## PACIFIC SALMON COMMISSION

 SELECTIVE FISHERY EVALUATION COMMITTEEANALYSIS OF COHO SALMON
DOUBLE INDEX TAG (DIT) GROUPS
FOR BROOD YEARS 1998-2011

## REPORT SFEC (21)-1

July 2021

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## ACRONYMS \& INITIALISMS

| ASFEC | Ad Hoc Selective Fishery Evaluation Committee |
| :--- | :--- |
| BC | British Columbia region |
| CDFO | Canadian Department of Fisheries and Oceans |
| COLR | Columbia River sub-region |
| CoTC | Coho Technical Committee |
| CR | Columbia River region |
| CWT | Coded Wire Tag |
| DIT | Double Index Tagging |
| ER | Exploitation Rate |
| ETD | Electronic Tag Detection |
| FRAM | Fishery Regulation Assessment Model |
| FRAS | Fraser River sub-region |
| GRAY | Gtrays Harbor sub-region |
| GST | Hood Canal sub-region |
| HC | Strait of Juan de Fuca sub-region (US) |
| JDF | Johnstone Strait sub-region |
| JNST | Mass Marking |
| MM | Mid Puget Sound sub-region |
| MPS | Mark Recognition Error |
| MRE | Mark-selective Fishery |
| MSF | Management Unit |
| MU | National Fish Hatchery |
| NFH | Northern Puget Sound sub-region |
| NPS | Non-selective Fishery |
| NSF | North Washington Coast sub-region |
| NWC | Pacific Fishery Management Council |
| PFMC | Paired-Ratio Method |
| PR | Puget Sound region |
| PS | Pacific Salmon Commission |
| PSC | Pacific Salmon Treaty |
| PST | Regional Mark Information System |
| RMIS | Selective Fishery Evaluation Technical Committee |
| SFEC | SFEC-Analytical Work Group |
| SFEC-AWG | Single Index Tagging |
| SIT | Unmarked Retention Error |
| URE | Washington Coast region |
| WC | West Coast Vancouver Island sub-region |
| WCVI | Washington Department of Fish and Wildlife |
| WDFW | Willapa Bay sub-region |
| WILP |  |

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## ExECUTIVE SUMMARY

## Background

Prior to the advent of mark-selective fisheries (MSFs), which require anglers to release salmon with an intact adipose fin (unmarked), we could rely on estimates of exploitation rates (ERs) derived from recoveries of salmon having coded-wire tags (CWTs) and clipped adipose fins (marked) to infer fishery impacts on associated natural fish populations. With MSFs, the exploitation patterns of marked fish and unmarked fish are now different. A clipped adipose fin, which originally had been sequestered as a visual cue that a fish contained a CWT, is now used as a mass mark for many hatchery-reared Coho and Chinook salmon. In order to provide a method for estimating impacts of MSFs on natural stocks, the Ad Hoc Selective Fishery Evaluation Committee (ASFEC) developed a double index tag (DIT) system comprised of three main components:

1. The release of paired groups of indicator stocks (DIT groups) containing different CWT codes. Paired releases consist of two groups of salmon that are identical in brood stock and size/time of release. One group is comprised of fish with a CWT and an adipose fin clip (marked) while the other group has a separate CWT code and is released with the adipose fin intact (unmarked).
2. Because the adipose fin clip could no longer be relied upon as a visual indicator that a fish contained a CWT, electronic tag detection (ETD) methods were needed throughout the migratory range to recover CWTs from unmarked DIT groups in non-selective fisheries and escapements and to reduce costs of recovering CWTs ${ }^{1}$.
3. DIT groups are used to represent natural stocks with significant production and which have differences in distribution, migration, and fishery exploitation patterns.

Coded-wire-tag recoveries from DIT groups were anticipated to provide the data needed to estimate impacts of MSFs on marked and unmarked components of Coho and Chinook salmon DIT groups.

A 2003 Joint Coho DIT Analysis Workgroup comprised of representatives of the Northwest Indian Fisheries Commission (NWIFC) and Washington Department of Fish and Wildlife (WDFW) issued a report on the results of the DIT program for brood years 1995-1997 (JCDAW 2003). That report covered a period when MSFs were just starting to be implemented on a limited scale. Differential impacts on the marked and unmarked components of the DIT groups could not be reliably detected because of insufficient numbers of Coho DIT recoveries, except for some stocks from the Washington Coast sub-region.

[^1]The implementation of a DIT system as originally envisioned has encountered several significant challenges:
a) Electronic tag detection (ETD) equipment and associated sampling methods had to be developed and widely deployed.
b) Existing CWT sampling programs and reporting systems had to be revised to accommodate the additional information required for DIT programs and DIT analyses. Complete and accurate reporting of this new information has been a challenge to reporting agencies and is a continuing issue that was evident during the development of this report.
c) Agency budgets are under extreme pressure; consequently, some agencies are reluctant to appropriate the fiscal resources needed to acquire and deploy ETD equipment or continue releasing DIT groups.
d) Regulations for conducting MSFs have become increasingly complex and catch sampling and reporting systems are not fully aligned with the conduct of MSFs; these issues are described in greater detail in the annual reports issued by the PSC's Selective Fishery Evaluation Committee (SFEC).

For a variety of reasons, the DIT system envisioned by the ASFEC never fully came into being. Consequently, the estimation of ERs using DIT groups has substantial deficiencies in the information available and the quality of estimates provided by the DIT program varies considerably from hatchery to hatchery and region to region.

Questions regarding the need for and value of continuing the DIT program are increasing. If the DIT program were discontinued, what are the consequences for stock assessment and fishery management? Does the information provided by the DIT program justify continued investment in the cost of DIT marking and ETD? This report provides information for PSC panels, technical committees, and fishery management agencies to address these questions.

## Contents of this Report Include:

- Analysis of DIT group returns for Coho Salmon from 22 different hatcheries in British Columbia, Washington, and Oregon covering brood years 1998-2011 (return years 20012014);
- Comparisons of estimated ERs of the marked and unmarked components of DIT groups and evaluation of different methods of estimating the ER for the unmarked component of a DIT group;
- Comparisons of ERs produced by the Fishery Regulation Assessment Model (FRAM), a bilateral tool developed by the PSC Coho Technical Committee for preseason planning and post-season estimation of ERs, to ERs estimated by analysis of DIT groups; and,
- Evaluation of DIT programs from each hatchery.


## Major Conclusions from this Report:

The conclusions and recommendations in this report pertain only to Coho Salmon and should not be extended to other species such as Chinook salmon.

- The PSC SFEC and Coho technical committees should provide agencies with recommendations for regional DIT and SIT programs that should be maintained for assessment of MSF impacts. [Sections 4.2; 7.6].
- The Paired Ratio (PR) method using either $\lambda^{R e l}$ or $\lambda^{E s c}$ is the recommended method for estimating the ER for the unmarked component of a DIT group ${ }^{2}$. Compared to the other methods evaluated, the PR method provides the most consistent and relatively precise estimates of both total ER and fishery-specific ERs for the unmarked component of a DIT group when its assumptions are met. If PR estimates are produced using both $\lambda^{\text {Rel }}$ and $\lambda^{E s c}$, total and fishery-specific estimates of ER for the unmarked component of a DIT group can be bracketed. [Sections 3.2; 3.4; 7.1]
- Analyses of DIT group data show that MSF impacts on Coho stocks can differ substantially by region, among hatcheries in the same region, and among brood years from the same hatchery. [Sections 7.2; Appendices 4 and 6]
- For some DIT programs, estimated MSF impacts have been so consistently small, or uncertainty in the estimates so large, that it is unlikely that useful information can be obtained from a continuation of these programs as they are currently implemented. Program characteristics that can contribute to inconsistent results include:[Section 6; Section 7.2]
- The ability to detect differences in exploitation rate estimates between the marked and unmarked components of a DIT group depends on the proportion of the total mortality occurring in MSFs, the return rate (survival) of the DIT groups, and the quality of the sampling programs for fisheries impacting a DIT group.
- For some DIT groups, ER estimates were highly uncertain due to insufficient numbers of CWT recoveries.
- The sequence of MSFs and non-selective fisheries (NSFs) affects the ability to detect differences in ERs between marked and unmarked fish. For instance, differences in ERs resulting from MSFs can be offset by subsequent non-selective fisheries.
- The proportion of CWT recoveries associated with DIT groups that are occurring in visually-sampled (as opposed to electronically-sampled) fisheries or mixedregulation fishery sampling strata are potentially introducing substantial bias and uncertainty into the DIT program results for some hatcheries.

[^2]
## Recommendations for DIT Programs

- Assuming that the magnitude and extent of MSFs impacting the brood years analyzed for this report will be indicative of what can be expected in the future, a system of regional DIT groups should be maintained to monitor MSF impacts. DIT groups with the following characteristics should be prioritized:
- The combination of the number of fish released in the DIT group and the expected return rate to the hatchery should result in at least $\mathbf{1 , 0 0 0}$ fish in the marked and unmarked components of the DIT group (individually) returning to the escapement (and to be available for sampling). [Section 7.2.1]
- The proportion of the estimated CWT recoveries from the marked component of a DIT group in MSFs should be at least one third (33\%) of all fishery recoveries. [Section 7.2.1]
- The difference between the expected ER for the marked and unmarked components of a DIT group should be $\geq+\mathbf{0 . 0 5}$. [Section 7.2.1]
- ETD and sampling programs should be in place for at least $\mathbf{8 0 \%}$ of the expected fishery recoveries, no more than $5 \%$ of the expected fishery recoveries should occur in mixed-regulation fishery strata, and no more than $\mathbf{5 \%}$ of the expected unmarked recoveries should occur in visually-sampled non-selective fisheries. [Section 7.3]
- Differences in return proportions between the marked and unmarked components of a DIT group that can be reliably detected will depend on the number of tagged fish released in each component and the survival and exploitation rates for the fish in each DIT group component. Larger release numbers will increase the probability that small but perhaps meaningful differences in return and exploitation rates between the DIT group components are detected when survival rates are low. For example, release sizes of 65,000 for both the marked and unmarked DIT group components and a return rate of $2 \%$ for marked fish would give the ability to detect a $0.2 \%$ difference in relative return proportions with Type I and II error rates of 5\% and $20 \%$, respectively. The relative return proportion is directly related to exploitation rates of marked and unmarked fish. [Section 2.5]

If the pattern or intensity of MSFs changes substantially, these recommendations should be revisited.

## Recommendations for Specific Hatchery Programs

$>$ The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

British Columbia region [Section 6.1.1]<br>Inch Creek Hatchery<br>Puget Sound region [Section 6.2.1]<br>Marblemount Hatchery<br>Wallace River Hatchery<br>Soos Creek Hatchery<br>George Adams Hatchery<br>Quilcene National Fish Hatchery<br>Washington Coast region [Section 6.3.1]<br>Quinault National Fish Hatchery<br>Solduc Hatchery<br>Bingham Creek Hatchery<br>Forks Creek Hatchery

Columbia River region [Section 6.4.1]
Lewis River Hatchery - north-migrating group
Lewis River Hatchery - south-migrating group
Sandy River Hatchery
$>$ The following DIT program(s) have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:

British Columbia region [Section 6.1.1]
Quinsam River Hatchery
Puget Sound region [Section 6.2.1]
Lower Elwha Hatchery
Kendall Creek Hatchery
Washington Coast region [Section 6.3.1]
Makah National Fish Hatchery
Salmon River Fish Culture

- The results for the following DIT program(s) are mixed and are difficult to categorize or there is an insufficient number of years of data to make a determination:

British Columbia region [Section 6.1.1]<br>Big Qualicum River Hatchery<br>Chilliwack River Hatchery<br>Robertson Creek Hatchery<br>$\xrightarrow{\text { Puget Sound region [Section 6.2.1] }}$<br>Voights Creek Hatchery<br>Columbia River region [Section 6.4.1]<br>Eagle Creek National Fish Hatchery

## Recommendations Regarding Analytical Methods

- The results of the hypothesis tests used in this report to compare estimated ERs for the marked and unmarked components of a DIT group and evaluate MSF impacts are sensitive to (a) the selective fishing mortality ( $s f m$ ) rates used for the MSFs and (b) uncertainty in the estimates of $s f m$ rates (which is currently assumed to be 0 ). Using different sfm rates and/or accounting for the uncertainty in the sfm rates would change the results for many of these hypotheses tests. A sensitivity analysis which examines the results of the hypothesis tests comparing the estimates of ERs for the marked and unmarked components of a DIT group to changes in sfm rates and to uncertainty in the sfin rates should be conducted. [Section 7.5.1]
- The single index tag (SIT)-based method may be an adequate method of estimating unmarked ERs for some hatcheries if expected ERs are relatively low (e.g., <40\%) and if survival rates and tagging levels are conducive to producing precise SIT-based estimates. However, further work is needed to determine the best statistical method to relate the SIT-based and DIT-based estimates (e.g., regression methods) and to compare SIT-based estimates of ER by fishery to those from the PR method. [Sections 4.2 and 7.6]
- For model-based estimates, interpretation of model-based estimates needs to account for the effects of average base-period ERs that are a key component of the models and uncertainty in CWT-based estimates of ERs. It is unreasonable to assume that the point estimates of annual ERs produced by the Coho FRAM are accurate and without error. Differences between post-season Coho FRAM and DIT-based ER estimates can be quite substantial and vary by stock. While there is relatively good correspondence between DIT-based and FRAM-based estimates of ER for the marked and/or unmarked components of DIT groups from many hatcheries, there are several hatcheries where the correspondence between the two is very poor. [Sections 5.2 and 7.6]
- Post-season estimates of ERs should not be based solely on post-season Coho FRAM. For fishery planning purposes, estimates of ERs should be accompanied by indications of confidence levels. Precautionary management principles would indicate that buffers or bias corrections for error should be considered and routinely employed as a best practice. [Sections 5.2 and 7.6]


## Possible Consequences of SFEC Recommendations Regarding DIT Programs that Support Management of Coho Salmon under the PST (Pacific Salmon Treaty)

- Costs of DIT marking could be reduced because DIT groups would not be released from some regions and/or hatcheries.
- Uncertainty in ER estimates for marked fish could be reduced by increasing release sizes or increasing fishery sampling rates, which in turn would improve ER estimates for unmarked fish associated with DIT groups. This would increase the costs of some rearing and sampling programs.
- Given that use of ETD is not complete throughout the range of southern Coho Salmon, and budgetary constraints exist, it is questionable if agencies will make commitments to expand future coverage. Any reduction in ETD in non-selective fisheries will result in increased uncertainty in ER estimates for those unmarked stocks impacted by these fisheries.
- Data to provide an independent means to evaluate performance of assumption-based methods such as SIT and Coho FRAM would be unavailable for some stocks. Precautionary management approaches to reflect increased uncertainty, such as buffers for ERs, for planning and evaluation are advised.
- Due to reductions in fishery exploitation rates in response to conservation concerns for naturally-produced Coho, large numbers of coded-wire-tagged fish can return to hatchery facilities. Sub-sampling of fish detected by ETD as containing a CWT can be employed to reduce the costs of processing tag recoveries without appreciably affecting the quality of recovery estimates. Cost savings are achieved by reducing the number of fish with positive detections that are processed by CWT head laboratories. This sub-sampling requires that all fish returning to a hatchery are subjected to ETD and there is a total accounting of mark-status. This type of sub-sampling is currently conducted in Washington State hatchery facilities.


## 1 Introduction

Coded-wire tagged (CWT) groups of hatchery salmon are used as indicators for naturallyspawning stocks of salmon originating within the same region and river basin. The intent of the indicator stock program is to derive information on which fisheries are impacting stocks and to estimate exploitation rates in fisheries using cohort analysis methods under the assumption that the hatchery fish will exhibit the same migration timing and ocean distribution patterns as the natural-origin fish they represent once they have left the watershed (ASFEC 1997). CWT recoveries from sampled fisheries and escapements are used to estimate retained and nonretained mortalities (e.g., shaker mortality and catch-and-release mortality in species-selective fisheries) which are used as inputs to cohort analysis.

Prior to the mid-1990s, the adipose fin was removed in order to visually identify hatchery fish with a CWT. In the mid-1990s, fishery managers began removing the adipose fin from almost all hatchery-produced Chinook and Coho salmon, a practice called mass marking (MM). MM provided a means of visually distinguishing hatchery from wild origin fish upon capture in fisheries and provided fishery managers the tool necessary for implementing mark-selective fisheries (MSFs) which allow the retention of marked salmon only. However, because the adipose fin clip could no longer be relied upon as a visual indicator of a fish containing a CWT, the practice of MM also affected managers' ability to estimate fishery impacts and exploitation rates on indicator stocks. Consequently, electronic tag detection (ETD) technology was developed to enable detection of CWTs regardless of clip status and is now widely used in catch, hatchery, and escapement sampling to identify both marked and unmarked fish containing CWTs. In this report "marked" refers to adipose fin-clipped fish, while "unmarked" refers to fish with an adipose fin.

Mass-marked fish experience different exploitation patterns than unmarked fish in MSFs. Because of this, hatchery fish marked with both CWTs and adipose fin clips can no longer be relied upon to provide the data needed to directly estimate fishery impacts on the naturallyspawning stocks they represent. Furthermore, MSFs introduce additional sources of bias due to mark-recognition error which previous methods of cohort analysis did not address (ASFEC 1997, SFEC-AWG 2002).

The first MSFs were implemented on a limited scale in order to develop methods for fishery monitoring, reporting of data, and stock assessment. As interest in MSFs increased, an Ad-hoc Selective Fishery Evaluation Committee (ASFEC) was convened by the Pacific Salmon Commission (PSC) to develop methods for estimating the impacts of MSFs on indicator stocks. The ASFEC developed Double Index Tagging (DIT) to provide methods for estimating the impacts of MSFs on unmarked stocks of Chinook and Coho salmon (ASFEC 1995). Under DIT, differences in recoveries of paired-release CWT groups (one group with the adipose fin removed to represent mass-marked hatchery fish and the other group with the adipose fin intact to represent unmarked naturally-spawning fish) provide the data to estimate impacts of MSFs on unmarked fish. The marked and unmarked components of each DIT group are to be treated in an identical manner in rearing, tagging, release, and recovery. The PSC now has a permanent Selective Fishery Evaluation Committee (SFEC) to review proposals for MM and MSFs.

Methods that used DIT groups to estimate unmarked mortalities due to catch and release in MSFs were proposed by the SFEC - Analytical Work Group (SFEC-AWG 2002). Markselective fisheries have been directed at Coho salmon since 1998 and CWT data from DIT groups impacted by these fisheries are available for brood years 1995-2016. Methods proposed by the SFEC-AWG were evaluated using an empirical analysis of data from brood years 1995 to 1997 by the Joint Coho DIT Analysis Workgroup (JCDAW 2003). The analysis showed only one method of analysis was usable for those years. The analysis also showed that the total impact of MSFs during this period was not large enough to be detected for individual DIT groups. However, when averaged over all DIT group releases and all return years there was a statistically significant difference in the exploitation rates for the marked and unmarked components of the DIT groups representing stocks on the Washington Coast.

There is increasing concern regarding the ability to implement the DIT methodology as a tool to monitor MSF impacts on unmarked fish (SFEC 2016). Specifically, the inability of agencies to fully fund application of CWTs, CWT sampling, and tag recovery, combined with incomplete ETD coverage, reduces the ability of the DIT program to provide data that can be used to estimate and evaluate impacts of MSFs independent from model-based methods (SFEC 2016). Regardless of these challenges, DIT is currently the only analytical tool available to estimate and evaluate impacts of MSFs on unmarked stocks independently from model-based methods.

This report summarizes analyses of CWT data for DIT groups of Coho salmon released by British Columbia, Washington, and Columbia River hatcheries for brood years 1998-2011 (SFEC 2019, Appendix B). During this period, mark-selective fisheries expanded substantially both in geographic area and in magnitude. This report has the following objectives: (1) evaluate and compare methods for estimating total exploitation rates of MSFs on unmarked groups using DIT data; (2) evaluate the ability of DIT to estimate fishery-specific mortalities of unmarked fish when multiple MSFs impact the same brood; (3) compare DIT-derived estimates of exploitation rates for marked and unmarked stocks to those generated by the Coho FRAM; and, (4) provide recommendations on changes that would lead to improvements in the Coho DIT program as it is currently designed and implemented.

Sections $1-5$ of this report describe the analytical methods used to evaluate and compare DIT groups. These sections also provide a general summary of the results across the brood years analyzed for the DIT groups released by hatcheries in four regional areas: British Columbia (BC); Puget Sound (PS); Washington Coast (WC); and Columbia River (CR). Detailed estimates by brood year and hatchery are provided in the appendices. Section 6 provides a detailed review of the DIT program results for each of the hatcheries in a region and an overall assessment of each hatchery's DIT program. Sections 7-9 provide further discussion of the results, outline a framework for evaluating DIT programs, and provide recommendations for improving DIT programs in general.

### 1.1 Retained Catch for Coho Salmon 2001-2014

Mark-selective fisheries for Coho salmon have been prosecuted since catch year 1998.
Figure 1-1 compares annual numbers of Coho salmon retained by MSFs and non-selective fisheries (NSFs) during catch years 2001-2014 for the Puget Sound (WA), Washington Coast, Columbia River, and Oregon Coast regions. For the Puget Sound region, only 3-17\% of the total estimated retained catch was caught in MSFs during this period (Table 1-1). In contrast, $14-52 \%$ of the total estimated retained catch was caught in MSFs for the Washington Coast region (Table 1-2) and 5-37\% for the Columbia River region (Table 1-3). Oregon's ocean fisheries were not electronically sampled until 2011 resulting in no unmarked recoveries in any non-selective ocean fishery occurring 2001-2010 (see Table 1-4 for estimates of total retained catch). Due to misalignment of catch estimates and fishery regulations in some recreational fisheries and incomplete catch monitoring coverage, the catch information by fishery type (mark-selective and non-selective) is not available for British Columbia fisheries.


Figure 1-1. Retained catch of Coho Salmon in mark-selective fisheries (MSF) and nonselective fisheries (NSF) from 2001-2014 in the Puget Sound, Washington Coast (including Grays Harbor and Willapa Bay), Columbia River, and Oregon Coast regions, by fishery type and catch year. For clarity, "mixed" fisheries catches are not shown

Table 1-1. Percent of estimated total retained Coho salmon catch, by fishery type, in Puget Sound (WA) fisheries from 2001-2014.

| Return <br> Year | SPORT |  | NET | TROLL |
| :---: | ---: | ---: | :---: | :---: |
| 2001 | $11.7 \%$ | $28.2 \%$ | $59.1 \%$ | $1.0 \%$ |
| 2002 | $8.1 \%$ | $16.4 \%$ | $75.5 \%$ | $0.0 \%$ |
| 2003 | $10.8 \%$ | $25.3 \%$ | $63.9 \%$ | $0.1 \%$ |
| 2004 | $6.4 \%$ | $10.7 \%$ | $80.5 \%$ | $2.5 \%$ |
| 2005 | $7.2 \%$ | $15.9 \%$ | $76.3 \%$ | $0.6 \%$ |
| 2006 | $3.2 \%$ | $9.9 \%$ | $86.6 \%$ | $0.3 \%$ |
| 2007 | $11.2 \%$ | $19.1 \%$ | $69.1 \%$ | $0.6 \%$ |
| 2008 | $4.4 \%$ | $9.1 \%$ | $86.2 \%$ | $0.3 \%$ |
| 2009 | $4.6 \%$ | $25.1 \%$ | $68.3 \%$ | $1.9 \%$ |
| 2010 | $6.2 \%$ | $8.7 \%$ | $85.0 \%$ | $0.1 \%$ |
| 2011 | $7.0 \%$ | $24.8 \%$ | $68.1 \%$ | $0.0 \%$ |
| 2012 | $12.1 \%$ | $25.6 \%$ | $62.2 \%$ | $0.1 \%$ |
| 2013 | $9.8 \%$ | $24.3 \%$ | $65.8 \%$ | $0.1 \%$ |
| 2014 | $16.6 \%$ | $24.5 \%$ | $58.9 \%$ | $0.1 \%$ |

Table 1-2. Percent of estimated total retained Coho salmon catch, by fishery type, in Washington Coast fisheries (including Grays Harbor and Willapa Bay) from 2001-2014.

| Return | SPORT <br> Year |  |  | MSF | Mix | NSF |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |

Table 1-3. Percent of estimated total retained Coho salmon catch, by fishery type, in Columbia River fisheries from 2001-2014.

| Return <br> Year | SPORT |  | NET <br> MSF |  |  |
| :---: | ---: | ---: | :---: | :---: | :---: |
| 2001 | $29.0 \%$ | $16.1 \%$ | $0.0 \%$ | $0.0 \%$ | $55.0 \%$ |
| 2002 | $4.8 \%$ | $12.2 \%$ | $0.0 \%$ | $0.0 \%$ | $83.0 \%$ |
| 2003 | $18.7 \%$ | $4.2 \%$ | $0.0 \%$ | $0.0 \%$ | $77.1 \%$ |
| 2004 | $18.0 \%$ | $2.7 \%$ | $0.0 \%$ | $0.0 \%$ | $79.3 \%$ |
| 2005 | $9.3 \%$ | $2.9 \%$ | $0.0 \%$ | $0.0 \%$ | $87.8 \%$ |
| 2006 | $15.6 \%$ | $2.4 \%$ | $0.0 \%$ | $0.0 \%$ | $82.1 \%$ |
| 2007 | $37.1 \%$ | $2.9 \%$ | $0.0 \%$ | $0.0 \%$ | $60.0 \%$ |
| 2008 | $35.4 \%$ | $2.1 \%$ | $0.0 \%$ | $0.0 \%$ | $62.6 \%$ |
| 2009 | $36.9 \%$ | $2.3 \%$ | $0.0 \%$ | $0.0 \%$ | $60.7 \%$ |
| 2010 | $25.8 \%$ | $1.9 \%$ | $0.0 \%$ | $0.0 \%$ | $72.3 \%$ |
| 2011 | $25.3 \%$ | $2.2 \%$ | $0.0 \%$ | $0.0 \%$ | $72.6 \%$ |
| 2012 | $36.3 \%$ | $5.9 \%$ | $0.0 \%$ | $0.0 \%$ | $57.8 \%$ |
| 2013 | $22.3 \%$ | $10.1 \%$ | $0.0 \%$ | $8.1 \%$ | $59.5 \%$ |
| 2014 | $16.1 \%$ | $14.3 \%$ | $0.3 \%$ | $11.0 \%$ | $58.3 \%$ |

Table 1-4. Percent of estimated total retained Coho salmon catch, by fishery type, in Oregon Coast fisheries from 2001-2014.

| Return | SPORT |  | TROLL |  |
| :---: | :---: | :---: | :---: | :---: |
| Year | MSF | NSF | MSF | NSF |
| 2001 | $90.9 \%$ | $0.0 \%$ | $9.1 \%$ | $0.0 \%$ |
| 2002 | $95.9 \%$ | $0.0 \%$ | $4.1 \%$ | $0.0 \%$ |
| 2003 | $94.4 \%$ | $0.0 \%$ | $5.6 \%$ | $0.0 \%$ |
| 2004 | $88.5 \%$ | $0.0 \%$ | $2.9 \%$ | $8.6 \%$ |
| 2005 | $83.8 \%$ | $0.0 \%$ | $16.2 \%$ | $0.0 \%$ |
| 2006 | $91.6 \%$ | $0.0 \%$ | $8.4 \%$ | $0.0 \%$ |
| 2007 | $91.6 \%$ | $0.0 \%$ | $0.0 \%$ | $8.4 \%$ |
| 2008 | $100.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
| 2009 | $90.6 \%$ | $0.0 \%$ | $0.0 \%$ | $9.4 \%$ |
| 2010 | $100.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
| 2011 | $64.8 \%$ | $35.2 \%$ | $0.0 \%$ | $0.0 \%$ |
| 2012 | $27.0 \%$ | $73.0 \%$ | $0.0 \%$ | $0.0 \%$ |
| 2013 | $72.7 \%$ | $27.3 \%$ | $0.0 \%$ | $0.0 \%$ |
| 2014 | $61.3 \%$ | $35.5 \%$ | $0.0 \%$ | $3.2 \%$ |

### 1.2 Estimation of Retained Catch and Non-landed Mortalities in Coho Salmon Fisheries from CWT Recoveries

The number of CWT fish retained in a fishery or returning to escapement is estimated by:

$$
\begin{equation*}
\hat{R}=\frac{o b s}{s r} \tag{1}
\end{equation*}
$$

and the variance is estimated by,

$$
\begin{equation*}
\hat{V}(\hat{R})=\frac{\hat{R}}{s r}(1-s r) \tag{2}
\end{equation*}
$$

where $\hat{R}$ is the estimated number of coded-wire tagged fish in the retained catch or escapement, $o b s$ is the number of tagged fish observed in the sample, and $s r$ is the sample rate (number of fish sampled / total retained catch or escapement) which can include adjustments due to factors such as lost tags. The large sample variance equation above (Eq. 2) assumes that estimated catch and escapements variances are either known without error, small relative to the sampling process, or unavailable (Bernard and Clark 1996).

Mortalities in non-selective fisheries include retained mortality and drop-off mortality. Drop-off mortality is typically estimated as $5 \%$ of retained catch in hook-and-line fisheries and $2 \%$ in commercial net fisheries (PFMC 2008). Drop-off mortality is used to account for total fisheryrelated mortalities when estimating fishery exploitation rates (ERs) in management forums (e.g., PFMC, PSC) and in the planning models used in these forums (e.g., FRAM). The mortality rates for released fish are assumed to be equal for marked and unmarked fish.

Mortalities in MSFs are comprised of:

- Release mortalities of unmarked fish that are volitionally released by fishers but later die due to injuries associated with the catch-and-release process. There are no tag samples from these fish to allow direct estimation of this mortality by stock. The DIT groups provide information used to estimate these mortalities (see Section 3).
- Drop-off mortalities of both marked and unmarked fish (see above).
- Mortalities due to the retention of unmarked fish by fishers in error (Unmarked Retention Error or URE). These fish are available for sampling and can be estimated from the sampled fish.
- Mortalities resulting from the release of marked fish by fishers (Mark Recognition Error or MRE). This includes the intentional release of marked fish by anglers (intentional catch and release). These mortalities cannot be estimated from samples and are assumed in this report to be zero. Estimates of total mortalities of marked and tagged fish will be underestimated if there are mortalities due to MRE or intentional catch and release.

Section 3 describes methods to estimate mortalities for unmarked fish using DIT groups.

### 1.3 Exploitation rates

Exploitation rates (ERs) are the ratio of fishery-related mortalities over the total cohort size of a tagged group. Cohort size is the sum of all fishery-related mortalities plus all escapement ${ }^{1}$. ER for one or more fisheries $(f)$ is estimated by,

$$
\begin{equation*}
\widehat{E R}_{f}=\frac{\sum_{f}(\text { Retained }+ \text { Dropoff Mortalities }+ \text { Release Mortalities })}{\sum_{f}(\text { Retained }+ \text { Dropoff Mortalities }+ \text { Release Mortalities })+\text { Escapement }} \tag{3}
\end{equation*}
$$

and the variance of $\widehat{E R}_{f}$ can be approximated using the delta method by,

$$
\begin{equation*}
V\left(\widehat{E R}_{f}\right) \doteq\left(\widehat{E R}_{f}\right)^{2}\left[\frac{V(\text { Numerator })}{\text { Numerator }^{2}}+\frac{V(\text { Denominator })}{\text { Denominator }^{2}}\right] . \tag{4}
\end{equation*}
$$

Exploitation rate estimates will be unbiased under these assumptions:

1) Estimates of the number of CWTs in the retained catch and the escapement are unbiased;
2) Estimates of drop-off mortality are unbiased;
3) All landed fish are retained in NSFs and all landed marked fish are retained in MSFs (no MRE); and,
4) All unmarked fish are released (no URE) in visually-sampled fisheries.

### 1.4 DIT Groups for Coho Salmon for Brood Years 1998-2011

Double index tagging has been in place since 1995 for Coho salmon. For brood years 19982011, eight DIT groups were consistently released from hatcheries in Puget Sound, six DIT groups from Washington Coast hatcheries, and four DIT groups from Columbia River hatcheries (Table 1-5). In British Columbia, two hatcheries consistently released DIT groups during this period. There were three hatcheries in British Columbia that had DIT group releases only for brood years 1998-2002; these hatcheries are included in the analyses.

The majority of these hatcheries released DIT groups annually during the period covered by this report; three hatcheries did not have releases for one to four years at the end of the 1998-2011 period. The Lewis River Hatchery is one of three Columbia River hatcheries consistently releasing DIT groups and this hatchery releases two different DIT groups annually referred to as North-migrating and South-migrating groups.

The numbers of marked and unmarked fish in the DIT groups released from these hatcheries, their associated CWT codes, and the ratio of unmarked-to-marked fish released ( $\lambda^{\text {Release }}$ ) for the 1998 through 2011 brood years are reported in Appendix Table 1.

[^3]Table 1-5. Years with Coho salmon DIT groups analyzed for this report, by hatchery, for brood years 1998-2011 (see Appendix 1 for details). Grey cells indicate years that were not analyzed due to a lack of a DIT release or identified data issues (see footnotes).

| Region Sub-region |  | Hatchery | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 1998 | 1999 | 2000 | 2001 | 2002 | 200 |  | 004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| BC | JNST |  | Quinsam River | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | GST | Big Qualicum River | X | X | X | X | X |  |  |  |  |  |  |  |  |  |  |
|  | FRAS | Chilliwack River | X | X | X | X | X |  |  |  |  |  |  |  |  |  |  |
|  |  | Inch Creek | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | WCVI | Robertson Creek | X | X | X | X | X |  |  |  |  |  |  |  |  |  |  |
| PS | JDF | Lower Elwha | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | NPS | Kendall Creek | X | X | X | X | X | X |  | X | X | X | X |  |  |  |  |
|  |  | Marblemount | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Wallace River | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | MPS | Soos Creek | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Voights Creek | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | HC | George Adams | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Quilcene NFH | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
| WC | NWC | Makah NFH | X | X | X | X | X | X |  | X | X | X | X | X | X | X |  |
|  |  | Quinault NFH | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Salmon R. Fish Culture | X | X | X | X | X | X |  | X | X | X | X | X | $\mathrm{X}^{2}$ | 3 | X |
|  |  | Solduc | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | GRAY | Bingham Creek | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  | WILP | Forks Creek | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
| CR | COLR | Lewis River - North | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Lewis River - South | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Eagle Creek NFH | X | X | X | X | X | X |  | X | X | X | X | X | X | X | X |
|  |  | Sandy River | X | X | X | X | X | X |  | X | X | X | X | X |  |  |  |

${ }^{2}$ There were no estimated coded-wire-tagged 3-year olds reported as recovered in the hatchery or escapement from either the marked or the unmarked component of the DIT group representing the 2009 brood year release from the Salmon River Fish Culture Facility. However, estimates of 2-year old recoveries of CWTs were recorded in the hatchery escapement and this brood was included in the return rate or exploitation rate analyses.
${ }^{3}$ There were no estimated coded-wire-tagged fish reported as recovered in the hatchery or escapement from either the marked or the unmarked component of the DIT group representing the 2009 brood year release from the Salmon River Fish Culture Facility. While the fishery recovery data are reported, where appropriate, this brood year was not included in the return rate or exploitation rate analyses.

## 2 Impact of MSFs on Coho Salmon Stocks

### 2.1 Age Composition

The majority of the CWT recoveries for the analyzed DIT groups were from age-3 Coho salmon. However, for some DIT groups, there were relatively high numbers of Coho that returned to the hatchery at age 2 . While CWTs from some age- 2 fish were recovered in fisheries, these numbers were typically small in comparison to the age-3 fishery recoveries. Table 2-1 summarizes the average percentage contribution of age-2 fish to the brood year escapement across all brood years used for the DIT analyses. While there were some age-4 and age-5 Coho in the CWT recoveries, these age groups were consistently rare and very sporadic. Because age- 2 Coho are infrequently caught in fisheries, their contribution to brood year escapement tends to increase return rates to the escapement and reduce brood year ERs.

The average contributions of age- 2 Coho to the brood year escapement were very similar for both the marked and unmarked components of each hatchery's DIT groups. For some hatcheries, the average contribution of age-2 Coho to the brood year escapement for the DIT groups was > $20 \%$ (e.g., Quinsam Hatchery, Big Qualicum Hatchery, Lower Elwha Hatchery, and Salmon River Fish Culture). Conversely, some hatcheries had consistently low contribution rates of age-2 fish to the escapement (e.g., Kendall Creek, Marblemount, Wallace River, Soos Creek, and Voights Creek).

Summaries by hatchery and brood year, which include the percentage contribution of age-2 recoveries to all fishery recoveries for the marked and unmarked components of each DIT group, are reported in Appendix Table 2.

### 2.2 Size of the Mark-Selective Fishery

DIT groups include both marked-and-tagged and unmarked-and-tagged components. One indicator of the intensity or size of the MSF impact on a stock is the proportion of total fishery recoveries of marked fish from a DIT group in MSFs. The relative impacts of MSFs on DIT groups is calculated as the number of marked recoveries that occurred in mark-selective fisheries divided by the total number of marked recoveries in all fisheries.

On average, the percentage of the marked fish harvested in MSFs was higher for DIT groups from hatcheries in the British Columbia and Columbia River regions compared to the other regions (Figure 2-1). For British Columbia DIT-group releases, the average percentage ${ }^{1}$ of marked fish recovered from MSFs was > 39\% for all hatcheries except Robertson Creek Hatchery (28\%). For the Columbia River region, the average percentage of marked fish recovered from MSFs was $\geq$ $68 \%$ for all hatcheries. Outside these two regions, the only other hatcheries where the average percentage recovered from MSFs was greater than $40 \%$ were the Wallace River (45\%), Makah NFH (65\%), and Solduc (47\%).

[^4]Appendix Table 3 provides estimates of the proportion of the marked recoveries that occurred in fisheries by fishery type (MSF, NSF, or Mixed) by hatchery and brood year. The fishery regulation type "Mixed" generally indicates a fishery sample stratum where an angler may retain different proportions of marked and unmarked fish, e.g., a maximum of two fish of which one can be unmarked are allowed to be retained (PSC 2016); Canada also uses the "Mixed" code for recoveries for which the regulation type they were caught under is unknown. The percent of all recoveries that were in the escapement is reported in Appendix Table 3, also.

Table 2-1. Mean percent of brood-year return (of all ages) to escapement that was age-2 for DIT groups analyzed, by hatchery. Number of brood years and minimum and maximum percentages observed are shown, also.

| Region | Hatchery | \# of <br> Brood <br> Years | Unmarked |  | Max. | Marked |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| BC | Quinsam River | 14 | 22.4\% | 5.7\% | 34.3\% | 21.9\% | 4.5\% | 33.8\% |
|  | Big Qualicum River | 5 | 20.3\% | 7.9\% | 39.3\% | 15.7\% | 3.2\% | 33.7\% |
|  | Chilliwack River | 5 | 5.8\% | 2.2\% | 8.4\% | 6.2\% | 1.7\% | 11.1\% |
|  | Inch Creek | 14 | 4.6\% | 0.7\% | 9.6\% | 4.8\% | 0.0\% | 9.3\% |
|  | Robertson Creek | 5 | 6.9\% | 4.2\% | 8.5\% | 6.8\% | 5.5\% | 7.5\% |
| PS | Lower Elwha | 14 | 27.8\% | 2.8\% | 60.1\% | 27.5\% | 2.8\% | 62.9\% |
|  | Kendall Creek | 10 | 0.8\% | 0.0\% | 2.6\% | 1.8\% | 0.0\% | 6.3\% |
|  | Marblemount | 14 | 0.7\% | 0.0\% | 3.8\% | 0.7\% | 0.0\% | 3.5\% |
|  | Wallace River | 14 | 0.4\% | 0.0\% | 0.9\% | 0.3\% | 0.0\% | 1.5\% |
|  | Soos Creek | 14 | 1.0\% | 0.0\% | 2.4\% | 1.0\% | 0.1\% | 3.6\% |
|  | Voights Creek | 14 | 1.8\% | 0.0\% | 9.6\% | 1.5\% | 0.0\% | 5.8\% |
|  | George Adams | 14 | 6.9\% | 1.1\% | 19.1\% | 7.7\% | 0.9\% | 23.9\% |
|  | Quilcene NFH | 14 | 7.9\% | 0.0\% | 20.3\% | 9.2\% | 0.8\% | 20.9\% |
| WC | Makah NFH | 13 | 11.6\% | 0.0\% | 31.2\% | 11.7\% | 0.0\% | 31.0\% |
|  | Quinault NFH | 14 | 9.8\% | 0.0\% | 25.4\% | 10.7\% | 0.0\% | 31.0\% |
|  | Salmon River Fish Culture | 13 | 22.3\% | 0.0\% | 100.0\% | 25.6\% | 0.0\% | 100.0\% |
|  | Solduc | 14 | 12.5\% | 2.0\% | 40.9\% | 12.0\% | 1.8\% | 22.6\% |
|  | Bingham Creek | 14 | 13.3\% | 2.0\% | 32.9\% | 11.9\% | 2.0\% | 34.9\% |
|  | Forks Creek | 14 | 6.5\% | 0.9\% | 18.0\% | 7.0\% | 1.8\% | 21.9\% |
| CR | Lewis River - North | 14 | 10.3\% | 2.9\% | 19.4\% | 12.6\% | 2.6\% | 24.9\% |
|  | Lewis River - South | 14 | 11.9\% | 4.9\% | 36.9\% | 13.4\% | 5.0\% | 40.8\% |
|  | Eagle Creek NFH | 14 | 8.4\% | 0.0\% | 34.9\% | 9.5\% | 0.0\% | 39.8\% |
|  | Sandy River | 11 | 4.1\% | 0.6\% | 13.1\% | 5.6\% | 0.0\% | 12.2\% |



Figure 2-1. Mean percentage of total fishery CWT recoveries of the marked DIT group occurring in mark-selective fisheries (MSF), non-selective fisheries (NSF), and mixed or unknown regulation fisheries (Mixed), for brood years 1998-2011, by hatchery.

### 2.3 Comparing Return Rates between Marked and Unmarked Components of DIT Groups

As a DIT group passes through mark-selective fisheries, the marked and unmarked groups will be subject to different impacts as unmarked encounters are released while marked fish are kept. As more unmarked fish survive the MSFs, a higher proportion of the unmarked component of a DIT group will enter the escapement.
Return rates of marked fish to the escapement (i.e., the estimated proportion of the marked fish at release that escape to the hatchery rack or spawning grounds, $\hat{p}_{m}=\frac{\text { Return Marked }}{\text { Release Marked }}$ ) were compared to the return rates of unmarked fish $\left(\hat{p}_{u}\right)$ to determine whether MSFs decreased the fishery mortality rate for the unmarked component of the DIT group relative to the marked component. A Z test (Fleiss 1981) is used to assess statistical significance:

$$
\begin{equation*}
Z=\frac{\hat{p}_{u}-\hat{p}_{m}}{\sqrt{\tilde{V}\left(\hat{p_{u}} u\right)+\hat{V}\left(\hat{p}_{m}\right)}} \tag{5}
\end{equation*}
$$

$V\left(\hat{p}_{u}\right)$ and $V\left(\hat{p}_{m}\right)$ are calculated to account for variation due to process error the number of fish surviving to escapement, given the number of fish released, was assumed to follow a binomial distribution) as well as variation due to sampling the escapement for coded wire tags.
$V\left(\hat{p}_{u}\right)$ is calculated as:

$$
\begin{equation*}
\hat{V}\left(\hat{p}_{u}\right)=\frac{\hat{p}_{u}\left(1-\hat{p}_{u}\right)}{N_{u}}+\frac{\hat{E}_{u}(1-s r)}{s r\left(N_{u}\right)^{2}} \tag{6}
\end{equation*}
$$

where $\widehat{E}_{u}$ is the estimated escapement of unmarked but tagged fish, $N_{u}$ is the total number released for an unmarked DIT group, and $s r$ is the sample rate at escapement to the hatchery. The same formula (substituting $p_{m}, \widehat{E}_{m}$, and $N_{m}$ ) is used to estimate $\widehat{V}\left(\hat{p}_{m}\right)$. See page 6 in JCDAW (2003) for the derivation of Eq. 6.

A negative test statistic occurs when a higher proportion of the marked component of a DIT group returns than the unmarked component which usually indicates: (1) unaccounted mortality for the unmarked component of the DIT group which may be due to fishery sampling problems;
(2) sampling problems in the hatchery; (3) imprecision of the estimates (i.e., small sample sizes); or, (4) a violation of the assumption that the two DIT groups were treated in an identical manner in rearing and release at the hatchery. Negative test statistics are a concern if they consistently occur for the DIT groups from a hatchery.

The ratio of the number of unmarked-to-marked fish in a DIT group is lambda $(\lambda=U / M)$, where $U$ is the number of unmarked fish and M is the number of marked fish for a given DIT group ${ }^{2}$. This ratio is commonly measured accurately and precisely in the hatchery at release and at return to the hatchery escapement; fishery samples typically do not provide precise estimates of $\lambda$. The variance of $\lambda$ (SFEC-AWG 2002) is estimated by:

$$
\begin{equation*}
\hat{V}(\hat{\lambda})=\left(\frac{1}{M}\right)^{2} \hat{V}(U)+\left(\frac{\widehat{\lambda}}{M}\right)^{2} \hat{V}(M) \tag{7}
\end{equation*}
$$

Because of the way smolts receiving a CWT at the hatchery are enumerated on release there is assumed to be no variance associated with $\lambda^{\text {Rel }}$. Similarly, because there is often $100 \%$ (or $>90 \%$ ) sampling of the return to the hatchery, the variance associated with $\lambda^{E s c}$ is usually relatively small. There are two assumptions related to the enumeration of DIT group fish returning to the escapement:

1) The number of fish in the marked and unmarked components of each DIT group are accurately counted or estimated; this requires the use of ETD to sample the escapement; And,
2) If only the escapement to the hatchery is included in $\lambda^{E s c}$, then stray rates to the spawning grounds are assumed to be equal for the marked and unmarked DIT-group components.

The ratio of these unmarked-to-marked ratios measured at release and escapement, $\lambda R$, is another measure used to compare the return rates of the DIT groups and is calculated as,

$$
\begin{equation*}
\lambda R=\frac{\lambda^{E s c}}{\lambda^{\text {Rel }}} . \tag{8}
\end{equation*}
$$

[^5]A $\lambda R$ of 1.0 indicates that the ratio did not change from release to escapement while a $\lambda R$ larger than one indicates a higher removal of marked fish compared to the unmarked fish in the DIT group, which is assumed to be due to MSFs.

Expressed in terms of the number of tagged fish released in each group, $N_{m}$ and $N_{u}$, and the probabilities of surviving natural sources of mortality, $S$, and not being caught in fisheries, ( $1-E R$ ), the expected number fish in the escapement is,

$$
E_{x}=N_{x} S\left(1-\widehat{E R}_{x}\right)
$$

where $S=$ survival rate of a DIT group from release to recruitment to fisheries (assumed to be equal for the marked and unmarked components of a DIT group), and
$\begin{aligned} \widehat{E R}_{x}= & \text { exploitation rate estimate for the unmarked }(u) \text { or marked }(m) \text { component of a } \\ & \text { DIT group }(x) .\end{aligned}$
The proportion of fish returning from those released, $p_{x}$, is,

$$
\begin{gather*}
p_{x}=\frac{N_{x} S\left(1-E R_{x}\right)}{N_{x}}, \text { or } \\
p_{x}=S\left(1-E R_{x}\right) . \tag{9}
\end{gather*}
$$

Expressing $\lambda^{E s c}$ in the same way,

$$
\begin{equation*}
\lambda^{E s c}=\frac{E_{u}}{E_{m}}=\frac{N_{u} S\left(1-E R_{u}\right)}{N_{m} S\left(1-E R_{m}\right)}=\lambda^{R e l} \frac{\left(1-E R_{u}\right)}{\left(1-E R_{m}\right)}, \tag{10}
\end{equation*}
$$

and subsequently, $\lambda R$ is,

$$
\begin{equation*}
\lambda R=\frac{\lambda^{E s c}}{\lambda^{R e l}}=\frac{\left(1-E R_{u}\right)}{\left(1-E R_{m}\right)} . \tag{11}
\end{equation*}
$$

As defined, the variance for the estimated relative return ratio, $\lambda R$, is:

$$
\begin{equation*}
\widehat{V}(\widehat{\lambda R})=\widehat{\lambda R}^{2}\left[\frac{1}{\widehat{E}_{u}}-\frac{1}{N_{u}}+\frac{1}{\widehat{E}_{m}}-\frac{1}{N_{m}}\right] \tag{12}
\end{equation*}
$$

(personal communication: K. Ryding, WDFW). This variance estimator accounts for the survival, fishing, and sampling processes leading to the hatchery returns. A $\lambda R$ that is significantly less than 1 indicates a higher proportion of the marked component of the DIT group returned relative to the unmarked component which is not expected in the presence of MSFs and indicates that one or more of the four issues that may cause a negative Z statistic (described above) in the comparison of return rates has occurred.

### 2.4 Results of the Comparison of Marked and Unmarked Return Rates

The results for the Z test (Eq. 5) comparing marked and unmarked return rates are summarized in Table 2-2; detailed results by hatchery and brood year are presented in Appendix Table 4. In Table 2-2, the number of brood years tested and the percentage of those tests that were nonsignificant (NS) are shown. The results for the tests that were significant $(P \leq 0.05)$ are summarized in two columns: a positive test statistic (+YES column) indicates a higher return rate for the unmarked component of a DIT group and a negative test statistic (-YES) indicates a higher
return rate for the marked component (which is not consistent with the expectation that only the marked component of a DIT group is experiencing substantial mortalities in MSFs).

Table 2-2. Percent of brood years where the $Z$ test comparing the return rates of the marked and unmarked components of a DIT group to hatchery escapement is not significant (NS), significant ( $P \leq 0.05$ ) and positive (+YES), or significant and negative (-YES), and number of brood years tested, by hatchery, for brood years 1998-2011.

| Region | Hatchery | NS | +YES | -YES | \# of Broods |
| :---: | :--- | :---: | :---: | :---: | :---: |
| BC | Quinsam River | $64 \%$ | $36 \%$ | $0 \%$ | 14 |
|  | Big Qualicum River | $40 \%$ | $60 \%$ | $0 \%$ | 5 |
|  | Chilliwack River | $20 \%$ | $80 \%$ | $0 \%$ | 5 |
|  | Inch Creek | $36 \%$ | $64 \%$ | $0 \%$ | 14 |
|  | Robertson Creek | $40 \%$ | $60 \%$ | $0 \%$ | 5 |
| PS | Lower Elwha | $57 \%$ | $29 \%$ | $14 \%$ | 14 |
|  | Kendall Creek | $90 \%$ | $10 \%$ | $0 \%$ | 10 |
|  | Marblemount | Wallace River | $71 \%$ | $29 \%$ | $0 \%$ |
|  | Soos Creek | $50 \%$ | $43 \%$ | $7 \%$ | 14 |
|  | Voights Creek | $72 \%$ | $21 \%$ | $7 \%$ | 14 |
|  | George Adams | $72 \%$ | $14 \%$ | $14 \%$ | 14 |
|  | Quilcene NFH | $72 \%$ | $14 \%$ | $14 \%$ | 14 |
| WC | Makah NFH | $64 \%$ | $29 \%$ | $7 \%$ | 14 |
|  | Quinault NFH | Salmon River Fish Culture | $77 \%$ | $0 \%$ | $23 \%$ |
|  | Solduc | $57 \%$ | $36 \%$ | $7 \%$ | 13 |
|  | Bingham Creek | $59 \%$ | $8 \%$ | $23 \%$ | 13 |
|  | Forks Creek | $43 \%$ | $43 \%$ | $7 \%$ | 14 |
| CR | Lewis River - North | Lewis River - South | $50 \%$ | $50 \%$ | $0 \%$ |
|  | Eagle Creek NFH | $14 \%$ | $86 \%$ | $0 \%$ | 14 |
|  | Sandy River | $14 \%$ | $86 \%$ | $0 \%$ | 14 |

For the British Columbia region, the majority of the test statistics were positive and significant at all hatcheries except Quinsam River. For the Puget Sound and Washington Coast regions, 50\% or more of the tests were not significant for all hatcheries. The DIT groups from the Columbia River hatcheries experienced consistently higher impacts in MSFs than in NSFs (Figure 2-1) and had significantly higher unmarked return rates to the hatchery escapement; more than $60 \%$ of the tests at each hatchery were significant and all of these tests were positive.

There were no significant Z tests with a negative test statistic (i.e., the return rate to the hatchery of the marked component of the DIT group was significantly greater than the return rate for the unmarked component) for hatcheries in the British Columbia and Columbia River regions. In the Puget Sound region, all hatcheries except Kendall Creek and Marblemount had one or two brood years with a significant negative Z statistic. In the Washington Coast region, all hatcheries except

Forks Creek had at least one brood year with a significant negative Z statistic. All of the significant Z tests for Makah NFH were negative and all but one of the tests for the Salmon River Fish Culture Facility were negative.

Figure 2-2 uses a box-and-whiskers plot to summarize the distributions of the $\lambda R \mathrm{~s}$ by hatchery for the 1998-2011 brood years. The distributions of the $\lambda R$ s for the British Columbia and Columbia River hatcheries lie almost entirely above 1.0, i.e., the unmarked-to-marked ratio increased from release to escapement consistent with substantial impacts from MSFs. While the medians of the distributions for the Puget Sound region are all > 1.0, 50\% of the brood years from the Soos Creek and Voights Creek hatcheries had $\lambda R \mathrm{~s}<1$. The medians of the distributions for the Washington Coast region are all > 1.0 except for the releases from Salmon River Fish Culture; the central $50 \%$ interquartile for Salmon River Fish Culture brood years was entirely below the $\lambda R=$ 1 line which is a strong indication of potential issues with rearing of the DIT groups, sampling issues at the hatchery, and reporting of releases and/or escapements. The majority of the central $50 \%$ interquartile for Makah NFH brood years was also < 1 . The $\lambda R$ s for the Sandy River Hatchery in the Columbia River region were generally the highest observed across all hatcheries and regions.


Figure 2-2. Distribution of $\lambda R \mathrm{~s}$ by hatchery for brood years 1998-2011. The box-and-whiskers plots show the interquartile range ( $25-75 \%$ range) in the box while the whiskers include all values within 1.5 of the interquartile range. The mean (x) and median $(-)$ are shown in the box while outlier points $\left({ }^{\circ}\right)$ are shown outside of the whiskers.

### 2.5 The Effect of Tag Release Numbers and Return Rates on the Power of the Test to Detect Differences Between $p_{u}$ and $\boldsymbol{p}_{\boldsymbol{m}}$

Across all brood years, $50 \%$ or more of the Z tests comparing the return rates of the marked and unmarked components of the DIT groups from each hatchery were not significant $(P>0.05)$. The exceptions were for hatcheries in the BC region (with the exception of Quinsam Hatchery) and the CR region (Appendix Table 4). However, the significance level only gives the probability of wrongfully detecting a difference in return rates when no difference exists but tells us nothing about the probability of making the wrong decision in not rejecting the null hypothesis, i.e., making the determination that no difference exists when one does in actuality. Interpreting Z tests that were not significant, requires some idea of the size of the difference that could be detected, and the associated probability of detecting that difference, for a given release size and expected return proportion of marked fish $\left(p_{m}\right)$. The probability of detecting a difference when one exists is the power of a test and is typically determined before fish are released. Its complement is failing to reject the null hypothesis when there is a significant difference or Type II error.

Relative difference is defined as,

$$
\begin{equation*}
\text { Rel Diff }=\frac{p_{u}-p_{m}}{p_{m}} \tag{13}
\end{equation*}
$$

Expressing $p_{m}$ and $p_{u}$ in terms of the survival and fishing processes of Eq. 9, the relative difference is,

$$
\begin{align*}
& \text { Rel Diff }=\frac{\left(1-E R_{u}\right)}{\left(1-E R_{m}\right)}-1 \\
& \text { Rel Diff }=\lambda R-1 \tag{14}
\end{align*}
$$

Hence, the relative difference is a way to relate the absolute difference to the relative return ratio, $\lambda R$. Further, because the variance of Rel Diff is equal to the variance of $\lambda R$, a hypothesis test of the form $H_{0}$ : Rel Diff $=0$ is equivalent to a statement framed in terms of ERs, i.e, $\mathrm{H}_{0}: \lambda R=1$. Either statement can be used to determine release numbers that are based on the ability to detect meaningful differences that are based on expected ERs. Ideally, what constitutes a "meaningful" difference in return rates should be based on fishery management objectives.

Minimal detectable relative differences for Type I and II error rates of 5\% and 20\%, respectively, were calculated for release sizes and return proportions of marked fish that were within the range of those observed in this report (Table 2-3). The relative difference between $4.5 \%$ for the marked fish $\left(p_{m}=0.04\right)$ and $5 \%$ for the unmarked fish $\left(p_{u}=0.05\right)$ is $25 \%(\%$ Rel Diff $=25 \%$ or $\lambda R=$ 1.25). A relative difference of $20 \%(\lambda R=1.20)$ is detectable with a Type 1 and II error rates of $5 \%$ and $20 \%$, respectively, for release sizes between 25,000 and 75,000 per group and marked return rates are $2 \%$ or $5 \%$ (Table 2-3). The same $20 \%$ relative difference, Type 1 error, and Type II error rates would be detectable only at the highest release number when return rates of marked fish are $0.5 \%$. The releases sizes in Table 2-3 correspond to those observed in this study. In terms of returning fish, for a $p_{m}$ of 0.01 ( $1 \%$ marked fish returning out of release) and a release size of 65,000 tagged fish for each group, we can say that anything less than a relative difference of $15.5 \%$ between $p_{u}$ and $p_{m}$ is not significantly different from 0 (return rates equal) and be correct
$80 \%$ of the time. This translates into escapement returns of 751 unmarked and 650 marked fish for tag release sizes of 65,000 in each group.

For a given Type I and II error rate, minimum detectable differences, relative and absolute, will depend on both sample size and the expected return rates of marked and unmarked fish to escapement. Return proportions are dependent on natural survival and exploitation rates. Lower return proportions, whether from low survival or high exploitation rates, will require higher release numbers to detect small differences in return rates and reduce the probability of being wrong in saying no difference exists between the rates. Conversely, for lower DIT group release numbers, higher return proportions are required to detect small differences. Details of the power analysis are provided in the Appendix 13.

Currently, there is no guidance for quantifying relative differences in return rates that are important to fisheries management. However, we can look at the average release numbers of marked and unmarked fish, and the average $p_{m}$ across the hatchery DIT programs in this report to calculate minimum relative differences between $p_{u}$ and $p_{m}$ that would satisfy Type I and II error rates of $5 \%$ and $20 \%$, respectively (Table 2-5). A Type II error rate gives an $80 \%$ chance of being correct when no difference is detected and is useful in interpreting non-significant results. At the lowest average release size of approximately 24,000 fish (Eagle Creek NFH) the average $p_{m}$ was $0.014(1.4 \%)$. For these values of Type 1 and II errors, release sizes, and $p_{m}$, the minimum detectable difference is $21.5 \%$, or a $\lambda R$ of 1.22 (Eq. 14). A test that results in a relative difference (Rel Diff) equal to $21.5 \%$ not being significantly different from 0 , when a difference exists, would be correct less than $80 \%$ of the time (incorrect more than $20 \%$ of the time). If expected return rates of marked fish are less than those presented in Table 2-5, the number of marked and unmarked fish released should increase in order to achieve similar precision goals. Relative differences in Table 2-5 are expressed as $\lambda R$ to compare with results in Appendix 6.

Table 2-3. The minimum detectable relative difference in return rates between marked and unmarked DIT groups, for release sizes between 25,000 and 95,000 and marked return proportion ( $p_{m}=0.5 \%, 1 \%, 2 \%$, and $5 \%$ ) assuming Type I and Type II errors of $5 \%$ and $20 \%$, respectively.

|  | Expected return proportion of marked fish $\left(p_{m}\right)$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Release numbers for <br> each DIT component | 0.005 <br> $(0.5 \%)$ | 0.01 <br> $(1 \%)$ | 0.02 | $(2 \%)$ | | 0.05 |
| :---: |
| 25,000 |

Table 2-4. The relative differences, $\lambda R$, detectable under Type I and Type II errors of $5 \%$ and $20 \%$, respectively, for the average release size (for each DIT group) and average return proportion of marked fish, $p_{m}$, from each hatchery.

| Region | Hatchery | Average <br> Release <br> Size | Average <br> $\boldsymbol{p}_{\boldsymbol{m}}$ | Relative <br> Difference <br> גR <br> Detectable |
| :---: | :--- | :---: | :---: | :---: |
|  | Quinsam River | 43,600 | 0.012 | 1.18 |
|  | Big Qualicum River | 40,575 | 0.013 | 1.18 |
|  | Chilliwack River | 37,186 | 0.018 | 1.15 |
|  | Inch Creek | 41,788 | 0.018 | 1.14 |
|  | Robertson Creek | 40,171 | 0.056 | 1.08 |
| PS | Lower Elwha | 73,825 | 0.002 | 1.31 |
|  | Kendall Creek | 47,683 | 0.007 | 1.22 |
|  | Marblemount | 43,056 | 0.032 | 1.11 |
|  | Wallace River | 43,273 | 0.044 | 1.09 |
|  | Soos Creek | 44,136 | 0.025 | 1.11 |
|  | Voights Creek | 45,173 | 0.015 | 1.15 |
|  | George Adams | 45,766 | 0.026 | 1.11 |
|  | Quilcene NFH | 40,303 | 0.018 | 1.15 |
| WC | Makah NFH | 38,895 | 0.018 | 1.15 |
|  | Makah NFH (2010) | 64,410 | 0.020 | 1.11 |
|  | Quinault NFH | 79,593 | 0.018 | 1.10 |
|  | Salmon River Fish Culture | 75,951 | 0.009 | 1.15 |
|  | Solduc | 76,214 | 0.024 | 1.09 |
|  | Bingham Creek | 71,419 | 0.025 | 1.09 |
|  | Forks Creek | 72,325 | 0.020 | 1.11 |
| CR | Lewis River - North | 72,068 | 0.022 | 1.10 |
|  | Lewis River - South | 72,875 | 0.024 | 1.10 |
|  | Eagle Creek NFH | 23,741 | 0.014 | 1.22 |
|  | Sandy River | 27,117 | 0.011 | 1.23 |

### 2.6 Summary

Figure 2-3 shows the percentage of Z tests that were significant $(P \leq 0.05)$ and had a positive test statistic (i.e., indicate a significantly higher return rate for the unmarked component of the DIT group compared to the marked component which is attributed to the impact of MSFs) for each brood year. Separate lines are shown for the combined data from the hatcheries in each region (the BC region does not include data from the three hatcheries with only five years of data as they only covered brood years 1998-2002). The heavy black line shows the results across all regions combined. The regional trend lines are quite variable across the brood years and there is no trend over time. Similarly, there is no temporal trend for the combined data; the percentage of significant tests with a positive test statistic fluctuated around 40\% over the 1998-2011 brood years.


Figure 2-3. Percentage of significant tests $(P \leq 0.05)$ with a positive test statistic for the hypothesis that return rates to the escapement are equal for the marked and unmarked components of DIT groups released from a hatchery summarized for each brood year by region and across all regions combined (Appendix Table 4).

Across all hatcheries and brood years, $48 \%$ of the 286 tests comparing $\hat{p}_{u}$ to $\hat{p}_{m}$ were significant; $87 \%$ of the significant tests had a positive Z-test statistic indicating that $\hat{p}_{u}$ was significantly greater than $\hat{p}_{m}$ which is expected if MSFs are having greater impacts on the marked component of a DIT group than the unmarked component. Similarly, across all hatcheries and brood years $76 \%$ of the $286 \lambda R \mathrm{~s}$ (Eq. 8) calculated were $\geq 1.0$, i.e., indicated a differential impact of MSFs on the marked and unmarked components of the DIT groups (Table 2-5).

Table 2-5. Percent of brood years with $\lambda R$ ratios (Eq. 8) less than 1.00 and greater than 1.00 , by region.

| Region | $\lambda \boldsymbol{R}<\mathbf{1 . 0 0}$ | $\lambda \boldsymbol{R} \geq \mathbf{1 . 0 0}$ |
| :--- | :---: | :---: |
| British Columbia | $9.3 \%$ | $90.7 \%$ |
| Puget Sound | $28.7 \%$ | $71.3 \%$ |
| Washington | $38.6 \%$ | $61.4 \%$ |
| Columbia River | $5.7 \%$ | $94.3 \%$ |
| All | $24.4 \%$ | $75.6 \%$ |

## 3 Estimating Unmarked Fish Mortalities

SFEC-AWG (2002) described several methods that can be used to estimate unmarked mortalities in MSFs using DIT group data. Two of the methods are used in this analysis, a version of a "Total method" and the "Paired-Ratio method". The Paired-Ratio method allows estimation of mortalities by fishery, whereas the Total method estimates the total exploitation rate (ER) across all fisheries.

For the exploitation rate estimates presented in Sections 3 and 4:

- CWT-recovery data from all ages (i.e., primarily age-2 and age-3 recoveries in fisheries and the escapement) are used. Therefore, the estimated ERs are for the entire cohort, not just the age-3 component of the cohort. Because of relatively large differences in the proportion of each hatchery release that returns as age- 2 among the hatcheries and regions, it is important to include the age-2 data.
- The estimated ERs do not include drop-off mortality in their calculation. The dropoff mortality rate is an assumed value depending upon the type of fishery (hook-andline or net). Omitting drop-off mortality from the analyses in these two sections was done to facilitate comparisons of estimates of unmarked ER from the different methods and for comparisons of unmarked ER to marked ER estimates. When dropoff mortality is not included in the ER estimates the effect of the selective fishery mortality rate ( $s f m$ ), the mortality rate associated with the intentional release of unmarked fish in mark-selective fisheries, is more apparent.

Section 5 compares DIT-group based estimates of ER to the calculations of ER from Postseason Coho FRAM. Drop-off mortality is included in the DIT-group based estimates of marked and unmarked ERs in Section 5. Also, the ER estimates in Section 5 are based only on the age- 3 component of the DIT group return. This was done so that the DIT-based estimates of ER would be comparable to the calculations of ER from Post-season Coho FRAM.

### 3.1 Total Method

The Total method described here is based on the difference in release and escapement lambdas ( $\lambda$ ) where the $\lambda R$ for a DIT group is used to estimate the ER for the unmarked component of a DIT group. From equations 8 and 11 in Section 2-3, $\lambda R$ is,

$$
\widehat{\lambda R}=\frac{\widehat{\lambda^{E s c}}}{\widehat{\lambda}^{\text {Rel }}}=\frac{\left(1-\widehat{E R} \widehat{x}_{u}\right)}{\left(1-\widehat{E R}_{m}\right)} .
$$

The ER for the marked component of a DIT group $\left(E R_{m}\right)$ is estimated as total fishery mortality over the total fishery mortality plus escapement (see Section 1.3). The ER for the unmarked component of a DIT group $(E R u)$ is then:

$$
\begin{equation*}
\widehat{E R}_{u}^{\text {Total }}=1-\left[\frac{\hat{\lambda}^{E s c}}{\hat{\lambda}^{\text {Rel }}}\left(1-\widehat{E R}_{m}\right)\right] \tag{15}
\end{equation*}
$$

and, based on Goodman (1960),

$$
\begin{equation*}
\widehat{V}\left(\widehat{E R}_{u}^{\text {Total }}\right)=\widehat{V}(\widehat{\lambda R})\left(1-\widehat{E R}_{m}\right)^{2}+\widehat{V}\left(\widehat{E R}_{m}\right)(\widehat{\lambda R})^{2}-\widehat{V}(\widehat{\lambda R}) \widehat{V}\left(\widehat{E R}_{m}\right) \tag{16}
\end{equation*}
$$

with

$$
\begin{equation*}
\widehat{V}\left(\widehat{E R}_{m}\right)=\widehat{E R}_{m}^{2}\left[\frac{\widehat{V}(\widehat{M})}{\widehat{M}^{2}}+\frac{\widehat{V}\left(C \widehat{\text { ohor }} t_{m}\right)}{\text { C } \widehat{\text { hor }} t_{m}^{2}}\right] \tag{17}
\end{equation*}
$$

where $M$ is the estimated number of total fishery mortalities for the marked component of a DIT group and Cohortm is the sum of the estimated fishery mortalities plus escapement for the marked component. This method provides unbiased estimates of $E R_{u}$ under these assumptions:

1) Estimates of $\lambda^{R e l}$ and $\lambda^{E s c}$ are unbiased, i.e., the reported numbers of fish released for the marked and unmarked components of a DIT group are accurate and the estimated numbers of tagged fish in the escapement for the marked and unmarked components of a DIT group are based on unbiased sampling at the hatchery (and spawning grounds if applicable).
2) Survival from release to recruitment to fisheries is equal for the marked and unmarked components of a DIT group, so $\lambda^{\text {Rel }}$ is an unbiased estimate of $\lambda$ for a DIT group entering the first mark-selective fishery.

Estimates of unmarked ER for a DIT group are sensitive to uncertainty in the estimates of the associated marked ER. With a low ER on the marked fish, and few CWT recoveries in the fishery, sampling errors can result in highly uncertain estimates of ER. Estimated marked ERs with high uncertainty can result in a negative estimate of the unmarked ER when using the Total method (Eq. 15). Further, when the quantity $\frac{\hat{\lambda}^{E s c}}{\frac{\hat{\lambda}^{\text {Rel }}}{}\left(1-\widehat{E R}_{m}\right) \text { is greater than one, as }{ }^{\text {E }} \text {. }}$ will be the case when $\lambda R$ is greater than $1 /\left(1-\widehat{E R}_{m}\right)$, estimates of the unmarked ER will be negative. For example, when $\lambda R$ is $\geq 1.25$ and the marked ER is 0.20 , the estimate of unmarked ER will be negative (Appendix Table 5). Negative estimates of unmarked ER using the Total method were much more common in DIT groups released from hatcheries in British Columbia and the Columbia River regions where both of these conditions occurred more often than in the Puget Sound and Washington Coast regions (Table 3-1; Appendix Table 6).

Table 3-1. Summary of the percentage of DIT groups with negative estimates of unmarked ER using the Total method, by region.

| Region | Percent of Brood Years with Negative <br> Estimates of Unmarked ER |
| :--- | :---: |
| British Columbia | $37.2 \%$ |
| Puget Sound | $1.9 \%$ |
| Washington | $1.2 \%$ |
| Columbia River | $28.3 \%$ |
| All | $11.9 \%$ |

### 3.2 Paired-Ratio Method

For the Paired-Ratio (PR) method, the number of unmarked mortalities $(U)$ can be calculated using an estimate of the unmarked-to-marked ratio ( $\lambda$ ) for a specific DIT group that comes from a non-selective fishery that is close to the MSF in time and location (SFEC-AWG 2002). For mark-selective fishery $i$, the number of encounters of unmarked fish in the DIT group is estimated as the product $\hat{\lambda}_{i} \widehat{M}_{i}$ which is then multiplied by a fishery-specific release mortality rate ( $s f m$ ) to estimate mortalities due to the release of unmarked fish. The total number of mortalities occurring in fisheries for the unmarked component of a DIT group is the sum of estimated landed mortalities occurring in NSFs, mortalities in MSFs due to release, and unmarked landed mortalities occurring in MSFs (due to URE). Totaling unmarked mortalities across all fisheries (based on CWT recoveries from the marked and unmarked components of a DIT group) provides an estimate of $U$. Visually-sampled (VS) NSFs present a complication when estimating the number of fish from the unmarked component of a DIT-group that are caught and kept in a VS NSF. Because of visual sampling, the unmarked component of a DIT group is rarely detected and sampled in these fisheries, therefore, these landings must be estimated. For VS NSFs, the number of unmarked fish from a DIT group landed by the fishery was calculated similarly to the estimate of unmarked release mortalities in MSFs, i.e., the number of unmarked mortalities were estimated as the product of the marked landed mortalities $\left(\widehat{M}_{i}\right)$ and $\hat{\lambda}_{i}$ with an assumed $s f m=1.0$. This gives:

$$
\begin{equation*}
\widehat{U}=\sum_{j}^{E T D} \widehat{U}_{j}+\sum_{k}^{V S} \widehat{M}_{k} \lambda_{k}+\sum_{i}\left(\lambda_{i} \widehat{M}_{i}-\widehat{U}_{i}\right) s f m_{i}+\sum_{i} \widehat{U}_{i} \tag{18}
\end{equation*}
$$

where $M_{x}$ and $U_{x}$ are the estimated numbers of marked and unmarked fish, respectively, for a given DIT group retained by fishery $x$ with $j$ indicating NSFs with ETD, $k$ indicating NSFs with visual sampling, and $i$ indicating MSFs ${ }^{1}$. The variance for the estimated number of total unmarked mortalities in all fisheries was estimated as:

$$
\begin{equation*}
\widehat{V}(\widehat{U})=\sum_{j}^{E T D} \widehat{V}\left(\widehat{U}_{j}\right)+\sum_{k}^{V S} \lambda_{k}^{2} \hat{V}\left(\widehat{M}_{k}\right)+\sum_{i}\left[\left(\lambda_{i} \operatorname{sfm}_{i}\right)^{2} \widehat{V}\left(\widehat{M}_{i}\right)+\left(1-s f m_{i}\right)^{2} \widehat{V}\left(\widehat{U}_{i}\right)\right] \tag{19}
\end{equation*}
$$

where $\lambda_{k}$ and $\lambda_{l}$ are assumed constant as discussed below.

