can be accessed by the CTC. The U.S. has funded a project to develop a regulation database in coordination with other management entities. This project provides an opportunity, at a minimum, to advance bilateral discussions of the types of regulation data necessary to facilitate the CTC exploitation rate analysis. Ensuring that the Data Sharing Committee, SFEC, and CTC are actively engaged in defining that database will be important to ensure that it serves the needs of the CTC.

The CTC (2022) noted challenges in implementing SIT 7 due to inconsistent usage of the data field (*adclip_selective*) used in the Regional Mark Information System to store CWT recoveries and sampling information. Consistent protocols for recording information on the type of fishery in which a CWT was recovered will be essential to avoid tedious review and recoding of the type of fishery in which each CWT recovery occurred. The Data Sharing Committee, SFEC, and CTC should revisit this topic to ensure consistent reporting and facilitate application in the CTC exploitation rate analysis.

Consistent reporting protocols are also needed for the kept and released catches of marked and unmarked Chinook salmon in MSF (see Recommendation 3.1). It would be valuable for the Data Sharing Committee, working with SFEC and CTC, to provide recommendations regarding agency reporting of post-season MSF information directly to the Regional Mark Information System or some similar database that can be accessed by CTC.

4.4 Summary of Recommendations

We recommend the following actions to implement the recommended methods to estimate CYERs, ensure a consistent and coordinated coastwide approach, and maximize the repeatability of future analyses.

> ***Recommendation 4.1. Update CTC cohort analysis (CTC task).*** The CTC cohort analysis computer program will need to be updated to incorporate the recommended method to estimate CYERs. This work should be initiated in 2023, with the target of conducting the 2024 exploitation rate analysis with the updated computer code.
>
> ***Recommendation 4.2. Review terminal fishery designations and fishery aggregation used in CTC cohort analysis (CTC task).*** The incorporation of methods to estimate CYERs in MSFs is a substantive change in the underlying framework of the CTC cohort analysis. Ensuring that the framework, including terminal fishery designations and level of fishery aggregation, remains appropriate will be important to successful implementation of the estimation methods. This work should be initiated in 2023 with a target of implementation for the 2024 exploitation rate analysis.
>
> ***Recommendation 4.3. Revise post-season information management process (SFEC task).*** Rather than the agency reporting of stock-specific mortalities in MSFs envisioned in the 2004 MOU, develop bilateral standards and reporting for MSF data and ensure that it is available to the CTC to conduct bilaterally agreed analyses. Any required changes to data sharing processes should be completed prior to submissions of post-season information for fisheries conducted in 2023.
>
> ***Recommendation 4.4***. ***Establish reporting protocols for MSF regulations and fishery data (Data Sharing Committee task)***. Task the Data Sharing Committee, working with the CTC and SFEC, with establishing reporting protocols and standards for MSF regulations and fishery data (catch and release by mark status) and ensure that this information is available for CTC analyses. WDFW has been awarded a U.S. grant to develop a regulation database that, at a minimum, provides an opportunity to advance bilateral discussions of the types of regulation data necessary to facilitate the CTC exploitation rate analysis. Any required changes to data sharing processes should be completed prior to submissions of post-season information for fisheries conducted in 2023.
>
> ***Recommendation 4.5. Task CYER WG with coordinating implementation of Recommendations 4.1-4.4***. With representatives from the CTC, SFEC, and Data Sharing Committee, the CYER WG is well positioned to share expertise and guide implementation of these recommendations.
>
> ***Recommendation 4.6. Adaptively manage CYER estimation (CTC and management entity tasks).*** Provide for an ongoing assessment of the performance of MSF analytic methods, assess critical uncertainties, and modify estimation and monitoring to incorporate new finding. Priority actions include: 1) develop and test additional estimators; 2) assess the mortality rate of fish released in MSFs; and 3) where MRE and URE values are relied upon to estimate exploitation rates in pure MSFs, periodically review MRE and URE rate estimates based on fishery

monitoring. Note that the CYER WG (2021) previously recommended that management entities 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.

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