DRAFT

Estimating Total Chinook Encounters using Catch Record Card-Based Estimates of Harvest

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INTRODUCTION

Background and Fishery Context

Based on agreements between the State of Washington and the Northwest Treaty Tribes, the Washington Department of Fish and Wildlife (WDFW) has been conducting pilot[1] recreational mark-selective Chinook fisheries (MSFs) in the marine catch areas of Puget Sound since 2003. The goal of these fisheries is to allow increased angler opportunities on hatchery-raised, marked (adipose fin-clipped) salmon while limiting impacts on unmarked (adipose fin intact; typically wild origin) stocks of conservation concern, particularly ESA-listed Puget Sound Chinook. Given that anglers will encounter and then release unmarked Chinook during MSFs, execution of proper sampling and monitoring strategies is critical in order to assess catch rates and estimate impacts on wild stocks.

WDFW implemented the first recreational Chinook MSFs in the marine waters of Washington State in Areas 5 and 6 (Strait of Juan de Fuca) during summer 2003. In subsequent years, WDFW has implemented additional pilot-level MSFs in other Puget Sound marine catch areas (Areas 7 through 13; Figure 1) during both the summer and winter seasons (see Appendix A in WDFW 2012 for a list of areas and seasons). For example, the first winter MSFs were established in Areas 8-1 and 8-2 from October 2005 through April 2006 and have continued each winter season since. Additionally, beginning in 2007, summer MSFs were established in Areas 9, 10, 11 and 13 and winter MSFs began in Areas 7, 9 and 10. During the winter of 2010 (February through April), Chinook MSFs occurred for the first time in Areas 11 and 12 and have continued each year thereafter. Similarly, beginning in the summer of 2012, a Chinook MSF was established in Area 12 (South of Ayock Point), from July 1 through October 15. This steady introduction of new fisheries has resulted in an increase in angler participation in MSFs from an estimated 24,593 angler trips during the 2003-04 fishing season to more than 150,000 angler trips during the 2012-13 fishing season.

Sampling and Monitoring Program

Given the pilot nature of the Chinook MSFs in Puget Sound, WDFW's Puget Sound Sampling Unit (PSSU) has been tasked with implementing a comprehensive monitoring program to collect the data needed to evaluate the impacts of MSFs on unmarked salmon. To monitor each fishery, PSSU implements one of the four following sampling designs: *i)* Full Murthy Estimate Design, *ii)* Reduced Murthy Estimate Design, *iii)* Aerial-Access Design or *iv)* Baseline Sampling Design. The design selected depends on area and season considerations, the magnitude of the fishery and State-Tribal agreements made prior to the start of the fishing season. For a complete description of the methods associated with these sampling designs, see WDFW's "Methods Report: Monitoring Mark-Selective Recreational Chinook Fisheries in the Marine Catch Areas of Puget Sound (Areas 5 through 13)," available at http://www.wdfw.wa.gov/publications/01357/.

[1] As stated in state-tribal agreement documents (e.g., WDFW and NWIFC 2009): "The purpose of the 'pilot' fishery is to collect information necessary to enable evaluation and planning of potential future mark-selective fisheries. The 'pilot' fishery provides a basis for determining if the data needed to estimate critical parameters can be collected and if the sample sizes needed to produce these estimates with agreed levels of precision can be realistically obtained."

Three of the above-mentioned designs (all except Baseline Sampling) are characterized as comprehensive, "intensive" monitoring programs, consisting of all or a subset of the following components:

1. Intensive dockside creel sampling to provide in-season estimates of effort (number of anglers and boats) and retained and released Chinook (including number of marked and unmarked);
2. Effort surveys (aerial or on-the-water surveys) to provide information on the proportion of effort originating from sampled sites;
3. Test fishing and/or an expanded Voluntary Trip Report (VTR) program to provide information on the size/mark-status composition of the population of fish being encountered.

PSSU has tailored each of the comprehensive monitoring programs to reliably estimate the following critical parameters needed for evaluating mark-selective fisheries: *i)* the mark rate of the targeted Chinook population, *ii)* the total number of Chinook salmon harvested (by size [legal or sublegal] and mark-status [marked or unmarked] group), *iii)* the total number of Chinook salmon released (by size and mark-status group), *iv)* the coded-wire tag- (CWT) and sometimes DNA-based stock composition of marked and unmarked Chinook mortalities, and *v)* the total mortality of marked and unmarked double index tag (DIT) CWT stocks. In addition, PSSU has acquired and analyzed relevant data characterizing other aspects of the pilot MSFs, including descriptors of fishing effort, fishing success (catch [landed Chinook] per unit effort), recreational fishing methods, the length and age composition of encountered Chinook, and the overall intensity of our sampling efforts. As such, the data collected through these comprehensive monitoring programs allow biologists to produce weekly in-season estimates and timely finalized post-season estimates of effort, catch, total encounters and fishery impacts.

The fourth sampling design, *Baseline Sampling*, is a scaled-back monitoring program that is currently implemented in lower-magnitude MSFs (and year-round in non-selective sport fisheries) throughout Puget Sound.

Table 1 presents a summary of the MSFs, by area and season in which PSSU has conducted Baseline Sampling. Samplers collect data on salmon catch (retained and released) and angler effort via dockside angler interviews and obtain on-water encounter rate data through distributing and collecting voluntary trip reports (VTR) from private anglers. In contrast to the three comprehensive monitoring programs mentioned above, the data collected through Baseline Sampling does not allow for in-season or immediate post-season estimates of angler effort, landed catch, total encounters, or fishery impacts. While the Catch Record Card (CRC)[2] system provides post-season estimates (approximately one year after the fishery) of angler effort and landed Chinook harvest in these MSFs, to date there has not been a method developed for estimating total encounters and release mortalities of unmarked Chinook in these fisheries. Affected fisheries include MSFs in Areas 6, 12 and 13 during the summer and Area 12 during the winter (Table 1).

[2] See Conrad and Alexandersdottir (1993) for an overview of the CRC system.

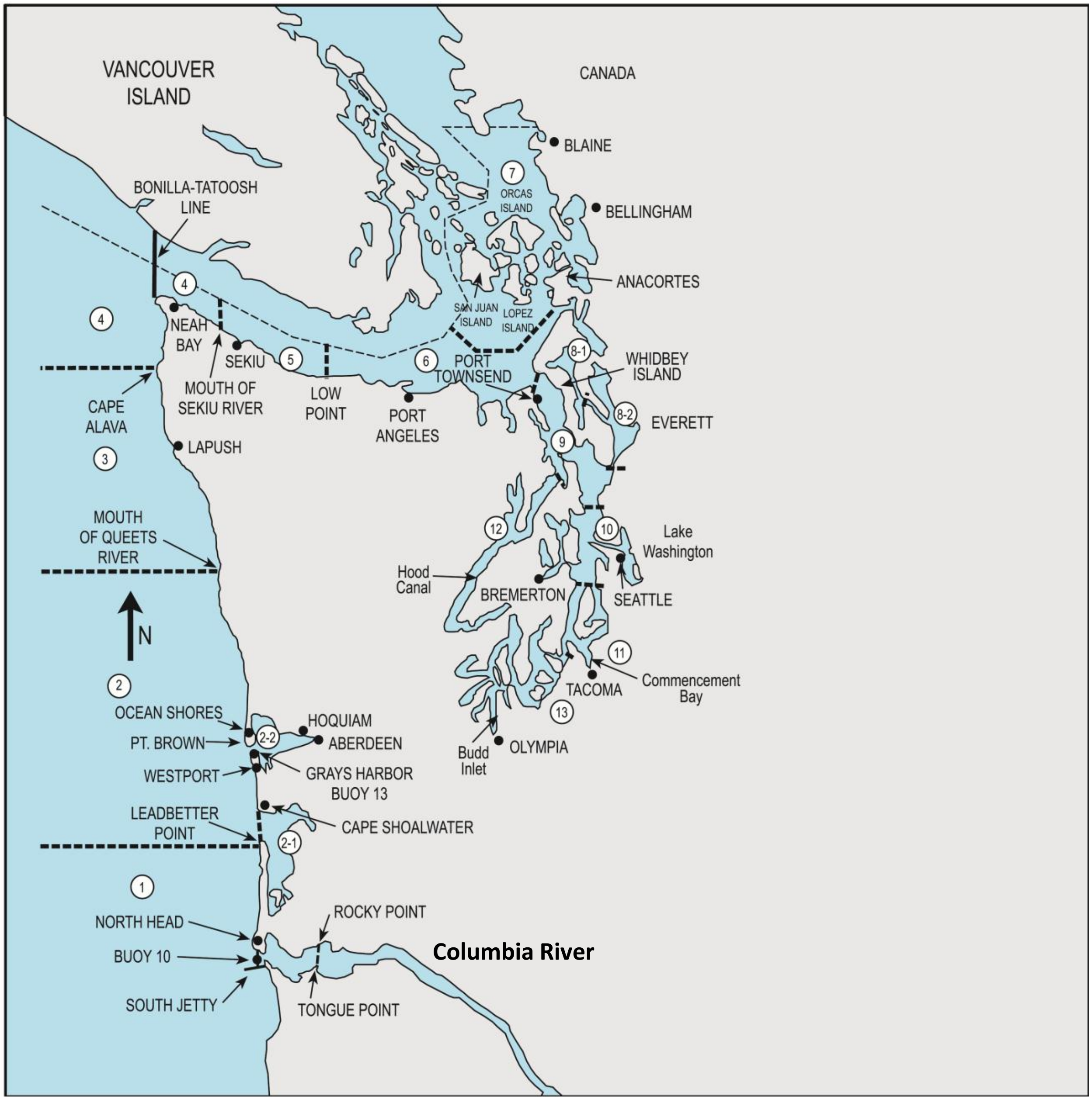

Figure 1. Map of Western Washington, showing the Marine Catch Areas of Puget Sound (Areas 5 through 13) and the Washington Coast (Areas 1 through 4).

Table 1. Summary of Chinook MSFs in Puget Sound in which PSSU had conducted Baseline Sampling.

Catch Area	Season	Year	Dates	Sampling Design
6	Summer	2008	Jul 1 – Aug 9	Baseline sampling, VTRs, CRC estimates
		2009	Jul 1 – Aug 6	
		2010	Jul 1 – Aug 15	
		2011	Jul 1 – Aug 15	
		2012	Jul 1 – Aug 15	
		2013	Jul 1 – Aug 15	
12 (S of Ayock Pt)	Summer	2012	Jul 1 – Oct 15	
		2013	Jul 1 – Oct 15	
12	Winter	2009-10	Feb 1 – Apr 30	
		2010-11	Feb 1 – Apr 30	
		2011-12	Feb 1 – Apr 30	
		2012-13	Oct 16 – Dec 31 & Feb 1 – Apr 30	
13	Summer	2007	May 1 – Sep 30	
		2008	May 1 – Sep 30	
		2009	May 1 – Sep 30	
		2010	May 1 – Sep 30	
		2011	May 1 – Sep 30	
		2012	May 1 – Sep 30	
		2013	May 1 – Sep 30	

'CRC for Encounters' Workgroup

To address the need for an agreed-to encounters estimation methodology for the Baseline-sampled MSFs (Table 1), the NWIFC and WDFW created a joint work group to develop a method for estimating total Chinook encounters and release mortalities in these MSFs. Periodic meetings of this 'CRC for Encounters' technical workgroup started in May 2011 and concluded in September 2013, when the new encounters estimation method was finalized. The primary goal and objectives of the workgroup were as follows:

> Goal: Estimate total Chinook encounters and mortalities for Puget Sound MSFs that rely on the CRC system for harvest estimates and are sampled on a Baseline level only.
>
> Objectives: Identify the most accurate (least biased, most precise) method for estimating encounters from CRC estimates. Apply this method to produce estimates of total Chinook encounters (ultimately mortalities) by size/mark-status group (legal-marked, legal-unmarked, sublegal-marked, sublegal-unmarked) when the only data available for a given Chinook MSF are: *i)* CRC estimates of total landed catch, *ii)* Baseline interview

data on retained and released salmon encounters and *iii)* (if available) on-the-water logs of salmon encounters supplied by anglers.

The workgroup's approach was informed by existing data and estimation approaches, specifically Conrad and McHugh's (2008) agreed-to method for estimating total Chinook encounters by size and mark-status for intensively-monitored Chinook MSFs in Puget Sound. Conrad and McHugh describe two methods for estimating total Chinook encounters:

- Method 1 (M1) estimates of total Chinook encounters are obtained by summing estimates of catch, based on sampled landings, and releases, based on values reported by anglers during interviews, generated from the creel survey design.
- Method 2 (M2) estimates of total Chinook encounters are obtained by dividing an estimate of total legal-marked (LM) Chinook harvest by the proportion of LM Chinook present in the targeted population, derived from test fishing or VTR data. This approach attempts to eliminate bias arising from recall error in angler-reported releases.

While both the M1 and M2 approaches are designed to estimate the same parameter, Conrad and McHugh (2008) ultimately recommend the M2 approach, with a bias correction that accounts for intentional and unintentional releases of LM Chinook.

Both methods require an estimate of total Chinook harvest, which cannot be produced using data collected through Baseline Sampling. Fishery-total estimates of catch and effort are eventually available (approximately one year after the close of the fishery) through WDFW's CRC system. The estimation framework developed in this report allows for the generation of M1 and M2 estimates of total Chinook encounters using CRC estimates of Chinook harvest as the primary building block. Before proceeding, however, it was necessary to evaluate the accuracy of the CRC-based harvest estimates.

Report Intent

The intention of this report is to document the methods, results, conclusions and recommendations resulting from the CRC for Encounters workgroup's efforts to identify a suitable method for estimating the total number of Chinook salmon encountered by size/mark-status category in a given MSF where the less intensive Baseline Sampling design is implemented and CRC estimates of landed catch are produced. The *Methods* section provides an overview of the encounters from CRC estimation scheme including: *i)* Description of available data, *ii)* Validation of catch record card Chinook harvest estimates, *iii)* Decision support tool for data analysis and *iv)* Estimators for total encounters, including associated assumptions. The *Results* section includes: *i)* Outcome of the validation of catch record card Chinook harvest estimates, *ii)* Validation of proposed encounters estimators and *iii)* Estimates resulting from application of the new method to Baseline-sampled MSFs in Areas 6, 12 and 13. Finally, the *Discussion* section provides further explanation and context for the observed results, discussion of the assumptions, cautions and caveats that accompany using the new method, as well as recommendations of the CRC for Encounters workgroup as the method is applied moving forward.