See Appendix 7 for a more complete description of the derivation of equations 18 and 19. The variances of $M_{i}$ and $U_{i}$ are estimated using Equation 2 (Section 1.2). For the PR method, the ER for the unmarked component of the DIT group was estimated as:

$$
\begin{equation*}
\widehat{E R}_{u}^{P R}=\frac{\stackrel{\widehat{U}}{ }}{\widehat{E}_{u}+\widehat{U}} \tag{20}
\end{equation*}
$$

with variance estimated using Equation 17.
In practice, it is very difficult to find a non-selective fishery that provides an unbiased and precise estimate of $\lambda_{i}$ to pair with a mark-selective fishery. If the non-selective fisheries occur after mark-selective fisheries, the $\lambda$ in the non-selective fishery is expected to be higher relative to the mark-selective fishery preceding it. Also, the precision of any estimate of $\lambda_{i}$ for

[^6]a DIT group depends on the number of tags used for that estimate and fishery recoveries are rarely sufficient to provide adequate precision for the estimate of $\lambda_{i}$.

Precise estimates of $\lambda$ for a DIT group are available at release ( $\left.\lambda^{\text {Rel }}\right)$ and at escapement ( $\lambda^{E s c}$ ) to the hatchery. The ratio $\lambda^{\text {Rel }}$ is likely to be more appropriate for mark-selective fisheries that take place in the earlier portion of migration, whereas $\lambda^{E s c}$ may be more appropriate for MSFs later in the migration or in terminal areas. The $\lambda \mathrm{s}$ at release and escapement should represent the minimum (before any fisheries) and maximum values (after all fisheries), respectively, and we assume that estimates using these two ratios should reasonably bound the estimates of unmarked mortalities and unmarked ER. Using a constant $\lambda$ in Equations 18 and 19 greatly simplifies calculations so that only fishery-specific values of $M_{i}$ and $s f m_{i}$ are required to estimate $\widehat{U}$.

The Paired-Ratio method requires the following assumptions:

1) The number of fish in the marked (M) and unmarked (U) components of each DIT group are accurately estimated in each fishery sampled and in the escapement;
2) $\lambda_{i}$ is an unbiased estimate of the $\lambda_{i}$ for a DIT group entering mark-selective fishery $i$;
3) $s f m_{i}$ is known with certainty;
4) All marked fish are retained (no MRE);
5) An unmarked fish is not encountered on multiple occasions in a mark-selective fishery; and,
6) All fish can be adequately represented as a single population, i.e., there are not substocks experiencing different impacts (PSC 2005).

The last assumption refers to the Paired-Ratio method having to assume a single-pool model where the entire population is subject to the same impacts simultaneously. No methods have been developed that can estimate MSF impacts on sub-stocks of unmarked fish that may have experienced differential MSF impacts owing to migration routes with different fishing patterns. For example, a portion of a stock migrating outside Vancouver Island where there are no mark-selective fisheries while another portion of the same stock migrates inside Vancouver Island where a mark-selective fishery occurs (PSC 2005).

The Paired-Ratio method is vulnerable to bias if the values used for $\lambda_{i}$ or the $s f m_{i}$ are biased. The values of $s f m_{i}$ used in this report are those provided by the management agencies for Coho salmon (Table 3-2; PFMC, 2008).

In NSFs where there is no electronic detection (i.e., visual sampling only) and unmarked-andtagged landed mortalities are not sampled, the Paired-Ratio method can be used to estimate the mortalities of the unmarked component of a DIT group based on the recoveries from the marked component of the DIT group.

Table 3-2. Release mortality ( $s f m$ ) and drop-off mortality $(D O)$ rates for Coho salmon used in this report.

| Region | Fishery | Release Mortality | Drop-off Mortality |
| :--- | :---: | :---: | :---: |
| All | Troll | 0.26 | 0.05 |
| All | Net | 0.26 | 0.02 |
| British Columbia | Sport | 0.10 | 0.05 |
| Washington Coast | Sport | 0.14 | 0.05 |
| Oregon Coast | Sport | 0.14 | 0.05 |
| Puget Sound | Sport | 0.07 | 0.05 |
| Columbia River | Sport | 0.19 | 0.05 |

### 3.3 Results: Estimates of Unmarked ER

Appendix Table 6 compares estimates of unmarked ER for the Total method (Eq. 15) and the PR method (Eqs. 18 and 20) using either $\lambda^{\text {Rel }}$ or $\lambda^{E s c}$. The notation PR $\lambda^{\text {Rel }}$ and PR $\lambda^{E s c}$ is used to indicate when unmarked mortalities are calculated using either $\lambda^{\text {Rel }}$ or $\lambda^{E s c}$ in Eq. 18, respectively. Brood years where the Z test statistic was significant $(P \leq 0.05)$ for the null hypothesis of equal return rates to the hatchery escapement for the marked and unmarked components of a DIT group are indicated in Appendix Table 6.

Estimates of unmarked ER from all three methods are positively correlated with estimates of marked ER as expected and all correlations are significant ( $P<0.001$ ). Estimates of unmarked ER from the two Paired-Ratio methods are highly correlated with each other ( $r=$ $0.999, P<0.001$ ). For the DIT groups analyzed, estimates of unmarked ER from the Total method are generally higher than the estimates from either PR method (Figure 3-1) as shown by the majority of the points in Figure 3-1 being below the one-to-line line. The negative ER estimates from the Total method are included in Figure 3-1.

Figure 3-2 compares distributions of brood year estimates of total unmarked ER, by hatchery, for the three unmarked ER estimation methods. Note that:

- The central $50 \%$ interquartile range is almost always wider for the Total method than the two PR methods indicating the Total method estimates are less precise (see Table 3-4); this is especially true for the British Columbia and Columbia River regions.
- Negative ER estimates from the Total method for the unmarked component of a DIT group are also much more common for the British Columbia and Columbia River regions compared to the other two regions.
- For hatcheries in the Puget Sound and Washington Coast regions, the central 50\% interquartile ranges of ER estimates for the unmarked group are generally similar for all three methods but the estimates using the Total method are consistently higher than the estimates from the PR methods.

The average difference between the estimates of unmarked ER from the two PR methods was largest for hatcheries in the Columbia River region (Table 3-3) but the difference was small ( $\approx$ -0.01 ). Across all regions, the average difference between the PR estimates of unmarked ER was only -0.004 . PR estimates of unmarked ER using $\lambda^{E s c}$ tended to be slightly higher, on
average, than estimates using $\lambda^{\text {Rel }}$. The percent standard errors (PSE) of the ER estimates for the PR methods were consistently less that for the Total method. Across all hatcheries and brood years, the average PSE for the Total method was more than twice that of the average PSE for the PR methods (Table 3-4).


Figure 3-1. Comparison of DIT-group based estimates of unmarked exploitation rates (ER) from the Total method to the two Paired-Ratio (PR) methods (top panel PR using $\lambda$ at release, bottom panel PR using $\lambda$ at escapement). One-to-one line shown for reference.


Figure 3-2. Box-and-whiskers plot comparing estimates of total unmarked ER using three methods: Total method Paired-Ratio method (PR) using $\lambda$ at release, and PR using $\lambda$ at escapement, by hatchery.

Table 3-3. Average difference between the estimates of $\widehat{E R}_{u}^{P R}$ calculated by the two PR methods (PR $\lambda^{\text {Rel }}-\mathrm{PR} \lambda^{E s c}$ ) for the unmarked component of a DIT group across brood years, by region.

| Region | Mean | Median | Minimum | Maximum |
| :--- | :---: | :---: | :---: | :---: |
| British Columbia | -0.007 | -0.003 | -0.034 | 0.001 |
| Puget Sound | -0.001 | 0.000 | -0.054 | 0.031 |
| Washington Coast | 0.001 | -0.001 | -0.013 | 0.095 |
| Columbia River | -0.012 | -0.011 | -0.071 | 0.007 |
| All | -0.004 | -0.001 | -0.071 | 0.095 |

Table 3-4. Average percent standard error estimates (PSE) for the three methods of estimating unmarked ER , by region. $\mathrm{PSE}=($ standard error of estimate/estimate $)$ $\mathrm{x} 100 \%$.

| Region | Total $^{\text {A }}$ | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PR $\lambda^{\text {Esc }}$ |
| :--- | :---: | :---: | :---: |
| British Columbia | $110.8 \%$ | $30.7 \%$ | $30.7 \%$ |
| Puget Sound | $17.2 \%$ | $12.6 \%$ | $12.7 \%$ |
| Washington Coast | $36.4 \%$ | $10.6 \%$ | $10.7 \%$ |
| Columbia River | $41.2 \%$ | $17.4 \%$ | $16.4 \%$ |
| All | $37.0 \%$ | $15.6 \%$ | $15.5 \%$ |

${ }^{\text {A }}$ Only valid ER estimates (ER estimates >0) were used for this calculation.

Examination of the results of comparing the return rates of the marked and unmarked fish in the DIT groups as described in Section 2.3 will indicate whether it is appropriate to estimate unmarked mortalities using the Total method. When the marked component of a DIT group has a significantly higher return rate to the escapement than the associated unmarked component, which is inconsistent with expectations if there are MSF impacts, the Total method should not be used. Figure 3-3 compares $\lambda R$ and exploitation rate estimates for the marked component of DIT groups where the ER estimate using the Total method was negative to DIT groups where the Total method ER was positive. The negative ER estimates from the Total method are usually associated with high values of $\lambda R$ and relatively low estimates of ER for the associated marked group, indicating a high level of uncertainty in expanded recovery estimates owing to sampling error, as discussed in Section 3.1.

### 3.4 Summary

The Total method supplied a valid (non-negative) estimate of unmarked ER in $88 \%$ of the 286 DIT groups examined (across all brood years and hatcheries). Excluding invalid data pairs (i.e., pairs where the Total method ER estimate was negative), the Total method estimates of unmarked ER were higher than the estimates from the PR method using $\lambda^{\text {Rel }}$ by about 0.06 on average (Table 3-5). The brood year differences between the estimates from the two methods ranged from -0.20 to +0.55 . The differences for the Columbia River region were, on average, larger than the differences for the other three regions. The estimates of unmarked ER from the Total method were also considerably less precise than the estimates from the two PR methods.


Figure 3-3. Scatter plot showing $\lambda R$ and exploitation rate (ER) estimates for the marked component of a DIT group and whether the estimated ER for the associated unmarked DIT group using the Total method was negative or not.

Table 3-5. Average difference between the Total method and PR $\lambda^{\text {Rel }}$ method (Total method - PR $\lambda^{\text {Rel }}$ ) for estimates of the exploitation rate for the unmarked component of a DIT group, by region. This analysis excludes data pairs with a negative Total ER estimate.

| Region | Mean | Median | Minimum | Maximum |
| :--- | :---: | :---: | :---: | :---: |
| British Columbia | 0.061 | 0.068 | -0.071 | 0.235 |
| Puget Sound | 0.052 | 0.040 | -0.196 | 0.547 |
| Washington Coast | 0.062 | 0.035 | -0.128 | 0.461 |
| Columbia River | 0.081 | 0.063 | -0.063 | 0.306 |
| All | 0.061 | 0.043 | -0.196 | 0.547 |

## 4 Can We Estimate Unmarked Mortalities with a Single Index Tag Program?

If there is not a double index tag group, estimates of mortalities, and exploitation rate, for unmarked Coho need to be made using recoveries from a marked and tagged group assumed to be representative of the unmarked fish, i.e., from a single index tag (SIT) program. Under the assumption that legal-size marked Coho are not voluntarily released, the number of marked mortalities for a SIT group in pre-terminal fisheries ( $M_{P}$ ) can be estimated for MSFs and NSFs as the sum,

$$
\begin{equation*}
\widehat{M}_{P}=\sum_{P} \widehat{M}^{M S F}+\sum_{P} \widehat{M}^{N S F} . \tag{21}
\end{equation*}
$$

The expected mortalities for the unmarked fish represented by the marked and tagged group in pre-terminal fisheries $\left(U_{P}\right)$ can be estimated as,

$$
\begin{equation*}
\widehat{U}_{P}=\sum_{P} \widehat{M}_{i}^{M S F} \lambda_{i} s f m_{i}+\sum_{P} \widehat{M}_{i}^{N S F} \lambda_{i} \tag{22}
\end{equation*}
$$

where $\lambda_{i}=$ the unmarked-to-marked ratio for the natural stock and the SIT group representing it in fishery $i$, (assumed to be 1.0 ), and

$$
s f m_{i}=\text { the release mortality rate for unmarked fish released in MSF } i
$$

Using a value of 1.0 for the unmarked-to-marked ratio $\left(\lambda_{i}\right)$ at recruitment to pre-terminal fisheries assumes equal cohort sizes ( $N=N_{m}=N_{u}$ ) for marked and unmarked fish. A new ratio after the pre-terminal fisheries for fish entering the terminal fishery area $\left(\lambda^{T R}\right)$ can be calculated as,

$$
\begin{equation*}
\hat{\lambda}^{T R}=\frac{N-\widehat{U}_{P}}{N-\widehat{M}_{P}} \tag{23}
\end{equation*}
$$

This estimate of the terminal run unmarked-to-marked ratio can then be used to calculate unmarked mortalities in terminal fisheries (either MSF or NSF) by,

$$
\widehat{U}_{T R}=\left[\begin{array}{lll}
\widehat{M}_{T R} \hat{\lambda}^{T R} & s f m_{T R} \tag{24}
\end{array}\right]
$$

where $s f m_{T R}$ is the release mortality in any terminal fishery, which would be set to 1.0 for a NSF.

The unmarked-to-marked ratio at escapement would be estimated by subtracting the terminal mortalities from the terminal run cohort size,

$$
\begin{equation*}
\hat{\lambda}^{E s c}=\frac{N-\widehat{U}_{P}-\sum_{i} \widehat{U}_{T R}}{N-\widehat{M}_{P}-\sum_{i} \widehat{M}_{T R}} \tag{25}
\end{equation*}
$$

$\lambda R$ would be equal to $\lambda^{E s c}$ since the $\lambda^{\text {Rel }}$ at release is assumed to equal 1.0. ERs are estimated for an unmarked group as the sum of the estimated unmarked mortalities over the cohort size, which with a $\lambda^{\text {Rel }}$ equal to 1.0 is the same as the associated marked cohort size. For preterminal NSFs, the ERs will be the same for the marked and unmarked groups, but for MSFs they will be different. In terminal fisheries with a new estimate of lambda ( $\hat{\lambda}^{T R}$ ), the ERs will be different for both types of fisheries.

The assumptions for this method of estimating the ER for unmarked fish are:

- the marked exploitation rate for the SIT group is an unbiased estimate of the encounter rate for the unmarked fish represented by the SIT group; and,
- $\quad s f m_{i}$ is an unbiased estimate of the release mortality rate in fishery $i$.


### 4.1 Results: Estimates of Unmarked ER

Table 4-1 summarizes the average total unmarked ER estimated with DIT (Eq. 18 and 20, Section 3.2) ${ }^{1}$ and using the SIT-based method, the average of the differences between the DIT-based and SIT-based estimates (DIT - SIT), and the percent of brood years where the DIT-based ER estimate was larger than the SIT-based estimate for each hatchery across all brood years. Across all hatcheries and brood years, the estimate of the ER for unmarked fish in the cohort from the DIT-based method was larger than the SIT-based method in $75 \%$ of the comparisons. The Puget Sound region had the highest percentage of comparisons where the unmarked ER estimated using the DIT method was greater than the SIT-based method (84\%) followed by the Washington Coast region ( $76 \%$ ).

The average difference between the ER estimates was greatest for the Puget Sound region (0.047). The average differences between the two methods for the other three regions ranged from 0.017 to 0.037 (Table 4-1). In two hatcheries the average difference across brood years was negative (i.e., the SIT-based ER average was > DIT-based ER average); those hatcheries were Bingham Creek in the WC region and Eagle Creek NFH in the CR region.

Figure 4-1 compares distributions of brood year estimates of total unmarked ER, by hatchery, for the PR $\lambda^{\text {Rel }}$ method and the SIT-based method. Based on the similarities of the ER distributions as compared in Figure 4-1 in terms of the locations of the average and median estimates and the spread of the central $50 \%$ interquartile, and the summary statistics reported in Table 4-1, the SIT-based estimates were fairly similar to the DIT-based estimates for these hatcheries:

- BC region - Quinsam River and Inch Creek;
- PS region - Lower Elwha, Wallace River, and George Adams;
- WC region - Solduc, Bingham Creek, and Forks Creek; and,
- CR region - Lewis River (South) and Eagle Creek NFH.

[^7]Table 4-1. Comparison of DIT-based (Eq. 20, Section 3.2) and SIT-based estimates of unmarked ER showing mean total ER, the mean of the differences between DITbased and SIT-based estimates (DIT - SIT), and the percent of brood years where the DIT-based ER estimate was larger than the SIT-based estimate. Regional totals are averages over all brood years for each hatchery in the region. The DIT-based estimate reported is the PR method using $\lambda$ at release.

| Region | Hatchery | Mean Total ER |  | Mean of ER Differences | $\begin{array}{\|c} \hline \text { Percent Broods } \\ \text { DIT }>\text { SIT } \end{array}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | DIT | SIT |  |  |
| British <br> Columbia | Quinsam River | 0.140 | 0.130 | 0.010 | 57.1\% |
|  | Big Qualicum River | 0.073 | 0.056 | 0.017 | 60.0\% |
|  | Chilliwack River | 0.071 | 0.044 | 0.027 | 80.0\% |
|  | Inch Creek | 0.086 | 0.077 | 0.009 | 78.6\% |
|  | Robertson Creek | 0.098 | 0.047 | 0.051 | 80.0\% |
| British Columbia Total |  | 0.102 | 0.084 | 0.017 | 69.8\% |
| Puget Sound | Lower Elwha | 0.237 | 0.211 | 0.025 | 42.9\% |
|  | Kendall Creek | 0.697 | 0.602 | 0.095 | 100.0\% |
|  | Marblemount | 0.354 | 0.307 | 0.048 | 92.9\% |
|  | Wallace River | 0.141 | 0.128 | 0.013 | 78.6\% |
|  | Soos Creek | 0.495 | 0.422 | 0.073 | 100.0\% |
|  | Voights Creek | 0.519 | 0.462 | 0.057 | 100.0\% |
|  | George Adams | 0.275 | 0.246 | 0.028 | 78.6\% |
|  | Quilcene NFH | 0.494 | 0.441 | 0.053 | 85.7\% |
| Puget Sound Total |  | 0.390 | 0.343 | 0.047 | 84.3\% |
| Washington Coast | Makah NFH | 0.143 | 0.107 | 0.036 | 92.3\% |
|  | Quinault NFH | 0.554 | 0.520 | 0.034 | 85.7\% |
|  | Salmon River FC | 0.717 | 0.586 | 0.131 | 92.3\% |
|  | Solduc | 0.288 | 0.265 | 0.022 | 71.4\% |
|  | Bingham Creek | 0.183 | 0.197 | -0.014 | 35.7\% |
|  | Forks Creek | 0.385 | 0.369 | 0.016 | 78.6\% |
| Washington Coast Total |  | 0.377 | 0.341 | 0.037 | 75.6\% |
| Columbia River | Lewis River - North | 0.250 | 0.186 | 0.064 | 92.9\% |
|  | Lewis River - South | 0.082 | 0.075 | 0.006 | 57.1\% |
|  | Eagle Creek NFH | 0.078 | 0.081 | -0.003 | 35.7\% |
|  | Sandy River | 0.158 | 0.133 | 0.025 | 54.5\% |
| Columbia River Total |  | 0.141 | 0.118 | 0.023 | 60.4\% |



Figure 4-1. Box-and-whiskers plot comparing estimates of total unmarked ER from the Paired-Ratio method (PR) using $\lambda$ at release to estimates from the SIT-based method, by hatchery.

### 4.2 Summary

Several assumptions are involved in using a SIT program to estimate the mortalities and ER for an unmarked surrogate stock, including: (1) legal-size marked fish are not voluntarily released; (2) cohort sizes of marked and unmarked fish recruited to pre-terminal fisheries are approximately equal, i.e., $\lambda_{i}=1$; (3) ERs in pre-terminal NSFs are the same for marked and unmarked fish; (4) the marked ER is an unbiased estimate of the encounter rate for unmarked fish in MSFs; (5) the $s f m_{i}$ is an unbiased estimate of the release mortality rate; and, (6) $\hat{\lambda}^{T R}$ is an unbiased estimate of the unmarked-to-marked ratio for the stock and the SIT group representing it.

In this analysis, the SIT-based ER estimates for the unmarked fish were less than the DITbased estimates using the PR $\lambda^{\text {Rel }}$ method $75 \%$ of the time. Average differences across hatcheries ranged from -0.014 to 0.131 and differences varied by region. Figure 4-2 compares estimates of unmarked ERs from the two methods by region. Estimates of unmarked ER from the PR method and the SIT-based method are highly correlated with each other $(r=0.956$, $P<0.001$ ). However, the unmarked ER estimate from the SIT-based method is more likely to be less than the PR-based estimate as the SIT-based ER increases. This was especially evident when estimates of unmarked ER from the SIT method were $\geq 0.40$. When the SITbased estimate of unmarked ER was $\geq 0.40,93 \%$ of the comparisons ( 66 out of 71 ) had a DIT-based estimate greater than the SIT-based estimate and the DIT-based estimate was, on
average, +0.062 greater than the SIT-based estimate. For comparison, when the SIT-based estimate of ER was < $0.40,69 \%$ of the comparisons had a DIT-based estimate of unmarked ER greater than the SIT-based estimate and the DIT-based estimate was, on average, +0.026 greater than the SIT-based estimate.


Figure 4-2. Scatter plot comparing exploitation rate (ER) estimates for the unmarked group from the Paired-Ratio (PR) method with $\lambda$ at release to the SIT-based method. One-to-one line shown for reference.

As a cost-saving measure, the SIT-based method may be an adequate method of estimating unmarked ERs for some hatcheries if expected ERs are relatively low (e.g., <40\%) and if survival rates and tagging levels are conducive to producing precise SIT-based estimates, as demonstrated by the power analysis in Section 2.5.

## 5 Comparison of DIT-Based Estimates of ER to Post-Season COHO FRAM Estimates

The Pacific Salmon Treaty (PST) Southern Coho Agreement is based on constraints of the total exploitation rate allowed on naturally-spawning Management Units (MUs). The Coho Fishery Regulation Assessment Model (FRAM) has been developed as a bilateral tool to provide a consistent basis for preseason fishery planning and post-season evaluation of exploitation rates on MUs resulting from various fishery regulations (PFMC 2008). Coho FRAM stock components must be aggregated into MUs. Coho FRAM contains a complex set of hatchery and natural, marked and unmarked stock components, and fishery-temporal strata. Coho FRAM also includes estimates of drop-off mortalities, release mortalities in markselective fisheries, and catch-non-retention mortalities (CNR) for fisheries where Coho may be caught but not retained (e.g., Chinook-only sport fisheries).

Coho FRAM is used for both preseason and post-season modeling. For preseason planning purposes, the model is used to project exploitation rates that will result from planned fishery regulations on forecasts of abundance. For post-season modeling, a post-season utility (Postseason Coho FRAM) reconstructs initial cohort sizes using estimates of landed catch and escapements (note that escapement estimates are only available for a single Canadian MU, Interior Fraser). The initial cohort sizes produced by post-season Coho FRAM are then used by the PSC Coho Technical Committee (CoTC) to calculate exploitation rates for the marked and unmarked component of each stock.

FRAM-based post-season exploitation rates were compared to the results of the DIT analyses. The DIT Paired-Ratio estimator using the unmarked-to-marked ratio at release for the DIT groups ( $\lambda^{\text {Rel }}$ ) was used for these comparisons. To incorporate drop-off mortalities, unmarked mortalities $(U)$ were estimated using a modification to equation 18:
$\widehat{U}=\sum_{j}^{E T D} \widehat{U}_{j}\left(1+D O_{j}\right)+\sum_{k}^{V S} \widehat{M}_{k} \hat{\lambda}_{k}\left(1+D O_{k}\right)+\sum_{i} \hat{\lambda}_{i} \widehat{M}_{i}\left(s f m_{i}+D O_{i}\right)+\sum_{i} \widehat{U}_{i}\left(1-s f m_{i}\right)$
where all notation is as previously defined and $D O$ is the drop-off mortality rate associated with fishery $i, j$, or $k$. See Appendix 7 for a more complete description of the derivation of Eq. 26.

In order to correspond to the Post-season FRAM-based ER estimates, only age-3 data for the DIT groups were used in these analyses. Fishery mortalities from both non-selective and mark-selective fisheries were summarized for each stock and included retained catch and catch-related mortalities (non-retention and drop-off). Exploitation rates for each stock were calculated as the total fishery mortalities divided by the total fishery mortalities plus escapement.

Exploitation rates from post-season FRAM for marked and unmarked DIT groups (which are surrogates for FRAM stocks) were compared to DIT-based ER estimates in four ways:

1) The ratio of ER estimated using DIT over FRAM-based ER was calculated for both the marked and unmarked components of a DIT group. A ratio of 1.0 indicates that the two ERs are the same, when the ratio is > 1.0 the DIT-based ER estimate is larger, and when the ratio is $<1.0$ the FRAM-based ER is larger.
2) Differences between the two different methods of estimating ERs were examined for both the marked and unmarked components of each DIT group.
3) Scatter plots comparing DIT-based ER estimates to corresponding Post-season FRAM ERs were constructed for both the marked and unmarked groups.
4) Finally, for the same method of estimation (DIT-based or FRAM-based), the ratio of the unmarked ER to the marked ER for a stock and brood year was calculated. When this ratio is < 1.0 it represents a measure of the relative reduction in the ER on the unmarked component relative to the marked component. It is assumed this reduction is the result of MSFs reducing the landed harvest of the unmarked component of the DIT group.

Differences between post-season Coho FRAM and DIT-based estimates of ERs are expected due to FRAM's reliance on average stock-fishery-time period exploitation rates during a referenced base period (1986-1992), the uncertainty associated with CWT-based estimates of exploitation rates, and uncertainty associated with other FRAM model parameters such as natural mortality rates, unmarked retention error, and mark recognition error. DIT program hatcheries may only represent a sub-component of more aggregate FRAM stocks. Consequently, FRAM results for individual years do not reflect annual deviations of stock distribution or migration patterns from base-period averages. Also, post-season Coho FRAM applies a bias-correction procedure in its calculation of fishery mortalities to account for possible multiple encounters of released unmarked Coho in a MSF; the PR method assumes an unmarked fish is not encountered on multiple occasions in a MSF. This effect on ER estimates is expected to be small.

Post-season Coho FRAM model runs for the calendar fishing years 2001-2014 (brood years 1998-2011) were obtained from the PSC Coho Technical Committee in a MS Access database file. The post-season FRAM ERs used in this report were based on model runs distributed September 30, 2019 (personal communication: Andy Rankis, Suquamish Tribe Fisheries Department and Coho Technical Committee). Model run values were obtained from the mortality and escapement tables for each year based on year and unique stock identifier. Post-season Coho FRAM marked and unmarked ERs were available for all hatcheries except the Chilliwack River Hatchery in British Columbia. Appendix Table 8 shows the alignment of FRAM stocks with the hatchery DIT programs analyzed for this report. FRAM stocks in the Columbia River region represent larger hatchery aggregates and thus DIT results from the Eagle Creek NFH, Lewis River - South, and Sandy River Hatcheries are all compared to a single FRAM stock.

Total ERs were compared for the Puget Sound and Washington Coast regions. Post-season Coho FRAM runs for the hatcheries in the British Columbia and Columbia River regions do not include all terminal-area fisheries. In these two regions, few terminal fisheries are modeled in post-season FRAM and thus excluded from this analysis. Terminal fisheries excluded were the Buoy 10 sport fishery in the Columbia River region and the Lower Fraser River Terminal and Upper Fraser River Terminal fisheries in the British Columbia region. Therefore, for these two regions the ER comparisons are of pre-terminal ERs.

### 5.1 Results

The distributions of the ratios of ER estimated for the marked and unmarked components of the DIT groups (calculated as DIT-based ER over FRAM-based ER) are shown in Figure 5-1, by hatchery.

For the marked DIT group components (Figure 5-1, upper plot):

- Hatcheries in the British Columbia region have the widest distribution of ratios ranging above 1.0 with the exception of Inch Creek.
- For the Puget Sound and Washington Coast regions, the distributions are relatively narrow for all hatcheries and the distributions for most hatcheries have a median near 1.0. The exceptions are the Voights Creek, George Adams, and Quilcene NFH hatcheries in Puget Sound and the Makah, Solduc, and Bingham Creek hatcheries in the Washington Coast region; with the exception of Voights Creek, the majority of the ratios for these hatcheries are < 1.0.
- In the Columbia River region, the Lewis River South and Eagle Creek NFH stocks are centered near 1.0. The majority of the ratios for DIT groups representing Lewis River North and Sandy River are > 1.0.

For the unmarked DIT group components (Figure 5-1, lower plot):

- In general, the distributions of ratios for the unmarked DIT groups are very similar to that of the marked DIT groups.
- Except for the Inch Creek and Lewis River North DIT groups, the central $50 \%$ interquartiles for the DIT groups in the British Columbia and Columbia River regions were relatively wide and wider than those seen for the marked group.

The average marked ER across brood years is shown in Table 5-1 for both methods of estimation, as well as the average difference between the two methods, and the percentage of broods where the DIT-based ER was larger than the FRAM-based ER. For marked ERs, the DIT-based ER estimate was greater than the FRAM-based ER estimate for $50 \%$ of the comparisons across all hatcheries and brood years (Appendix Table 9). There is no indication of consistent differences (relative bias) in either direction between the two methods of estimation except at the highest levels of exploitation (>0.80) where the DIT-based estimate of ER is usually greater than the FRAM-based estimate (Figure 5-2, upper plot). For nine of the 22 hatcheries examined, the average FRAM-based estimate of marked ER was greater than the average DIT-based estimate. There were eight hatcheries where the average difference in marked ER estimates was $> \pm 0.10$; all other average differences were within $\pm 0.10$. The largest positive average difference (DIT ER > FRAM ER) in marked ERs was +0.16 for the Sandy River Hatchery; the largest negative average difference (DIT ER < FRAM ER) was -0.275 for the George Adams Hatchery.


Figure 5-1. Distribution of the ratio of exploitation rates (ER) estimated using DIT over FRAM-based ER estimates for the marked group (upper plot) and unmarked group (lower plot), by hatchery. For the unmarked groups, extreme outlier ratios for Lower Elwha (20.0), Marblemount (14.4), Voights Creek (13.6), and Quilcene NFH (14.4) are not shown for scaling purposes; all these extreme outliers were associated with the 2001 brood year.

Table 5-1. Comparison of mean exploitation rates (ER) for marked and unmarked groups (catch years 2001-2014) from DIT-based analysis and FRAM-based ER. The mean of the differences between DIT-based estimates and FRAM-based ERs and the percent of brood years where the DIT-based ER estimate was larger than the FRAM-based ER are shown, also. Regional totals are averages over all brood years for each hatchery and over all broods for each region. The DITbased estimate reported is the PR method using $\lambda$ at release.

| Region | Hatchery | Marked DIT Component ER Estimates |  |  |  | Unmarked DIT Component ER Estimates |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Mean ER |  | Mean Difference | $\begin{gathered} \% \\ \text { DIT }>\text { Froods } \\ \text { DRAM } \end{gathered}$ | Mean ER |  | Mean Difference | $\begin{gathered} \text { \% Broods } \\ \text { DIT > FRAM } \end{gathered}$ |
|  |  | DIT | FRAM |  |  | DIT | FRAM |  |  |
| British <br> Columbia (Pre-terminal ER) | Quinsam River | 0.213 | 0.227 | -0.013 | 57.1\% | 0.167 | 0.139 | 0.028 | 57.1\% |
|  | Big Qualicum River | 0.155 | 0.090 | 0.065 | 80.0\% | 0.084 | 0.056 | 0.028 | 60.0\% |
|  | Chilliwack River |  |  |  |  |  |  |  |  |
|  | Inch Creek | 0.178 | 0.214 | -0.035 | 35.7\% | 0.090 | 0.133 | -0.042 | 21.4\% |
|  | Robertson Creek | 0.244 | 0.200 | 0.044 | 40.0\% | 0.107 | 0.084 | 0.023 | 40.0\% |
| British Columbia Total |  | 0.197 | 0.201 | -0.004 | 50.0\% | 0.120 | 0.119 | 0.001 | 42.1\% |
| Puget <br> Sound (Terminal ER) | Lower Elwha | 0.439 | 0.389 | 0.049 | 64.3\% | 0.311 | 0.315 | -0.003 | 50.0\% |
|  | Kendall Creek | 0.755 | 0.633 | 0.122 | 70.0\% | 0.705 | 0.576 | 0.130 | 70.0\% |
|  | Marblemount | 0.437 | 0.373 | 0.064 | 50.0\% | 0.366 | 0.298 | 0.067 | 57.1\% |
|  | Wallace River | 0.236 | 0.229 | 0.007 | 50.0\% | 0.150 | 0.171 | -0.021 | 21.4\% |
|  | Soos Creek | 0.530 | 0.582 | -0.052 | 35.7\% | 0.505 | 0.515 | -0.010 | 42.9\% |
|  | Voights Creek | 0.582 | 0.465 | 0.117 | 64.3\% | 0.532 | 0.406 | 0.126 | 57.1\% |
|  | George Adams | 0.361 | 0.636 | -0.275 | 7.1\% | 0.296 | 0.565 | -0.269 | 14.3\% |
|  | Quilcene NFH | 0.582 | 0.701 | -0.119 | 28.6\% | 0.523 | 0.629 | -0.106 | 28.6\% |
| Puget Sound Total |  | 0.480 | 0.496 | -0.016 | 45.4\% | 0.413 | 0.429 | -0.016 | 41.7\% |
| Washington Coast (Terminal ER) | Makah NFH | 0.283 | 0.476 | -0.193 | 30.8\% | 0.178 | 0.394 | -0.217 | 25.0\% |
|  | Quinault NFH | 0.648 | 0.566 | 0.083 | 92.9\% | 0.586 | 0.544 | 0.042 | 78.6\% |
|  | Salmon River FC | 0.738 | 0.702 | 0.035 | 66.7\% | 0.747 | 0.666 | 0.082 | 66.7\% |
|  | Solduc | 0.415 | 0.605 | -0.189 | 7.1\% | 0.321 | 0.594 | -0.272 | 7.1\% |
|  | Bingham Creek | 0.266 | 0.353 | -0.086 | 14.3\% | 0.205 | 0.316 | -0.111 | 14.3\% |
|  | Forks Creek | 0.521 | 0.466 | 0.054 | 64.3\% | 0.410 | 0.437 | -0.027 | 35.7\% |
| Washington Coast Total |  | 0.475 | 0.524 | -0.050 | 45.7\% | 0.405 | 0.490 | -0.085 | 37.5\% |
| Columbia River (Pre-terminal ER) | Lewis River - North | 0.369 | 0.251 | 0.118 | 100.0\% | 0.110 | 0.090 | 0.020 | 50.0\% |
|  | Lewis River - South | 0.200 | 0.182 | 0.018 | 42.9\% | 0.088 | 0.067 | 0.021 | 50.0\% |
|  | Eagle Creek NFH | 0.181 | 0.182 | -0.001 | 42.9\% | 0.078 | 0.067 | 0.011 | 28.6\% |
|  | Sandy River | 0.337 | 0.179 | 0.158 | 90.9\% | 0.126 | 0.059 | 0.067 | 63.6\% |
| Columbia River Total |  | 0.268 | 0.200 | 0.068 | 67.9\% | 0.099 | 0.071 | 0.028 | 47.2\% |

For unmarked ERs, the DIT-based ER estimate was greater than the FRAM-based ER estimate for $42 \%$ of the comparisons across all hatcheries and brood years (Appendix Table 9). Similar to the marked groups, there is no indication of consistent differences in either direction between the two methods of estimation except at the highest levels of exploitation ( $>0.70$ ) where the DIT-based estimate of ER is usually greater than the FRAMbased estimate (Figure 5-2, lower plot). For 10 of the 22 hatcheries examined, the average FRAM-based estimate of unmarked ER was greater than the average DIT-based estimate. There were seven hatcheries where the average difference in marked ER estimates was > $\pm 0.10$, all other average differences were within $\pm 0.10$. The largest positive average difference (DIT ER > FRAM ER) in unmarked ERs was +0.130 for the Kendall Creek Hatchery and the largest negative average difference (DIT ER < FRAM ER) was -0.272 for the Solduc Hatchery.



Figure 5-2. Scatter plot comparing exploitation rate (ER) estimates for the marked and unmarked groups from the Paired-Ratio (PR) with $\lambda$ at release to the post-season FRAM estimates. One-to-one line shown for reference.

Figure 5-3 compares the distributions of U/M ER ratios for the two methods, by hatchery. For most hatcheries, the box plot means and medians of the ratios are relatively similar for the two methods of estimation. The ratios from the DIT-based method often are more variable compared to the FRAM-based ratios (e.g., in the WC and CR regions). The DIT-based estimates indicate a greater effect of MSFs (greater reduction in unmarked ER relative to marked ER) compared to the FRAM-based estimates for the Inch Creek, Wallace River, George Adams, Makah NFH, Solduc, Bingham Creek, Forks Creek, and Lewis River North DIT groups.


Figure 5-3. Box-and-whiskers plot comparing the ratios of unmarked-to-marked exploitation rates (ER) for the Paired-Ratio method using $\lambda$ at release and from post-season FRAM, by hatchery.

### 5.2 Summary

The ER estimates from the DIT group analyses and the post-season FRAM are not as highly correlated as other ER comparisons reported earlier ( $r>0.85$ ); for the marked component of the DIT groups $r=0.65(P<0.001)$ and for the unmarked component of the groups $r=0.69$ ( $P<0.001$ ). Overall, about $30 \%$ of the ER differences between these two methods were within $\pm 0.05$ for both the marked and unmarked DIT group components. In comparison, $50 \%$ of the differences between ERs were $\geq \pm 0.10$ for the marked component of the DIT groups and $44 \%$ for the unmarked component of the DIT groups.

Figure 5-4 shows the differences between the two ER estimates (DIT-based - post-season FRAM), by brood year, for each hatchery separately for the marked and unmarked components of each DIT group. It also shows the average differences reported in Table 5-1 relative to these brood-year differences. This figure illustrates that:

- While the average difference across brood years might be relatively small (<0.05) for some hatcheries, the differences between the estimates can be large (e.g., Quinsam River, Lower Elwha, and Soos Creek for both the marked and unmarked DIT group components).
- Consistent differences are evident for some groups. For example, the FRAM ER is consistently greater than the DIT-based estimate for both the marked and unmarked DIT group components from the George Adams, Makah NFH, Solduc, and Bingham Creek hatcheries. The FRAM ER is consistently less than the DIT-based estimate for both the marked and unmarked DIT group components from Kendall Creek and Quinault NFH and for the marked group DIT group component for Lewis River North and Sandy River hatcheries.
- There is generally good agreement between the DIT-based and FRAM-based estimates of ER for the marked DIT group from Wallace River and the unmarked component of the Big Qualicum River and Lewis River North DIT groups.

In general, average DIT-based and FRAM based U/M ER ratios were similar for DIT groups from British Columbia and Puget Sound hatcheries (Table 5-2). The DIT-based method estimated a much greater average reduction in unmarked ER relative to marked ER (assumed to be due to MSFs) for DIT groups from Washington Coast hatcheries. Conversely, the FRAM-based method estimated a greater reduction in unmarked ER relative to marked ER for DIT groups from Columbia River hatcheries.

Table 5-2. Mean unmarked-to-marked ER ratio for all DIT groups in a region for the DITbased and FRAM-based methods.

| Region | DIT-Based U/M ER | FRAM-Based U/M ER |
| :--- | :---: | :---: |
| British Columbia | 0.585 | 0.607 |
| Puget Sound | 0.843 | 0.814 |
| Washington Coast | 0.790 | 0.931 |
| Columbia River | 0.453 | 0.360 |
| All | 0.719 | 0.733 |



Figure 5-4. Plot showing exploitation rate (ER) differences between the Paired-Ratio with $\lambda$ at release and the post-season FRAM estimates for the marked and unmarked DIT groups, for all brood years by hatchery. Mean difference indicated by $\boldsymbol{\Delta}$.

## 6 Evaluation of DIT Programs by Region and Hatchery

The precision of estimates of marked and unmarked ERs based on CWTs depends upon the number of tags recovered in fisheries and the escapement. The number of tags recovered from any DIT group is a function of:

- the number of marked and unmarked tagged fish released;
- the number of released fish surviving and entering fisheries;
- the intensity (size) of the intercepting fisheries;
- the catch sampling rate in those fisheries;
- the eventual return rate to the escapement; and,
- the sampling rate of fish in the escapement.

All these factors influence the number of CWTs recovered and the precision of the ER estimates.

The accuracy of the ER estimates depends upon how well the assumptions necessary for the estimates are met. Foremost of these assumptions is random sampling of the catch and escapement so that every fish (whether marked or unmarked) has an equal probability of being sampled and a CWT being detected, if present. This key assumption is violated by visual sampling, either in a fishery or the escapement; only ETD sampling assures an equal probability of CWT detection in both the marked and unmarked DIT-group components. It is also assumed that the size of the catch being sampled is accurately estimated so that catch sample expansion factors are accurate and unbiased. Finally, visually-sampled NSFs and mixed-regulation fisheries are another source of uncertainty and potential bias for the ER estimates because unmarked recoveries in these fisheries are estimated using methods similar to those used to estimate release mortalities in MSFs.

In this section, data summaries and analyses are presented to assess the DIT groups from each hatchery in a region relative to the factors and assumptions discussed above. Specifically, summaries and figures are presented examining:

1) The number of fish released in the marked and unmarked components of the DIT groups from each hatchery across the brood years analyzed.
2) The sampling rate ${ }^{1}$ of fish from a DIT group returning to the escapement (hatchery and spawning grounds where applicable).
3) The proportion of the fish that were directly sampled from the escapement and were screened using ETD to recover CWTs.
4) The estimated return rates to the escapement of the marked and unmarked components of the DIT groups from each hatchery.
5) A comparison of the estimated return rates ( RR ) to the hatchery of the marked and unmarked components of the DIT groups including an assessment of whether the difference in return rates between the two mark-status groups was consistently in the

[^8]direction expected (unmarked $R R>$ marked $R R$ ) and whether the differences were statistically significant.
6) The number of estimated CWT recoveries from the marked and unmarked components of the DIT groups from each hatchery in fisheries and the escapement.
7) The distribution of CWT recoveries from the marked component of DIT groups in MSFs, NSFs, mixed-regulation fisheries, and escapement.
8) The type of sampling in the major fisheries impacting DIT groups from a hatchery: electronic sampling (all coded wire tagged fish in a sample have an equal chance of being recovered whether marked or unmarked) or visual sampling (the adipose fin clip is used to subset catch to sample for detection of coded wire tagged fish and thus only marked fish are typically sampled).
9) An assessment of the impact of mark-selective fisheries on the marked and unmarked groups, i.e., measurable and statistically significant differences between the exploitation rate estimates for the marked and unmarked components of a DIT group and were those differences consistently in the direction expected (marked ER > unmarked ER). Non-overlapping 95\% confidence intervals for the estimated exploitation rates of the marked and unmarked components of a DIT group were used as a proxy for a test of significance. Non-overlapping 95\% CIs indicate a significant difference between the estimates with $P<0.05$. This is a conservative approach to assessing significant differences in ERs.
10) A temporal examination of the ER data for each hatchery's DIT groups for noticeable trends.

The appendices provide detailed results and estimates by hatchery and brood year. Appendix Table 1 summarizes the number of marked and unmarked fish released in each hatchery's DIT groups, by brood year. Appendix Table 2 presents age composition information for the marked and unmarked components of each hatchery's DIT groups, by brood year, based on CWT recoveries. For the marked group, Appendix Table 3 summarizes the percentage of fishery recoveries by fishery regulation (MSF, NSF, or mixed), percentage of all recoveries in the escapement, and the total number of CWT recoveries by brood year. Appendix Table 4 presents results of the hypothesis tests of no difference in return rates between the marked and unmarked components of the DIT groups. Appendix Table 6 provides ER estimates for the marked component of each DIT group and ER estimates for the unmarked component of each DIT group for each of the three estimation methods examined (Total, PR $\lambda^{\text {Rel }}$, and PR $\lambda^{E s c}$ ). Figures in Appendix 10 compare estimated total exploitation rates for the marked and unmarked components of the DIT groups (including 95\% confidence intervals) for each hatchery, by brood year.

### 6.1 British Columbia (BC) Region

There have been releases of Coho salmon DIT groups from two hatcheries for brood years 1998-2011 and three hatcheries for brood years 1998-2002 only (Table 6-1). Coded-wire-tag recoveries in fisheries were queried in November, 2019, from the Regional Mark Information System (RMIS, 2019) for these DIT groups. Data for DIT groups from BC hatcheries recovered during sampling in BC fisheries were supplied by CDFO with corrections to the
"adclip selective_fishery" data field in RMIS (which indicates the regulation type in the fishery). However, escapement recoveries have not been reported to RMIS since brood year 2001 and were provided by Cheryl Lynch (personal communication, Sept 2018: CDFO).

Table 6-1. Hatcheries in the British Columbia region with Coho salmon DIT groups analyzed for this report, brood years 1998-2011.

| Hatchery | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Quinsam River | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Big Qualicum River | X | X | X | X | X |  |  |  |  |  |  |  |  |  |
| Chilliwack River | X | X | X | X | X |  |  |  |  |  |  |  |  |  |
| Inch Creek | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Robertson Creek | X | X | X | X | X |  |  |  |  |  |  |  |  |  |

The numbers of Coho salmon released in the marked and unmarked components of the DIT groups from BC hatcheries were remarkably consistent across hatcheries and brood years. On average, about 40,000 fish were released in the marked and the unmarked components of DIT groups from BC hatcheries in most brood years (Table 6-2). Across all hatcheries and brood years, the minimum number released in a DIT group component was about 32,000 fish and the maximum about 50,000 fish. The consistency of the number of fish released is reflected by the coefficients of variation ${ }^{2}(\mathrm{CV})$ for the average numbers released which were $<11 \%$ for all hatcheries.

Table 6-2. Summary statistics for the number of Coho salmon with CWTs released in the marked and unmarked components of British Columbia DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | $\mathbf{C V}^{\mathbf{a}}$ |
| :---: | :--- | ---: | ---: | ---: | :---: |
| Quinsam River | Marked | 42,604 | 37,150 | 44,600 | $5.3 \%$ |
|  | Unmarked | 43,600 | 37,236 | 48,864 | $5.8 \%$ |
| Big Qualicum River | Marked | 40,983 | 38,940 | 42,566 | $3.4 \%$ |
|  | Unmarked | 40,575 | 37,275 | 42,471 | $5.0 \%$ |
| Chilliwack River | Marked | 37,916 | 35,162 | 42,795 | $8.0 \%$ |
|  | Unmarked | 37,186 | 31,851 | 42,643 | $10.8 \%$ |
| Inch Creek | Marked | 41,802 | 39,035 | 50,004 | $9.6 \%$ |
|  | Unmarked | 41,788 | 39,161 | 50,024 | $9.3 \%$ |
| Robertson Creek | Marked | 40,143 | 39,878 | 40,317 | $0.4 \%$ |
|  | Unmarked | 40,233 | 39,468 | 40,834 | $1.3 \%$ |

${ }^{\mathrm{a}} \mathrm{CV}=$ coefficient of variation.

[^9]Because BC hatcheries inspect all of the return for CWTs, no expansion is required to account for sampling (Table 6-3). This eliminates one source of variation from the return rate estimates and the estimates of marked and unmarked ERs. ETD was used for all Coho salmon sampled in the escapements to BC hatcheries; there was no visual sampling of the returning fish in these escapements (Table 6-3), removing any potential bias associated with visual sampling of the unmarked component of the returning DIT groups.

Note that a small proportion of hatchery origin fish spawned in the Chilliwack, Robertson, Quinsam and Qualicum Rivers, and were unsampled. For that small proportion of hatcheryorigin fish that spawned in the rivers, the clipped and unclipped proportions are expected to be the same as for those that swam into the hatcheries.

Table 6-3. Summary statistics for the percent of the escapement directly sampled (\% Sampled) and the proportion of the sampled fish that were sampled electronically (Prop ETD) for British Columbia DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | :---: | :---: | :---: | :---: |
|  | \% Sampled | $100.0 \%$ | $100.0 \%$ | $100.0 \%$ | $0.0 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Big Qualicum River | \% Sampled | $100.0 \%$ | $100.0 \%$ | $100.0 \%$ | $0.0 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Chilliwack River | \% Sampled | $100.0 \%$ | $100.0 \%$ | $100.0 \%$ | $0.0 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Inch Creek | \% Sampled | $100.0 \%$ | $100.0 \%$ | $100.0 \%$ | $0.0 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Robertson Creek | \% Sampled | $100.0 \%$ | $100.0 \%$ | $100.0 \%$ | $0.0 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |

Average return rates to the escapement for the marked and unmarked components of BC DIT groups varied by hatchery (Table 6-4). The expectation is that if MSFs are having a measurable impact on the unmarked component of a DIT group (i.e., reduction in the number of fishery-related mortalities), then the return rate to the hatchery will be higher for the unmarked component. Average return rates of the unmarked component were higher than the marked component for the DIT groups from all BC hatcheries. Average return rates to the Quinsam River and Big Qualicum River hatcheries were the lowest for both mark-status groups. Return rates to Robertson Creek Hatchery were relatively high and were between 3 and $9 \%$ for the five brood years analyzed. Minimum return rates for all other BC hatcheries were $<1 \%$. The return rates for DIT groups from Big Qualicum Hatchery were the most variable while the return rates for DIT groups from Robertson Creek Hatchery were the most consistent relative to the other hatcheries.

Table 6-4. Summary statistics for the return rates of Coho salmon in the marked and unmarked components of British Columbia DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | :---: | :---: | :---: | :---: |
|  | Marked | $1.20 \%$ | $0.25 \%$ | $2.03 \%$ | $42.8 \%$ |
|  | Unmarked | $1.32 \%$ | $0.29 \%$ | $2.03 \%$ | $39.1 \%$ |
| Big Qualicum River | Marked | $1.27 \%$ | $0.10 \%$ | $2.26 \%$ | $75.3 \%$ |
|  | Unmarked | $1.58 \%$ | $0.13 \%$ | $2.96 \%$ | $69.4 \%$ |
| Chilliwack River | Marked | $2.02 \%$ | $0.48 \%$ | $3.35 \%$ | $56.4 \%$ |
|  | Unmarked | $2.55 \%$ | $0.49 \%$ | $4.29 \%$ | $60.5 \%$ |
| Inch Creek | Marked | $1.84 \%$ | $0.61 \%$ | $4.42 \%$ | $61.7 \%$ |
|  | Unmarked | $2.12 \%$ | $0.71 \%$ | $5.31 \%$ | $64.3 \%$ |
| Robertson Creek | Marked | $5.60 \%$ | $3.47 \%$ | $8.06 \%$ | $37.2 \%$ |
|  | Unmarked | $6.25 \%$ | $3.37 \%$ | $8.60 \%$ | $33.0 \%$ |

The Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in $60 \%$ or more of the brood years for each hatchery, with the exception of DIT groups from Quinsam River Hatchery (Table 6-5). For all DIT groups examined from BC hatcheries, $56 \%$ of the 43 Z tests conducted were significant and all of the significant tests had $\lambda R$ ratios $\left(\frac{\lambda^{\text {Escapement }}}{\lambda^{\text {Release }}}\right)$ greater than 1.0.

Table 6-5. Percent of brood years where the $Z$ test comparing return rates of marked and unmarked DIT groups to escapement is significant ( $P \leq 0.05$ ) and positive (+YES), significant and negative (-YES), or not significant (NS), and number of brood years tested for British Columbia hatcheries and brood years 1998-2011.

| Hatchery | NS | +YES | -YES | \# of Broods |
| :--- | :---: | :---: | :---: | :---: |
| Quinsam River | $64 \%$ | $36 \%$ | $0 \%$ | 14 |
| Big Qualicum River | $40 \%$ | $60 \%$ | $0 \%$ | 5 |
| Chilliwack River | $20 \%$ | $80 \%$ | $0 \%$ | 5 |
| Inch Creek | $36 \%$ | $64 \%$ | $0 \%$ | 14 |
| Robertson Creek | $40 \%$ | $60 \%$ | $0 \%$ | 5 |
| Regional Total | $\mathbf{4 4 \%}$ | $\mathbf{5 6 \%}$ | $\mathbf{0 \%}$ | $\mathbf{4 3}$ |

$\lambda R$ ratios with approximate $95 \%$ confidence intervals (CIs) are shown for each hatchery, by brood year, in Figure 6-1. A $\lambda R$ greater than one indicates a higher removal of the marked component of the DIT group compared to the unmarked component, which is assumed to be due to the impact of MSFs. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are
indicated with an *. For the two hatcheries with an extended series (>5) of brood year releases, only the Inch Creek DIT groups show relatively consistent $\lambda R$ ratios indicating measurable impact by MSFs across the range of brood years examined. The effect of the higher return rates for DIT groups from Robertson Creek Hatchery, resulting in higher numbers of CWTs recovered from fisheries and the escapement (Table 6-6), is reflected in the much narrower 95\% CIs for the corresponding $\lambda R$ ratios.

Table 6-6. Average number of estimated CWT recoveries and general recovery location for the marked and unmarked components of British Columbia hatchery DIT groups (averaged across brood years).

| Hatchery | Mark Status | Fishery Location |  | Total Fishery |  | Escapement | Average Annual Total Recoveries |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | PreTerminal | Terminal | \# | $\%$ |  |  |
| Quinsam River | Marked | 113.1 | 33.8 | 146.9 | 21.7\% | 509.3 | 656.2 |
|  | Unmarked | 6.0 | 11.4 | 17.4 | 3.5\% | 565.2 | 582.7 |
| Big Qualicum River | Marked | 81.0 | 32.1 | 113.1 | 17.9\% | 520.4 | 633.6 |
|  | Unmarked | 3.7 | 21.5 | 25.3 | 4.8\% | 651.5 | 676.7 |
| Chilliwack River | Marked | 95.2 | 76.6 | 171.8 | 18.1\% | 778.5 | 950.3 |
|  | Unmarked | 11.4 | 14.4 | 25.7 | 4.8\% | 987.6 | 1,013.3 |
| Inch Creek | Marked | 169.4 | 138.4 | 307.9 | 23.1\% | 787.5 | 1,095.4 |
|  | Unmarked | 30.5 | 20.6 | 51.2 | 5.2\% | 906.6 | 957.7 |
| Robertson Creek | Marked | 846.1 | 52.5 | 898.6 | 25.8\% | 2,248.1 | 3,146.7 |
|  | Unmarked | 200.5 | 24.5 | 225.0 | 6.2\% | 2,516.8 | 2,741.8 |

The average (across brood years) total number of estimated CWT recoveries for each mark status ranged from about 500-700 for the Quinsam River and Big Qualicum River hatcheries to more than 2,700 for the Robertson Creek Hatchery (Table 6-6). The average percent of total (fishery plus escapement) estimated recoveries that occurred in fisheries ranged from $18 \%$ to $26 \%$ for marked fish and $3 \%$ to $6 \%$ for unmarked fish. The majority of the fishery recoveries for the marked component of the DIT groups was in pre-terminal fisheries for each of the hatcheries.


Figure 6-1. $\quad \lambda R$ ratios with approximate $95 \%$ confidence intervals for DIT groups released by British Columbia hatcheries for brood years 1998-2011. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are indicated with an *.

Figure 6-2 shows the average percentage ${ }^{3}$ of estimated CWT recoveries in fisheries (across brood years) by location (pre-terminal or terminal), gear type (sport, troll, or net), and fishery type (NSF, MSF, or Mixed) for the marked and unmarked components of each hatchery's DIT groups. Three details to note in this figure are:

- There is a measurable percentage of the recoveries that occurred in "mixed" regulation, pre-terminal sport fisheries for the marked component of DIT groups from all BC hatcheries but the Chilliwack River Hatchery. This finding may introduce unknown bias and add to the uncertainty of estimates of unmarked ERs in these fisheries as some of the fish caught in the mixed-regulation category may actually be caught under partial NSF regulations. The majority of both marked and unmarked recoveries from Robertson Creek DIT groups occurred in mixed-regulation sport fishery strata.
- For the marked component of DIT groups, the majority of the CWT recoveries occurred in pre-terminal sport fisheries while most of the recoveries for the unmarked component occurred in terminal non-selective net fisheries (with the exception of DIT groups from Robertson Creek Hatchery).
- The potential impact of fisheries with visual sampling (i.e., no ETD) can be seen by comparing the percentage of the marked DIT group recoveries that occurred in NSF sport fisheries to the percentage of the corresponding unmarked DIT groups that occurred in these same fisheries. If a large percentage of the recoveries for the marked DIT group occurred in NSF sport fisheries but a relatively small percentage of the unmarked DIT group recoveries occurred in these same fisheries then this also may be a source of unknown bias and adds to the uncertainty of estimates of unmarked ERs in these fisheries (even though the methods estimated these impacts based on recoveries of the marked component of the DIT group in the same fishery). This issue is especially evident for DIT groups from the Quinsam River, Big Qualicum River, and Chilliwack River hatcheries.


Figure 6-2. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from BC hatcheries.

[^10]

Figure 6-2. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from BC hatcheries (continued).

Major fisheries impacting BC DIT groups were sampled both electronically and visually. For the marked component of the DIT groups, in total, $79 \%$ of the total estimated CWT recoveries from fisheries were from visually-sampled fisheries (Table 6-7) with visually-sampled (VS) BC sport fisheries accounting for $75 \%$ of the recoveries. Visual sampling was the dominant CWT detection method used in the major fisheries impacting BC DIT groups. This approach results in lower recoveries of CWTs from the unmarked component of DIT groups and potentially introduces bias. Also, approximately $30 \%$ of all marked DIT-group recoveries were in mixed-regulation, VS sport fisheries in BC, i.e., there was no information on whether a CWT was recovered in a MSF or NSF. This lack of information may also introduce unknown bias and add to the uncertainty of estimates of unmarked ERs in these fisheries ${ }^{4}$.

Table 6-7. Percentage of all estimated CWT recoveries of marked fish associated with DIT groups released from BC hatcheries (brood years 1998-2011) by detection method (electronic or visual) and fishery type (NSF, MSF, Mixed).

| Region Fishery | Electronically Sampled |  |  | Visually Sampled |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | NSF | MSF | Total | NSF | MSF | Mixed | Total |
| Alaska |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.30\% | 0.00\% | 0.00\% | 0.30\% |
| Sport | 0.00\% | 0.00\% | 0.00\% | 0.16\% | 0.00\% | 0.00\% | 0.16\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 2.13\% | 0.00\% | 0.00\% | 2.13\% |
| British Columbia |  |  |  |  |  |  |  |
| Net | 0.01\% | 1.72\% | 1.73\% | 0.01\% | 0.00\% | 0.00\% | 0.01\% |
| Sport | 0.16\% | 0.19\% | 0.35\% | 6.29\% | 38.56\% | 30.02\% | 74.88\% |
| Troll | 0.74\% | 0.27\% | 1.01\% | 0.99\% | 0.36\% | 0.00\% | 1.35\% |
| Puget Sound |  |  |  |  |  |  |  |
| Net | 3.14\% | 0.00\% | 3.14\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.57\% | 5.42\% | 5.99\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Washington Coast |  |  |  |  |  |  |  |
| Sport | 0.11\% | 5.02\% | 5.13\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 3.37\% | 0.00\% | 3.37\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Oregon Coast |  |  |  |  |  |  |  |
| Sport | 0.00\% | 0.05\% | 0.05\% | 0.14\% | 0.26\% | 0.00\% | 0.40\% |
| Troll | 0.00\% | 0.02\% | 0.02\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Totals | 8.09\% | 12.69\% | 20.78\% | 10.02\% | 39.18\% | 30.02\% | 79.22\% |

[^11]A large percentage of DIT group recoveries from BC hatchery releases were taken in VS fisheries, including some VS NSFs. To estimate unmarked recoveries in NSFs with no ETD, recoveries for the associated marked component of the DIT group were multiplied by the unmarked-to-marked ratio at release (see Paired-Ratio method in Section 3.2). Table 6-8 shows that estimated unmarked recoveries in VS NSFs were a very large percentage of Quinsam River Hatchery recoveries (about 78\%), whereas in other BC hatcheries they represent $12-21 \%$ of all unmarked recoveries. More than $60 \%$ of the fishery recoveries for both the marked ( $66 \%$ ) and unmarked ( $71 \%$ ) DIT group components from Robertson Creek Hatchery occurred in VS, mixed-regulation fisheries. For other BC hatcheries, the percentage of fishery recoveries occurring in mixed-regulation fisheries ranged from 0 to $14 \%$ for the marked component of BC DIT groups. For the marked component of DIT groups from BC hatcheries, the percentage of total estimated CWT recoveries occurring in MSFs, across all brood years, ranged from $28 \%$ for Robertson Creek Hatchery to $88 \%$ for Chilliwack River Hatchery.

Figure 6-3 compares total exploitation rates estimated by the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$ (Section 3.2) for the marked and unmarked ${ }^{5}$ components of the DIT groups from each hatchery for each brood year. Years when the Z test comparing the return rates to the escapement of the marked and unmarked components of a DIT group was significant are indicated with an *. The proportion of the estimated unmarked ER occurring in MSFs is also shown. The estimated unmarked ER is always less than the marked ER across all hatcheries and brood years for BC DIT groups. Figure 10A in (Appendix 10) compares ER estimates for the marked and unmarked components of the BC DIT groups by hatchery and brood year (with approximate $95 \%$ confidence intervals for the estimates). For the two hatcheries with an extended time series of DIT group releases (Quinsam River and Inch Creek), there is no indication of long-term trends in ERs. Patterns in marked group ERs are similar for these two hatcheries with peaks for the 2001, 2004, 2006, and 2010 brood years. Peaks in unmarked ER did not always correspond to the peaks in the marked ER. Generally, a higher proportion of the unmarked ER was estimated to occur in MSFs for Inch Creek DIT groups compared to Quinsam River DIT groups.

The unmarked ER is consistently lower than the marked ER for all DIT groups and brood years. For a DIT group, differences between the marked and unmarked ER estimates ranged from +0.006 to +0.347 (Table 6-9). Across all hatcheries and brood years, the estimated ER for the marked component of the DIT groups was, on average, +0.116 greater than the ER for the unmarked component. For $100 \%$ of the DIT groups analyzed from the BC region, the estimated ER for the marked component was greater than the ER estimated for the unmarked component.

[^12]Table 6-8. Percentage of DIT recoveries in fisheries with electronic sampling (ETD) and without electronic sampling (Visual), by fishery type. Unmarked recoveries in NSFs without electronic sampling are estimated (Estimated). Bold number is total number of estimated recoveries in fisheries for DIT groups released from BC hatcheries for the 1998-2011 brood years.

| Hatchery | Fishery Type | Marked Component |  |  | Unmarked Component |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | ETD <br> Sample | Visual Sample | Total | ETD <br> Sample | Visual Sample | Estimated | Total |
| Quinsam River |  |  |  |  |  |  |  |  |
|  | NSF | 6.1\% | 42.5\% | 48.7\% | 8.2\% | 0.0\% | 78.4\% | 86.7\% |
|  | MSF | 3.5\% | 37.2\% | 40.7\% | 2.1\% | 10.8\% | 0.0\% | 13.0\% |
|  | Mixed | 0.0\% | 10.7\% | 10.7\% | 0.0\% | 0.4\% | 0.0\% | 0.4\% |
|  | Total | 9.6\% | 90.4\% | 2,056.7 | 10.4\% | 11.2\% | 78.4\% | 1,132.5 |

Biq Qualicum River

|  | NSF | $9.7 \%$ | $6.1 \%$ | $15.8 \%$ | $43.9 \%$ | $0.0 \%$ | $21.2 \%$ | $65.1 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $16.0 \%$ | $53.9 \%$ | $69.9 \%$ | $6.4 \%$ | $28.5 \%$ | $0.0 \%$ | $34.9 \%$ |
|  | Mixed | $0.0 \%$ | $14.3 \%$ | $14.3 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $25.7 \%$ | $74.3 \%$ | $\mathbf{5 6 5 . 7}$ | $50.3 \%$ | $28.5 \%$ | $21.2 \%$ | $\mathbf{1 6 0 . 2}$ |

Chilliwack River

|  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $8.8 \%$ | $3.0 \%$ | $11.7 \%$ | $73.6 \%$ | $0.0 \%$ | $16.0 \%$ | $89.6 \%$ |
|  | MSF | $30.2 \%$ | $58.1 \%$ | $88.3 \%$ | $4.0 \%$ | $6.4 \%$ | $0.0 \%$ | $10.4 \%$ |
|  | Mixed | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
| Total | $39.0 \%$ | $61.0 \%$ | $\mathbf{8 5 9 . 0}$ | $77.6 \%$ | $6.4 \%$ | $16.0 \%$ | $\mathbf{1 5 3 . 1}$ |  |

Inch Creek

|  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $15.2 \%$ | $2.1 \%$ | $17.4 \%$ | $75.8 \%$ | $0.5 \%$ | $11.5 \%$ | $87.8 \%$ |
|  | MSF | $17.3 \%$ | $55.1 \%$ | $72.4 \%$ | $10.9 \%$ | $1.3 \%$ | $0.0 \%$ | $12.2 \%$ |
|  | Mixed | $0.0 \%$ | $10.3 \%$ | $10.3 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $32.5 \%$ | $67.5 \%$ | $\mathbf{4 , 3 1 0 . 5}$ | $86.7 \%$ | $1.8 \%$ | $11.5 \%$ | $\mathbf{8 0 9 . 1}$ |

Robertson Creek

|  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $1.9 \%$ | $4.5 \%$ | $6.4 \%$ | $4.4 \%$ | $0.0 \%$ | $15.4 \%$ | $19.9 \%$ |
|  | MSF | $8.7 \%$ | $19.3 \%$ | $28.0 \%$ | $8.9 \%$ | $0.0 \%$ | $0.0 \%$ | $8.9 \%$ |
|  | Mixed | $0.0 \%$ | $65.6 \%$ | $65.6 \%$ | $0.0 \%$ | $71.2 \%$ | $0.0 \%$ | $71.2 \%$ |
| Total | $10.6 \%$ | $89.4 \%$ | $\mathbf{4 , 4 9 2 . 9}$ | $13.4 \%$ | $71.2 \%$ | $15.4 \%$ | $\mathbf{1 , 3 3 0 . 2}$ |  |



Figure 6-3. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by British Columbia hatcheries for brood years 1998-2011.


Figure 6-3. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by British Columbia hatcheries for brood years 1998-2011 (continued).

Table 6-9. Average difference between the estimated exploitation rates (ER) for the marked and unmarked components of BC DIT groups. Unmarked ER estimated using the PR method with $\lambda$ at release.

|  | Number | Difference Marked ER - Unmarked ER |  |  |
| :--- | :---: | :---: | :---: | :---: |
| Hatchery | of Years | Mean | Minimum | Maximum |
| Quinsam River | 14 | 0.078 | 0.018 | 0.147 |
| Big Qualicum River | 5 | 0.106 | 0.006 | 0.154 |
| Chilliwack River | 5 | 0.111 | 0.045 | 0.170 |
| Inch Creek | 14 | 0.144 | 0.054 | 0.347 |
| Robertson Creek | 5 | 0.160 | 0.055 | 0.220 |
| Regional Total | $\mathbf{4 3}$ | $\mathbf{0 . 1 1 6}$ | $\mathbf{0 . 0 0 6}$ | $\mathbf{0 . 3 4 7}$ |

### 6.1.1 Conclusions and Recommendations for British Columbia Hatchery DIT Groups

- The CWT sampling of Coho returning to BC hatcheries was very rigorous. Virtually all returning Coho were directly sampled and all sampling was done using ETD.
- For all DIT groups examined from BC hatcheries, $56 \%$ of the 43 Z tests conducted were significant and all of the significant tests had $\lambda R$ ratios $>1.0$ (i.e., the return rate of the unmarked component was significantly greater than for the marked component indicating a measurable impact of MSFs).
- About $75 \%$ of the estimated CWT recoveries from fisheries for the marked component of British Columbia DIT groups were from visually-sampled sport fisheries in British Columbia. These fisheries were predominantly mark-selective (39\% of recoveries) and mixed-regulation ( $30 \%$ of recoveries) fisheries.
- Almost $80 \%$ of the fishery impacts to the unmarked component of the DIT group from Quinsam River Hatchery occurred in visually-sampled NSFs. Therefore, the impacts from these fisheries on the unmarked component must be estimated based on either $\lambda^{\text {Rel }}$ or $\lambda^{E s c}$ and recoveries from the marked component of the DIT group. This may be a potential source of bias and adds uncertainty to the estimates for these DIT groups.
- Fishery recoveries from Robertson Creek Hatchery DIT groups occurred primarily in sport fisheries identified as mixed regulation ( $66 \%$ of marked recoveries and $71 \%$ of unmarked recoveries) where it is unknown whether the recovery could be attributed to a MSF or NSF. These mixed-regulation fisheries are not sampled electronically. This again may be a potential source of bias and adds uncertainty to the estimates for these DIT groups.
- CWT recoveries from mixed-regulation fishery strata is a potential issue affecting almost all the BC DIT groups examined. Except for the DIT groups from the Chilliwack River Hatchery, more than $10 \%$ of the recoveries for the marked component of DIT groups from the other BC hatcheries was in mixed-regulation fishery strata.
- Although the ER for the marked component of the DIT groups from BC hatcheries was, on average, +0.116 greater than the ER for the unmarked component of the DIT group, this difference should be viewed with caution because of possible biases in the estimated ER of the unmarked component resulting from visual sampling in BC fisheries, and the large proportion of recoveries from mixed-regulation fishery strata in the BC region.
- MSFs appeared to be effective in decreasing the exploitation rate on unmarked Coho stocks represented by the DIT groups for the BC region. The ER for the unmarked component of the DIT group was consistently estimated to be less than the ER for the marked component for all the DIT groups.


## Recommendations

It is difficult to fully evaluate the DIT programs from the Big Qualicum River, Chilliwack River, and Robertson Creek hatcheries because there were only five brood years of DIT group data available, and the brood years were in the early period of MSF implementation. However, because such a high proportion of the fishery recoveries from the Robertson Creek Hatchery occurred in mixed-regulation fisheries which were not electronically sampled, the ER estimates from that program should be viewed cautiously. For any future Robertson Creek DIT programs to be useful would require that this issue be addressed.

The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

1. Data for the DIT groups from Inch Creek Hatchery provided the most consistent and reliable estimates of marked and unmarked ER in comparison to the other BC hatcheries.
a. The Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in 64\% of the brood years.
b. Estimated total recoveries averaged about 1,000 for each brood year for both the marked and unmarked components of the DIT groups.
c. $\lambda R$ ratios that were greater than 1.0 and had $95 \%$ CIs that did not include 1.0 occurred across the range of brood years analyzed.
d. The average difference between ERs for the marked and unmarked components of the DIT groups (+0.144) was the second largest of the BC DIT groups analyzed.
e. The ER for the marked component was higher than that of the unmarked component for all 14 of the brood years examined.
f. For seven of the 14 brood years analyzed, the estimated ER for the unmarked component of the DIT group was less than for the marked component and the two estimates had non-overlapping $95 \%$ confidence intervals.

The following DIT program(s) have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:

1. Data and reliable estimates for the DIT groups from Quinsam River Hatchery are challenged by a number of issues.
a. Return rates for Quinsam River Hatchery DIT groups were, on average, the lowest of the BC hatcheries examined.
b. The Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish)
for only $36 \%$ of the brood years; this was the lowest percentage for any of the BC hatcheries examined.
c. There were relatively few $\lambda R$ ratios > 1.0 which had $95 \%$ CIs that did not include 1.0 and most of those that did occurred in the first half of the time series of brood years examined.
d. A very high percentage $(\approx 43 \%)$ of the fishery recoveries for the marked component of DIT groups from Quinsam River Hatchery occurred in visuallysampled NSFs. Therefore, the number of unmarked recoveries in these NSFs had to be estimated based on the marked recoveries. For Quinsam River Hatchery, $78 \%$ of the total recoveries of the unmarked component of DIT groups were estimated to occur in the visually-sampled NSFs. This is a potential source of bias and adds uncertainty to the estimates for these DIT groups.
e. The average difference between ERs for the marked and unmarked components of the DIT groups $(+0.078)$ was the smallest of the BC DIT groups analyzed.
f. While the estimated ER for the marked component was higher than that of the unmarked component for all 14 of the brood years examined, the $95 \%$ confidence intervals for the estimates always overlapped.

### 6.2 Puget Sound (PS) Region

There are eight hatcheries in the Puget Sound region which had DIT groups analyzed (Table 6-10). All hatcheries except Kendall Creek had DIT-group releases for brood years 19982011; Kendall Creek only had DIT-group releases for the 1998-2007 brood years.

Table 6-10. Hatcheries in the Puget Sound region with Coho salmon DIT groups analyzed for this report, brood years 1998-2011.

| Hatchery | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Lower Elwha | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Kendall Creek | X | X | X | X | X | X | X | X | X | X |  |  |  |  |
| Marblemount | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Wallace River | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Soos Creek | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Voights Creek | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| George Adams | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Quilcene NFH | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Average numbers of Coho salmon released in the marked and unmarked components of the DIT groups from PS hatcheries were generally similar across hatcheries and averaged $\approx 42,000-45,000$ fish (Table 6-11). The exception was the Lower Elwha Hatchery which averaged about 75,000 fish released each brood year for both the marked and unmarked groups. Across all hatcheries and brood years, the minimum number released in a DIT group component was about 20,000 fish (Quilcene NFH) and the maximum about 83,000 fish (Lower Elwha Hatchery). Fairly consistent numbers of fish were released annually for the DIT groups from all hatcheries (CVs for the average number released < 16\%) except for Quilcene NFH which had CVs of $\approx 25 \%$ and had a range of numbers released from 20,00070,000 fish.

Sub-sampling the escapement was common for PS hatcheries. Across brood years, the average percentage of the Coho in the escapement that were directly sampled ${ }^{6}$ ranged from $\approx 62 \%$ to $94 \%$ (Table 6-12). All PS hatcheries except the Lower Elwha and George Adams hatcheries had at least one brood year where less than half ( $50 \%$ ) of the escapement was directly sampled. Sub-sampling the escapement requires expansion factors to expand observed CWTs recovered into total estimated CWTs in the escapement to the hatchery or spawning grounds. This adds variation to the estimates of the return rate and estimates of marked and unmarked ERs. ETD was used on more than $99.5 \%$ of the directly-sampled Coho

[^13](Table 6-12). This practice removes any potential bias associated with visual sampling of the unmarked component of the returning DIT groups.

Table 6-11. Summary statistics for the number of Coho salmon with CWTs released in the marked and unmarked components of Puget Sound DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | $\mathbf{C V}^{\mathbf{a}}$ |
| :---: | :--- | ---: | ---: | ---: | ---: |
| Lower Elwha | Marked | 75,229 | 62,465 | 82,395 | $8.1 \%$ |
|  | Unmarked | 73,825 | 51,084 | 83,081 | $11.8 \%$ |
| Kendall Creek | Marked | 46,821 | 43,242 | 49,402 | $4.6 \%$ |
|  | Unmarked | 47,769 | 45,254 | 49,700 | $3.3 \%$ |
| Marblemount | Marked | 45,817 | 39,635 | 69,844 | $15.9 \%$ |
|  | Unmarked | 43,056 | 32,421 | 47,206 | $8.4 \%$ |
| Wallace River | Marked | 42,887 | 30,182 | 47,762 | $10.2 \%$ |
|  | Unmarked | 43,273 | 30,300 | 48,378 | $10.0 \%$ |
| Soos Creek | Marked | 43,584 | 34,055 | 47,334 | $7.5 \%$ |
|  | Unmarked | 45,331 | 36,440 | 56,293 | $8.8 \%$ |
| Voights Creek | Marked | 44,203 | 28,136 | 56,863 | $13.8 \%$ |
|  | Unmarked | 43,959 | 28,181 | 47,680 | $10.9 \%$ |
| George Adams | Marked | 44,603 | 41,584 | 49,399 | $4.1 \%$ |
|  | Unmarked | 45,286 | 41,288 | 53,098 | $7.3 \%$ |
| Quilcene NFH | Marked | 42,659 | 20,699 | 71,292 | $26.1 \%$ |
|  | Unmarked | 42,477 | 20,476 | 70,746 | $25.4 \%$ |

${ }^{\mathrm{a}} \mathrm{CV}=$ coefficient of variation.

Average return rates to the escapement for the marked and unmarked components of PS DIT groups varied by hatchery (Table 6-13). The expectation is that if MSFs are having a measurable impact on the unmarked component of a DIT group (i.e., reduction in the number of fishery-related mortalities), the return rate to the hatchery will be higher for the unmarked component. Average return rates of the unmarked component were slightly higher than the marked component for the DIT groups from all PS hatcheries except the Soos Creek Hatchery. Average return rates to the Lower Elwha and Kendall Creek hatcheries were the lowest at < $1.0 \%$. Average return rates to Wallace River Hatchery were relatively high at $\approx 4.5 \%$. Minimum return rates to Wallace River Hatchery were $>1.4 \%$; for all other PS hatcheries the minimum return rates were $<0.7 \%$. DIT group return rates to the Lower Elwha, Kendall Creek, and Voights Creek were highly variable with CVs $>75 \%$ relative to the averages.

Table 6-12. Summary statistics for the percent of the escapement directly sampled (\% Sampled) and the proportion of the sampled fish that were sampled electronically (Prop ETD) for Puget Sound DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | ---: | ---: | ---: | ---: |
|  | \% Sampled | $93.9 \%$ | $65.3 \%$ | $99.9 \%$ | $10.1 \%$ |
|  | Prop ETD | 1.000 | 0.999 | 1.000 | $0.0 \%$ |
| Kendall Creek | \% Sampled | $74.0 \%$ | $30.9 \%$ | $100.0 \%$ | $31.3 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Marblemount | \% Sampled | $71.5 \%$ | $35.1 \%$ | $100.0 \%$ | $35.3 \%$ |
|  | Prop ETD | 1.000 | 0.998 | 1.000 | $0.1 \%$ |
| Wallace River | \% Sampled | $73.4 \%$ | $31.6 \%$ | $99.8 \%$ | $37.7 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Soos Creek | \% Sampled | $75.0 \%$ | $45.7 \%$ | $100.0 \%$ | $23.3 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Voights Creek | \% Sampled | $72.8 \%$ | $25.0 \%$ | $98.0 \%$ | $26.8 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| George Adams | \% Sampled | $88.1 \%$ | $67.4 \%$ | $100.0 \%$ | $12.2 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Quilcene NFH | \% Sampled | $61.9 \%$ | $20.5 \%$ | $95.5 \%$ | $38.4 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |

Table 6-13. Summary statistics for the return rates of Coho salmon in the marked and unmarked components of Puget Sound DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | ---: | ---: | ---: | :---: |
| Lower Elwha | Marked | $0.28 \%$ | $0.03 \%$ | $0.81 \%$ | $85.3 \%$ |
|  | Unmarked | $0.29 \%$ | $0.02 \%$ | $0.80 \%$ | $79.7 \%$ |
| Kendall Creek | Marked | $0.72 \%$ | $0.06 \%$ | $2.49 \%$ | $112.3 \%$ |
|  | Unmarked | $0.74 \%$ | $0.07 \%$ | $2.38 \%$ | $101.3 \%$ |
| Marblemount | Marked | $3.04 \%$ | $0.46 \%$ | $4.94 \%$ | $38.7 \%$ |
|  | Unmarked | $3.21 \%$ | $0.45 \%$ | $5.25 \%$ | $39.3 \%$ |
| Wallace River | Marked | $4.50 \%$ | $1.44 \%$ | $7.65 \%$ | $38.8 \%$ |
|  | Unmarked | $4.70 \%$ | $1.57 \%$ | $7.45 \%$ | $38.5 \%$ |
| Soos Creek | Marked | $2.48 \%$ | $0.69 \%$ | $4.69 \%$ | $44.5 \%$ |
|  | Unmarked | $2.46 \%$ | $0.64 \%$ | $4.58 \%$ | $50.2 \%$ |
| Voights Creek | Marked | $1.61 \%$ | $0.10 \%$ | $4.28 \%$ | $77.4 \%$ |
|  | Unmarked | $1.62 \%$ | $0.08 \%$ | $4.22 \%$ | $80.4 \%$ |
| George Adams | Marked | $2.61 \%$ | $0.61 \%$ | $5.02 \%$ | $56.7 \%$ |
|  | Unmarked | $2.65 \%$ | $0.58 \%$ | $5.51 \%$ | $62.1 \%$ |
| Quilcene NFH | Marked | $1.90 \%$ | $0.41 \%$ | $3.76 \%$ | $53.6 \%$ |


|  | Unmarked | $2.07 \%$ | $0.30 \%$ | $4.12 \%$ |
| :--- | :--- | :---: | :---: | :---: | group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in less than $30 \%$ of the brood years for each hatchery, with the exception of releases from Wallace River Hatchery where $43 \%$ of the tests were significant and positive (Table 6-2E). For all DIT groups examined from PS hatcheries, only $32 \%$ of the 108 Z tests conducted returned a significant result and only $24 \%$ of the test results were both significant and had a $\lambda R$ ratio $>1.0$.

Figure 6-4 shows $\lambda R$ ratios with approximate $95 \%$ confidence intervals (CIs) for each hatchery, by brood year. Brood years with a significant ( $P \leq 0.05$ ) Z test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are indicated with an *. The effect of the lower return rates for DIT groups from the Lower Elwha and Kendall Creek hatcheries, resulting in lower numbers of CWTs recovered in the escapement (Table 6-14), is reflected in the much wider $95 \%$ CIs for the corresponding $\lambda R$ ratios. In comparison, the $95 \%$ confidence interval widths for the Marblemount, Wallace River, Soos Creek, and George Adams hatcheries are narrower because their higher return rates result in larger number of CWTs recovered (> 1,000 tags recovered annually at the hatchery or on the spawning grounds on average). Based on $\lambda R$ ratios, there is little indication of annually consistent measurable impact by MSFs on Puget Sound DIT groups. The possible exception may be for DIT groups from Wallace River Hatchery where 6 of the 14 brood years had a significant Z test $(P \leq 0.05)$ with a $\lambda R$ ratio $>1.0$ and $50 \%$ of the $\lambda R$ ratios were $>1.0$ and had $95 \%$ CIs that did not include 1.0.

Table 6-14. Percent of brood years where the $Z$ test comparing return rates of marked and unmarked DIT groups to escapement is significant ( $P \leq 0.05$ ) and positive (+YES), significant and negative (-YES), or not significant (NS), and number of brood years tested for Puget Sound hatcheries and brood years 1998-2011.

| Hatchery | NS | +YES | -YES | \# of Broods |
| :--- | :---: | :---: | :---: | :---: |
| Lower Elwha | $57 \%$ | $29 \%$ | $14 \%$ | 14 |
| Kendall Creek | $90 \%$ | $10 \%$ | $0 \%$ | 10 |
| Marblemount | $71 \%$ | $29 \%$ | $0 \%$ | 14 |
| Wallace River | $50 \%$ | $43 \%$ | $7 \%$ | 14 |
| Soos Creek | $72 \%$ | $21 \%$ | $7 \%$ | 14 |
| Voights Creek | $72 \%$ | $14 \%$ | $14 \%$ | 14 |
| George Adams | $72 \%$ | $14 \%$ | $14 \%$ | 14 |
| Quilcene NFH | $64 \%$ | $29 \%$ | $7 \%$ | 14 |
| Regional Total | $68 \%$ | $24 \%$ | $8 \%$ | 108 |



Figure 6-4. $\quad \lambda R$ ratios with approximate $95 \%$ confidence intervals for DIT groups released by Puget Sound hatcheries for brood years 1998-2011. Brood years with a significant ( $P \leq 0.05$ ) Z test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are indicated with an *.


Figure 6-4 $\quad \lambda R$ ratios with approximate $95 \%$ confidence intervals for DIT groups released by Puget Sound hatcheries for brood years 1998-2011 (continued).

The average number of estimated CWT recoveries (marked or unmarked) from individual PS hatchery DIT groups ranged from a low of 320 and 274, respectively, for Lower Elwha Hatchery releases to more than 2,000 recoveries for both marked and unmarked DIT groups from the Marblemount, Wallace River, and Soos Creek hatcheries (Table 6-15). The average percent of total (fishery plus escapement) estimated recoveries (across brood years) that occurred in fisheries ranged from $23 \%$ to $75 \%$ for marked fish and $13 \%$ to $69 \%$ for unmarked fish. The majority of the fishery recoveries for the marked component of the DIT groups was in pre-terminal fisheries for the Lower Elwha, Marblemount, Wallace River, and George Adams DIT groups. In contrast, the majority of the fishery recoveries for the marked component of the DIT groups was in terminal fisheries for the Kendall Creek, Soos Creek, Voights Creek, and Quilcene hatcheries.

Figure 6-5 shows the average percentage (across brood years) of estimated CWT recoveries in fisheries by location (pre-terminal or terminal), gear type (sport, troll, or net), and fishery type (NSF, MSF, or Mixed) for the marked and unmarked components of each hatchery's DIT groups. Three details to note in this figure are:

- There is a measurable but small percentage of the recoveries that occurred in "mixed" regulation, pre-terminal sport fisheries for the marked component of DIT groups from all PS hatcheries. Corresponding unmarked recoveries in mixed-regulation fisheries are estimated identically to those from MSFs for the analyses in this report. This approach may introduce unknown bias and add to the uncertainty of estimates of unmarked ERs in these fisheries as some of the fish caught in the mixed-regulation category may actually be caught under partial NSF regulations.
- For the marked component of the DIT groups, the majority of the CWT recoveries occurred in pre-terminal sport fisheries and terminal net fisheries while the majority ( $>60 \%$ ) of the recoveries for the unmarked component occurred in terminal nonselective net fisheries for the DIT groups from all hatcheries except Wallace River.

For Wallace River Hatchery DIT groups, most of the recoveries from the unmarked component of the DIT groups were in pre-terminal non-selective sport fisheries followed by non-selective terminal net fisheries.

Table 6-15. Average number of estimated CWT recoveries and general recovery location for the marked and unmarked components of Puget Sound hatchery DIT groups (averaged across brood years).

| Hatchery | Mark Status | Fishery Location |  | Total Fishery |  | Escapement | Total Recoveries |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Pre- <br> Terminal | Terminal | \# | \% |  |  |
| Lower Elwha | Marked | 56.3 | 54.3 | 110.6 | 35.8\% | 209.7 | 320.3 |
|  | Unmarked | 10.5 | 49.5 | 60.0 | 19.4\% | 214.2 | 274.2 |
| Kendall Creek | Marked | 171.7 | 597.8 | 769.5 | 74.7\% | 322.2 | 1,091.7 |
|  | Unmarked | 31.3 | 615.6 | 646.9 | 68.6\% | 349.1 | 996.0 |
| Marblemount | Marked | 550.5 | 521.7 | 1,072.2 | 42.8\% | 1,390.3 | 2,462.6 |
|  | Unmarked | 201.3 | 473.2 | 674.5 | 34.5\% | 1,369.8 | 2,044.3 |
| Wallace River | Marked | 483.7 | 88.1 | 571.8 | 22.8\% | 1,907.9 | 2,479.7 |
|  | Unmarked | 205.9 | 82.0 | 287.9 | 12.8\% | 2,009.4 | 2,297.4 |
| Soos Creek | Marked | 447.9 | 789.6 | 1,237.6 | 52.1\% | 1,063.1 | 2,300.6 |
|  | Unmarked | 213.2 | 883.1 | 1,096.3 | 48.7\% | 1,106.1 | 2,202.4 |
| Voights Creek | Marked | 317.0 | 495.8 | 812.9 | 57.2\% | 681.4 | 1,494.3 |
|  | Unmarked | 117.5 | 510.5 | 628.0 | 51.1\% | 688.4 | 1,316.5 |
| George Adams | Marked | 263.9 | 256.1 | 520.0 | 33.7\% | 1,167.2 | 1,687.2 |
|  | Unmarked | 88.0 | 243.4 | 331.5 | 26.4\% | 1,201.2 | 1,532.7 |
| Quilcene NFH | Marked | 357.6 | 581.3 | 938.9 | 55.3\% | 786.2 | 1,725.1 |
|  | Unmarked | 126.8 | 641.8 | 768.6 | 48.7\% | 852.2 | 1,620.8 |

- The potential impact of fisheries with visual sampling (i.e., no ETD) can be seen by comparing the percentage of the marked DIT group recoveries that occurred in NSFs to the percentage of the corresponding unmarked DIT groups that occurred in these same fisheries. For PS DIT groups, the percentage of recoveries from the unmarked component of the DIT group is about equal to or greater than the percentage for the corresponding marked group. Therefore, potential bias due to visually-sampled fisheries does not appear to be an issue with PS DIT groups.

The major fisheries impacting PS DIT groups primarily used electronic sampling. For the marked component of these DIT groups, in total, $91 \%$ of the total estimated recoveries from fisheries were by sampling programs with ETD (Table 6-16); visually-sampled fisheries accounted for only $9 \%$ of the estimated recoveries. About $79 \%$ of all marked fish recoveries for Puget Sound DIT groups were in electronically sampled fisheries in Puget Sound; over $50 \%$ of these recoveries were in Puget Sound non-selective net fisheries. Only 4\% of the
recoveries from the marked component of PS DIT groups occurred in mixed-regulation fishery strata.


Figure 6-5. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from PS hatcheries.


Figure 6-5. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from PS hatcheries (continued).

Table 6-16. Percentage of all estimated CWT recoveries of marked fish associated with DIT groups released from PS hatcheries (brood years 1998-2011) by detection method (electronic or visual) and fishery type (NSF, MSF, Mixed).

| Region Fishery | Electronically Sampled |  |  |  | Visually Sampled |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | NSF | MSF | Mixed | Total | NSF | MSF | Mixed | Total |
| Alaska |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.02\% | 0.00\% | 0.00\% | 0.02\% |
| Sport | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.12\% | 0.00\% | 0.00\% | 0.12\% |
| British Columbia |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.07\% | 0.16\% | 0.00\% | 0.23\% | 0.33\% | 3.44\% | 3.36\% | 7.12\% |
| Troll | 0.01\% | 0.01\% | 0.31\% | 0.32\% | 0.05\% | 0.02\% | 0.00\% | 0.07\% |
| Puget Sound |  |  |  |  |  |  |  |  |
| Net | 54.56\% | 0.00\% | 0.00\% | 54.56\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 13.15\% | 11.10\% | 0.00\% | 24.25\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Washington Coast |  |  |  |  |  |  |  |  |
| Net | 0.02\% | 0.00\% | 0.00\% | 0.02\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.09\% | 7.92\% | 0.00\% | 8.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 3.26\% | 0.56\% | 0.00\% | 3.82\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Oregon Coast and Columbia River |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.01\% | 0.00\% | 0.01\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.03\% | 0.18\% | 0.00\% | 0.21\% | 0.01\% | 1.09\% | 0.00\% | 1.09\% |
| Troll | 0.02\% | 0.00\% | 0.00\% | 0.02\% | 0.13\% | 0.02\% | 0.00\% | 0.15\% |
| Totals | 71.19\% | 19.93\% | 0.31\% | 91.43\% | 0.65\% | 4.57\% | 3.36\% | 8.57\% |

About $90 \%$ percent or more of the estimated CWT recoveries in all fisheries, for both the marked and unmarked components of DIT groups, were in electronically-sampled fisheries for the Kendall Creek, Marblemount, Soos Creek, Voights Creek, George Adams, and Quilcene hatcheries (Table 6-17). For the PS region, DIT groups from the Lower Elwha Hatchery had the lowest percentage of recoveries in ETD fisheries with $76 \%$ for the marked and $84 \%$ for the unmarked component of the DIT groups. For the marked component of DIT groups from PS hatcheries, the percentage of the estimated CWT recoveries that occurred in mixed-regulation fisheries ranged from 1.6 to $6.4 \%$. Estimated recoveries for unmarked DIT groups in VS NSFs were < $2.5 \%$ for all hatcheries except for the Lower Elwha Hatchery $(14.2 \%)$. For the marked component of DIT groups from PS hatcheries, the percentage of total estimated CWT recoveries occurring in MSFs, across all brood years, ranged from $13 \%$ for Kendall Creek Hatchery to $47 \%$ for Wallace River Hatchery.

Table 6-17. Percentage of DIT recoveries in fisheries with electronic sampling (ETD) and without electronic sampling (Visual), by fishery type. Unmarked recoveries in NSFs without electronic sampling are estimated (Estimated). Bold number is
total number of estimated recoveries in fisheries for DIT groups released from PS hatcheries for the 1998-2011 brood years.

|  |  | Mark | d Comp | nent |  | marked | Compone |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Fishery Type | ETD Sample | Visual <br> Sample |  | ETD <br> Sample | Visual <br> Sample | Estimated | Total |
| Lower Elwha |  |  |  |  |  |  |  |  |
|  | NSF | 57.4\% | 9.0\% | 66.4\% | 83.4\% | 0.6\% | 14.2\% | 98.2\% |
|  | MSF | 18.9\% | 8.3\% | 27.1\% | 0.9\% | 0.0\% | 0.0\% | 0.9\% |
|  | Mixed | 0.0\% | 6.4\% | 6.4\% | 0.0\% | 0.8\% | 0.0\% | 0.8\% |
|  | Total | 76.3\% | 23.7\% | 1,548.8 | 84.4\% | 1.4\% | 14.2\% | 979.1 |


| Kendall Creek |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $80.5 \%$ | $0.4 \%$ | $80.9 \%$ | $98.5 \%$ | $0.0 \%$ | $0.5 \%$ | $98.9 \%$ |
|  | MSF | $11.5 \%$ | $1.8 \%$ | $13.3 \%$ | $1.0 \%$ | $0.1 \%$ | $0.0 \%$ | $1.1 \%$ |
|  | Mixed | $3.2 \%$ | $2.6 \%$ | $5.8 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $95.2 \%$ | $4.8 \%$ | $\mathbf{7 , 6 9 5 . 4}$ | $99.5 \%$ | $0.1 \%$ | $0.5 \%$ | $\mathbf{6 , 4 9 9 . 1}$ |


| Marblemount |  |  |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $66.6 \%$ | $0.1 \%$ | $66.8 \%$ | $98.4 \%$ | $0.1 \%$ | $0.2 \%$ | $98.6 \%$ |
|  | MSF | $23.1 \%$ | $5.3 \%$ | $28.4 \%$ | $1.2 \%$ | $0.1 \%$ | $0.0 \%$ | $1.3 \%$ |
|  | Mixed | $0.0 \%$ | $4.9 \%$ | $4.9 \%$ | $0.0 \%$ | $0.1 \%$ | $0.0 \%$ | $0.1 \%$ |
|  | Total | $89.8 \%$ | $10.2 \%$ | $\mathbf{1 5 , 0 1 1 . 3}$ | $99.6 \%$ | $0.2 \%$ | $0.2 \%$ | $\mathbf{9 , 4 5 8 . 4}$ |
| Wallace River |  |  |  |  |  |  |  |  |
|  | $\mathbf{N S F}$ | $47.9 \%$ | $0.8 \%$ | $48.7 \%$ | $95.1 \%$ | $0.0 \%$ | $1.5 \%$ | $96.6 \%$ |
|  | MSF | $35.2 \%$ | $11.6 \%$ | $46.8 \%$ | $2.8 \%$ | $0.3 \%$ | $0.0 \%$ | $3.1 \%$ |
|  | Mixed | $0.0 \%$ | $4.4 \%$ | $4.4 \%$ | $0.0 \%$ | $0.4 \%$ | $0.0 \%$ | $0.4 \%$ |
|  | Total | $83.1 \%$ | $16.9 \%$ | $\mathbf{8 , 0 0 5} .6$ | $97.9 \%$ | $0.7 \%$ | $1.5 \%$ | $\mathbf{4 , 0 9 0 . 9}$ |


| Soos Creek |  |  |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $77.6 \%$ | $0.6 \%$ | $78.2 \%$ | $97.4 \%$ | $0.0 \%$ | $0.7 \%$ | $98.1 \%$ |
|  | MSF | $15.8 \%$ | $3.1 \%$ | $18.8 \%$ | $1.7 \%$ | $0.1 \%$ | $0.0 \%$ | $1.8 \%$ |
|  | Mixed | $0.0 \%$ | $3.0 \%$ | $3.0 \%$ | $0.0 \%$ | $0.1 \%$ | $0.0 \%$ | $0.1 \%$ |
|  | Total | $93.4 \%$ | $6.6 \%$ | $\mathbf{1 7 , 3 2 6 . 1}$ | $99.1 \%$ | $0.2 \%$ | $0.7 \%$ | $\mathbf{1 5 , 4 5 8 . 2}$ |


| Voights Creek |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $78.2 \%$ | $0.5 \%$ | $78.7 \%$ | $98.7 \%$ | $0.0 \%$ | $0.6 \%$ | $99.3 \%$ |
|  | MSF | $15.3 \%$ | $3.2 \%$ | $18.5 \%$ | $0.6 \%$ | $0.1 \%$ | $0.0 \%$ | $0.7 \%$ |
|  | Mixed | $0.0 \%$ | $2.8 \%$ | $2.8 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $93.5 \%$ | $6.5 \%$ | $\mathbf{1 1 , 3 8 0 . 3}$ | $99.3 \%$ | $0.1 \%$ | $0.6 \%$ | $\mathbf{8 , 8 4 9 . 9}$ |


| George Adams |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $64.4 \%$ | $1.5 \%$ | $65.9 \%$ | $95.0 \%$ | $0.1 \%$ | $2.3 \%$ | $97.3 \%$ |
|  | MSF | $26.5 \%$ | $3.5 \%$ | $30.0 \%$ | $2.7 \%$ | $0.0 \%$ | $0.0 \%$ | $2.7 \%$ |
|  | Mixed | $0.0 \%$ | $4.1 \%$ | $4.1 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $90.9 \%$ | $9.1 \%$ | $\mathbf{7 , 2 7 9 . 7}$ | $97.6 \%$ | $0.1 \%$ | $2.3 \%$ | $\mathbf{4 , 7 4 9 . 9}$ |

Quilcene NFH

| Quicene N |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $76.1 \%$ | $0.1 \%$ | $76.1 \%$ | $99.2 \%$ | $0.0 \%$ | $0.1 \%$ | $99.3 \%$ |
|  | MSF | $17.8 \%$ | $4.4 \%$ | $22.3 \%$ | $0.7 \%$ | $0.0 \%$ | $0.0 \%$ | $0.7 \%$ |
|  | Mixed | $0.0 \%$ | $1.6 \%$ | $1.6 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $93.9 \%$ | $6.1 \%$ | $\mathbf{1 3 , 1 4 4 . 2}$ | $99.9 \%$ | $0.0 \%$ | $0.1 \%$ | $\mathbf{1 0 , 7 7 1 . 6}$ |

Figure 6-6 compares total exploitation rates estimated by the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$ (Section 3.2) for the marked and unmarked components of the DIT groups from each hatchery for each brood year. Years when the Z test comparing the return rates to the
escapement of the marked and unmarked components of a DIT group was significant are indicated with an *. The proportion of the estimated unmarked ER occurring in MSFs is shown, also. While the estimated unmarked ER is usually lower than the marked ER across all hatcheries and brood years in Puget Sound, for $10 \%$ of the DIT groups analyzed ( 11 out of 108) the estimated ER for the unmarked component was greater than the estimate for the marked component - which is contrary to expectations. For eight of these 11 DIT groups, the unmarked ER was less than +0.05 greater than the marked ER. Differences of this size may be attributed to sampling error associated with small sample sizes from the fishery and/or escapement sampling resulting in relatively low numbers of CWTs recovered. For three of the 11 DIT groups, the unmarked ER was more than +0.15 greater than the marked ER. This observation is an indication of a more serious violation of the necessary assumptions such as:

- Unequal survival for the marked and unmarked groups after release;
- Biased sampling in the fisheries impacting these DIT groups; and,
- Incomplete tag recovery reporting, especially at the hatchery (i.e., recovered CWTs not being reported to RMIS).
There were two DIT groups where the marked ER estimate was lower and significantly different from the unmarked ER estimate, i.e., they had non-overlapping $95 \%$ confidence intervals (Figure 10B in Appendix10): Lower Elwha 1999 and Soos Creek 2010. There is no indication of similar long-term trends in ERs among the hatcheries. Peaks in unmarked ER generally corresponded to the peaks in the marked ER. The proportion of the unmarked ER estimated to occur in MSFs fluctuated greatly for Lower Elwha DIT brood years. In contrast, this proportion was relatively consistent across brood years for the DIT groups from Wallace River, Soos Creek, and Voights Creek hatcheries.

Differences between the ER estimates ranged from -0.202 to +0.386 (Table 6-18). Across all hatcheries and brood years, the ER for the marked component of the DIT groups was, on average, +0.067 greater than the ER for the unmarked component.

Table 6-18. Average difference between the estimated exploitation rates (ER) for the marked and unmarked components of PS DIT groups. Unmarked ER estimated using the PR method with $\lambda$ at release.

|  | Number | Difference Marked ER - Unmarked ER |  |  |
| :--- | :---: | :---: | :---: | :---: |
| Hatchery | of Years | Mean | Minimum | Maximum |
| Lower Elwha | 14 | 0.122 | -0.202 | 0.386 |
| Kendall Creek | 10 | 0.050 | 0.017 | 0.077 |
| Marblemount | 14 | 0.050 | 0.017 | 0.077 |
| Wallace River | 14 | 0.087 | 0.020 | 0.130 |
| Soos Creek | 14 | 0.027 | -0.202 | 0.107 |
| Voights Creek | 14 | 0.053 | -0.015 | 0.101 |
| George Adams | 14 | 0.062 | -0.041 | 0.116 |
| Quilcene NFH | 14 | 0.059 | -0.013 | 0.164 |
| Regional Total | $\mathbf{1 0 8}$ | $\mathbf{0 . 0 6 7}$ | $\mathbf{- 0 . 2 0 2}$ | $\mathbf{0 . 3 8 6}$ |



Figure 6-6. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by Puget Sound hatcheries for brood years 1998-2011.


Figure 6-6. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by Puget Sound hatcheries for brood years 1998-2011 (continued).


Figure 6-6. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by Puget Sound hatcheries for brood years 1998-2011 (continued).

### 6.2.1 Conclusions and Recommendations for Puget Sound Hatchery DIT Groups

- Sub-sampling the escapement was common for PS escapements. Across brood years, the average percentage of the Coho in the escapement that were directly sampled ranged from $\approx 62 \%$ to $94 \%$. All PS escapements except the Lower Elwha and George Adams hatcheries had at least one brood year where less than half (50\%) of the escapement was directly sampled. Sub-sampling the escapement requires expansion factors to expand observed CWTs recovered into total estimated CWTs in the escapement to the hatchery or spawning grounds. This adds variation to the estimates of the return rate and estimates of marked and unmarked ERs.
- Nearly all returning Coho that were directly sampled at PS hatcheries were screened for CWTs with ETD. This eliminates a source of potential bias for the estimates of the number of fish in the unmarked component of DIT groups.
- For all DIT groups examined from PS hatcheries, only $32 \%$ of the 108 Z tests conducted yielded significant results and only $24 \%$ of the tests were both significant and had a $\lambda R$ ratio greater than 1.0 (i.e., the return rate of the unmarked component was significantly greater than the rate for the marked component which is interpreted as a measurable impact of MSFs).
- More than $50 \%$ of the estimated CWT recoveries from fisheries for the marked component of Puget Sound DIT groups were in non-selective net fisheries in Puget Sound. About $24 \%$ of the estimated fishery recoveries for PS DIT groups occurred in non-selective (13\%) and mark-selective (11\%) sport fisheries in Puget Sound.
- $90 \%$ or more of the estimated CWT recoveries from fisheries for most DIT groups from Puget Sound hatcheries (both the marked and unmarked components) were in electronically-sampled fisheries. The exceptions were for the marked (76\%) and unmarked ( $84 \%$ ) components for Lower Elwha Hatchery DIT groups and the marked component of Wallace River DIT groups (83\%).
- Across all hatcheries and brood years, the percentage of CWT recoveries in mixedregulation fisheries for the marked component of PS DIT groups ranged from about 2 to $6 \%$.
- CWT recoveries from visually-sampled fisheries or mixed-regulation fisheries are generally not an issue with Puget Sound DIT groups. However, DIT groups from the Lower Elwha Hatchery had the largest percentage of CWT recoveries from fisheries that were either visually sampled and/or with mixed regulations. DIT groups from the Lower Elwha Hatchery also had a considerably higher estimated percentage of CWT tags for the unmarked component of its DIT groups recovered in NSFs that were not electronically sampled (14\%).
- While the estimated exploitation for the unmarked component of the Puget Sound DIT groups was estimated to be less than that of the marked component for $90 \%$ of the brood years, only the DIT groups from Kendall Creek, Marblemount, and Wallace River hatcheries had consistent differences where the marked ER was greater than the unmarked ER across all the brood years examined.

Even with the large majority of CWT recoveries for Puget Sound DIT groups occurring in NSFs and MSFs that are electronically sampled, the differences between estimated ERs for the marked and unmarked components of the DIT groups are quite variable between brood years and hatcheries. For the 108 brood year comparisons:

- $10 \%$ had an unmarked ER estimate > than the marked ER estimate;
- $25 \%$ had a difference in ER estimates (marked ER - unmarked ER) that were $>0$ and $\leq 0.05$;
- $42 \%$ had a difference in ER estimates that were $>0.05$ and $\leq 0.10$;
- $17 \%$ had a difference in ER estimates that were $>0.10$ and $\leq 0.15$; and,
- $6.5 \%$ had a difference in ER estimates >0.15.

Although the ER for the marked component of the DIT groups from PS hatcheries was, on average, +0.067 greater than the ER for the unmarked component of the DIT group, this difference should be viewed with caution because for $10 \%$ of the brood years examined the estimated unmarked ER was greater than the marked ER. Some of the smaller differences that are contrary to expectations may be related to sample sizes and the precision of the associated estimates. However, the larger differences may indicate more serious violations of the necessary assumptions for the analyses such as:

- Unequal survival for the marked and unmarked groups after release;
- Biased sampling in the fisheries impacting these DIT groups; and,
- Incomplete tag recovery reporting, especially at the hatchery (i.e., recovered CWTs not being reported to RMIS).


## Recommendations

The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

1. Data for the DIT groups from Marblemount Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. Although there were only four brood years where the Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement produced significant results, they were all positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Average return rate estimates for Marblemount DIT groups were the second highest in PS (> 3\%).
c. Estimated total recoveries averaged more than 2,000 for each brood year for both the marked and unmarked components of DIT groups from Marblemount Hatchery.
d. The estimates for the $\lambda \mathrm{R}$ ratio were relatively precise compared to other PS hatcheries; 12 of the $14 \lambda$ R ratios were $>1.0$.
e. For Marblemount Hatchery, $28 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
f. CWT data for Marblemount Hatchery DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
g. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.05 and the ER for the marked component was higher than that of the unmarked component for every brood year.
2. Data for the DIT groups from Wallace River Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. For PS DIT groups, Wallace River Hatchery had the highest percentage of $Z$ test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement that were significant and positive (43\%).
b. Average return rate estimates for Wallace River DIT groups were the highest in PS (> 4.5\%).
c. Estimated total recoveries averaged more than 2,000 for each brood year for both the marked and unmarked components of DIT groups from Wallace River Hatchery.
d. The estimates for the $\lambda \mathrm{R}$ ratio were relatively precise compared to other PS hatcheries; 11 of the $14 \lambda \mathrm{R}$ ratios were > 1.0.
e. $\lambda \mathrm{R}$ ratios that were greater than 1.0 and had $95 \%$ CIs that did not include 1.0 occurred across the range of brood years analyzed.
f. For Wallace River Hatchery, $47 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs; this was the highest percentage for any of the PS hatcheries.
g. CWT data for Wallace River Hatchery DIT groups had moderately small impacts from visually-sampled fisheries and mixed-regulation fisheries.
h. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.09 and the ER for the marked component was higher than that of the unmarked component for every brood year.
i. For nine of the 14 brood years analyzed, the estimated ER for the unmarked component of the DIT group was less than for the marked component and the two estimates had non-overlapping $95 \%$ confidence intervals.
3. Data for the DIT groups from Soos Creek Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs. However, the data were not as consistent when compared to the DIT groups from Marblemount and Wallace River hatcheries.
a. There were four brood years where the Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement produced significant results and three of the four were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Estimated total recoveries averaged more than 2,000 for each brood year for both the marked and unmarked components of DIT groups from Soos Creek Hatchery.
c. Soos Creek Hatchery had the highest average number of estimated recoveries in fisheries ( $>1,000$ per brood year) for both the mark and unmarked components of its DIT groups compared to other PS DIT groups.
d. The estimates for the $\lambda \mathrm{R}$ ratio were relatively precise compared to other PS hatcheries.
e. $\lambda \mathrm{R}$ ratios that were greater than 1.0 and had $95 \%$ CIs that did not include 1.0 occurred across the range of brood years analyzed. However, half (7 of 14) of the $\lambda \mathrm{R}$ ratios were < 1.0.
f. About $19 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
g. CWT data for Soos Creek Hatchery DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
h. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.03 and the ER for the marked component was higher than that of the unmarked component for 11 of the 14 brood years.
4. Data for the DIT groups from George Adams Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs and was similar to Soos Creek in that the data were not as consistent when compared to the DIT groups from Marblemount and Wallace River hatcheries.
a. There were four brood years where the Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant but only two of the four were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Estimated total recoveries averaged more than 1,500 for each brood year for both the marked and unmarked components of DIT groups from George Adams Hatchery.
c. The estimates for the $\lambda \mathrm{R}$ ratio were relatively precise compared to other PS hatcheries. $\lambda$ R ratios were greater than 1.0 for 12 of the 14 brood years analyzed.
d. About $30 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs; this was the second highest percentage for any of the PS hatcheries.
e. CWT data for George Adams Hatchery DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
f. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.06 and the ER for the marked component was higher than that of the unmarked component for 12 of the 14 brood years.
5. Data for the DIT groups from Quilcene NFH provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs and was similar to Soos Creek and George Adams Hatchery in that the data were not as consistent when compared to the DIT groups from Marblemount and Wallace River hatcheries.
a. Quilcene had the lowest rate of direct sampling of the escapement compared to other PS hatchery DIT groups ( $62 \%$ ).
b. There were five brood years where the Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and four of the five were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
c. Estimated total recoveries averaged more than 1,600 for each brood year for both the marked and unmarked components of DIT groups from Quilcene NFH.
d. The estimates for the $\lambda \mathrm{R}$ ratio were relatively precise compared to other PS hatcheries. $\lambda$ R ratios were greater than 1.0 for 13 of the 14 brood years analyzed.
e. About $22 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
f. CWT data for Quilcene NFH DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
g. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.06 and the ER for the marked component was higher than that of the unmarked component for 12 of the 13 brood years.

The following DIT program(s) have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:
2. Data and reliable estimates for the DIT groups from the Lower Elwha Hatchery are challenged by a number of issues.
a. Very low average return rates ( $<0.30 \%$ ) resulted in relatively low numbers of CWT recoveries for DIT groups from the Lower Elwha Hatchery (despite having average release numbers about $60 \%$ larger than the other Puget Sound DIT programs examined) which negatively impacts the precision of the return rate and ER estimates and reduces the effectiveness of this DIT program as an indicator of the impacts of MSFs on unmarked stocks.
b. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) for only $29 \%$ of the brood years.
c. There were only two brood years that had a $\lambda R$ ratio > 1.0 with a $95 \%$ CI that did not include 1.0. In addition, there were two brood years with a $\lambda R$ ratio < 1.0 (i.e., the return rate of the marked component was higher than the
unmarked component of the DIT group) with a corresponding 95\% CI that did not include 1.0 .
d. Compared to other PS hatchery DIT groups, a relatively high percentage ( $\approx 9 \%$ ) of the fishery recoveries for the marked component of DIT groups from the Lower Elwha Hatchery were in NSFs that were not electronically sampled. Therefore, the number of unmarked recoveries in these NSFs had to be estimated based on the marked recoveries. For the Lower Elwha Hatchery, $14 \%$ of the total recoveries of the unmarked component of DIT groups were estimated to occur in the visually-sampled NSFs. This is a potential source of bias and adds uncertainty to the estimates for these DIT groups.
3. Data and reliable estimates for the DIT groups from the Kendall Creek Hatchery are challenged by a number of issues.
a. Low average return rates ( $<0.75 \%$ ) and average release sizes of $\approx 45,000$ fish resulted in relatively low numbers of CWT recoveries for DIT groups from the Kendall Creek Hatchery which negatively impacts the precision of the return rate and ER estimates and reduced the effectiveness of this DIT program as an indicator of the impacts of MSFs on unmarked stocks.
b. Average return rate estimates for Kendall Creek DIT groups were the second lowest in PS and highly variable (CVs $>100 \%$ ).
c. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) for only one of the 10 brood years examined.
d. Only one brood year had a $\lambda R$ ratio $>1.0$ with a $95 \% \mathrm{CI}$ that did not include 1.0 .
e. For Kendall Creek Hatchery, only $14 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
f. The differences between estimates of ER for the marked and unmarked components of Kendall Creek DIT groups were all relatively small and were not statistically different.

The results for the following DIT program(s) are mixed and are difficult to categorize:

1. Data for the DIT groups from Voights Creek Hatchery provided results that are very similar to those for Soos Creek Hatchery.
a. The primary concern for the Voights Creek data is that the precision of the estimates of return rates, $\lambda R$ ratios, and marked and unmarked ERs has noticeably gotten worse over the last six to seven brood years examined.
b. Average return rate estimates for Voights Creek DIT groups were the third lowest in PS and highly variable (CVs $>75 \%$ ). For the 2005-2011 brood years, there was only one year which had return rates for the marked and unmarked components of the DIT groups that were > $1.0 \%$.
c. Voights Creek Hatchery averaged relatively low numbers of total CWT recoveries for both the marked and unmarked components of its DIT groups $(1,500)$ and averaged less than 700 CWT recoveries in the escapement.

### 6.3 Washington Coast (WC) Region

There are six hatcheries in the Washington Coast sub-region which had DIT groups analyzed (Table 6-19). All hatcheries except Makah NFH had DIT-group releases for brood years 1998-2011; Makah NFH had DIT-group releases for the 1998-2010 brood years.

Returns to the Salmon River Fish Culture Facility for the 2009 brood year do not appear to be completely reported. There were also no estimated CWT recoveries reported for the escapement (hatchery and spawning grounds) from both the marked and unmarked DIT groups released for the 2010 brood year from the Salmon River Fish Culture Facility even though there were hundreds of recoveries reported for the terminal net fisheries in the river for that brood year; therefore, the 2010 brood year was not included in the return rate or ER analyses for this hatchery. CWT recoveries from a terminal in-river net fishery downstream of the Solduc Hatchery were not completely reported to RMIS for catch years 2001-2007 (brood years 1998-2004) and represent a known data deficiency affecting the Solduc Hatchery DIT analyses for these brood years.

Table 6-19. Hatcheries in the Washington Coast sub-region with Coho salmon DIT groups analyzed for this report, brood years 1998-2011. Cells with X indicate years with recognized data issues. Grey cells indicate years that were not analyzed due to a lack of a DIT release or identified data issues

| Hatchery |  | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\mathbf{1 9 9 9}$ | $\mathbf{2 0 0 0}$ | $\mathbf{2 0 0 1}$ | $\mathbf{2 0 0 2}$ | $\mathbf{2 0 0 3}$ | $\mathbf{2 0 0 4}$ | $\mathbf{2 0 0 5}$ | $\mathbf{2 0 0 6}$ | $\mathbf{2 0 0 7}$ | $\mathbf{2 0 0 8}$ | $\mathbf{2 0 0 9}$ | $\mathbf{2 0 1 0}$ | $\mathbf{2 0 1 1}$ |
| Makah NFH | X | X | X | X | X | X | X | X | X | X | X | X | X |  |
| Quinault NFH | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Salmon R. Fish Culture | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Solduc | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Bingham Creek | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Forks Creek | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Average numbers of Coho salmon released in the marked and unmarked components of the DIT groups from WC hatcheries were generally similar across hatcheries and averaged $\approx 70,000-75,000$ fish (Table 6-20). The exceptions were Makah NFH which averaged about 40,000 fish released each brood year and Quinault NFH which averaged about 93,000 fish released each brood year for both the marked and unmarked DIT group components. Across all hatcheries and brood years, the minimum number released in a DIT group component was about 35,000 fish (Makah NFH) and the maximum about 140,000 fish (Quinault NFH). Fairly consistent numbers of fish were released annually for the DIT groups from the Salmon River Fish Culture, Solduc, Bingham Creek, and Forks Creek hatcheries (CVs for the average number released $<10 \%$ ). DIT group releases from Makah NFH and Quinault NFH were slightly more variable with CVs of $\approx 16 \%$ and $25 \%$, respectively.

Sub-sampling the escapement was common for WC hatcheries and $100 \%$ of the Coho were rarely sampled. Across brood years, the mean percentage of the Coho in the escapement that were directly sampled ranged from $\approx 37 \%$ to $72 \%$ (Table 6-21). Makah NFH and Quinault NFH both had mean sampling rates less than $50 \%$. Sub-sampling the escapement requires expansion factors to expand observed CWT tags recovered into total estimated tags recovered. This adds variation to the estimates of return rates and marked and unmarked ERs. More than $99.5 \%$ of the directly-sampled fish from all DIT groups were sampled with ETD by WC hatcheries (Table 6-21). This removes any potential bias associated with visual sampling of the unmarked component of the returning DIT groups.

Table 6-20. Summary statistics for the number of Coho salmon with CWTs released in the marked and unmarked components of Washington Coast DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | $\mathbf{C V}^{\mathbf{a}}$ |
| :---: | :--- | ---: | ---: | ---: | ---: |
|  | Marked | 40,491 | 35,602 | 61,907 | $16.3 \%$ |
|  | Unmarked | 40,857 | 36,221 | 64,410 | $17.7 \%$ |
| Quinault NFH | Marked | 93,087 | 73,686 | 139,154 | $26.2 \%$ |
|  | Unmarked | 93,659 | 73,190 | 143,988 | $26.0 \%$ |
| Salmon R. Fish Culture | Marked | 73,592 | 68,440 | 80,105 | $5.3 \%$ |
|  | Unmarked | 76,333 | 71,602 | 81,407 | $4.8 \%$ |
| Solduc | Marked | 75,953 | 70,389 | 96,400 | $8.7 \%$ |
|  | Unmarked | 74,055 | 64,087 | 80,185 | $5.1 \%$ |
| Bingham Creek | Marked | 70,947 | 65,986 | 73,833 | $3.3 \%$ |
|  | Unmarked | 71,419 | 67,861 | 73,371 | $2.4 \%$ |
| Forks Creek | Marked | 72,302 | 65,860 | 74,500 | $3.0 \%$ |
|  | Unmarked | 72,635 | 62,718 | 75,301 | $5.1 \%$ |

${ }^{\text {a }} \mathrm{CV}=$ coefficient of variation.
Table 6-21. Summary statistics for the percent of the escapement directly sampled (\% Sampled) and the proportion of the sampled fish that were sampled electronically (Prop ETD) for Washington Coast DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | ---: | ---: | ---: | ---: |
|  | \% Sampled | $39.2 \%$ | $10.9 \%$ | $77.8 \%$ | $47.5 \%$ |
|  | Prop ETD | 1.000 | 0.998 | 1.000 | $0.1 \%$ |
| Quinault NFH | \% Sampled | $36.9 \%$ | $21.1 \%$ | $70.0 \%$ | $39.3 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Salmon R. Fish Culture | \% Sampled | $51.5 \%$ | $12.4 \%$ | $88.2 \%$ | $45.2 \%$ |
|  | Prop ETD | 1.000 | 0.999 | 1.000 | $0.0 \%$ |
| Solduc | \% Sampled | $72.2 \%$ | $30.6 \%$ | $99.3 \%$ | $35.9 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |
| Bingham Creek | \% Sampled | $61.5 \%$ | $29.0 \%$ | $97.1 \%$ | $34.5 \%$ |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |


| Forks Creek | \% Sampled | $62.1 \%$ | $33.7 \%$ | $97.9 \%$ | $29.1 \%$ |
| :--- | :--- | ---: | ---: | ---: | ---: |
|  | Prop ETD | 1.000 | 1.000 | 1.000 | $0.0 \%$ |

Average return rates to the escapement for the marked and unmarked components of WC DIT groups varied by hatchery (Table 6-22). The expectation is that if MSFs are having a measurable impact on the unmarked component of a DIT group (i.e., reduction in the number of fishery-related mortalities), the return rate to the hatchery will be higher for the unmarked component. Average return rates of the unmarked component were higher than the marked component for the DIT groups from all WC hatcheries except for Makah NFH and Salmon River Fish Culture. The average return rates to the Salmon River Fish Culture Facility were the lowest at < $1.0 \%$; average return rates to all other WC hatcheries were in the $1.7-2.5 \%$ range. DIT group return rates to Salmon River Fish Culture were the most variable with CVs $>90 \%$. DIT group return rates to Quinault NFH were the least variable with CVs $\approx 40 \%$.

Table 6-22. Summary statistics for the return rates of Coho salmon in the marked and unmarked components of Washington Coast DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | :---: | :---: | :---: | :---: |
| Makah NFH | Marked | $1.82 \%$ | $0.19 \%$ | $4.50 \%$ | $70.0 \%$ |
|  | Unmarked | $1.71 \%$ | $0.19 \%$ | $4.07 \%$ | $69.2 \%$ |
| Quinault NFH | Marked | $2.01 \%$ | $0.62 \%$ | $3.59 \%$ | $40.8 \%$ |
|  | Unmarked | $2.15 \%$ | $0.59 \%$ | $3.89 \%$ | $44.8 \%$ |
| Salmon R. Fish Culture | Marked | $0.90 \%$ | $0.05 \%$ | $4.76 \%$ | $138.3 \%$ |
|  | Unmarked | $0.53 \%$ | $0.03 \%$ | $1.37 \%$ | $93.1 \%$ |
| Solduc | Marked | $2.45 \%$ | $0.35 \%$ | $4.50 \%$ | $52.7 \%$ |
|  | Unmarked | $2.52 \%$ | $0.47 \%$ | $5.23 \%$ | $55.5 \%$ |
| Bingham Creek | Marked | $2.48 \%$ | $0.67 \%$ | $5.30 \%$ | $60.8 \%$ |
|  | Unmarked | $2.64 \%$ | $0.60 \%$ | $5.88 \%$ | $61.8 \%$ |
| Forks Creek | Marked | $1.96 \%$ | $0.60 \%$ | $7.13 \%$ | $93.6 \%$ |
|  | Unmarked | $2.21 \%$ | $0.54 \%$ | $7.34 \%$ | $87.4 \%$ |

The Z tests comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant $(P \leq 0.05)$ and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in $50 \%$ or less of the brood years for each hatchery (Table 6-23). For all DIT groups examined from WC hatcheries, $43 \%$ of the 82 Z tests conducted were significant and only $31 \%$ of the tests were both significant and had a $\lambda R$ ratio > 1.0. For Makah NFH, none of the 13 brood years had a significant Z-test result when the $\lambda R$ ratio was $>1.0$. Similarly, for Salmon River FC only one of the 13 brood years had a significant Z-test result when the $\lambda R$ ratio was $>1.0$.

Table 6-23. Percent of brood years where the $Z$ test comparing return rates of marked and unmarked DIT groups to escapement is significant $(P \leq 0.05)$ and positive (+YES), significant and negative (-YES), or not significant (NS), and number of brood years tested for Washington Coast hatcheries and brood years 1998-2011.

| Hatchery | NS | +YES | -YES | \# of Broods |
| :--- | :---: | :---: | :---: | :---: |
| Makah NFH | $77 \%$ | $0 \%$ | $23 \%$ | 13 |
| Quinault NFH | $57 \%$ | $36 \%$ | $7 \%$ | 14 |
| Salmon R. Fish Culture | $69 \%$ | $8 \%$ | $23 \%$ | 13 |
| Solduc | $50 \%$ | $43 \%$ | $7 \%$ | 14 |
| Bingham Creek | $43 \%$ | $43 \%$ | $14 \%$ | 14 |
| Forks Creek | $50 \%$ | $50 \%$ | $0 \%$ | 14 |
| Regional Total | $57 \%$ | $31 \%$ | $12 \%$ | 82 |

Figure 6-7 shows $\lambda R$ ratios with approximate $95 \%$ confidence intervals for each hatchery, by brood year. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates of the marked and unmarked components of a DIT group to the escapement are indicated with an *. Both Makah NFH and Salmon River Fish Culture had $\lambda R$ ratios < 1.0 and the $95 \%$ CI did not include 1.0 (i.e., the marked component had a higher return rate to the hatchery than the unmarked component) for about one third of the brood years analyzed. Four of the WC hatcheries had return rate data that indicated a fairly consistent and measurable impact of MSFs, i.e., they had at least six brood years with significant ( $P \leq 0.05$ ) Z tests with $\lambda R$ ratios > 1.0 and had $95 \%$ CIs that did not include 1.0: Quinault NFH; Solduc;, Bingham Creek; and Forks Creek hatcheries.

The average number of estimated CWT recoveries (marked or unmarked) from individual WC hatchery DIT groups ranged from a low of 962 and 777, respectively, for Makah NFH releases to more than 4,500 brood year recoveries for both marked and unmarked DIT groups from Quinault NFH (Table 6-24). The average percent of total (fishery plus escapement) estimated recoveries (across brood years) that occurred in fisheries ranged from $24 \%$ to $73 \%$ for marked fish and $11 \%$ to $72 \%$ for unmarked fish. The majority of the fishery recoveries for the marked component was in terminal fisheries for the DIT groups from all hatcheries except Makah NFH.


Figure 6-7. $\quad \lambda R$ ratios with approximate $95 \%$ confidence intervals for DIT groups released by Washington Coast hatcheries for brood years 1998-2011. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are indicated with an *.

Table 6-24. Average number of estimated CWT recoveries and general recovery location for the marked and unmarked components of Washington Coast hatchery DIT groups (averaged across brood years).

| Hatchery | Mark Status | Fishery Location |  | Total Fishery |  | Escapement | Total Recoveries |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Pre- | Termina | \# | \% |  |  |
| Makah NFH | Marked | 186.5 | 29.4 | 215.9 | 25.3\% | 745.6 | 961.5 |
|  | Unmarked | 31.8 | 30.4 | 62.2 | 10.7\% | 714.5 | 776.7 |
| Quinault <br> NFH | Marked | 664.8 | 2,330.6 | 2,995.5 | 61.6\% | 1,858.8 | 4,854.3 |
|  | Unmarked | 97.9 | 2,428.8 | 2,526.7 | 54.3\% | 2,013.6 | 4,540.3 |
| Salmon R. Fish Culture | Marked | 295.1 | 900.6 | 1,195.7 | 73.1\% | 606.6 | 1,802.3 |
|  | Unmarked | 41.8 | 771.3 | 813.2 | $72.1 \%$ | 372.8 | 1,186.0 |
| Solduc | Marked | 526.0 | 864.1 | 1,390.2 | 38.2\% | 1,854.8 | 3,244.9 |
|  | Unmarked | 90.4 | 916.4 | 1,006.7 | 26.4\% | 1,861.4 | 2,868.2 |
| Bingham Creek | Marked | 213.5 | 342.2 | 555.7 | 24.2\% | 1,769.9 | 2,325.6 |
|  | Unmarked | 80.3 | 307.4 | 387.8 | 16.8\% | 1,897.3 | 2,285.0 |
| Forks Creek | Marked | 527.9 | 824.8 | 1,352.6 | 49.6\% | 1,420.3 | 2,773.0 |
|  | Unmarked | 90.2 | 852.7 | 942.9 | 36.5\% | 1,596.6 | 2,539.6 |

Figure 6-8 shows the average percentage (across brood years) of estimated CWT recoveries in fisheries by location (pre-terminal or terminal), gear type (sport, troll, or net), and fishery type (NSF, MSF, or Mixed) for the marked and unmarked components of each hatchery's DIT groups. Three details to note in this figure are:

- There is a measurable but small percentage of the recoveries that occurred in "mixed" regulation, pre-terminal sport fisheries for the marked component of DIT groups from all WC hatcheries. The marked component of DIT groups from Makah NFH and the Solduc Hatchery show the highest percentage of recoveries in mixed-regulation fisheries. Corresponding unmarked recoveries in mixed-regulation fisheries are estimated identically to those from MSFs for the analyses in this report. This may introduce unknown bias and add to the uncertainty of estimates of unmarked ERs in these fisheries as some of the fish caught in the mixed-regulation category may actually be caught under partial NSF regulations.
- For the marked DIT groups, the majority of the CWT recoveries occurred in preterminal sport fisheries and terminal net fisheries while the majority ( $\geq 60 \%$ ) of the recoveries for the unmarked component occurred in terminal non-selective net fisheries. The exception was for DIT groups from Makah NFH where pre-terminal troll fisheries had a higher percentage of the recoveries than terminal net fisheries for both the marked and unmarked components.
- The potential impact of fisheries with visual sampling (i.e., no ETD) can be seen by comparing the percentage of the marked DIT group recoveries that occurred in NSFs to the percentage of the corresponding unmarked DIT groups that occurred in these same fisheries. For WC DIT groups, the percentage of recoveries from the unmarked component of the DIT group is about equal to or greater than the percentage for the corresponding marked group. Therefore, potential bias due to visually-sampled fisheries does not appear to be an issue with WC DIT groups.


Figure 6-8. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from WC hatcheries.


Figure 6-8. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from WC hatcheries (continued).

The major fisheries impacting WC DIT groups primarily used electronic sampling. For the marked component of the DIT groups, in total, $92 \%$ of the total estimated CWT recoveries from fisheries were by electronic sampling programs (Table 6-25) with visually-sampled fisheries accounting for only $8 \%$ of estimated recoveries. About $89 \%$ of all CWT recoveries for the marked component of Washington Coast DIT groups were in electronically sampled fisheries in the Washington Coastal region. About $1 \%$ of the recoveries from the marked component of Washington Coast DIT groups were in mixed-regulation fishery strata. About $67 \%$ of the total estimated recoveries of the marked component of WC DIT groups were in non-selective net fisheries with ETD sampling in the Washington Coast region.

Approximately $90 \%$ or more of the estimated CWT recoveries in fisheries for both the marked and unmarked components of DIT groups from WC hatcheries were in electronicallysampled fisheries (Table 6-26). The exception was Makah NFH where $74 \%$ and $88 \%$ of the estimated CWT recoveries were in electronically-sampled fisheries for the marked and unmarked components of the DIT groups, respectively. For the marked component of DIT groups from WC hatcheries, less than 3\% of the estimated CWT recoveries from any hatchery occurred in mixed-regulation fisheries. Estimated recoveries for unmarked DIT groups in NSFs without electronic sampling were $\leq 4 \%$ for all hatcheries except Makah NFH ( $12 \%$ ). For the marked component of DIT groups from WC hatcheries, the percentage of total
estimated CWT recoveries occurring in MSFs, across all brood years, ranged from 18\% for Quinault NFH to $66 \%$ for Makah NFH.
Table 6-25. Percentage of all estimated CWT recoveries of marked fish associated with DIT groups released from WC hatcheries (brood years 1998-2011) by detection method (electronic or visual) and fishery type (NSF, MSF, Mixed).

| Region <br> Fishery | Electronically Sampled |  |  |  | Visually Sampled |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | NSF | MSF | Mixed | Total | NSF | MSF | Mixed | Total |
| Alaska |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.03\% | 0.00\% | 0.00\% | 0.03\% |
| Sport | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.23\% | 0.00\% | 0.00\% | 0.23\% |
| British Columbia |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.02\% | 0.06\% | 0.00\% | 0.07\% | 0.35\% | 2.01\% | 0.78\% | 3.14\% |
| Troll | 0.09\% | 0.01\% | 0.06\% | 0.15\% | 0.16\% | 0.07\% | 0.01\% | 0.24\% |
| Puget Sound |  |  |  |  |  |  |  |  |
| Net | 0.05\% | 0.00\% | 0.00\% | 0.05\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.30\% | 0.85\% | 0.00\% | 1.15\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Washington Coast |  |  |  |  |  |  |  |  |
| Net | 67.37\% | 0.00\% | 0.00\% | 67.37\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 2.69\% | 14.29\% | 0.00\% | 16.97\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 3.38\% | 1.41\% | 0.00\% | 4.79\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Oregon Coast and Columbia River |  |  |  |  |  |  |  |  |
| Net | 0.02\% | 0.02\% | 0.00\% | 0.03\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.18\% | 1.30\% | 0.00\% | 1.48\% | 0.00\% | 3.64\% | 0.00\% | 3.64\% |
| Troll | 0.09\% | 0.01\% | 0.00\% | 0.10\% | 0.00\% | 0.47\% | 0.07\% | 0.54\% |
| Totals | 74.18\% | 17.94\% | 0.06\% | 92.17\% | 0.77\% | 6.19\% | 0.86\% | 7.83\% |

Figure 6-9 compares total exploitation rates estimated by the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$ (Section 3.2) for the marked and unmarked components of the DIT groups from each hatchery for each brood year. Years when the Z test comparing the return rates to the escapement of the marked and unmarked components of a DIT group was significant are indicated with an *. The proportion of the estimated unmarked ER occurring in MSFs is shown, also. Figure 10C in Appendix 10 compares ER estimates for the marked and unmarked components of the WC DIT groups by hatchery and brood year (with approximate $95 \%$ confidence intervals for the estimates). While the estimated unmarked ER is usually lower than the marked ER across all hatcheries and brood years for Washington Coast DIT groups (Figure 6-9), for $15 \%$ of the DIT groups analyzed (12 out of 82) the estimated ER for the unmarked component was greater than the estimate for the marked component - which is
contrary to expectations. For 10 of these 12 DIT groups, the unmarked ER was less than +0.03 greater than the marked ER. Differences of this size may be attributed to

Table 6-26. Percentage of DIT recoveries in fisheries with electronic sampling (ETD) and without electronic sampling (Visual), by fishery type. Unmarked recoveries in NSFs without electronic sampling are estimated (Estimated). Bold number is total number of estimated recoveries in fisheries for DIT groups released from WC hatcheries for the 1998-2011 brood years.

|  |  | Mark | ed Comp | onent |  | marked | ompone |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Fishery Type | $\begin{gathered} \text { ETD } \\ \text { Sample } \end{gathered}$ | Visual Sample | Total | $\begin{gathered} \text { ETD } \\ \text { Sample } \\ \hline \end{gathered}$ | Visual Sample | Estimated | Total |
| Makah NFH |  |  |  |  |  |  |  |  |
|  | NSF | 27.8\% | 3.8\% | 31.6\% | 83.0\% | 0.0\% | 11.8\% | 94.8\% |
|  | MSF | 46.2\% | 19.5\% | 65.7\% | 4.9\% | 0.2\% | 0.0\% | 5.2\% |
|  | Mixed | 0.1\% | 2.7\% | 2.7\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |
|  | Total | 74.0\% | 26.0\% | 2,807.0 | 87.9\% | 0.2\% | 11.8\% | 916.8 |
| Quinault NFH |  |  |  |  |  |  |  |  |
|  | NSF | 80.7\% | 0.7\% | 81.4\% | 98.8\% | 0.0\% | 0.8\% | 99.6\% |
|  | MSF | 13.8\% | 4.3\% | 18.1\% | 0.3\% | 0.0\% | 0.0\% | 0.4\% |
|  | Mixed | 0.0\% | 0.6\% | 0.6\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |
|  | Total | 94.5\% | 5.5\% | 41,936.4 | 99.1\% | 0.1\% | 0.8\% | 35,659.2 |

Salmon River Fish Culture

|  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $79.0 \%$ | $0.9 \%$ | $79.9 \%$ | $97.7 \%$ | $0.0 \%$ | $1.4 \%$ | $99.1 \%$ |
|  | MSF | $15.0 \%$ | $4.6 \%$ | $19.5 \%$ | $0.7 \%$ | $0.1 \%$ | $0.0 \%$ | $0.8 \%$ |
|  | Mixed | $0.0 \%$ | $0.5 \%$ | $0.5 \%$ | $0.0 \%$ | $0.1 \%$ | $0.0 \%$ | $0.1 \%$ |
|  | Total | $94.0 \%$ | $6.0 \%$ | $\mathbf{1 6 , 7 4 0 . 4}$ | $98.4 \%$ | $0.2 \%$ | $1.4 \%$ | $\mathbf{1 1 , 5 4 2 . 4}$ |

Solduc

|  | NSF | $69.5 \%$ | $1.1 \%$ | $70.6 \%$ | $98.0 \%$ | $0.0 \%$ | $1.5 \%$ | $99.5 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $21.1 \%$ | $6.2 \%$ | $27.3 \%$ | $0.5 \%$ | $0.0 \%$ | $0.0 \%$ | $0.5 \%$ |
|  | Mixed | $0.2 \%$ | $1.9 \%$ | $2.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $90.8 \%$ | $9.2 \%$ | $\mathbf{1 9 , 4 6 2 . 3}$ | $98.5 \%$ | $0.0 \%$ | $1.5 \%$ | $\mathbf{1 4 , 3 0 5 . 0}$ |

Bingham Creek

|  | NSF | $75.0 \%$ | $2.9 \%$ | $78.0 \%$ | $94.4 \%$ | $0.1 \%$ | $4.0 \%$ | $98.5 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $17.7 \%$ | $3.8 \%$ | $21.5 \%$ | $1.5 \%$ | $0.0 \%$ | $0.0 \%$ | $1.5 \%$ |
|  | Mixed | $0.3 \%$ | $0.2 \%$ | $0.6 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $93.0 \%$ | $7.0 \%$ | $\mathbf{7 , 7 7 9 . 9}$ | $95.9 \%$ | $0.1 \%$ | $4.0 \%$ | $\mathbf{5 , 6 5 7 . 2}$ |

Forks Creek

|  | NSF | $66.9 \%$ | $1.8 \%$ | $68.7 \%$ | $96.2 \%$ | $0.1 \%$ | $2.5 \%$ | $98.8 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $22.5 \%$ | $8.5 \%$ | $30.9 \%$ | $1.0 \%$ | $0.2 \%$ | $0.0 \%$ | $1.2 \%$ |
|  | Mixed | $0.0 \%$ | $0.4 \%$ | $0.4 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $89.3 \%$ | $10.7 \%$ | $\mathbf{1 8 , 9 3 6 . 9}$ | $97.2 \%$ | $0.3 \%$ | $2.5 \%$ | $\mathbf{1 3 , 5 3 9 . 3}$ |



Figure 6-9. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by WC hatcheries for brood years 1998-2011.


Figure 6-9. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by WC hatcheries for brood years 1998-2011 (continued).
sampling error associated with small sample sizes from fishery and/or escapement sampling resulting in relatively low numbers of CWT recovered. For two of the 12 DIT groups, the unmarked ER was more than +0.08 greater than the marked ER. Both of these DIT groups were from Salmon River Fish Culture (brood years 2002 and 2003). Differences of this size, with the estimated unmarked ER being higher than the estimated marked ER, indicate a more serious violation of the necessary assumptions such as:

- Unequal survival for the marked and unmarked groups after release,
- Biased sampling in the fisheries impacting these DIT groups, and
- Incomplete tag recovery reporting, especially at the hatchery (i.e., recovered CWTs not being reported to RMIS).

The Salmon River FC DIT groups also had four other brood years where the estimated ER for the unmarked component of the DIT group was slightly higher than the estimated ER for the marked component.

Differences between the ER estimates ranged from -0.299 to +0.442 (Table 6-27). Across all hatcheries and brood years, the ER for the marked component of the DIT groups was, on average, +0.072 greater than the ER for the unmarked component of the DIT group. Across brood years, the average ER for the unmarked component of Salmon River FC DIT groups was about 0.01 larger than the average ER for the marked component which is contrary to expectations.

Table 6-27. Average difference between the estimated exploitation rates (ER) for the marked and unmarked components of WC DIT groups. Unmarked ER estimated using the PR method with $\lambda$ at release.

|  | Humber | Difference Marked ER - Unmarked ER |  |  |
| :--- | :---: | :---: | :---: | :---: |
| Hatchery | of Years | Mean | Minimum | Maximum |
| Makah NFH | 13 | 0.110 | -0.014 | 0.306 |
| Quinault NFH | 14 | 0.061 | -0.016 | 0.442 |
| Salmon R. Fish Culture | 13 | -0.007 | -0.299 | 0.120 |
| Solduc | 14 | 0.095 | -0.002 | 0.253 |
| Bingham Creek | 14 | 0.059 | -0.027 | 0.187 |
| Forks Creek | 14 | 0.111 | 0.038 | 0.374 |
| Regional Total | 82 | 0.072 | -0.299 | 0.442 |

### 6.3.1 Conclusions and Recommendations for Washington Coast Hatchery DIT Groups

- The numbers of fish released in DIT groups from WC hatcheries were generally averaged more than 70,000 fish released in both the marked and unmarked components and the minimum numbers released in a DIT group in any brood year exceeding 60,000 fish. These release numbers would be adequate to detect differences in return proportions of marked and unmarked fish under low survival and/or sampling rates (Section 2.5). The exception was Makah NFH which averaged about 40,000 fish released per mark status group per brood year.
- Sub-sampling the escapement was common for WC hatcheries. Less than $50 \%$ of the returning Coho were directly sampled for about half the brood years analyzed for the WC region. For Makah NFH and Quinault NFH more than $70 \%$ of the brood years were sub-sampled at a rate $<50 \%$. Across brood years, the average percentage of the Coho in the escapement that were directly sampled was $39 \%$ for Makah NFH and $37 \%$ for Quinault NFH. Sub-sampling affects the power of the Z test that compares the return rates of the marked and unmarked components of a DIT group. Lower sampling rates result in decreased power for these tests.
- Nearly all returning Coho that were directly sampled at WC hatcheries were screened for CWTs with ETD. This eliminates a source of potential bias for the estimates of the number of fish in the unmarked component of DIT groups.
- For all DIT groups examined from WC hatcheries, $43 \%$ of the 82 Z tests conducted produced significant results and only $31 \%$ of the tests were both significant and had a $\lambda R$ ratio greater than 1.0 (i.e., the return rate of the unmarked component was significantly greater than for the marked component indicating a measurable impact of MSFs).
- The Z-test statistic result was significant and negative for $23 \%$ of the brood years from two hatcheries (Makah NFH and Salmon River Fish Culture) indicating that a higher proportion of the marked component of the DIT groups returned to the hatchery than the unmarked component. As this finding is against expectations, i.e., with MSFs a higher proportion of the unmarked component of the DIT groups should return, it points to an issue either in the release number, rearing and release strategy, or in the sampling of the hatchery return. These programs should be re-evaluated as to their value as DIT group programs.
- Relatively small numbers of CWT recoveries for DIT groups from Makah NFH and Salmon River Fish Culture impact the estimation precision and effectiveness of these DIT programs.
- About $90 \%$ or more of the estimated CWT recoveries from fisheries for most DIT groups from Washington Coast hatcheries (both the marked and unmarked components) were in electronically-sampled fisheries. The exception was the marked component of the DIT groups from Makah NFH (74\%).
- MSF impacts for DIT groups from the WC region are influenced by geographical location. A higher proportion of impacts on the marked component of the DIT groups from Makah NFH occurred in MSFs (> 65\% of fishery recoveries) compared to other hatcheries in the region ( $\leq 31 \%$ ).
- Across all hatcheries and brood years, less than 3\% of the estimated CWT recoveries in fisheries for the marked component of Washington Coast DIT groups occurred in mixed-regulation fisheries.
- CWT samples from visually-sampled fisheries or mixed-regulation fisheries are generally not an issue with Washington Coast DIT groups. However, DIT groups from Makah NFH had the largest percentage of CWT recoveries from fisheries that were either visually sampled and/or with mixed regulations. DIT groups from Makah NFH also had a considerably higher estimated percentage of CWT recoveries for the unmarked component of its DIT groups occurring in NSFs that were not electronically sampled: $12 \%$ compared to $\leq 4 \%$ for all other WC hatcheries.
- While the exploitation on the unmarked component of the Washington Coast DIT groups was estimated to be less than that of the marked component for the majority of brood years ( $85 \%$ ), only for DIT groups from Forks Creek Hatchery were the differences between marked and unmarked ER estimates consistently significant.

Even with the large majority of CWT recoveries for Washington Coast DIT groups occurring in NSFs and MSFs that are electronically sampled, the differences between estimated ERs for the marked and unmarked components of the DIT groups are quite variable between brood years and hatcheries. For the 82 brood year comparisons:

- $15 \%$ had an unmarked ER estimate $>$ than the marked ER estimate;
- $30 \%$ had a difference in ER estimates (marked ER - unmarked ER) that were $>0$ and $\leq 0.05$;
- $32 \%$ had a difference in ER estimates that were $>0.05$ and $\leq 0.10$;
- $8 \%$ had a difference in ER estimates that were $>0.10$ and $\leq 0.15$; and,
- $15 \%$ of the differences were $>0.15$.

Although the ER for the marked component of the DIT groups from WC hatcheries was, on average, +0.072 greater than the ER for the unmarked component of the DIT group, this difference should be viewed with caution because for $15 \%$ of the brood years examined the estimated unmarked ER was greater than the marked ER. Some of the smaller differences that are contrary to expectations may be related to sample sizes and the precision of the associated estimates. However, the larger differences may be indicative of more serious violations of the necessary assumptions for the analyses such as:

- Unequal survival for the marked and unmarked groups after release;
- Biased sampling in the fisheries impacting these DIT groups; and;
- Incomplete tag recovery reporting, especially at the hatchery (i.e., recovered CWTs not being reported to RMIS).