METHODS

Description of Available Data

Conrad and McHugh (2008) provided two methods for estimating total encounters in Puget Sound Chinook MSFs. The first method, M1, requires estimates of retained and released Chinook generated from the creel survey design which includes dockside sampling and angler interview data. A critical assumption of this method is that anglers accurately recall and report all Chinook that were encountered and released. The second method, M2, requires an estimate of LM (legal-sized and marked) Chinook harvest and an independent estimate of the proportion of LM fish in the population being targeted, derived from test fishing or VTR data. This method assumes that all LM Chinook that are encountered by anglers are retained. After a rigorous bias analysis, Conrad and McHugh (2008) recommended the M2 approach over the M1 approach and suggested a bias-correction factor of 0.13 to account for the intentional and unintentional release of LM Chinook.

Test fishing or VTR data (given a sufficient sample size, discussed below) are required in order to proceed with an M2 approach. These data sets provide counts of Chinook encountered by size and mark-status group. All fish that are brought to the boat are designated into one of four groups: legal-marked (LM), legal-unmarked (LU), sublegal-marked (SM), and sublegal-unmarked (SU). These counts are used to estimate the proportion of fish in the population being targeted that is both legal and marked. Currently, test fishing is conducted only in the Areas 9 and 10 (summer and winter) and Area 7 (winter) Chinook MSFs, all of which are sampled using one of the comprehensive monitoring programs. VTRs are distributed and collected by dockside samplers during all Puget Sound MSFs, however, angler participation varies significantly by area. In order to proceed with an M2 approach, these data need to meet minimum sample size requirements (see below).

Dockside sampling and angler interview data are an essential element in estimating total Chinook encounters, particularly if small test fishery or VTR sample sizes require an M1 approach. At designated sites on sample days, samplers attempt to intercept all anglers returning from a given fishery, recording the size and mark-status of their catch and the angler-reported number of Chinook released by mark-status (marked, unmarked, unknown). As there is generally a small proportion of Chinook harvest that is sublegal and/or unmarked, information on the size and mark-status composition of sampled catch can be used to estimate the LM Chinook harvest based on total Chinook harvest estimates provided by CRCs.

For fisheries monitored using Baseline Sampling, fishery-total Chinook harvest estimates are a critical data component required to estimate total Chinook encounters. As discussed above, these are available through the WDFW CRC system, which can provide fishery-specific estimates of total Chinook harvest, with associated variance. These estimates are a building block in the estimation of total Chinook encounters, regardless of whether an M1- or M2-based approach is utilized.

Validation of Catch Record Card Chinook Harvest Estimates

Upon purchasing a state fishing license, anglers are provided with a Catch Record Card that they are required to complete and return at the end of the fishing year. For every salmon harvested, the angler provides the catch area, date, species and mark-status. This information is compiled by WDFW and used to produce estimates of total salmon harvest by catch area and statistical week or month. To adjust for non-response bias, correction factors of 1.00 and 0.68 are applied to estimates in Marine Area 5 and Marine Areas 6-13, respectively, as described in Conrad and Alexandersdottir (1993). Effort (in angler trips) is estimated by dividing CRC-based salmon harvest estimates by the catch-per-unit-effort (CPUE) from dockside sampling data for the area/time period of interest. Total salmon harvest can then be apportioned into species-specific harvest estimates using species composition proportions from dockside sampling observations. These species compositions are used instead of those reported on CRCs under the assumption that they provide a more accurate representation due to more accurate species identification by trained samplers than by the general fishing public. For full details on the estimation of salmon harvest using CRCs see Conrad and Alexandersdottir (1993).

As more than 20 years have passed since the non-response bias correction factors were produced, it was necessary to evaluate recent CRC estimates to ensure that they continue to produce valid, statistically accurate harvest estimates. To accomplish this evaluation, in an approach similar to that of Conrad and Alexandersdottir (1993), we compared the bias-corrected CRC-based estimates of Chinook harvest to independently derived Chinook harvest estimates from intensive creel surveys for all Puget Sound MSFs that have been comprehensively monitored. In these comparisons it was assumed that the estimates provided by the creel surveys were unbiased.

Since the start and end dates of each MSF did not always coincide with time strata in the standard CRC reporting process, separate estimates of Chinook harvest were produced that match the specific dates of each Puget Sound MSF, beginning with the summer 2003 season through the summer 2011 season (the most recent CRC estimates that are available). These estimates were then paired with complementary creel survey estimates. Our full analysis of these comparisons is presented in the *Results* section and in Appendix A1.

Methods Determination Scheme

We propose the following decision support schematic as a guide in determining the most appropriate method for estimating total Chinook encounters in MSFs (Figure 2). For all fisheries, it is assumed that a CRC-based estimate of Chinook harvest is available. The availability of other data will vary by fishery, which will ultimately determine the method used to estimate total Chinook encounters.

Given past work, the preferred methodology is the M2-based approach, using test fishing data to estimate the proportion of LM fish (p_{LM}) in the target population. Test fishing data are believed to be of higher quality than VTR data, as they are collected by trained samplers. When these data are available, it is important to ensure that sample sizes are sufficient to meet precision requirements. As a guideline, we recommend a coefficient of variation threshold of 20% around M2 total encounters estimates. If test fishing sample sizes are insufficient, they can be combined with VTR data if χ^2 tests indicate that the proportions of the two data sets are not significantly different. In situations where the CV is greater than 20% an M1 approach should be employed.

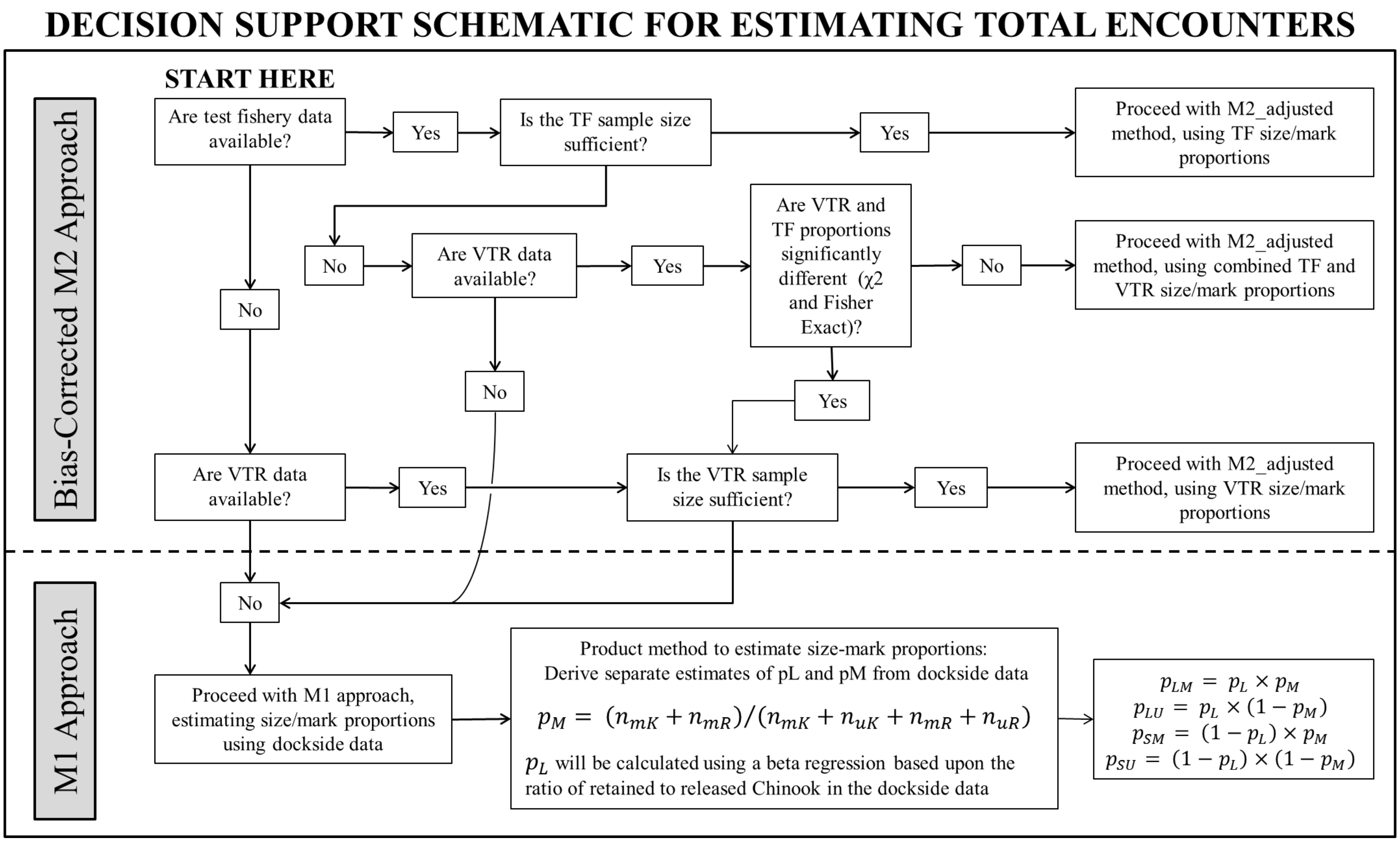

Figure 2. Decision support schematic for determining the most appropriate method for estimating total Chinook encounters.

If test fishing data do not exist for a given fishery, which is the case for past fisheries and has necessitated the development of the CRC for Encounters framework, or if sample sizes are too small and cannot be combined with VTR data, the next best option is to use a bias-corrected M2 approach and estimate p_{LM} using only VTR data. Again, it is essential to evaluate sample sizes to ensure the precision around total encounters estimates will be acceptable (target CV = 20%).

Finally, if test fishing or VTR data are not available in sufficient sample sizes, an analog to the M1 approach is recommended. In this case the relationship between the number of Chinook encountered and retained in dockside sampling and angler interview data is used to estimate total encounters. Since test fishing or VTR data are unavailable, estimates of the size/mark-status composition will need to be derived using an alternate data source. The methods developed to provide alternate estimates of size/mark-status composition are described below.

Encounters Estimators

<u>M2 Estimator</u>:

Given a sufficient sample size of test fishery or VTR (or a combination) data, the proportion of fish that belongs to each size/mark-status group can be estimated by applying the same methods used for intensive creel studies as outlined in the WDFW Methods Report (WDFW 2012).

The M2 approach requires an estimate of LM Chinook harvest, which can be derived by apportioning the CRC-based estimate of total Chinook harvest into size and mark-status groups using proportions ($\hat{d}$) from the dockside sampled catch as follows:

(1) $\hat{d}_{XYK} = n_{XYK}/(n_K)$

(2) $var(\hat{d}_{XYK}) = [\hat{d}_{XYK} * (1 - \hat{d}_{XYK})]/(n_K - 1)$

where *X*=legal (*L*) or sublegal (*S*), *Y*=marked (*M*) or unmarked (*U*), and subscript *K* indicates kept. n_K and n_{XYK} are season total dockside counts of landed fish and the subset of fish in a given size/mark-status group.

Estimates of harvest by size/mark-status and associated variances are calculated as:

(3) $\hat{K}_{XY} = \hat{d}_{XYK} * \hat{K}_{CRC}$

(4) $var(\hat{K}_{XY}) = var(\hat{K}_{CRC}) * \hat{d}_{XYK}{}^2 + \hat{K}_{CRC}{}^2 * var(\hat{d}_{XYK}) - var(\hat{K}_{CRC}) * var(\hat{d}_{XYK})$

where $\hat{K}_{CRC}$ is the CRC-based estimate of total Chinook harvest.

With an estimate of legal-marked Chinook harvest, the bias-corrected M2 estimate of total Chinook encounters and its variance is calculated as:

(5) $\hat{E}_{CRC-M2} = \hat{K}_{LM}/[\hat{p}_{LM}(1 - p_{LMR})]$

(6) $var(\hat{E}_{CRC-M2}) = (\hat{E}_{CRC-M2})^2 \left(\frac{var(\hat{K}_{LM})}{\hat{K}_{LM}{}^2} + \frac{var(\hat{p}_{LM})}{\hat{p}_{LM}{}^2} - \frac{var(\hat{K}_{LM})}{\hat{K}_{LM}{}^2} * \frac{var(\hat{p}_{LM})}{\hat{p}_{LM}{}^2}\right)$

where $\hat{p}_{LM}$ is the proportion of LM fish in the target population and p_{LMR} is the bias correction factor to account for encountered LM Chinook that are released (estimated at 0.13 by Conrad and McHugh 2008) which is treated as a known constant with no variance.

Finally, total estimated Chinook encounters can be apportioned into the four size/mark-status groups and associated mortalities can be calculated as described in the WDFW Methods Report (WDFW 2012).

M1 Estimator:

If the available data do not permit an M2 approach, we can estimate total Chinook encounters using an M1 approach. First we calculate the number of retained (kept) and released Chinook in the dockside sampling and angler interview data. The number of retained Chinook is calculated as:

(7) $k_{DS} = n_{mk} + n_{uk}$

where n_{mk} is the number of marked Chinook retained, n_{uk} is the number of unmarked Chinook retained, and the *DS* subscript indicates that the sample data are from dockside sampling.

The dockside interview data includes a field for released salmon of unknown species, which needs to be incorporated into estimates of released Chinook. To do this we estimate the proportion of all released salmon of known species that are Chinook and its variance and apportion the number of released unidentified salmon accordingly.

(8) $\hat{p}_{CHIN} = (n_{mr} + n_{ur} + n_{unkr})/(n_{mr} + n_{ur} + n_{unkr} + n_{osr})$

(9) $var(\hat{p}_{CHIN}) = \left(\hat{p}_{CHIN}(1 - \hat{p}_{CHIN})\right)/(n - 1)$

where n_{mr}, n_{ur} and n_{unkr} are the number of Chinook reported released that were of marked, unmarked and unknown mark-status, and n_{osr} is the number of other salmon (positively identified species other than Chinook) reported released.

With an estimate of $\hat{p}_{CHIN}$, we estimate the number of released Chinook and its variance as:

(10) $\hat{r}_{DS} = (n_{mr} + n_{ur} + n_{unkr}) + (\hat{p}_{CHIN} * n_{usr})$

(11) $var(\hat{r}_{DS}) = {n_{usr}}^2 * var(\hat{p}_{CHIN})$

where n_{usr} is the number of unknown (species) salmon released.

To estimate total Chinook encounters, we first calculate the ratio ($\hat{R}$) of encountered Chinook to retained Chinook in the dockside sampling and interview data and its variance:

(12) $\hat{R} = \hat{e}_{DS}/k_{DS}$

(13) $var(\hat{R}) = \hat{R}^2 * \left(var(\hat{r}_{DS})/{\hat{e}_{DS}}^2\right)$

where $\hat{e}_{DS}$ is the estimated number of encounters in the dockside data ($k_{DS} + \hat{r}_{DS}$) during the given fishery. Since k_{DS} is a count with no associated variance, $var(\hat{r}_{DS}) = var(\hat{e}_{DS})$.

The ratio, $\hat{R}$, is then applied to the CRC-based estimate of harvested Chinook to provide an M1 estimate of total Chinook encounters:

$$(14)\quad \hat{E}_{CRC-M1} = \hat{K}_{CRC} \cdot \hat{R}$$

with estimated variance:

$$(15)\quad var(\hat{E}_{CRC-M1}) = \hat{K}_{CRC}^{\ 2} * var(\hat{R}) + \hat{R}^2 * var(\hat{K}_{CRC}) - var(\hat{K}_{CRC}) * var(\hat{R})$$

To apportion the estimate of total Chinook encounters into size/mark-status groups, estimates of the proportion of each group present in the target population are needed. Given that an M1 approach is being used, this information is not available through test fishery or VTR data and must be derived using an alternate data source. To determine the proportion of each group, we recommend a product method, where the mark-rate ($\hat{p}_M$) and legal proportion ($\hat{p}_L$) are estimated independently and combined to provide an estimate of the proportion for each group as follows:

$$(16)\quad \hat{p}_{LM} = \hat{p}_L \cdot \hat{p}_M$$
$$(17)\quad \hat{p}_{LU} = \hat{p}_L \cdot (1 - \hat{p}_M)$$
$$(18)\quad \hat{p}_{SM} = (1 - \hat{p}_L) \cdot \hat{p}_M$$
$$(19)\quad \hat{p}_{SU} = (1 - \hat{p}_L) \cdot (1 - \hat{p}_M)$$

where the variance for each estimated proportion is equivalent to:

$$(20)\quad var(\hat{p}_{LM}) = \hat{p}_L^{\ 2} * var(\hat{p}_M) + \hat{p}_M^{\ 2} * var(\hat{p}_L) - var(\hat{p}_L) * var(\hat{p}_M)$$

The proportion of encounters that are marked (p_M) can be estimated using the dockside sampling and angler interview data. First, released Chinook of unknown mark-status, as well as unidentified salmon releases, are apportioned into the n_{mr} and n_{ur} categories based on known species and mark-status composition reported to have been released. The proportion of encounters that are marked is then calculated by:

$$(21)\quad \hat{p}_M = (n_{mk} + n_{mr})/(n_{mk} + n_{mr} + n_{uk} + n_{ur})$$

where n_{mr} and n_{ur} include the apportioned Chinook of unknown mark-status and unidentified salmon that were reported released. The variance of $\hat{p}_M$ is computed as:

$$(22)\quad var(\hat{p}_M) = \left(\hat{p}_M(1 - \hat{p}_M)\right)/(n - 1)$$

where *n* is the total number of Chinook encounters from the dockside sampling and angler interview data.

The proportion of encounters that are legal-sized ($\hat{p}_L$) will be estimated based on the relationship between test fishery and/or VTR estimates of this parameter and dockside interview-based estimates of released-to-retained Chinook fitted to data from past MSFs that were intensively monitored. In this situation linear regression is unsuitable given the existence of $\hat{p}_L$observations near the bounds of 0 and 1 and high variability in dockside interview data, as it would yield predictions outside the range of possibilities. Thus, we used a beta regression, which is commonly used to model variables that assume values in the standard unit interval (Cribari-Neto and Zeileis 2010). The predictor variable is the ratio of released to retained Chinook ($\log_e$-transformed), computed from dockside creel data, and the response is the fraction of total test fishery or VTR encounters that are legal in size for each Puget Sound Chinook MSF (through the summer of 2012). Within the beta regression model we used a logit link function and weighted the data by the total number of test fishery or VTR encounters.

This model yields estimates of intercept (β_0), slope (β_1) and precision (ϕ) parameters of the relationship between p_L and $\ln(Rel_{DS}/Ret_{DS})$, which can be used to generate predictions for new fisheries as follows:

$$(23)\quad \hat{p}_L = e^{g(x)}/\left(1 + e^{g(x)}\right)$$

where $g(x)$ is a linear function of the form:

$$(24)\quad g(x) = \beta_0 + \beta_1[\ln(Rel_{DS}/Ret_{DS})]$$

The variance of $\hat{p}_L$ predictions will be estimated as:

$$(25)\quad var(\hat{p}_L) = \left(\hat{p}_L * (1 - \hat{p}_L)\right)/(1 + \phi)$$

In order for the product method to provide reliable estimates of the size/mark-status proportions in a fishery, two key assumptions need to be met: (1) dockside interview-based estimates of the proportion of encounters that are marked and model-predicted estimates of the proportion of encounters that are legal need to be accurate, and (2) mark rates need to be similar for legal and sublegal size classes and the size composition needs to be similar for marked and unmarked fish, (i.e., statistical independence of $\hat{p}_L$and $\hat{p}_M$). Although these assumptions will likely be violated in some years/fisheries, an analysis of available data suggests that they are well met on average (Appendix A3).

Estimates of Chinook retention by size and mark-status can be derived using the same methods from the M2 estimator (Equations 1-4). Lastly, estimates of Chinook releases and associated mortalities can be calculated as described in the WDFW Methods Report (WDFW 2012).

RESULTS

Validation of Catch Record Card Chinook Harvest Estimates

Upon initial inspection, an anomalously large discrepancy was observed between CRC and creel harvest estimates during some winter MSFs in Area 10. We hypothesized that this discrepancy may be caused by an extensive shore-based angling effort targeting chum during October and November in Area 10. While captured in the CRC data, this chum harvest may not be accurately accounted for in the sampling data, resulting in an inflated Chinook harvest estimate when CRC-based total salmon harvest estimates are apportioned using PSSU species composition. To solve this problem, we replaced the PSSU species compositions with those from the CRCs during the months of October and November in Area 10 (see Appendix A2 for full discussion on this topic).

As an initial comparison, we calculated the ratio of CRC to creel Chinook harvest for each fishery. For all 55 MSFs where both CRC and creel harvest estimates existed, the mean ratio was 1.10 (SD = 0.287). Boxplots of the ratio for each fishery show a relative consistency across areas, ranging mostly between 0.8 and 1.5 (Figure 3). We also plotted CRC harvest estimates against creel harvest estimates (Figure 4). This view of the data clearly illustrates that the magnitude of harvest in summer fisheries is typically much higher than that of winter fisheries. While they generally match well with the creel estimates, there appears to be a slight positive bias in the CRC harvest estimates, which becomes more prominent with increasing harvest.

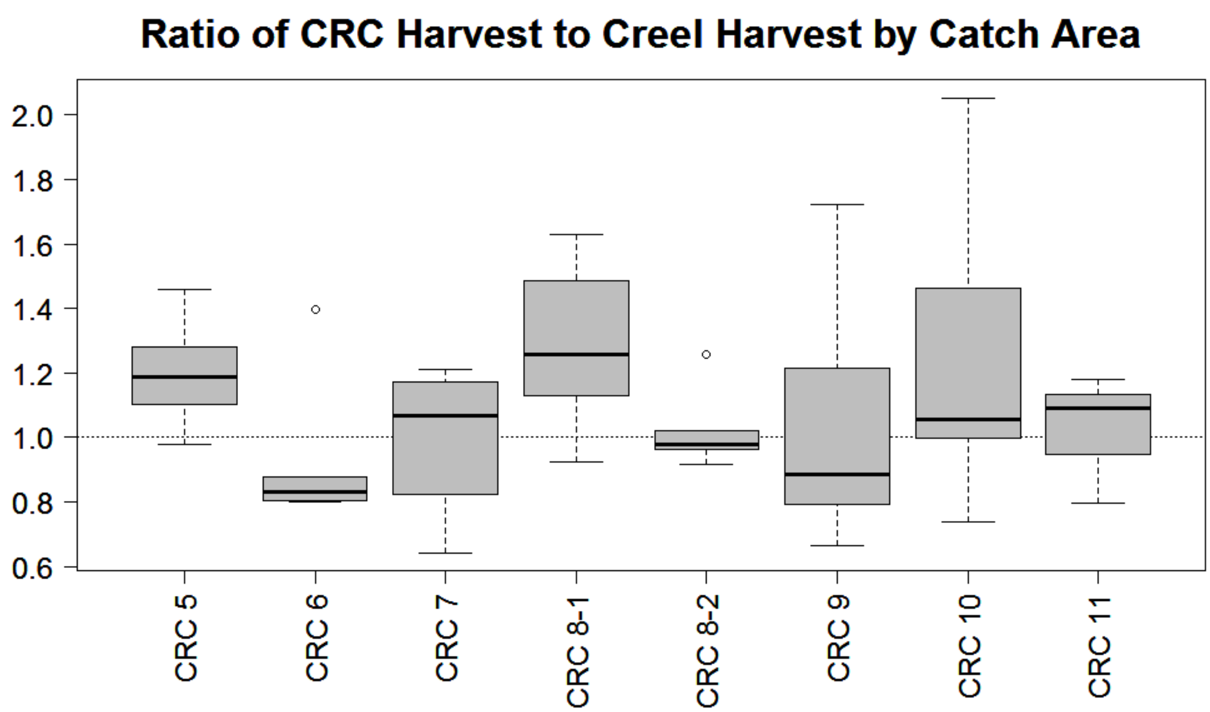

Figure 3. Boxplots depicting the ratio of estimated CRC harvest to creel harvest for each fishery by marine area. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

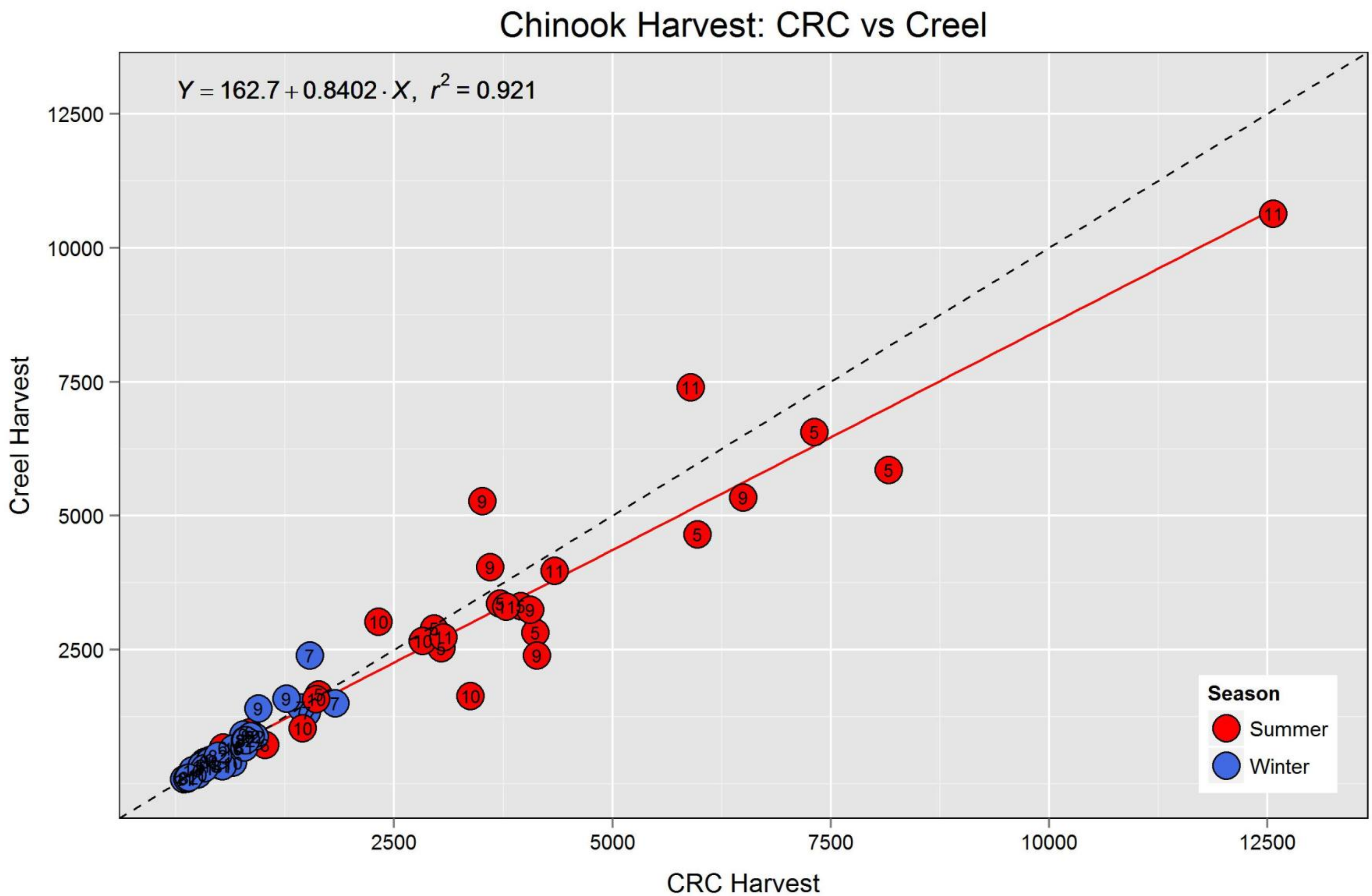

Figure 4. Comparison of CRC versus creel Chinook harvest estimates (# of fish) for all Puget Sound Chinook MSFs that were comprehensively monitored between 2003 and 2011. The dotted line is the line of unity where both harvest estimates are equal; the solid red line is the regression described by the equation in the upper left corner. CRC areas are indicated by numbers in circles.