## Recommendations

The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

1. Data for the DIT groups from Quinault NFH provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. There were six brood years where the Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and five of the six were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. The average size of the DIT groups released from Quinault NFH were the highest in the WC region ( $\approx 93,000$ per brood year).
c. Estimated total recoveries averaged more than 4,500 for each brood year for both the marked and unmarked components of DIT groups from Quinault NFH.
d. The estimates for the $\lambda R$ ratio were relatively precise and 6 of the $14 \lambda R$ ratios were > 1.0 and had $95 \%$ CIs that did not include 1.0.
e. For Quinault NFH, $18 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
f. CWT data for Quinault NFH DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
g. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.06 and the ER for the marked component was higher than that of the unmarked component for 11 of the 14 brood years examined.
2. Because of the possible data reporting issue associated with the CWT recovery data for the 1997 through 2004 brood years identified at the beginning of the Washington Coast section, the evaluation of the Solduc Hatchery should focus on the last seven brood years of data (2005-2011).
a. Four of the last seven brood years had Z test results that were significant and all four were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Estimated total recoveries averaged more than 2,800 for each brood year for both the marked and unmarked components of DIT groups from Solduc Hatchery.
c. The estimates for the $\lambda R$ ratio were relatively precise and four of the last seven brood years had $\lambda R$ ratios that were > 1.0 and had $95 \%$ CIs that did not include 1.0 .
d. For Solduc Hatchery, $27 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
e. CWT data for Solduc Hatchery DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
f. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.05 and the ER for the marked component was higher than that of the unmarked component for six of the last seven brood years.
3. Data for the DIT groups from Bingham Creek Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. There were eight brood years where the Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and six of the eight were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Estimated total recoveries averaged more than 2,200 for each brood year for both the marked and unmarked components of DIT groups from Bingham Creek Hatchery.
c. The estimates for the $\lambda R$ ratio were relatively precise and 7 of the $14 \lambda R$ ratios were > 1.0 and had $95 \%$ CIs that did not include 1.0.
d. For Bingham Creek Hatchery, $22 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
e. CWT data for Bingham Creek DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
f. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.06 and the ER for the marked component was higher than that of the unmarked component for 13 of the 14 brood years examined.
4. Data for the DIT groups from Forks Creek Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. There were seven brood years where the Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and all seven were positive (a significantly higher proportion of unmarked fish returned to the hatchery than marked fish).
b. Estimated total recoveries averaged more than 2,500 for each brood year for both the marked and unmarked components of DIT groups from Forks Creek Hatchery.
c. The estimates for the $\lambda R$ ratio were relatively precise and 8 of the $14 \lambda R$ ratios were > 1.0 and had $95 \%$ CIs that did not include 1.0.
d. For Forks Creek Hatchery, $31 \%$ of the total recoveries of the marked component of DIT groups were estimated to occur in MSFs.
e. CWT data for Forks Creek DIT groups had relatively small impacts from visually-sampled fisheries and mixed-regulation fisheries.
f. The average difference between estimated ERs for the marked and unmarked components of the DIT groups was +0.11 and the ER for the marked
component was higher than that of the unmarked component for all 14 of the brood years examined.

The following DIT program(s) have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:

1. Data and reliable estimates for the DIT groups from Makah NFH are challenged by a number of issues.
a. Relatively small numbers released for both the marked and unmarked DITgroup components and a low average return rate ( $<2 \%$ ) resulted in low numbers of total CWT recoveries for DIT groups from Makah NFH which negatively impacts the precision of the return rate and ER estimates and reduces the effectiveness of this DIT program as an indicator of the impacts of MSFs on unmarked stocks.
b. Makah NFH had an average sampling rate of the escapement of only $39 \%$. The sampling rate of the return to escapement for 9 of the 13 brood years examined was < $50 \%$ and four brood years had sampling rates < 20\%. Subsampling the escapement requires expansion factors to expand observed CWT tags recovered into total estimated tags recovered and increases the uncertainty of the estimates of return rates.
c. None of the $Z$ test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) for the 13 brood years examined.
d. There were only two brood years that had a $\lambda R$ ratio $>1.0$ with a $95 \%$ CI that did not include 1.0. In addition, there were four brood years with a $\lambda R$ ratio $<$ 1.0 (i.e., the return rate of the marked component was higher than the unmarked component of the DIT group) with a corresponding $95 \%$ CI that did not include 1.0 .
e. Compared to other WC hatchery DIT groups, a relatively high percentage ( $\approx 12 \%$ ) of the total fishery recoveries of the unmarked component of DIT groups were estimated to occur in the visually-sampled NSFs. This is a potential source of bias and adds uncertainty to the estimates for these DIT groups.
2. Data and reliable estimates for the DIT groups from the Salmon River Fish Culture Facility are challenged by a number of issues.
a. DIT groups from Salmon River FC had the lowest average return rate in the WC region ( $<1 \%$ ) and were highly variable (CVs $>90 \%$ ).
b. Salmon River FC had an average sampling rate of the escapement of $51 \%$. The sampling rate of the return to escapement for 6 of the 13 brood years examined was < $50 \%$ and one brood year had a sampling rate of only $12 \%$. Sub-sampling the escapement requires expansion factors to expand observed

CWT tags recovered into total estimated tags recovered and increases the uncertainty of the estimates of return rates
c. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) for only 1 of the 13 brood years examined.
d. There was only one brood year that had a $\lambda R$ ratio $>1.0$ with a $95 \% \mathrm{CI}$ that did not include 1.0. In addition, there were four brood years with a $\lambda R$ ratio $<1.0$ (i.e., the return rate of the marked component was higher than the unmarked component of the DIT group) with a corresponding 95\% CI that did not include 1.0.
e. The average difference between the estimated ERs for the marked and unmarked components of the DIT groups was -0.007, i.e., on average the estimated ER for the unmarked component of the DIT group was higher than for the marked component. The ER for the marked component was higher than that of the unmarked component for only 6 of the 13 brood years examined. There was little indication of measurable and consistent impact of MSFs on Salmon River Fish Culture DIT groups.

### 6.4 Columbia River (CR) Region

There are three hatcheries in the Columbia River region which had DIT groups analyzed (Table 6-28). Two DIT groups are released annually from the Lewis River Hatchery: a northmigrating group and a south-migrating group. All hatcheries except Sandy River had DITgroup releases for brood years 1998-2011; Sandy River only had DIT-group releases for the 1998-2008 brood years.

Table 6-28. Hatcheries in the Columbia River region with Coho salmon DIT groups analyzed for this report, brood years 1998-2011.

| Hatchery | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Lewis River - North | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Lewis River - South | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Eagle Creek NFH | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Sandy River | X | X | X | X | X | X | X | X | X | X | X |  |  |  |

Average numbers of Coho salmon released in the marked and unmarked components of the DIT groups from CR hatcheries varied by hatchery (Table 6-29). For the Lewis River hatchery, marked and unmarked DIT group releases averaged about 70,000 fish for each stock (north-migrating and south-migrating) for each brood year. Release numbers from Eagle Creek NFH and Sandy Creek Hatchery were generally in the 20,000-25,000 range for each of the DIT group components. Across all hatcheries and brood years, the minimum number
released in a DIT group component was about 18,000 fish (Eagle Creek NFH) and the maximum about 81,000 fish (Lewis River - North). Fairly consistent numbers of fish were released annually for the DIT groups from the Lewis River and Eagle Creek hatcheries (CVs $<10 \%$ for the average number released). There was one brood year with a relatively large number of fish released in the marked component from Sandy River Hatchery.

Sub-sampling the escapement was common for CR hatcheries and $100 \%$ of the Coho were rarely directly sampled. Across brood years, the mean percentage of the Coho in the escapement that were directly sampled ranged from $\approx 56 \%$ to $98 \%$ (Table 6-30). Lewis River DIT groups had the lowest mean sampling rates (<60\%). Sub-sampling the escapement requires expansion factors to expand observed CWT tags recovered into total estimated tags recovered and adds variation to the estimates of return rates and marked and unmarked ERs. In contrast, nearly all Coho returning in the escapement to Sandy River Hatchery were directly sampled (mean sample rate $=97.6 \%$ ). ETD was used on $99 \%$ or more of the directlysampled fish in the escapements to CR hatcheries (Table 6-30). This practice removes any potential bias associated with visual sampling of the unmarked component of the returning DIT groups.

Table 6-29. Summary statistics for the number of Coho salmon with CWTs released in the marked and unmarked components of Columbia River DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | $\mathbf{C V}^{\mathbf{a}}$ |
| :---: | :--- | ---: | ---: | ---: | :---: |
| Lewis River - <br> North | Marked | 70,623 | 62,198 | 76,503 | $7.1 \%$ |
|  | Unmarked | 72,068 | 62,408 | 80,842 | $7.3 \%$ |
| Lewis River - <br> South | Marked | 71,744 | 66,831 | 76,668 | $4.3 \%$ |
|  | Unmarked | 72,875 | 68,702 | 75,818 | $3.3 \%$ |
| Eagle Creek NFH | Marked | 23,898 | 17,825 | 25,069 | $7.7 \%$ |
|  | Unmarked | 23,741 | 18,733 | 24,925 | $6.6 \%$ |
| Sandy River | Marked | 31,106 | 25,794 | 70,665 | $42.2 \%$ |
|  | Unmarked | 26,946 | 25,205 | 27,999 | $3.7 \%$ |

${ }^{\text {a }} \mathrm{CV}=$ coefficient of variation.

Table 6-30. Summary statistics for the percent of the escapement directly sampled (\% Sampled) and the proportion of the sampled fish that were sampled electronically (Prop ETD) for Columbia River DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | ---: | ---: | ---: | ---: |
| Lewis River - <br> North | \% Sampled | $58.1 \%$ | $34.9 \%$ | $81.1 \%$ | $24.6 \%$ |
|  | Prop ETD | 1.000 | 0.997 | 1.000 | $0.1 \%$ |
| Lewis River <br> South | \% Sampled | $55.9 \%$ | $33.5 \%$ | $95.1 \%$ | $30.7 \%$ |
|  | Prop ETD | 1.000 | 0.999 | 1.000 | $0.0 \%$ |
| Eagle Creek NFH | \% Sampled | $74.0 \%$ | $41.1 \%$ | $99.2 \%$ | $25.5 \%$ |
|  | Prop ETD | 0.996 | 0.990 | 1.000 | $0.3 \%$ |
| Sandy River | \% Sampled | $97.6 \%$ | $91.4 \%$ | $99.6 \%$ | $2.9 \%$ |
|  | Prop ETD | 0.998 | 0.993 | 1.000 | $0.2 \%$ |

Average return rates to the escapement for the marked and unmarked components of CR DIT groups varied by hatchery (Table 6-31). The expectation is that if MSFs are having a measurable impact on the unmarked component of a DIT group (i.e., reduction in the number of fishery-related mortalities), the return rate to the hatchery will be higher for the unmarked component. Average return rates of the unmarked component were higher than the marked component for the DIT groups from all CR hatcheries. Average return rates for DIT groups to the Lewis River Hatchery were higher than those to Eagle Creek NFH and Sandy River Hatchery. Return rates for the DIT groups to Eagle Creek Hatchery were more variable with rates varying from $<0.3 \%$ to $\approx 4 \%$ and CVs for the average return rates $>65 \%$.

Table 6-31. Summary statistics for the return rates of Coho salmon in the marked and unmarked components of Columbia River DIT groups, by hatchery (averaged across brood years).

| Hatchery | Mark Status | Mean | Minimum | Maximum | CV |
| :---: | :--- | :---: | :---: | :---: | :---: |
| Lewis River - <br> North | Marked | $2.15 \%$ | $0.30 \%$ | $4.00 \%$ | $44.4 \%$ |
|  | Unmarked | $2.58 \%$ | $0.38 \%$ | $4.83 \%$ | $44.9 \%$ |
| Lewis River - <br> South | Marked | $2.38 \%$ | $0.08 \%$ | $4.64 \%$ | $53.5 \%$ |
|  | Unmarked | $3.01 \%$ | $0.07 \%$ | $5.78 \%$ | $55.9 \%$ |
| Eagle Creek NFH | Marked | $1.45 \%$ | $0.27 \%$ | $4.06 \%$ | $76.8 \%$ |
|  | Unmarked | $1.82 \%$ | $0.28 \%$ | $4.10 \%$ | $66.4 \%$ |
| Sandy River | Marked | $1.22 \%$ | $0.59 \%$ | $2.71 \%$ | $50.6 \%$ |
|  | Unmarked | $1.83 \%$ | $0.63 \%$ | $3.35 \%$ | $44.3 \%$ |

The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant $(P \leq 0.05)$ and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in more than $60 \%$ of the brood years for each hatchery (Table 6-32). For all DIT groups examined from CR hatcheries, $79 \%$ of the 53 Z tests conducted were significant and all of the significant tests had $\lambda R$ ratios > 1.0.

Table 6-32. Percent of brood years where the $Z$ test results comparing return rates of marked and unmarked DIT groups to escapement is significant ( $P \leq 0.05$ ) and positive (+YES), significant and negative (-YES), or not significant (NS), and number of brood years tested for CR hatcheries and brood years 1998-2011.

| Hatchery | NS | +YES | -YES | \# of Broods |
| :--- | :---: | :---: | :---: | :---: |
| Lewis River - North | $14 \%$ | $86 \%$ | $0 \%$ | 14 |
| Lewis River - South | $14 \%$ | $86 \%$ | $0 \%$ | 14 |
| Eagle Creek NFH | $36 \%$ | $64 \%$ | $0 \%$ | 14 |
| Sandy River | $18 \%$ | $82 \%$ | $0 \%$ | 11 |
| Regional Total | $21 \%$ | $79 \%$ | $0 \%$ | 53 |

Figure 6-10 shows $\lambda R$ ratios with approximate $95 \%$ confidence intervals for each hatchery, by brood year. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates of the marked and unmarked components of a DIT group to the escapement are indicated with an *. The $95 \%$ confidence interval widths for the north-migrating and south-migrating DIT groups from the Lewis River Hatchery are relatively narrow because of the large number of CWTs recovered (>1,500 tags recovered annually at the hatchery or on the spawning grounds on average). The majority of brood years for each hatchery had $\lambda R$ ratios > 1.0 and the $95 \%$ CI did not include 1.0, i.e., they indicated a fairly consistent and measurable impact of MSFs. For CR hatcheries, there were only three DIT groups that had $\lambda R$ ratios $<1.0$.


Figure 6-10. $\lambda R$ ratios with approximate $95 \%$ confidence intervals for DIT groups released by Columbia River hatcheries for brood years 1998-2011. Brood years with a significant $(P \leq 0.05) \mathrm{Z}$ test comparing the return rates to the escapement of the marked and unmarked components of a DIT group are indicated with an *.

The average annual number of estimated CWT recoveries (marked or unmarked) from individual CR hatchery DIT groups ranged from a low about 460 for Eagle Creek NFH releases to more than 2,000 annually for both the marked and unmarked DIT groups released for the north-migrating and south-migrating stocks from Lewis River Hatchery (Table 6-33). The average percent of total (fishery plus escapement) estimated recoveries (across brood years) that occurred in fisheries ranged from $23 \%$ to $45 \%$ for marked fish and $4 \%$ to $21 \%$ for unmarked fish. The majority of the fishery recoveries for the marked component was in preterminal fisheries for the DIT groups from all hatcheries.

Table 6-33. Average number of estimated CWT recoveries and general recovery location for the marked and unmarked components of Columbia River hatchery DIT groups (averaged across brood years).

| Hatchery | Mark Status | Fishery Location |  | Total Fishery |  | Escapement | Total <br> Recoveries |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | PreTerminal |  |  | \% |  |  |
| Lewis River North | Marked | 826.4 | 585.5 | 1,411.8 | 44.9\% | 1,514.7 | 2,926.5 |
|  | Unmarked | 49.2 | 501.4 | 550.6 | 20.7\% | 1,844.2 | 2,394.8 |
| Lewis River South | Marked | 431.4 | 247.0 | 678.4 | 25.3\% | 1,700.8 | 2,379.1 |
|  | Unmarked | 24.8 | 75.2 | 100.0 | 4.5\% | 2,190.2 | 2,290.2 |
| Eagle Creek NFH | Marked | 81.5 | 47.4 | 128.9 | 23.3\% | 340.0 | 468.9 |
|  | Unmarked | 9.6 | 22.6 | 32.2 | 5.7\% | 422.9 | 455.1 |
| Sandy River | Marked | 193.9 | 97.3 | 291.2 | 40.2\% | 357.7 | 648.9 |
|  | Unmarked | 4.8 | 45.6 | 50.3 | 10.7\% | 490.3 | 540.6 |

Figure 6-11 shows the average percentage (across brood years) of estimated CWT recoveries in fisheries by location (pre-terminal or terminal), gear type (sport, troll, or net), and fishery type (NSF, MSF, or Mixed) for the marked and unmarked components of each hatchery's DIT groups. Three details to note in this figure are:

- There is a measurable but small percentage of the recoveries that occurred in "mixed" regulation fisheries only for Lewis River North DIT groups. Corresponding unmarked recoveries in mixed-regulation fisheries are estimated identically to those from MSFs for the analyses in this report. This approach may introduce unknown bias and add to the uncertainty of estimates of unmarked ERs in these fisheries as some of the fish caught in the mixed-regulation category may actually be caught under partial NSF regulations.
- For the marked DIT groups, the majority of the CWT recoveries occurred in preterminal mark-selective sport fisheries while the majority of the recoveries for the unmarked component occurred in terminal non-selective net fisheries.
- The potential impact of fisheries with visual sampling (i.e., no ETD) can be seen by comparing the percentage of the marked DIT group recoveries that occurred in NSFs to the percentage of the corresponding unmarked DIT groups that occurred in these same fisheries. For CR DIT groups, the percentage of recoveries from the unmarked component of the DIT group is greater than the percentage for the corresponding marked group. Therefore, potential bias due to visually-sampled fisheries does not appear to be an issue with CR DIT groups.

The majority of fisheries impacting CR DIT groups were electronically sampled. For the marked DIT groups, in total, $74 \%$ of the total estimated CWT recoveries from fisheries were by electronic sampling programs (Table 6-34). However, $24 \%$ of the CWT recoveries were from visually-sampled mark-selective sport fisheries in Oregon. Other fisheries with a substantial proportion of the CWT recoveries of the marked component from CR DIT groups were electronically sampled included: Washington Coast sport ( $28 \%$ of recoveries) and

Columbia River net (22\%). Another 20\% of the recoveries occurred in electronically-sampled sport fisheries in the Oregon Coast and Columbia River region. Less than $1 \%$ of the recoveries from Columbia River marked DIT groups were in mixed-regulation fishery strata.


Figure 6-11. Bar charts comparing average percentage, across brood years, of total estimated CWT recoveries in fisheries, by fishery type and location, for marked and unmarked DIT group releases from CR hatcheries.

Table 6-34. Percentage of all estimated CWT recoveries of marked fish associated with DIT groups released from CR hatcheries (brood years 1998-2011) by detection method (electronic or visual) and fishery type (NSF, MSF, Mixed).

| Region | Electronically Sampled |  |  |  | Visually Sampled |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Fishery | NSF | MSF | Mixed | Total | NSF | MSF | Mixed | Total |
| Alaska |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| British Columbia |  |  |  |  |  |  |  |  |
| Net | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.01\% | 0.05\% | 0.00\% | 0.06\% | 0.00\% | 0.83\% | 0.27\% | 1.10\% |
| Troll | 0.01\% | 0.03\% | 0.00\% | 0.04\% | 0.00\% | 0.04\% | 0.00\% | 0.04\% |
| Puget Sound |  |  |  |  |  |  |  |  |
| Net | 0.07\% | 0.00\% | 0.00\% | 0.07\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.07\% | 0.70\% | 0.00\% | 0.77\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Washington Coast |  |  |  |  |  |  |  |  |
| Net | 0.24\% | 0.00\% | 0.00\% | 0.24\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Sport | 0.63\% | 27.44\% | 0.00\% | 28.06\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Troll | 1.16\% | 0.91\% | 0.00\% | 2.07\% | 0.00\% | 0.00\% | 0.00\% | 0.00\% |
| Oregon Coast and Columbia River |  |  |  |  |  |  |  |  |
| Net | 17.10\% | 5.03\% | 0.04\% | 22.18\% | 0.01\% | 0.00\% | 0.00\% | 0.01\% |
| Sport | 2.77\% | 17.26\% | 0.03\% | 20.06\% | 0.08\% | 23.76\% | 0.00\% | 23.84\% |
| Troll | 0.04\% | 0.01\% | 0.00\% | 0.05\% | 0.90\% | 0.38\% | 0.00\% | 1.29\% |
| California |  |  |  |  |  |  |  |  |
| Sport | 0.00\% | 0.00\% | 0.00\% | 0.00\% | 0.12\% | 0.00\% | 0.00\% | 0.12\% |
| Totals | 22.11\% | 51.43\% | 0.07\% | 73.60\% | 1.12\% | 25.01\% | 0.27\% | 26.40\% |

Approximately $81 \%$ of the estimated CWT recoveries in all fisheries for the marked component of the north-migrating DIT group from the Lewis River Hatchery were in electronically-sampled fisheries (Table 6-35). For the marked components of the other three CR hatcheries, only 58-73\% of the fishery recoveries occurred in electronically-sampled fisheries. The percentages of recoveries in ETD fisheries for the unmarked DIT groups from CR hatcheries were similar to their corresponding marked components. Less than $1 \%$ of the estimated CWT recoveries from any hatchery occurred in mixed-regulation fisheries. Estimated recoveries for unmarked DIT groups in NSFs without electronic sampling were $\leq 2.5 \%$ for all CR hatcheries. For the marked component of DIT groups from CR hatcheries, the percentage of total estimated CWT recoveries occurring in MSFs, across all brood years, ranged from $71 \%$ for Lewis River - North to $86 \%$ for Lewis River - South.

Table 6-35. Percentage of DIT recoveries in fisheries with electronic sampling (ETD) and without electronic sampling (Visual), by fishery type. Unmarked recoveries in NSFs without electronic sampling are estimated (Estimated). Bold number is total number of estimated recoveries in fisheries for DIT groups released from CR hatcheries for the 1998-2011 brood years.

| Hatchery | Fishery Type | Marked Component |  |  | Unmarked Component |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | ETD <br> Sample | Visual Sample | Total | ETD <br> Sample | Visual <br> Sample | Estimated | Total |
| Le wis River - North |  |  |  |  |  |  |  |  |
|  | NSF | 27.6\% | 0.8\% | 28.4\% | 27.3\% | 0.8\% | 0.8\% | 28.9\% |
|  | MSF | 53.1\% | 18.0\% | 71.1\% | 52.6\% | 17.9\% | 0.0\% | 70.5\% |
|  | Mixed | 0.1\% | 0.4\% | 0.5\% | 0.1\% | 0.4\% | 0.0\% | 0.5\% |
|  | Total | 80.7\% | 19.3\% | 19,765.8 | 80.1\% | 19.1\% | 0.8\% | 19,928.8 |

Lewis River - South

|  |  |  |  |  |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | NSF | $12.1 \%$ | $1.5 \%$ | $13.6 \%$ | $11.9 \%$ | $1.4 \%$ | $1.5 \%$ | $14.8 \%$ |
|  | MSF | $52.1 \%$ | $34.3 \%$ | $86.4 \%$ | $51.3 \%$ | $33.8 \%$ | $0.0 \%$ | $85.2 \%$ |
|  | Mixed | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $64.2 \%$ | $35.8 \%$ | $\mathbf{9 , 4 9 7 . 3}$ | $63.3 \%$ | $35.3 \%$ | $1.5 \%$ | $\mathbf{9 , 6 3 8 . 7}$ |

## Eagle Creek NFH

|  | NSF | $20.0 \%$ | $2.3 \%$ | $22.3 \%$ | $19.6 \%$ | $2.2 \%$ | $2.2 \%$ | $24.0 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $52.5 \%$ | $25.3 \%$ | $77.7 \%$ | $51.3 \%$ | $24.7 \%$ | $0.0 \%$ | $76.0 \%$ |
|  | Mixed | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ | $0.0 \%$ |
|  | Total | $72.5 \%$ | $27.5 \%$ | $\mathbf{1 , 8 0 4 . 7}$ | $70.9 \%$ | $26.9 \%$ | $2.2 \%$ | $\mathbf{1 , 8 4 5 . 1}$ |

Sandy River

|  | NSF | $19.5 \%$ | $1.4 \%$ | $20.9 \%$ | $19.2 \%$ | $1.4 \%$ | $1.2 \%$ | $21.9 \%$ |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | MSF | $38.6 \%$ | $40.3 \%$ | $78.8 \%$ | $38.1 \%$ | $39.8 \%$ | $0.0 \%$ | $77.9 \%$ |
|  | Mixed | $0.0 \%$ | $0.3 \%$ | $0.3 \%$ | $0.0 \%$ | $0.3 \%$ | $0.0 \%$ | $0.3 \%$ |
|  | Total | $58.0 \%$ | $42.0 \%$ | $\mathbf{3 , 2 0 2 . 8}$ | $57.3 \%$ | $41.5 \%$ | $1.2 \%$ | $\mathbf{3 , 2 4 2 . 9}$ |

Figure 6-12 compares total exploitation rates estimated by the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$ (Section 3.2) for the marked and unmarked components of the DIT groups from each hatchery for each brood year. Years when the Z test comparing the return rates to the escapement of the marked and unmarked components of a DIT group was significant are indicated with an $*$. The proportion of the estimated unmarked ER occurring in MSFs is shown, also. The estimated unmarked ER is always lower than the marked ER across all hatcheries and brood years for CR DIT groups (Figure 6-12) and the 95\% CIs for the two estimates usually do not overlap (Figure 10D, Appendix 10).


Figure 6-12. Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by Columbia River hatcheries for brood years 1998-2011.


Figure 6-12 Comparison of estimates of exploitation rates (ER) for the marked and unmarked components of DIT groups released by Columbia River hatcheries for brood years 1998-2011 (continued).

The unmarked ER is consistently lower than the marked ER for all DIT groups and brood years. For a DIT group, differences between the marked and unmarked ER estimates ranged from +0.018 to +0.405 (Table 6-36). Across all hatcheries and brood years, the estimated ER for the marked component of the DIT groups was, on average, +0.190 greater than the ER for the unmarked component. For $100 \%$ of the DIT groups analyzed from the CR region, the estimated ER for the marked component was greater than the ER estimated for the unmarked component.

Table 6-36. Average difference between the estimated exploitation rates (ER) for the marked and unmarked components of CR DIT groups. Unmarked ER estimated using the PR method with $\lambda$ at release.

| Hatchery | Number | Difference Marked ER - Unmarked ER |  |  |
| :--- | :---: | :---: | :---: | :---: |
| of Year | Mean | Minimum | Maximum |  |
| Lewis River - North | 14 | 0.200 | 0.118 | 0.323 |
| Lewis River - South | 14 | 0.171 | 0.051 | 0.346 |
| Eagle Creek NFH | 14 | 0.155 | 0.018 | 0.254 |
| Sandy River | 11 | 0.244 | 0.091 | 0.405 |
| Regional Total | 53 | 0.190 | 0.018 | 0.405 |

### 6.4.1 Conclusions and Recommendations for Columbia River Hatchery DIT Groups

- Sub-sampling the escapement was fairly common for CR DIT groups. In about $25 \%$ of the CR DIT groups, less than $50 \%$ of the returning Coho were directly sampled. The average percentage of the Coho in the escapement that were directly sampled was < $60 \%$ for the DIT groups from the Lewis River Hatchery (both the north-migrating and south-migrating groups). For the Lewis River Hatchery, 5 out of 14 (northmigrating) and 6 out of 14 (south-migrating) brood years had sampling rates $<50 \%$. Sub-sampling affects the power of the Z test that compares the return rates of the marked and unmarked components of a DIT group. Lower sampling rates result in decreased power for these tests.
- Nearly all returning Coho that were directly sampled at CR hatcheries were screened for CWTs with ETD. This practice eliminates a source of potential bias for the estimates of the number of fish in the unmarked component of DIT groups.
- For all DIT groups examined from CR hatcheries, $79 \%$ of the 53 Z tests conducted were significant and all of the significant tests had $\lambda R$ ratios $>1.0$ (i.e., the return rate of the unmarked component was significantly greater than for the marked component indicating a measurable impact of MSFs).
- Relatively small numbers of CWT recoveries of Eagle Creek NFH and Sandy River Hatchery DIT groups result in more imprecision in ER estimates for these DIT groups compared to the Lewis River Hatchery DIT groups.
- Across all hatcheries and brood years, the percentage of CWT recoveries in mixedregulation fisheries for the marked component of CR DIT groups was less than $0.1 \%$.
- Only the Lewis River North DIT groups had $80 \%$ or more their estimated CWT recoveries from electronically-sampled fisheries (both the marked and unmarked components). The marked component of the DIT groups from Lewis River South, Eagle Creek NFH, and Sandy River Hatchery had $64 \%$ to $73 \%$ of their fishery recoveries in electronically-sampled fisheries.
- Across all hatcheries and brood years, less than $0.1 \%$ of the estimated CWT recoveries in fisheries for the marked component of Columbia River DIT groups occurred in mixed-regulation fisheries.
- A moderately high percentage of CWT recoveries for the marked component of the CR DIT groups occurred in visually-sampled mark-selective fisheries ( $18 \%$ across all hatcheries and brood years). Visual sampling in Oregon sport fisheries increases the probability of bias in the estimation of unmarked ER.
- The exploitation on the unmarked component of the Columbia River DIT groups was estimated to be less than that of the marked component for all brood years ( $100 \%$ ) and the difference between the two ER estimates was usually significant ( $85 \%$ of the brood years).
- MSFs appeared to be effective in decreasing the exploitation rate on unmarked Coho stocks represented by the DIT groups for the CR region. The ER for the unmarked component of the DIT group was consistently estimated to be less than the ER for the marked component for all the DIT groups.

For the 53 DIT group comparisons for the Columbia River region:

- 0\% had an unmarked ER estimate > than the marked ER estimate;
- $4 \%$ had a difference in ER estimates (marked ER - unmarked ER) that were > 0 and $\leq 0.05$;
- $11 \%$ had a difference in ER estimates that were $>0.05$ and $\leq 0.10$;
- $21 \%$ had a difference in ER estimates that were $>0.10$ and $\leq 0.15$, and,
- $64 \%$ of the differences were $>0.15$.


## Recommendations

The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

1. Data for the DIT groups from Lewis River Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs for both the north-migrating and south-migrating groups.
a. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in $96 \%$ of the brood years for both the north-migrating and south-migrating groups.
b. Estimated total recoveries averaged about 2,000 for each brood year.
c. $\lambda R$ ratios that were greater than 1.0 and had $95 \%$ CIs that did not include 1.0 occurred across the range of brood years analyzed.
d. The average difference between ERs for the marked and unmarked components of the DIT groups were relatively large $(+0.20$ for north-migrating and 0.17 for south migrating groups).
e. The ER for the marked component was higher than that of the unmarked component for all 14 of the brood years examined for both the north-migrating and south-migrating groups.
f. For 13 of the 14 north-migrating brood years and 12 of the 14 south-migrating brood years analyzed, the estimated ER for the unmarked component of the DIT group was less than for the marked component and the two estimates had non-overlapping $95 \%$ confidence intervals.
2. Data for the DIT groups from Sandy River Hatchery provided relatively consistent and reliable estimates of marked and unmarked return rates and ERs.
a. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in $82 \%$ of the brood years.
b. Estimated average total recoveries averaged $>500$ for both the marked and unmarked DIT group components.
c. $\lambda R$ ratios that were greater than 1.0 and had $95 \%$ CIs that did not include 1.0 occurred across the range of brood years analyzed. There was only one brood year with a $\lambda R$ ratio < 1.0 .
d. The average difference between ERs for the marked and unmarked components of the DIT groups was relatively large ( +0.24 ).
e. The ER for the marked component was higher than that of the unmarked component for all 11 of the brood years examined.
f. For 10 of the 11 brood years analyzed, the estimated ER for the unmarked component of the DIT group was less than for the marked component and the two estimates had non-overlapping 95\% confidence intervals.

The results for the following DIT program(s) are mixed and are difficult to categorize:

1. Data for the DIT groups from Eagle Creek NFH provided mixed.
a. The Z test results comparing the return rates of the marked and unmarked components of a DIT group to the escapement were significant and positive (a higher proportion of unmarked fish returned to the hatchery than marked fish) in $64 \%$ of the brood years; this is the lowest rate for CR DIT groups.
b. The precision of the estimates of return rates, $\lambda R$ ratios, and marked and unmarked ERs is more variable and often lower (worse) when compared to the other DIT groups in the CR region.
c. About a third of the $\lambda R$ ratios had $95 \%$ CIs that included 1.0, by far the highest percentage for CR hatcheries.
d. There were DIT group data only through brood year 2008 for Eagle Creek NFH.

## 7 DISCuSsion and Conclusions

The objective of the Coho Double Index Tagging (DIT) program is to provide data to estimate and evaluate the impacts of mark-selective fisheries (MSFs) on unmarked stocks of Coho salmon. MSFs are designed to reduce the impact on unmarked (usually naturally-produced) Coho salmon while supporting fisheries that target marked (hatchery-produced) Coho. This section of the report evaluates whether the data analyzed for DIT groups from British Columbia, Puget Sound, Washington Coast, and Columbia River hatcheries for the 19982011 brood years provide evidence consistent with meeting that objective. It includes: an examination of how well some of the assumptions related to fishery sampling are met and discusses the potential impacts of sampling deficits on the estimates (Section 7.3); an assessment of the exploitation rates for marked and unmarked Coho stocks produced by the Post-season Coho FRAM model to corresponding ER estimates for the marked and unmarked components of related DIT groups (Section 7.4); a discussion of issues related to the selective-fishery mortality ( $s f m$ ) rates used for the analyses and DIT program data quality (Section 7.5); and finally, an assessment of whether there are alternatives to the DIT program that could provide the necessary information for fisheries management when there are MSFs (Section 7.6).

Three methods of estimating the exploitation rate for the unmarked component of a DIT group using CWT data were examined. Before evaluating the DIT programs, a brief discussion of the three methods is presented.

### 7.1 Evaluation of Estimation Methods for the Exploitation Rate of the Unmarked DIT-Group Component

The three analytical methods (as opposed to model-based methods) used to estimate the exploitation rate for the unmarked component of a DIT group were:

1) a Total ER method using DIT group release-and-recovery data;
2) a Paired-Ratio (PR) method using DIT group release-and-recovery data and either $\lambda$ at release or $\lambda$ estimated from hatchery and escapement sampling; and,
3) a method using only the release-and-recovery data from the marked component of the DIT group (i.e., SIT-based).

The Total method supplied non-negative estimates of unmarked ERs in $88 \%$ of the 286 DIT groups examined (across all brood years and hatcheries). Comparing the non-negative estimates from the Total method to their corresponding estimates from the PR method using $\lambda^{\text {Rel }}$ :

- the Total method estimates of unmarked ER were higher than the estimates from the PR method using $\lambda^{\text {Rel }}$ in $78 \%$ of the comparisons;
- the average difference in ER estimates (Total - PR $\lambda^{\text {Rel }) ~ w a s ~}+0.061$ (median difference $=+0.043$ ); and,
- the estimates of unmarked ER from the Total method were also considerably less precise than the estimates from the PR method - the average percent standard error
(PSE) for the methods was $37 \%$ for the Total method compared to $14 \%$ for the PR $\lambda^{\text {Rel }}$ method.

The Total method is not recommended as a method for estimating the ER for the unmarked component of a DIT group because:

1. it can result in negative estimates of ER for the unmarked component - for the DIT groups examined in this report $12 \%$ of the estimates from the Total method were negative;
2. in comparison to either of the PR methods of estimation, the Total method appears to be biased and over-estimates the ER for the unmarked component of the DIT group;
3. the estimates of ER for the unmarked component from the Total method are considerably less precise than the estimates from either of the PR methods; and,
4. the Total method does not provide fishery-specific estimates of ER - only the total ER across all fisheries is estimated.

Estimates of unmarked ER from the PR method using $\lambda$ at release and the SIT-based method were highly correlated with each other ( $r=0.956, P<0.001$ ). The SIT-based estimates of unmarked ER were lower than the estimates from the PR method using $\lambda$ at release in $75 \%$ of the comparisons; this was especially evident when estimates of unmarked ER were greater than 0.40. The average difference in ER estimates (SIT - PR $\lambda^{\text {Rel }}$ ) was -0.035 (median difference $=-0.022$ ). When the SIT-based ER estimate is $<0.40$, the average difference between the two methods is -0.026 compared to an average difference of -0.062 when the SIT-based ER estimate is $\geq 0.40$. The SIT-based method of estimation can provide fisheryspecific estimates of ER. Relying on the SIT-based method would, on average, result in an underestimate of the ER on the unmarked component of DIT groups relative to either of the two PR methods. However, further work is needed to determine whether statistical methods that relate the SIT-based and DIT-based estimates (e.g., regression methods - see Section 7.6) may decrease the differences between the two methods of estimating unmarked ER and to compare SIT-based estimates of ER by fishery to those from the PR methods.

The PR method using either $\lambda^{\text {Rel }}$ or $\lambda^{E s c}$ can provide relatively precise, fishery-specific estimates of the ER for the unmarked component of a DIT group in addition to estimates of total ER. The average difference between estimates of the Total ER for the unmarked component of a DIT group using the PR method and $\lambda^{\text {Rel }}$ compared to the PR method using $\lambda^{E s c}$ was less than 0.005 (individual DIT group differences ranged from -0.071 to +0.095 ). The estimate of unmarked ER from the PR $\lambda^{E s c}$ method was greater than the estimate from PR $\lambda^{\text {Rel }}$ for $76 \%$ of the DIT groups analyzed; this is expected as $\lambda^{E s c}$ is expected to be greater than $\lambda^{\text {Rel }}$ if MSFs are impacting the DIT groups. If PR calculations are done using both $\lambda^{\text {Rel }}$ and $\lambda^{\text {Esc }}$, then total and fishery-specific estimates of ER for the unmarked component of a DIT group can be bracketed.

Although the estimates of the exploitation rate for the unmarked component of a DIT group from all three methods (Total, PR, and SIT-based) were significantly correlated with one another, only the PR method supplied consistently reliable and precise estimates of
unmarked ER when its assumptions were met. The PR method using either $\lambda^{\text {Rel }}$ or $\lambda^{\text {Esc }}$ (or both to bracket the range of ERs) is the recommended method for estimating the ER for the unmarked component of a DIT group. For the PR method, $\lambda^{\text {Rel }}$ is measured very precisely as the numbers of fish in the marked and unmarked components of DIT groups are essentially counted at most hatcheries. The precision of the estimates of $\lambda^{E s c}$ is a function of the degree of sub-sampling of returning fish done at the hatchery since there is very little spawning ground sampling conducted and almost $100 \%$ of most hatchery sampling is done using ETD. The degree of sub-sampling varies by hatchery but as the proportion of the return directly sampled decreases the variability associated with the estimate of $\lambda^{E s c}$ increases.

### 7.2 Evaluation of DIT program results

Three statistical procedures were used to compare estimates for the marked and unmarked components of each DIT group from each brood year for each hatchery. The purpose of these tests was to determine whether there was evidence of statistically significant impacts of markselective fisheries on the unmarked component of the DIT groups. Specifically, was there evidence of a significantly reduced exploitation rate (ER) on the unmarked component of the DIT group relative to the marked component? We addressed this question using the following three tests:

1) $Z$ tests comparing the estimated return rates to the hatchery (number of fish returning to the hatchery or spawning ground / number of fish released) of the marked and unmarked components of each DIT group. Under MSFs, it is expected that the return rate of the unmarked component of a DIT group will be higher than for the marked component.
2) An assessment of whether the $95 \%$ confidence interval around the $\lambda R$ ratio $\left(\frac{\lambda^{\text {Escapement }}}{\lambda^{\text {Release }}}\right)$ for each DIT group included 1.0. Under MSFs, it is expected that this ratio will be greater than 1 .
3) Z tests comparing the estimated total exploitation rates of the marked and unmarked components of each DIT group. Under MSFs, it is expected that the exploitation rate on the marked component of a DIT group will be higher than on the unmarked component.

A significant result for either of these tests $(P \leq 0.05)$ provides non-subjective evidence that mark-selective fisheries reduced the impact on the unmarked component of a DIT group relative to the marked component. This applies when (1) the return rate of the unmarked component was higher than the marked component, (2) the $\lambda R$ ratio was $>1.0$, or (3) the estimated ER for the marked component was greater than the estimated ER for the unmarked component. These are the expected results if MSFs are having more impacts on the marked fish compared to the unmarked fish. There were some cases where a test was significant but in the opposite direction of our expectations (i.e., the return rate of the marked component of the DIT group was significantly higher than for the unmarked component, or the $\lambda R$ ratio was significantly less than 1.0 , or the unmarked component of the DIT group had a significantly higher ER than the marked component).

Based on the results from these three statistical tests, the results for each brood year's DIT group from each hatchery were categorized as follows:

1. Test result(s) counter to expectations - The results from at least one of the three tests was significant but in the opposite direction of what is expected from DIT groups that are impacted by MSFs (see paragraph above).
2. Test results not informative - None of the three tests had a significant result; there is no statistically significant evidence of differences between the marked and unmarked components of the DIT groups.
3. One or two test results significant - One or two of the three tests were significant and in the direction of what is expected from DIT groups that are impacted by MSFs.
4. All test results significant - All three of the tests were significant and in the direction of what is expected from DIT groups that are impacted by MSFs.

It is important to consider the power of the statistical tests for those DIT groups in category 2 above. The power of a test is the probability of detecting a difference when one exists. Nonsignificant tests may be a result of the low power for the test due to low sample sizes (e.g., a small number of CWTs recovered) and high variability in the estimates. For a proper assessment of the power of the tests, the size of the difference between estimates that is important to detect needs to be defined. Currently there is no guidance for selecting either absolute or relative differences in return rates or exploitation rates that are important to fisheries management.

There was a total of 286 DIT groups for which all three tests were conducted. Table 7-1 shows the results of the categorization by region. Figure 7-1 compares the percent of DIT release groups categorized as described above ( $1,2,3$, or 4 ) for each hatchery. Over all hatcheries and brood years, $29 \%$ of the DIT groups were categorized as 4 and $34 \%$ as 3 (provided evidence of MSF impacts). Eight percent (8\%) of all DIT groups were categorized as 1 (had at least one significant test that was in the opposite direction of what was expected for a DIT group). None of the three tests were significant for $29 \%$ of the DIT groups (they supplied no evidence of significant effects of MSFs on the DIT group).

Table 7-1. Percentage of DIT release groups placed in each assessment category according to the results of three statistical tests performed on the data for DIT groups from each hatchery.

|  | Number of | Assessment Category |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Region <br> DIT Release <br> Groups | $\mathbf{1}$ <br> Contrary | $\mathbf{2}$ <br> No Sig. | $\mathbf{3}$ <br> $\mathbf{1 - 2 ~ S i g . ~}$ | All Tests Sig. |  |
| British Columbia | 43 | $0.0 \%$ | $23.3 \%$ | $39.5 \%$ | $37.2 \%$ |
| Puget Sound | 108 | $9.3 \%$ | $44.4 \%$ | $35.2 \%$ | $11.1 \%$ |
| Washington Coast | 82 | $14.6 \%$ | $29.3 \%$ | $36.6 \%$ | $19.5 \%$ |
| Columbia River | 53 | $0.0 \%$ | $3.8 \%$ | $22.6 \%$ | $73.6 \%$ |
| Percent of Total | 286 | $7.7 \%$ | $29.4 \%$ | $33.9 \%$ | $29.0 \%$ |
| Number of Years |  | 22 | 84 | 97 | 83 |

For the 180 DIT release groups that were categorized as either 3 or 4 (i.e., provided some evidence of MSF impacts), 83 ( $46 \%$ ) were in category 4 - all three tests were significant and in the direction expected. For category 3, only the $\mathbf{Z}$ test comparing estimated ERs for the marked and unmarked DIT group components was significant for $51(28 \%)$ of the release groups and there were 30 release groups ( $17 \%$ ) where both the return rate Z test result was significant and the $95 \% \mathrm{CI}$ for the $\lambda R$ ratio did not include 1.


Figure 7-1. Percentage of brood years placed in each assessment category according to the results of three statistical tests performed on the data for DIT groups from each hatchery. The four assessment categories are: 1: at least one test was significant, but the result was in the opposite direction of what is expected from MSF impacts; 2 . None of the three tests had a significant result; 3. One or two of the three tests were significant and in the direction of what is expected from DIT groups that are impacted by MSFs; 4. All three tests were significant and indicate MSF impacts.

For the British Columbia (with the exception of Quinsam River Hatchery) and Columbia River regions, $80 \%$ or more the DIT groups from each hatchery were categorized as 3 or 4 . There were very few brood years from hatcheries in the CR region where at least one of the tests was not significant. There were no DIT groups placed into category 1 from these two regions. However, the results for these two regions, especially for BC, may be affected by the relatively high proportion of CWTs being recovered in visually-sampled fisheries and in mixed-regulation sampling strata.

The results for the Puget Sound and Washington Coast regions were more variable between hatcheries. The percentage of DIT groups from a hatchery categorized as 3 or 4 varied from about $20 \%$ or less for the Kendall Creek, Voights Creek, and Salmon River Fish Culture hatcheries to more than $70 \%$ for the Marblemount, Wallace River, Solduc, Bingham Creek, and Forks Creek hatcheries. About 44\% of the DIT groups from the Puget Sound region were categorized as 2, i.e., they supplied no evidence of significant effects of MSFs on the DIT groups. All the DIT groups placed into category 1 were from DIT groups from either the PS ( $9 \%$ of the PS DIT groups) or WC ( $15 \%$ of the WC DIT groups) regions.

Based on the above results, the DIT programs for several hatcheries in the Puget Sound and Washington Coast regions should undergo additional review to determine their continued value to the DIT program. These hatcheries are:

1) Lower Elwha Hatchery where only $36 \%$ of the DIT groups provided results that indicated some measurable impact of MSFs and $21 \%$ of the DIT groups were categorized as 1 as they had a significant test that was in the opposite direction of what was expected from a DIT group. The DIT programs for this hatchery were also recommended for further review in Section 6.2.
2) Kendall Creek Hatchery where only $20 \%$ of the DIT groups provided results that indicated some measurable impact of MSFs. The DIT programs for this hatchery were also recommended for further review in Section 6.2.
3) Soos Creek Hatchery where only $36 \%$ of the DIT groups provided results that indicated some measurable impact of MSFs. The DIT programs for this hatchery were recommended for continuation in Section 6.2.
4) Voights Creek Hatchery where only $21 \%$ of the DIT groups provided results that indicated some measurable impact of MSFs. The DIT programs for this hatchery were also recommended for further review in Section 6.2. The results from the DIT programs for this hatchery were viewed as mixed in Section 6.2.
5) Makah NFH where $31 \%$ of the DIT groups were categorized as 1 as they had a significant test that was in the opposite direction of what was expected from a DIT group. The DIT programs for this hatchery were also recommended for further review in Section 6.3.
6) Salmon River Fish Culture where only $8 \%$ of the DIT groups provided results that indicated some measurable impact of MSFs and $31 \%$ of the DIT groups were categorized as 1 as they had a significant test that was in the opposite direction of what was expected from a DIT group. The DIT programs for this hatchery were also recommended for further review in Section 6.3.

### 7.2.1 Comparison of DIT Group Characteristics by Assessment Category

Different characteristics of the DIT groups were compared across each of the assessment categories described above to examine whether some characteristics are consistently associated with the DIT groups that show the greatest evidence of significant effects of MSFs.

The characteristics examined were:

1) Number of fish released for the marked and unmarked components of the DIT group;
2) Number of fish in the marked and unmarked components of the DIT group that returned to the hatchery and escapement;
3) The estimated return rate of the marked and unmarked components of the DIT group (number of fish returning to the hatchery and escapement / number of fish released);
4) The estimated number of CWTs from the marked component of the DIT group recovered in all fisheries, estimated number of CWTs from the marked component of the DIT group recovered in mark-selective fisheries, and proportion of marked component CWT fishery recoveries that occurred in MSFs;
5) Estimated exploitation rates for the marked and unmarked components of the DIT group; and,
6) Difference between the estimated return rates for the marked and unmarked components of the same DIT group and difference between the estimated total exploitation rates for the marked and unmarked components of the same DIT group.

Appendix Table 11A summarizes the mean, median, minimum, and maximum values for each of the characteristics by assessment category.

There were no large differences among the four assessment categories in the numbers of fish released in the unmarked or marked components of the DIT groups (Figure 7-2). Median releases sizes for all assessment categories were between about 45,000 to 50,000 fish per component.

Generally, there were more fish returning to the hatchery or escapement for both the marked and unmarked components of the DIT groups (Figure 7-3) which had some evidence of impact by MSFs (categories 3 and 4). The median numbers of unmarked Coho in the escapement for categories 3 and $4(\approx 970$ and 1,600 , respectively) were about twice that as for categories 1 and 2 ( $\approx 335$ and 535, respectively). However, there was considerable variability in these numbers. For example, in category 4 there were several DIT groups where the total number of unmarked CWTs in the return to escapement was < 300. Similarly, for the marked groups the median numbers of fish in the escapement for categories 3 and $4(\approx 900$ and 1,400 , respectively) was greater than that of categories 1 and 2 ( $\approx 625$ and 525 , respectively). In category 4 there were several DIT groups where the total number of marked CWTs in the return to escapement was < 200 .

Median return rates for both the marked and unmarked components of DIT groups in assessment categories 3 and 4 were $\geq 0.018$ compared to less than 0.01 for the other two assessment categories (Figure 7-4).


Figure 7-2. Comparison by assessment category of the numbers of marked (upper plot) and unmarked (lower plot) Coho released in the DIT groups analyzed.


Figure 7-3. Comparison by assessment category of the numbers of marked (upper plot) and unmarked (lower plot) Coho returning to the hatchery or escapement for the DIT groups analyzed.


Figure 7-4. Comparison by assessment category of the estimated return rates to the hatchery or escapement for the marked (upper plot) and unmarked (lower plot) components of the DIT groups analyzed.

There were no large differences among the four assessment categories in the estimated number of CWTs recovered in all fisheries for the marked component of the DIT groups (Figure 7-5, upper plot); median numbers of CWTs recovered in all fisheries ranged from 500-625. Not unexpectedly, the marked component of DIT groups in category 4 generally had a greater number of estimated tags recovered in MSFs relative to the other assessment categories (Figure $7-5$, middle plot: median $\approx 290$ ). It also had a higher proportion of total fishery recoveries estimated to occur in MSFs (Figure 7-5, lower plot: median $\approx 0.63$ ). In comparison, for the other assessment categories the medians for the number of estimated tags recovered in MSFs were less than 150 and all medians for the proportion of total fishery recoveries estimated to occur in MSFs were less than 0.35 (Table 11A Appendix 11).

Based on the comparisons summarized in Figures 7-2, 7-3, 7-4, and 7-5, to provide the sample sizes needed to consistently detect significant impacts by MSFs on the unmarked component of a DIT group the following guidelines are suggested:

- The combination of the number of fish released in the DIT group and the expected return rate to the hatchery should result in at least 1,000 fish in the marked and unmarked components of the DIT group (individually) returning to the escapement (and be available for sampling).
- For the marked component of a DIT group, at least one-third (33\%) of all estimated CWT recoveries in fisheries should be expected to occur in MSFs to reliably detect MSF impacts using the tests in this report.

Figure 7-6 compares estimated exploitation rates for the marked and unmarked components of the DIT groups for each assessment category. Note that the median estimated exploitation rates for both the marked and unmarked components of the DIT groups which had some evidence of impact by MSFs (categories 3 and 4) were actually less than those for the other two assessment categories which did not provide evidence of significant impacts by MSFs.

Finally, Figure 7-7 compares differences between the marked and unmarked components of a DIT group for the return rate to the escapement and for the estimated total exploitation rate. As expected, these differences tend to increase as the assessment category increases; category 4 (composed of DIT groups with the most evidence of significant impacts by MSFs) has the largest median difference between return rates $(0.005 \%)$ and exploitation rates $(0.15)$ for the marked and unmarked components of the DIT groups.

## These figures emphasize that it is the differences in the return rates and the exploitation rates between the marked and unmarked components of the DIT groups that are important and that high return rates or exploitation rates by themselves are not the most important factor determining whether MSF impacts are detected.

One might expect that these two differences (difference between the marked and unmarked components of a DIT group in the estimated return rate and difference in the estimated exploitation rate) would be highly correlated. However, the correlation between these differences while significant ( $P<0.001$ ) is not particularly high ( $r=0.522$ ) and explains only $27 \%$ of the variability between the two differences.


Figure 7-5. Comparison by assessment category of the estimated numbers of CWTs recovered in all fisheries (upper plot), estimated numbers of CWTs recovered in mark-selective fisheries (middle plot), and the proportion of all fishery recoveries in MSFs (lower plot) for the marked DIT group component.


Figure 7-6. Comparison by assessment category of the estimated exploitation rates for the marked (upper plot) and unmarked (lower plot) components of the DIT groups analyzed.


Figure 7-7. Comparison by assessment category of the differences between the estimated return rates (upper plot) and exploitation rates (lower plot) for the marked and unmarked components of the DIT groups analyzed.

### 7.3 Evaluation of Fishery Sampling

Exploitation rate estimates provided by the DIT program are unbiased under these assumptions:

- Estimates of the number of CWTs in the return to the escapement (hatchery and spawning grounds) are unbiased.
- Estimates of the number of CWTs in the retained catch are unbiased for both the marked and unmarked components of a DIT group.
- All fish are retained in NSFs and all marked fish are retained in MSFs.
- All unmarked fish are released in visually-sampled fisheries.

When all, or nearly all, of the escapement to a hatchery is sampled, bias will not be an issue. As the rate of sub-sampling the escapement to the hatchery increases, the potential for bias increases unless very strict sub-sampling protocols are followed to ensure a random sample of the returning fish is collected.

The type of sampling used in the major fisheries impacting a DIT group determines how well the second critical assumption is met. Electronic sampling (all coded wire tagged fish in a NSF or MSF sample have an equal chance of being recovered) when properly implemented provides unbiased estimates of the number of CWT recoveries from both the marked and unmarked components of a DIT group. Visual sampling (the adipose fin clip is used to subset catch to sample for detection of coded wire tagged fish and thus only marked fish are sampled) provides biased CWT recovery data as there is no opportunity for unmarked fish with a CWT to be recovered. There were two issues with fishery sampling that potentially impacted the estimates for some DIT groups: (1) visually-sampled NSFs; and (2) mixedregulation fishery sample strata. The alignment of the fishery sample strata with fisheryregulation strata is critical to providing unbiased data for DIT analysis. If the type of fishery (NSF or MSF) is unknown, or the sample is composed of a mixture from both fishery types, then proper estimation of mortalities for the DIT group components is compromised. A description and evaluation of each year's proposed mark-selective fisheries that will impact Coho salmon is included in the annual reports issued by the PSC's Selective Fishery Evaluation Committee (SFEC 2019). This SFEC annual report highlights some of the detrimental issues related to MSF sampling discussed in this report.

This section summarizes three factors related to the overall quality of fishery sampling as it relates to DIT program estimates. The percentages of all CWT recoveries in fisheries for all DIT groups released from a hatchery (brood years 1998-2011) were calculated for three different sampling methods or regulation strata. They were:

1) The percentage of all estimated recoveries from the marked component of DIT groups from a hatchery that was recovered in electronically-sampled fisheries.
2) The percentage of all estimated recoveries from the marked component of DIT groups from a hatchery that was recovered in mixed-regulation fisheries.
3) The percentage of all estimated unmarked recoveries in fisheries that occurred in visually-sampled (non-electronically sampled) NS fisheries.

The majority of CWT recoveries from marked DIT groups in the BC region occur in visuallysampled fisheries (Figure 7-8). DIT groups in the BC region also have a consistently higher percentage of marked fish recoveries occurring in mixed-regulation sampling strata compared to the other regions. Estimates of unmarked ERs from the BC DIT groups should be interpreted with caution because of the additional uncertainty due to the prevalence of visual sampling in BC fisheries, the reliance on voluntary returns from BC sport fisheries, and the relatively high proportion of recoveries estimated from mixed-regulation fishery sampling strata in BC. The effects on DIT groups from other regions may not be as pronounced because the proportion of fish caught in BC fisheries is not as high.


Figure 7-8. Percentage of estimated CWT recoveries in fisheries by different sampling methods or regulation strata. Percentages are based on all CWT recoveries from the marked component of all DIT groups released from a hatchery for brood years 1998-2011.

More than $70 \%$ of the CWT recoveries of marked fish for DIT groups from the PS and WC regions occurred in electronically-sampled fisheries. Mixed-regulation sampling strata and unmarked recoveries in visually-sampled NSFs were generally not an issue with DIT groups from these two regions. With the exception of the DIT groups from the Lower Elwha Hatchery and Makah NFH, the proportion of CWT fishery recoveries for the unmarked DIT component that is estimated to occur in visually-sampled NSFs is low.

From 60 to $80 \%$ of the CWT recoveries of marked fish for DIT groups from the Columbia River region occurred in electronically-sampled fisheries. The proportion of unmarked recoveries estimated to occur in visually-sampled NSFs was small for all DIT groups from the CR region. Recoveries of CWTs for the mark component from mixed-regulation sampling strata were not an issue with DIT groups from the CR region.

A subset of hatcheries in the PS, WC, and CR regions that had a high proportion (> $65 \%$ ) of DIT groups placed into assessment categories 3 and 4 were identified. Based on those hatcheries, it is recommended that for the fisheries expected to impact DIT groups released from a hatchery:

- ETD and sampling programs are in place for at least $80 \%$ of fishery recoveries for the marked component of the DIT group;
- no more than 5\% of the estimated fishery recoveries for the marked component of the DIT group occur in mixed-regulation fishery strata; and,
- no more than 5\% of the estimated recoveries for the unmarked component of the DIT group occur in visually-sampled, non-selective fisheries.

Data from hatcheries in the BC region were not used in this evaluation because of the potential biases that could result from the relatively high proportion of DIT group recoveries occurring in visually-sampled NSFs or fisheries with mixed-regulation sampling strata.

### 7.4 Comparison of DIT ER Estimates to Post-season FRAM Estimates

Exploitation rate estimates for both the marked and unmarked components of the DIT groups analyzed were compared to corresponding estimates from the Post-season Coho FRAM. The PR method using $\lambda$ at release was used for the unmarked ER estimates. Drop-off mortality was included in the ER estimates for both the marked and unmarked components of the DIT groups and the DIT analysis was limited to age-3 fish to better align with FRAM ERs.

The correlations between the total brood year ER estimates were 0.65 ( $P<0.001$ ) for the marked groups and $0.69(P<0.001)$ for the unmarked groups. Because FRAM uses average stock-fishery-time period exploitation rates during a referenced base period, it is more appropriate to compare mean ER estimates for stocks rather than focusing on year-to-year differences (Table 5-1). Overall, $30 \%$ of the ER differences between the methods were within $\pm 0.05$ for the marked group. For the unmarked group, $32 \%$ of the ER differences between the methods were within $\pm 0.05$.

Consistent biases were evident for some groups. For example:

- The FRAM ER was greater than the DIT-based estimate for $\geq 75 \%$ of the brood years for unmarked groups from Inch Creek, Wallace River, George Adams, Makah NFH, Solduc, and Bingham Creek hatcheries.
- The FRAM ER was less than the DIT-based estimate for $\geq 75 \%$ of the brood years for unmarked groups from Quinault NFH.
- The FRAM ER was greater than the DIT-based estimate for $\geq 75 \%$ of the brood years for marked groups from George Adams, Solduc, and Bingham Creek hatcheries.
- The FRAM ER was less than the DIT-based estimate for $\geq 75 \%$ of the brood years for marked groups from Big Qualicum River, Quinault NFH, Lewis River - North, and Sandy Creek hatcheries.

Using the following general criteria:

- the mean difference between the FRAM and DIT-based ER estimates was $\leq \pm 0.05$ (relatively small error); and,
- between 40-60\% of the brood years have a DIT-based ER estimate greater than the FRAM-based ER estimate (relatively unbiased),
DIT groups from these hatcheries are considered to be adequately modeled by the Post-season FRAM:
- Marked DIT groups from the following hatcheries meet both criteria: Quinsam River, Robertson Creek, Wallace River, Lewis River - South, and Eagle Creek NFH.
- Unmarked DIT groups from the following hatcheries meet both criteria: Quinsam River, Big Qualicum River, Robertson Creek, Lower Elwha, Soos Creek, Lewis River - North, and Lewis River - South.

The DIT-based method estimated a greater impact (a greater reduction in the estimated ER on the unmarked component of the DIT group when compared to the marked component of the DIT group) by mark-selective fisheries on the unmarked component of the DIT groups compared to Post-season FRAM estimates for DIT groups from the BC and WC regions (Table 5-1). For DIT groups from the PS and CR regions, the DIT-based method estimated a smaller impact by mark-selective fisheries on the unmarked component of the DIT groups. While there is relatively good correspondence between DIT-based and FRAM-based estimates of ER for the marked and/or unmarked components of DIT groups from many hatcheries, there are several hatcheries where the correspondence between the two is very poor: for marked groups - Kendall Creek, Voights Creek, George Adams, Quilcene NFH, Makah NFH, Solduc, Bingham Creek, Lewis River - North, and Sandy River hatcheries; for unmarked groups - Kendall Creek, Voights Creek, George Adams, Quilcene NFH, Makah NFH, Solduc, and Bingham Creek hatcheries.

### 7.5 Selective Fishery Mortality Rates and Data Quality Issues

The introduction of mass marking and the addition of DIT groups to the coastwide CWT system greatly increased the complexity of the system. Additional analytical methods are needed to estimate fishery impacts on unmarked groups of Coho salmon and these new analytical methods require additional assumptions. The complexity of the data management system also increased as two types of CWT groups are now being released from many facilities (DIT groups and SIT groups) and the type of fishery that a CWT is recovered in (NSF, MSF, or mixed) must be recorded for each recovery as well as the type of sampling associated with each CWT recovery (visual or electronic).

### 7.5.1 Selective fishery mortality rates

One new critical assumption under DIT is the selective fishery mortality (sfm) rate (release mortality rate) for mark-selective fisheries. These rates (Table 3-2) were based on studies conducted in the 1980s and 1990s (PFMC 2000) and are treated as constants with no associated uncertainty. Estimates of unmarked mortalities and the exploitation rate for the unmarked component of the DIT group are very sensitive to the selective-fishery mortality rate and its variability (Zhou 2002). If, on average, the actual sfm rates experienced by the unmarked fish are higher than assumed then unmarked mortalities will be underestimated and the differences between the ER estimates for the marked and unmarked components of the DIT group will be smaller than reported here. Conversely, if $s f m$ rates are, on average, lower than assumed then unmarked mortalities will be overestimated and the differences between the ER estimates for the marked and unmarked components of the DIT group will be larger than reported here.

Sfm rates are assumed to vary between fisheries of different types (e.g., sport, troll, net). Realistically, sfm rates may also vary between fisheries of the same type depending upon the predominant gear used and environmental conditions at the time of capture and also vary between years (for similar reasons). The results of the Z tests that were used in the evaluation of MSF impacts to Coho DIT groups (Section 7.2) which compared the estimated ERs for the marked and unmarked components of a DIT group are sensitive to:

- the $s f m$ rates used for the MSFs; and,
- the uncertainty in the estimates of $s f m$ rates (which is currently assumed to be 0 ).

Using different sfm rates and/or accounting for the uncertainty in the sfm rates could change the results for many of these hypothesis tests. E.g., tests that are now significant and indicate a differential impact on the marked and unmarked components of a DIT group and MSF impacts may become non-significant and the reverse may occur for tests that are currently non-significant. Further examination of this issue by a sensitivity analysis is recommended.

### 7.5.2 Data quality issues

Many issues related to the identification of the proper set of CWT data required to conduct a DIT analysis became apparent during the data compilation stages for the DIT analyses summarized in this report. Other data quality issues were also identified. Many of these same data quality issues were identified and discussed in JCDAW (2003). Details for the analyses in this report are discussed below.

Multiple groups of Coho that are part of a DIT group are often released from a hatchery and it is common for more than one CWT code to be used in tagging the marked and unmarked components of the DIT group released from a hatchery in a given year. When multiple CWT codes are used to tag the marked or unmarked components of a DIT group release, and other CWT codes for SIT groups are also released, identifying which group of CWT codes to use in a DIT analysis can be challenging. For example, during the development of this report, an
initial set of CWT codes was identified for the DIT analyses. A later review of these initial CWT codes (involving only DIT groups from the Puget Sound, Washington Coast, and Columbia River regions) after initial analyses had already been conducted identified the following issues:

- 16 CWT codes associated with the marked component of a DIT group were identified as not actually belonging to a DIT group;
- There were 5 instances where a CWT code associated with either the marked or unmarked component of a DIT group was omitted in the initial analysis:
- In three of these cases data from a CWT code associated with a marked component of a DIT group were missing; and,
- In two of these cases, data from a CWT code associated with an unmarked component of a DIT group were missing.
These issues were all addressed; the analyses presented in this report used these revised data.
Finally, a new data query to the RMIS CWT recovery data base was conducted for the final set of tag codes for the DIT groups included in the analysis; this new query was done only for DIT groups in the Puget Sound, Washington Coast, and Columbia River regions. This query was conducted approximately 18 months after the query used to draw data for the initial drafts of this report. This query added hundreds of tag recoveries to some DIT groups. It was clear that new data had been reported to RMIS after the original query and recovery data for some tags codes from brood years as far back as the early 2000s had been added. The timely reporting of recovery data, especially from some terminal areas, is a major issue challenging these types of analyses. This late-reporting problem affected multiple DIT groups from hatcheries in the Puget Sound and Washington Coast region.

The issues discussed above illustrate that an analyst cannot simply make a query to RMIS to retrieve data for a DIT analysis under the assumption that CWT recovery data are complete and correct. Careful review of all the data is needed and input from regional experts that are very familiar with the data is needed to identify potential data quality issues such as incomplete or incorrect release information, missing fishery and escapement recoveries, and/or misspecification of fishery type, i.e., NSF, MSF or mixed, or DIT groups that have not been correctly identified in RMIS as a DIT. The review should also include review of the data associated with the rearing of the DIT groups such as stock, average size at release, release date, release location, and mark status at recovery relative to release (see item 2 in the "Framework for Evaluating DIT Programs" in the following section of this report).

### 7.6 Are there Reliable Alternatives to the DIT Program for Estimating the Exploitation Rate on Unmarked Coho Stocks?

This section examines whether two alternative methods of producing estimates of the exploitation rates on unmarked Coho stocks examined earlier in the report might, under certain circumstances, be reliable substitutes for estimates from a DIT program:

- Single index tag (SIT) methods (Section 4); and,
- Post-season FRAM (FRAM) estimates (Section 5).

This section is predicated on the assumption that DIT program estimates using the PR method with $\lambda^{\text {Rel }}$ provide the "best available" estimates of the ER on unmarked stocks. This is probably a reasonable assumption for the majority of the DIT programs examined in this report. However, there are some DIT programs that were identified in Section 6 of this report that may not be providing robust and reliable estimates of the ER on the unmarked component of the DIT groups. Those programs are identified in the following analyses. The analyses in this section are not presented as final alternative models but rather as initial steps in identifying whether alternative methods could be used to produce estimates of the ER on unmarked stocks that are useful for management purposes. Further exploration and more in-depth analyses are required before any alternative method could be implemented as a substitute for a DIT program.

Ordinary least squares regression was used to relate the ER estimates for unmarked stocks from the alternative method (the independent $X$ variable) to the DIT-based estimate of the ER on the corresponding unmarked component of the DIT group (the dependent $Y$ variable).
Three statistics are used to summarize the regression results:

1. the coefficient of determination $\left(\mathrm{R}^{2}\right)$ for the regression model which is the percentage of the variation in the dependent variable that is explained by the regression model;
2. the significance $(P)$ of the regression model based on the F statistic; and,
3. the mean absolute difference (MAD) between the DIT-based estimate of unmarked ER and the model based estimate of unmarked ER for the brood years used to estimate the regression model ${ }^{1}$.

There are distinct differences between the data used for the assessments of the two methods. For the comparison of SIT-based estimates to DIT-based estimates, both estimates are based on the data described in Section 4:

- the ER estimates are for all ages;
- the estimates do not include drop-out|drop-off mortalities; and,
- the estimates compared are for total ER across all fisheries.

[^14]For the comparison of FRAM-based estimates to DIT-based estimates, both estimates are based on the data described in Section 5:

- the ER estimates are for age-3 Coho only;
- the estimates include drop-out|drop-off mortalities; and,
- the estimates compared are for:
- pre-terminal ERs for hatcheries in the BC and CR regions; and,
- for total ER across all fisheries for hatcheries in the PS and WC regions.

Table 7-2 summarizes the results for the regressions models for each method, by hatchery. Hatchery names are shaded to indicate their classification in Section 6:

Green indicates hatcheries with DIT programs that provided relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT group.
Yellow indicates hatcheries with DIT programs that have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT programs should be discontinued.

Table 7-2. Summary of regression model results, including mean absolute difference (MAD), relating single index tag (SIT) and post-season FRAM based estimates of the exploitation rate on unmarked stocks to estimates using DIT-based (PR $\lambda^{\text {Rel }}$ ) estimates, by hatchery. Refer to text for additional explanation.

| Hatchery | Method | $\mathbf{R}^{\mathbf{2}}$ | Regression <br> $\boldsymbol{P}$ value | MAD |
| :---: | :--- | :---: | :---: | :---: |
| British Columbia Region |  |  |  |  |
|  | SIT | $87.7 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.023 |
|  | FRAM | $4.3 \%$ | $\mathbf{0 . 0 4 3}$ | 0.088 |
| Inch Creek | SIT | $86.4 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.012 |
|  | FRAM | $3.1 \%$ | 0.547 | 0.039 |

Puget Sound Region

| Lower Elwha River | SIT | 28.9\% | 0.048 | 0.069 |
| :---: | :---: | :---: | :---: | :---: |
|  | FRAM | 1.9\% | 0.641 | 0.075 |
| Kendall Creek | SIT | 64.6\% | 0.005 | 0.067 |
|  | FRAM | 4.9\% | 0.538 | 0.118 |
| Marblemount | SIT | 93.0\% | <0.001 | 0.027 |
|  | FRAM | 10.6\% | 0.255 | 0.101 |
| Wallace River | SIT | 72.3\% | <0.001 | 0.014 |
|  | FRAM | 45.9\% | 0.008 | 0.022 |
| Soos Creek | SIT | 68.3\% | <0.001 | 0.047 |
|  | FRAM | 1.4\% | 0.691 | 0.100 |
| Voights Creek | SIT | 92.5\% | <0.001 | 0.029 |
|  | FRAM | 2.7\% | 0.573 | 0.105 |
| George Adams | SIT | 96.2\% | <0.001 | 0.023 |
|  | FRAM | 32.0\% | 0.035 | 0.128 |
| Quilcene | SIT | 91.6\% | <0.001 | 0.043 |
|  | FRAM | 37.2\% | 0.021 | 0.119 |

Washington Coast Region

| Makah NFH | SIT | $87.2 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.023 |
| :---: | :--- | :---: | :---: | :---: |
|  | FRAM | $12.0 \%$ | 0.271 | 0.095 |
| Quinault NFH | SIT | $34.2 \%$ | $\mathbf{0 . 0 2 8}$ | 0.061 |
|  | FRAM | $0.3 \%$ | 0.845 | 0.090 |
| Salmon River Fish <br> Culture | SIT | $63.9 \%$ | $\mathbf{0 . 0 0 1}$ | 0.085 |
|  | FRAM | $10.4 \%$ | 0.307 | 0.149 |
| Solduc | SIT | $97.4 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.028 |
|  | FRAM | $27.4 \%$ | 0.055 | 0.180 |
| Bingham Creek | SIT | $68.9 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.032 |
|  | FRAM | $3.6 \%$ | 0.513 | 0.066 |
| Forks Creek | SIT | $57.7 \%$ | $\mathbf{0 . 0 0 2}$ | 0.056 |
|  | FRAM | $10.5 \%$ | 0.259 | 0.120 |

Columbia River Region

| Lewis River - North | SIT | $72.3 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.049 |
| :---: | :--- | :---: | :---: | :---: |
|  | FRAM | $19.3 \%$ | 0.116 | 0.038 |
| Lewis River - South | SIT | $11.4 \%$ | 0.237 | 0.025 |
|  | FRAM | $1.8 \%$ | 0.649 | 0.062 |
| Eagle Creek | SIT | $19.3 \%$ | 0.116 | 0.034 |
|  | FRAM | $15.2 \%$ | 0.167 | 0.059 |
| Sandy River | SIT | $85.2 \%$ | $<\mathbf{0 . 0 0 1}$ | 0.034 |
|  | FRAM | $7.6 \%$ | 0.411 | 0.058 |

Unshaded indicates hatcheries with DIT programs that provided mixed results and were difficult to categorize.

See Appendix 12 for plots of the regression models presented in Table 7-2. The Big Qualicum River, Chilliwack River, and Robertson Creek hatcheries in the BC region were not analyzed because there were only five brood years with DIT estimates for each of these hatcheries.