Validation of Encounters Estimators: Comparison with Existing Creel Estimates

For areas that were comprehensively monitored and creel-based total encounters estimates have been provided, we estimated CRC-based total encounters using both the M2 and M1 estimators (Appendix A4). We calculated the ratio of CRC-based M2 total encounters to creel-based total encounters for each fishery. For all 55 MSFs where both CRC and creel estimates of total Chinook encounters existed, the mean ratio was 1.09 (SD = 0.301). Boxplots of the ratio for each fishery show a relative consistency across areas, ranging mostly between 0.8 and 1.4 (Figure 5). CRC-based total encounters estimates derived from both the M2 (Figure 6) and M1 (Figure 7) estimators were also plotted against and compared with creel-based total encounters estimates.

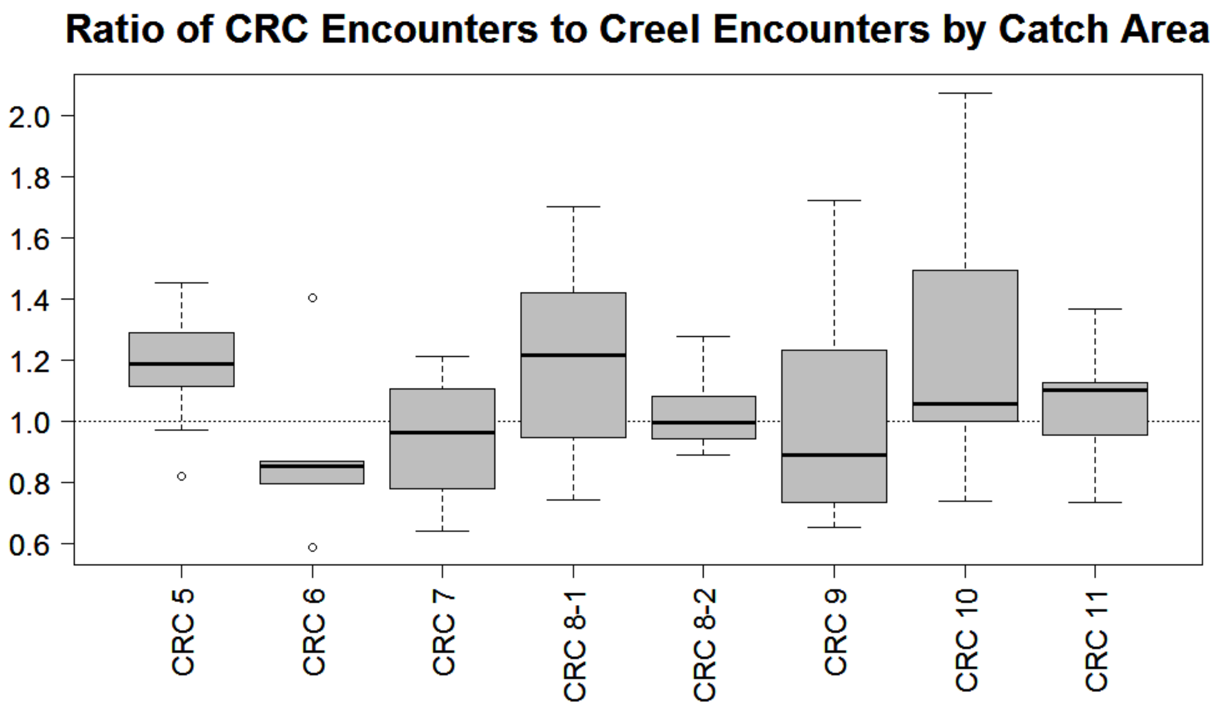

Figure 5. Boxplots depicting the ratio of CRC-based to creel-based M2 estimates of total Chinook encounters for each MSF by marine catch area in Puget Sound. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

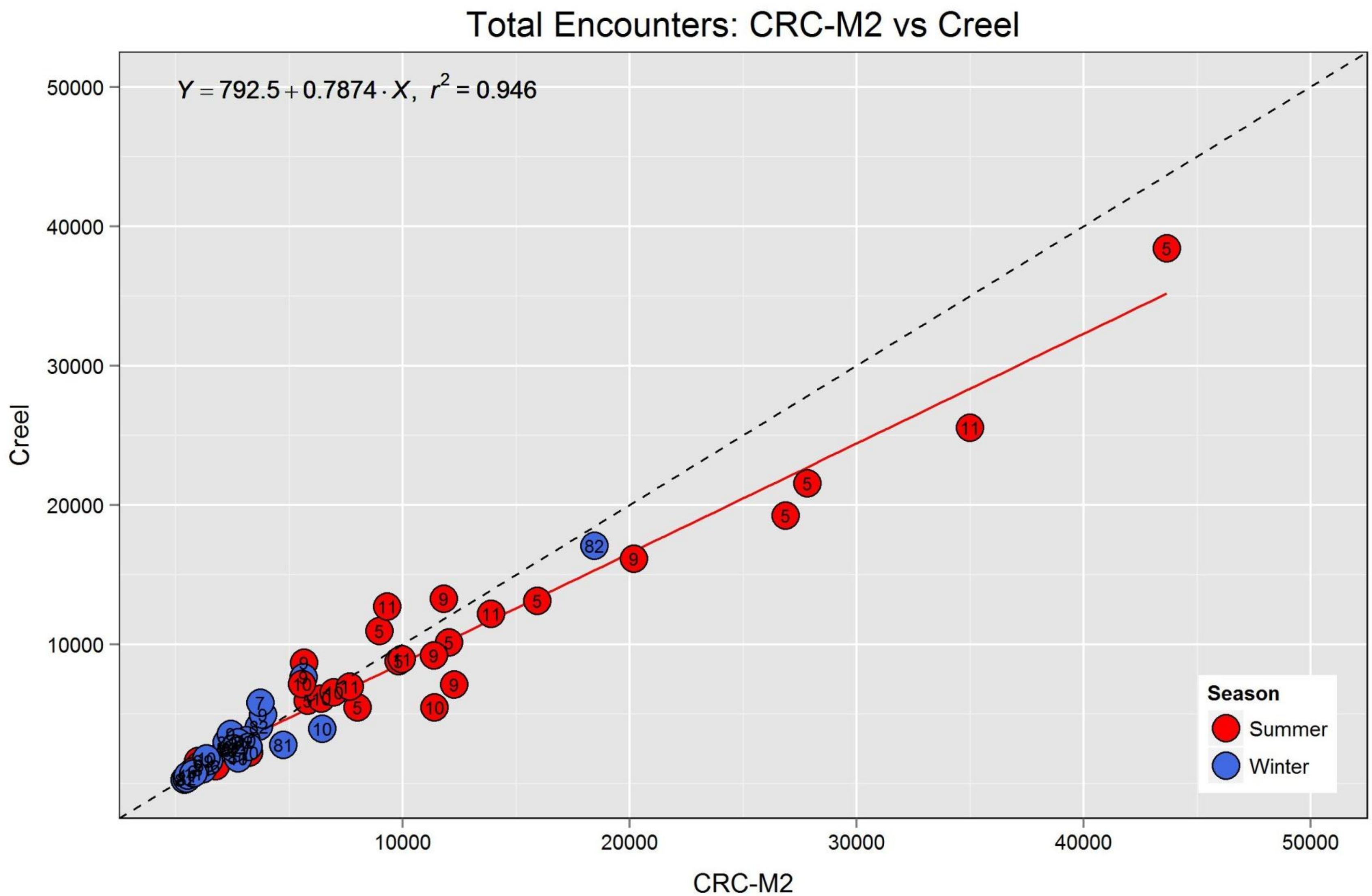

Figure 6. Comparison of CRC-based versus creel-based M2 estimates of total Chinook encounters for all Puget Sound Chinook MSFs that were comprehensively monitored between 2003 and 2011. The dotted line is the line of unity where both estimates are equal; the solid red line is the regression described by the equation in the upper left corner. CRC areas are indicated by numbers in circles.

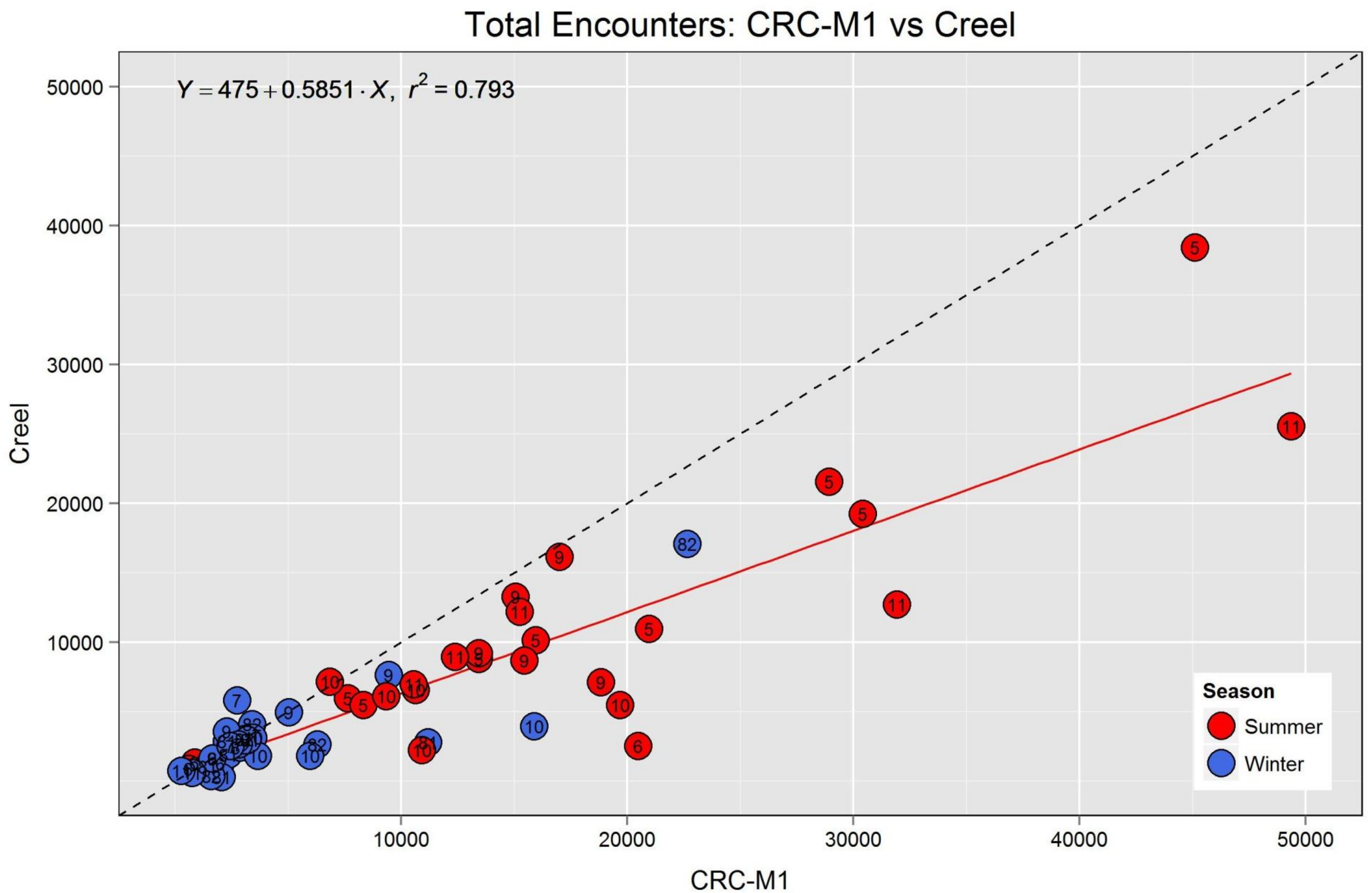

Figure 7. Comparison of CRC-M1 versus creel-M2 total Chinook encounters estimates for all Puget Sound Chinook MSFs that were comprehensively monitored between 2003 and 2011. The dotted line is the line of unity where both estimates are equal; the solid red line is the regression described by the equation in the upper left corner. CRC areas are indicated by numbers in circles.

Application of Methods: Total Encounters Estimates in Areas without Creel Estimates

For the Areas 6, 12 and 13 MSFs that have been monitored using Baseline Sampling and have no existing estimates of total encounters, we used CRC harvest estimates and VTR encounters to estimate the CV of bias-corrected M2 total encounters estimates using equations provided in the WDFW Methods Report (WDFW 2012). Considering these CV estimates and based on a threshold of 20%, the most appropriate methodology for generating total Chinook encounters estimates based on the available data is recommended in Table 2. CRC-based estimates of total Chinook encounters are provided in Table 3 along with the method used to generate them.

In order to estimate size/mark-status proportions for a given fishery using the product method, we used equations 21-25 to predict both $\hat{p}_M$ and $\hat{p}_L$. A graphical representation of the beta regression analysis is provided in Figure 8, which yielded intercept, slope and precision parameters of β_0=1.370, β_1=1.147 and ϕ=12.93. The proportions used to allocate total encounters estimates into the four size/mark-status groups, and the data source that they were derived from, are provided in Table 4.

A summary of the sampling data available for the CRC-M1 and CRC-M2 estimates of total Chinook encounters for MSFs in Areas 6, 12 and 13 is presented in Appendix Table A5. Appendix Table A6 reports estimates of total Chinook retained and released by size and mark-status categories using the recommended estimation method for these fisheries.

Table 2. CRC-based Chinook harvest estimates, VTR encounters by size and mark-status, estimated CV of total encounters estimates and recommended methodology for estimation of total Chinook encounters.