There were 11 hatchery DIT programs (out of the 20 examined) that had $\mathrm{R}^{2}$ estimates > $70 \%$ for the simple linear regression models based on SIT-based ER estimates. The majority of these DIT programs had average ER estimates for the unmarked component of the DIT group $<40 \%$ (an ER level recommended in Section 4 as conducive to producing SIT-based estimates that are similar to DIT-based estimates). The following hatchery DIT programs meet those two criteria: Quinsam River; Inch Creek; Marblemount; Wallace River; George Adams; Makah NFH; Solduc; Lewis River (North); and Sandy River. For these nine hatcheries, the mean absolute difference (MAD) between the SIT-based and DIT-based estimates of unmarked ER ranged from 0.012 to 0.049 .

The highest $\mathrm{R}^{2}$ for any of the regression models relating FRAM-based ER to DIT-based ER was only $46 \%$ (Wallace River Hatchery). The regression model $R^{2}$ for 16 of the 20 DIT programs was $<20 \%$. Mean absolute differences between the FRAM-based and DIT-based estimates of unmarked ER ranged from 0.022 to 0.180 for the FRAM-based regression models. As discussed earlier in this report, differences between Post-season Coho FRAM and DIT-based estimates of ERs are expected due to FRAM's reliance on average stock-fisherytime period exploitation rates during a referenced base period (1986-1992). Consequently, FRAM results for individual years do not reflect annual deviations of stock distribution or migration patterns from base-period averages. The results presented in Table 7-2 provide additional confirmation that Post-season Coho FRAM is not useful for assessing impacts on an annual basis but is best used to assess multi-year averages. Post-season assessments of annual ERs should not be based solely on post-season Coho FRAM.

## 8 Framework for Evaluating DIT Programs

An evaluation of the Coho salmon DIT programs providing information to the Pacific Salmon Commission for international management should be conducted on a regular basis. While this report supplies a major portion of the information needed for such an evaluation, it is not intended to be a complete review of each DIT program. The information in this report can be used to address items $2 \mathrm{~b}, 3 \mathrm{a}, 3 \mathrm{~b}, 3 \mathrm{c}, 4 \mathrm{a}, 4 \mathrm{c}$, and 5 a in the evaluation framework described below. Some of the items not addressed in this report are discussed in SFEC (2012).

1. Is there adequate coverage of DIT groups for important stock groups?
a) Does the DIT program provide information needed to support management of a Coho salmon stock(s) important to the Pacific Salmon Treaty?
b) Are there existing DIT programs already providing information on the stock(s) being represented?

## 2. Rearing and Release Conditions

a) Is the assumption that the only difference between the marked and unmarked components of a DIT group is their mark status valid?
i. Are the marked and unmarked components reared under identical conditions?
ii. Are the marked and unmarked components released at the same time and location?
b) Are the number of fish released in the marked and unmarked groups sufficient to estimate impacts given expected (average) survival rates to age 2 ?
c) Are the CWT tag codes for the marked and unmarked groups clearly and correctly associated in RMIS?
d) Are the number of fish released in the marked and unmarked components of each DIT group accurately enumerated?
e) Is all the release information being accurately reported to RMIS and verified for accuracy in RMIS after reporting?

## 3. Fishery Sampling

a) Is electronic sampling conducted in the major fisheries expected to impact this DIT group?
b) Are the non-selective and/or mixed-regulation fisheries that are expected to impact the DIT group electronically sampled?
i. If not, is there a reliable indirect estimate available using auxiliary information?
c) Are catch estimation strata, CWT sample strata, and fishery regulation strata aligned?
d) Is fishery recovery information properly expanded and reported to RMIS and verified for accuracy in RMIS after reporting?

## 4. Escapement Sampling

a) Is the escapement, hatchery and spawning grounds, electronically sampled?
b) Is escapement sampling conducted in a manner that provides unbiased estimates of the return rates for both the marked and unmarked groups?
i. Are fish that are passed upstream sampled?
c) Is escapement sampling sufficient to obtain sample sizes that provide accurate and precise estimates of the return rate for both the marked and unmarked groups?
d) Is escapement recovery information properly expanded and reported to RMIS and verified for accuracy in RMIS after reporting?

## 5. Fishery Impacts

a) Is the marked fish component of a DIT pair susceptible to current or potential MSFs that are large enough such that the return rate estimates for the marked and unmarked groups will be significantly different?
b) Is the marked fish component of a DIT pair susceptible to current or potential MSFs large enough such that the exploitation rate estimates for the marked and unmarked groups will be significantly different?

## 9 Recommendations

1. The Paired-Ratio method using either $\lambda^{\text {Rel }}$ or $\lambda^{\text {Esc }}$ is the recommended method for estimating the exploitation rate for the unmarked component of a DIT group.
2. The following guidelines are suggested to increase the probability that significant impacts by MSFs on the unmarked component of DIT groups will be consistently detected:

- The combination of the number of fish released in the DIT group and the expected return rate to the hatchery should result in at least 1,000 fish in the marked and unmarked components of the DIT group (individually) returning to the escapement (and to be available for sampling).
- For the marked component of a DIT group, at least one third (33\%) of all estimated CWT recoveries in fisheries should be expected to occur in MSFs.

3. For fisheries expected to impact DIT groups released from a hatchery, it is recommended that:

- ETD and sampling programs are in place for at least $80 \%$ of fishery recoveries;
- no more than 5\% of expected DIT group fishery recoveries occur in mixedregulation fishery strata; and,
- no more than 5\% of the estimated recoveries for the unmarked component of the DIT group occur in visually-sampled, non-selective fisheries.

4. A sensitivity analysis which examines the results of the hypothesis tests comparing the estimates of ERs for the marked and unmarked components of a DIT group to changes in sfm rates and to uncertainty in the sfm rates should be conducted.
5. The SIT-based method may be an adequate method of estimating unmarked ERs for some hatcheries if expected ERs are relatively low (e.g., < 40\%) and if survival rates and tagging levels are conducive to producing precise SIT-based estimates.
6. The comparisons of total ERs produced by Coho DIT and Coho FRAM presented in this report suggest that Coho DIT could provide a valuable source of data to evaluate the performance of Coho FRAM. Coho FRAM is the bilateral tool that is relied upon to produce fishery specific preseason and postseason estimates for ERs imparted by US and Canadian fisheries on individual coho management units included in the Southern Coho PST Agreement. Because Coho FRAM depends heavily on a variety of assumptions, including average stock distribution and harvest patterns derived from CWT groups that were released several decades ago for its reference base period, differences with ERs estimated from annual CWT recovery data are expected. It is recommended that a collaborative effort involving SFEC and CoTC be undertaken to investigate the ability to utilize CWT DIT and SIT recovery data to produce the stockfishery ERs needed for reporting of the Southern Coho Agreement and provide information to help interpret estimates produced by Coho FRAM.

Finally, the following recommendations are made for the DIT programs analyzed in this report (details for the basis of these recommendations are provided in Section 6):
$>$ The following DIT program(s) provide relatively consistent, reliable, and relatively precise estimates that can be used to evaluate the impacts of MSFs on the unmarked component of DIT groups:

British Columbia region Inch Creek Hatchery
Puget Sound region
Marblemount Hatchery
Wallace River Hatchery
Soos Creek Hatchery
George Adams Hatchery
Quilcene NFH
Washington Coast region
Quinault NFH
Solduc Hatchery
Bingham Creek Hatchery
Forks Creek Hatchery
Columbia River region
Lewis River Hatchery - north-migrating group
Lewis River Hatchery - south-migrating group
Sandy River Hatchery.
$>$ The following DIT program(s) have potential issues that decrease their effectiveness and require further review to determine if these issues can be addressed or if the DIT program(s) should be discontinued:

British Columbia region
Quinsam River Hatchery
Puget Sound region
Lower Elwha Hatchery
Kendall Creek Hatchery
Washington Coast region
Makah NFH
Salmon River Fish Culture.
$>$ The results for the following DIT program(s) are mixed and are difficult to categorize or there is an insufficient number of years of data to make a determination:

British Columbia region
Big Qualicum River Hatchery
Chilliwack River Hatchery
Robertson Creek Hatchery
Puget Sound region
Voights Creek Hatchery
Columbia River region
Eagle Creek NFH.

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## Appendices

Appendix 1: CWT codes, number of unmarked and marked fish released, and unmarked-to-marked ratio ( $\lambda$ ) for Coho salmon DIT groups by region, hatchery, and brood year.

Appendix Table 1A. CWT codes, number of unmarked and marked fish released, and unmarked-to-marked ratio $(\lambda)$ for Coho salmon DIT groups from the British Columbia region: by hatchery and brood year.

| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked <br> Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quinsam River | 1998 | 184236 | 10,473 | 184232 | 10,532 |  |
|  |  | 184237 | 10,240 | 184233 | 10,562 |  |
|  |  | 184238 | 10,060 | 184234 | 10,463 |  |
|  |  | 184239 | 10,712 | 184235 | 10,795 |  |
|  | 1998 Total |  | 41,485 |  | 42,352 | 0.980 |
|  | 1999 | 182730 | 21,590 | 183026 | 21,528 |  |
|  |  | 183704 | 10,769 | 183703 | 10,751 |  |
|  |  | 183952 | 10,801 | 183705 | 10,717 |  |
|  | 1999 Total |  | $43,160$ |  | 42,996 | 1.004 |
|  | 2000 | 182117 | 21,342 | 181633 | 21,163 |  |
|  |  | 184253 | 10,838 | 184252 | 10,772 |  |
|  |  | 184255 | 10,792 | 184254 | 10,730 |  |
|  | 2000 Total |  | 42,972 |  | 42,665 | 1.007 |
|  | 2001 | 183946 | 10,887 | 183945 | 10,861 |  |
|  |  | 185338 | 32,337 | 185337 | 32,053 |  |
|  | 2001 Total |  | 43,224 |  | 42,914 | 1.007 |
|  | 2002 | 184033 | 10,783 | 184136 | 10,806 |  |
|  |  | 184034 | 10,903 | 184137 | 10,874 |  |
|  |  | 184035 | 10,857 | 184149 | 10,849 |  |
|  |  | 184036 | 10,913 | 184150 | 10,869 |  |
|  | 2002 Total |  | 43,456 |  | 43,398 | 1.001 |
|  | 2003 | 182710 | 10,784 | 184115 | 10,738 |  |
|  |  | 184138 | 10,831 | 184139 | 10,900 |  |
|  |  | 184140 | 10,904 | 184141 | 10,906 |  |
|  |  | 184142 | 10,885 | 184153 | 5,454 |  |
|  |  | 184154 | 5,460 | - | - |  |
|  | 2003 Total |  | 48,864 |  | 37,998 | 1.286 |
|  | 2004 | 184314 | 10,905 | 181662 | 10,930 |  |
|  |  | 184315 | 10,918 | 181663 | 10,925 |  |
|  |  | 185332 | 10,919 | 184220 | 10,910 |  |
|  |  | 185333 | 10,932 | 184401 | 10,907 |  |
|  | 2004 Total |  | $43,674$ |  | 43,672 | 1.000 |
|  | $2005$ | 185846 | 10,809 | 185842 | 9,929 |  |
|  |  | 185847 | 11,604 | 185843 | 11,600 |  |
|  |  | 185848 | 12,018 | 185845 | 11,492 |  |
|  |  | 185849 | 11,861 | 185944 | 11,427 |  |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked <br> Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quinsam River | 2005 Total |  | 46,292 |  | 44,448 | 1.041 |
|  | 2006 | 185854 | 10,902 | 185851 | 10,994 |  |
|  |  | 185855 | 11,255 | 185852 | 11,030 |  |
|  |  | 185862 | 10,594 | 185853 | 11,187 |  |
|  |  | 185863 | 11,062 | 185901 | 11,059 |  |
|  | 2006 Total |  | 43,813 |  | 44,270 | 0.990 |
|  | 2007 | 186121 | 11,097 | 186117 | 10,943 |  |
|  |  | 186122 | 11,304 | 186118 | 10,953 |  |
|  |  | 186123 | 11,310 | 186119 | 11,415 |  |
|  |  | 186124 | 11,319 | 186120 | 11,289 |  |
|  | 2007 Total |  | 45,030 |  | 44,600 | 1.010 |
|  | 2008 | 180288 | 10,833 | 186127 | 10,747 |  |
|  |  | 180289 | 11,159 | 186128 | 10,399 |  |
|  |  | 180290 | 10,996 | 186129 | 11,374 |  |
|  |  | 180291 | 11,002 | 186130 | 10,874 |  |
|  | 2008 Total |  | $43,990$ |  | 43,394 | 1.014 |
|  | 2009 | 180294 | 10,918 | 180768 | 11,041 |  |
|  |  | 180577 | 11,043 | 180978 | 10,618 |  |
|  |  | 180578 | 11,002 | 180979 | 11,485 |  |
|  |  | 186114 | 11,038 | 180980 | 11,003 |  |
|  | 2009 Total |  | 44,001 |  | 44,147 | 0.997 |
|  | 2010 | 185761 | 10,511 | 181920 | 10,190 |  |
|  |  | 185762 | 11,880 | 181921 | 10,690 |  |
|  |  | 185763 | 9,989 | 181922 | 10,820 |  |
|  |  | 185801 | 10,818 | 181923 | 10,756 |  |
|  | 2010 Total |  | 43,198 |  | 42,456 | 1.017 |
|  | 2011 | 182272 | 18,361 | 182271 | 18,339 |  |
|  |  | 182274 | 18,875 | 182273 | 18,811 |  |
|  | 2011 Total |  | 37,236 |  | 37,150 | 1.002 |
| Big Qualicum River | 1998 | 184225 | 10,218 | 184224 | 10,426 |  |
|  |  | 184227 | 10,326 | 184226 | 10,218 |  |
|  |  | 184229 | 10,492 | 184228 | 10,362 |  |
|  |  | 184231 | 10,621 | 184230 | 9,830 |  |
|  | 1998 Total |  | 41,657 |  | 40,836 | 1.020 |
|  | 1999 | 183938 | 10,140 | 183937 | 10,118 |  |
|  |  | 183940 | 10,072 | 183939 | 10,119 |  |
|  |  | 183942 | 10,009 | 183941 | 9,980 |  |
|  |  | 183944 | 9,990 | 183943 | 10,379 |  |
|  | 1999 Total |  | 40,211 |  | 40,596 | 0.991 |
|  | 2000 | 184248 | 9,973 | 184009 | 10,102 |  |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked <br> Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Big Qualicum River |  | 184249 | 10,328 | 184010 | 10,355 |  |
|  |  | 184250 | 10,461 | 184011 | 10,919 |  |
|  |  | 184251 | 10,498 | 184012 | 10,602 |  |
|  | 2000 Total |  | 41,260 |  | 41,978 | 0.983 |
|  | 2001 | 185311 | 42,471 | 185310 | 42,566 | 0.998 |
|  | 2002 | 185512 | 37,275 | 185511 | 38,940 | 0.957 |
| Chilliwack River | 1998 | 183649 | 9,346 | 183648 | 9,271 |  |
|  |  | 184037 | 14,041 | 184038 | 13,850 |  |
|  |  | 184039 | 14,019 | 184040 | 13,855 |  |
|  | 1998 Total |  | 37,406 |  | 36,976 | 1.012 |
|  | 1999 | 184423 | 14,048 | 184424 | 14,221 |  |
|  |  | 184425 | 14,307 | 184426 | 14,229 |  |
|  |  | 184427 | 14,288 | 184428 | 14,345 |  |
|  | 1999 Total |  | 42,643 |  | 42,795 | 0.996 |
|  | 2000 | 184531 | 38,821 | 184530 | 38,726 | 1.002 |
|  | 2001 | 184863 | 35,207 | 184862 | 35,162 | 1.001 |
|  | 2002 | 185521 | 31,851 | 185520 | 35,923 | 0.887 |
| Inch Creek | 1998 | 183655 | 9,972 | 183651 | 9,900 |  |
|  |  | 183656 | 10,038 | 183652 | 10,125 |  |
|  |  | 183657 | 9,994 | 183653 | 10,080 |  |
|  |  | 183658 | 10,094 | 183654 | 10,096 |  |
|  | 1998 Total |  | 40,098 |  | 40,201 | 0.997 |
|  | 1999 | 184527 | 40,090 | 184526 | 39,911 | 1.004 |
|  | 2000 | 184525 | 40,157 | 184901 | 39,998 | 1.004 |
|  | 2001 | 185315 | 39,509 | 185314 | 39,819 | 0.992 |
|  | 2002 | 185522 | 39,709 | 185523 | 39,595 | 1.003 |
|  | 2003 | 185526 | 39,986 | 185525 | 39,986 | 1.000 |
|  | 2004 | 184835 | 15,052 | 184834 | 15,085 |  |
|  |  | 185219 | 25,006 | 185218 | 24,639 |  |
|  | 2004 Total |  | 40,058 |  | 39,724 | 1.008 |
|  | 2005 | 185923 | 39,270 | 185922 | 39,035 | 1.006 |
|  | 2006 | 185931 | 40,117 | 185930 | 40,117 | 1.000 |
|  | 2007 | 180179 | 40,235 | 180178 | 40,306 | 0.998 |
|  | 2008 | 180476 | 39,161 | 180181 | 39,197 | 0.999 |
|  | 2009 | 181581 | 47,508 | 181580 | 47,802 | 0.994 |
|  | 2010 | 182279 | 24,505 | 182277 | 24,838 |  |
|  |  | 182280 | 24,611 | 182278 | 24,697 |  |
|  | 2010 Total |  | 49,116 |  | 49,535 | 0.992 |
|  | 2011 | 181771 | 25,047 | 181770 | 25,023 |  |



Appendix Table 1B. CWT codes, number of unmarked and marked fish released, and unmarked-to-marked ratio ( $\lambda$ ) for Coho salmon DIT groups from the Puget Sound region: by hatchery and brood year.

| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked <br> Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Lower Elwha | 1998 | 631101 | 76,733 | 210220 | 79,438 | 0.966 |
|  | 1999 | 631105 | 61,865 | 210171 | 62,465 | 0.990 |
|  | 2000 | 210192 | 71,362 | 630965 | 70,742 | 1.009 |
|  | 2001 | 210409 | 73,722 | 210222 | 72,867 | 1.012 |
|  | 2002 | 210376 | 75,185 | 210426 | 74,683 | 1.007 |
|  | 2003 | 632680 | 51,084 | 210549 | 63,274 | 0.807 |
|  | 2004 | 632692 | 78,779 | 210587 | 77,661 | 1.014 |
|  | 2005 | 633187 | 76,246 | 210676 | 76,159 | 1.001 |
|  | 2006 | 210747 | 79,887 | 633980 | 78,303 | 1.020 |
|  | 2007 | 634375 | 79,013 | 210785 | 78,972 | 1.001 |
|  | 2008 | 635084 | 79,897 | 210839 | 79,575 | 1.004 |
|  | 2009 | 635190 | 80,086 | 210904 | 80,405 | 0.996 |
|  | 2010 | 635585 | 83,081 | 210956 | 82,395 | 1.008 |
|  | 2011 | 636189 | 66,615 | 211025 | 76,261 | 0.874 |
| Kendall Creek | 1998 | 630813 | 46,455 | 630812 | 43,242 | 1.074 |
|  | 1999 | 630472 | 30,169 | 630473 | 29,042 |  |
|  |  | 631348 | 7,537 | 631351 | 7,306 |  |
|  |  | 631353 | 7,548 | 631354 | 7,273 |  |
|  | 1999 Total |  | 45,254 |  | 43,621 | 1.037 |
|  | 2000 | 630382 | 9,731 | 630383 | 9,245 |  |
|  |  | 630384 | 9,891 | 630385 | 9,385 |  |
|  |  | 630983 | 29,370 | 630982 | 28,509 |  |
|  | 2000 Total |  | 48,992 |  | 47,139 | 1.039 |
|  | 2001 | 631261 | 9,739 | 631260 | 9,621 |  |
|  |  | 631262 | 9,822 | 631263 | 9,668 |  |
|  |  | 631568 | 29,941 | 631493 | 29,820 |  |
|  | 2001 Total |  | 49,502 |  | 49,109 | 1.008 |
|  | 2002 | 631689 | 29,140 | 631690 | 29,145 |  |
|  |  | 631697 | 9,279 | 631698 | 9,265 |  |
|  |  | 631699 | 9,182 | 631764 | 9,046 |  |
|  | 2002 Total |  | 47,601 |  | 47,456 | 1.003 |
|  | 2003 | 632670 | 47,738 | 632671 | 46,271 | 1.032 |
|  | 2004 | 632695 | 46,335 | 633095 | 46,079 | 1.006 |
|  | 2005 | 633576 | 49,402 | 633575 | 49,402 | 1.000 |
|  | 2006 | 634169 | 49,700 | 634170 | 49,328 | 1.008 |
|  | 2007 | 634492 | 46,713 | 634491 | 46,561 | 1.003 |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Marblemount | 1998 | 631108 | 40,525 | 631107 | 40,398 | 1.003 |
|  | 1999 | 630298 | 45,052 | 630299 | 45,831 | 0.983 |
|  | 2000 | 630386 | 10,988 | 630387 | 10,777 |  |
|  |  | 630945 | 10,988 | 630946 | 10,783 |  |
|  |  | 630947 | 10,969 | 630948 | 10,861 |  |
|  |  | 630949 | 10,935 | 630950 | 10,582 |  |
|  | 2000 Total |  | 43,880 |  | 43,003 | 1.020 |
|  | 2001 | 631069 | 6,887 | 631175 | 28,871 |  |
|  |  | 631254 | 7,472 | 631253 | 9,013 |  |
|  |  | 631256 | 9,063 | 631255 | 9,975 |  |
|  |  | 631258 | 8,999 | 631257 | 10,745 |  |
|  |  | - | - | 631259 | 11,240 |  |
|  | 2001 Total |  | 32,421 |  | 69,844 | 0.464 |
|  | 2002 | 632092 | 10,967 | 632088 | 10,781 |  |
|  |  | 632093 | 9,781 | 632089 | 6,947 |  |
|  |  | 632094 | 10,878 | 632090 | 11,046 |  |
|  |  | 632095 | 11,100 | 632091 | 10,861 |  |
|  | 2002 Total |  | 42,726 |  | 39,635 | 1.078 |
|  | 2003 | 632289 | 46,823 | 631997 | 46,348 | 1.010 |
|  | 2004 | 633197 | 41,300 | 633099 | 47,305 | 0.873 |
|  | 2005 | 633572 | 43,575 | 633571 | 43,100 | 1.011 |
|  | 2006 | 633690 | 47,206 | 633691 | 47,072 | 1.003 |
|  | 2007 | 634485 | 44,604 | 634484 | 44,174 | 1.010 |
|  | 2008 | 634496 | 43,568 | 634495 | 43,359 | 1.005 |
|  | 2009 | 635382 | 43,354 | 635381 | 44,465 | 0.975 |
|  | 2010 | 635798 | 42,100 | 635799 | 41,840 | 1.006 |
|  | 2011 | 636376 | 45,650 | 636377 | 45,068 | 1.013 |
| Wallace River | 1998 | 631236 | 22,524 | 631223 | 20,665 |  |
|  |  | 631238 | 23,049 | 631237 | 22,350 |  |
|  | 1998 Total |  | 45,573 |  | 43,015 | 1.059 |
|  | 1999 | 630467 | 21,154 | 630466 | 23,171 |  |
|  |  | 631052 | 21,698 | 631160 | 24,591 |  |
|  | 1999 Total |  | 42,852 |  | 47,762 | 0.897 |
|  | 2000 | 631284 | 19,384 | 631286 | 20,186 |  |
|  |  | 631285 | 19,960 | 631287 | 19,372 |  |
|  | 2000 Total |  | 39,344 |  | 39,558 | 0.995 |
|  | 2001 | 631575 | 22,377 | 631576 | 20,672 |  |
|  |  | 631577 | 21,263 | 631578 | 18,935 |  |
|  | 2001 Total |  | 43,640 |  | 39,607 | 1.102 |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Wallace River | 2002 | 632197 | 23,280 | 632196 | 23,036 |  |
|  |  | 632198 | 23,379 | 632199 | 23,416 |  |
|  | 2002 Total |  | 46,659 |  | 46,452 | 1.004 |
|  | 2003 | 632678 | 43,575 | 632679 | 43,217 | 1.008 |
|  | 2004 | 633267 | 30,300 | 633266 | 30,182 | 1.004 |
|  | 2005 | 633681 | 48,378 | 633680 | 46,804 | 1.034 |
|  | 2006 | 634175 | 45,883 | 634176 | 44,693 | 1.027 |
|  | 2007 | 634494 | 45,310 | 634493 | 45,604 | 0.994 |
|  | 2008 | 634893 | 42,077 | 634892 | 42,318 | 0.994 |
|  | 2009 | 635896 | 42,508 | 635895 | 42,851 | 0.992 |
|  | 2010 | 635990 | 45,293 | 635988 | 44,305 | 1.022 |
|  | 2011 | 636384 | 44,425 | 636383 | 44,056 | 1.008 |
| Soos Creek | 1998 | 631218 | 13,161 | 631219 | 21,512 |  |
|  |  | 631220 | 21,296 | 631233 | 21,465 |  |
|  |  | 631232 | 21,836 | - | - |  |
|  | 1998 Total |  | 56,293 |  | 42,977 | 1.310 |
|  | 1999 | 631358 | 36,440 | 631357 | 34,055 | 1.070 |
|  |  | 631265 | 22,075 | 631266 | 20,792 |  |
|  |  | 631268 | 21,700 | 631267 | 21,287 |  |
|  | 2000 Total |  | 43,775 |  | 42,079 | 1.040 |
|  | 2001 | 631485 | 45,242 | 631486 | 44,482 | 1.017 |
|  | 2002 | 631995 | 44,415 | 631994 | 42,720 | 1.040 |
|  | 2003 | 632674 | 44,922 | 632673 | 45,404 | 0.989 |
|  | 2004 | 633269 | 45,000 | 633199 | 44,838 | 1.004 |
|  | 2005 | 633685 | 44,927 | 633684 | 45,047 | 0.997 |
|  | 2006 | 634174 | 45,472 | 634173 | 45,233 | 1.005 |
|  | 2007 | 634489 | 45,487 | 634488 | 45,271 | 1.005 |
|  | 2008 | 634891 | 44,403 | 634890 | 40,164 | 1.106 |
|  | 2009 | 634895 | 47,225 | 634894 | 47,334 | 0.998 |
|  | 2010 | 635865 | 45,608 | 635864 | 44,862 | 1.017 |
|  | 2011 | 635992 | 45,428 | 636382 | 45,704 | 0.994 |
| Voights Creek | 1998 | 631222 | 14,319 | 631221 | 14,043 |  |
|  |  | 631235 | 13,862 | 631234 | 14,093 |  |
|  | 1998 Total |  | 28,181 |  | 28,136 | 1.002 |
|  | 1999 | 630295 | 44,105 | 630296 | 43,713 | 1.009 |
|  | 2000 | 630590 | 41,580 | 630589 | 37,566 | 1.107 |
|  | 2001 | 631483 | 47,233 | 631484 | 47,471 | 0.995 |
|  | 2002 | 631525 | 45,881 | 631488 | 46,061 | 0.996 |
|  | 2003 | 632669 | 45,257 | 632668 | 45,257 | 1.000 |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Voights Creek | 2004 | 633097 | 44,624 | 633098 | 44,328 | 1.007 |
|  | 2005 | 633573 | 47,680 | 633574 | 56,863 | 0.839 |
|  | 2006 | 633693 | 45,209 | 633692 | 44,668 | 1.012 |
|  | 2007 | 634482 | 46,114 | 634483 | 45,674 | 1.010 |
|  | 2008 | 634886 | 45,028 | 634885 | 44,484 | 1.012 |
|  | 2009 | 635383 | 43,632 | 635384 | 44,302 | 0.985 |
|  | 2010 | 635987 | 45,785 | 635986 | 45,001 | 1.017 |
|  | 2011 | 636378 | 45,119 | 636379 | 45,314 | 0.996 |
| George <br> Adams | 1998 | 630917 | 41,288 | 630918 | 42,496 | 0.972 |
|  | 1999 | 630371 | 26,198 | 630372 | 24,221 |  |
|  |  | 630374 | 25,207 | 630373 | 25,178 |  |
|  | 1999 Total |  | 51,405 |  | 49,399 | 1.041 |
|  | 2000 | 630592 | 43,518 | 630591 | 43,686 | 0.996 |
|  | 2001 | 631473 | 21,763 | 631517 | 22,260 |  |
|  |  | 631474 | 21,881 | 631518 | 21,359 |  |
|  | 2001 Total |  | 43,644 |  | 43,619 | 1.001 |
|  | 2002 | 632080 | 21,612 | 632078 | 21,650 |  |
|  |  | 632081 | 22,269 | 632079 | 22,036 |  |
|  | 2002 Total |  | 43,881 |  | 43,686 | 1.004 |
|  | 2003 | 632672 | 41,626 | 632290 | 41,584 | 1.001 |
|  | 2004 | 633264 | 44,879 | 633265 | 44,965 | 0.998 |
|  | 2005 | 633678 | 43,193 | 633679 | 43,785 | 0.986 |
|  | 2006 | 634167 | 53,098 | 634168 | 45,482 | 1.167 |
|  | 2007 | 634487 | 45,669 | 634486 | 45,669 | 1.000 |
|  | 2008 | 634888 | 45,371 | 634887 | 44,613 | 1.017 |
|  | 2009 | 635386 | 45,815 | 635385 | 45,698 | 1.003 |
|  | 2010 | 635989 | 45,568 | 635985 | 45,259 | 1.007 |
|  | 2011 | 636380 | 45,042 | 636381 | 44,504 | 1.012 |
| Quilcene <br> NFH | 1998 | 055160 | 11,602 | 055159 | 12,031 |  |
|  |  | 055162 | 10,843 | 055161 | 12,061 |  |
|  |  | 055204 | 9,900 | 055163 | 11,978 |  |
|  |  | 055206 | 12,271 | 055205 | 12,123 |  |
|  | 1998 Total |  | 44,616 |  | 48,193 | 0.926 |
|  | 1999 | 050379 | 9,387 | 050378 | 12,468 |  |
|  |  | 050381 | 12,971 | 050380 | 10,611 |  |
|  |  | 050383 | 9,020 | 050382 | 11,113 |  |
|  |  | 050385 | 10,551 | 050384 | 12,077 |  |
|  | 1999 Total |  | $41,929$ |  | 46,269 | 0.906 |
|  | 2000 | 050592 | 12,435 | 050591 | 12,564 |  |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quilcene NFH |  | 050594 | 11,863 | 050593 | 11,659 |  |
|  |  | 050596 | 11,870 | 050595 | 12,596 |  |
|  |  | 050598 | 12,625 | 050597 | 12,494 |  |
|  | 2000 Total |  | 48,793 |  | 49,313 | 0.989 |
|  | 2001 | 051077 | 12,790 | 051076 | 11,449 |  |
|  |  | 051079 | 12,017 | 051078 | 11,640 |  |
|  |  | 051081 | 12,158 | 051080 | 12,148 |  |
|  | 2001 Total |  | 36,965 |  | 35,237 | 1.049 |
|  | 2002 | 051669 | 11,785 | 051668 | 10,243 |  |
|  |  | 051671 | 11,728 | 051670 | 10,708 |  |
|  |  | 051673 | 11,118 | 051672 | 11,090 |  |
|  |  | 051675 | 10,450 | 051674 | 11,072 |  |
|  | 2002 Total |  | 45,081 |  | 43,113 | 1.046 |
|  | 2003 | 052297 | 11,145 | 052296 | 11,221 |  |
|  |  | 052299 | 10,117 | 052298 | 10,143 |  |
|  |  | 052365 | 10,272 | 052364 | 10,404 |  |
|  |  | 052367 | 7,043 | 052366 | 9,239 |  |
|  | 2003 Total |  | 38,577 |  | 41,007 | 0.941 |
|  | 2004 | 052764 | 11,591 | 052699 | 11,263 |  |
|  |  | 052766 | 12,816 | 052765 | 11,502 |  |
|  |  | 052768 | 13,144 | 052767 | 12,562 |  |
|  |  | 052770 | 11,540 | 052769 | 12,467 |  |
|  | 2004 Total |  | 49,091 |  | 47,794 | 1.027 |
|  | 2005 | 053279 | 11,345 | 053278 | 11,027 |  |
|  |  | 053281 | 12,160 | 053280 | 12,889 |  |
|  |  | 053283 | 10,616 | 053282 | 11,343 |  |
|  |  | 053285 | 6,408 | 053284 | 6,321 |  |
|  | 2005 Total |  | $40,529$ |  | 41,580 | 0.975 |
|  | 2006 | 053966 | 6,923 | 053965 | 6,832 |  |
|  |  | 053973 | 8,469 | 053972 | 8,566 |  |
|  |  | 053975 | 9,445 | 053974 | 9,172 |  |
|  |  | 053977 | 9,510 | 053976 | 9,569 |  |
|  | 2006 Total |  | 34,347 |  | 34,139 | 1.006 |
|  | 2007 | 054474 | 9,578 | 054473 | 9,580 |  |
|  |  | 054476 | 10,006 | 054475 | 9,861 |  |
|  |  | 054478 | 9,647 | 054477 | 9,858 |  |
|  |  | 054480 | 9,717 | 054479 | 7,168 |  |
|  | 2007 Total |  | 38,948 |  | 36,467 | 1.068 |
|  | 2008 | 054766 | 9,961 | 054767 | 9,903 |  |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quilcene NFH |  | 054768 | 10,405 | 054769 | 9,919 |  |
|  |  | 054770 | 10,025 | 054771 | 9,691 |  |
|  |  | 054772 | 9,935 | 054765 | 8,422 |  |
|  | 2008 Total |  | 40,326 |  | 37,935 | 1.063 |
|  | 2009 | 055174 | 10,350 | 055173 | 10,249 |  |
|  |  | 055176 | 10,126 | 055175 | 10,450 |  |
|  | 2009 Total |  | 20,476 |  | 20,699 | 0.989 |
|  | 2010 | 055329 | 9,495 | 055328 | 9,429 |  |
|  |  | 055335 | 10,012 | 055334 | 9,817 |  |
|  |  | 055465 | 24,752 | 055464 | 24,936 |  |
|  | 2010 Total |  | 44,259 |  | 44,182 | 1.002 |
|  | 2011 | 055483 | 70,746 | 055484 | 71,292 | 0.992 |

Appendix Table 1C. CWT codes, number of unmarked and marked fish released, and unmarked-to-marked ratio ( $\lambda$ ) for Coho salmon DIT groups from the Washington Coast region: by hatchery and brood year.

| Hatchery | Brood <br> Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Makah <br> NFH <br> Tsoo-Yes <br> River | 1998 | 055152 | 9,500 | 055151 | 9,489 |  |
|  |  | 055154 | 9,696 | 055153 | 9,394 |  |
|  |  | 055156 | 9,935 | 055155 | 9,349 |  |
|  |  | 055158 | 9,937 | 055157 | 9,620 |  |
|  | 1998 Total |  | 39,068 |  | 37,852 | 1.032 |
|  | 1999 | 050387 | 8,790 | 050386 | 8,682 |  |
|  |  | 050389 | 9,099 | 050388 | 8,510 |  |
|  |  | 050391 | 10,670 | 050390 | 10,012 |  |
|  |  | 050393 | 10,668 | 050392 | 10,762 |  |
|  | 1999 Total |  | $39,227$ |  | 37,966 | 1.033 |
|  | 2000 | 050584 | 9,808 | 050583 | 9,362 |  |
|  |  | 050586 | 9,846 | 050585 | 10,296 |  |
|  |  | 050588 | 9,921 | 050587 | 9,892 |  |
|  |  | 050590 | 9,533 | 050589 | 9,972 |  |
|  | 2000 Total |  | 39,108 |  | 39,522 | 0.990 |
|  | 2001 | 050188 | 8,392 | 051084 | 9,360 |  |
|  |  | 051085 | 9,506 | 051086 | 9,482 |  |
|  |  | 051087 | 8,959 | 051088 | 8,557 |  |
|  |  | 051089 | 9,364 | 051090 | 8,203 |  |
|  | 2001 Total |  | $36,221$ |  | 35,602 | 1.017 |
|  | 2002 | 051893 | 9,685 | 051892 | 9,190 |  |
|  |  | 051895 | 9,482 | 051894 | 9,420 |  |
|  |  | 051897 | 9,627 | 051896 | 9,111 |  |
|  |  | 051899 | 9,161 | 051898 | 8,893 |  |
|  | 2002 Total |  | 37,955 |  | 36,614 | 1.037 |
|  | 2003 | 052398 | 8,966 | 052397 | 9,046 |  |
|  |  | 052464 | 9,218 | 052399 | 9,514 |  |
|  |  | 052466 | 9,276 | 052465 | 10,896 |  |
|  |  | 052468 | 8,857 | 052467 | 9,114 |  |
|  | 2003 Total |  | 36,317 |  | 38,570 | 0.942 |
|  | 2004 | 052880 | 9,777 | 052469 | 9,973 |  |
|  |  | 052882 | 10,355 | 052881 | 10,460 |  |
|  |  | 052884 | 10,090 | 052883 | 10,192 |  |
|  |  | 052886 | 9,766 | 052885 | 9,926 |  |
|  | 2004 Total |  | 39,988 |  | 40,551 | 0.986 |
|  | 2005 | 053364 | 9,071 | 053299 | 9,182 |  |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Makah <br> NFH <br> Tsoo-Yes River |  | 053366 | 9,605 | 053365 | 9,130 |  |
|  |  | 053368 | 9,728 | 053367 | 9,995 |  |
|  |  | 053370 | 9,445 | 053369 | 9,406 |  |
|  | 2005 Total |  | 37,849 |  | 37,713 | 1.004 |
|  | 2006 | 053894 | 9,725 | 053893 | 9,979 |  |
|  |  | 053896 | 9,786 | 053895 | 9,582 |  |
|  |  | 053898 | 10,158 | 053897 | 10,070 |  |
|  |  | 053964 | 10,147 | 053899 | 9,736 |  |
|  | 2006 Total |  | 39,816 |  | 39,367 | 1.011 |
|  | 2007 | 054495 | 9,932 | 054494 | 9,916 |  |
|  |  | 054497 | 10,211 | 054496 | 10,282 |  |
|  |  | 054499 | 10,169 | 054498 | 10,221 |  |
|  |  | 054565 | 10,447 | 054564 | 10,088 |  |
|  | 2007 Total |  | 40,759 |  | 40,507 | 1.006 |
|  | 2008 | 055094 | 10,214 | 055093 | 10,304 |  |
|  |  | 055096 | 10,128 | 055095 | 9,980 |  |
|  |  | 055098 | 10,235 | 055097 | 10,125 |  |
|  |  | 055164 | 9,854 | 055099 | 9,930 |  |
|  | 2008 Total |  | 40,431 |  | 40,339 | 1.002 |
|  | 2009 | 055321 | 9,587 | 055320 | 10,145 |  |
|  |  | 055323 | 10,047 | 055322 | 9,565 |  |
|  |  | 055325 | 9,791 | 055324 | 9,797 |  |
|  |  | 055327 | 10,571 | 055326 | 10,368 |  |
|  | 2009 Total |  | 39,996 |  | 39,875 | 1.003 |
|  | 2010 | 055467 | 64,410 | 055466 | 61,907 | 1.040 |
| Quinault <br> NFH <br> Cook <br> Creek | 1998 | 055143 | 19,585 | 055142 | 19,480 |  |
|  |  | 055145 | 20,498 | 055144 | 20,210 |  |
|  |  | 055147 | 19,657 | 055146 | 19,997 |  |
|  |  | 055149 | 20,117 | 055148 | 20,310 |  |
|  |  | 055216 | 64,131 | 055215 | 59,157 |  |
|  | 1998 Total |  | 143,988 |  | 139,154 | 1.035 |
|  | 1999 | 050370 | 20,613 | 050369 | 20,344 |  |
|  |  | 050372 | 17,849 | 050371 | 17,965 |  |
|  |  | 050374 | 18,352 | 050373 | 18,832 |  |
|  |  | 050376 | 20,199 | 050375 | 20,010 |  |
|  | 1999 Total |  | $77,013$ |  | 77,151 | 0.998 |
|  | 2000 | 050174 | 18,669 | 050173 | 16,947 |  |
|  |  | 050176 | 16,744 | 050175 | 16,353 |  |
|  |  | 050178 | 18,044 | 050177 | 16,565 |  |



| Hatchery | Brood <br> Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quinault <br> NFH <br> Cook <br> Creek | 2006 Total |  | 78,329 |  | 78,359 | 1.000 |
|  | 2007 | 054486 | 20,445 | 054485 | 20,534 |  |
|  |  | 054488 | 20,653 | 054487 | 20,442 |  |
|  |  | 054490 | 20,800 | 054489 | 20,601 |  |
|  |  | 054492 | 20,101 | 054491 | 19,328 |  |
|  | 2007 Total |  | 81,999 |  | 80,905 | 1.014 |
|  | 2008 | 054696 | 19,676 | 054695 | 20,090 |  |
|  |  | 054698 | 19,078 | 054697 | 20,890 |  |
|  |  | 054973 | 19,577 | 054972 | 20,091 |  |
|  |  | 054975 | 20,283 | 054974 | 20,686 |  |
|  | 2008 Total |  | 78,614 |  | 81,757 | 0.962 |
|  | 2009 | 055290 | 19,740 | 055289 | 19,696 |  |
|  |  | 055292 | 14,764 | 055291 | 14,728 |  |
|  |  | 055294 | 18,184 | 055293 | 18,943 |  |
|  |  | 055296 | 20,502 | 055295 | 20,319 |  |
|  | 2009 Total |  | $73,190$ |  | 73,686 | 0.993 |
|  | 2010 | 055312 | 20,796 | 055311 | 20,180 |  |
|  |  | 055314 | 20,338 | 055313 | 19,913 |  |
|  |  | 055316 | 20,005 | 055315 | 20,117 |  |
|  |  | 055318 | 19,862 | 055317 | 19,840 |  |
|  | 2010 Total |  | 81,001 |  | 80,050 | 1.012 |
|  | 2011 | 055482 | 78,850 | 055481 | 79,407 | 0.993 |
| Salmon <br> River <br> Fish Culture | 1998 | 631103 | 72,008 | 210227 | 68,440 | 1.052 |
|  | 1999 | 630575 | 72,796 | 210198 | 69,441 | 1.048 |
|  | 2000 | 631190 | 71,602 | 210330 | 72,257 | 0.991 |
|  | 2001 | 210395 | 73,408 | 631413 | 72,882 | 1.007 |
|  | 2002 | 210499 | 40,719 | 210518 | 74,207 |  |
|  |  | 210505 | 33,721 | - | - |  |
|  | 2002 Total |  | 74,440 |  | 74,207 | 1.003 |
|  | 2003 | 632691 | 74,130 | 210572 | 70,869 | 1.046 |
|  | 2004 | 633191 | 78,945 | 210635 | 79,912 | 0.988 |
|  | 2005 | 210692 | 81,321 | 633175 | 73,041 | 1.113 |
|  | 2006 | 210731 | 81,407 | 633481 | 72,133 | 1.129 |
|  | 2007 | 634181 | 75,056 | 210772 | 68,967 | 1.088 |
|  | 2008 | 634768 | 77,578 | 210854 | 73,581 | 1.054 |
|  | 2009 | 635189 | 81,078 | 210924 | 80,105 | 1.012 |
|  | 2010 | 635586 | 80,161 | 210965 | 79,280 | 1.011 |
|  | 2011 | 636188 | 74,732 | 211003 | 75,171 | 0.994 |


| Hatchery | Brood <br> Year | Tag code | Unmarked <br> Released | Tag code | Marked <br> Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |


| Solduc Hatchery | 1998 | 631216 | 36,032 | 631217 | 34,895 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 631230 | 36,134 | 631231 | 36,858 |  |
|  | 1998 Total |  | 72,166 |  | 71,753 | 1.006 |
|  | 1999 | 630574 | 64,087 | 630291 | 71,348 | 0.898 |
|  | 2000 | 631180 | 48,872 | 631181 | 47,890 |  |
|  |  | 631274 | 12,226 | 631275 | 12,501 |  |
|  |  | 631276 | 12,016 | 631277 | 12,140 |  |
|  | 2000 Total |  | 73,114 |  | 72,531 | 1.008 |
|  | 2001 | 631565 | 51,600 | 631303 | 10,369 |  |
|  |  | 631678 | 12,359 | 631304 | 10,189 |  |
|  |  | 631680 | 9,780 | 631564 | 50,964 |  |
|  |  | - | - | 631677 | 12,297 |  |
|  |  | - | - | 631679 | 12,581 |  |
|  | 2001 Total |  | 73,739 |  | 96,400 | 0.765 |
|  | 2002 | 631685 | 48,379 | 631988 | 47,031 |  |
|  |  | 632264 | 11,482 | 632265 | 11,580 |  |
|  |  | 632267 | 11,884 | 632266 | 11,778 |  |
|  | 2002 Total |  | 71,745 |  | 70,389 | 1.019 |
|  | 2003 | 632690 | 73,234 | 632684 | 73,248 | 1.000 |
|  | 2004 | 633189 | 75,932 | 633188 | 72,097 | 1.053 |
|  | 2005 | 633676 | 71,195 | 633677 | 72,242 | 0.986 |
|  | 2006 | 634090 | 76,684 | 634091 | 76,439 | 1.003 |
|  | 2007 | 633183 | 75,261 | 633184 | 75,208 | 1.001 |
|  | 2008 | 634969 | 77,549 | 634968 | 77,081 | 1.006 |
|  | 2009 | 635465 | 75,700 | 635464 | 77,397 | 0.978 |
|  | 2010 | 635878 | 80,185 | 635877 | 80,757 | 0.993 |
|  | 2011 | 635882 | 76,179 | 635881 | 76,456 | 0.996 |
| Bingham Creek | 1998 | 630915 | 72,076 | 630916 | 65,986 | 1.092 |
|  | 1999 | 630288 | 67,861 | 630289 | 69,347 | 0.979 |
|  | 2000 | 630964 | 71,016 | 630899 | 71,665 | 0.991 |
|  | 2001 | 631531 | 69,866 | 631475 | 69,765 | 1.001 |
|  | 2002 | 631874 | 71,462 | 631875 | 69,462 | 1.029 |
|  | 2003 | 632481 | 72,242 | 632480 | 72,242 | 1.000 |
|  | 2004 | 633090 | 71,973 | 632693 | 72,621 | 0.991 |
|  | 2005 | 633499 | 71,752 | 633564 | 71,290 | 1.006 |
|  | 2006 | 633674 | 73,371 | 633675 | 73,728 | 0.995 |
|  | 2007 | 634572 | 73,326 | 634571 | 73,833 | 0.993 |
|  | 2008 | 634966 | 72,179 | 634967 | 71,762 | 1.006 |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Bingham Creek | 2009 | 635468 | 67,954 | 635467 | 67,388 | 1.008 |
|  | 2010 | 635880 | 71,753 | 635879 | 71,234 | 1.007 |
|  | 2011 | 636394 | 73,041 | 636393 | 72,929 | 1.002 |
| Forks Creek | 1998 | 631214 | 37,323 | 631215 | 36,764 |  |
|  |  | 631228 | 37,978 | 631229 | 37,130 |  |
|  | 1998 Total |  | 75,301 |  | 73,894 | 1.019 |
|  | 1999 | 631106 | 62,718 | 631208 | 70,599 | 0.888 |
|  | 2000 | 630966 | 73,402 | 630967 | 73,031 | 1.005 |
|  | 2001 | 631534 | 71,350 | 631533 | 65,860 | 1.083 |
|  | 2002 | 631987 | 66,048 | 631986 | 71,067 | 0.929 |
|  | 2003 | 632681 | 73,576 | 632682 | 73,731 | 0.998 |
|  | 2004 | 633091 | 73,465 | 633092 | 72,188 | 1.018 |
|  | 2005 | 633192 | 74,669 | 633193 | 72,726 | 1.027 |
|  | 2006 | 633672 | 72,880 | 633673 | 72,458 | 1.006 |
|  | 2007 | 634580 | 74,810 | 634579 | 73,458 | 1.018 |
|  | 2008 | 634971 | 75,029 | 634970 | 73,794 | 1.017 |
|  | 2009 | 635398 | 74,496 | 635397 | 71,993 | 1.035 |
|  | 2010 | 635399 | 74,139 | 635466 | 72,928 | 1.017 |
|  | 2011 | 636395 | 75,008 | 636396 | 74,500 | 1.007 |

Appendix Table 1D. CWT codes, number of unmarked and marked fish released, and unmarked-to-marked ratio ( $\lambda$ ) for Coho salmon DIT groups from the Columbia River region: hatchery; stock; and brood year.

| Hatchery | Brood <br> Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Lewis <br> River <br> Hatchery - <br> North | 1998 | 630913 | 66,425 | 630914 | 66,447 | 1.000 |
|  | 1999 | 636233 | 40,672 | 636232 | 37,329 |  |
|  |  | 636335 | 40,170 | 636336 | 36,605 |  |
|  | 1999 Total |  | 80,842 |  | 73,934 | 1.093 |
|  | 2000 | 630898 | 73,267 | 630897 | 72,322 | 1.013 |
|  | 2001 | 631191 | 74,479 | 631476 | 69,246 | 1.076 |
|  | 2002 | 631563 | 72,713 | 631562 | 64,936 | 1.126 |
|  | 2003 | 631985 | 62,408 | 631983 | 62,198 | 1.003 |
|  | 2004 | 633088 | 71,146 | 633087 | 70,382 | 1.011 |
|  | 2005 | 633581 | 70,576 | 633580 | 71,582 | 0.986 |
|  | 2006 | 633668 | 76,165 | 633669 | 76,503 | 0.996 |
|  | 2007 | 634577 | 75,755 | 634578 | 75,929 | 0.998 |
|  | 2008 | 634899 | 75,767 | 634898 | 76,149 | 0.995 |
|  | 2009 | 635393 | 76,178 | 635394 | 76,178 | 1.000 |
|  | 2010 | 635875 | 63,141 | 635876 | 62,444 | 1.011 |
|  | 2011 | 636193 | 70,088 | 636192 | 70,471 | 0.995 |
| Lewis <br> River | 1998 | 630820 | 74,530 | 630823 | 73,830 | 1.009 |
| Hatchery - | 1999 | 631209 | 73,858 | 631104 | 66,831 | 1.105 |
| South | 2000 | 630577 | 73,940 | 630576 | 72,278 | 1.023 |
|  | 2001 | 631366 | 73,603 | 631367 | 69,997 | 1.052 |
|  | 2002 | 631536 | 73,258 | 631535 | 69,661 | 1.052 |
|  | 2003 | 631984 | 71,255 | 631982 | 68,438 | 1.041 |
|  | 2004 | 632983 | 69,677 | 632982 | 70,295 | 0.991 |
|  | 2005 | 633566 | 69,716 | 633565 | 72,157 | 0.966 |
|  | 2006 | 633670 | 74,700 | 633671 | 75,500 | 0.989 |
|  | 2007 | 634575 | 75,818 | 634576 | 76,668 | 0.989 |
|  | 2008 | 634965 | 75,306 | 634964 | 74,570 | 1.010 |
|  | 2009 | 635396 | 75,411 | 635395 | 75,411 | 1.000 |
|  | 2010 | 635873 | 68,702 | 635874 | 68,380 | 1.005 |
|  | 2011 | 635883 | 70,476 | 635884 | 70,398 | 1.001 |
| Eagle Creek | 1998 | 054247 | 23,080 | 054248 | 23,095 | 0.999 |
|  | 1999 | 050190 | 24,096 | 050189 | 24,947 | 0.966 |
|  | 2000 | 054253 | 23,820 | 054249 | 24,128 | 0.987 |
|  | 2001 | 054035 | 24,392 | 054036 | 24,366 | 1.001 |


| Hatchery | Brood Year | Tag code | Unmarked Released | Tag code | Marked Released | $\lambda$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Eagle <br> Creek <br> NFH | 2002 | 053354 | 22,955 | 053355 | 23,674 | 0.970 |
|  | 2003 | 053353 | 24,702 | 054860 | 24,661 | 1.002 |
|  | 2004 | 050483 | 23,753 | 050484 | 23,732 | 1.001 |
|  | 2005 | 052587 | 24,290 | 052586 | 24,295 | 1.000 |
|  | 2006 | 053775 | 18,733 | 053774 | 17,825 | 1.051 |
|  | 2007 | 054183 | 24,925 | 054182 | 25,069 | 0.994 |
|  | 2008 | 054372 | 24,825 | 054371 | 24,815 | 1.000 |
|  | 2009 | 054388 | 24,834 | 054389 | 24,850 | 0.999 |
|  | 2010 | 054582 | 24,312 | 054583 | 24,534 | 0.991 |
|  | 2011 | 054589 | 23,656 | 054588 | 24,586 | 0.962 |
| Sandy <br> River <br> Hatchery | 1998 | 092639 | 6,979 | 092728 | 26,491 |  |
|  |  | 092938 | 18,226 |  |  |  |
|  | 1998 Total |  | 25,205 |  | 26,491 | 0.951 |
|  | 1999 | 093219 | 27,070 | 092748 | 70,665 | 0.383 |
|  | 2000 | 093355 | 27,883 | 093354 | 26,889 | 1.037 |
|  | 2001 | 093637 | 27,999 | 093463 | 27,936 | 1.002 |
|  | 2002 | 093918 | 26,363 | 093734 | 27,597 | 0.955 |
|  | 2003 | 094117 | 26,312 | 094116 | 26,909 | 0.978 |
|  | 2004 | 094309 | 25,348 | 094308 | 25,794 | 0.983 |
|  | 2005 | 094420 | 27,212 | 094503 | 26,813 | 1.015 |
|  | 2006 | 094638 | 27,427 | 094637 | 27,075 | 1.013 |
|  | 2007 | 090163 | 27,687 | 090162 | 27,830 | 0.995 |
|  | 2008 | 090260 | 27,901 | 090261 | 28,169 | 0.990 |

Appendix 2: Estimated number and percent of all brood-year recoveries that were age 2 for the unmarked and marked components of each brood-year's DIT group, by hatchery.

Appendix Table 2A. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

BRITISH COLUMBIA REGION

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Quinsam River Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 207.9 | 24.9\% |  |  | 186.8 | 21.7\% |  |  |
| 1999 | 255.5 | 29.1\% |  |  | 201.8 | 26.7\% |  |  |
| 2000 | 84.0 | 13.9\% |  |  | 72.2 | 15.8\% |  |  |
| 2001 | 34.6 | 5.7\% |  |  | 22.7 | 4.5\% |  |  |
| 2002 | 106.2 | 34.3\% |  |  | 91.7 | 32.5\% |  |  |
| 2003 | 42.6 | 30.1\% |  |  | 32.5 | 33.8\% |  |  |
| 2004 | 83.9 | 20.5\% | 32.9 | 78.8\% | 69.6 | 19.8\% | 32.9 | 13.3\% |
| 2005 | 82.5 | 19.2\% |  |  | 76.5 | 20.5\% |  |  |
| 2006 | 45.3 | 6.0\% |  |  | 48.3 | 6.6\% |  |  |
| 2007 | 168.5 | 29.8\% | 10.1 | 72.0\% | 134.4 | 28.3\% |  |  |
| 2008 | 124.4 | 21.6\% |  |  | 107.1 | 20.7\% | 18.3 | 10.4\% |
| 2009 | 114.8 | 28.0\% | 24.7 | 45.5\% | 124.1 | 33.2\% | 8.2 | 4.3\% |
| 2010 | 201.7 | 29.4\% | 40.7 | 51.8\% | 156.4 | 23.5\% | 40.9 | 9.1\% |
| 2011 | 151.2 | 21.5\% |  |  | 133.3 | 19.5\% | 9.3 | 4.8\% |
| Big Qualicum River Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 154.8 | 16.4\% |  |  | 156.0 | 17.2\% |  |  |
| 1999 | 468.3 | 39.3\% |  |  | 309.5 | 33.7\% |  |  |
| 2000 | 78.0 | 19.0\% |  |  | 55.7 | 18.9\% |  |  |
| 2001 | 52.7 | 7.9\% |  |  | 13.9 | 3.2\% |  |  |
| 2002 | 9.0 | 18.8\% |  |  | 2.2 | 5.4\% |  |  |
| Chilliwack River Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 118.2 | 7.4\% |  |  | 93.7 | 7.6\% |  |  |
| 1999 | 130.0 | 8.4\% |  |  | 86.3 | 7.5\% |  |  |
| 2000 | 35.9 | 3.3\% |  |  | 28.9 | 3.3\% |  |  |
| 2001 | 12.1 | 2.2\% |  |  | 8.0 | 1.7\% |  |  |
| 2002 | 12.0 | 7.7\% |  |  | 19.0 | 11.1\% |  |  |

Appendix Table 2A. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

BRITISH COLUMBIA REGION (continued)

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Inch Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 152.0 | 7.1\% |  |  | 133.0 | 7.5\% |  |  |
| 1999 | 18.6 | 2.6\% | 4.0 | 14.5\% | 21.5 | 3.4\% |  |  |
| 2000 | 25.6 | 8.3\% |  |  | 17.7 | 7.3\% |  |  |
| 2001 | 6.2 | 0.8\% |  |  | 22.8 | 2.7\% |  |  |
| 2002 | 33.7 | 4.9\% |  |  | 21.0 | 4.1\% |  |  |
| 2003 | 9.1 | 3.2\% |  |  | 7.9 | 2.8\% |  |  |
| 2004 | 40.9 | 8.0\% |  |  | 42.1 | 9.3\% |  |  |
| 2005 | 2.0 | 0.7\% |  |  | 0.0 | 0.0\% |  |  |
| 2006 | 14.6 | 3.4\% |  |  | 18.6 | 5.3\% | 5.8 | 5.9\% |
| 2007 | 27.5 | 2.2\% |  |  | 22.4 | 2.0\% | 27.2 | 21.0\% |
| 2008 | 23.4 | 4.5\% |  |  | 22.4 | 4.4\% |  |  |
| 2009 | 66.1 | 4.0\% |  |  | 69.7 | 4.6\% |  |  |
| 2010 | 171.8 | 9.6\% |  |  | 126.6 | 9.2\% | 16.1 | 2.0\% |
| 2011 | 60.1 | 4.5\% |  |  | 53.9 | 4.6\% | 5.7 | 1.3\% |
| Robertson Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 130.5 | 4.2\% |  |  | 167.2 | 5.5\% |  |  |
| 1999 | 115.1 | 5.6\% |  |  | 130.2 | 6.8\% |  |  |
| 2000 | 281.7 | 8.0\% |  |  | 232.8 | 7.2\% |  |  |
| 2001 | 116.4 | 8.5\% |  |  | 104.8 | 7.5\% |  |  |
| 2002 | 204.8 | 8.0\% |  |  | 116.9 | 7.2\% |  |  |

Appendix Table 2B. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

PUGET SOUND REGION

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Lower Elwha Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 14.0 | 2.8\% |  |  | 15.0 | 2.8\% |  |  |
| 1999 | 43.0 | 12.7\% |  |  | 38.0 | 11.1\% |  |  |
| 2000 | 17.0 | 8.8\% |  |  | 17.0 | 11.2\% |  |  |
| 2001 | 28.0 | 10.1\% |  |  | 39.0 | 14.6\% |  |  |
| 2002 | 53.5 | 21.4\% |  |  | 50.5 | 23.7\% |  |  |
| 2003 | 27.5 | 41.4\% |  |  | 79.5 | 48.0\% | 1.6 | 1.5\% |
| 2004 | 20.8 | 34.6\% |  |  | 8.3 | 21.0\% | 3.8 | 15.4\% |
| 2005 | 4.5 | 36.1\% | 1.6 | 15.2\% | 11.2 | 42.7\% |  |  |
| 2006 | 15.0 | 16.3\% |  |  | 10.0 | 11.6\% |  |  |
| 2007 | 196.2 | 31.2\% | 2.9 | 2.2\% | 171.4 | 26.9\% | 3.1 | 1.4\% |
| 2008 | 117.4 | 54.1\% |  |  | 73.6 | 44.1\% |  |  |
| 2009 | 21.5 | 36.0\% |  |  | 23.6 | 40.3\% | 4.8 | 6.9\% |
| 2010 | 35.0 | 24.1\% |  |  | 30.0 | 23.8\% |  |  |
| 2011 | 97.0 | 60.1\% |  |  | 68.7 | 62.9\% | 14.6 | 28.4\% |
| Kendall Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 28.3 | 2.6\% | 1.9 | 0.2\% | 28.3 | 2.6\% |  |  |
| 1999 | 5.2 | 0.7\% |  |  | 8.6 | 1.1\% |  |  |
| 2000 | 9.5 | 2.0\% |  |  | 6.0 | 1.4\% |  |  |
| 2001 | 0.0 | 0.0\% |  |  | 1.0 | 0.5\% |  |  |
| 2002 | 0.0 | 0.0\% | 3.4 | 1.0\% | 0.0 | 0.0\% |  |  |
| 2003 | 2.0 | 2.5\% |  |  | 1.0 | 1.2\% |  |  |
| 2004 | 0.0 | 0.0\% |  |  | 7.0 | 4.5\% |  |  |
| 2005 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2006 | 0.0 | 0.0\% |  |  | 1.9 | 6.3\% |  |  |
| 2007 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |

Appendix Table 2B. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

PUGET SOUND REGION (continued)

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Marblemount Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 2.0 | 0.1\% |  |  | 4.0 | 0.2\% |  |  |
| 1999 | 2.0 | 0.1\% |  |  | 0.0 | 0.0\% |  |  |
| 2000 | 7.0 | 1.1\% | 2.5 | 0.3\% | 8.0 | 1.3\% | 6.1 | 0.4\% |
| 2001 | 0.0 | 0.0\% | 3.4 | 0.3\% | 0.0 | 0.0\% |  |  |
| 2002 | 5.0 | 0.3\% |  |  | 8.0 | 0.6\% |  |  |
| 2003 | 0.0 | 0.0\% | 3.4 | 1.1\% | 0.0 | 0.0\% |  |  |
| 2004 | 1.9 | 0.1\% |  |  | 2.0 | 0.1\% | 4.1 | 0.6\% |
| 2005 | 1.1 | 0.1\% |  |  | 6.8 | 0.5\% |  |  |
| 2006 | 15.3 | 1.0\% |  |  | 10.1 | 0.7\% |  |  |
| 2007 | 3.3 | 0.4\% |  |  | 1.7 | 0.2\% |  |  |
| 2008 | 25.8 | 1.7\% |  |  | 33.0 | 2.3\% |  |  |
| 2009 | 7.8 | 0.5\% |  |  | 5.2 | 0.4\% |  |  |
| 2010 | 6.0 | 0.3\% |  |  | 2.0 | 0.1\% |  |  |
| 2011 | 55.9 | 3.8\% |  |  | 48.2 | 3.5\% |  |  |
| Wallace River Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 10.0 | 0.3\% |  |  | 7.0 | 0.2\% |  |  |
| 1999 | 0.0 | 0.0\% | 3.5 | 1.4\% | 0.0 | 0.0\% |  |  |
| 2000 | 21.5 | 0.8\% |  |  | 10.2 | 0.4\% |  |  |
| 2001 | 25.8 | 0.9\% |  |  | 35.9 | 1.5\% |  |  |
| 2002 | 7.0 | 0.2\% |  |  | 6.1 | 0.2\% | 4.7 | 0.5\% |
| 2003 | 6.0 | 0.4\% | 2.5 | 1.0\% | 5.0 | 0.4\% |  |  |
| 2004 | 12.4 | 0.7\% |  |  | 4.1 | 0.3\% |  |  |
| 2005 | 2.0 | 0.3\% |  |  | 0.0 | 0.0\% |  |  |
| 2006 | 1.0 | 0.1\% | 2.0 | 0.8\% | 0.0 | 0.0\% |  |  |
| 2007 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2008 | 8.3 | 0.4\% |  |  | 2.8 | 0.2\% |  |  |
| 2009 | 2.0 | 0.1\% |  |  | 3.0 | 0.1\% |  |  |
| 2010 | 18.4 | 0.9\% |  |  | 9.8 | 0.5\% |  |  |
| 2011 | 7.0 | 0.5\% |  |  | 3.2 | 0.2\% |  |  |

Appendix Table 2B. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

PUGET SOUND REGION (continued)

| HatcheryBrood Year | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
|  | \# | \% | \# | \% | \# | \% | \# | \% |
| Soos Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 24.0 | 1.6\% | 2.4 | 0.1\% | 38.0 | 3.6\% |  |  |
| 1999 | 1.0 | 0.1\% |  |  | 4.0 | 0.3\% |  |  |
| 2000 | 12.0 | 1.0\% |  |  | 11.0 | 1.1\% | 1.7 | 0.1\% |
| 2001 | 0.0 | 0.0\% |  |  | 2.8 | 0.1\% | 2.4 | 0.1\% |
| 2002 | 34.0 | 2.4\% |  |  | 25.0 | 2.2\% | 6.4 | 0.5\% |
| 2003 | 4.0 | 0.9\% |  |  | 5.0 | 1.6\% |  |  |
| 2004 | 7.9 | 0.8\% |  |  | 1.0 | 0.1\% | 5.2 | 0.5\% |
| 2005 | 5.4 | 0.5\% |  |  | 5.3 | 0.5\% |  |  |
| 2006 | 9.4 | 0.8\% | 8.7 | 1.0\% | 11.8 | 1.0\% | 3.0 | 0.3\% |
| 2007 | 1.5 | 0.4\% |  |  | 6.0 | 1.4\% |  |  |
| 2008 | 17.3 | 1.5\% |  |  | 2.9 | 0.3\% | 3.6 | 0.4\% |
| 2009 | 12.2 | 0.7\% | 1.3 | 0.1\% | 11.9 | 0.8\% | 4.3 | 0.4\% |
| 2010 | 5.8 | 2.0\% |  |  | 8.2 | 0.9\% |  |  |
| 2011 | 7.3 | 1.2\% |  |  | 4.7 | 0.7\% |  |  |
| Voights Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 3.1 | 0.4\% |  |  | 6.2 | 0.7\% |  |  |
| 1999 | 4.5 | 0.2\% |  |  | 6.7 | 0.4\% |  |  |
| 2000 | 7.5 | 0.6\% |  |  | 5.1 | 0.5\% |  |  |
| 2001 | 4.5 | 0.5\% |  |  | 3.4 | 0.4\% |  |  |
| 2002 | 27.0 | 1.7\% | 5.2 | 0.7\% | 16.3 | 1.1\% | 3.6 | 0.4\% |
| 2003 | 8.0 | 2.4\% |  |  | 8.2 | 2.0\% |  |  |
| 2004 | 12.2 | 2.1\% | 3.9 | 0.5\% | 3.2 | 0.7\% | 8.3 | 0.9\% |
| 2005 | 1.4 | 1.5\% |  |  | 23.5 | 5.8\% |  |  |
| 2006 | 5.2 | 1.4\% | 7.8 | 0.8\% | 6.2 | 1.6\% | 3.4 | 0.2\% |
| 2007 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2008 | 11.0 | 2.7\% |  |  | 4.0 | 1.0\% |  |  |
| 2009 | 72.8 | 9.6\% | 3.1 | 0.7\% | 37.6 | 5.0\% | 14.4 | 2.3\% |
| 2010 | 0.0 | 0.0\% |  |  | 1.0 | 0.3\% |  |  |
| 2011 | 6.4 | 2.6\% |  |  | 3.8 | 1.7\% | 1.5 | 0.3\% |

Appendix Table 2B. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

PUGET SOUND REGION (continued)

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| George Adams Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 73.0 | 4.1\% |  |  | 89.0 | 4.9\% | 19.1 | 2.6\% |
| 1999 | 32.0 | 1.1\% |  |  | 23.0 | 0.9\% |  |  |
| 2000 | 29.6 | 1.8\% | 2.7 | 0.5\% | 34.9 | 2.3\% | 3.6 | 0.4\% |
| 2001 | 82.0 | 4.2\% |  |  | 69.9 | 4.0\% |  |  |
| 2002 | 107.5 | 5.5\% |  |  | 100.6 | 5.2\% |  |  |
| 2003 | 46.3 | 19.1\% |  |  | 73.3 | 23.9\% |  |  |
| 2004 | 56.9 | 4.8\% | 5.4 | 3.2\% | 69.6 | 6.2\% | 1.4 | 0.4\% |
| 2005 | 119.4 | 12.9\% |  |  | 98.8 | 11.3\% |  |  |
| 2006 | 69.6 | 11.0\% | 1.6 | 0.3\% | 151.6 | 14.4\% | 1.6 | 0.2\% |
| 2007 | 16.7 | 6.0\% |  |  | 20.5 | 7.4\% |  |  |
| 2008 | 61.0 | 5.5\% |  |  | 66.0 | 6.3\% |  |  |
| 2009 | 82.0 | 13.0\% | 8.6 | 2.5\% | 57.0 | 10.1\% |  |  |
| 2010 | 29.5 | 2.1\% |  |  | 33.6 | 2.6\% |  |  |
| 2011 | 18.0 | 6.1\% |  |  | 23.0 | 8.0\% |  |  |
| Quilcene Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 6.4 | 0.5\% |  |  | 19.1 | 1.4\% | 2.8 | 0.2\% |
| 1999 | 169.4 | 9.8\% |  |  | 164.5 | 9.4\% |  |  |
| 2000 | 27.5 | 1.9\% |  |  | 45.7 | 3.8\% |  |  |
| 2001 | 12.2 | 1.0\% |  |  | 7.8 | 0.8\% |  |  |
| 2002 | 106.8 | 10.1\% |  |  | 133.6 | 13.9\% |  |  |
| 2003 | 5.6 | 4.8\% |  |  | 2.4 | 1.4\% |  |  |
| 2004 | 50.2 | 7.3\% |  |  | 77.2 | 11.6\% | 24.4 | 2.4\% |
| 2005 | 15.0 | 4.0\% |  |  | 8.0 | 2.5\% |  |  |
| 2006 | 39.8 | 8.2\% |  |  | 29.2 | 6.9\% |  |  |
| 2007 | 43.9 | 14.7\% |  |  | 56.7 | 20.4\% |  |  |
| 2008 | 219.3 | 20.3\% |  |  | 196.7 | 20.9\% |  |  |
| 2009 | 102.7 | 16.9\% |  |  | 117.5 | 20.5\% |  |  |
| 2010 | 96.0 | 11.7\% |  |  | 118.3 | 14.5\% |  |  |
| 2011 | 0.0 | 0.0\% |  |  | 7.6 | 1.4\% |  |  |

Appendix Table 2C. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

WASHINGTON COAST REGION

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Makah NFH |  |  |  |  |  |  |  |  |
| 1998 | 34.0 | 4.5\% |  |  | 38.7 | 5.1\% |  |  |
| 1999 | 38.1 | 5.3\% |  |  | 29.1 | 3.6\% |  |  |
| 2000 | 93.7 | 19.7\% |  |  | 80.3 | 17.4\% |  |  |
| 2001 | 0.0 | 0.0\% |  |  | 47.3 | 11.5\% |  |  |
| 2002 | 104.3 | 12.1\% |  |  | 106.2 | 12.9\% |  |  |
| 2003 | 18.4 | 10.9\% |  |  | 3.7 | 2.7\% |  |  |
| 2004 | 16.9 | 22.1\% |  |  | 16.9 | 22.4\% |  |  |
| 2005 | 14.0 | 5.1\% | 2.5 | 11.8\% | 13.5 | 4.4\% | 1.9 | 3.9\% |
| 2006 | 436.3 | 26.9\% |  |  | 409.1 | 27.5\% |  |  |
| 2007 | 97.6 | 12.5\% |  |  | 138.2 | 13.7\% |  |  |
| 2008 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2009 | 68.9 | 31.2\% |  |  | 99.3 | 31.0\% | 2.9 | 4.4\% |
| 2010 | 0.0 | 0.0\% | 1.6 | 3.0\% | 0.0 | 0.0\% |  |  |
| Quinault NFH |  |  |  |  |  |  |  |  |
| 1998 | 522.4 | 10.9\% |  |  | 426.5 | 11.2\% | 10.3 | 0.2\% |
| 1999 | 29.9 | 2.9\% |  |  | 19.9 | 1.6\% |  |  |
| 2000 | 81.3 | 3.7\% | 2.4 | 0.1\% | 62.4 | 3.2\% |  |  |
| 2001 | 69.4 | 3.9\% |  |  | 75.8 | 4.0\% |  |  |
| 2002 | 172.5 | 9.6\% |  |  | 176.9 | 10.0\% |  |  |
| 2003 | 75.9 | 16.2\% |  |  | 104.8 | 22.8\% |  |  |
| 2004 | 382.4 | 18.4\% |  |  | 255.1 | 16.0\% | 2.5 | 0.1\% |
| 2005 | 114.2 | 7.1\% | 4.0 | 0.2\% | 79.7 | 6.0\% | 5.0 | 0.2\% |
| 2006 | 183.3 | 6.8\% | 5.0 | 0.1\% | 179.2 | 7.8\% | 5.1 | 0.1\% |
| 2007 | 187.7 | 10.3\% | 4.1 | 0.1\% | 178.4 | 10.0\% |  |  |
| 2008 | 774.9 | 25.4\% |  |  | 742.0 | 25.3\% |  |  |
| 2009 | 168.3 | 22.5\% |  |  | 236.1 | 31.0\% |  |  |
| 2010 | 0.0 | 0.0\% | 4.5 | 0.3\% | 0.0 | 0.0\% | 4.5 | 0.2\% |
| 2011 | 5.3 | 0.2\% | 7.4 | 0.2\% | 9.2 | 0.4\% | 4.9 | 0.1\% |