Area / Season	Year	K_{CRC}	$v(K_{CRC})$	*LM*	*LU*	*SM*	*SU*	Est. CV%	Method
6/S	2008	537	3,840	81	50	0	2	13.5	M2
6/S	2009	2,372	29,988	117	53	10	12	9.3	M2
6/S	2010	1,400	12,932	179	61	5	3	9.0	M2
6/S	2011	3,320	79,356	126	60	25	18	10.4	M2
12/W	2009-10	252	1,026	2	6	8	4	69.4	M1
12/W	2010-11	435	6,489	6	2	9	6	39.8	M1
13/S	2007	2,876	113,855	12	11	28	4	28.1	M1
13/S	2008	1,335	15,262	31	4	5	2	13.1	M2
13/S	2009	1,268	12,176	13	9	12	2	24.0	M1
13/S	2010	667	8,776	21	3	3	1	17.8	M2
13/S	2011	1,022	26,944	12	8	0	1	25.0	M1

Table 3. CRC-based estimates of total Chinook encounters for MSFs sampled using Baseline Sampling. For each fishery the method used to generate estimates (M1 vs. M2) is provided, along with the ratio $\hat{\boldsymbol{R}}$ (encountered-to-retained Chinook ratio) and its variance for fisheries where an M1 approach was utilized.

Area / Season	Year	Method	$\hat{R}$	$v(\hat{R})$	$\hat{E}_{CRC}$	$v(\hat{E}_{CRC})$	CV%	95% CI
6/S	2008	M2	NA	NA	1,011	18,507	13.5	744 -1,277
6/S	2009	M2	NA	NA	4,406	168,817	9.3	3,600 - 5,211
6/S	2010	M2	NA	NA	2,220	40,196	9.0	1,827 - 2,613
6/S	2011	M2	NA	NA	6,690	483,223	10.4	5,327 - 8,052
12/W	2009-10	M1	3.25	$1.51x10^{-8}$	818	10,818	12.7	615 - 1,022
12/W	2010-11	M1	2.95	0	1,283	56,444	18.5	817 - 1,749
13/S	2007	M1	3.00	$3.92x10^{-7}$	8,622	1,023,363	11.7	6,640 - 10,605
13/S	2008	M2	NA	NA	2,067	73,376	13.1	1,536 - 2,598
13/S	2009	M1	3.25	$3.47x10^{-6}$	4,125	128,873	8.7	3,421 - 4,829
13/S	2010	M2	NA	NA	990	31,699	18.0	641 - 1,339
13/S	2011	M1	1.82	$4.10x10^{-8}$	1,861	89,358	16.1	1,275 - 2,447

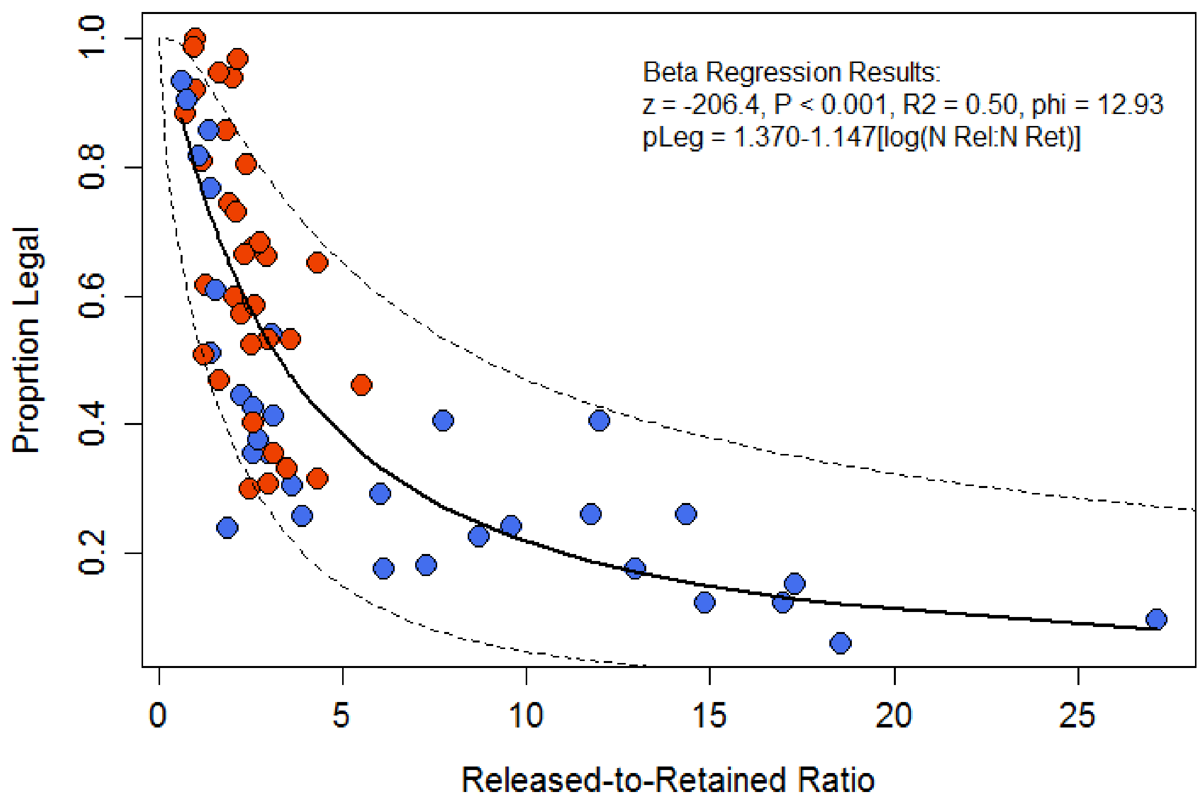

Figure 8. Relationship between the released-to-retained ratio from dockside sampling data and the proportion of legal Chinook from the test fishery or VTR data, including parameters resulting from the beta regression model. The dotted lines represent 95% confidence bounds.

Table 4. Size and mark-status proportions used to apportion CRC-based estimates of total Chinook encounters into size and mark-status groups. Data source denotes whether the proportions were derived from VTR data or by the product method using dockside sampling data (DS).

Area / Season	Year	Data Source	p_{LM}	$v(p_{LM})$	p_{LU}	$v(p_{LU})$	p_{SM}	$v(p_{SM})$	p_{SU}	$v(p_{SU})$
6/S	2008	VTR	0.61	0.0018	0.38	0.0018	0.00	0.0000	0.02	0.0001
6/S	2009	VTR	0.61	0.0012	0.28	0.0010	0.05	0.0003	0.06	0.0003
6/S	2010	VTR	0.72	0.0008	0.25	0.0008	0.02	0.0001	0.01	0.0000
6/S	2011	VTR	0.55	0.0011	0.26	0.0008	0.11	0.0004	0.08	0.0003
12/W	2009-10	DS	0.51	0.0123	0.10	0.0123	0.33	0.0123	0.06	0.0123
12/W	2010-11	DS	0.53	0.0112	0.12	0.0112	0.29	0.0112	0.07	0.0112
13/S	2007	DS	0.44	0.0079	0.20	0.0079	0.25	0.0079	0.11	0.0079
13/S	2008	VTR	0.74	0.0047	0.10	0.0021	0.12	0.0026	0.05	0.0011
13/S	2009	DS	0.49	0.0113	0.12	0.0113	0.31	0.0113	0.08	0.0113
13/S	2010	VTR	0.75	0.0069	0.11	0.0035	0.11	0.0035	0.04	0.0013
13/S	2011	DS	0.68	0.0072	0.15	0.0072	0.14	0.0072	0.03	0.0072

CONCLUSIONS AND RECOMMENDATIONS

Before moving forward with the development of methods to generate fishery total Chinook encounters using CRC harvest estimates, it was necessary to evaluate recent CRC estimates to ensure that they continue to produce valid, statistically accurate harvest estimates. For the 55 mark-selective Chinook fisheries conducted between 2003 and 2011 for which harvest estimates exist through comprehensive creel surveys, comparisons with bias-corrected CRC harvest estimates displayed a strong agreement (R^2 = 0.92, Figure 4), with a slight positive overall bias in the CRC estimates.

Conclusion*: The CRC estimation framework continues to provide accurate estimates of total Chinook harvest by catch area and month for recreational MSFs in Puget Sound.*

This finding is particularly striking given that the fisheries in question occurred under substantially different regulations (i.e., MSFs) than those used to generate the original CRC non-response corrections (Conrad and Alexandersdottir 1993) and the bias-correction factors are more than 20 years old. With the regression line below the line of unity (Figure 4) and an average CRC-to-creel ratio just greater than one, the CRC harvest estimates appear to be slightly more conservative than those produced by the intensive creel surveys. This was a necessary step towards the development of a methodology for estimating total fishery encounters based on CRC harvest estimates.

Given that CRC harvest estimates are only one component of the estimation framework, it was also necessary to develop a set of objective criteria to guide choices regarding other data elements. Before a final estimate of total encounters can be computed, decisions must be made regarding estimate type (M1 vs. M2) and the source of data used to apportion the encounters total into size/mark-status groups.

Recommendation*: We recommend the decision tree presented in Figure 2 be used as the basis for determining the appropriate method for estimating total Chinook encounters in Puget Sound Chinook MSFs.*

Conclusion*: When there are independent estimates of the size/mark-status composition of the fish population based on test fishery and/or VTR encounter samples, and they are of sufficient sample size, M2 is the preferred method for estimating Chinook encounters.*

With these M2 total encounters estimates we can estimate subsequent mortalities using a methodology very similar to that currently used in areas that are comprehensively monitored (WDFW 2012).

Conclusion*: When test fishery or VTR data are lacking (or sample sizes are insufficient), M1 is the preferred method for estimating Chinook encounters.*

With M1, total encounters estimates are derived based upon the relationship between encountered to retained Chinook in the dockside sampling and angler interview data. Also, when this method is employed, size/mark-status composition data (required to apportion total encounters into size/mark-status groups) are not available through test fishery or VTR encounters.

Recommendation*: We recommend the "product method" to estimate the proportion of legal fish and the proportion of marked fish separately based on dockside sampling and angler interview data and that these be used to estimate the proportions for each of the size/mark-status groups.*

There is very good agreement between the CRC-M2 estimates of total Chinook encounters and those provided by comprehensive creel surveys. For the 55 MSFs conducted between 2003 and 2011 for which harvest estimates exist through comprehensive creel surveys, comparisons with CRC-M2 estimates of total Chinook encounters displayed a strong agreement ($R^2 = 0.95$, Figure 6) with a slight positive overall bias in the CRC-M2 estimates. The agreement between CRC-M1 estimates of total Chinook encounters and those provided by comprehensive creel surveys is not as strong. Relative to the CRC-M2 estimates, the CRC-M1 estimates are more variable as evidenced by a lower R^2 ($R^2 = 0.79$) and the positive overall bias in the CRC estimates is greater (Figure 7). The greater degree of overestimation of total Chinook encounters is due to the reliance of CRC-M1 on Chinook release numbers reported by anglers during dockside angler interviews. Conrad and McHugh (2008) demonstrated that angler-reported numbers of fish released are, on average, positively biased.

Typically the estimate of total Chinook encounters provided by CRC-M1 is more precise (has a smaller CV) than the estimate provided by CRC-M2 (Appendix Table A4). This is primarily due to the much larger sample sizes provided by the baseline sampling where there are often thousands of Chinook encounters reported at dockside and used in the M1 estimates compared to the sample size for test fishery or VTR encounters upon which M2 estimates are based, typically being 100 or less. In addition, the larger estimates provided by the M1 relative to M2 results in lower CVs even when variance estimates are similar. However, the trade-off for the better precision of the CRC-M1 estimates is increased bias (typically overestimation of encounters) as discussed above.

The methods described in this report were applied to 11 previously conducted MSFs for which estimates of total Chinook encounters had not yet been provided. The recommended guidelines from this report were followed to determine the method of estimation (CRC-M1 or CRC-M2). Total encounters estimates ranged from 818 to 8,622 Chinook. The CVs for these estimates ranged from 8.7 to 18.5%. This demonstrates our ability to implement the proposed methods with existing data and that the methods provide feasible estimates.

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APPENDICES

A1. CRC-based and creel-based estimates of effort (angler trips) and total Chinook harvest ($\hat{K}$) by fishery

Area	Season	Year	Open	Close	Sampling	CRC Estimates				Creel Estimates			
						Effort	v(Effort)	$\hat{K}$	v($\hat{K}$)	Effort	v(Effort)	$\hat{K}$	v($\hat{K}$)
5	Summer	2003	5-Jul	3-Aug	Creel	23,646	796,781	3,040	22,007	19,398	3,618,965	2,529	66,291
5	Summer	2004	1-Jul	8-Aug	Creel	27,042	1,041,838	2,958	22,970	25,174	2,507,693	2,900	47,736
5	Summer	2005	1-Jul	10-Aug	Creel	33,827	1,805,252	1,635	6,970	30,115	1,122,927	1,669	24,459
5	Summer	2006	1-Jul	21-Aug	Creel	32,268	3,114,791	3,946	35,119	23,177	1,421,222	3,318	58,031
5	Summer	2007	1-Jul	9-Aug	Creel	24,676	1,390,825	3,710	41,166	18,830	823,923	3,367	59,815
5	Summer	2008	1-Jul	9-Aug	Creel	19,150	2,481,196	4,114	124,439	13,004	74,544	2,819	7,377
5	Summer	2009	1-Jul	6-Aug	Creel	29,256	1,326,969	7,308	92,177	24,258	2,767,286	6,561	337,606
5	Summer	2010	1-Jul	15-Aug	Creel	26,131	3,265,476	8,160	260,210	17,189	867,825	5,855	327,489
5	Summer	2011	1-Jul	15-Aug	Creel	30,243	908,739	5,970	50,986	24,848	1,150,870	4,655	154,382
6	Summer	2003	5-Jul	3-Aug	Creel	5,914	198,353	846	3,327	5,195	145,389	964	8,423
6	Summer	2004	1-Jul	8-Aug	Creel	4,175	443,378	541	4,786	4,251	95,506	676	4,290
6	Summer	2005	1-Jul	10-Aug	Creel	3,670	484,494	328	3,026	3,971	195,793	408	14,941
6	Summer	2006	1-Jul	21-Aug	Creel	2,847	240,075	290	2,315	3,077	23,600	349	1,996
6	Summer	2007	1-Jul	9-Aug	Creel	4,723	127,776	1,019	6,797	3,221	56,185	729	6,721
6	Summer	2008	1-Jul	9-Aug	Baseline	2,812	120,740	537	3,840	NA	NA	NA	NA
6	Summer	2009	1-Jul	6-Aug	Baseline	9,394	449,588	2,372	29,988	NA	NA	NA	NA
6	Summer	2010	1-Jul	15-Aug	Baseline	4,744	215,859	1,400	12,932	NA	NA	NA	NA
6	Summer	2011	1-Jul	15-Aug	Baseline	10,463	510,950	3,320	79,356	NA	NA	NA	NA
7	Winter	2007-08	1-Feb	29-Feb	Creel	5,578	537,082	1,499	38,770	4,862	85,264	1,327	5,589
7	Winter	2008-09	1-Feb	15-Apr	Creel	9,562	459,404	1,822	15,991	8,515	16,355	1,505	1,067
7	Winter	2009-10	1-Dec	30-Apr	Creel	8,436	532,600	1,433	13,471	9,714	368,805	1,427	11,035
7	Winter	2010-11	1-Dec	30-Apr	Creel	9,741	1,400,927	1,535	17,815	11,862	1,347,437	2,392	48,528