Appendix Table 2C. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages. ${ }^{1}$

## WASHINGTON COAST REGION (continued)

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
| Brood Year | \# | \% | \# | \% | \# | \% | \# | \% |
| Salmon River Fish Culture |  |  |  |  |  |  |  |  |
| 1998 | 24.7 | 2.9\% | 1.0 | 0.1\% | 15.5 | 1.9\% | 2.0 | 0.2\% |
| 1999 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2000 | 14.3 | 66.1\% |  |  | 21.4 | 65.0\% |  |  |
| 2001 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| 2002 | 10.4 | 8.2\% |  |  | 4.6 | 0.1\% |  |  |
| 2003 | 0.0 | 0.0\% |  |  | 131.3 | 54.5\% | 2.1 | 0.2\% |
| 2004 | 149.8 | 75.8\% |  |  | 146.1 | 67.0\% | 6.0 | 2.1\% |
| 2005 | 11.3 | 5.7\% |  |  | 16.4 | 8.4\% | 3.0 | 0.7\% |
| 2006 | 160.1 | 14.4\% | 6.4 | 0.3\% | 148.5 | 19.6\% | 10.4 | 0.4\% |
| 2007 | 13.2 | 2.5\% |  |  | 9.9 | 1.8\% |  |  |
| 2008 | 149.0 | 14.9\% |  |  | 142.3 | 14.2\% |  |  |
| 2009 | 44.3 | 100.0\% |  |  | 44.3 | 100.0\% |  |  |
| 2010 | 0.0 |  |  |  | 0.0 |  |  |  |
| 2011 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| Solduc Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 228.1 | 11.5\% | 1.0 | 1.3\% | 291.7 | 15.3\% |  |  |
| 1999 | 285.0 | 12.4\% |  |  | 264.5 | 9.8\% |  |  |
| 2000 | 164.6 | 11.0\% |  |  | 131.3 | 11.4\% |  |  |
| 2001 | 186.9 | 9.7\% |  |  | 175.7 | 7.0\% |  |  |
| 2002 | 431.3 | 14.7\% |  |  | 518.3 | 18.9\% | 4.6 | 0.4\% |
| 2003 | 46.2 | 8.4\% |  |  | 35.8 | 7.5\% |  |  |
| 2004 | 69.2 | 8.6\% |  |  | 131.1 | 8.6\% |  |  |
| 2005 | 23.9 | 2.0\% | 7.0 | 0.7\% | 21.8 | 1.8\% | 7.0 | 0.6\% |
| 2006 | 565.3 | 14.1\% | 4.8 | 0.1\% | 565.1 | 16.4\% | 4.0 | 0.1\% |
| 2007 | 68.8 | 3.7\% | 3.0 | 0.2\% | 93.5 | 5.4\% | 5.9 | 0.4\% |
| 2008 | 434.3 | 14.4\% |  |  | 533.2 | 17.3\% | 3.6 | 0.2\% |
| 2009 | 144.4 | 40.9\% |  |  | 61.8 | 22.6\% | 1.6 | 0.3\% |
| 2010 | 62.2 | 6.1\% |  |  | 74.9 | 8.2\% | 2.7 | 0.2\% |
| 2011 | 439.4 | 17.1\% |  |  | 398.4 | 17.3\% | 3.2 | 0.1\% |

[^15]Appendix Table 2C. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

## WASHINGTON COAST REGION (continued)

| Hatchery | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
|  | \# | \% | \# | \% | \# | \% | \# | \% |
| Bingham Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 131.4 | 6.0\% | 4.2 | 0.6\% | 106.9 | 5.5\% | 17.6 | 2.1\% |
| 1999 | 93.8 | 3.9\% | 101.8 | 24.3\% | 99.9 | 4.3\% | 79.8 | 14.8\% |
| 2000 | 776.0 | 32.9\% | 101.3 | 33.6\% | 647.0 | 34.9\% | 87.7 | 16.5\% |
| 2001 | 66.5 | 10.4\% | 3.8 | 1.5\% | 75.1 | 12.7\% | 3.8 | 1.7\% |
| 2002 | 146.0 | 16.3\% | 2.2 | 1.7\% | 146.0 | 16.0\% | 3.4 | 0.7\% |
| 2003 | 175.8 | 16.6\% |  |  | 174.5 | 19.2\% | 15.5 | 5.4\% |
| 2004 | 87.3 | 15.9\% |  |  | 69.0 | 9.8\% | 4.3 | 1.8\% |
| 2005 | 16.0 | 3.7\% | 10.1 | 17.4\% | 12.0 | 2.5\% | 2.6 | 2.6\% |
| 2006 | 643.8 | 23.2\% | 9.6 | 2.9\% | 599.6 | 19.0\% | 18.7 | 2.9\% |
| 2007 | 76.4 | 2.0\% | 12.8 | 11.6\% | 68.9 | 2.0\% | 10.8 | 3.0\% |
| 2008 | 398.5 | 17.3\% |  |  | 370.0 | 17.0\% | 2.2 | 0.4\% |
| 2009 | 84.6 | 7.9\% |  |  | 105.0 | 11.8\% |  |  |
| 2010 | 190.3 | 10.3\% | 17.8 | 4.4\% | 62.4 | 3.9\% | 4.0 | 0.8\% |
| 2011 | 872.8 | 20.3\% | 4.1 | 0.2\% | 324.7 | 8.4\% | 18.0 | 0.9\% |
| Forks Creek Hatchery |  |  |  |  |  |  |  |  |
| 1998 | 280.0 | 12.7\% | 5.4 | 0.3\% | 190.0 | 10.8\% | 2.0 | 0.1\% |
| 1999 | 34.0 | 2.3\% | 1.9 | 0.1\% | 35.0 | 2.4\% |  |  |
| 2000 | 219.0 | 8.3\% |  |  | 188.0 | 8.7\% |  |  |
| 2001 | 91.0 | 9.1\% | 3.3 | 0.7\% | 82.0 | 9.1\% |  |  |
| 2002 | 277.0 | 8.7\% |  |  | 205.0 | 6.7\% | 7.0 | 0.3\% |
| 2003 | 3.4 | 0.9\% |  |  | 19.6 | 4.4\% |  |  |
| 2004 | 34.0 | 4.6\% |  |  | 42.0 | 7.0\% | 7.2 | 1.2\% |
| 2005 | 11.0 | 2.0\% | 1.0 | 0.4\% | 9.0 | 1.8\% | 2.9 | 1.1\% |
| 2006 | 100.0 | 8.4\% | 1.0 | 0.2\% | 94.0 | 11.4\% | 2.0 | 0.2\% |
| 2007 | 90.9 | 6.1\% | 2.0 | 14.3\% | 74.7 | 6.7\% | 14.0 | 1.8\% |
| 2008 | 48.4 | 5.4\% |  |  | 25.1 | 3.3\% |  |  |
| 2009 | 90.4 | 18.0\% |  |  | 105.5 | 21.9\% | 7.1 | 1.3\% |
| 2010 | 12.0 | 2.2\% |  |  | 11.0 | 2.3\% |  |  |
| 2011 | 150.7 | 2.7\% |  |  | 117.2 | 2.2\% |  |  |

Appendix Table 2D. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

COLUMBIA RIVER REGION

| HatcheryBrood Year | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
|  | \# | \% | \# | \% | \# | \% | \# | \% |
| Lewis River - North |  |  |  |  |  |  |  |  |
| 1998 | 469.1 | 14.6\% | 24.1 | 1.5\% | 479.8 | 18.0\% | 133.1 | 4.3\% |
| 1999 | 55.5 | 7.5\% |  |  | 59.6 | 8.3\% | 51.0 | 6.7\% |
| 2000 | 474.0 | 19.4\% | 5.7 | 0.4\% | 500.1 | 24.9\% | 25.9 | 1.0\% |
| 2001 | 227.1 | 14.9\% | 8.2 | 0.7\% | 216.0 | 18.8\% | 3.1 | 0.1\% |
| 2002 | 126.2 | 6.1\% |  |  | 124.2 | 8.7\% |  |  |
| 2003 | 191.8 | 11.6\% |  |  | 203.6 | 13.9\% | 6.5 | 1.0\% |
| 2004 | 247.1 | 14.7\% | 1.2 | 0.2\% | 240.1 | 17.4\% | 26.7 | 1.4\% |
| 2005 | 82.4 | 4.6\% | 4.0 | 3.2\% | 56.9 | 3.7\% | 5.0 | 0.8\% |
| 2006 | 393.5 | 14.5\% | 13.3 | 1.9\% | 365.2 | 16.2\% | 225.8 | 7.2\% |
| 2007 | 61.9 | 2.9\% | 2.0 | 0.7\% | 47.5 | 2.6\% | 11.6 | 1.7\% |
| 2008 | 173.9 | 9.0\% |  |  | 180.8 | 12.0\% |  |  |
| 2009 | 26.4 | 9.2\% | 19.1 | 41.0\% | 41.4 | 18.0\% |  |  |
| 2010 | 77.1 | 8.2\% |  |  | 56.0 | 7.9\% |  |  |
| 2011 | 185.0 | 6.8\% | 10.0 | 1.7\% | 154.0 | 6.8\% | 76.6 | 4.2\% |
| Lewis River - South |  |  |  |  |  |  |  |  |
| 1998 | 628.8 | 14.6\% | 1.0 | 0.5\% | 559.3 | 17.4\% | 26.1 | 1.7\% |
| 1999 | 72.7 | 4.9\% |  |  | 57.6 | 5.0\% | 7.0 | 2.4\% |
| 2000 | 568.0 | 13.3\% |  |  | 649.0 | 19.3\% |  |  |
| 2001 | 154.0 | 6.2\% |  |  | 152.0 | 8.5\% |  |  |
| 2002 | 173.6 | 9.5\% |  |  | 161.5 | 10.2\% | 7.4 | 4.5\% |
| 2003 | 198.7 | 12.9\% | 2.0 | 2.1\% | 206.9 | 14.1\% |  |  |
| 2004 | 280.1 | 13.5\% |  |  | 257.9 | 16.7\% | 6.4 | 1.0\% |
| 2005 | 200.8 | 8.3\% | 26.0 | 23.2\% | 168.5 | 9.1\% | 68.4 | 21.4\% |
| 2006 | 805.8 | 36.9\% | 4.6 | 2.1\% | 653.7 | 40.8\% | 91.0 | 5.0\% |
| 2007 | 103.6 | 7.1\% | 1.0 | 3.5\% | 92.9 | 7.9\% | 28.1 | 9.6\% |
| 2008 | 94.5 | 6.8\% |  |  | 71.0 | 6.0\% |  |  |
| 2009 | 6.0 | 10.8\% |  |  | 5.0 | 7.8\% |  |  |
| 2010 | 121.9 | 9.9\% |  |  | 107.9 | 12.7\% | 7.1 | 2.7\% |
| 2011 | 471.3 | 12.0\% | 4.2 | 1.6\% | 367.2 | 12.3\% | 29.7 | 2.2\% |

Appendix Table 2D. Estimated number (\#) and percent (\%) of all brood-year recoveries that were age 2 for the unmarked and marked components of each broodyear's DIT group, by hatchery. Percent is the percentage of total escapement recoveries or total fishery recoveries of all ages.

## COLUMBIA RIVER REGION (continued)

| HatcheryBrood Year | Unmarked |  |  |  | Marked |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Escapement |  | Fishery |  | Escapement |  | Fishery |  |
|  | \# | \% | \# | \% | \# | \% | \# | \% |
| Eagle Creek NFH |  |  |  |  |  |  |  |  |
| 1998 | 124.0 | 14.7\% | 4.0 | 2.6\% | 105.0 | 14.7\% |  |  |
| 1999 | 20.5 | 5.1\% |  |  | 13.7 | 3.4\% |  |  |
| 2000 | 158.8 | 34.9\% |  |  | 127.6 | 39.8\% |  |  |
| 2001 | 28.8 | 8.2\% |  |  | 17.3 | 7.1\% | 5.3 | 10.3\% |
| 2002 | 13.5 | 3.9\% |  |  | 9.8 | 3.1\% |  |  |
| 2003 | 47.3 | 18.2\% |  |  | 68.5 | 32.2\% |  |  |
| 2004 | 26.3 | 3.4\% |  |  | 28.3 | 5.4\% |  |  |
| 2005 | 21.8 | 7.4\% |  |  | 13.1 | 8.8\% | 1.0 | 2.6\% |
| 2006 | 6.9 | 1.2\% |  |  | 13.8 | 3.4\% | 1.0 | 0.4\% |
| 2007 | 6.3 | 5.3\% |  |  | 6.3 | 8.2\% |  |  |
| 2008 | 3.0 | 1.5\% |  |  | 0.0 | 0.0\% |  |  |
| 2009 | 2.0 | 2.9\% |  |  | 0.0 | 0.0\% |  |  |
| 2010 | 29.6 | 10.7\% |  |  | 16.3 | 6.8\% | 4.7 | 11.9\% |
| 2011 | 0.0 | 0.0\% |  |  | 0.0 | 0.0\% |  |  |
| Sandy River |  |  |  |  |  |  |  |  |
| 1998 | 11.0 | 1.5\% | 1.0 | 0.9\% | 11.0 | 2.4\% | 1.0 | 0.2\% |
| 1999 | 1.0 | 0.6\% |  |  | 8.2 | 1.7\% |  |  |
| 2000 | 7.1 | 2.5\% |  |  | 8.1 | 4.4\% |  |  |
| 2001 | 15.3 | 3.3\% |  |  | 20.4 | 4.4\% |  |  |
| 2002 | 7.1 | 1.4\% |  |  | 4.0 | 1.3\% |  |  |
| 2003 | 13.0 | 3.0\% |  |  | 15.0 | 6.2\% |  |  |
| 2004 | 65.7 | 13.1\% |  |  | 29.8 | 10.6\% |  |  |
| 2005 | 2.0 | 0.7\% |  |  | 0.0 | 0.0\% | 1.0 | 1.1\% |
| 2006 | 40.4 | 4.4\% | 2.0 | 2.7\% | 89.9 | 12.2\% | 8.7 | 1.7\% |
| 2007 | 43.4 | 8.6\% | 6.0 | 28.1\% | 21.2 | 7.1\% |  |  |
| 2008 | 34.0 | 5.9\% |  |  | 35.0 | 11.2\% |  |  |

Appendix 3: Total number of all CWT recoveries for marked Coho salmon DIT groups and total number of CWT recoveries in fisheries for brood years 1998-2011.

Appendix Table 3A. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

BRITISH COLUMBIA REGION

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| $\begin{gathered} \text { BC } \\ \text { JNST } \end{gathered}$ | Quinsam River Hatchery | \%S | 89.1\% | 43.0\% | 10.7\% | 41.7\% | 14.0\% | 7.2\% | 27.4\% | 67.6\% | 59.6\% | 47.4\% | 21.8\% | 17.6\% | 63.1\% | 39.6\% | 39.3\% |
|  |  | \%N | 10.9\% | 46.3\% | 89.3\% | 48.8\% | 86.0\% | 92.8\% | 72.6\% | 32.4\% | 40.4\% | 52.6\% | 38.3\% | 54.0\% | 34.1\% | 34.3\% | 52.3\% |
|  |  | \%M | 0.0\% | 10.7\% | 0.0\% | 9.5\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 39.8\% | 28.4\% | 2.8\% | 26.1\% | 8.4\% |
|  |  | \# F | 34.1 | 157.8 | 109.1 | 154.6 | 49.6 | 32.5 | 247.2 | 37.1 | 178.3 | 45.9 | 175.3 | 191.7 | 448.1 | 195.4 | 146.9 |
|  |  | \% E | 96.2\% | 82.7\% | 80.7\% | 76.5\% | 85.0\% | 74.7\% | 58.7\% | 91.0\% | 80.5\% | 91.2\% | 74.7\% | 66.1\% | 59.7\% | 77.8\% | 78.3\% |
|  | \# Total |  | 894.8 | 913.6 | 565.7 | 659.0 | 331.4 | 128.7 | 598.5 | 410.0 | 914.7 | 520.6 | 692.9 | 565.3 | 1,112.0 | 879.5 | 656.2 |
| $\begin{gathered} \text { BC } \\ \text { GST } \end{gathered}$ | Big Qualicum River Hatchery | \%S | 90.7\% | 68.4\% | 63.5\% | 46.8\% | 74.1\% |  |  |  |  |  |  |  |  |  | 68.7\% |
|  |  | \%N | 1.5\% | 4.4\% | 36.5\% | 32.9\% | 25.9\% |  |  |  |  |  |  |  |  |  | 20.2\% |
|  |  | \%M | 7.8\% | 27.2\% | 0.0\% | 20.2\% | 0.0\% |  |  |  |  |  |  |  |  |  | 11.1\% |
|  |  | \# F | 190.1 | 141.1 | 92.8 | 136.4 | 5.3 |  |  |  |  |  |  |  |  |  | 113.1 |
|  |  | \% E | 82.7\% | 86.7\% | 76.1\% | 76.3\% | 88.5\% |  |  |  |  |  |  |  |  |  | 82.1\% |
|  | \# Total |  | 1,098.3 | 1,059.2 | 388.1 | 576.2 | 46.1 |  |  |  |  |  |  |  |  |  | 633.6 |
| $\begin{gathered} \text { BC } \\ \text { FRAS } \end{gathered}$ | Chilliwack River Hatchery | \%S | 90.9\% | 91.5\% | 87.4\% | 74.2\% | 78.1\% |  |  |  |  |  |  |  |  |  | 84.4\% |
|  |  | \%N | 9.1\% | 8.5\% | 12.6\% | 25.8\% | 21.9\% |  |  |  |  |  |  |  |  |  | 15.6\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |  |  |  |  |  |  |  |  |  | 0.0\% |
|  |  | \# F | 307.9 | 305.7 | 110.7 | 82.8 | 52.0 |  |  |  |  |  |  |  |  |  | 171.8 |
|  |  | \% E | 80.1\% | 79.0\% | 88.8\% | 84.7\% | 76.7\% |  |  |  |  |  |  |  |  |  | 81.9\% |
|  | \# Total |  | 1,548.1 | 1,453.5 | 984.8 | 542.2 | 222.9 |  |  |  |  |  |  |  |  |  | 950.3 |
| $\begin{gathered} \text { BC } \\ \text { FRAS } \end{gathered}$ | Inch Creek Hatchery | \%S | 97.4\% | 70.8\% | 70.9\% | 57.4\% | 60.4\% | 28.5\% | 60.1\% | 88.7\% | 59.6\% | 84.5\% | 44.4\% | 51.2\% | 78.0\% | 43.4\% | 64.0\% |
|  |  | \%N | 2.6\% | 29.2\% | 29.1\% | 42.6\% | 23.3\% | 71.5\% | 39.9\% | 11.3\% | 30.4\% | 15.5\% | 9.2\% | 17.4\% | 11.1\% | 32.3\% | 26.1\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 16.3\% | 0.0\% | 0.0\% | 0.0\% | 10.0\% | 0.0\% | 46.4\% | 31.4\% | 11.0\% | 24.2\% | 9.9\% |
|  |  | \# F | 1,352.6 | 63.8 | 55.0 | 286.3 | 97.6 | 98.1 | 193.0 | 42.0 | 98.8 | 129.6 | 115.9 | 544.8 | 809.4 | 423.4 | 307.9 |
|  |  | \% E | 56.8\% | 90.8\% | 81.6\% | 74.7\% | 83.9\% | 74.4\% | 70.0\% | 86.3\% | 78.0\% | 89.4\% | 81.3\% | 73.7\% | 63.0\% | 73.4\% | 76.9\% |
|  | \# Total |  | 3,129.6 | 692.4 | 298.4 | 1,131.0 | 606.3 | 382.9 | 644.1 | 305.9 | 449.4 | 1,225.5 | 620.9 | 2,068.6 | 2,187.6 | 1,592.5 | 1,095.4 |
| $\begin{gathered} \text { BC } \\ \text { WCVI } \end{gathered}$ | Robertson Creek Hatchery | \%S | 22.3\% | 16.0\% | 36.8\% | 27.2\% | 39.8\% |  |  |  |  |  |  |  |  |  | 28.4\% |
|  |  | \%N | 1.5\% | 12.7\% | 8.8\% | 4.2\% | 19.3\% |  |  |  |  |  |  |  |  |  | 9.3\% |
|  |  | \%M | 76.2\% | 71.3\% | 54.4\% | 68.6\% | 41.0\% |  |  |  |  |  |  |  |  |  | 62.3\% |
|  |  | \# F | 2,263.7 | 167.8 | 816.0 | 532.4 | 712.9 |  |  |  |  |  |  |  |  |  | 898.6 |
|  |  | \% E | 57.3\% | 92.0\% | 79.9\% | 72.4\% | 69.5\% |  |  |  |  |  |  |  |  |  | 74.2\% |
|  | \# Total |  | 5,305.5 | 2,095.2 | 4,063.8 | 1,929.1 | 2,339.9 |  |  |  |  |  |  |  |  |  | 3,146.7 |

Appendix Table 3B. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

PUGET SOUND REGION

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| $\begin{aligned} & \text { PS } \\ & \text { JDF } \end{aligned}$ | Lower Elwha Hatchery | \%S | 12.2\% | 15.8\% | 53.8\% | 9.2\% | 25.2\% | 48.9\% | 29.3\% | 30.3\% | 61.4\% | 12.9\% | 49.1\% | 67.3\% | 35.3\% | 59.4\% | 36.4\% |
|  |  | \%N | 87.8\% | 84.2\% | 46.2\% | 83.4\% | 66.8\% | 40.5\% | 70.7\% | 69.7\% | 38.6\% | 87.1\% | 32.3\% | 14.9\% | 28.5\% | 40.6\% | 56.5\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 7.4\% | 8.0\% | 10.6\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 18.6\% | 17.8\% | 36.3\% | 0.0\% | 7.0\% |
|  |  | \# F | 308.9 | 40.2 | 78.4 | 232.5 | 198.8 | 104.7 | 24.6 | 11.5 | 51.5 | 225.0 | 65.5 | 70.3 | 85.6 | 51.3 | 110.6 |
|  |  | \% E | 63.7\% | 89.5\% | 66.0\% | 53.5\% | 51.8\% | 61.2\% | 61.6\% | 69.5\% | 62.6\% | 73.9\% | 71.8\% | 45.5\% | 59.5\% | 68.0\% | 64.2\% |
|  | \# Total |  | 851.9 | 383.4 | 230.7 | 499.7 | 412.3 | 270.2 | 64.1 | 37.7 | 137.6 | 863.3 | 232.6 | 128.9 | 211.6 | 160.6 | 320.3 |
| $\begin{gathered} \text { PS } \\ \text { NPS } \end{gathered}$ | Kendall Creek Hatchery | \%S | 16.1\% | 15.2\% | 29.6\% | 13.0\% | 19.4\% | 4.7\% | 14.4\% | 6.6\% | 13.9\% | 5.4\% |  |  |  |  | 13.8\% |
|  |  | \%N | 83.0\% | 80.7\% | 67.0\% | 84.5\% | 74.9\% | 30.8\% | 77.2\% | 93.4\% | 83.5\% | 93.4\% |  |  |  |  | 76.9\% |
|  |  | \%M | 0.9\% | 4.1\% | 3.4\% | 2.5\% | 5.7\% | 64.5\% | 8.4\% | 0.0\% | 2.6\% | 1.2\% |  |  |  |  | 9.3\% |
|  |  | \# F | 1,433.5 | 1,037.4 | 477.0 | 1,353.3 | 394.6 | 399.9 | 401.3 | 266.9 | 526.9 | 1,404.5 |  |  |  |  | 769.5 |
|  |  | \% E | 42.9\% | 42.3\% | 46.6\% | 13.1\% | 17.7\% | 17.4\% | 28.0\% | 19.7\% | 5.3\% | 19.6\% |  |  |  |  | 25.3\% |
|  | \# Total |  | 2,511.9 | 1,798.5 | 893.1 | 1,556.5 | 479.5 | 484.3 | 557.1 | 332.3 | 556.6 | 1,747.5 |  |  |  |  | 1,091.7 |
| PS NPS | Marblemount Hatchery | \%S | 45.6\% | 32.5\% | 37.1\% | 33.0\% | 18.0\% | 21.4\% | 34.9\% | 17.7\% | 31.0\% | 21.0\% | 18.3\% | 27.4\% | 17.8\% | 27.0\% | 27.3\% |
|  |  | \%N | 51.5\% | 66.1\% | 59.0\% | 65.5\% | 79.3\% | 75.7\% | 53.9\% | 82.3\% | 61.0\% | 79.0\% | 78.1\% | 66.1\% | 66.8\% | 69.6\% | 68.1\% |
|  |  | \%M | 2.9\% | 1.4\% | 3.9\% | 1.5\% | 2.7\% | 2.9\% | 11.2\% | 0.0\% | 8.0\% | 0.0\% | 3.6\% | 6.5\% | 15.4\% | 3.4\% | 4.5\% |
|  |  | \# F | 762.3 | 701.4 | 1,483.9 | 3,303.0 | 1,083.0 | 379.6 | 713.1 | 439.3 | 1,066.9 | 332.4 | 1,180.2 | 1,168.5 | 1,557.5 | 840.0 | 1,072.2 |
|  |  | \% E | 68.6\% | 76.3\% | 28.8\% | 41.3\% | 56.7\% | 36.1\% | 67.4\% | 75.7\% | 58.6\% | 67.9\% | 54.5\% | 54.8\% | 52.7\% | 61.9\% | 57.2\% |
|  | \# Total |  | 2,428.3 | 2,964.4 | 2,084.9 | 5,623.3 | 2,502.3 | 594.3 | 2,188.7 | 1,804.7 | 2,574.6 | 1,033.9 | 2,593.8 | 2,585.0 | 3,290.5 | 2,207.1 | 2,462.6 |
| $\begin{gathered} \text { PS } \\ \text { NPS } \end{gathered}$ | Wallace River Hatchery | \%S | 51.2\% | 55.1\% | 61.6\% | 57.3\% | 47.5\% | 46.1\% | 37.2\% | 30.2\% | 49.9\% | 32.1\% | 45.0\% | 36.5\% | 41.4\% | 33.5\% | 44.6\% |
|  |  | \%N | 48.1\% | 41.9\% | 38.4\% | 40.3\% | 47.5\% | 49.3\% | 58.5\% | 61.5\% | 41.0\% | 67.9\% | 50.6\% | 58.0\% | 52.0\% | 58.4\% | 51.0\% |
|  |  | \%M | 0.7\% | 3.0\% | 0.0\% | 2.3\% | 5.0\% | 4.6\% | 4.3\% | 8.3\% | 9.2\% | 0.0\% | 4.4\% | 5.6\% | 6.6\% | 8.2\% | 4.4\% |
|  |  | \# F | 849.6 | 590.0 | 582.1 | 838.0 | 898.5 | 442.0 | 426.6 | 210.0 | 641.2 | 90.1 | 569.5 | 594.2 | 638.3 | 635.6 | 571.8 |
|  |  | \% E | 79.5\% | 81.6\% | 80.7\% | 73.6\% | 75.0\% | 75.1\% | 78.3\% | 76.3\% | 70.9\% | 89.4\% | 75.2\% | 79.1\% | 75.1\% | 71.0\% | 77.2\% |
|  | \# Total |  | 4,141.6 | 3,201.4 | 3,010.6 | 3,180.2 | 3,600.6 | 1,776.3 | 1,963.7 | 884.7 | 2,204.5 | 851.9 | 2,296.4 | 2,847.0 | 2,562.7 | 2,194.7 | 2,479.7 |
| PS MPS | Soos Creek Hatchery | \%S | 22.4\% | 12.6\% | 22.2\% | 23.9\% | 16.9\% | 11.0\% | 14.8\% | 17.9\% | 22.8\% | 21.4\% | 14.8\% | 19.9\% | 19.1\% | 21.3\% | 18.6\% |
|  |  | \%N | 76.8\% | 86.9\% | 74.3\% | 75.6\% | 78.1\% | 87.9\% | 78.9\% | 80.4\% | 70.8\% | 78.6\% | 84.2\% | 74.3\% | 72.9\% | 73.7\% | 78.1\% |
|  |  | \%M | 0.8\% | 0.5\% | 3.4\% | 0.5\% | 4.9\% | 1.1\% | 6.3\% | 1.7\% | 6.5\% | 0.0\% | 1.0\% | 5.9\% | 8.0\% | 5.0\% | 3.3\% |
|  |  | \# F | 1,823.1 | 1,548.3 | 1,648.6 | 2,678.7 | 1,217.8 | 1,733.2 | 1,027.6 | 553.1 | 965.1 | 210.5 | 819.8 | 1,208.1 | 1,021.7 | 870.5 | 1,237.6 |
|  |  | \% E | 36.4\% | 50.8\% | 38.5\% | 41.4\% | 48.3\% | 15.2\% | 46.9\% | 65.6\% | 56.3\% | 67.4\% | 55.9\% | 56.7\% | 48.4\% | 42.8\% | 47.9\% |
|  | \# Total |  | 2,865.1 | 3,144.3 | 2,682.4 | 4,567.5 | 2,357.3 | 2,044.3 | 1,934.7 | 1,606.8 | 2,209.5 | 645.6 | 1,859.5 | 2,791.7 | 1,979.7 | 1,520.7 | 2,300.6 |

Appendix Table 3B. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

PUGET SOUND REGION (continued)

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| PS MPS | Voights Creek Hatchery | \%S | 11.2\% | 10.8\% | 21.1\% | 27.4\% | 22.3\% | 12.2\% | 18.3\% | 9.1\% | 22.3\% | 13.8\% | 17.5\% | 16.4\% | 22.2\% | 18.6\% | 17.4\% |
|  |  | \%N | 88.8\% | 89.2\% | 78.9\% | 70.0\% | 75.5\% | 85.1\% | 80.3\% | 90.9\% | 75.0\% | 81.3\% | 66.9\% | 74.9\% | 71.1\% | 75.0\% | 78.8\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 2.6\% | 2.2\% | 2.7\% | 1.4\% | 0.0\% | 2.7\% | 4.9\% | 15.6\% | 8.7\% | 6.6\% | 6.4\% | 3.8\% |
|  |  | \# F | 1,062.7 | 1,053.7 | 1,027.5 | 1,467.3 | 976.2 | 886.8 | 959.6 | 364.0 | 1,399.7 | 102.1 | 387.9 | 626.5 | 524.3 | 542.2 | 812.9 |
|  |  | \% E | 43.8\% | 63.9\% | 51.5\% | 36.2\% | 60.6\% | 31.5\% | 32.1\% | 52.9\% | 21.3\% | 31.0\% | 51.5\% | 54.4\% | 39.3\% | 29.2\% | 42.8\% |
|  | \# Total |  | 1,892.3 | 2,922.5 | 2,116.8 | 2,298.7 | 2,478.3 | 1,294.0 | 1,413.7 | 772.3 | 1,779.1 | 148.0 | 799.9 | 1,374.5 | 863.8 | 766.0 | 1,494.3 |
| $\begin{aligned} & \text { PS } \\ & \text { HC } \end{aligned}$ | George Adams Hatchery | \%S | 35.4\% | 41.3\% | 34.6\% | 48.3\% | 38.4\% | 17.8\% | 32.9\% | 16.9\% | 16.6\% | 19.8\% | 25.9\% | 26.6\% | 29.4\% | 20.1\% | 28.9\% |
|  |  | \%N | 64.6\% | 58.4\% | 62.4\% | 45.1\% | 52.6\% | 81.9\% | 58.3\% | 83.1\% | 79.3\% | 80.2\% | 70.0\% | 67.8\% | 59.4\% | 77.1\% | 67.2\% |
|  |  | \%M | 0.0\% | 0.2\% | 3.1\% | 6.5\% | 9.0\% | 0.3\% | 8.8\% | 0.0\% | 4.1\% | 0.0\% | 4.1\% | 5.6\% | 11.2\% | 2.8\% | 4.0\% |
|  |  | \# F | 736.5 | 412.4 | 899.7 | 711.6 | 599.9 | 615.9 | 352.0 | 384.1 | 908.6 | 90.1 | 278.2 | 446.7 | 504.7 | 339.4 | 520.0 |
|  |  | \% E | 71.1\% | 85.8\% | 63.1\% | 71.0\% | 76.2\% | 33.2\% | 76.2\% | 69.4\% | 53.7\% | 75.4\% | 79.1\% | 55.9\% | 72.2\% | 46.0\% | 66.3\% |
|  | \# Total |  | 2,544.5 | 2,894.3 | 2,440.3 | 2,457.2 | 2,516.6 | 922.7 | 1,479.2 | 1,255.4 | 1,961.4 | 366.5 | 1,329.3 | 1,012.8 | 1,812.2 | 628.0 | 1,687.2 |
| PSHC | Quilcene NFH | \%S | 28.4\% | 27.5\% | 63.0\% | 31.2\% | 25.7\% | 27.3\% | 21.5\% | 8.1\% | 14.7\% | 2.1\% | 16.2\% | 12.9\% | 12.7\% | 44.1\% | 24.0\% |
|  |  | \%N | 70.3\% | 72.5\% | 37.0\% | 66.4\% | 74.3\% | 69.9\% | 76.7\% | 91.9\% | 80.7\% | 97.9\% | 82.4\% | 87.1\% | 82.4\% | 55.9\% | 74.7\% |
|  |  | \%M | 1.3\% | 0.0\% | 0.0\% | 2.4\% | 0.0\% | 2.8\% | 1.8\% | 0.0\% | 4.6\% | 0.0\% | 1.4\% | 0.0\% | 4.9\% | 0.0\% | 1.4\% |
|  |  | \# F | 1,161.2 | 352.3 | 706.6 | 1,301.6 | 1,381.7 | 709.3 | 1,015.4 | 1,401.1 | 1,239.8 | 407.4 | 1,565.7 | 719.4 | 926.7 | 256.1 | 938.9 |
|  |  | \% E | 53.9\% | 83.2\% | 63.1\% | 43.4\% | 41.1\% | 19.3\% | 39.7\% | 18.5\% | 25.3\% | 40.6\% | 37.5\% | 44.4\% | 46.8\% | 68.5\% | 44.7\% |
|  | \# Total |  | 2,518.4 | 2,093.4 | 1,913.2 | 2,300.2 | 2,344.2 | 879.4 | 1,683.0 | 1,719.9 | 1,660.4 | 685.4 | 2,506.8 | 1,293.3 | 1,741.7 | 811.8 | 1,725.1 |

Appendix Table 3C. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates. ${ }^{19}$

WASHINGTON COAST REGION

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| WC NWC | Makah NFH | \%S | 66.6\% | 68.4\% | 40.1\% | 88.6\% | 81.3\% | 55.4\% | 52.9\% | 43.5\% | 74.2\% | 70.2\% | 68.0\% | 70.1\% | 66.2\% |  | 65.0\% |
|  |  | \%N | 33.4\% | 25.1\% | 59.5\% | 11.4\% | 15.3\% | 44.6\% | 30.5\% | 56.5\% | 22.2\% | 29.8\% | 27.0\% | 29.9\% | 33.8\% |  | 32.2\% |
|  |  | \%M | 0.0\% | 6.4\% | 0.4\% | 0.0\% | 3.4\% | 0.0\% | 16.6\% | 0.0\% | 3.6\% | 0.0\% | 5.0\% | 0.0\% | 0.0\% |  | 2.7\% |
|  |  | \# F | 100.4 | 151.7 | 509.1 | 144.1 | 520.6 | 65.8 | 106.9 | 48.0 | 272.0 | 101.6 | 391.0 | 65.1 | 330.9 |  | 215.9 |
|  |  | \% E | 88.4\% | 84.4\% | 47.6\% | 74.1\% | 61.3\% | 67.6\% | 41.3\% | 86.4\% | 84.6\% | 90.8\% | 82.3\% | 83.1\% | 79.3\% |  | 74.7\% |
|  | \# Total |  | 865.3 | 969.7 | 970.9 | 557.2 | 1,345.8 | 202.8 | 182.2 | 352.2 | 1,760.2 | 1,107.5 | 2,206.1 | 385.3 | 1,594.6 |  | 961.5 |
| WC NWC | Quinault NFH | \%S | 26.1\% | 18.2\% | 21.8\% | 16.8\% | 19.3\% | 19.2\% | 38.0\% | 3.9\% | 18.1\% | 7.4\% | 15.9\% | 10.8\% | 25.0\% | 12.6\% | 18.1\% |
|  |  | \%N | 73.7\% | 81.8\% | 78.0\% | 82.0\% | 80.2\% | 80.6\% | 60.3\% | 96.1\% | 81.6\% | 92.4\% | 83.8\% | 85.4\% | 73.8\% | 87.0\% | 81.2\% |
|  |  | \%M | 0.2\% | 0.0\% | 0.2\% | 1.2\% | 0.5\% | 0.2\% | 1.8\% | 0.0\% | 0.4\% | 0.3\% | 0.3\% | 3.8\% | 1.3\% | 0.4\% | 0.7\% |
|  |  | \# F | 5,002.1 | 1,982.5 | 3,655.0 | 2,837.8 | 2,932.3 | 1,172.2 | 2,123.8 | 2,013.7 | 5,447.8 | 3,560.9 | 3,104.2 | 1,189.2 | 1,844.6 | 5,070.1 | 2,995.5 |
|  |  | \% E | 43.3\% | 38.8\% | 34.8\% | 40.2\% | 37.5\% | 28.2\% | 42.8\% | 39.8\% | 29.7\% | 33.4\% | 48.6\% | 39.0\% | 51.4\% | 30.4\% | 38.4\% |
|  | \# Total |  | 8,816.5 | 3,238.3 | 5,608.3 | 4,745.2 | 4,695.4 | 1,632.5 | 3,714.6 | 3,346.0 | 7,746.3 | 5,345.7 | 6,042.7 | 1,949.9 | 3,799.1 | 7,279.8 | 4,854.3 |
| WC <br> NWC | Salmon River Fish Culture | \%S | 23.8\% | 13.7\% | 33.3\% | 20.2\% | 15.9\% | 14.8\% | 47.5\% | 11.9\% | 16.4\% | 7.7\% | 26.3\% | 10.8\% | 33.4\% | 27.4\% | 21.6\% |
|  |  | \%N | 76.2\% | 86.3\% | 66.7\% | 79.8\% | 82.9\% | 85.2\% | 52.5\% | 88.1\% | 82.1\% | 92.3\% | 71.2\% | 89.2\% | 66.6\% | 72.6\% | 78.0\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 1.2\% | 0.0\% | 0.0\% | 0.0\% | 1.4\% | 0.0\% | 2.6\% | 0.0\% | 0.0\% | 0.0\% | 0.4\% |
|  |  | \# F | 1,130.2 | 1,980.9 | 1,263.0 | 684.3 | 2,680.9 | 1,011.7 | 284.7 | 405.0 | 2,335.3 | 1,450.6 | 994.1 | 322.3 | 301.8 | 1,895.6 | 1,195.7 |
|  |  | \% E | 41.8\% | 8.5\% | 2.5\% | 34.4\% | 56.9\% | 19.2\% | 43.3\% | 32.5\% | 24.5\% | 27.6\% | 50.2\% | 12.1\% | 0.0\% | 22.8\% | 26.9\% |
|  | \# Total |  | 1,942.4 | 2,165.0 | 1,295.9 | 1,042.7 | 6,216.6 | 1,252.5 | 502.6 | 600.0 | 3,092.4 | 2,003.4 | 1,994.8 | 366.7 | 301.8 | 2,455.8 | 1,802.3 |
| WC NWC | Solduc Hatchery | \%S | 80.9\% | 76.1\% | 86.8\% | 62.1\% | 76.3\% | 77.8\% | 72.1\% | 13.5\% | 18.2\% | 18.7\% | 19.4\% | 11.4\% | 24.1\% | 14.6\% | 46.6\% |
|  |  | \%N | 19.1\% | 17.8\% | 13.2\% | 29.6\% | 18.5\% | 20.5\% | 16.1\% | 86.5\% | 79.9\% | 80.7\% | 79.8\% | 88.6\% | 70.7\% | 85.1\% | 50.4\% |
|  |  | \%M | 0.0\% | 6.2\% | 0.0\% | 8.3\% | 5.3\% | 1.7\% | 11.7\% | 0.0\% | 1.8\% | 0.5\% | 0.8\% | 0.0\% | 5.2\% | 0.3\% | 3.0\% |
|  |  | \# F | 332.1 | 350.5 | 320.6 | 610.7 | 1,060.5 | 244.9 | 438.2 | 1,111.3 | 6,101.9 | 1,547.9 | 1,644.5 | 591.4 | 1,321.3 | 3,786.4 | 1,390.2 |
|  |  | \% E | 85.1\% | 88.5\% | 78.3\% | 80.5\% | 72.1\% | 66.1\% | 77.8\% | 52.1\% | 36.0\% | 52.8\% | 65.2\% | 31.6\% | 40.8\% | 37.8\% | 61.8\% |
|  | \# Total |  | 2,235.9 | 3,042.0 | 1,477.0 | 3,134.0 | 3,797.2 | 721.4 | 1,970.6 | 2,318.4 | 9,541.7 | 3,278.4 | 4,729.4 | 864.5 | 2,231.0 | 6,087.4 | 3,244.9 |
| WC GRAY | Bingham Creek Hatchery | \%S | 17.5\% | 18.0\% | 38.9\% | 12.2\% | 19.3\% | 22.6\% | 29.1\% | 9.1\% | 56.8\% | 48.2\% | 27.0\% | 4.5\% | 20.8\% | 6.8\% | 23.6\% |
|  |  | \%N | 82.5\% | 82.0\% | 59.5\% | 87.8\% | 75.6\% | 74.4\% | 70.9\% | 90.9\% | 43.2\% | 51.8\% | 73.0\% | 95.5\% | 79.2\% | 93.2\% | 75.7\% |
|  |  | \%M | 0.0\% | 0.0\% | 1.6\% | 0.0\% | 5.1\% | 3.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.7\% |
|  |  | \# F | 823.3 | 539.9 | 530.5 | 223.1 | 491.3 | 288.4 | 240.4 | 100.6 | 653.0 | 366.2 | 564.8 | 429.8 | 484.9 | 2,043.8 | 555.7 |
|  |  | \% E | 70.1\% | 81.0\% | 77.7\% | 72.6\% | 65.0\% | 75.9\% | 74.4\% | 82.6\% | 82.9\% | 90.3\% | 79.4\% | 67.5\% | 76.8\% | 65.4\% | 75.8\% |
|  | \# Total |  | 2,751.6 | 2,840.6 | 2,383.3 | 815.3 | 1,401.9 | 1,195.5 | 940.6 | 577.5 | 3,815.5 | 3,768.4 | 2,743.1 | 1,323.1 | 2,091.8 | 5,910.2 | 2,325.6 |

[^16]Appendix Table 3C. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

WASHINGTON COAST REGION (continued)

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| WC WILP | Forks Creek Hatchery | \%S | 24.0\% | 23.6\% | 41.2\% | 29.4\% | 29.7\% | 26.2\% | 50.4\% | 17.2\% | 46.2\% | 16.5\% | 15.7\% | 27.0\% | 29.7\% | 34.4\% | 29.4\% |
|  |  | \%N | 76.0\% | 75.6\% | 58.8\% | 70.6\% | 68.7\% | 73.8\% | 46.8\% | 82.8\% | 53.8\% | 82.9\% | 84.3\% | 73.0\% | 70.3\% | 65.6\% | 70.2\% |
|  |  | \%M | 0.0\% | 0.8\% | 0.0\% | 0.0\% | 1.6\% | 0.0\% | 2.9\% | 0.0\% | 0.0\% | 0.6\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.4\% |
|  |  | \# F | 1,924.8 | 2,594.8 | 3,170.7 | 711.0 | 2,008.8 | 928.0 | 607.4 | 268.9 | 962.2 | 776.8 | 842.5 | 532.9 | 391.1 | 3,217.0 | 1,352.6 |
|  |  | \% E | 47.8\% | 36.3\% | 40.4\% | 56.0\% | 60.4\% | 32.3\% | 49.7\% | 65.0\% | 46.2\% | 58.9\% | 47.5\% | 47.5\% | 55.1\% | 62.3\% | 50.4\% |
|  |  | \# Total | 3,690.8 | 4,073.9 | 5,321.7 | 1,615.0 | 5,071.7 | 1,370.6 | 1,208.0 | 768.7 | 1,789.5 | 1,892.1 | 1,606.2 | 1,015.3 | 871.7 | 8,526.4 | 2,773.0 |

Appendix Table 3D. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

COLUMBIA RIVER REGION

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| $\begin{gathered} \text { CR } \\ \text { COLR } \end{gathered}$ | Lewis River Hatchery - North | \%S | 92.5\% | 33.0\% | 57.2\% | 61.2\% | 54.8\% | 57.2\% | 74.9\% | 71.1\% | 79.5\% | 59.9\% | 86.7\% | 79.5\% | 84.2\% | 66.8\% | 68.5\% |
|  |  | \%N | 7.5\% | 67.0\% | 42.3\% | 38.8\% | 42.6\% | 39.6\% | 25.1\% | 24.6\% | 20.5\% | 40.1\% | 13.3\% | 15.0\% | 13.6\% | 32.7\% | 30.2\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.5\% | 0.0\% | 2.6\% | 3.1\% | 0.0\% | 4.3\% | 0.0\% | 0.0\% | 0.0\% | 5.4\% | 2.2\% | 0.5\% | 1.3\% |
|  |  | \# F | 3,064.9 | 760.8 | 2,629.4 | 2,228.4 | 601.8 | 667.8 | 1,878.0 | 614.7 | 3,131.5 | 699.6 | 862.9 | 158.9 | 648.7 | 1,818.4 | 1,411.8 |
|  |  | \% E | 46.5\% | 48.7\% | 43.3\% | 34.0\% | 70.4\% | 68.8\% | 42.4\% | 71.6\% | 41.9\% | 72.7\% | 63.5\% | 59.2\% | 52.3\% | 55.5\% | 55.1\% |
|  | \# Total |  | 5,724.7 | 1,482.7 | 4,636.3 | 3,378.7 | 2,032.3 | 2,137.9 | 3,261.7 | 2,161.5 | 5,389.9 | 2,561.3 | 2,366.1 | 389.1 | 1,360.6 | 4,088.7 | 2,926.5 |
| $\begin{gathered} \text { CR } \\ \text { COLR } \end{gathered}$ | Lewis River Hatchery - South | \%S | 97.3\% | 47.8\% | 96.4\% | 96.1\% | 62.0\% | 76.8\% | 92.2\% | 89.4\% | 94.3\% | 84.0\% | 81.2\% | 100.0\% | 54.2\% | 63.9\% | 81.1\% |
|  |  | \%N | 2.7\% | 52.2\% | 3.6\% | 3.9\% | 38.0\% | 23.2\% | 7.8\% | 10.6\% | 5.7\% | 16.0\% | 18.8\% | 0.0\% | 45.8\% | 36.1\% | 18.9\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |
|  |  | \# F | 1,556.7 | 288.3 | 1,425.6 | 835.4 | 164.6 | 260.3 | 645.3 | 319.7 | 1,811.0 | 293.9 | 283.1 | 20.8 | 262.4 | 1,330.2 | 678.4 |
|  |  | \% E | 67.4\% | 80.1\% | 70.2\% | 68.1\% | 90.6\% | 84.9\% | 70.5\% | 85.3\% | 46.9\% | 80.0\% | 80.7\% | 75.4\% | 76.3\% | 69.2\% | 74.7\% |
|  | \# Total |  | 4,773.1 | 1,449.8 | 4,780.6 | 2,614.8 | 1,750.7 | 1,727.3 | 2,190.5 | 2,169.7 | 3,411.3 | 1,470.0 | 1,463.9 | 84.6 | 1,108.8 | 4,313.2 | 2,379.1 |

Appendix Table 3D. Total number of all CWT recoveries for marked Coho salmon DIT groups (\# Total) and total number of CWT recoveries in fisheries (\#F) for brood years 1998-2011. Percent of the fishery recoveries by fishery regulation type are shown, also. Type $\% \mathrm{~S}=$ mark-Selective fishery, $\% \mathrm{~N}=$ Non-selective fishery, $\% \mathrm{M}=$ mixed MSF/NSF. $\% \mathrm{E}=$ percent of total CWT recoveries in the escapement. Recoveries are expanded for sampling rates.

## COLUMBIA RIVER REGION (continued)

| Region | Hatchery | Type | Brood Year |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | Average |
| $\begin{gathered} \text { CR } \\ \text { COLR } \end{gathered}$ | Eagle Creek NFH | \%S | 98.7\% | 48.0\% | 77.5\% | 81.7\% | 62.0\% | 63.8\% | 86.2\% | 80.7\% | 84.3\% | 81.9\% | 95.1\% | 75.9\% | 84.8\% | 57.3\% | 77.0\% |
|  |  | \%N | 1.3\% | 52.0\% | 22.5\% | 18.3\% | 38.0\% | 36.2\% | 13.8\% | 19.3\% | 15.7\% | 18.1\% | 4.9\% | 24.1\% | 15.2\% | 42.7\% | 23.0\% |
|  |  | \%M | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |
|  |  | \# F | 425.1 | 76.7 | 47.1 | 51.6 | 43.4 | 79.1 | 224.8 | 37.8 | 250.1 | 24.4 | 20.5 | 24.3 | 39.5 | 460.2 | 128.9 |
|  |  | \% E | 62.6\% | 84.0\% | 87.2\% | 82.4\% | 88.0\% | 72.9\% | 70.0\% | 79.6\% | 61.7\% | 75.7\% | 82.4\% | 73.5\% | 85.8\% | 68.5\% | 76.7\% |
|  | \# Total |  | 1,137.2 | 479.9 | 367.7 | 293.7 | 360.7 | 292.0 | 749.7 | 185.4 | 653.4 | 100.3 | 116.4 | 91.6 | 278.1 | 1,458.8 | 468.9 |
| $\begin{gathered} \text { CR } \\ \text { COLR } \end{gathered}$ | Sandy River Hatchery | \%S | 99.0\% | 47.0\% | 76.8\% | 91.7\% | 63.4\% | 82.4\% | 87.6\% | 85.5\% | 85.8\% | 94.5\% | 57.6\% |  |  |  | 79.2\% |
|  |  | \%N | 1.0\% | 53.0\% | 21.4\% | 8.3\% | 36.6\% | 17.6\% | 12.4\% | 14.5\% | 14.2\% | 5.5\% | 42.4\% |  |  |  | 20.6\% |
|  |  | \%M | 0.0\% | 0.0\% | 1.8\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% | 0.0\% |  |  |  | 0.2\% |
|  |  | \# F | 518.3 | 603.9 | 452.6 | 370.4 | 58.3 | 79.7 | 319.8 | 88.4 | 517.4 | 73.8 | 120.3 |  |  |  | 291.2 |
|  |  | \% E | 46.9\% | 44.7\% | 29.1\% | 55.4\% | 84.3\% | 75.3\% | 46.8\% | 64.1\% | 58.7\% | 80.2\% | 72.3\% |  |  |  | 59.8\% |
|  | \# Total |  | 976.7 | 1,092.9 | 638.2 | 830.1 | 371.4 | 322.6 | 601.0 | 245.9 | 1,251.6 | 373.0 | 434.0 |  |  |  | 648.9 |

Appendix 4: Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

Appendix Table 4A. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.


Appendix Table 4A. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

BRITISH COLUMBIA REGION (continued)

| Hatchery | Brood Year | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Inch Creek Hatchery | 1998 | 2,131.0 | 5.31\% | 1,777.0 | 4.42\% | 0.894\% | 5.888 | <0.001 | Yes | 1.20 |
|  | 1999 | 729.2 | 1.82\% | 628.6 | 1.57\% | 0.244\% | 2.646 | 0.008 | Yes | 1.15 |
|  | 2000 | 308.6 | 0.77\% | 243.3 | 0.61\% | 0.160\% | 2.742 | 0.006 | Yes | 1.26 |
|  | 2001 | 787.9 | 1.99\% | 844.7 | 2.12\% | -0.127\% | -1.261 | 0.207 | - | 0.94 |
|  | 2002 | 685.8 | 1.73\% | 508.7 | 1.28\% | 0.442\% | 5.116 | <0.001 | Yes | 1.34 |
|  | 2003 | 282.8 | 0.71\% | 284.9 | 0.71\% | -0.005\% | -0.086 | 0.931 | - | 0.99 |
|  | 2004 | 512.1 | 1.28\% | 451.0 | 1.14\% | 0.143\% | 1.849 | 0.064 | - | 1.13 |
|  | 2005 | 285.5 | 0.73\% | 263.9 | 0.68\% | 0.051\% | 0.855 | 0.393 | - | 1.08 |
|  | 2006 | 429.3 | 1.07\% | 350.6 | 0.87\% | 0.196\% | 2.830 | 0.005 | Yes | 1.22 |
|  | 2007 | 1,237.5 | 3.08\% | 1,095.8 | 2.72\% | 0.357\% | 3.020 | 0.003 | Yes | 1.13 |
|  | 2008 | 520.7 | 1.33\% | 505.0 | 1.29\% | 0.041\% | 0.509 | 0.611 | - | 1.03 |
|  | 2009 | 1,656.4 | 3.49\% | 1,523.7 | 3.19\% | 0.299\% | 2.570 | 0.010 | Yes | 1.09 |
|  | 2010 | 1,788.6 | 3.64\% | 1,378.2 | 2.78\% | 0.859\% | 7.654 | <0.001 | Yes | 1.31 |
|  | 2011 | 1,336.5 | 2.67\% | 1,169.1 | 2.34\% | 0.334\% | 3.379 | 0.001 | Yes | 1.14 |
| Robertson Creek Hatchery | 1998 | 3,104.2 | 7.71\% | 3,041.8 | 7.57\% | 0.140\% | 0.748 | 0.454 | - | 1.02 |
|  | 1999 | 2,056.7 | 5.21\% | 1,927.4 | 4.81\% | 0.401\% | 2.590 | 0.010 | Yes | 1.08 |
|  | 2000 | 3,512.0 | 8.60\% | 3,247.7 | 8.06\% | 0.545\% | 2.811 | 0.005 | Yes | 1.07 |
|  | 2001 | 1,364.6 | 3.37\% | 1,396.7 | 3.47\% | -0.099\% | -0.777 | 0.437 | - | 0.97 |
|  | 2002 | 2,546.7 | 6.35\% | 1,627.0 | 4.08\% | 2.272\% | 14.469 | $<0.001$ | Yes | 1.56 |

Appendix Table 4B. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

|  | Brood | Unmarked |  | Marked |  | $U-M$ <br> Difference | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Year | \# Returned | \% Return | \# Returned | \% Return |  | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
|  | 1998 | 495.0 | 0.65\% | 543.0 | 0.68\% | -0.038\% | -0.935 | 0.350 | - | 0.94 |
|  | 1999 | 337.6 | 0.55\% | 343.2 | 0.55\% | -0.004\% | -0.086 | 0.931 | - | 0.99 |
|  | 2000 | 193.6 | 0.27\% | 152.3 | 0.22\% | 0.056\% | 2.142 | 0.032 | Yes | 1.26 |
|  | 2001 | 277.5 | 0.38\% | 267.2 | 0.37\% | 0.010\% | 0.283 | 0.777 | - | 1.03 |
|  | 2002 | 250.5 | 0.33\% | 213.5 | 0.29\% | 0.047\% | 1.646 | 0.100 | - | 1.17 |
|  | 2003 | 66.5 | 0.13\% | 165.5 | 0.26\% | -0.131\% | -5.063 | <0.001 | Yes | 0.50 |
| Lower Elwha | 2004 | 59.9 | 0.08\% | 39.5 | 0.05\% | 0.025\% | 1.969 | 0.049 | Yes | 1.50 |
| Hatchery | 2005 | 12.5 | 0.02\% | 26.2 | 0.03\% | -0.018\% | -2.142 | 0.032 | Yes | 0.48 |
|  | 2006 | 92.2 | 0.12\% | 86.1 | 0.11\% | 0.005\% | 0.322 | 0.748 | - | 1.05 |
|  | 2007 | 629.7 | 0.80\% | 638.3 | 0.81\% | -0.011\% | -0.242 | 0.809 | - | 0.99 |
|  | 2008 | 217.2 | 0.27\% | 167.0 | 0.21\% | 0.062\% | 2.031 | 0.042 | Yes | 1.30 |
|  | 2009 | 59.5 | 0.07\% | 58.7 | 0.07\% | 0.001\% | 0.096 | 0.924 | - | 1.02 |
|  | 2010 | 145.1 | 0.17\% | 126.0 | 0.15\% | 0.022\% | 1.093 | 0.274 | - | 1.14 |
|  | 2011 | 161.4 | 0.24\% | 109.2 | 0.14\% | 0.099\% | 4.171 | <0.001 | Yes | 1.69 |
|  | 1998 | 1,105.2 | 2.38\% | 1,078.4 | 2.49\% | -0.115\% | -1.009 | 0.313 | - | 0.95 |
|  | 1999 | 756.2 | 1.67\% | 761.1 | 1.74\% | -0.074\% | -0.630 | 0.529 | - | 0.96 |
|  | 2000 | 485.2 | 0.99\% | 416.1 | 0.88\% | 0.108\% | 1.725 | 0.085 | - | 1.12 |
|  | 2001 | 227.9 | 0.46\% | 203.2 | 0.41\% | 0.047\% | 0.941 | 0.347 | - | 1.11 |
| Kendall Creek | 2002 | 114.1 | 0.24\% | 84.8 | 0.18\% | 0.061\% | 2.047 | 0.041 | Yes | 1.34 |
| Hatchery | 2003 | 81.6 | 0.17\% | 84.4 | 0.18\% | -0.011\% | -0.330 | 0.741 | - | 0.94 |
|  | 2004 | 204.6 | 0.44\% | 155.7 | 0.34\% | 0.104\% | 1.403 | 0.161 | - | 1.31 |
|  | 2005 | 95.4 | 0.19\% | 65.5 | 0.13\% | 0.061\% | 1.726 | 0.084 | - | 1.46 |
|  | 2006 | 34.2 | 0.07\% | 29.7 | 0.06\% | 0.009\% | 0.491 | 0.623 | - | 1.14 |
|  | 2007 | 387.0 | 0.83\% | 343.0 | 0.74\% | 0.092\% | 1.591 | 0.112 | - | 1.12 |

Appendix Table 4B. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

PUGET SOUND REGION (continued)

| Hatchery | Brood | Unmarked |  | Marked |  | U-M <br> Difference | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Year | \# Returned | \% Return | \# Returned | \% Return |  | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Marblemount Hatchery | 1998 | 1,822.0 | 4.50\% | 1,666.0 | 4.12\% | 0.372\% | 2.606 | 0.009 | Yes | 1.09 |
|  | 1999 | 2,365.0 | 5.25\% | 2,263.0 | 4.94\% | 0.312\% | 2.137 | 0.033 | Yes | 1.06 |
|  | 2000 | 657.0 | 1.50\% | 601.0 | 1.40\% | 0.100\% | 1.230 | 0.219 | - | 1.07 |
|  | 2001 | 1,186.0 | 3.66\% | 2,320.3 | 3.32\% | 0.336\% | 2.687 | 0.007 | Yes | 1.10 |
|  | 2002 | 1,593.0 | 3.73\% | 1,419.3 | 3.58\% | 0.148\% | 1.116 | 0.264 | - | 1.04 |
|  | 2003 | 209.0 | 0.45\% | 214.7 | 0.46\% | -0.017\% | -0.277 | 0.782 | - | 0.96 |
|  | 2004 | 1,352.3 | 3.27\% | 1,475.6 | 3.12\% | 0.155\% | 1.202 | 0.229 | - | 1.05 |
|  | 2005 | 1,363.1 | 3.13\% | 1,365.4 | 3.17\% | -0.040\% | -0.281 | 0.778 | - | 0.99 |
|  | 2006 | 1,531.6 | 3.24\% | 1,507.7 | 3.20\% | 0.041\% | 0.284 | 0.776 | - | 1.01 |
|  | 2007 | 751.2 | 1.68\% | 701.5 | 1.59\% | 0.096\% | 0.799 | 0.424 | - | 1.06 |
|  | 2008 | 1,521.5 | 3.49\% | 1,413.6 | 3.26\% | 0.232\% | 1.184 | 0.236 | - | 1.07 |
|  | 2009 | 1,517.8 | 3.50\% | 1,416.5 | 3.19\% | 0.315\% | 2.018 | 0.044 | Yes | 1.10 |
|  | 2010 | 1,854.0 | 4.40\% | 1,733.0 | 4.14\% | 0.262\% | 1.195 | 0.232 | - | 1.06 |
|  | 2011 | 1,454.3 | 3.19\% | 1,367.1 | 3.03\% | 0.152\% | 0.775 | 0.438 | - | 1.05 |
| Wallace River Hatchery | 1998 | 3,397.0 | 7.45\% | 3,292.0 | 7.65\% | -0.199\% | -1.120 | 0.263 | - | 0.97 |
|  | 1999 | 2,476.2 | 5.78\% | 2,611.4 | 5.47\% | 0.311\% | 1.891 | 0.059 | - | 1.06 |
|  | 2000 | 2,625.5 | 6.67\% | 2,428.6 | 6.14\% | 0.534\% | 2.856 | 0.004 | Yes | 1.09 |
|  | 2001 | 2,751.2 | 6.30\% | 2,342.2 | 5.91\% | 0.391\% | 2.198 | 0.028 | Yes | 1.07 |
|  | 2002 | 2,833.0 | 6.07\% | 2,702.1 | 5.82\% | 0.255\% | 1.599 | 0.110 | - | 1.04 |
|  | 2003 | 1,344.8 | 3.09\% | 1,334.2 | 3.09\% | -0.001\% | -0.010 | 0.992 | - | 1.00 |
|  | 2004 | 1,671.2 | 5.52\% | 1,537.1 | 5.09\% | 0.423\% | 2.276 | 0.023 | Yes | 1.08 |
|  | 2005 | 761.1 | 1.57\% | 674.7 | 1.44\% | 0.132\% | 1.649 | 0.099 | - | 1.09 |
|  | 2006 | 1,504.2 | 3.28\% | 1,563.3 | 3.50\% | -0.220\% | -1.532 | 0.126 | - | 0.94 |
|  | 2007 | 944.7 | 2.08\% | 761.8 | 1.67\% | 0.414\% | 2.569 | 0.010 | Yes | 1.25 |
|  | 2008 | 1,964.2 | 4.67\% | 1,727.0 | 4.08\% | 0.587\% | 2.409 | 0.016 | Yes | 1.14 |
|  | 2009 | 2,446.7 | 5.76\% | 2,252.8 | 5.26\% | 0.499\% | 2.592 | 0.010 | Yes | 1.09 |
|  | 2010 | 2,018.7 | 4.46\% | 1,924.4 | 4.34\% | 0.113\% | 0.458 | 0.647 | - | 1.03 |
|  | 2011 | 1,393.5 | 3.14\% | 1,559.1 | 3.54\% | -0.402\% | -1.973 | 0.049 | Yes | 0.89 |

Appendix Table 4B. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

PUGET SOUND REGION (continued)

|  | Brood Year | Unmarked |  | Marked |  | U-M <br> Difference | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery |  | \# Returned | \% Return | \# Returned | \% Return |  | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Soos Creek Hatchery | 1998 | 1,464.0 | 2.60\% | 1,042.0 | 2.42\% | 0.176\% | 1.761 | 0.078 | - | 1.07 |
|  | 1999 | 1,618.0 | 4.44\% | 1,596.0 | 4.69\% | -0.246\% | -1.566 | 0.117 | - | 0.95 |
|  | 2000 | 1,159.9 | 2.65\% | 1,033.8 | 2.46\% | 0.193\% | 1.524 | 0.127 | - | 1.08 |
|  | 2001 | 2,073.0 | 4.58\% | 1,888.8 | 4.25\% | 0.336\% | 2.295 | 0.022 | Yes | 1.08 |
|  | 2002 | 1,431.0 | 3.22\% | 1,139.6 | 2.67\% | 0.554\% | 4.341 | <0.001 | Yes | 1.21 |
|  | 2003 | 440.6 | 0.98\% | 311.1 | 0.69\% | 0.296\% | 4.055 | <0.001 | Yes | 1.43 |
|  | 2004 | 942.2 | 2.09\% | 907.0 | 2.02\% | 0.071\% | 0.696 | 0.486 | - | 1.04 |
|  | 2005 | 989.8 | 2.20\% | 1,053.7 | 2.34\% | -0.136\% | -1.297 | 0.195 | - | 0.94 |
|  | 2006 | 1,198.1 | 2.63\% | 1,244.4 | 2.75\% | -0.116\% | -0.951 | 0.342 | - | 0.96 |
|  | 2007 | 405.2 | 0.89\% | 435.0 | 0.96\% | -0.070\% | -0.802 | 0.423 | - | 0.93 |
|  | 2008 | 1,137.5 | 2.56\% | 1,039.7 | 2.59\% | -0.027\% | -0.195 | 0.845 | - | 0.99 |
|  | 2009 | 1,717.6 | 3.64\% | 1,583.6 | 3.35\% | 0.292\% | 1.763 | 0.078 | - | 1.09 |
|  | 2010 | 291.2 | 0.64\% | 957.9 | 2.14\% | -1.497\% | -15.413 | <0.001 | Yes | 0.30 |
|  | 2011 | 616.8 | 1.36\% | 650.2 | 1.42\% | -0.065\% | -0.562 | 0.574 | - | 0.95 |
| Voights Creek Hatchery | 1998 | 786.2 | 2.79\% | 829.6 | 2.95\% | -0.158\% | -1.079 | 0.280 | - | 0.95 |
|  | 1999 | 1,859.9 | 4.22\% | 1,868.8 | 4.28\% | -0.058\% | -0.398 | 0.691 | - | 0.99 |
|  | 2000 | 1,304.5 | 3.14\% | 1,089.3 | 2.90\% | 0.238\% | 1.789 | 0.074 | - | 1.08 |
|  | 2001 | 864.2 | 1.83\% | 831.4 | 1.75\% | 0.078\% | 0.806 | 0.420 | - | 1.04 |
|  | 2002 | 1,589.3 | 3.46\% | 1,502.1 | 3.26\% | 0.203\% | 1.618 | 0.106 | - | 1.06 |
|  | 2003 | 332.0 | 0.73\% | 407.2 | 0.90\% | -0.166\% | -2.218 | 0.027 | Yes | 0.82 |
|  | 2004 | 565.8 | 1.27\% | 454.1 | 1.02\% | 0.244\% | 2.903 | 0.004 | Yes | 1.24 |
|  | 2005 | 89.8 | 0.19\% | 408.3 | 0.72\% | -0.530\% | -6.301 | <0.001 | Yes | 0.26 |
|  | 2006 | 371.3 | 0.82\% | 379.4 | 0.85\% | -0.028\% | -0.320 | 0.749 | - | 0.97 |
|  | 2007 | 38.8 | 0.08\% | 45.9 | 0.10\% | -0.016\% | -0.812 | 0.417 | - | 0.84 |
|  | 2008 | 413.6 | 0.92\% | 412.0 | 0.93\% | -0.008\% | -0.106 | 0.915 | - | 0.99 |
|  | 2009 | 758.2 | 1.74\% | 748.0 | 1.69\% | 0.049\% | 0.470 | 0.638 | - | 1.03 |
|  | 2010 | 421.9 | 0.92\% | 339.5 | 0.75\% | 0.167\% | 2.165 | 0.030 | Yes | 1.22 |
|  | 2011 | 242.7 | 0.54\% | 223.8 | 0.49\% | 0.044\% | 0.726 | 0.468 | - | 1.09 |

Appendix Table 4B. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

PUGET SOUND REGION (continued)

|  | Brood | Unma | ked | Mar |  | U-M | Hyp | hesis Te | sult |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Year | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
|  | 1998 | 1,799.0 | 4.36\% | 1,808.0 | 4.25\% | 0.103\% | 0.732 | 0.464 | - | 1.02 |
|  | 1999 | 2,832.3 | 5.51\% | 2,481.9 | 5.02\% | 0.486\% | 3.420 | 0.001 | Yes | 1.10 |
|  | 2000 | 1,622.0 | 3.73\% | 1,540.6 | 3.53\% | 0.201\% | 1.454 | 0.146 | - | 1.06 |
|  | 2001 | 1,931.3 | 4.43\% | 1,745.6 | 4.00\% | 0.423\% | 2.721 | 0.007 | Yes | 1.11 |
|  | 2002 | 1,954.5 | 4.45\% | 1,916.8 | 4.39\% | 0.066\% | 0.385 | 0.700 | - | 1.02 |
|  | 2003 | 243.1 | 0.58\% | 306.8 | 0.74\% | -0.154\% | -2.455 | 0.014 | Yes | 0.79 |
| George Adams | 2004 | 1,188.6 | 2.65\% | 1,127.3 | 2.51\% | 0.141\% | 1.236 | 0.216 | - | 1.06 |
| Hatchery | 2005 | 923.8 | 2.14\% | 871.3 | 1.99\% | 0.149\% | 1.517 | 0.129 | - | 1.07 |
|  | 2006 | 631.2 | 1.19\% | 1,052.8 | 2.31\% | -1.126\% | -11.401 | <0.001 | Yes | 0.51 |
|  | 2007 | 278.7 | 0.61\% | 276.5 | 0.61\% | 0.005\% | 0.087 | 0.931 | - | 1.01 |
|  | 2008 | 1,104.0 | 2.43\% | 1,051.1 | 2.36\% | 0.077\% | 0.759 | 0.448 | - | 1.03 |
|  | 2009 | 632.6 | 1.38\% | 566.0 | 1.24\% | 0.142\% | 1.865 | 0.062 | - | 1.11 |
|  | 2010 | 1,379.9 | 3.03\% | 1,307.5 | 2.89\% | 0.139\% | 1.225 | 0.221 | - | 1.05 |
|  | 2011 | 295.9 | 0.66\% | 288.7 | 0.65\% | 0.008\% | 0.148 | 0.883 | - | 1.01 |
| Quilcene NFH | 1998 | 1,387.5 | 3.11\% | 1,357.2 | 2.82\% | 0.294\% | 1.317 | 0.188 | - | 1.10 |
|  | 1999 | 1,728.3 | 4.12\% | 1,741.1 | 3.76\% | 0.359\% | 1.202 | 0.229 | - | 1.10 |
|  | 2000 | 1,458.2 | 2.99\% | 1,206.6 | 2.45\% | 0.542\% | 3.130 | 0.002 | Yes | 1.22 |
|  | 2001 | 1,185.5 | 3.21\% | 998.5 | 2.83\% | 0.373\% | 2.508 | 0.012 | Yes | 1.13 |
|  | 2002 | 1,053.8 | 2.34\% | 962.6 | 2.23\% | 0.105\% | 0.824 | 0.410 | - | 1.05 |
|  | 2003 | 116.7 | 0.30\% | 170.1 | 0.41\% | -0.112\% | -2.327 | 0.020 | Yes | 0.73 |
|  | 2004 | 688.2 | 1.40\% | 667.7 | 1.40\% | 0.005\% | 0.045 | 0.964 | - | 1.00 |
|  | 2005 | 373.6 | 0.92\% | 318.8 | 0.77\% | 0.155\% | 2.166 | 0.030 | Yes | 1.20 |
|  | 2006 | 482.7 | 1.41\% | 420.6 | 1.23\% | 0.173\% | 1.479 | 0.139 | - | 1.14 |
|  | 2007 | 297.8 | 0.76\% | 277.9 | 0.76\% | 0.002\% | 0.038 | 0.970 | - | 1.00 |
|  | 2008 | 1,079.7 | 2.68\% | 941.1 | 2.48\% | 0.197\% | 1.614 | 0.107 | - | 1.08 |
|  | 2009 | 606.5 | 2.96\% | 574.0 | 2.77\% | 0.189\% | 1.101 | 0.271 | - | 1.07 |
|  | 2010 | 822.3 | 1.86\% | 815.1 | 1.84\% | 0.013\% | 0.104 | 0.917 | - | 1.01 |
|  | 2011 | 650.3 | 0.92\% | 555.7 | 0.78\% | 0.140\% | 2.150 | 0.032 | Yes | 1.18 |