A1. (Continued)

Area	Season	Year	Open	Close	Sampling	CRC Estimates				Creel Estimates			
						Effort	v(Effort)	$\hat{K}$	v($\hat{K}$)	Effort	v(Effort)	$\hat{K}$	v($\hat{K}$)
81	Winter	2005-06	1-Oct	30-Apr	Creel	5,506	947,738	508	10,288	3,977	165,094	342	2,204
81	Winter	2006-07	1-Oct	30-Apr	Creel	4,366	550,576	534	9,261	3,454	77,336	328	813
81	Winter	2007-08	1-Nov	30-Apr	Creel	4,209	287,334	782	7,488	3,288	100,478	679	6,149
81	Winter	2008-09	1-Jan	30-Apr	Creel	3,327	331,187	383	5,101	2,518	20,935	414	1,350
81	Winter	2009-10	1-Nov	30-Apr	Creel	3,593	354,902	328	1,913	3,221	100,846	291	2,430
81	Winter	2010-11	1-Nov	30-Apr	Creel	4,841	7,264,309	130	2,613	2,398	87,124	95	580
82	Winter	2005-06	1-Oct	30-Apr	Creel	7,796	354,877	787	3,889	8,521	103,579	810	1,757
82	Winter	2006-07	1-Oct	30-Apr	Creel	10,961	1,308,732	901	6,286	7,848	36,481	882	1,064
82	Winter	2007-08	1-Nov	30-Apr	Creel	5,248	282,457	855	5,849	5,678	36,927	887	2,063
82	Winter	2008-09	1-Jan	30-Apr	Creel	5,936	1,056,430	483	13,634	5,979	224,992	527	3,222
82	Winter	2009-10	1-Nov	30-Apr	Creel	6,825	985,549	802	17,096	6,770	239,270	813	6,903
82	Winter	2010-11	1-Nov	30-Apr	Creel	4,468	677,805	150	563	3,511	169,967	119	350
9	Summer	2007	16-Jul	31-Jul	Creel	23,570	2,156,905	3,506	91,787	18,160	1,149,841	5,272	176,702
9	Winter	2007-08	16-Jan	15-Apr	Creel	5,890	512,567	947	13,598	6,888	182,348	1,408	29,938
9	Summer	2008	16-Jul	15-Aug	Creel	25,025	1,650,676	3,599	42,789	20,399	379,152	4,048	238,431
9	Winter	2008-09	1-Nov	15-Apr	Creel	6,369	861,954	769	14,414	7,085	65,655	920	3,035
9	Summer	2009	16-Jul	31-Aug	Creel	59,494	1,558,159	4,059	24,376	42,225	7,016,778	3,248	134,496
9	Winter	2009-10	1-Nov	15-Apr	Creel	6,701	559,908	1,264	16,655	6,870	589,627	1,593	124,797
9	Summer	2010	16-Jul	31-Aug	Creel	40,264	2,228,904	6,496	61,335	31,407	3,159,701	5,344	128,814
9	Winter	2010-11	1-Nov	15-Apr	Creel	4,659	393,736	391	4,174	4,835	254,423	442	3,435
9	Summer	2011	16-Jul	31-Aug	Creel	64,794	2,726,283	4,135	32,677	37,862	7,008,612	2,399	34,344

A1. (Continued)

Area	Season	Year	Open	Close	Sampling	CRC Estimates				Creel Estimates			
						Effort	v(Effort)	$\widehat{K}$	v($\widehat{K}$)	Effort	v(Effort)	$\widehat{K}$	v($\widehat{K}$)
10	Summer	2007	16-Jul	28-Jul	Creel	11,653	537,871	1,606	13,372	8,374	343,591	1,577	20,888
10	Winter	2007-08	1-Dec	31-Jan	Creel	3,058	661,859	654	30,386	2,544	51,851	656	6,075
10	Summer	2008	16-Jul	15-Aug	Creel	15,306	905,408	1,452	8,688	13,808	590,314	1,034	3,993
10	Winter	2008-09	1-Dec	31-Jan	Creel	1,650	34,290	188	408	2,033	27,385	255	2,570
10	Summer	2009	16-Jul	31-Aug	Creel	33,309	1,461,207	3,372	20,213	23,255	528,815	1,643	11,166
10	Winter	2009-10	1-Oct	31-Jan	Creel	12,471	1,808,780	651	5,466	5,563	170,849	398	11,555
10	Summer	2010	16-Jul	31-Aug	Creel	17,333	887,346	2,320	20,895	21,636	932,445	3,029	29,476
10	Winter	2010-11	1-Oct	31-Jan	Creel	21,187	6,813,589	248	2,739	4,481	208,555	169	970
10	Summer	2011	16-Jul	31-Aug	Creel	29,509	744,415	2,825	14,205	27,753	2,538,244	2,671	67,370
11	Summer	2007	1-Jun	30-Sep	Creel	88,243	4,847,793	12,562	120,957	78,958	5,747,287	10,641	289,380
11	Summer	2008	1-Jun	30-Sep	Creel	55,172	4,307,035	5,892	66,598	65,728	6,409,741	7,400	750,158
11	Summer	2009	1-Jun	30-Sep	Creel	91,645	8,483,552	3,785	35,125	81,000	15,360,955	3,307	109,560
11	Winter	2009-10	1-Feb	30-Apr	Creel	2,978	239,587	294	3,307	3,156	72,512	339	2,813
11	Summer	2010	1-Jun	30-Sep	Creel	50,410	7,434,667	4,336	62,442	54,604	8,903,695	3,975	111,441
11	Winter	2010-11	1-Feb	30-Apr	Creel	1,997	548,679	93	560	1,515	43,850	91	780
11	Summer	2011	1-Jun	30-Sep	Creel	79,078	8,930,382	3,062	33,411	70,206	28,816,815	2,736	43,127
12	Winter	2009-10	1-Feb	30-Apr	Baseline	1,736	97,120	252	1,026	NA	NA	NA	NA
12	Winter	2010-11	1-Feb	30-Apr	Baseline	2,425	236,420	435	6,489	NA	NA	NA	NA
13	Summer	2007	1-May	30-Sep	Baseline	28,080	10,326,502	2,876	113,855	NA	NA	NA	NA
13	Summer	2008	1-May	30-Sep	Baseline	22,494	2,357,811	1,335	15,262	NA	NA	NA	NA
13	Summer	2009	1-May	30-Sep	Baseline	40,967	13,921,930	1,268	12,176	NA	NA	NA	NA
13	Summer	2010	1-May	30-Sep	Baseline	27,060	22,129,577	667	8,776	NA	NA	NA	NA
13	Summer	2011	1-May	30-Sep	Baseline	15,818	5,356,794	1,022	26,944	NA	NA	NA	NA

A2. CRC Species Composition: Area 10 Winter Discrepancies

The initial comparison of CRC/Creel Chinook harvest ratios for Area 10 were anomalously high compared with other areas (Figure A2.1). We believe this is caused by an extensive shore-based angling effort targeting chum salmon during October and November in Area 10. The effort and total salmon (all species) catch from this shore-based fishery are accounted for in the CRC data, but not in the species composition proportions estimated from Baseline Sampling interview data. Baseline Sampling emphasized boat-based effort during this period, which typically targets Chinook and Coho salmon, whereas the shore-based fishery was chum focused. This results in an inflated CRC estimate of Chinook landings. This hypothesis was supported by plotting the CRC/Creel Chinook harvest ratio by month for all Area 10 fisheries (Figure A2.2). To address this apparent bias in CRC Chinook estimates we applied CRC-based (in place of creel-based) species compositions to total salmon harvest estimates from Area 10 in October and November. This reduced the CRC harvest estimates of Chinook, making them more comparable to creel estimates from Area 10 in October and November (Figure A2.3) and bringing the overall Area 10 CRC/creel ratios in line with those from the other Marine Areas (Figure A2.4). Original and updated CRC Chinook harvest estimates, along with creel Chinook harvest estimates, are provided in Table A2.1 for Area 10 MSFs that occurred in October and November.

In years where the baseline sampling data does not capture the Area 10 shore-based angling effort in October and November, we recommend substituting the CRC-based species compositions to apportion total salmon harvest for these months. Beginning in 2013, the Puget Sound Sampling unit has expanded its sampling design in October and November in an effort to capture the shore based angling effort and chum harvest. When CRC harvest estimates become available for this fishery we recommend a re-evaluation of the best approach for estimating CRC Chinook harvest.

Table A2.1 Summary of creel-based and CRC-based total Chinook harvest estimates during Area 10 winter MSFs that occurred in October and November. CRC-based estimates were estimated in two ways: (1) using species compositions from the Puget Sound Sampling Program (2) replacing October and November species compositions with those reported in CRCs.

Area	Season	Year	Creel		CRC			
					Creel Species Comp		CRC Species Comp	
			est	var(est)	est	var(est)	est	var(est)
10	Winter	2009-10	398	11,555	803	10,585	651	5,466
10	Winter	2010-11	169	970	597	8,807	248	2,739
10	Winter	2011-12	256	5,475	576	11,538	339	4,573

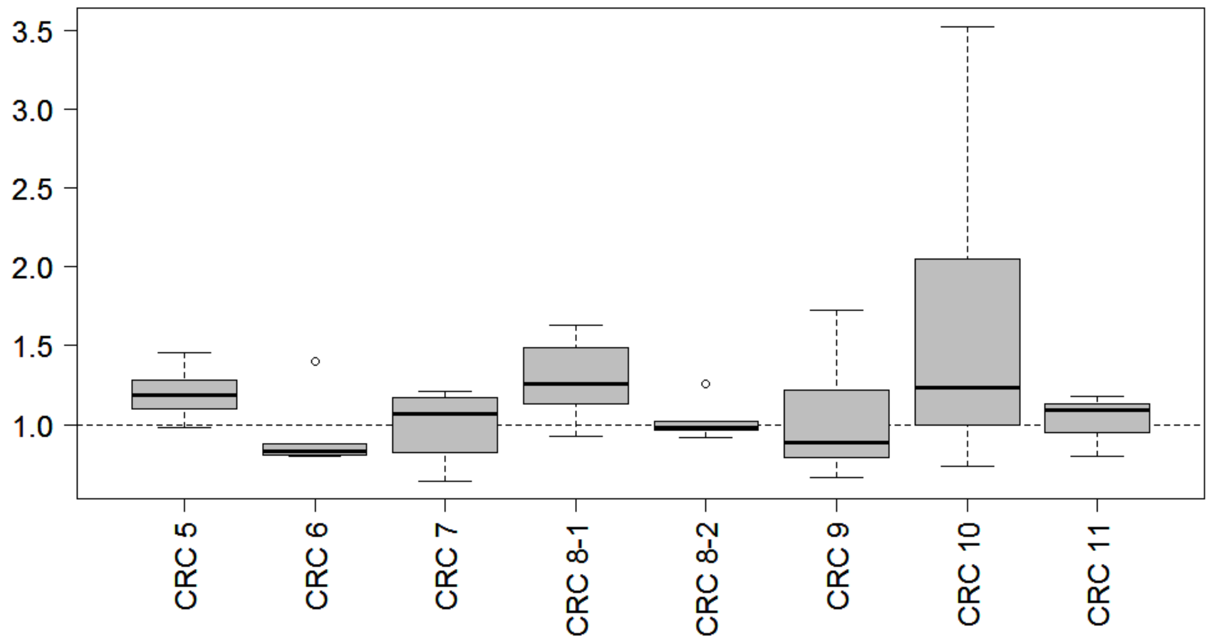

Figure A2.1 Boxplots depicting the ratio of CRC harvest to creel harvest for each fishery by marine catch area, before species composition adjustments in Area 10. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

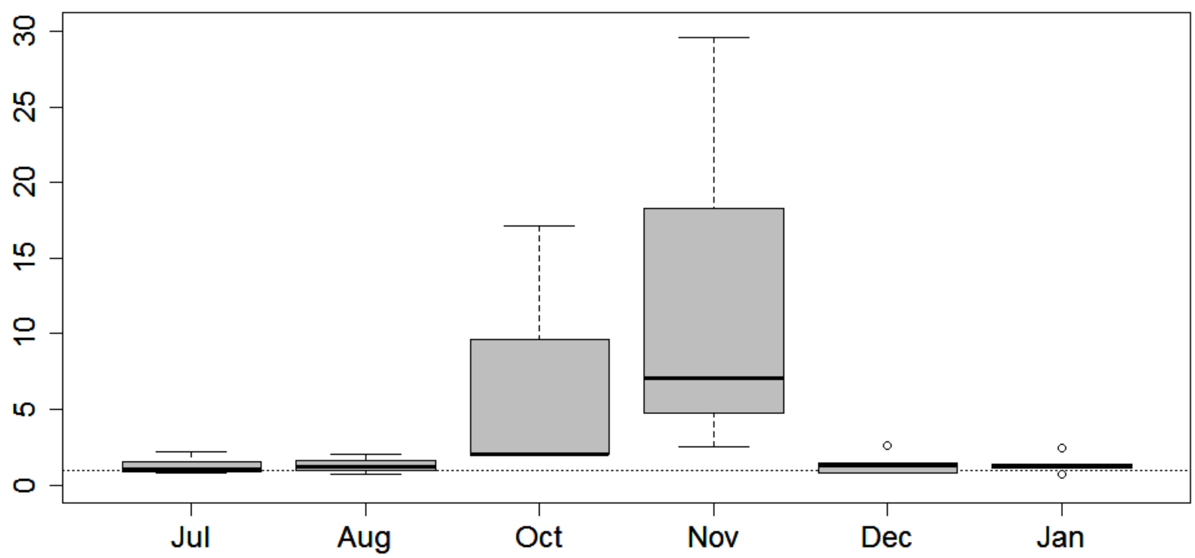

Figure A2.2 Boxplots depicting the ratio of CRC Chinook harvest to creel Chinook harvest by month in Area 10 MSFs before species composition updates. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