Appendix Table 4C. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

WASHINGTON COAST REGION

| Hatchery | Brood Year | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Makah NFH | 1998 | 762.3 | 1.95\% | 764.9 | 2.02\% | -0.070\% | -0.299 | 0.765 | - | 0.97 |
|  | 1999 | 724.2 | 1.85\% | 817.9 | 2.15\% | -0.308\% | -0.997 | 0.319 | - | 0.86 |
|  | 2000 | 475.4 | 1.22\% | 461.8 | 1.17\% | 0.047\% | 0.267 | 0.790 | - | 1.04 |
|  | 2001 | 439.1 | 1.21\% | 413.1 | 1.16\% | 0.052\% | 0.399 | 0.690 | - | 1.04 |
|  | 2002 | 864.9 | 2.28\% | 825.2 | 2.25\% | 0.025\% | 0.158 | 0.874 | - | 1.01 |
|  | 2003 | 168.3 | 0.46\% | 137.1 | 0.36\% | 0.108\% | 1.561 | 0.119 | - | 1.30 |
|  | 2004 | 76.4 | 0.19\% | 75.3 | 0.19\% | 0.005\% | 0.154 | 0.877 | - | 1.03 |
|  | 2005 | 271.5 | 0.72\% | 304.3 | 0.81\% | -0.090\% | -0.850 | 0.395 | - | 0.89 |
|  | 2006 | 1,619.2 | 4.07\% | 1,488.3 | 3.78\% | 0.286\% | 1.178 | 0.239 | - | 1.08 |
|  | 2007 | 783.2 | 1.92\% | 1,005.9 | 2.48\% | -0.562\% | -2.407 | 0.016 | Yes | 0.77 |
|  | 2008 | 1,503.0 | 3.72\% | 1,815.0 | 4.50\% | -0.782\% | -4.038 | <0.001 | Yes | 0.83 |
|  | 2009 | 221.0 | 0.55\% | 320.1 | 0.80\% | -0.250\% | -3.109 | 0.002 | Yes | 0.69 |
|  | 2010 | 1,380.4 | 2.14\% | 1,263.7 | 2.04\% | 0.102\% | 0.920 | 0.357 | - | 1.05 |
| Quinault NFH | 1998 | 4,793.9 | 3.33\% | 3,814.3 | 2.74\% | 0.588\% | 4.939 | <0.001 | Yes | 1.21 |
|  | 1999 | 1,040.7 | 1.35\% | 1,255.8 | 1.63\% | -0.276\% | -2.619 | 0.009 | Yes | 0.83 |
|  | 2000 | 2,225.9 | 1.75\% | 1,953.3 | 1.53\% | 0.222\% | 2.418 | 0.016 | Yes | 1.15 |
|  | 2001 | 1,767.4 | 1.34\% | 1,907.4 | 1.41\% | -0.069\% | -0.810 | 0.418 | - | 0.95 |
|  | 2002 | 1,802.3 | 1.57\% | 1,763.1 | 1.54\% | 0.029\% | 0.333 | 0.739 | - | 1.02 |
|  | 2003 | 467.9 | 0.59\% | 460.3 | 0.62\% | -0.033\% | -0.523 | 0.601 | - | 0.95 |
|  | 2004 | 2,078.8 | 2.42\% | 1,590.8 | 2.00\% | 0.426\% | 2.684 | 0.007 | Yes | 1.21 |
|  | 2005 | 1,611.2 | 2.03\% | 1,332.3 | 1.63\% | 0.397\% | 3.795 | <0.001 | Yes | 1.24 |
|  | 2006 | 2,694.0 | 3.44\% | 2,298.4 | 2.93\% | 0.506\% | 2.690 | 0.007 | Yes | 1.17 |
|  | 2007 | 1,831.0 | 2.23\% | 1,784.8 | 2.21\% | 0.027\% | 0.178 | 0.859 | - | 1.01 |
|  | 2008 | 3,055.5 | 3.89\% | 2,938.5 | 3.59\% | 0.293\% | 1.511 | 0.131 | - | 1.08 |
|  | 2009 | 747.4 | 1.02\% | 760.7 | 1.03\% | -0.011\% | -0.178 | 0.858 | - | 0.99 |
|  | 2010 | 1,936.1 | 2.39\% | 1,954.5 | 2.44\% | -0.051\% | -0.498 | 0.618 | - | 0.98 |
|  | 2011 | 2,138.7 | 2.71\% | 2,209.7 | 2.78\% | -0.070\% | -0.634 | 0.526 | - | 0.97 |

Appendix Table 4C. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

WASHINGTON COAST REGION (continued)

|  | Brood | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Year | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
|  | 1998 | 841.4 | 1.17\% | 812.2 | 1.19\% | -0.018\% | -0.254 | 0.800 | - | 0.98 |
|  | 1999 | 131.5 | 0.18\% | 184.1 | 0.27\% | -0.084\% | -2.418 | 0.016 | Yes | 0.68 |
|  | 2000 | 21.7 | 0.03\% | 32.9 | 0.05\% | -0.015\% | -1.291 | 0.197 | - | 0.66 |
|  | 2001 | 327.6 | 0.45\% | 358.4 | 0.49\% | -0.046\% | -0.846 | 0.397 | - | 0.91 |
|  | 2002 | 127.9 | 0.17\% | 3,535.6 | 4.76\% | -4.593\% | -37.624 | <0.001 | Yes | 0.04 |
|  | 2003 | 75.7 | 0.10\% | 240.9 | 0.34\% | -0.238\% | -7.107 | <0.001 | Yes | 0.30 |
| Salmon River Fish | 2004 | 197.6 | 0.25\% | 217.9 | 0.27\% | -0.022\% | -0.817 | 0.414 | - | 0.92 |
| Culture | 2005 | 200.4 | 0.25\% | 195.0 | 0.27\% | -0.021\% | -0.724 | 0.469 | - | 0.92 |
|  | 2006 | 1,114.2 | 1.37\% | 757.1 | 1.05\% | 0.319\% | 4.365 | <0.001 | Yes | 1.30 |
|  | 2007 | 536.1 | 0.71\% | 552.7 | 0.80\% | -0.087\% | -0.924 | 0.355 | - | 0.89 |
|  | 2008 | 999.3 | 1.29\% | 1,000.7 | 1.36\% | -0.072\% | -0.638 | 0.523 | - | 0.95 |
|  | 2009 | 44.3 | 0.05\% | 44.3 | 0.06\% | -0.001\% | -0.020 | 0.984 | - | 0.99 |
|  | 2010 |  |  |  |  |  |  |  |  |  |
|  | 2011 | 602.0 | 0.81\% | 560.2 | 0.75\% | 0.060\% | 0.617 | 0.538 | - | 1.08 |
|  | 1998 | 1,990.3 | 2.76\% | 1,903.7 | 2.65\% | 0.105\% | 1.221 | 0.222 | - | 1.04 |
|  | 1999 | 2,298.9 | 3.59\% | 2,691.5 | 3.77\% | -0.185\% | -1.313 | 0.189 | - | 0.95 |
|  | 2000 | 1,498.8 | 2.05\% | 1,156.4 | 1.59\% | 0.456\% | 6.469 | <0.001 | Yes | 1.29 |
|  | 2001 | 1,925.0 | 2.61\% | 2,523.2 | 2.62\% | -0.007\% | -0.088 | 0.930 | - | 1.00 |
|  | 2002 | 2,931.3 | 4.09\% | 2,736.8 | 3.89\% | 0.198\% | 1.860 | 0.063 | - | 1.05 |
|  | 2003 | 547.4 | 0.75\% | 476.5 | 0.65\% | 0.097\% | 2.156 | 0.031 | Yes | 1.15 |
|  | 2004 | 808.8 | 1.07\% | 1,532.4 | 2.13\% | -1.060\% | -15.894 | <0.001 | Yes | 0.50 |
| Solduc Hatchery | 2005 | 1,211.1 | 1.70\% | 1,207.2 | 1.67\% | 0.030\% | 0.398 | 0.691 | - | 1.02 |
|  | 2006 | 4,008.5 | 5.23\% | 3,439.8 | 4.50\% | 0.727\% | 4.252 | <0.001 | Yes | 1.16 |
|  | 2007 | 1,870.1 | 2.48\% | 1,730.5 | 2.30\% | 0.184\% | 1.613 | 0.107 | - | 1.08 |
|  | 2008 | 3,019.9 | 3.89\% | 3,084.8 | 4.00\% | -0.108\% | -0.625 | 0.532 | - | 0.97 |
|  | 2009 | 352.6 | 0.47\% | 273.1 | 0.35\% | 0.113\% | 2.902 | 0.004 | Yes | 1.32 |
|  | 2010 | 1,022.8 | 1.28\% | 909.6 | 1.13\% | 0.149\% | 2.137 | 0.033 | Yes | 1.13 |
|  | 2011 | 2,574.2 | 3.38\% | 2,301.0 | 3.01\% | 0.370\% | 2.244 | 0.025 | Yes | 1.12 |

Appendix Table 4C. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

WASHINGTON COAST REGION (continued)

| Hatchery | Brood Year | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Bingham Creek Hatchery | 1998 | 2,200.5 | 3.05\% | 1,928.3 | 2.92\% | 0.131\% | 1.406 | 0.160 | - | 1.04 |
|  | 1999 | 2,401.8 | 3.54\% | 2,300.7 | 3.32\% | 0.222\% | 1.826 | 0.068 | - | 1.07 |
|  | 2000 | 2,358.0 | 3.32\% | 1,852.8 | 2.59\% | 0.735\% | 5.992 | <0.001 | Yes | 1.28 |
|  | 2001 | 640.5 | 0.92\% | 592.1 | 0.85\% | 0.068\% | 1.215 | 0.224 | - | 1.08 |
|  | 2002 | 894.2 | 1.25\% | 910.5 | 1.31\% | -0.059\% | -0.859 | 0.390 | - | 0.95 |
|  | 2003 | 1,058.3 | 1.46\% | 907.1 | 1.26\% | 0.209\% | 2.716 | 0.007 | Yes | 1.17 |
|  | 2004 | 548.0 | 0.76\% | 700.2 | 0.96\% | -0.203\% | -3.058 | 0.002 | Yes | 0.79 |
|  | 2005 | 433.4 | 0.60\% | 476.9 | 0.67\% | -0.065\% | -1.380 | 0.167 | - | 0.90 |
|  | 2006 | 2,776.7 | 3.78\% | 3,162.5 | 4.29\% | -0.505\% | -2.806 | 0.005 | Yes | 0.88 |
|  | 2007 | 3,734.7 | 5.09\% | 3,402.2 | 4.61\% | 0.485\% | 3.824 | <0.001 | Yes | 1.11 |
|  | 2008 | 2,303.6 | 3.19\% | 2,178.3 | 3.04\% | 0.156\% | 0.889 | 0.374 | - | 1.05 |
|  | 2009 | 1,074.7 | 1.58\% | 893.3 | 1.33\% | 0.256\% | 2.628 | 0.009 | Yes | 1.19 |
|  | 2010 | 1,843.0 | 2.57\% | 1,606.9 | 2.26\% | 0.313\% | 2.208 | 0.027 | Yes | 1.14 |
|  | 2011 | 4,294.5 | 5.88\% | 3,866.4 | 5.30\% | 0.578\% | 2.919 | 0.004 | Yes | 1.11 |
| Forks Creek Hatchery | 1998 | 2,212.3 | 2.94\% | 1,766.0 | 2.39\% | 0.548\% | 6.504 | <0.001 | Yes | 1.23 |
|  | 1999 | 1,454.0 | 2.32\% | 1,479.0 | 2.09\% | 0.223\% | 1.930 | 0.054 | - | 1.11 |
|  | 2000 | 2,652.0 | 3.61\% | 2,151.0 | 2.95\% | 0.668\% | 4.880 | <0.001 | Yes | 1.23 |
|  | 2001 | 1,005.5 | 1.41\% | 904.0 | 1.37\% | 0.037\% | 0.396 | 0.692 | - | 1.03 |
|  | 2002 | 3,200.3 | 4.85\% | 3,062.8 | 4.31\% | 0.536\% | 3.179 | 0.001 | Yes | 1.12 |
|  | 2003 | 397.5 | 0.54\% | 442.6 | 0.60\% | -0.060\% | -1.289 | 0.197 | - | 0.90 |
|  | 2004 | 741.3 | 1.01\% | 600.6 | 0.83\% | 0.177\% | 3.360 | 0.001 | Yes | 1.21 |
|  | 2005 | 563.0 | 0.75\% | 499.8 | 0.69\% | 0.067\% | 1.180 | 0.238 | - | 1.10 |
|  | 2006 | 1,189.0 | 1.63\% | 827.3 | 1.14\% | 0.490\% | 6.836 | <0.001 | Yes | 1.43 |
|  | 2007 | 1,486.8 | 1.99\% | 1,115.2 | 1.52\% | 0.469\% | 3.901 | <0.001 | Yes | 1.31 |
|  | 2008 | 892.0 | 1.19\% | 763.7 | 1.03\% | 0.154\% | 2.163 | 0.031 | Yes | 1.15 |
|  | 2009 | 502.4 | 0.67\% | 482.5 | 0.67\% | 0.004\% | 0.086 | 0.931 | - | 1.01 |
|  | 2010 | 553.9 | 0.75\% | 480.6 | 0.66\% | 0.088\% | 1.495 | 0.135 | - | 1.13 |
|  | 2011 | 5,502.7 | 7.34\% | 5,309.4 | 7.13\% | 0.209\% | 1.114 | 0.265 | - | 1.03 |

Appendix Table 4D. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

COLUMBIA RIVER REGION

|  | Brood | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Year | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
|  | 1998 | 3,209.2 | 4.83\% | 2,659.8 | 4.00\% | 0.828\% | 5.289 | <0.001 | Yes | 1.21 |
|  | 1999 | 739.4 | 0.91\% | 721.9 | 0.98\% | -0.062\% | -0.987 | 0.324 | - | 0.94 |
|  | 2000 | 2,437.4 | 3.33\% | 2,006.9 | 2.77\% | 0.552\% | 4.127 | <0.001 | Yes | 1.20 |
|  | 2001 | 1,522.2 | 2.04\% | 1,150.2 | 1.66\% | 0.383\% | 3.601 | <0.001 | Yes | 1.23 |
|  | 2002 | 2,057.8 | 2.83\% | 1,430.5 | 2.20\% | 0.627\% | 6.099 | <0.001 | Yes | 1.28 |
|  | 2003 | 1,650.3 | 2.64\% | 1,470.1 | 2.36\% | 0.281\% | 2.597 | 0.009 | Yes | 1.12 |
| Lewis River | 2004 | 1,680.7 | 2.36\% | 1,383.7 | 1.97\% | 0.396\% | 3.846 | <0.001 | Yes | 1.20 |
| Hatchery - North | 2005 | 1,794.1 | 2.54\% | 1,546.8 | 2.16\% | 0.381\% | 3.841 | <0.001 | Yes | 1.18 |
|  | 2006 | 2,710.0 | 3.56\% | 2,258.4 | 2.95\% | 0.606\% | 3.887 | <0.001 | Yes | 1.21 |
|  | 2007 | 2,153.9 | 2.84\% | 1,861.7 | 2.45\% | 0.391\% | 2.874 | 0.004 | Yes | 1.16 |
|  | 2008 | 1,936.8 | 2.56\% | 1,503.2 | 1.97\% | 0.582\% | 5.024 | <0.001 | Yes | 1.29 |
|  | 2009 | 287.0 | 0.38\% | 230.2 | 0.30\% | 0.075\% | 1.929 | 0.054 | - | 1.25 |
|  | 2010 | 934.9 | 1.48\% | 711.8 | 1.14\% | 0.341\% | 4.771 | <0.001 | Yes | 1.30 |
|  | 2011 | 2,705.1 | 3.86\% | 2,270.3 | 3.22\% | 0.638\% | 5.807 | <0.001 | Yes | 1.20 |
|  | 1998 | 4,311.3 | 5.78\% | 3,216.3 | 4.36\% | 1.428\% | 8.957 | <0.001 | Yes | 1.33 |
|  | 1999 | 1,478.7 | 2.00\% | 1,161.5 | 1.74\% | 0.264\% | 2.464 | 0.014 | Yes | 1.15 |
|  | 2000 | 4,274.5 | 5.78\% | 3,355.0 | 4.64\% | 1.139\% | 6.024 | <0.001 | Yes | 1.25 |
|  | 2001 | 2,468.1 | 3.35\% | 1,779.4 | 2.54\% | 0.811\% | 6.326 | <0.001 | Yes | 1.32 |
|  | 2002 | 1,834.1 | 2.50\% | 1,586.1 | 2.28\% | 0.227\% | 2.307 | 0.021 | Yes | 1.10 |
|  | 2003 | 1,546.1 | 2.17\% | 1,467.0 | 2.14\% | 0.026\% | 0.243 | 0.808 | - | 1.01 |
| Lewis River | 2004 | 2,082.0 | 2.99\% | 1,545.2 | 2.20\% | 0.790\% | 6.866 | <0.001 | Yes | 1.36 |
| Hatchery - South | 2005 | 2,416.4 | 3.47\% | 1,850.0 | 2.56\% | 0.902\% | 6.535 | <0.001 | Yes | 1.35 |
|  | 2006 | 2,186.4 | 2.93\% | 1,600.4 | 2.12\% | 0.807\% | 5.723 | <0.001 | Yes | 1.38 |
|  | 2007 | 1,460.5 | 1.93\% | 1,176.1 | 1.53\% | 0.392\% | 3.625 | <0.001 | Yes | 1.26 |
|  | 2008 | 1,390.2 | 1.85\% | 1,180.8 | 1.58\% | 0.263\% | 3.135 | 0.002 | Yes | 1.17 |
|  | 2009 | 55.6 | 0.07\% | 63.8 | 0.08\% | -0.011\% | -0.730 | 0.466 | - | 0.87 |
|  | 2010 | 1,231.6 | 1.79\% | 846.3 | 1.24\% | 0.555\% | 6.070 | <0.001 | Yes | 1.45 |
|  | 2011 | 3,927.8 | 5.57\% | 2,983.0 | 4.24\% | 1.336\% | 10.644 | <0.001 | Yes | 1.32 |

Appendix Table 4D. Results for $Z$ tests of the hypothesis that the hatchery return rate from release is equal for the unmarked and marked Coho DIT groups from brood years 1998-2011.

|  | Brood | Unmarked |  | Marked |  | U-M | Hypothesis Test Result |  |  | $\lambda R$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Year | \# Returned | \% Return | \# Returned | \% Return | Difference | Z-Stat. | Sig. (P) | $P \leq 0.05$ |  |
| Eagle Creek NFH | 1998 | 844.2 | 3.66\% | 712.1 | 3.08\% | 0.574\% | 3.098 | 0.002 | Yes | 1.19 |
|  | 1999 | 401.4 | 1.67\% | 403.1 | 1.62\% | 0.050\% | 0.337 | 0.736 | - | 1.03 |
|  | 2000 | 455.4 | 1.91\% | 320.6 | 1.33\% | 0.583\% | 4.090 | <0.001 | Yes | 1.44 |
|  | 2001 | 350.6 | 1.44\% | 242.1 | 0.99\% | 0.444\% | 4.138 | <0.001 | Yes | 1.45 |
|  | 2002 | 347.7 | 1.51\% | 317.3 | 1.34\% | 0.174\% | 1.369 | 0.171 | - | 1.13 |
|  | 2003 | 260.4 | 1.05\% | 212.9 | 0.86\% | 0.191\% | 2.025 | 0.043 | Yes | 1.22 |
|  | 2004 | 767.8 | 3.23\% | 524.8 | 2.21\% | 1.021\% | 6.169 | <0.001 | Yes | 1.46 |
|  | 2005 | 292.9 | 1.21\% | 147.6 | 0.61\% | 0.598\% | 4.300 | <0.001 | Yes | 1.98 |
|  | 2006 | 570.4 | 3.04\% | 403.3 | 2.26\% | 0.782\% | 2.944 | 0.003 | Yes | 1.35 |
|  | 2007 | 117.4 | 0.47\% | 75.9 | 0.30\% | 0.168\% | 2.386 | 0.017 | Yes | 1.55 |
|  | 2008 | 195.9 | 0.79\% | 95.9 | 0.39\% | 0.403\% | 5.846 | <0.001 | Yes | 2.04 |
|  | 2009 | 69.3 | 0.28\% | 67.3 | 0.27\% | 0.008\% | 0.175 | 0.861 | - | 1.03 |
|  | 2010 | 277.6 | 1.14\% | 238.6 | 0.97\% | 0.169\% | 1.751 | 0.080 | - | 1.17 |
|  | 2011 | 969.4 | 4.10\% | 998.6 | 4.06\% | 0.036\% | 0.154 | 0.878 | - | 1.01 |
| Sandy River Hatchery | 1998 | 756.4 | 3.00\% | 458.4 | 1.73\% | 1.270\% | 9.443 | <0.001 | Yes | 1.73 |
|  | 1999 | 169.7 | 0.63\% | 489.0 | 0.69\% | -0.065\% | -1.129 | 0.259 | - | 0.91 |
|  | 2000 | 279.4 | 1.00\% | 185.5 | 0.69\% | 0.312\% | 3.968 | <0.001 | Yes | 1.45 |
|  | 2001 | 468.8 | 1.67\% | 459.7 | 1.65\% | 0.029\% | 0.263 | 0.793 | - | 1.02 |
|  | 2002 | 492.1 | 1.87\% | 313.0 | 1.13\% | 0.732\% | 6.960 | <0.001 | Yes | 1.65 |
|  | 2003 | 428.4 | 1.63\% | 242.9 | 0.90\% | 0.725\% | 7.141 | <0.001 | Yes | 1.80 |
|  | 2004 | 503.0 | 1.98\% | 281.2 | 1.09\% | 0.894\% | 7.925 | <0.001 | Yes | 1.82 |
|  | 2005 | 289.8 | 1.07\% | 157.6 | 0.59\% | 0.478\% | 6.121 | <0.001 | Yes | 1.81 |
|  | 2006 | 920.1 | 3.35\% | 734.2 | 2.71\% | 0.643\% | 4.350 | <0.001 | Yes | 1.24 |
|  | 2007 | 505.4 | 1.83\% | 299.2 | 1.08\% | 0.750\% | 7.380 | <0.001 | Yes | 1.70 |
|  | 2008 | 580.4 | 2.08\% | 313.8 | 1.11\% | 0.966\% | 9.100 | $<0.001$ | Yes | 1.87 |

## Appendix 5. Why does the Total method sometimes result in negative exploitation rates?

Estimates of unmarked exploitation rate (ER) are sensitive to uncertainty in the estimate of marked ER. When the marked ER is small, leading to a small number of recoveries, sampling error results in high uncertainty in the estimate of marked ER. When marked ER is low and the $\lambda R$ ratio $\left[\frac{\lambda^{E s c}}{\lambda^{R e l}}\right]$ is large, the value of $\left[\frac{\bar{\lambda}^{E s c}}{\hat{\lambda}^{\text {Rel }}}\left(1-\widehat{E R}_{m}\right)\right]$ can be larger than one and the resulting estimate of unmarked ER from equation (15) is negative. The table below shows the relationship of the unmarked ER estimate to the $\lambda R$ ratio and marked ER. For any value of the marked ER, the unmarked estimate of ER decreases as the $\lambda R$ ratio increases and can become negative. An unmarked estimate of ER will be negative if, for example, the marked ER is 0.20 and the $\lambda R$ ratio is over 1.25 .

Estimates of unmarked exploitation rate using the Total method versus the $\lambda R$ ratio for values of marked ER ranging from 0.10 to 0.50 .

| $\lambda \boldsymbol{R}$ Ratio | Marked Component |  |  |  |  |  |  |  |  |  |  | Estimated |  |  |  |  |  |  |  |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\mathbf{0 . 1 0}$ | $\mathbf{0 . 1 5}$ | $\mathbf{0 . 2 0}$ | $\mathbf{0 . 2 5}$ | $\mathbf{0 . 3 0}$ | $\mathbf{0 . 3 5}$ | $\mathbf{0 . 4 0}$ | $\mathbf{0 . 4 5}$ | $\mathbf{0 . 5 0}$ |  |  |  |  |  |  |  |  |  |  |
| 1.00 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 |  |  |  |  |  |  |  |  |  |  |
| 1.05 | 0.05 | 0.11 | 0.16 | 0.21 | 0.27 | 0.32 | 0.37 | 0.42 | 0.48 |  |  |  |  |  |  |  |  |  |  |
| 1.10 | 0.01 | 0.06 | 0.12 | 0.18 | 0.23 | 0.29 | 0.34 | 0.40 | 0.45 |  |  |  |  |  |  |  |  |  |  |
| 1.15 | -0.04 | 0.02 | 0.08 | 0.14 | 0.20 | 0.25 | 0.31 | 0.37 | 0.43 |  |  |  |  |  |  |  |  |  |  |
| 1.20 | -0.08 | -0.02 | 0.04 | 0.10 | 0.16 | 0.22 | 0.28 | 0.34 | 0.40 |  |  |  |  |  |  |  |  |  |  |
| 1.25 | -0.13 | -0.06 | 0.00 | 0.06 | 0.13 | 0.19 | 0.25 | 0.31 | 0.38 |  |  |  |  |  |  |  |  |  |  |
| 1.30 | -0.17 | -0.11 | -0.04 | 0.02 | 0.09 | 0.16 | 0.22 | 0.29 | 0.35 |  |  |  |  |  |  |  |  |  |  |
| 1.35 | -0.22 | -0.15 | -0.08 | -0.01 | 0.05 | 0.12 | 0.19 | 0.26 | 0.33 |  |  |  |  |  |  |  |  |  |  |
| 1.40 | -0.26 | -0.19 | -0.12 | -0.05 | 0.02 | 0.09 | 0.16 | 0.23 | 0.30 |  |  |  |  |  |  |  |  |  |  |
| 1.45 | -0.31 | -0.23 | -0.16 | -0.09 | -0.02 | 0.06 | 0.13 | 0.20 | 0.28 |  |  |  |  |  |  |  |  |  |  |
| 1.50 | -0.35 | -0.28 | -0.20 | -0.13 | -0.05 | 0.02 | 0.10 | 0.18 | 0.25 |  |  |  |  |  |  |  |  |  |  |
| 1.55 | -0.40 | -0.32 | -0.24 | -0.16 | -0.09 | -0.01 | 0.07 | 0.15 | 0.23 |  |  |  |  |  |  |  |  |  |  |
| 1.60 | -0.44 | -0.36 | -0.28 | -0.20 | -0.12 | -0.04 | 0.04 | 0.12 | 0.20 |  |  |  |  |  |  |  |  |  |  |
| 1.65 | -0.49 | -0.40 | -0.32 | -0.24 | -0.16 | -0.07 | 0.01 | 0.09 | 0.18 |  |  |  |  |  |  |  |  |  |  |
| 1.70 | -0.53 | -0.45 | -0.36 | -0.28 | -0.19 | -0.11 | -0.02 | 0.06 | 0.15 |  |  |  |  |  |  |  |  |  |  |
| 1.75 | -0.58 | -0.49 | -0.40 | -0.31 | -0.23 | -0.14 | -0.05 | 0.04 | 0.13 |  |  |  |  |  |  |  |  |  |  |
| 1.80 | -0.62 | -0.53 | -0.44 | -0.35 | -0.26 | -0.17 | -0.08 | 0.01 | 0.10 |  |  |  |  |  |  |  |  |  |  |
| 1.85 | -0.67 | -0.57 | -0.48 | -0.39 | -0.30 | -0.20 | -0.11 | -0.02 | 0.07 |  |  |  |  |  |  |  |  |  |  |
| 1.90 | -0.71 | -0.62 | -0.52 | -0.43 | -0.33 | -0.24 | -0.14 | -0.05 | 0.05 |  |  |  |  |  |  |  |  |  |  |
| 1.95 | -0.76 | -0.66 | -0.56 | -0.46 | -0.37 | -0.27 | -0.17 | -0.07 | 0.02 |  |  |  |  |  |  |  |  |  |  |
| 2.00 | -0.80 | -0.70 | -0.60 | -0.50 | -0.40 | -0.30 | -0.20 | -0.10 | 0.00 |  |  |  |  |  |  |  |  |  |  |

Appendix 6: Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio method (Section 3.2 ) with release ratio ( $\left.\lambda^{\text {Rel }}\right)$; and Paired-Ratio method with escapement ratio ( $\left.\lambda^{\mathrm{Esc}}\right)$.

Appendix Table 6A. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }) \text {; and }}$ PR method with escapement ratio $\left(\lambda^{E s c}\right)$. ( $\mathrm{PSE}=$ estimate standard error/estimate $\mathrm{x} 100 \%$ ).

BRITISH COLUMBIA REGION

|  | $\begin{gathered} \text { Z test } \\ P \leq 0.05 \end{gathered}$ | $\lambda R$ | $\begin{gathered} \text { Mar } \\ \text { ER } \end{gathered}$ | ER PSE | Estimates of Unmarked Total ER | Unmarked Unmarked ER PSE | oitation Ra Unmarked $\text { PR } \lambda^{\text {Rel }} \text { ER }$ | (ER) and P Unmarked ER PSE | nt Standard Unmarked $\operatorname{PR} \lambda^{E s c} \mathrm{ER}$ | Error (PSE) Unmarked ER PSE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quinsam River Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 0.991 | 0.038 | 44.1\% | 0.047 | 103.6\% | 0.010 | 41.7\% | 0.010 | 41.7\% |
| 1999 | Yes | 1.157 | 0.173 | 42.5\% | 0.043 | 228.0\% | 0.089 | 52.9\% | 0.100 | 53.7\% |
| 2000 | Yes | 1.312 | 0.193 | 46.6\% | -0.059 | -228.6\% | 0.144 | 50.0\% | 0.178 | 51.0\% |
| 2001 | Yes | 1.204 | 0.235 | 27.0\% | 0.078 | 120.0\% | 0.109 | 38.4\% | 0.127 | 38.8\% |
| 2002 | - | 1.098 | 0.150 | 70.4\% | 0.066 | 208.6\% | 0.131 | 74.0\% | 0.142 | 74.5\% |
| 2003 | - | 1.142 | 0.253 | 56.6\% | 0.146 | 134.8\% | 0.217 | 59.6\% | 0.241 | 59.9\% |
| 2004 | Yes | 1.165 | 0.413 | 36.4\% | 0.316 | 57.4\% | 0.335 | 40.5\% | 0.363 | 41.2\% |
| 2005 | - | 1.106 | 0.090 | 35.6\% | -0.006 | -1358.1\% | 0.034 | 34.6\% | 0.038 | 34.6\% |
| 2006 | - | 1.038 | 0.195 | 20.7\% | 0.164 | 36.5\% | 0.078 | 27.9\% | 0.080 | 27.8\% |
| 2007 | Yes | 1.180 | 0.088 | 34.1\% | -0.076 | -99.2\% | 0.053 | 37.4\% | 0.059 | 36.3\% |
| 2008 | - | 1.096 | 0.253 | 20.1\% | 0.182 | 41.0\% | 0.113 | 26.6\% | 0.123 | 26.7\% |
| 2009 | - | 1.102 | 0.339 | 20.4\% | 0.271 | 33.9\% | 0.272 | 20.5\% | 0.285 | 20.7\% |
| 2010 | - | 1.015 | 0.403 | 13.8\% | 0.394 | 16.5\% | 0.256 | 16.0\% | 0.258 | 16.0\% |
| 2011 | - | 1.024 | 0.222 | 18.1\% | 0.204 | 29.0\% | 0.113 | 20.4\% | 0.116 | 20.4\% |
| Big Qualicum River Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 1.016 | 0.173 | 31.4\% | 0.160 | 42.1\% | 0.032 | 26.5\% | 0.032 | 26.5\% |
| 1999 | Yes | 1.310 | 0.133 | 40.0\% | -0.135 | -63.0\% | 0.054 | 61.2\% | 0.057 | 58.0\% |
| 2000 | Yes | 1.416 | 0.239 | 42.5\% | -0.077 | -214.0\% | 0.090 | 61.1\% | 0.115 | 65.3\% |
| 2001 | Yes | 1.519 | 0.237 | 23.4\% | -0.159 | -68.9\% | 0.082 | 16.3\% | 0.095 | 17.9\% |
| 2002 | - | 1.217 | 0.115 | 43.3\% | -0.077 | -306.9\% | 0.108 | 35.9\% | 0.110 | 35.3\% |
| Chilliwack River Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.279 | 0.199 | 27.7\% | -0.025 | -325.4\% | 0.035 | 19.8\% | 0.040 | 20.2\% |
| 1999 | Yes | 1.362 | 0.210 | 31.4\% | -0.075 | -131.5\% | 0.040 | 22.9\% | 0.049 | 22.3\% |
| 2000 | Yes | 1.224 | 0.112 | 25.6\% | -0.086 | -69.8\% | 0.030 | 20.7\% | 0.033 | 20.4\% |
| 2001 | Yes | 1.190 | 0.153 | 17.5\% | -0.009 | -810.4\% | 0.061 | 22.4\% | 0.064 | 22.1\% |
| 2002 | - | 1.029 | 0.233 | 43.9\% | 0.211 | 64.6\% | 0.188 | 46.7\% | 0.189 | 46.5\% |

Appendix Table 6A. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio ( $\lambda^{E s c}$ ). (PSE = estimate standard error/estimate $\times 100 \%$ ).

BRITISH COLUMBIA REGION (continued)

|  | Z test | $\lambda R$ | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery |  |  |  |  | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked | marked |
| Brood Year | $\leq 0.05$ |  | ER | ER PSE | Total ER | ER PSE | PR $\lambda^{\text {Rel }}$ ER | ER PSE | PR $\lambda^{\text {Esc }}$ ER | ER PSE |
| Inch Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.202 | 0.432 | 38.7\% | 0.317 | 63.7\% | 0.086 | 25.5\% | 0.096 | 26.7\% |
| 1999 | Yes | 1.155 | 0.092 | 23.8\% | -0.048 | -127.9\% | 0.039 | 23.6\% | 0.040 | 23.2\% |
| 2000 | Yes | 1.263 | 0.184 | 22.3\% | -0.030 | -338.1\% | 0.037 | 31.8\% | 0.040 | 29.9\% |
| 2001 | - | 0.940 | 0.253 | 14.2\% | 0.298 | 16.2\% | 0.130 | 11.4\% | 0.129 | 11.5\% |
| 2002 | Yes | 1.344 | 0.161 | 36.0\% | -0.128 | -79.6\% | 0.044 | 19.2\% | 0.047 | 19.9\% |
| 2003 | - | 0.993 | 0.256 | 25.2\% | 0.261 | 34.0\% | 0.184 | 38.1\% | 0.184 | 38.0\% |
| 2004 | - | 1.126 | 0.300 | 17.3\% | 0.212 | 36.5\% | 0.160 | 26.0\% | 0.168 | 26.7\% |
| 2005 | - | 1.075 | 0.137 | 25.0\% | 0.072 | 120.4\% | 0.072 | 35.9\% | 0.074 | 35.4\% |
| 2006 | Yes | 1.224 | 0.220 | 31.7\% | 0.045 | 243.6\% | 0.094 | 32.4\% | 0.105 | 32.5\% |
| 2007 | Yes | 1.131 | 0.106 | 19.3\% | -0.012 | -406.9\% | 0.031 | 27.3\% | 0.033 | 26.5\% |
| 2008 | - | 1.032 | 0.187 | 21.3\% | 0.161 | 41.3\% | 0.055 | 19.4\% | 0.055 | 19.3\% |
| 2009 | Yes | 1.094 | 0.263 | 11.1\% | 0.194 | 21.9\% | 0.078 | 14.2\% | 0.081 | 13.8\% |
| 2010 | Yes | 1.309 | 0.370 | 11.2\% | 0.175 | 35.1\% | 0.080 | 9.8\% | 0.091 | 9.6\% |
| 2011 | Yes | 1.143 | 0.266 | 10.1\% | 0.161 | 28.0\% | 0.116 | 10.3\% | 0.119 | 10.1\% |
| Robertson Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 1.019 | 0.427 | 26.5\% | 0.416 | 27.9\% | 0.249 | 26.3\% | 0.250 | 26.3\% |
| 1999 | Yes | 1.083 | 0.080 | 29.6\% | 0.003 | 1166.0\% | 0.025 | 45.1\% | 0.026 | 44.3\% |
| 2000 | Yes | 1.068 | 0.201 | 10.8\% | 0.147 | 20.9\% | 0.069 | 18.9\% | 0.072 | 19.2\% |
| 2001 | - | 0.971 | 0.276 | 19.8\% | 0.297 | 20.0\% | 0.062 | 18.6\% | 0.061 | 18.6\% |
| 2002 | Yes | 1.557 | 0.305 | 12.4\% | -0.082 | -82.2\% | 0.085 | 12.3\% | 0.118 | 12.1\% |

Appendix Table 6B. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE $=$ estimate standard error/estimate $\times 100 \%$ ).

PUGET SOUND REGION

| Hatchery Brood Year | $\begin{gathered} Z \text { test } \\ P \leq 0.05 \end{gathered}$ | $\lambda R$ |  | ER PSE | Estimates of Unmarked Total ER | Unmarked Unmarked ER PSE | oitation Ra Unmarked PR $\boldsymbol{\lambda}^{\text {Rel }} \mathrm{ER}$ | (ER) and P Unmarked ER PSE | nt Standard Unmarked PR $\lambda^{E s c} E R$ | Error (PSE) Unmarked ER PSE |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Marblemount Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.090 | 0.314 | 8.7\% | 0.252 | 12.7\% | 0.235 | 9.6\% | 0.236 | 9.6\% |
| 1999 | Yes | 1.063 | 0.237 | 5.4\% | 0.188 | 8.2\% | 0.177 | 5.5\% | 0.178 | 5.5\% |
| 2000 | - | 1.071 | 0.712 | 5.2\% | 0.691 | 8.4\% | 0.607 | 5.2\% | 0.609 | 5.2\% |
| 2001 | Yes | 1.101 | 0.587 | 3.7\% | 0.546 | 6.0\% | 0.523 | 5.2\% | 0.524 | 5.2\% |
| 2002 | - | 1.041 | 0.433 | 5.4\% | 0.409 | 7.1\% | 0.340 | 4.7\% | 0.340 | 4.7\% |
| 2003 | - | 0.964 | 0.639 | 10.0\% | 0.652 | 13.1\% | 0.607 | 8.9\% | 0.607 | 8.9\% |
| 2004 | - | 1.050 | 0.326 | 8.0\% | 0.292 | 10.4\% | 0.246 | 9.0\% | 0.247 | 8.9\% |
| 2005 | - | 0.987 | 0.243 | 7.8\% | 0.253 | 8.3\% | 0.222 | 8.9\% | 0.222 | 8.9\% |
| 2006 | - | 1.013 | 0.414 | 7.3\% | 0.407 | 8.4\% | 0.272 | 7.8\% | 0.272 | 7.8\% |
| 2007 | - | 1.061 | 0.321 | 8.5\% | 0.280 | 12.1\% | 0.291 | 8.3\% | 0.291 | 8.3\% |
| 2008 | - | 1.071 | 0.455 | 5.8\% | 0.416 | 8.0\% | 0.404 | 5.8\% | 0.405 | 5.8\% |
| 2009 | Yes | 1.099 | 0.452 | 7.6\% | 0.398 | 10.6\% | 0.362 | 7.9\% | 0.363 | 7.8\% |
| 2010 | - | 1.063 | 0.473 | 6.2\% | 0.440 | 8.0\% | 0.393 | 6.0\% | 0.394 | 5.9\% |
| 2011 | - | 1.050 | 0.381 | 7.4\% | 0.349 | 9.5\% | 0.282 | 9.2\% | 0.282 | 9.2\% |
| Wallace River Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 0.974 | 0.205 | 7.2\% | 0.226 | 6.7\% | 0.133 | 10.8\% | 0.132 | 10.8\% |
| 1999 | - | 1.057 | 0.184 | 9.4\% | 0.138 | 13.8\% | 0.109 | 13.7\% | 0.111 | 13.9\% |
| 2000 | Yes | 1.087 | 0.193 | 7.4\% | 0.123 | 13.5\% | 0.098 | 10.2\% | 0.100 | 10.1\% |
| 2001 | Yes | 1.066 | 0.264 | 6.3\% | 0.215 | 9.0\% | 0.134 | 8.9\% | 0.135 | 8.8\% |
| 2002 | - | 1.044 | 0.250 | 7.5\% | 0.217 | 9.6\% | 0.137 | 7.0\% | 0.137 | 7.0\% |
| 2003 | - | 1.000 | 0.249 | 11.2\% | 0.249 | 11.8\% | 0.170 | 9.2\% | 0.170 | 9.2\% |
| 2004 | Yes | 1.083 | 0.217 | 10.0\% | 0.152 | 16.3\% | 0.131 | 12.1\% | 0.131 | 12.0\% |
| 2005 | - | 1.091 | 0.237 | 15.7\% | 0.168 | 25.5\% | 0.137 | 17.0\% | 0.137 | 16.9\% |
| 2006 | - | 0.937 | 0.291 | 10.3\% | 0.335 | 8.8\% | 0.166 | 11.1\% | 0.164 | 11.1\% |
| 2007 | Yes | 1.248 | 0.106 | 19.6\% | -0.116 | -22.9\% | 0.086 | 24.5\% | 0.087 | 24.2\% |
| 2008 | Yes | 1.144 | 0.248 | 10.1\% | 0.140 | 21.4\% | 0.142 | 11.6\% | 0.143 | 11.5\% |
| 2009 | Yes | 1.095 | 0.209 | 10.8\% | 0.134 | 19.1\% | 0.122 | 15.7\% | 0.123 | 15.6\% |
| 2010 | - | 1.026 | 0.249 | 10.1\% | 0.229 | 11.8\% | 0.193 | 12.8\% | 0.193 | 12.8\% |
| 2011 | Yes | 0.886 | 0.290 | 9.4\% | 0.370 | 6.9\% | 0.212 | 13.1\% | 0.210 | 13.2\% |

Appendix Table 6B. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

PUGET SOUND REGION (continued)


Appendix Table 6B. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

PUGET SOUND REGION (continued)

| Hatchery | Z test |  | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Unmarked <br> Total ER | Unmarked ER PSE | Unmarked PR $\boldsymbol{\lambda}^{\text {Rel }} \mathrm{ER}$ | Unmarked ER PSE | Unmarked PR $\lambda^{E s c} E R$ | Unmarked ER PSE |
| Brood Year $P \leq 0.05$ |  | $\lambda R$ |  |  |  |  |  |  | ER | ER PSE |
| Soos Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 1.073 | 0.636 | 4.8\% | 0.610 | 7.0\% | 0.602 | 4.5\% | 0.602 | 4.5\% |
| 1999 | - | 0.947 | 0.492 | 4.0\% | 0.519 | 4.7\% | 0.464 | 4.1\% | 0.464 | 4.1\% |
| 2000 | - | 1.078 | 0.615 | 5.0\% | 0.584 | 7.4\% | 0.508 | 4.8\% | 0.509 | 4.8\% |
| 2001 | Yes | 1.079 | 0.586 | 4.2\% | 0.554 | 6.0\% | 0.541 | 4.3\% | 0.541 | 4.3\% |
| 2002 | Yes | 1.208 | 0.517 | 7.7\% | 0.416 | 13.0\% | 0.445 | 7.5\% | 0.449 | 8.1\% |
| 2003 | Yes | 1.431 | 0.848 | 6.4\% | 0.782 | 15.1\% | 0.802 | 5.6\% | 0.802 | 5.6\% |
| 2004 | - | 1.035 | 0.531 | 6.8\% | 0.515 | 8.8\% | 0.452 | 7.0\% | 0.453 | 7.0\% |
| 2005 | - | 0.942 | 0.344 | 10.0\% | 0.382 | 9.2\% | 0.339 | 10.9\% | 0.338 | 10.9\% |
| 2006 | - | 0.958 | 0.437 | 7.5\% | 0.461 | 7.7\% | 0.438 | 6.2\% | 0.438 | 6.3\% |
| 2007 | - | 0.927 | 0.326 | 11.3\% | 0.375 | 10.7\% | 0.298 | 12.4\% | 0.297 | 12.4\% |
| 2008 | - | 0.990 | 0.441 | 7.1\% | 0.447 | 8.0\% | 0.459 | 6.8\% | 0.459 | 6.8\% |
| 2009 | - | 1.087 | 0.433 | 6.5\% | 0.383 | 9.1\% | 0.345 | 6.9\% | 0.346 | 6.9\% |
| 2010 | Yes | 0.299 | 0.516 | 6.9\% | 0.855 | 1.7\% | 0.718 | 7.5\% | 0.711 | 7.6\% |
| 2011 | - | 0.954 | 0.572 | 7.7\% | 0.592 | 8.8\% | 0.513 | 7.7\% | 0.512 | 7.7\% |
| Voights Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 0.946 | 0.562 | 7.4\% | 0.585 | 8.0\% | 0.515 | 7.8\% | 0.515 | 7.8\% |
| 1999 | - | 0.986 | 0.361 | 4.6\% | 0.369 | 5.4\% | 0.373 | 4.2\% | 0.373 | 4.2\% |
| 2000 | - | 1.082 | 0.485 | 6.9\% | 0.443 | 9.4\% | 0.428 | 5.6\% | 0.429 | 5.6\% |
| 2001 | - | 1.045 | 0.638 | 6.1\% | 0.622 | 8.4\% | 0.561 | 4.9\% | 0.562 | 4.9\% |
| 2002 | - | 1.062 | 0.394 | 7.6\% | 0.356 | 9.8\% | 0.321 | 6.7\% | 0.321 | 6.7\% |
| 2003 | Yes | 0.815 | 0.685 | 7.3\% | 0.743 | 7.8\% | 0.700 | 6.3\% | 0.700 | 6.3\% |
| 2004 | Yes | 1.238 | 0.679 | 6.3\% | 0.602 | 12.4\% | 0.578 | 5.4\% | 0.580 | 5.4\% |
| 2005 | Yes | 0.262 | 0.471 | 16.6\% | 0.861 | 2.9\% | 0.457 | 37.3\% | 0.451 | 38.1\% |
| 2006 | - | 0.967 | 0.787 | 11.2\% | 0.794 | 12.7\% | 0.733 | 16.1\% | 0.733 | 16.1\% |
| 2007 | - | 0.836 | 0.690 | 13.6\% | 0.741 | 19.9\% | 0.663 | 12.1\% | 0.663 | 12.1\% |
| 2008 | - | 0.992 | 0.485 | 11.7\% | 0.489 | 13.4\% | 0.443 | 10.6\% | 0.443 | 10.6\% |
| 2009 | - | 1.029 | 0.456 | 8.6\% | 0.440 | 10.7\% | 0.368 | 8.2\% | 0.368 | 8.2\% |
| 2010 | Yes | 1.222 | 0.607 | 9.5\% | 0.520 | 17.0\% | 0.513 | 7.8\% | 0.515 | 7.8\% |
| 2011 | - | 1.089 | 0.708 | 9.0\% | 0.682 | 14.5\% | 0.608 | 7.4\% | 0.609 | 7.4\% |

Appendix Table 6B. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

PUGET SOUND REGION (continued)


Appendix Table 6C. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE $=$ estimate standard error/estimate $\times 100 \%$ ).

WASHINGTON COAST REGION

| Hatchery | Z test$P \leq 0.05$ | $\lambda R$ | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked |
| Brood Year |  |  | ER | ER PSE | Total ER | ER PSE | PR $\lambda^{\text {Rel }}$ ER | ER PSE | PR $\lambda^{\text {Esc }}$ ER | ER PSE |
| Makah NFH |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 0.966 | 0.116 | 16.9\% | 0.146 | 13.5\% | 0.085 | 18.1\% | 0.084 | 18.1\% |
| 1999 | - | 0.857 | 0.156 | 16.0\% | 0.277 | 8.1\% | 0.086 | 21.3\% | 0.083 | 21.8\% |
| 2000 | - | 1.040 | 0.524 | 11.7\% | 0.505 | 14.4\% | 0.350 | 15.1\% | 0.351 | 15.0\% |
| 2001 | - | 1.045 | 0.259 | 19.9\% | 0.225 | 25.1\% | 0.105 | 19.7\% | 0.106 | 19.5\% |
| 2002 | - | 1.011 | 0.387 | 12.7\% | 0.380 | 13.9\% | 0.137 | 10.6\% | 0.138 | 10.6\% |
| 2003 | - | 1.304 | 0.324 | 29.7\% | 0.119 | 112.8\% | 0.225 | 31.7\% | 0.239 | 30.9\% |
| 2004 | - | 1.029 | 0.587 | 27.5\% | 0.575 | 33.2\% | 0.280 | 26.3\% | 0.283 | 26.2\% |
| 2005 | - | 0.889 | 0.136 | 23.3\% | 0.232 | 12.9\% | 0.124 | 28.0\% | 0.119 | 27.5\% |
| 2006 | - | 1.076 | 0.154 | 10.4\% | 0.091 | 20.2\% | 0.075 | 15.4\% | 0.076 | 15.1\% |
| 2007 | Yes | 0.774 | 0.092 | 18.9\% | 0.297 | 4.7\% | 0.062 | 29.5\% | 0.057 | 30.2\% |
| 2008 | Yes | 0.826 | 0.177 | 11.5\% | 0.320 | 5.5\% | 0.080 | 18.9\% | 0.073 | 18.6\% |
| 2009 | Yes | 0.688 | 0.169 | 25.0\% | 0.428 | 7.2\% | 0.184 | 25.9\% | 0.177 | 26.8\% |
| 2010 | - | 1.050 | 0.207 | 10.2\% | 0.168 | 14.1\% | 0.065 | 15.7\% | 0.067 | 15.7\% |
| Quinault NFH |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.215 | 0.567 | 3.3\% | 0.475 | 5.7\% | 0.485 | 3.5\% | 0.488 | 3.5\% |
| 1999 | Yes | 0.830 | 0.612 | 5.1\% | 0.678 | 4.9\% | 0.602 | 5.7\% | 0.600 | 5.8\% |
| 2000 | Yes | 1.146 | 0.652 | 3.9\% | 0.601 | 6.1\% | 0.589 | 4.2\% | 0.591 | 4.2\% |
| 2001 | - | 0.951 | 0.598 | 5.4\% | 0.618 | 5.8\% | 0.596 | 5.5\% | 0.595 | 5.5\% |
| 2002 | - | 1.019 | 0.625 | 5.2\% | 0.617 | 6.3\% | 0.183 | 10.9\% | 0.183 | 10.9\% |
| 2003 | - | 0.947 | 0.718 | 6.1\% | 0.733 | 8.3\% | 0.734 | 5.6\% | 0.733 | 5.6\% |
| 2004 | Yes | 1.213 | 0.572 | 4.8\% | 0.481 | 8.4\% | 0.437 | 4.9\% | 0.443 | 4.9\% |
| 2005 | Yes | 1.243 | 0.602 | 4.5\% | 0.505 | 8.6\% | 0.556 | 4.4\% | 0.556 | 4.4\% |
| 2006 | Yes | 1.173 | 0.703 | 3.8\% | 0.652 | 5.9\% | 0.668 | 3.8\% | 0.669 | 3.8\% |
| 2007 | - | 1.012 | 0.666 | 3.6\% | 0.662 | 4.9\% | 0.673 | 3.5\% | 0.673 | 3.5\% |
| 2008 | - | 1.081 | 0.514 | 3.8\% | 0.474 | 5.4\% | 0.519 | 3.6\% | 0.519 | 3.6\% |
| 2009 | - | 0.989 | 0.610 | 5.7\% | 0.614 | 7.5\% | 0.593 | 5.4\% | 0.593 | 5.4\% |
| 2010 | - | 0.979 | 0.486 | 3.8\% | 0.496 | 4.7\% | 0.456 | 3.6\% | 0.455 | 3.6\% |
| 2011 | - | 0.975 | 0.696 | 3.1\% | 0.704 | 4.2\% | 0.670 | 3.4\% | 0.670 | 3.4\% |

Appendix Table 6C. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

WASHINGTON COAST REGION (continued)

|  |  | $\lambda R$ | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Z test |  |  |  | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked |
| Brood Year | $\leq 0.05$ |  | ER | ER PSE | Total ER | ER PSE | PR $\boldsymbol{\lambda}^{\text {Rel }}$ ER | ER PSE | PR $\lambda^{\text {Esc }}$ ER | ER PSE |
| Salmon River Fish Culture |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 0.985 | 0.582 | 7.8\% | 0.588 | 9.0\% | 0.583 | 7.7\% | 0.583 | 7.7\% |
| 1999 | Yes | 0.681 | 0.915 | 5.2\% | 0.942 | 8.3\% | 0.930 | 5.5\% | 0.929 | 5.6\% |
| 2000 | - | 0.664 | 0.975 | 6.1\% | 0.983 | 18.6\% | 0.975 | 8.0\% | 0.974 | 8.2\% |
| 2001 | - | 0.907 | 0.656 | 12.8\% | 0.688 | 12.8\% | 0.628 | 13.9\% | 0.627 | 13.9\% |
| 2002 | Yes | 0.036 | 0.431 | 19.1\% | 0.979 | 0.3\% | 0.730 | 28.6\% | 0.635 | 34.3\% |
| 2003 | Yes | 0.300 | 0.808 | 10.3\% | 0.942 | 4.3\% | 0.890 | 6.9\% | 0.888 | 7.0\% |
| 2004 | - | 0.918 | 0.567 | 10.6\% | 0.602 | 12.4\% | 0.514 | 11.6\% | 0.509 | 11.2\% |
| 2005 | - | 0.923 | 0.675 | 8.5\% | 0.700 | 11.7\% | 0.692 | 7.2\% | 0.692 | 7.2\% |
| 2006 | Yes | 1.304 | 0.755 | 4.5\% | 0.681 | 9.4\% | 0.635 | 4.7\% | 0.638 | 4.7\% |
| 2007 | - | 0.891 | 0.724 | 6.6\% | 0.754 | 7.6\% | 0.692 | 6.9\% | 0.692 | 6.9\% |
| 2008 | - | 0.947 | 0.498 | 6.3\% | 0.525 | 6.9\% | 0.471 | 5.9\% | 0.470 | 5.9\% |
| 2009 | - | 0.988 | 0.879 | 10.2\% | 0.881 | 23.1\% | 0.866 | 10.3\% | 0.866 | 10.3\% |
| 2010 |  |  |  |  |  |  |  |  |  |  |
| 2011 | - | 1.081 | 0.772 | 4.3\% | 0.753 | 8.0\% | 0.719 | 4.5\% | 0.720 | 4.5\% |
| Solduc Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 1.040 | 0.149 | 8.0\% | 0.115 | 11.5\% | 0.063 | 12.7\% | 0.064 | 12.6\% |
| 1999 | - | 0.951 | 0.115 | 10.7\% | 0.159 | 7.7\% | 0.033 | 13.9\% | 0.032 | 14.0\% |
| 2000 | Yes | 1.286 | 0.217 | 8.4\% | -0.007 | -386.4\% | 0.046 | 14.5\% | 0.056 | 14.1\% |
| 2001 | - | 0.997 | 0.195 | 8.6\% | 0.197 | 9.0\% | 0.088 | 9.3\% | 0.088 | 9.3\% |
| 2002 | - | 1.051 | 0.279 | 6.7\% | 0.243 | 8.7\% | 0.085 | 7.1\% | 0.087 | 7.1\% |
| 2003 | Yes | 1.149 | 0.339 | 14.2\% | 0.241 | 25.1\% | 0.087 | 14.8\% | 0.094 | 14.7\% |
| 2004 | Yes | 0.501 | 0.222 | 9.1\% | 0.610 | 1.8\% | 0.149 | 9.8\% | 0.121 | 11.0\% |
| 2005 | - | 1.018 | 0.479 | 5.8\% | 0.470 | 7.3\% | 0.449 | 5.5\% | 0.449 | 5.5\% |
| 2006 | Yes | 1.162 | 0.640 | 3.7\% | 0.581 | 5.6\% | 0.558 | 4.1\% | 0.559 | 4.1\% |
| 2007 | - | 1.080 | 0.472 | 7.0\% | 0.430 | 9.1\% | 0.465 | 7.3\% | 0.466 | 7.2\% |
| 2008 | - | 0.973 | 0.348 | 6.1\% | 0.365 | 6.1\% | 0.350 | 6.5\% | 0.350 | 6.5\% |
| 2009 | Yes | 1.320 | 0.684 | 11.1\% | 0.583 | 21.1\% | 0.582 | 11.6\% | 0.584 | 11.6\% |
| 2010 | Yes | 1.132 | 0.592 | 5.5\% | 0.538 | 8.8\% | 0.508 | 5.3\% | 0.511 | 5.3\% |
| 2011 | Yes | 1.123 | 0.622 | 5.4\% | 0.576 | 7.4\% | 0.563 | 5.6\% | 0.564 | 5.5\% |

Appendix Table 6C. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

WASHINGTON COAST REGION (continued)

|  |  | $\lambda R$ | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hatchery | Z test |  |  |  | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked | marked |
| Brood Year | $\leq 0.05$ |  | ER | ER PSE | Total ER | ER PSE | PR $\boldsymbol{\lambda}^{\text {Rel }}$ ER | ER PSE | PR $\lambda^{\text {Esc }}$ ER | ER PSE |
| Bingham Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | - | 1.045 | 0.299 | 6.2\% | 0.268 | 8.1\% | 0.248 | 6.5\% | 0.248 | 6.5\% |
| 1999 | - | 1.067 | 0.190 | 8.2\% | 0.136 | 12.9\% | 0.163 | 8.9\% | 0.164 | 9.1\% |
| 2000 | Yes | 1.284 | 0.223 | 8.9\% | 0.002 | 1736.4\% | 0.129 | 9.9\% | 0.134 | 9.9\% |
| 2001 | - | 1.080 | 0.274 | 10.8\% | 0.216 | 16.7\% | 0.300 | 10.0\% | 0.301 | 10.0\% |
| 2002 | - | 0.955 | 0.350 | 9.3\% | 0.380 | 9.2\% | 0.164 | 12.9\% | 0.162 | 12.9\% |
| 2003 | Yes | 1.167 | 0.241 | 10.7\% | 0.115 | 28.5\% | 0.204 | 11.7\% | 0.207 | 11.7\% |
| 2004 | Yes | 0.790 | 0.256 | 10.3\% | 0.412 | 5.7\% | 0.220 | 14.0\% | 0.214 | 14.1\% |
| 2005 | - | 0.903 | 0.174 | 15.6\% | 0.254 | 10.5\% | 0.133 | 22.8\% | 0.131 | 22.9\% |
| 2006 | Yes | 0.882 | 0.171 | 7.6\% | 0.269 | 4.5\% | 0.123 | 10.6\% | 0.121 | 10.8\% |
| 2007 | Yes | 1.105 | 0.097 | 10.1\% | 0.002 | 532.1\% | 0.037 | 14.7\% | 0.038 | 14.6\% |
| 2008 | - | 1.051 | 0.206 | 11.6\% | 0.165 | 15.7\% | 0.129 | 13.1\% | 0.130 | 13.0\% |
| 2009 | Yes | 1.193 | 0.325 | 10.8\% | 0.194 | 23.2\% | 0.232 | 11.0\% | 0.233 | 11.1\% |
| 2010 | Yes | 1.139 | 0.232 | 8.5\% | 0.125 | 19.2\% | 0.188 | 9.5\% | 0.189 | 9.4\% |
| 2011 | Yes | 1.109 | 0.346 | 6.5\% | 0.274 | 9.6\% | 0.293 | 6.6\% | 0.294 | 6.6\% |
| Forks Creek Hatchery |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.229 | 0.522 | 3.3\% | 0.412 | 7.2\% | 0.459 | 2.8\% | 0.461 | 2.8\% |
| 1999 | - | 1.107 | 0.637 | 3.7\% | 0.598 | 6.1\% | 0.599 | 4.0\% | 0.600 | 4.0\% |
| 2000 | Yes | 1.227 | 0.596 | 3.4\% | 0.504 | 6.5\% | 0.486 | 3.9\% | 0.491 | 3.9\% |
| 2001 | - | 1.027 | 0.440 | 6.4\% | 0.425 | 8.3\% | 0.341 | 6.6\% | 0.341 | 6.6\% |
| 2002 | Yes | 1.124 | 0.396 | 5.6\% | 0.321 | 8.5\% | 0.306 | 6.7\% | 0.309 | 6.8\% |
| 2003 | - | 0.900 | 0.677 | 10.1\% | 0.709 | 10.5\% | 0.635 | 10.5\% | 0.633 | 10.1\% |
| 2004 | Yes | 1.213 | 0.503 | 7.0\% | 0.397 | 13.6\% | 0.297 | 7.7\% | 0.309 | 7.8\% |
| 2005 | - | 1.097 | 0.350 | 10.0\% | 0.287 | 15.7\% | 0.297 | 10.9\% | 0.298 | 10.9\% |
| 2006 | Yes | 1.429 | 0.538 | 7.8\% | 0.339 | 20.3\% | 0.380 | 9.6\% | 0.390 | 9.4\% |
| 2007 | Yes | 1.309 | 0.411 | 7.8\% | 0.228 | 20.6\% | 0.037 | 17.9\% | 0.045 | 18.4\% |
| 2008 | Yes | 1.149 | 0.525 | 8.6\% | 0.454 | 13.1\% | 0.459 | 8.3\% | 0.460 | 8.3\% |
| 2009 | - | 1.006 | 0.525 | 7.2\% | 0.522 | 9.7\% | 0.486 | 7.8\% | 0.486 | 7.8\% |
| 2010 | - | 1.134 | 0.449 | 11.6\% | 0.375 | 17.8\% | 0.316 | 13.7\% | 0.318 | 13.6\% |
| 2011 | - | 1.029 | 0.377 | 3.6\% | 0.359 | 4.4\% | 0.298 | 4.1\% | 0.299 | 4.0\% |

Appendix Table 6D. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE = estimate standard error/estimate $\times 100 \%$ ).

COLUMBIA RIVER REGION

| Hatchery | Z test |  | Marked |  | Estimates of Unmarked Exploitation Rate (ER) and Percent Standard Error (PSE) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked | Unmarked |
| Brood Year | $P \leq 0.05$ | $\lambda R$ |  |  | ER | ER PSE | Total ER | ER PSE | PR $\lambda^{\text {Rel }}$ ER | ER PSE | PR $\lambda^{\text {Esc }}$ ER | ER PSE |
| Lewis River - North |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.207 | 0.535 | 5.7\% | 0.439 | 9.1\% | 0.354 | 3.0\% | 0.369 | 3.0\% |
| 1999 | - | 0.937 | 0.513 | 7.7\% | 0.544 | 8.2\% | 0.390 | 6.4\% | 0.389 | 6.4\% |
| 2000 | Yes | 1.199 | 0.567 | 3.4\% | 0.481 | 6.4\% | 0.402 | 4.1\% | 0.409 | 4.0\% |
| 2001 | Yes | 1.230 | 0.660 | 3.2\% | 0.581 | 7.0\% | 0.467 | 2.8\% | 0.476 | 2.7\% |
| 2002 | Yes | 1.285 | 0.296 | 5.0\% | 0.096 | 23.9\% | 0.159 | 4.6\% | 0.165 | 4.5\% |
| 2003 | Yes | 1.119 | 0.312 | 8.4\% | 0.231 | 13.8\% | 0.194 | 6.9\% | 0.198 | 6.9\% |
| 2004 | Yes | 1.202 | 0.576 | 4.1\% | 0.490 | 7.6\% | 0.336 | 3.2\% | 0.349 | 3.2\% |
| 2005 | Yes | 1.176 | 0.284 | 10.0\% | 0.158 | 22.4\% | 0.100 | 7.3\% | 0.106 | 7.5\% |
| 2006 | Yes | 1.205 | 0.581 | 4.3\% | 0.495 | 7.2\% | 0.287 | 4.9\% | 0.302 | 4.7\% |
| 2007 | Yes | 1.160 | 0.273 | 5.9\% | 0.157 | 13.4\% | 0.135 | 4.6\% | 0.138 | 4.6\% |
| 2008 | Yes | 1.295 | 0.365 | 7.6\% | 0.177 | 22.2\% | 0.115 | 9.3\% | 0.130 | 8.9\% |
| 2009 | - | 1.247 | 0.408 | 13.6\% | 0.262 | 31.4\% | 0.179 | 26.6\% | 0.190 | 24.9\% |
| 2010 | Yes | 1.299 | 0.477 | 7.6\% | 0.320 | 17.4\% | 0.154 | 9.8\% | 0.175 | 9.0\% |
| 2011 | Yes | 1.198 | 0.445 | 5.0\% | 0.335 | 9.1\% | 0.223 | 4.7\% | 0.232 | 4.6\% |
| Lewis River - South |  |  |  |  |  |  |  |  |  |  |
| 1998 | Yes | 1.328 | 0.326 | 4.7\% | 0.105 | 21.4\% | 0.095 | 5.5\% | 0.113 | 5.0\% |
| 1999 | Yes | 1.152 | 0.199 | 10.4\% | 0.077 | 32.9\% | 0.102 | 9.5\% | 0.105 | 9.6\% |
| 2000 | Yes | 1.245 | 0.298 | 4.4\% | 0.126 | 14.5\% | 0.077 | 7.3\% | 0.088 | 6.8\% |
| 2001 | Yes | 1.319 | 0.319 | 6.0\% | 0.102 | 27.7\% | 0.069 | 12.3\% | 0.085 | 12.5\% |
| 2002 | Yes | 1.100 | 0.094 | 11.1\% | 0.004 | 315.4\% | 0.043 | 12.7\% | 0.044 | 12.5\% |
| 2003 | - | 1.012 | 0.151 | 18.0\% | 0.140 | 19.9\% | 0.077 | 23.6\% | 0.077 | 23.5\% |
| 2004 | Yes | 1.359 | 0.295 | 6.5\% | 0.041 | 71.1\% | 0.070 | 14.2\% | 0.088 | 12.9\% |
| 2005 | Yes | 1.352 | 0.147 | 16.4\% | -0.153 | -21.8\% | 0.058 | 22.5\% | 0.064 | 20.8\% |
| 2006 | Yes | 1.381 | 0.531 | 6.3\% | 0.352 | 14.8\% | 0.185 | 7.1\% | 0.217 | 6.6\% |
| 2007 | Yes | 1.256 | 0.200 | 12.4\% | -0.005 | -691.6\% | 0.047 | 13.1\% | 0.054 | 12.7\% |
| 2008 | Yes | 1.166 | 0.193 | 13.7\% | 0.060 | 53.9\% | 0.053 | 19.4\% | 0.057 | 18.5\% |
| 2009 | - | 0.872 | 0.246 | 37.5\% | 0.343 | 25.8\% | 0.128 | 51.4\% | 0.122 | 53.8\% |
| 2010 | Yes | 1.448 | 0.237 | 11.6\% | -0.106 | -40.4\% | 0.051 | 14.0\% | 0.058 | 12.9\% |
| 2011 | Yes | 1.315 | 0.308 | 9.4\% | 0.090 | 43.4\% | 0.091 | 11.9\% | 0.100 | 11.4\% |

Appendix Table 6D. Estimates of marked and unmarked exploitation rate (ER) percentage, with percent standard error (PSE), based on three methods: Total method (Section 3.1); Paired-Ratio (PR) method (Section 3.2) with release ratio ( $\lambda^{\text {Rel }}$ ); and PR method with escapement ratio $\left(\lambda^{E s c}\right)$. (PSE $=$ estimate standard error/estimate $\times 100 \%$ ).

COLUMBIA RIVER REGION (continued)


## Appendix 7: Estimating Total Unmarked Fishery Mortalities

This appendix provides a more detailed description of the derivation of the equations used to estimate total unmarked fishery-related mortalities using the Paired-Ratio estimators described in Sections 3.2 and 5 of the report.

## Equations that do not include drop-off mortality (report Section 3.2):

For the unmarked component of a DIT group, the estimate of total mortalities ( $\widehat{U}$ ) due to both NSFs and MSFs has four components:

1. Landed mortalities of unmarked fish in NSFs that have ETD sampling (under the assumption that no fish are released),
2. Landed mortalities of unmarked fish in NSFs that have visual sampling (under the assumption that no fish are released),
3. Mortalities due to the release of unmarked fish in MSFs (which is the product of estimated encounters and the sfim rate for a fishery), and
4. Landed mortalities in MSFs due to unmarked retention error (URE).

Therefore,

$$
\begin{equation*}
\widehat{U}=\overbrace{\sum_{j}^{E T D} \widehat{U}_{j}}^{1}+\overbrace{\sum_{k}^{V S} \widehat{M}_{k} \hat{\lambda}_{k}}^{2}+\overbrace{\sum_{i}\left[\left(\hat{\lambda}_{i} \widehat{M}_{i}\right)-\widehat{U}_{i}\right] s f m_{i}}^{3}+\overbrace{\sum_{i} \widehat{U}_{i}}^{4} \tag{A7-1}
\end{equation*}
$$

where $M_{x}$ and $U_{x}$ are the estimated numbers of marked and unmarked fish, respectively, for a given DIT group retained by fishery $x$ with $j$ indicating NSFs with ETD, $k$ indicating NSFs with visual sampling, and $i$ indicating MSFs. Component 3 of Eq. A7-1 estimates the unmarked mortalities due to the release of unmarked fish in MSFs. The estimate of the number of unmarked encounters for a DIT group in $\operatorname{MSF}_{i}\left(\hat{\lambda}_{i} \widehat{M}_{i}\right)$ must be adjusted to account for unmarked fish retained due to URE before the sfm rate can be applied to estimate unmarked mortalities due to the release of fish. Eq. A7-1 can be re-arranged as:

$$
\begin{equation*}
\widehat{U}=\sum_{j}^{E T D} \widehat{U}_{j}+\sum_{k}^{V S} \widehat{M}_{k} \lambda_{k}+\sum_{i}\left[\left(\lambda_{i} \widehat{M}_{i}\right) \operatorname{sfm}_{i}+\widehat{U}_{i}\left(1-\operatorname{sfm}_{i}\right)\right] \tag{A7-2}
\end{equation*}
$$

with estimated variance:

$$
\begin{equation*}
\widehat{V}(\widehat{U})=\sum_{j}^{E T D} \widehat{V}\left(\widehat{U}_{j}\right)+\sum_{k}^{V S} \lambda_{k}^{2} \hat{V}\left(\widehat{M}_{k}\right)+\sum_{i}\left[\left(\lambda_{i} s f m_{i}\right)^{2} \widehat{V}\left(\widehat{M}_{i}\right)+\left(1-\operatorname{sfm_{i}}\right)^{2} \widehat{V}\left(\widehat{U}_{i}\right)\right] . \tag{A7-3}
\end{equation*}
$$

where $\lambda_{k}$ and $\lambda_{l}$ are assumed constant.

## Equations that include drop-off mortality (report Section 5):

FRAM-based post-season exploitation rates were compared to the results of the DIT analyses. Post-season Coho FRAM includes calculations of drop-off mortalities in all fisheries in its calculations of ERs. Post-season Coho FRAM calculates drop-off mortalities as either:

1. the product of landed catch and a drop-off mortality rate in NSFs, or the
2. the product of unmarked encounters and the drop-off mortality rate in MSFs.

Drop-off mortalities were incorporated into the DIT-based estimates of unmarked fishery mortalities by modifying Eq. A7-1 to:

$$
\begin{equation*}
\widehat{U}=\overbrace{\sum_{j}^{E T D} \widehat{U}_{j}\left(1+D O_{j}\right)}^{1}+\overbrace{\sum_{k}^{V S} \widehat{M}_{k} \lambda_{k}\left(1+D O_{k}\right)}^{2}+\overbrace{\sum_{i}\left[\left(\lambda_{i} \widehat{M}_{i}\right)-\widehat{U}_{i}\right] s f m_{i}}^{3}+\overbrace{\sum_{i} \widehat{U}_{i}}^{4}+\overbrace{\sum_{i}\left(\lambda_{i} \widehat{M}_{i}\right) D O_{i}}^{5} \tag{A7-4}
\end{equation*}
$$

where all notation is as previously defined and $D O$ is the drop-off mortality rate associated with fishery $i, j$, or $k$. For the unmarked component of a DIT group, the estimate of total mortalities $(\widehat{U})$ due to both NSFs and MSFs has five components:

1. Landed mortalities of unmarked fish in NSFs that have ETD sampling (under the assumption that no fish are released) plus drop-off mortalities,
2. Landed mortalities of unmarked fish in NSFs that have visual sampling (under the assumption that no fish are released) plus drop-off mortalities,
3. Mortalities due to the release of unmarked fish in MSFs (which is the product of estimated encounters and the $s f m$ rate for a fishery),
4. Landed mortalities in MSFs due to unmarked retention error (URE), and
5. Drop-off mortalities in MSFs which are function of unmarked encounters.