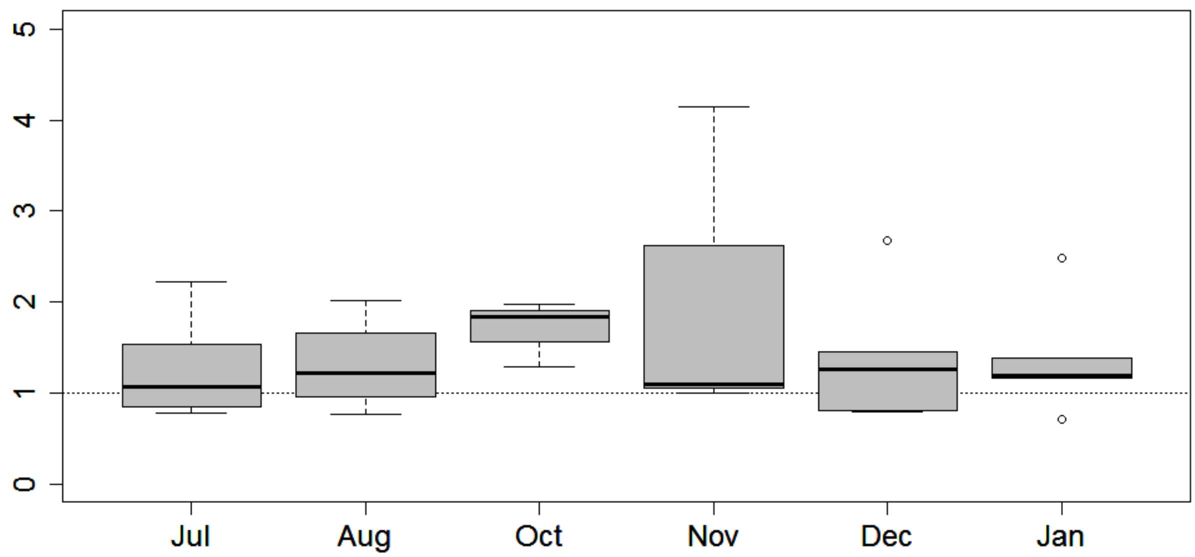

Figure A2.3 Boxplots depicting the ratio of CRC Chinook harvest to creel Chinook harvest by month in Area 10 MSFs after species composition updates. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

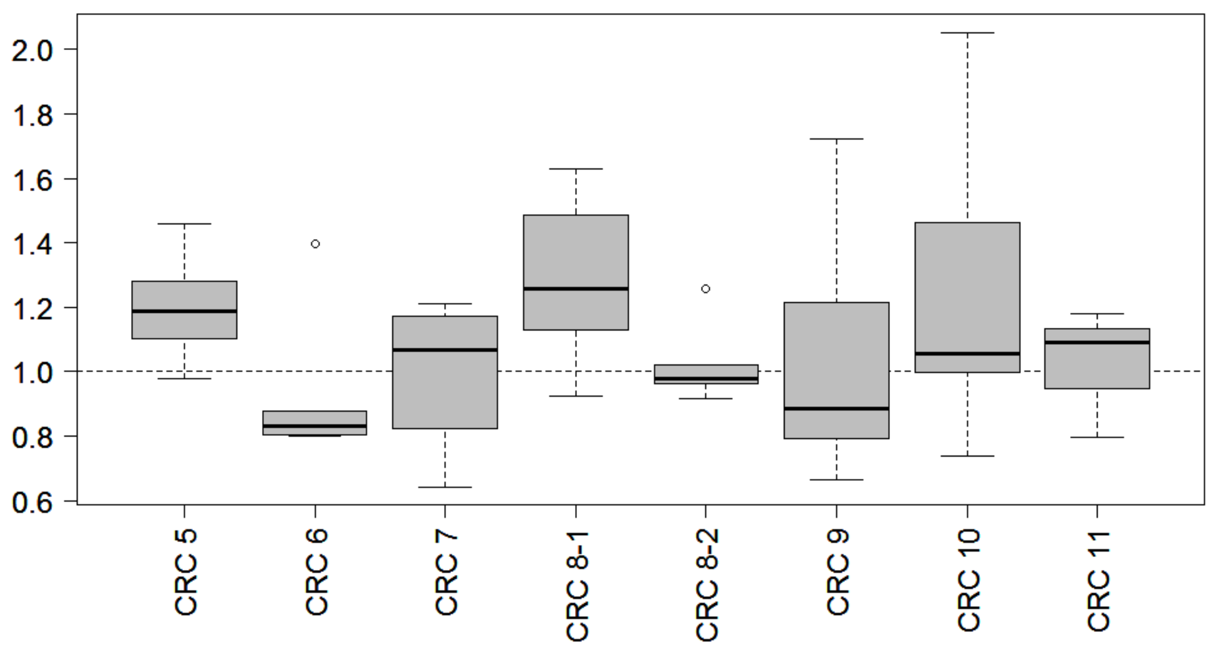

Figure A2.4 Boxplots depicting the ratio of CRC harvest to creel harvest for each fishery by marine catch area, after species composition adjustments in Area 10. Black bars denote the median while the upper and lower bounds of the boxes represent the first and third quartiles. Whiskers represent the minimum and maximum values within 1.5 IQR (interquartile range) of the box bounds and outliers are any points beyond the whiskers. The horizontal dotted line represents a 1-to-1 relationship between the two estimates.

A3. Evaluation of product method assumptions

For fisheries lacking on-the-water observations (test fishery, VTRs) of Chinook encounters, it is necessary to rely on the 'product method' (Equations 16-25) to apportion total encounters, and ultimately fishery impacts, into the four size/mark-status categories. Two conditions must be satisfied in order for this method to provide reliable insight on the size/mark-status composition of Chinook encounters for a particular fishery:

1. Dockside interview-based estimates of the proportion of encounters that are marked (p_M) and model-predicted estimates of the proportion of encounters that are legal (p_L) must be accurate.
2. Mark rates (p_M) must be similar for legal and sublegal size classes and the size composition (p_L) must be similar for marked and unmarked fish.

Whereas the latter part of Assumption 1 (the accuracy of model-predicted p_L) can only be assessed from model fit diagnostics (i.e., in the absence of independent data), the remaining assumptions can be verified by pairing on-the-water encounters data (assumed to be accurate) with baseline dockside sampling programs and comparing appropriate metrics. Accordingly, we used sampling data collected across all Puget Sound MSFs between 2003 and 2012 in order to determine whether dockside mark rates correspond well with what is observed on the water and whether the conditions outlined under Assumption 2 are met reasonably well.

Assumption 1. Can mark rates be accurately estimated from dockside data?

A comparison of dockside-based fishery mark rate estimates with those from combined test fishery/VTR data sets indicates that the answer to this question is yes, but only under certain conditions. Specifically, dockside and on-the-water mark rates were statistically indistinguishable at or above a fishery mark rate of *ca*. 55%, and below this threshold dockside values were consistently less than on-the-water values (Figure A3.1, A-C). Further, while it might appear that there are seasonal differences in dockside vs. on-the-water agreement, this is primarily due to the fact that the only two fisheries in the dataset with consistently low mark rates (Areas 5 and 6) have operated under summer-only seasons during the period in question. With the exception of Area 5 (mean deviation = 0.14), the absolute deviation between intensive and dockside estimates of mark rate averaged less than 0.07 for all fisheries (Figure A3.1, D). Considering (i) the high level of agreement between dockside and on-the-water estimates at moderate-to-high mark rates, (ii) the prevalence of high mark rates across Puget Sound marine areas, and (iii) the error introduced by relying on dockside data for fisheries with low mark rates is conservative from an impact assessment standpoint (i.e., a greater fraction of impacts will be assigned to unmarked groups), it is reasonable to accept the conditions of Assumption 1 as 'true' for product method application purposes.

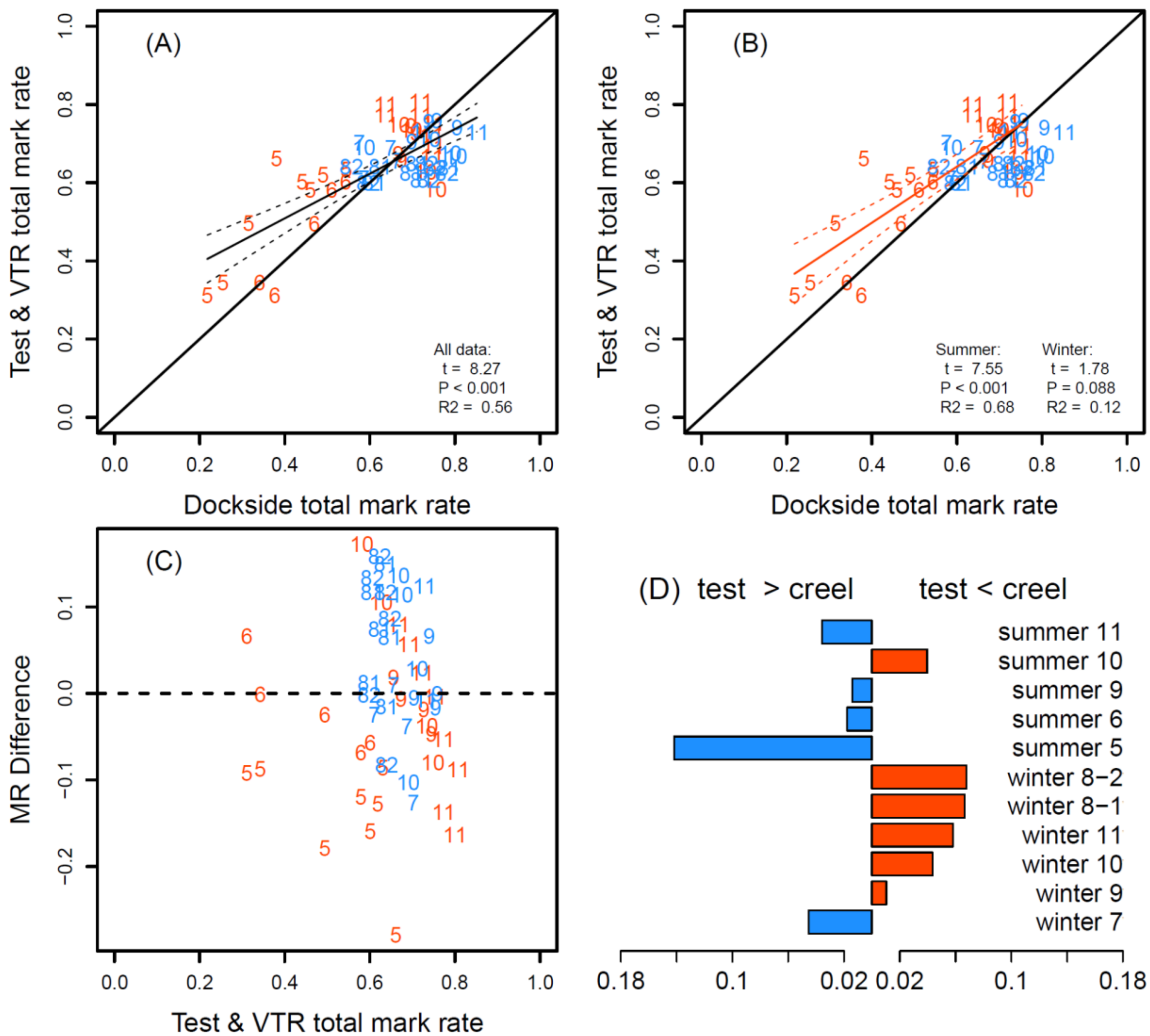

Figure A3.1 Assessment of accuracy of mark rates estimated from dockside data relative to values derived from on-the-water sampling (test fishery and VTR; assumed to be correct). Regression-based comparisons for pooled (A) and season-specific (B) mark rate estimates, relative to hypothesized equality (i.e., the diagonal reference line). (C) Mark rate difference (creel minus on-the-water estimate) as a function of on-the-water mark rate. (D) Mean absolute difference of creel and on-the-water mark rate estimates. In A-C, red denotes summer whereas blue denotes winter and numbers correspond to catch record card reporting areas. Regression lines and confidence intervals (95%) are displayed where significant (*P* < 0.05) relationships were detected.

Assumption 2. Is p_M similar for legal and sublegal fish and/or is p_L similar for marked and unmarked fish?

The product method is a viable means for estimating p_{LM}(as well as other size/mark-status proportions) if $p_L$and $p_M$are statistically independent. This can be stated as testable hypotheses in probability terms,

(A) $p_M = p_{M|L} = p_{M|S}$

(B) $p_L = p_{L|M} = p_{L|U}$

which we evaluated by computing and comparing conditional probabilities (size class membership given mark status [A] and vice versa [B]) from the combined test fishery/VTR Chinook encounters dataset. Regression-based comparisons illustrate that statistical independence, and thus product method validity, can be reasonably assumed in many cases (Figure A3.2, A-B); however, these data also clearly show some dependence of mark-status on size class membership and vice versa. For fisheries with relatively high mark rates, for instance, there is a tendency towards a higher marked fraction among legal- than sublegal-sized fish (Figure A3.2, A). Similarly, a higher fraction of marked than unmarked fish were legal in size, primarily in fisheries with a relatively high sublegal presence (i.e., $p_L < 0.50$, Figure A3.2, B). Where evident, however, the level of deviation between observed data (i.e., the fitted regression line) and expectations based on statistical independence (i.e., equality or 1:1 line) was relatively minor overall (0.05-0.10). Given these results, we further assessed Assumption 2's validity by computing joint probabilities (i.e., p_{LM}, etc.) using the product method approach and comparing results with values based on true size/mark-status group membership. These comparisons illustrate a clear correspondence between calculated (product method) and actual probabilities (Figure A3.2, C; note, although not displayed, results were similar for the other three size/mark-status groups) and therefore suggest that the conditions of Assumption 2 are sufficiently valid for practical purposes.

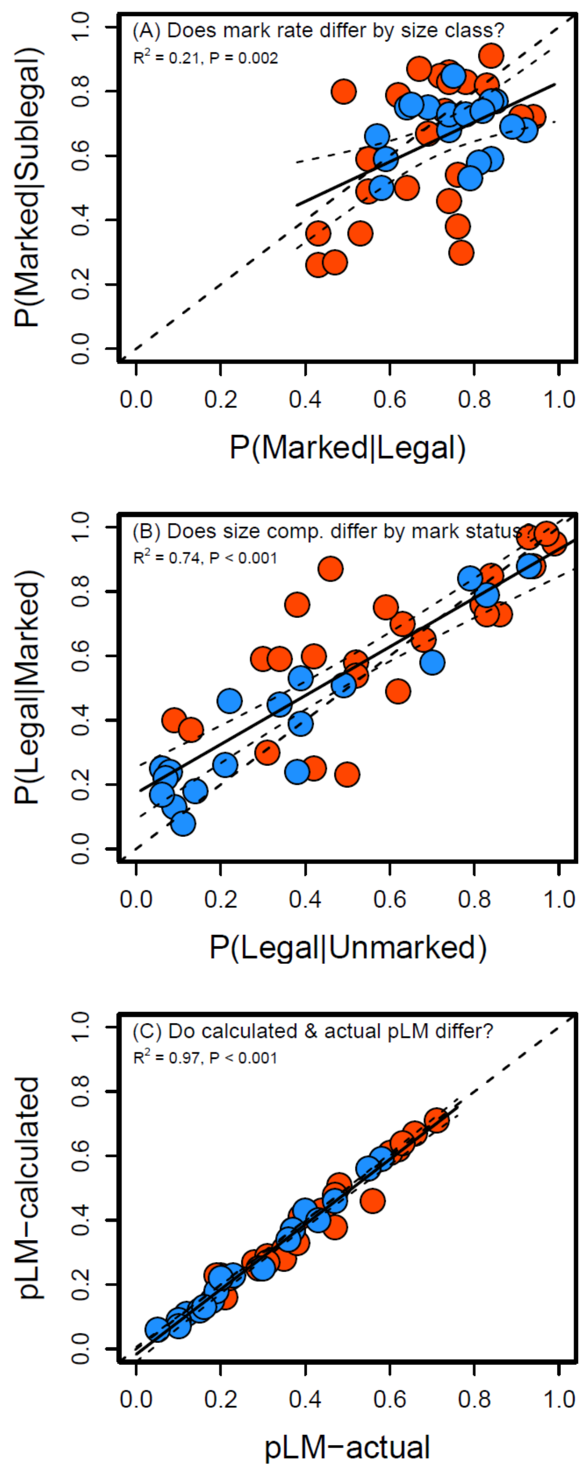

Figure A3.2 Evaluation of assumption of similar p_M for legal and sublegal fish (A), similar p_L for marked and unmarked fish (B), and comparison of p_{LM} calculated via the product method and computed based on actual observations. In all figures, red denotes summer whereas blue denotes winter, the diagonal line is the reference for hypothesized equality, and regression lines and 95% confidence intervals are displayed where significant ($P < 0.05$) relationships were detected.

A4. CRC-based and creel-based estimates of total Chinook encounters by fishery estimated using a bias-corrected M2 approach

Area/ Season	Year	Test/VTR Encounters				Dockside Retained				$\hat{E}_{CRC-M2}$	v($\hat{E}_{CRC-M2}$)	$\hat{E}_{CRC-M1}$	v($\hat{E}_{CRC-M1}$)	$\hat{E}_{Creel}$	v($\hat{E}_{Creel}$)
		LM	LU	SM	SU	LM	LU	SM	SU						
5-S	2003	66	89	48	132	70	7	1	0	15,917	4,058,048	255,345	155,264,923	13,131	5,430,256
5-S	2004	48	62	21	38	377	27	100	0	8,954	1,463,200	20,958	1,153,094	10,950	3,377,032
5-S	2005	40	33	30	34	409	27	8	9	5,811	696,568	7,646	152,431	5,984	1,331,123
5-S	2006	74	65	25	46	794	50	3	2	12,038	1,609,852	15,937	572,866	10,129	1,993,945
5-S	2007	31	23	15	11	742	70	4	16	9,814	2,223,290	13,423	538,875	8,808	2,719,075
5-S	2008	29	17	1	3	984	16	3	0	7,999	1,410,106	8,314	508,218	5,496	627,442
5-S	2009	85	96	167	224	1,312	302	15	70	43,651	22,701,902	45,103	3,511,063	38,423	32,140,191
5-S	2010	188	149	102	124	1,646	73	2	0	26,864	5,390,602	30,395	3,610,479	19,250	5,177,447
5-S	2011	55	105	21	60	1,081	70	13	4	27,829	12,057,323	28,911	1,195,732	21,570	10,392,888
6-S	2003	63	76	3	6	31	0	1	0	2,213	72,536	20,464	1,947,048	2,542	158,488
6-S	2004	69	74	4	1	268	1	100	0	969	23,472	1,672	45,738	1,649	62,300
6-S	2005	20	34	3	0	145	0	0	3	1,053	66,897	868	21,189	1,324	288,284
6-S	2006	11	14	0	0	149	1	0	0	753	44,814	586	9,445	882	72,220
6-S	2007	50	25	1	0	392	4	2	0	1,753	41,423	2,010	26,435	1,249	41,210
7-W	2007-08	152	107	27	16	429	9	100	0	2,730	156,030	3,201	176,836	2,967	66,818
7-W	2008-09	95	42	9	1	706	7	4	0	3,191	87,252	2,805	37,911	2,635	29,304
7-W	2009-10	153	64	16	7	608	8	0	0	2,550	58,171	2,438	38,990	2,540	51,083
7-W	2010-11	41	30	8	8	711	3	2	0	3,718	283,591	2,736	56,580	5,800	727,245
81-W	2005-06	85	53	177	135	147	19	1	0	2,721	368,934	2,358	221,686	1,914	258,894
81-W	2006-07	199	76	958	541	142	19	2	1	4,738	846,480	11,182	4,061,260	2,781	367,332
81-W	2007-08	126	54	106	47	231	13	2	0	2,231	86,550	3,303	133,581	3,000	788,909
81-W	2008-09	16	2	51	32	176	3	1	0	2,717	636,196	2,289	182,280	2,870	504,744
81-W	2009-10	64	11	97	38	103	4	0	0	1,191	40,924	1,444	37,067	1,056	46,285
81-W	2010-11	13	2	13	9	21	2	1	0	372	28,104	2,064	658,412	284	9,977
82-W	2005-06	69	54	114	60	408	22	4	0	3,660	234,711	3,408	72,931	4,116	2,416,430
82-W	2006-07	59	16	750	381	405	53	6	1	18,438	8,180,087	22,656	3,974,488	17,071	14,449,708
82-W	2007-08	83	19	98	29	427	42	5	1	2,437	94,397	2,878	66,285	2,428	94,701
82-W	2008-09	17	1	47	14	208	6	0	0	2,508	645,087	6,276	2,302,180	2,660	419,367

Area	Year	Test/VTR Encounters				Dockside Retained				$\hat{E}_{CRC-M2}$	$v(\hat{E}_{CRC-M2})$	$\hat{E}_{CRC-M1}$	$v(\hat{E}_{CRC-M1})$	$\hat{E}_{Creel}$	$v(\hat{E}_{Creel})$
		LM	LU	SM	SU	LM	LU	SM	SU						
82-W	2009-10	64	11	97	38	388	5	1	0	2,979	330,442	3,059	248,754	3,012	196,815
82-W	2010-11	13	2	13	9	41	2	0	0	468	16,659	1,598	63,911	367	10,329
9-S	2007	80	14	19	4	849	26	4	6	5,654	366,725	15,445	1,781,463	8,697	992,981
9-W	2007-08	40	8	36	10	215	12	1	0	2,412	172,906	2,293	79,698	3,570	518,334
9-S	2008	23	8	16	19	786	2	2	0	11,811	4,460,555	15,049	754,348	13,290	9,929,133
9-W	2008-09	48	9	151	104	294	5	2	0	5,612	1,313,346	9,450	2,176,567	7,627	2,292,296
9-S	2009	22	8	52	18	602	27	4	0	20,168	15,179,392	16,999	427,656	16,145	12,977,878
9-W	2009-10	71	15	90	25	324	20	3	1	3,829	288,789	5,037	264,481	4,956	2,059,065
9-S	2010	45	16	6	2	1,547	3	6	1	11,375	1,202,031	13,418	262,479	9,219	993,712
9-W	2010-11	42	10	50	36	134	1	0	0	1,466	93,631	1,643	73,702	1,643	81,275
9-S	2011	34	15	29	14	582	20	6	2	12,270	3,116,436	18,822	677,832	7,121	1,270,413
10-S	2007	16	5	31	7	339	17	4	1	6,392	2,102,328	9,339	452,981	6,107	2,637,034
10-W	2007-08	24	7	75	14	116	21	3	0	3,114	1,004,843	3,446	843,654	3,120	644,424
10-S	2008	18	8	3	6	231	1	1	0	3,217	329,384	10,900	526,699	2,246	161,979
10-W	2008-09	32	4	114	52	63	1	0	0	1,343	68,360	3,663	154,956	1,821	222,060
10-S	2009	17	1	26	10	448	35	1	0	11,396	5,575,024	19,668	690,775	5,489	1,379,982
10-W	2009-10	43	9	272	95	85	10	0	1	6,456	1,453,038	15,873	3,250,162	3,965	1,740,802
10-S	2010	16	5	5	8	1,001	13	7	2	5,545	1,164,039	6,825	181,122	7,177	1,868,243
10-W	2010-11	26	8	125	112	35	3	0	0	2,737	599,283	5,971	1,588,340	1,830	243,146
10-S	2011	33	21	12	8	688	26	3	3	6,958	911,708	10,640	202,039	6,573	1,146,383
11-S	2007	115	38	115	24	2,716	95	27	8	34,988	7,428,558	49,355	1,867,322	25,558	6,265,487
11-S	2008	80	16	14	2	2,035	28	8	2	9,308	478,552	31,928	1,969,143	12,703	5,035,254
11-S	2009	205	73	223	188	806	30	7	6	13,882	1,144,164	15,229	568,722	12,180	2,133,571
11-W	2009-10	35	8	12	1	90	3	0	0	523	13,443	743	21,117	598	13,266
11-S	2010	496	130	103	45	1,025	7	8	0	7,665	238,421	10,554	369,975	6,967	390,840
11-W	2010-11	3	3	11	8	27	3	1	0	776	212,945	279	5,037	752	240,899
11-S	2011	246	178	168	133	595	18	3	4	9,954	625,340	12,374	545,670	8,940	704,693

A5. Sampling data required for M1 and M2 estimates of Chinook encounters for fisheries sampled using Baseline Sampling.

Area	Season	Year	VTR Encounters				Dockside Retained				Dockside Released				
			LM	LU	SM	SU	LM	LU	SM	SU	AD	UM	UK	Other Salmon	Unid. Salmon
6	Summer	2008	81	50	0	2	339	0	1	0	5	251	1	8	0
6	Summer	2009	117	53	10	12	514	8	0	0	140	407	157	1,613	7
6	Summer	2010	179	61	5	3	723	2	1	0	36	228	9	7	4
6	Summer	2011	126	60	25	18	926	28	2	4	220	600	324	2,677	14
12	Winter	2009-10	2	6	8	4	117	4	0	0	132	39	97	1	4
12	Winter	2010-11	6	2	9	6	77	1	1	0	77	29	48	0	0
13	Summer	2007	12	11	28	4	346	13	10	0	197	165	362	203	17
13	Summer	2008	31	4	5	2	169	1	0	0	109	54	235	290	101
13	Summer	2009	13	9	12	2	49	3	1	0	47	18	52	28	3
13	Summer	2010	21	3	3	1	62	0	2	0	13	15	35	14	5
13	Summer	2011	12	8	0	1	125	1	1	0	35	22	47	631	2

A6. Chinook encounters and mortality by size and mark-status for fisheries sampled using Baseline Sampling.

Area	Season	Year	Chinook Retained				Chinook Released				Chinook Mortality				Total Encounters	Total Mortality
			LM	LU	SM	SU	LM	LU	SM	SU	LM	LU	SM	SU		
6	Summer	2008	535	2	0	0	80	378	0	15	547	58	0	3	1,011	609
6	Summer	2009	2,336	0	36	0	349	1,216	193	275	2,388	182	75	55	4,406	2,700
6	Summer	2010	1,394	2	4	0	208	544	41	27	1,425	84	12	5	2,220	1,526
6	Summer	2011	3,202	7	97	14	479	1,746	634	512	3,274	269	224	116	6,690	3,883
12	Winter	2009-10	244	0	8	0	176	79	262	51	270	12	61	10	818	353
12	Winter	2010-11	424	6	6	0	252	148	364	84	462	28	78	17	1,283	585
13	Summer	2007	2,697	78	101	0	1,095	1,648	2,032	971	2,861	325	508	194	8,622	3,888
13	Summer	2008	1,327	0	8	0	198	197	238	98	1,357	30	55	20	2,067	1,462
13	Summer	2009	1,172	24	72	0	839	471	1,227	320	1,298	95	317	64	4,125	1,774
13	Summer	2010	646	21	0	0	97	85	106	35	661	34	21	7	990	723
13	Summer	2011	1,006	8	8	0	266	268	250	56	1,046	48	58	11	1,861	1,163