Eq. A7-4 can be re-arranged as:

$$
\widehat{U}=\sum_{j}^{E T D} \widehat{U}_{j}\left(1+D O_{j}\right)+\sum_{k}^{V S} \widehat{M}_{k} \lambda_{k}\left(1+D O_{k}\right)+\sum_{i} \lambda_{i} \widehat{M}_{i}\left(s f m_{i}+D O_{i}\right)+\sum_{i} \widehat{U}_{i}\left(1-s f m_{i}\right) .
$$

Appendix 8. Alignment of hatcheries with Coho DIT group releases and stock structure represented in the Coho Fishery Regulation Assessment Model (FRAM).

| RMIS Hatchery | DIT release location names in RMIS | FRAM Stock | FRAM Stock ID |
| :---: | :---: | :---: | :---: |
| GEORGE ADAMS HATCHERY | PURDY CR 16.0005 | George Adams Hatchery Unmarked | 57 |
|  |  | George Adams Hatchery Marked | 58 |
| KENDALL CR HATCHERY | KENDALL CR 01.0406 | Kendall Creek Hatchery UnMarked | 3 |
|  |  | Kendall Creek Hatchery Marked | 4 |
| LOWER ELWHA <br> HATCHERY; LOWER <br> ELWHA HATCH - HOUSE | ELWHA R 18.0272; LOWER ELWHA HATCH HOUSE; LOWER ELWHA HATCHERY; | Elwha Hatchery UnMarked | 113 |
|  |  | Elwha Hatchery Marked | 114 |
| MARBLEMOUNT HATCHERY | CASCADE R 03.1411 | Skagit River Hatchery UnMarked | 19 |
|  |  | Skagit River Hatchery Marked | 20 |
| QUILCENE NFH | BIG QUILCENE 17.0012 | Quilcene Hatchery UnMarked | 47 |
|  |  | Quilcene Hatchery <br> Marked | 48 |
| SOOS CREEK HATCHERY | BIG SOOS CR 09.0072 | Green River Hatchery UnMarked | 95 |
|  |  | Green River Hatchery Marked | 96 |
| VOIGHTS CRHATCHERY; PUYALLUP HATCHERY | VOIGHT CR 10.0414 | Puyallup River Hatchery UnMarked | 83 |
|  |  | Puyallup River Hatchery Marked | 84 |
| WALLACE R HATCHERY | WALLACE R 07.0940 | Snohomish River Hatchery UnMarked | 37 |
|  |  | Snohomish River Hatchery Marked | 38 |
| BINGHAM CR HATCHERY | SATSOP R -EF 22.0360 | Chehalis River Hatchery UnMarked | 151 |
|  |  | Chehalis River Hatchery Marked | 152 |
| EAGLE CR NFH | EAGLE CR (CLACKAMAS) | Columbia River Early Hatchery UnMarked | 165 |
|  |  | Columbia River Early Hatchery Marked | 166 |
| FORKS CREEK HATCHERY | FORK CR $24.0356 ;$ <br> WILLAPA R 24.0251 | Willapa Bay Hatchery UnMarked | 163 |

$\left.\begin{array}{|l|l|l|c|}\hline \text { RMIS Hatchery } & \begin{array}{c}\text { DIT release location names } \\ \text { in RMIS }\end{array} & \begin{array}{c}\text { FRAM Stock }\end{array} & \begin{array}{c}\text { FRAM } \\ \text { Stock ID }\end{array} \\ \hline \text { H-Big Qualicum River H } & \text { R-Big Qualicum R } & \begin{array}{c}\text { Willapa Bay Hatchery } \\ \text { Marked }\end{array} & 164 \\ \hline & \text { R-Chilliwack R } & \begin{array}{c}\text { Georgia Strait Vanc. } \\ \text { Isl. Hatchery } \\ \text { UnMarked }\end{array} & 209 \\ \hline \text { H-Chilliwack River H } & \text { R-Inch Cr } & \begin{array}{c}\text { Georgia Strait Vanc. } \\ \text { Isl. Hatchery Marked }\end{array} & 210 \\ \hline \text { H-Inch Creek H } & \begin{array}{c}\text { Lower Fraser River } \\ \text { Hatchery UnMarked }\end{array} & 225 \\ \hline \text { H-Quinsam River H } & \text { R-Quinsam R } & \begin{array}{c}\text { Lower Fraser River } \\ \text { Hatchery UnMarked }\end{array} & 226 \\ \hline \text { H-Robertson Creek H } & \text { R-Robertson Cr } & \begin{array}{c}\text { Lower Fraser River } \\ \text { Hatchery UnMarked }\end{array} & 225 \\ \hline & \text { Lower Fraser River } \\ \text { Hatchery Marked }\end{array}\right] 226$

| RMIS Hatchery | DIT release location names <br> in RMIS | FRAM Stock | FRAM <br> Stock ID |
| :--- | :--- | :---: | :---: |
| SANDY HATCHERY | CEDAR CR \#1 (SANDY R; <br>  <br> BAY | Columbia River Early <br> Hatchery UnMarked | 165 |
| SOLDUC HATCHERY | SOL DUC R 20.0096 | Columbia River Early <br> Hatchery Marked | 166 |
|  | Quillayute River Fall <br> Hatchery UnMarked | 133 |  |

Appendix 9: Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the Paired-Ratio method with release $\lambda\left(\mathrm{PR} \lambda^{R e l}\right)$.

Appendix Table 9A. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

BRITISH COLUMBIA REGION

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference |
| Quinsam River Hatchery |  |  |  |  |  |  |
| 1998 | 0.054 | 0.058 | -0.004 | 0.015 | 0.053 | -0.038 |
| 1999 | 0.159 | 0.051 | 0.108 | 0.122 | 0.046 | 0.076 |
| 2000 | 0.181 | 0.060 | 0.120 | 0.170 | 0.025 | 0.145 |
| 2001 | 0.219 | 0.038 | 0.181 | 0.124 | 0.009 | 0.116 |
| 2002 | 0.204 | 0.160 | 0.044 | 0.195 | 0.120 | 0.076 |
| 2003 | 0.257 | 0.146 | 0.111 | 0.295 | 0.086 | 0.209 |
| 2004 | 0.409 | 0.217 | 0.192 | 0.360 | 0.138 | 0.222 |
| 2005 | 0.043 | 0.490 | -0.447 | 0.038 | 0.164 | -0.126 |
| 2006 | 0.158 | 0.469 | -0.311 | 0.082 | 0.139 | -0.057 |
| 2007 | 0.095 | 0.150 | -0.055 | 0.057 | 0.097 | -0.040 |
| 2008 | 0.247 | 0.241 | 0.006 | 0.146 | 0.196 | -0.050 |
| 2009 | 0.382 | 0.241 | 0.141 | 0.304 | 0.182 | 0.123 |
| 2010 | 0.383 | 0.421 | -0.038 | 0.290 | 0.285 | 0.005 |
| 2011 | 0.199 | 0.434 | -0.235 | 0.140 | 0.415 | -0.275 |
| Big Qualicum River Hatchery |  |  |  |  |  |  |
| 1998 | 0.161 | 0.083 | 0.078 | 0.041 | 0.068 | -0.027 |
| 1999 | 0.121 | 0.071 | 0.050 | 0.035 | 0.054 | -0.019 |
| 2000 | 0.177 | 0.098 | 0.079 | 0.111 | 0.036 | 0.075 |
| 2001 | 0.188 | 0.022 | 0.166 | 0.097 | 0.010 | 0.087 |
| 2002 | 0.125 | 0.175 | -0.050 | 0.136 | 0.113 | 0.023 |
| Chilliwack River Hatchery |  |  |  |  |  |  |
| 1998 | 0.107 |  |  | 0.034 |  |  |
| 1999 | 0.082 |  |  | 0.036 |  |  |
| 2000 | 0.080 |  |  | 0.033 |  |  |
| 2001 | 0.139 |  |  | 0.069 |  |  |
| 2002 | 0.275 |  |  | 0.213 |  |  |

Appendix Table 9A. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

BRITISH COLUMBIA REGION (continued)

| Hatchery Brood Year | Marked PR $\lambda^{\text {Rel }}$ | Marked Exploitation Rate | ate <br> Difference | Unmark PR $\lambda^{\text {Rel }}$ | Unmarked Exploitation Rate | Rate <br> Difference |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Inch Creek Hatchery |  |  |  |  |  |  |
| 1998 | 0.130 | 0.117 | 0.012 | 0.051 | 0.086 | -0.035 |
| 1999 | 0.086 | 0.119 | -0.033 | 0.043 | 0.076 | -0.033 |
| 2000 | 0.169 | 0.167 | 0.001 | 0.047 | 0.079 | -0.032 |
| 2001 | 0.276 | 0.080 | 0.196 | 0.141 | 0.049 | 0.092 |
| 2002 | 0.109 | 0.176 | -0.067 | 0.047 | 0.095 | -0.047 |
| 2003 | 0.273 | 0.183 | 0.090 | 0.199 | 0.093 | 0.106 |
| 2004 | 0.265 | 0.253 | 0.012 | 0.177 | 0.117 | 0.060 |
| 2005 | 0.100 | 0.199 | -0.099 | 0.076 | 0.095 | -0.019 |
| 2006 | 0.154 | 0.293 | -0.139 | 0.089 | 0.130 | -0.041 |
| 2007 | 0.048 | 0.105 | -0.057 | 0.028 | 0.072 | -0.043 |
| 2008 | 0.156 | 0.237 | -0.081 | 0.060 | 0.194 | -0.134 |
| 2009 | 0.214 | 0.217 | -0.003 | 0.085 | 0.145 | -0.060 |
| 2010 | 0.277 | 0.385 | -0.108 | 0.091 | 0.224 | -0.133 |
| 2011 | 0.238 | 0.459 | -0.221 | 0.127 | 0.401 | -0.274 |
| Robertson Creek Hatchery |  |  |  |  |  |  |
| 1998 | 0.444 | 0.111 | 0.334 | 0.277 | 0.105 | 0.172 |
| 1999 | 0.083 | 0.108 | -0.025 | 0.029 | 0.101 | -0.072 |
| 2000 | 0.175 | 0.192 | -0.016 | 0.056 | 0.058 | -0.002 |
| 2001 | 0.291 | 0.115 | 0.175 | 0.081 | 0.018 | 0.063 |
| 2002 | 0.229 | 0.476 | -0.247 | 0.089 | 0.139 | -0.049 |

Appendix Table 9B. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age- 3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

## PUGET SOUND REGION

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference |
| Lower Elwha Hatchery |  |  |  |  |  |  |
| 1998 | 0.375 | 0.470 | -0.095 | 0.299 | 0.445 | -0.145 |
| 1999 | 0.119 | 0.449 | -0.330 | 0.342 | 0.398 | -0.056 |
| 2000 | 0.375 | 0.317 | 0.058 | 0.148 | 0.213 | -0.065 |
| 2001 | 0.513 | 0.249 | 0.264 | 0.425 | 0.015 | 0.410 |
| 2002 | 0.558 | 0.486 | 0.071 | 0.431 | 0.426 | 0.005 |
| 2003 | 0.555 | 0.551 | 0.004 | 0.268 | 0.492 | -0.224 |
| 2004 | 0.408 | 0.539 | -0.131 | 0.273 | 0.441 | -0.168 |
| 2005 | 0.441 | 0.400 | 0.041 | 0.541 | 0.368 | 0.172 |
| 2006 | 0.413 | 0.626 | -0.213 | 0.295 | 0.556 | -0.262 |
| 2007 | 0.329 | 0.348 | -0.019 | 0.272 | 0.326 | -0.054 |
| 2008 | 0.422 | 0.347 | 0.075 | 0.339 | 0.306 | 0.033 |
| 2009 | 0.662 | 0.189 | 0.473 | 0.271 | 0.126 | 0.145 |
| 2010 | 0.484 | 0.203 | 0.281 | 0.207 | 0.131 | 0.076 |
| 2011 | 0.488 | 0.275 | 0.213 | 0.246 | 0.162 | 0.084 |
| Kendall Creek Hatchery |  |  |  |  |  |  |
| 1998 | 0.583 | 0.584 | -0.001 | 0.511 | 0.557 | -0.047 |
| 1999 | 0.586 | 0.489 | 0.097 | 0.556 | 0.457 | 0.100 |
| 2000 | 0.545 | 0.535 | 0.010 | 0.482 | 0.474 | 0.008 |
| 2001 | 0.873 | 0.372 | 0.501 | 0.840 | 0.149 | 0.690 |
| 2002 | 0.827 | 0.511 | 0.316 | 0.754 | 0.455 | 0.299 |
| 2003 | 0.833 | 0.639 | 0.194 | 0.767 | 0.584 | 0.183 |
| 2004 | 0.735 | 0.715 | 0.020 | 0.657 | 0.652 | 0.005 |
| 2005 | 0.807 | 0.831 | -0.024 | 0.772 | 0.833 | -0.062 |
| 2006 | 0.951 | 0.840 | 0.111 | 0.931 | 0.795 | 0.137 |
| 2007 | 0.807 | 0.809 | -0.002 | 0.783 | 0.800 | -0.017 |

Appendix Table 9B. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

PUGET SOUND REGION (continued)

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference |
| Marblemount Hatchery |  |  |  |  |  |  |
| 1998 | 0.324 | 0.360 | -0.036 | 0.247 | 0.311 | -0.064 |
| 1999 | 0.243 | 0.266 | -0.022 | 0.185 | 0.208 | -0.024 |
| 2000 | 0.721 | 0.313 | 0.408 | 0.623 | 0.204 | 0.419 |
| 2001 | 0.595 | 0.080 | 0.515 | 0.533 | 0.037 | 0.496 |
| 2002 | 0.441 | 0.387 | 0.054 | 0.348 | 0.307 | 0.041 |
| 2003 | 0.646 | 0.378 | 0.268 | 0.615 | 0.289 | 0.326 |
| 2004 | 0.334 | 0.451 | -0.118 | 0.257 | 0.318 | -0.060 |
| 2005 | 0.249 | 0.320 | -0.071 | 0.227 | 0.268 | -0.041 |
| 2006 | 0.425 | 0.433 | -0.008 | 0.287 | 0.284 | 0.003 |
| 2007 | 0.329 | 0.420 | -0.091 | 0.301 | 0.394 | -0.093 |
| 2008 | 0.468 | 0.419 | 0.049 | 0.417 | 0.376 | 0.041 |
| 2009 | 0.463 | 0.380 | 0.082 | 0.376 | 0.306 | 0.070 |
| 2010 | 0.482 | 0.476 | 0.007 | 0.404 | 0.400 | 0.004 |
| 2011 | 0.398 | 0.543 | -0.145 | 0.301 | 0.476 | -0.175 |
| Wallace River Hatchery |  |  |  |  |  |  |
| 1998 | 0.213 | 0.221 | -0.009 | 0.142 | 0.192 | -0.050 |
| 1999 | 0.191 | 0.170 | 0.021 | 0.117 | 0.130 | -0.013 |
| 2000 | 0.201 | 0.164 | 0.037 | 0.108 | 0.086 | 0.021 |
| 2001 | 0.275 | 0.139 | 0.136 | 0.146 | 0.050 | 0.096 |
| 2002 | 0.257 | 0.214 | 0.043 | 0.147 | 0.153 | -0.007 |
| 2003 | 0.257 | 0.200 | 0.057 | 0.180 | 0.128 | 0.052 |
| 2004 | 0.225 | 0.288 | -0.063 | 0.140 | 0.190 | -0.051 |
| 2005 | 0.244 | 0.222 | 0.022 | 0.144 | 0.184 | -0.040 |
| 2006 | 0.300 | 0.303 | -0.003 | 0.178 | 0.201 | -0.022 |
| 2007 | 0.110 | 0.120 | -0.010 | 0.091 | 0.097 | -0.006 |
| 2008 | 0.257 | 0.216 | 0.041 | 0.152 | 0.181 | -0.030 |
| 2009 | 0.217 | 0.282 | -0.066 | 0.131 | 0.238 | -0.107 |
| 2010 | 0.259 | 0.333 | -0.074 | 0.205 | 0.290 | -0.084 |
| 2011 | 0.299 | 0.340 | -0.041 | 0.225 | 0.281 | -0.055 |

Appendix Table 9B. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

PUGET SOUND REGION (continued)

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference |
| Soos Creek Hatchery |  |  |  |  |  |  |
| 1998 | 0.652 | 0.703 | -0.051 | 0.614 | 0.684 | -0.070 |
| 1999 | 0.499 | 0.454 | 0.045 | 0.472 | 0.409 | 0.063 |
| 2000 | 0.624 | 0.425 | 0.199 | 0.520 | 0.336 | 0.184 |
| 2001 | 0.594 | 0.444 | 0.150 | 0.549 | 0.079 | 0.470 |
| 2002 | 0.529 | 0.438 | 0.090 | 0.460 | 0.372 | 0.088 |
| 2003 | 0.853 | 0.478 | 0.376 | 0.807 | 0.412 | 0.396 |
| 2004 | 0.538 | 0.704 | -0.166 | 0.464 | 0.642 | -0.178 |
| 2005 | 0.350 | 0.649 | -0.299 | 0.345 | 0.628 | -0.283 |
| 2006 | 0.447 | 0.687 | -0.240 | 0.448 | 0.624 | -0.176 |
| 2007 | 0.336 | 0.571 | -0.235 | 0.307 | 0.556 | -0.249 |
| 2008 | 0.447 | 0.569 | -0.121 | 0.471 | 0.542 | -0.070 |
| 2009 | 0.443 | 0.630 | -0.187 | 0.357 | 0.596 | -0.240 |
| 2010 | 0.527 | 0.703 | -0.177 | 0.731 | 0.673 | 0.058 |
| 2011 | 0.583 | 0.699 | -0.116 | 0.527 | 0.659 | -0.132 |
| Voights Creek Hatchery |  |  |  |  |  |  |
| 1998 | 0.572 | 0.339 | 0.233 | 0.525 | 0.296 | 0.228 |
| 1999 | 0.367 | 0.227 | 0.140 | 0.380 | 0.164 | 0.216 |
| 2000 | 0.495 | 0.245 | 0.251 | 0.439 | 0.129 | 0.310 |
| 2001 | 0.647 | 0.152 | 0.495 | 0.573 | 0.042 | 0.531 |
| 2002 | 0.403 | 0.461 | -0.057 | 0.332 | 0.397 | -0.065 |
| 2003 | 0.695 | 0.308 | 0.388 | 0.712 | 0.222 | 0.489 |
| 2004 | 0.685 | 0.426 | 0.259 | 0.591 | 0.305 | 0.286 |
| 2005 | 0.492 | 0.586 | -0.094 | 0.470 | 0.558 | -0.088 |
| 2006 | 0.793 | 0.785 | 0.008 | 0.740 | 0.741 | -0.002 |
| 2007 | 0.696 | 0.403 | 0.293 | 0.671 | 0.381 | 0.289 |
| 2008 | 0.496 | 0.519 | -0.023 | 0.462 | 0.489 | -0.027 |
| 2009 | 0.470 | 0.571 | -0.101 | 0.401 | 0.531 | -0.130 |
| 2010 | 0.617 | 0.824 | -0.207 | 0.525 | 0.806 | -0.281 |
| 2011 | 0.718 | 0.661 | 0.056 | 0.623 | 0.616 | 0.007 |

Appendix Table 9B. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

PUGET SOUND REGION (continued)

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference |
| George Adams Hatchery |  |  |  |  |  |  |
| 1998 | 0.304 | 0.431 | -0.127 | 0.230 | 0.380 | -0.149 |
| 1999 | 0.149 | 0.344 | -0.195 | 0.102 | 0.270 | -0.168 |
| 2000 | 0.381 | 0.376 | 0.005 | 0.274 | 0.249 | 0.025 |
| 2001 | 0.307 | 0.448 | -0.141 | 0.199 | 0.175 | 0.024 |
| 2002 | 0.256 | 0.482 | -0.226 | 0.158 | 0.395 | -0.237 |
| 2003 | 0.731 | 0.869 | -0.138 | 0.756 | 0.845 | -0.089 |
| 2004 | 0.257 | 0.622 | -0.365 | 0.148 | 0.506 | -0.358 |
| 2005 | 0.338 | 0.784 | -0.446 | 0.220 | 0.764 | -0.544 |
| 2006 | 0.508 | 0.788 | -0.279 | 0.519 | 0.720 | -0.201 |
| 2007 | 0.259 | 0.791 | -0.532 | 0.200 | 0.781 | -0.580 |
| 2008 | 0.227 | 0.679 | -0.452 | 0.181 | 0.650 | -0.469 |
| 2009 | 0.476 | 0.794 | -0.319 | 0.400 | 0.765 | -0.365 |
| 2010 | 0.291 | 0.718 | -0.427 | 0.210 | 0.675 | -0.465 |
| 2011 | 0.568 | 0.781 | -0.213 | 0.546 | 0.735 | -0.188 |
| Quilcene Hatchery |  |  |  |  |  |  |
| 1998 | 0.474 | 0.748 | -0.274 | 0.334 | 0.726 | -0.391 |
| 1999 | 0.188 | 0.378 | -0.191 | 0.186 | 0.305 | -0.119 |
| 2000 | 0.388 | 0.322 | 0.067 | 0.224 | 0.184 | 0.040 |
| 2001 | 0.577 | 0.384 | 0.193 | 0.482 | 0.033 | 0.448 |
| 2002 | 0.632 | 0.909 | -0.277 | 0.611 | 0.878 | -0.266 |
| 2003 | 0.814 | 0.781 | 0.033 | 0.691 | 0.714 | -0.023 |
| 2004 | 0.634 | 0.845 | -0.211 | 0.642 | 0.765 | -0.123 |
| 2005 | 0.822 | 0.806 | 0.016 | 0.784 | 0.783 | 0.001 |
| 2006 | 0.765 | 0.789 | -0.024 | 0.720 | 0.714 | 0.006 |
| 2007 | 0.653 | 0.680 | -0.028 | 0.579 | 0.663 | -0.084 |
| 2008 | 0.683 | 0.812 | -0.128 | 0.623 | 0.794 | -0.171 |
| 2009 | 0.618 | 0.840 | -0.223 | 0.563 | 0.818 | -0.254 |
| 2010 | 0.578 | 0.805 | -0.227 | 0.552 | 0.773 | -0.220 |
| 2011 | 0.327 | 0.718 | -0.391 | 0.325 | 0.658 | -0.333 |

Appendix Table 9C. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

WASHINGTON COAST REGION

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference |
| Makah NFH |  |  |  |  |  |  |
| 1998 | 0.126 | 0.529 | -0.403 | 0.094 | 0.504 | -0.410 |
| 1999 | 0.168 | 0.589 | -0.421 | 0.099 | 0.555 | -0.456 |
| 2000 | 0.580 | 0.681 | -0.101 | 0.415 | 0.637 | -0.222 |
| 2001 | 0.292 | 0.359 | -0.066 | 0.119 | 0.288 | -0.169 |
| 2002 | 0.432 | 0.658 | -0.226 | 0.178 | 0.619 | -0.441 |
| 2003 | 0.341 | 0.340 | 0.001 | 0.261 | 0.249 | 0.011 |
| 2004 | 0.658 | 0.650 | 0.008 | 0.367 | 0.571 | -0.205 |
| 2005 | 0.143 | 0.786 | -0.644 |  |  |  |
| 2006 | 0.209 | 0.518 | -0.309 | 0.109 | 0.416 | -0.307 |
| 2007 | 0.109 | 0.346 | -0.237 | 0.076 | 0.322 | -0.245 |
| 2008 | 0.184 | 0.138 | 0.046 | 0.091 | 0.083 | 0.007 |
| 2009 | 0.228 | 0.203 | 0.025 | 0.251 | 0.145 | 0.106 |
| 2010 | 0.215 | 0.393 | -0.177 | 0.073 | 0.342 | -0.269 |
| Quinault NFH |  |  |  |  |  |  |
| 1998 | 0.602 | 0.416 | 0.186 | 0.523 | 0.369 | 0.153 |
| 1999 | 0.622 | 0.487 | 0.135 | 0.616 | 0.460 | 0.156 |
| 2000 | 0.664 | 0.654 | 0.011 | 0.606 | 0.620 | -0.015 |
| 2001 | 0.614 | 0.507 | 0.107 | 0.612 | 0.623 | -0.010 |
| 2002 | 0.655 | 0.659 | -0.005 | 0.213 | 0.638 | -0.426 |
| 2003 | 0.771 | 0.518 | 0.252 | 0.772 | 0.489 | 0.283 |
| 2004 | 0.622 | 0.527 | 0.094 | 0.500 | 0.473 | 0.027 |
| 2005 | 0.621 | 0.575 | 0.046 | 0.579 | 0.560 | 0.018 |
| 2006 | 0.725 | 0.667 | 0.058 | 0.690 | 0.623 | 0.067 |
| 2007 | 0.694 | 0.673 | 0.020 | 0.701 | 0.659 | 0.042 |
| 2008 | 0.592 | 0.567 | 0.025 | 0.598 | 0.543 | 0.055 |
| 2009 | 0.699 | 0.659 | 0.040 | 0.660 | 0.635 | 0.024 |
| 2010 | 0.492 | 0.476 | 0.017 | 0.464 | 0.436 | 0.028 |
| 2011 | 0.703 | 0.533 | 0.170 | 0.676 | 0.490 | 0.186 |

Appendix Table 9C. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age- 3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

WASHINGTON COAST REGION (continued)

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference |
| Salmon River Fish Culture |  |  |  |  |  |  |
| 1998 | 0.593 | 0.635 | -0.042 | 0.598 | 0.583 | 0.015 |
| 1999 | 0.917 | 0.886 | 0.031 | 0.931 | 0.875 | 0.056 |
| 2000 | 0.991 | 0.728 | 0.263 | 0.992 | 0.677 | 0.315 |
| 2001 | 0.662 | 0.587 | 0.075 | 0.635 | 0.694 | -0.058 |
| 2002 | 0.438 | 0.774 | -0.336 | 0.763 | 0.737 | 0.026 |
| 2003 | 0.904 | 0.718 | 0.186 | 0.893 | 0.669 | 0.224 |
| 2004 | 0.801 | 0.637 | 0.164 | 0.821 | 0.521 | 0.300 |
| 2005 | 0.697 | 0.615 | 0.082 | 0.710 | 0.588 | 0.122 |
| 2006 | 0.797 | 0.776 | 0.021 | 0.676 | 0.694 | -0.018 |
| 2007 | 0.732 | 0.733 | -0.001 | 0.703 | 0.710 | -0.008 |
| 2008 | 0.544 | 0.685 | -0.141 | 0.520 | 0.650 | -0.130 |
| 2009 |  |  |  |  |  |  |
| 2010 |  |  |  |  |  |  |
| 2011 | 0.777 | 0.655 | 0.123 | 0.727 | 0.589 | 0.137 |
| Solduc Hatchery |  |  |  |  |  |  |
| 1998 | 0.178 | 0.612 | -0.435 | 0.079 | 0.596 | -0.516 |
| 1999 | 0.132 | 0.409 | -0.277 | 0.045 | 0.390 | -0.345 |
| 2000 | 0.247 | 0.660 | -0.413 | 0.066 | 0.640 | -0.573 |
| 2001 | 0.215 | 0.447 | -0.232 | 0.107 | 0.501 | -0.394 |
| 2002 | 0.333 | 0.580 | -0.247 | 0.111 | 0.566 | -0.455 |
| 2003 | 0.368 | 0.654 | -0.286 | 0.112 | 0.641 | -0.529 |
| 2004 | 0.247 | 0.563 | -0.315 | 0.183 | 0.527 | -0.345 |
| 2005 | 0.488 | 0.502 | -0.015 | 0.459 | 0.494 | -0.034 |
| 2006 | 0.686 | 0.892 | -0.206 | 0.603 | 0.882 | -0.280 |
| 2007 | 0.492 | 0.545 | -0.054 | 0.482 | 0.536 | -0.055 |
| 2008 | 0.398 | 0.513 | -0.115 | 0.393 | 0.498 | -0.105 |
| 2009 | 0.741 | 0.692 | 0.049 | 0.708 | 0.681 | 0.027 |
| 2010 | 0.620 | 0.680 | -0.060 | 0.534 | 0.663 | -0.129 |
| 2011 | 0.671 | 0.714 | -0.042 | 0.615 | 0.693 | -0.078 |

Appendix Table 9C. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

WASHINGTON COAST REGION (continued)

| Hatchery | Mark | xploitation |  | Unmark | Exploitatio | Rate |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Brood Year | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference | PR $\boldsymbol{\lambda}^{\text {Rel }}$ | PS FRAM | Difference |
| Bingham Creek Ha |  |  |  |  |  |  |
| 1998 | 0.314 | 0.291 | 0.024 | 0.266 | 0.254 | 0.012 |
| 1999 | 0.178 | 0.248 | -0.069 | 0.142 | 0.226 | -0.084 |
| 2000 | 0.276 | 0.294 | -0.018 | 0.144 | 0.252 | -0.108 |
| 2001 | 0.305 | 0.121 | 0.184 | 0.328 | 0.065 | 0.263 |
| 2002 | 0.398 | 0.417 | -0.019 | 0.198 | 0.395 | -0.197 |
| 2003 | 0.278 | 0.424 | -0.145 | 0.242 | 0.393 | -0.151 |
| 2004 | 0.279 | 0.382 | -0.104 | 0.260 | 0.322 | -0.062 |
| 2005 | 0.179 | 0.319 | -0.140 | 0.121 | 0.280 | -0.158 |
| 2006 | 0.206 | 0.390 | -0.184 | 0.162 | 0.314 | -0.152 |
| 2007 | 0.100 | 0.228 | -0.128 | 0.038 | 0.202 | -0.164 |
| 2008 | 0.244 | 0.383 | -0.139 | 0.159 | 0.359 | -0.200 |
| 2009 | 0.359 | 0.479 | -0.119 | 0.253 | 0.460 | -0.207 |
| 2010 | 0.242 | 0.486 | -0.244 | 0.204 | 0.455 | -0.251 |
| 2011 | 0.371 | 0.480 | -0.109 | 0.350 | 0.449 | -0.100 |
| Forks Creek Hatche |  |  |  |  |  |  |
| 1998 | 0.556 | 0.371 | 0.186 | 0.500 | 0.296 | 0.204 |
| 1999 | 0.648 | 0.426 | 0.222 | 0.612 | 0.380 | 0.232 |
| 2000 | 0.625 | 0.479 | 0.147 | 0.518 | 0.394 | 0.125 |
| 2001 | 0.472 | 0.319 | 0.153 | 0.371 | 0.717 | -0.346 |
| 2002 | 0.420 | 0.475 | -0.055 | 0.334 | 0.431 | -0.097 |
| 2003 | 0.693 | 0.552 | 0.141 | 0.646 | 0.506 | 0.141 |
| 2004 | 0.528 | 0.462 | 0.066 | 0.323 | 0.344 | -0.021 |
| 2005 | 0.358 | 0.364 | -0.006 | 0.307 | 0.320 | -0.013 |
| 2006 | 0.576 | 0.670 | -0.094 | 0.413 | 0.577 | -0.164 |
| 2007 | 0.429 | 0.304 | 0.126 | 0.043 | 0.258 | -0.215 |
| 2008 | 0.539 | 0.567 | -0.028 | 0.480 | 0.532 | -0.052 |
| 2009 | 0.590 | 0.558 | 0.032 | 0.545 | 0.517 | 0.028 |
| 2010 | 0.462 | 0.433 | 0.029 | 0.331 | 0.368 | -0.038 |
| 2011 | 0.391 | 0.547 | -0.157 | 0.314 | 0.479 | -0.165 |

Appendix Table 9D. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age-3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda$ ( $\mathrm{PR} \lambda^{\text {Rel })}$.

COLUMBIA RIVER REGION

| $\begin{array}{\|l\|} \hline \text { Hatchery } \\ \text { Brood Year } \end{array}$ | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference |
| Lewis River - North |  |  |  |  |  |  |
| 1998 | 0.439 | 0.271 | 0.168 | 0.131 | 0.082 | 0.050 |
| 1999 | 0.288 | 0.245 | 0.044 | 0.086 | 0.087 | -0.001 |
| 2000 | 0.516 | 0.337 | 0.179 | 0.147 | 0.098 | 0.049 |
| 2001 | 0.622 | 0.253 | 0.370 | 0.230 | 0.040 | 0.190 |
| 2002 | 0.230 | 0.197 | 0.034 | 0.050 | 0.063 | -0.013 |
| 2003 | 0.218 | 0.206 | 0.012 | 0.061 | 0.084 | -0.024 |
| 2004 | 0.550 | 0.403 | 0.147 | 0.190 | 0.179 | 0.012 |
| 2005 | 0.164 | 0.097 | 0.067 | 0.035 | 0.038 | -0.003 |
| 2006 | 0.512 | 0.371 | 0.142 | 0.156 | 0.119 | 0.037 |
| 2007 | 0.183 | 0.162 | 0.021 | 0.038 | 0.054 | -0.017 |
| 2008 | 0.292 | 0.201 | 0.091 | 0.060 | 0.065 | -0.005 |
| 2009 | 0.389 | 0.238 | 0.150 | 0.100 | 0.119 | -0.019 |
| 2010 | 0.438 | 0.274 | 0.163 | 0.130 | 0.110 | 0.020 |
| 2011 | 0.322 | 0.262 | 0.060 | 0.124 | 0.114 | 0.010 |
| Lewis River - South |  |  |  |  |  |  |
| 1998 | 0.304 | 0.183 | 0.120 | 0.256 | 0.056 | 0.200 |
| 1999 | 0.101 | 0.178 | -0.077 | 0.152 | 0.062 | 0.090 |
| 2000 | 0.319 | 0.263 | 0.056 | 0.021 | 0.079 | -0.058 |
| 2001 | 0.318 | 0.141 | 0.176 | 0.112 | 0.042 | 0.069 |
| 2002 | 0.065 | 0.126 | -0.060 | 0.084 | 0.044 | 0.040 |
| 2003 | 0.081 | 0.150 | -0.069 | 0.022 | 0.065 | -0.043 |
| 2004 | 0.319 | 0.320 | -0.001 | 0.037 | 0.106 | -0.069 |
| 2005 | 0.080 | 0.071 | 0.009 | 0.048 | 0.028 | 0.020 |
| 2006 | 0.521 | 0.277 | 0.244 | 0.036 | 0.088 | -0.052 |
| 2007 | 0.138 | 0.118 | 0.020 | 0.131 | 0.037 | 0.093 |
| 2008 | 0.076 | 0.137 | -0.062 | 0.030 | 0.045 | -0.015 |
| 2009 | 0.136 | 0.175 | -0.039 | 0.244 | 0.094 | 0.149 |
| 2010 | 0.155 | 0.196 | -0.041 | 0.016 | 0.084 | -0.069 |
| 2011 | 0.190 | 0.216 | -0.026 | 0.041 | 0.105 | -0.065 |

Appendix Table 9D. Comparison of DIT-based and Post-season FRAM-based (PS FRAM) exploitations rates (ERs) for the marked and unmarked components of DIT groups, by hatchery and brood year. ERs are for age- 3 fish only and include drop-off mortalities. ERs for the unmarked component of DIT groups estimated using the PairedRatio method with release $\lambda\left(\mathrm{PR} \lambda^{\text {Rel }}\right)$.

COLUMBIA RIVER REGION (continued)

| Hatchery Brood Year | Marked Exploitation Rate |  |  | Unmarked Exploitation Rate |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference | PR $\lambda^{\text {Rel }}$ | PS FRAM | Difference |
| Eagle Creek NFH |  |  |  |  |  |  |
| 1998 | 0.287 | 0.183 | 0.104 | 0.249 | 0.056 | 0.193 |
| 1999 | 0.080 | 0.178 | -0.099 | 0.117 | 0.062 | 0.056 |
| 2000 | 0.124 | 0.263 | -0.139 | 0.030 | 0.079 | -0.049 |
| 2001 | 0.133 | 0.141 | -0.008 | 0.038 | 0.042 | -0.005 |
| 2002 | 0.081 | 0.126 | -0.044 | 0.013 | 0.044 | -0.031 |
| 2003 | 0.267 | 0.150 | 0.117 | 0.047 | 0.065 | -0.018 |
| 2004 | 0.287 | 0.320 | -0.033 | 0.043 | 0.106 | -0.063 |
| 2005 | 0.139 | 0.071 | 0.068 | 0.120 | 0.028 | 0.092 |
| 2006 | 0.343 | 0.277 | 0.066 | 0.015 | 0.088 | -0.073 |
| 2007 | 0.207 | 0.118 | 0.089 | 0.265 | 0.037 | 0.227 |
| 2008 | 0.113 | 0.137 | -0.024 | 0.031 | 0.045 | -0.013 |
| 2009 | 0.140 | 0.175 | -0.034 | 0.032 | 0.094 | -0.062 |
| 2010 | 0.120 | 0.196 | -0.076 | 0.004 | 0.084 | -0.081 |
| 2011 | 0.216 | 0.216 | 0.000 | 0.089 | 0.105 | -0.016 |
| Sandy River |  |  |  |  |  |  |
| 1998 | 0.417 | 0.183 | 0.234 | 0.344 | 0.056 | 0.288 |
| 1999 | 0.381 | 0.178 | 0.203 | 0.142 | 0.062 | 0.080 |
| 2000 | 0.649 | 0.263 | 0.386 | 0.190 | 0.079 | 0.112 |
| 2001 | 0.430 | 0.141 | 0.289 | 0.134 | 0.042 | 0.092 |
| 2002 | 0.107 | 0.126 | -0.019 | 0.128 | 0.044 | 0.084 |
| 2003 | 0.220 | 0.150 | 0.069 | 0.017 | 0.065 | -0.047 |
| 2004 | 0.517 | 0.320 | 0.197 | 0.073 | 0.106 | -0.033 |
| 2005 | 0.231 | 0.071 | 0.160 | 0.151 | 0.028 | 0.123 |
| 2006 | 0.396 | 0.277 | 0.119 | 0.012 | 0.088 | -0.076 |
| 2007 | 0.170 | 0.118 | 0.053 | 0.150 | 0.037 | 0.112 |
| 2008 | 0.185 | 0.137 | 0.048 | 0.042 | 0.045 | -0.002 |

Appendix 10: Comparisons of estimated annual total exploitation rates as estimated by the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$ (Section 3.2) for marked and unmarked DIT groups (with 95\% confidence intervals) by region and brood year.


Appendix Figure 10A. Comparison of estimated total exploitation rates (ER) for marked and unmarked DIT groups (with 95\% confidence intervals) for British Columbia region hatcheries, by brood year.


Appendix Figure 10B. Comparison of estimated total exploitation rates (ER) for marked and unmarked DIT groups (with 95\% confidence intervals) for Puget Sound region hatcheries, by brood year.


Appendix Figure 10C. Comparison of estimated total exploitation rates (ER) for marked and unmarked DIT groups (with 95\% confidence intervals) for Washington Coast region hatcheries, by brood year.


Appendix Figure 10D. Comparison of estimated total exploitation rates (ER) for marked and unmarked DIT groups (with $95 \%$ confidence intervals) for Columbia River region hatcheries, by brood year.

Appendix 11: Comparisons between estimated annual total exploitation rates as estimated by the Paired-Ratio (PR) method and $\lambda^{R e l}$ (Section 3.2) and the single index tag (SIT) method (Section 4).

Appendix Table 11A Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

BRITISH COLUMBIA REGION

| Hatchery Brood Year | $\begin{aligned} & \text { PR } \lambda^{\mathrm{Rel}} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| Quinsam River Hatchery |  |  |  |
| 1998 | 0.010 | 0.007 | 0.002 |
| 1999 | 0.089 | 0.089 | 0.000 |
| 2000 | 0.144 | 0.174 | -0.031 |
| 2001 | 0.109 | 0.127 | -0.018 |
| 2002 | 0.131 | 0.131 | 0.001 |
| 2003 | 0.217 | 0.237 | -0.020 |
| 2004 | 0.335 | 0.311 | 0.023 |
| 2005 | 0.034 | 0.036 | -0.001 |
| 2006 | 0.078 | 0.091 | -0.013 |
| 2007 | 0.053 | 0.051 | 0.003 |
| 2008 | 0.113 | 0.113 | 0.001 |
| 2009 | 0.272 | 0.199 | 0.073 |
| 2010 | 0.256 | 0.164 | 0.092 |
| 2011 | 0.113 | 0.091 | 0.023 |


| Big Qualicum River Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.032 | 0.020 | 0.012 |
| 1999 | 0.054 | 0.019 | 0.035 |
| 2000 | 0.090 | 0.104 | -0.014 |
| 2001 | 0.082 | 0.095 | -0.013 |
| 2002 | 0.108 | 0.042 | 0.067 |

Chilliwack River Hatchery

| 1998 | 0.035 | 0.036 | -0.001 |
| ---: | ---: | ---: | ---: |
| 1999 | 0.040 | 0.038 | 0.003 |
| 2000 | 0.030 | 0.025 | 0.005 |
| 2001 | 0.061 | 0.051 | 0.009 |
| 2002 | 0.188 | 0.070 | 0.118 |

Appendix Table 11A. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

## BRITISH COLUMBIA REGION (continued)

| Hatchery Brood Year | $\begin{aligned} & \text { PR } \lambda^{\mathrm{Rel}} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| Inch Creek Hatchery |  |  |  |
| 1998 | 0.086 | 0.053 | 0.032 |
| 1999 | 0.039 | 0.032 | 0.006 |
| 2000 | 0.037 | 0.066 | -0.030 |
| 2001 | 0.130 | 0.124 | 0.006 |
| 2002 | 0.044 | 0.050 | -0.006 |
| 2003 | 0.184 | 0.191 | -0.007 |
| 2004 | 0.160 | 0.139 | 0.021 |
| 2005 | 0.072 | 0.027 | 0.045 |
| 2006 | 0.094 | 0.083 | 0.012 |
| 2007 | 0.031 | 0.026 | 0.006 |
| 2008 | 0.055 | 0.034 | 0.021 |
| 2009 | 0.078 | 0.068 | 0.011 |
| 2010 | 0.080 | 0.075 | 0.005 |
| 2011 | 0.116 | 0.106 | 0.009 |
| Robertson Creek Hatchery |  |  |  |
| 1998 | 0.249 | 0.048 | 0.200 |
| 1999 | 0.025 | 0.017 | 0.008 |
| 2000 | 0.069 | 0.043 | 0.026 |
| 2001 | 0.062 | 0.039 | 0.023 |
| 2002 | 0.085 | 0.089 | -0.004 |

Appendix Table 11B. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

PUGET SOUND REGION

$\left.$| Hatchery <br> Brood Year | PR $\lambda^{\text {Rel }}$ <br> DIT ER | SIT ER |
| ---: | ---: | ---: | ---: | | Difference |
| :---: |
| DIT-SIT | \right\rvert\,


| Kendall Creek Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.497 | 0.485 | 0.011 |
| 1999 | 0.547 | 0.479 | 0.068 |
| 2000 | 0.467 | 0.377 | 0.090 |
| 2001 | 0.836 | 0.753 | 0.082 |
| 2002 | 0.751 | 0.637 | 0.115 |
| 2003 | 0.749 | 0.396 | 0.353 |
| 2004 | 0.649 | 0.575 | 0.074 |
| 2005 | 0.768 | 0.755 | 0.013 |
| 2006 | 0.930 | 0.810 | 0.120 |
| 2007 | 0.779 | 0.758 | 0.022 |


| Marblemount Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.235 | 0.178 | 0.057 |
| 1999 | 0.177 | 0.166 | 0.012 |
| 2000 | 0.607 | 0.456 | 0.151 |
| 2001 | 0.523 | 0.412 | 0.110 |
| 2002 | 0.340 | 0.353 | -0.013 |
| 2003 | 0.607 | 0.502 | 0.105 |
| 2004 | 0.246 | 0.192 | 0.053 |
| 2005 | 0.222 | 0.205 | 0.017 |
| 2006 | 0.272 | 0.272 | 0.001 |
| 2007 | 0.291 | 0.262 | 0.029 |
| 2008 | 0.404 | 0.367 | 0.037 |
| 2009 | 0.362 | 0.315 | 0.047 |
| 2010 | 0.393 | 0.334 | 0.059 |
| 2011 | 0.282 | 0.278 | 0.003 |

Appendix Table 11B. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

PUGET SOUND REGION (continued)

| Hatchery Brood Year | PR $\lambda^{\text {Rel }}$ DIT ER | SIT ER | $\begin{gathered} \text { Difference } \\ \text { DIT-SIT } \\ \hline \end{gathered}$ |
| :---: | :---: | :---: | :---: |
| Wallace River Hatchery |  |  |  |
| 1998 | 0.133 | 0.111 | 0.022 |
| 1999 | 0.109 | 0.089 | 0.021 |
| 2000 | 0.098 | 0.088 | 0.010 |
| 2001 | 0.134 | 0.126 | 0.008 |
| 2002 | 0.137 | 0.131 | 0.005 |
| 2003 | 0.170 | 0.138 | 0.033 |
| 2004 | 0.131 | 0.137 | -0.006 |
| 2005 | 0.137 | 0.157 | -0.020 |
| 2006 | 0.166 | 0.139 | 0.027 |
| 2007 | 0.086 | 0.076 | 0.010 |
| 2008 | 0.142 | 0.138 | 0.003 |
| 2009 | 0.122 | 0.130 | -0.008 |
| 2010 | 0.193 | 0.144 | 0.048 |
| 2011 | 0.212 | 0.183 | 0.029 |
| Soos Creek Hatchery |  |  |  |
| 1998 | 0.602 | 0.506 | 0.096 |
| 1999 | 0.464 | 0.436 | 0.028 |
| 2000 | 0.508 | 0.476 | 0.031 |
| 2001 | 0.541 | 0.463 | 0.077 |
| 2002 | 0.445 | 0.416 | 0.029 |
| 2003 | 0.802 | 0.759 | 0.043 |
| 2004 | 0.452 | 0.433 | 0.019 |
| 2005 | 0.339 | 0.283 | 0.055 |
| 2006 | 0.438 | 0.324 | 0.115 |
| 2007 | 0.298 | 0.265 | 0.033 |
| 2008 | 0.459 | 0.380 | 0.080 |
| 2009 | 0.345 | 0.333 | 0.013 |
| 2010 | 0.718 | 0.394 | 0.324 |
| 2011 | 0.513 | 0.436 | 0.076 |
| Voights Creek Hatchery |  |  |  |
| 1998 | 0.515 | 0.506 | 0.009 |
| 1999 | 0.373 | 0.326 | 0.047 |
| 2000 | 0.428 | 0.395 | 0.033 |
| 2001 | 0.561 | 0.471 | 0.090 |
| 2002 | 0.321 | 0.307 | 0.014 |
| 2003 | 0.700 | 0.595 | 0.106 |
| 2004 | 0.578 | 0.560 | 0.018 |
| 2005 | 0.457 | 0.433 | 0.025 |
| 2006 | 0.733 | 0.613 | 0.121 |
| 2007 | 0.663 | 0.574 | 0.089 |
| 2008 | 0.443 | 0.341 | 0.103 |
| 2009 | 0.368 | 0.352 | 0.015 |
| 2010 | 0.513 | 0.451 | 0.062 |
| 2011 | 0.608 | 0.548 | 0.060 |

Appendix Table 11B. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

PUGET SOUND REGION (continued)

| Hatchery Brood Year | $\begin{aligned} & \hline \text { PR } \lambda^{\text {Rel }} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| George Adams Hatchery |  |  |  |
| 1998 | 0.213 | 0.197 | 0.015 |
| 1999 | 0.096 | 0.089 | 0.007 |
| 2000 | 0.261 | 0.245 | 0.016 |
| 2001 | 0.182 | 0.148 | 0.034 |
| 2002 | 0.141 | 0.136 | 0.005 |
| 2003 | 0.708 | 0.561 | 0.148 |
| 2004 | 0.137 | 0.150 | -0.013 |
| 2005 | 0.190 | 0.260 | -0.070 |
| 2006 | 0.481 | 0.380 | 0.101 |
| 2007 | 0.188 | 0.204 | -0.016 |
| 2008 | 0.165 | 0.153 | 0.012 |
| 2009 | 0.363 | 0.317 | 0.046 |
| 2010 | 0.199 | 0.177 | 0.022 |
| 2011 | 0.522 | 0.431 | 0.091 |


| Quilcene Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.321 | 0.338 | -0.017 |
| 1999 | 0.165 | 0.126 | 0.039 |
| 2000 | 0.206 | 0.163 | 0.042 |
| 2001 | 0.467 | 0.398 | 0.068 |
| 2002 | 0.577 | 0.455 | 0.121 |
| 2003 | 0.667 | 0.591 | 0.075 |
| 2004 | 0.616 | 0.478 | 0.138 |
| 2005 | 0.773 | 0.757 | 0.016 |
| 2006 | 0.696 | 0.621 | 0.075 |
| 2007 | 0.534 | 0.584 | -0.050 |
| 2008 | 0.561 | 0.529 | 0.032 |
| 2009 | 0.510 | 0.492 | 0.018 |
| 2010 | 0.513 | 0.450 | 0.064 |
| 2011 | 0.316 | 0.190 | 0.126 |

Appendix Table 11C. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

WASHINGTON COAST REGION

| Hatchery Brood Year | $\begin{aligned} & \text { PR } \lambda^{\mathrm{Rel}} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| Makah NFH |  |  |  |
| 1998 | 0.085 | 0.050 | 0.034 |
| 1999 | 0.086 | 0.054 | 0.031 |
| 2000 | 0.350 | 0.343 | 0.007 |
| 2001 | 0.105 | 0.057 | 0.048 |
| 2002 | 0.137 | 0.096 | 0.041 |
| 2003 | 0.225 | 0.167 | 0.059 |
| 2004 | 0.280 | 0.226 | 0.054 |
| 2005 | 0.124 | 0.086 | 0.038 |
| 2006 | 0.075 | 0.052 | 0.023 |
| 2007 | 0.062 | 0.037 | 0.025 |
| 2008 | 0.080 | 0.065 | 0.016 |
| 2009 | 0.184 | 0.064 | 0.119 |
| 2010 | 0.065 | 0.088 | -0.023 |
| Quinault NFH |  |  |  |
| 1998 | 0.485 | 0.443 | 0.043 |
| 1999 | 0.602 | 0.519 | 0.083 |
| 2000 | 0.589 | 0.531 | 0.058 |
| 2001 | 0.596 | 0.508 | 0.088 |
| 2002 | 0.183 | 0.518 | -0.335 |
| 2003 | 0.734 | 0.598 | 0.135 |
| 2004 | 0.437 | 0.378 | 0.059 |
| 2005 | 0.556 | 0.582 | -0.026 |
| 2006 | 0.668 | 0.599 | 0.069 |
| 2007 | 0.673 | 0.624 | 0.049 |
| 2008 | 0.519 | 0.444 | 0.075 |
| 2009 | 0.593 | 0.533 | 0.060 |
| 2010 | 0.456 | 0.379 | 0.077 |
| 2011 | 0.670 | 0.623 | 0.046 |
| Salmon River Fish Culture |  |  |  |
| 1998 | 0.583 | 0.466 | 0.118 |
| 1999 | 0.930 | 0.810 | 0.120 |
| 2000 | 0.975 | 0.700 | 0.275 |
| 2001 | 0.628 | 0.543 | 0.086 |
| 2002 | 0.730 | 0.368 | 0.361 |
| 2003 | 0.890 | 0.706 | 0.184 |
| 2004 | 0.514 | 0.336 | 0.178 |
| 2005 | 0.692 | 0.606 | 0.087 |
| 2006 | 0.635 | 0.643 | -0.008 |
| 2007 | 0.692 | 0.677 | 0.015 |
| 2008 | 0.471 | 0.375 | 0.096 |
| 2009 | 0.866 | 0.797 | 0.069 |
| 2010 |  |  |  |
| 2011 | 0.719 | 0.595 | 0.124 |

Appendix Table 11C. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

WASHINGTON COAST REGION (continued)

| Hatchery <br> Brood Year | PR $\lambda^{\text {Rel }}$ <br> DIT ER | SIT ER |
| ---: | ---: | ---: | ---: | | Difference |
| :---: |
| DIT-SIT |$|$| Solduc Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.063 | 0.045 | 0.017 |
| 1999 | 0.033 | 0.033 | 0.000 |
| 2000 | 0.046 | 0.056 | -0.010 |
| 2001 | 0.088 | 0.077 | 0.011 |
| 2002 | 0.085 | 0.082 | 0.003 |
| 2003 | 0.087 | 0.107 | -0.020 |
| 2004 | 0.149 | 0.061 | 0.088 |
| 2005 | 0.449 | 0.423 | 0.026 |
| 2006 | 0.558 | 0.537 | 0.021 |
| 2007 | 0.465 | 0.396 | 0.070 |
| 2008 | 0.350 | 0.289 | 0.061 |
| 2009 | 0.582 | 0.617 | -0.035 |
| 2010 | 0.508 | 0.446 | 0.063 |
| 2011 | 0.563 | 0.547 | 0.016 |


| Bingham Creek Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.248 | 0.255 | -0.007 |
| 1999 | 0.163 | 0.161 | 0.002 |
| 2000 | 0.129 | 0.146 | -0.016 |
| 2001 | 0.300 | 0.245 | 0.055 |
| 2002 | 0.164 | 0.279 | -0.115 |
| 2003 | 0.204 | 0.189 | 0.015 |
| 2004 | 0.220 | 0.191 | 0.029 |
| 2005 | 0.133 | 0.161 | -0.028 |
| 2006 | 0.123 | 0.088 | 0.035 |
| 2007 | 0.037 | 0.057 | -0.020 |
| 2008 | 0.129 | 0.158 | -0.028 |
| 2009 | 0.232 | 0.312 | -0.080 |
| 2010 | 0.188 | 0.191 | -0.003 |
| 2011 | 0.293 | 0.327 | -0.034 |


| Forks Creek Hatchery |  |  |  |
| ---: | ---: | ---: | ---: |
| 1998 | 0.459 | 0.416 | 0.042 |
| 1999 | 0.599 | 0.506 | 0.093 |
| 2000 | 0.486 | 0.390 | 0.095 |
| 2001 | 0.341 | 0.329 | 0.012 |
| 2002 | 0.306 | 0.290 | 0.016 |
| 2003 | 0.635 | 0.523 | 0.112 |
| 2004 | 0.297 | 0.272 | 0.025 |
| 2005 | 0.297 | 0.299 | -0.001 |
| 2006 | 0.380 | 0.326 | 0.054 |
| 2007 | 0.037 | 0.351 | -0.314 |
| 2008 | 0.459 | 0.454 | 0.005 |
| 2009 | 0.486 | 0.404 | 0.082 |
| 2010 | 0.316 | 0.336 | -0.020 |
| 2011 | 0.298 | 0.269 | 0.029 |

Appendix Table 11D. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

## COLUMBIA RIVER REGION

| Hatchery Brood Year | $\begin{aligned} & \text { PR } \lambda^{\text {Rel }} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| Lewis River - North |  |  |  |
| 1998 | 0.354 | 0.138 | 0.217 |
| 1999 | 0.390 | 0.368 | 0.022 |
| 2000 | 0.402 | 0.290 | 0.112 |
| 2001 | 0.467 | 0.316 | 0.151 |
| 2002 | 0.159 | 0.150 | 0.009 |
| 2003 | 0.194 | 0.152 | 0.042 |
| 2004 | 0.336 | 0.210 | 0.126 |
| 2005 | 0.100 | 0.105 | -0.004 |
| 2006 | 0.287 | 0.196 | 0.091 |
| 2007 | 0.135 | 0.134 | 0.000 |
| 2008 | 0.115 | 0.099 | 0.017 |
| 2009 | 0.179 | 0.113 | 0.067 |
| 2010 | 0.154 | 0.132 | 0.022 |
| 2011 | 0.223 | 0.197 | 0.026 |
| Lewis River - South |  |  |  |
| 1998 | 0.095 | 0.063 | 0.031 |
| 1999 | 0.102 | 0.119 | -0.017 |
| 2000 | 0.077 | 0.055 | 0.021 |
| 2001 | 0.069 | 0.059 | 0.010 |
| 2002 | 0.043 | 0.045 | -0.002 |
| 2003 | 0.077 | 0.055 | 0.022 |
| 2004 | 0.070 | 0.063 | 0.007 |
| 2005 | 0.058 | 0.038 | 0.020 |
| 2006 | 0.185 | 0.116 | 0.069 |
| 2007 | 0.047 | 0.060 | -0.013 |
| 2008 | 0.053 | 0.064 | -0.011 |
| 2009 | 0.128 | 0.044 | 0.084 |
| 2010 | 0.051 | 0.128 | -0.078 |
| 2011 | 0.091 | 0.145 | -0.054 |

Appendix Table 11D. Comparison of DIT-based (PR method using $\lambda$ at release) and SIT-based estimates of unmarked ER.

## COLUMBIA RIVER REGION (continued)

| Hatchery Brood Year | $\begin{aligned} & \text { PR } \lambda^{\mathrm{Rel}} \\ & \text { DIT ER } \end{aligned}$ | SIT ER | Difference DIT-SIT |
| :---: | :---: | :---: | :---: |
| Eagle Creek NFH |  |  |  |
| 1998 | 0.195 | 0.080 | 0.116 |
| 1999 | 0.142 | 0.095 | 0.047 |
| 2000 | 0.079 | 0.045 | 0.035 |
| 2001 | 0.039 | 0.056 | -0.018 |
| 2002 | 0.043 | 0.056 | -0.013 |
| 2003 | 0.046 | 0.123 | -0.077 |
| 2004 | 0.069 | 0.081 | -0.012 |
| 2005 | 0.034 | 0.067 | -0.033 |
| 2006 | 0.129 | 0.113 | 0.017 |
| 2007 | 0.051 | 0.073 | -0.022 |
| 2008 | 0.055 | 0.035 | 0.020 |
| 2009 | 0.045 | 0.100 | -0.055 |
| 2010 | 0.030 | 0.041 | -0.012 |
| 2011 | 0.132 | 0.165 | -0.033 |
| Sandy River |  |  |  |
| 1998 | 0.190 | 0.104 | 0.086 |
| 1999 | 0.411 | 0.332 | 0.079 |
| 2000 | 0.371 | 0.237 | 0.134 |
| 2001 | 0.131 | 0.099 | 0.032 |
| 2002 | 0.066 | 0.073 | -0.007 |
| 2003 | 0.066 | 0.070 | -0.004 |
| 2004 | 0.127 | 0.139 | -0.012 |
| 2005 | 0.099 | 0.105 | -0.006 |
| 2006 | 0.136 | 0.116 | 0.020 |
| 2007 | 0.057 | 0.040 | 0.018 |
| 2008 | 0.083 | 0.144 | -0.061 |

Appendix 12: Summary statistics for DIT groups in each of the assessment categories defined by the results of the three hypothesis tests used to examine DIT groups for evidence of significant impact by mark-selective fisheries (Sections 7.2 and 7.2.1). Exploitation rate (ER) for the unmarked component of DIT groups estimated using the Paired-Ratio method with release $\lambda\left(\lambda^{\text {Rel }}\right)$.

Appendix Table 12A. Summary statistics for DIT groups in each of the assessment categories defined by the results of the three hypothesis tests used to examine DIT groups for evidence of significant impact by mark-selective fisheries (Sections 7.2 and 7.2.1). Exploitation rate (ER) for the unmarked component of DIT groups estimated using the Paired-Ratio method with release $\lambda\left(\lambda^{R e l}\right)$.

|  |  | Number Released |  |  | Number in Escapement |  |  | Return Rate to Escapement |  |  |  | Estimated Recoveries in Fisheries |  |  | Estimated ER |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Assessment Category | Summary Statistic | Unmarked | Marked | $\lambda^{\text {Rel }}$ | Unmarked | Marked | $\lambda^{E S C}$ | Unmarked | Marked |  | $\lambda R$ | All <br> Fisheries | MSF <br> Fisheries Only | Proportion in MSF | Marked | Unmarked | Differ. (Mrk Unmrk) |
| 1. Test(s) Counter to Expectations$(n=22)$ | Mean | 57,300 | 57,217 | 1.002 | 581.4 | 932.7 | 0.655 | 0.0107 | 0.0167 | -0.0059 | 0.651 | 747.5 | 164.9 | 0.334 | 0.4287 | 0.4366 | -0.008 |
|  | Median | 52,091 | 59,664 | 1.003 | 334.8 | 626.5 | 0.746 | 0.0068 | 0.0093 | -0.0027 | 0.752 | 625.8 | 130.9 | 0.232 | 0.4094 | 0.4585 | 0.012 |
|  | Minimum | 38,577 | 37,966 | 0.810 | 12.5 | 26.2 | 0.040 | 0.0002 | 0.0003 | -0.0459 | 0.040 | 11.5 | 3.5 | 0.080 | 0.0917 | 0.0618 | -0.299 |
|  | Maximum | 77,013 | 77,151 | 1.170 | 2,776.7 | 3,535.6 | 0.980 | 0.0378 | 0.0476 | 0.0000 | 0.990 | 2,680.9 | 426.7 | 0.720 | 0.9150 | 0.9297 | 0.239 |
| 2. Tests Not Informative$(n=84)$ | Mean | 54,756 | 53,866 | 1.019 | 732.6 | 714.3 | 1.036 | 0.0146 | 0.0145 | 0.0001 | 1.016 | 788.4 | 146.6 | 0.254 | 0.4833 | 0.4367 | 0.047 |
|  | Median | 45,965 | 45,293 | 1.006 | 532.7 | 521.4 | 1.019 | 0.0093 | 0.0091 | 0.0001 | 1.008 | 537.6 | 101.9 | 0.196 | 0.4890 | 0.4540 | 0.037 |
|  | Minimum | 20,476 | 20,699 | 0.890 | 21.7 | 29.7 | 0.660 | 0.0003 | 0.0005 | -0.0025 | 0.660 | 5.3 | 2.3 | 0.020 | 0.0382 | 0.0095 | -0.027 |
|  | Maximum | 131,619 | 135,143 | 1.310 | 3,104.2 | 3,084.8 | 1.470 | 0.0771 | 0.0757 | 0.0024 | 1.460 | 5,070.1 | 639.3 | 1.000 | 0.9746 | 0.9749 | 0.306 |
| 3. 1 or 2 Tests Significant ( $\mathrm{n}=97$ ) | Mean | 52,545 | 53,561 | 0.987 | 1,214.5 | 1,154.4 | 1.113 | 0.0232 | 0.0216 | 0.0016 | 1.127 | 818.6 | 227.1 | 0.409 | 0.3665 | 0.2580 | 0.109 |
|  | Median | 44,922 | 45,259 | 1.003 | 969.4 | 908.2 | 1.088 | 0.0203 | 0.0184 | 0.0015 | 1.079 | 491.3 | 152.3 | 0.330 | 0.3155 | 0.1794 | 0.099 |
|  | Minimum | 22,955 | 23,674 | 0.380 | 59.5 | 39.5 | 0.350 | 0.0007 | 0.0005 | -0.0022 | 0.910 | 20.5 | 7.2 | 0.040 | 0.0881 | 0.0296 | -0.005 |
|  | Maximum | 127,273 | 127,942 | 1.090 | 5,502.7 | 5,309.4 | 2.040 | 0.0745 | 0.0765 | 0.0070 | 2.040 | 5,447.8 | 1,107.2 | 0.950 | 0.8478 | 0.8016 | 0.442 |
| 4. All Tests Significant$(n=83)$ | Mean | 55,054 | 54,593 | 1.007 | 1,715.6 | 1,398.1 | 1.297 | 0.0314 | 0.0257 | 0.0057 | 1.290 | 882.3 | 481.5 | 0.628 | 0.3321 | 0.1642 | 0.168 |
|  | Median | 51,405 | 50,004 | 1.001 | 1,604.6 | 1,378.2 | 1.253 | 0.0294 | 0.0228 | 0.0051 | 1.224 | 569.5 | 285.9 | 0.630 | 0.2982 | 0.1019 | 0.154 |
|  | Minimum | 18,733 | 17,825 | 0.870 | 161.4 | 109.2 | 1.040 | 0.0024 | 0.0014 | 0.0010 | 1.060 | 37.8 | 19.6 | 0.050 | 0.0801 | 0.0253 | 0.047 |
|  | Maximum | 143,988 | 139,154 | 1.130 | 4,793.9 | 3,814.3 | 1.980 | 0.0860 | 0.0806 | 0.0227 | 1.980 | 6,101.9 | 2,834.3 | 0.990 | 0.7552 | 0.6349 | 0.405 |
| $\begin{gathered} \text { Total } \\ (\mathrm{n}=286) \end{gathered}$ | Mean | 54,288 | 54,231 | 1.003 | 1,169.7 | 1,078.8 | 1.108 | 0.0221 | 0.0203 | 0.0018 | 1.105 | 822.8 | 272.5 | 0.422 | 0.3956 | 0.2970 | 0.099 |
|  | Median | 45,800 | 45,701 | 1.003 | 885.1 | 845.5 | 1.088 | 0.0187 | 0.0167 | 0.0014 | 1.082 | 528.7 | 171.4 | 0.334 | 0.3599 | 0.2122 | 0.080 |
|  | Minimum | 18,733 | 17,825 | 0.380 | 12.5 | 26.2 | 0.040 | 0.0002 | 0.0003 | -0.0459 | 0.040 | 5.3 | 2.3 | 0.020 | 0.0382 | 0.0095 | -0.299 |
|  | Maximum | 143,988 | 139,154 | 1.310 | 5,502.7 | 5,309.4 | 2.040 | 0.0860 | 0.0806 | 0.0227 | 2.040 | 6,101.9 | 2,834.3 | 1.000 | 0.9746 | 0.9749 | 0.442 |

Appendix 13: Plots showing regression models relating SIT-based and FRAM-based estimates of the exploitation rate on unmarked fish to DIT-based estimates using the Paired-Ratio (PR) method and $\lambda^{\text {Rel }}$, by hatchery (see Section 7.6 for more details).





















## Appendix 14: Sensitivity and Power Analysis for Z Test Of Differences In Return Rates of marked and unmarked groups of a DIT pair

Tests for differences in the returning proportion of marked and unmarked fish in a DIT group, i.e., $p^{m}$ and $p^{u}$, respectively, is one method used to assess impacts of mark-selective fisheries. The ability to detect meaningful differences in return rates is governed by the precision of proportion estimates. Higher variances (less precision) will reduce the power of tests differential return rates. The total variance for the proportion of group $i$ fish (marked or unmarked) returning to the hatchery, $p^{i}$, out of the number released from group $I, N^{i}$, is,

$$
\operatorname{Var}\left(p^{i}\right)=\frac{p^{i}\left(1-p^{i}\right)}{N^{i}}+\frac{E^{i}\left(1-s^{H}\right)}{s^{H}},
$$

where $N^{i}=$ the number of tagged released in group $i(i=$ marked or unmarked $)$,
$E^{m}=$ the number of expected tags returning to the hatchery from group $i$ out of $N^{i}$ releases,
$p_{i}=$ the proportion of marked fish returning to the hatchery in group $i$.
The first term of the variance is the process error, which should not change under subsampling. The second term is the contribution from sampling and lowering $s^{H}$ from 1 will increase $\operatorname{Var}\left(p_{i}\right)$. Consequently, sub-sampling of hatchery escapement will reduce the ability to detect small but potentially important differences in the proportions of marked and unmarked fish returning to the hatchery from double index tagged (DIT) groups.

To examine the effects of reduced hatchery sampling on being able to detect the absolute difference in proportions of marked and unmarked fish returning to the hatchery, we looked reductions in the power of a test for different values of the sampling effort. The power equation for a two-tailed significance test is a follows,

$$
\text { Power }=P\left(Z_{\beta / 2}<\frac{\left(Z_{\alpha / 2} \sqrt{\operatorname{Var}\left(d_{0}\right)}\right)-d^{a b s}}{\sqrt{\operatorname{Var}\left(d_{a}\right)}}\right)+P\left(Z_{1-\beta / 2}>\frac{\left(Z_{1-\alpha / 2} \sqrt{\operatorname{Var}\left(d_{0}\right)}\right)-d^{a b s}}{\sqrt{\operatorname{Var}\left(d_{a}\right)}}\right),
$$

where $d^{a b s}$ is the minimum detectable difference between the null and alternative hypotheses,
$d_{0}=p^{u}-p^{m}$ under the null hypothesis $H_{o}$,
$d_{a}=p^{u}-p^{m}$ under the alternative hypothesis, $H_{a}$,
$Z=$ the standard normal random variate.
The term is $d_{a}-d_{0}$ is the detectable difference, or $d^{a b s}$, for the test. If we are testing for equal proportions then $d_{0}=0$. By formulating the detectable difference in this manner any differences of interest can be examined. For example, one could test a predicted difference
based on pre-season modeling results against an expected difference based on in-season fishery sampling.
The variance of the absolute difference is,

$$
\operatorname{Var}\left(p^{u}-p^{\prime}\right)=\frac{p^{u}\left(1-p^{u}\right)}{N^{u}}+\frac{p^{m}\left(1-p^{m}\right)}{N^{m}}+\left[\left(\frac{E^{u}}{\left(N^{u}\right)^{2}}+\frac{E^{m}}{\left(N^{m}\right)^{2}}\right) \frac{\left(1-s^{H}\right)}{s^{H}}\right]
$$

If we let $N^{u}=N^{m}=N, d^{a b s}=p^{u}-p^{m}, E^{u}=N p^{u}$, and $E^{m}=N p^{m}=N\left(p^{u}-d\right)$,then variance of the difference is,

$$
\operatorname{Var}(d)=\frac{p^{u}\left(1-p^{u}\right)}{N}+\frac{\left(p^{u}-d^{a b s}\right)\left(1-p^{u}+d^{a b s}\right)}{N}+\frac{\left(p^{u}+\left(p^{u}-d^{a b s}\right)\right)\left(1-s^{H}\right)}{N s^{H}} .
$$

Sampling at $100 \%$ the last term, the contribution to the variance from sampling error is 0 .
Sub-sampling will increase variances and decrease power for a given alpha level, release size, $N, p^{u}$, and $d^{a b s}$.
An alternative test statistic is the relative difference of the proportion of marked and unmarked returns, expressed as follows,

$$
d^{\text {rel }}=\frac{p_{u}-p_{m}}{p_{m}} .
$$

The variance of the relative difference calculated as,

$$
\operatorname{Var}\left(\frac{\left(p_{u}-p_{m}\right)}{p_{m}}\right)=\left[\frac{p_{u}}{p_{m}}\right]^{2}\left[\left(\frac{p_{u}\left(1-p_{u}\right)}{N_{u} p_{u}^{2}}+\frac{E_{u}\left(1-s^{H}\right)}{p_{u}^{2} N_{u}^{2} s^{H}}\right)+\left(\frac{p_{m}\left(1-p_{m}\right)}{N_{m} p_{m}^{2}}+\frac{E_{m}\left(1-s^{H}\right)}{p_{m}^{2} N_{u}^{2} s^{H}}\right)\right] .
$$

and the power to detect relative difference, $d^{r e l}$, is calculated as follows,

$$
\text { Power }=P\left(Z_{\beta / 2}<\frac{\left(Z_{\alpha / 2} \sqrt{\operatorname{Var}\left(d_{0}\right)}\right)-d^{r e l}}{\sqrt{\operatorname{Var}\left(d_{a}\right)}}\right)+P\left(Z_{1-\beta / 2}>\frac{\left(Z_{1-\alpha / 2} \sqrt{\operatorname{Var}\left(d_{0}\right)}\right)-d^{\text {rel }}}{\sqrt{\operatorname{Var}\left(d_{a}\right)}}\right)
$$

Essential to either analysis is obtaining a value either $p^{m}$ and $p^{u}$. For the purposes of this analysis we calculated $p^{m}$ as the proportion of returns averaged across all available brood years as a guide for what the proportions might be expected for a given hatchery. As yet, there is no guidance for selecting either absolute or relative differences that are important to fisheries management. For the purposes of this analysis in Section 2.5, a Type 1 error rate $5 \%(a=0.05)$ and a desired power is approximately $80 \%$ (Type II error of 0.2 ) to obtain relative differences achievable with the range of average release sizes and return rates observed in the DIT groups analyzed


[^0]:    ${ }^{1}$ Past committee members who greatly contributed to this report include Ms. Marianna Alexandersdottir, Mr. Robert Conrad, Mr. Tommy Garrison, and Mr. Joel Sawada.

[^1]:    ${ }^{1}$ Increased costs that are incurred by unnecessarily collecting and processing heads from ad-clipped fish that do not have a CWT.

[^2]:    ${ }^{2} \lambda$ is the ratio of the number of unmarked fish to marked fish in a DIT group measured either at release from the hatchery or in escapement (hatchery and spawning ground samples).

[^3]:    ${ }^{1}$ Escapement consists primarily of returns to the hatchery but, in some cases, includes recoveries from sampling on the spawning grounds and strays.

[^4]:    ${ }^{1}$ Averages calculated across brood years.

[^5]:    ${ }^{2} \lambda^{R e l}$ is used to specify lambda at release from the hatchery and $\lambda^{E s c}$ is used to specify lambda of the escapement.

[^6]:    ${ }^{1}$ In this report, CWT recoveries from mixed-regulation fisheries, i.e., recoveries where the "Adclip Selective Fishery" field in the recovery record were coded as "M", were treated as mark-selective fisheries.

[^7]:    ${ }^{1}$ The Paired-Ratio method using $\lambda^{\text {Rel }}$ was used for the DIT ER estimate. These DIT and SIT estimates do not include drop-off mortality.

[^8]:    ${ }^{1}$ Sampling at the hatchery (or on the spanning grounds) means directly handling a fish and assessing its mark and tag status.

[^9]:    ${ }^{2}$ The coefficient of variation $($ or CV $)=($ standard error of mean/mean $) \times 100 \%$. .

[^10]:    ${ }^{3}$ Percentages are based on total fishery recoveries and do not include escapement recoveries in the denominator.

[^11]:    ${ }^{4}$ Mixed-regulation fisheries were treated as mark-selective fisheries for the analyses.

[^12]:    ${ }^{5}$ Unmarked ER estimates include estimates of mortalities due to the release of unmarked fish in MSFs.

[^13]:    ${ }^{6}$ Directly sampled means a fish was physically examined, either by ETD or visually.

[^14]:    ${ }^{1}$ We acknowledge that this is a minimal estimate of expected average error since the model is being assessed using the same data used to estimate the model and that a jackknife assessment of model performance is more appropriate. However, for this initial investigation, we used the naïve assessment and recommend that future assessments use more robust estimation procedures, investigate alternative estimation models, and use additional model assessment methods.

[^15]:    ${ }^{1}$ For brood years 2009 and 2010, Salmon River Fish Culture, only some escapement recoveries were reported to RMIS. See notes in Table 1-5.

[^16]:    ${ }^{19}$ For brood years 2009 and 2010, Salmon River Fish Culture, only some escapement recoveries were reported to RMIS. See notes in Table 1-5; pg. 8.

