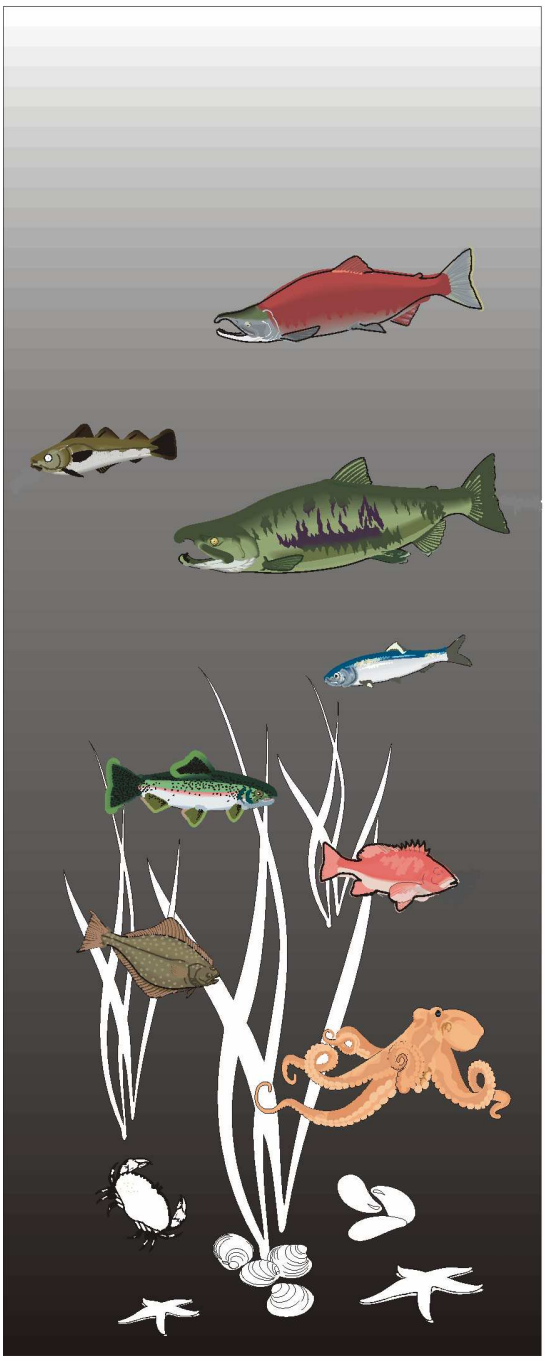
Northwest Fishery Resource Bulletin



Analysis of Coho Salmon Double Index Tag (DIT) Data for the Brood Years 1995-1997

By

Joint Coho DIT Analysis Workgroup

Project Report Series No. 12

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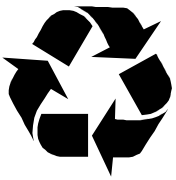

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Analysis of Coho Salmon Double Index (DIT) Data for the Brood Years 1995-1997

by

Joint Coho DIT Analysis Workgroup

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EXECUTIVE SUMMARY

Coded-wire tagged (CWT) hatchery groups are used as indicator stocks to represent naturally-spawning stocks originating within the same basin and region. The intent of the indicator stock program is to derive information on fishery distribution and exploitation rates in ocean fisheries using cohort analysis methods (ASFEC 1997). The CWT recoveries from sampled fisheries and escapement are used to estimate landed and non-landed mortalities (e.g., shaker mortality, catch-and-release mortality in species-selective fisheries) for input to the cohort analysis. Mass-marking of hatchery production using an adipose fin clip has provided management with the option of using mark-selective fisheries which allow the release of unmarked fish while marked (adipose fin clipped) hatchery fish can be exploited. This introduced a new type of non-landed mortality that previous methods in cohort analysis did not address (ASFEC 1997, SFEC-AWG 2002). The indicator stock program was changed to include double indexed tag (DIT) groups. Double index tagged (DIT) groups are paired coded wire tagged (CWT) groups that are reared and released in a similar manner and are identical with the exception that one of the groups in the pair is adipose fin clipped (marked) and the second is not clipped (unmarked).

A workgroup of biologists and biometricians from Washington State Tribes and the Washington Department of Fish and Wildlife analyzed double index tag data for coho salmon from brood years 1995-1997. Attempts were made to analyze each of the stocks with four methods (SFEC-AWG 2002). All of these methods rely on the ratio of the unmarked and marked tag groups in each DIT indicator group. Two of the methods estimate the total mortality of unmarked fish in all mark-selective fisheries combined. The remaining two methods estimate the total mortality of unmarked fish in individual fisheries.

For each analysis, the assumptions of the four methods were evaluated and several concerns identified. These concerns range from assumption violations due to sampling methods that may be alleviated to violations due to inherent impacts of conducting mark-selective fisheries that may not be correctable. An overall analysis is also conducted to examine whether the mark-selective fisheries have detectable impacts on the coho salmon tag groups in these years.

Seventeen hatchery-release DIT programs for Washington coastal stocks and Washington Puget Sound stocks are analyzed for brood years 1995, 1996, and 1997. During the analyses two concerns related to sampling and data were identified.

Inadequate reporting and sampling: Some spawning ground escapements and fisheries were not sampled for coded wire tags. There are also fisheries with no recorded catch, and tagged recoveries from escapements and catches that were not accounted for. These sources of unsampled or non-reported mortalities or escapements would impact exploitation rate analysis whether fish were double index tagged or not and whether fisheries were mark-selective or not. The consequences of inadequate reporting and sampling are biased estimates of exploitation rates.

Reporting errors: There were errors noted in the release database fields[1] relating to whether a tag code was DIT, whether the fishery is mark-selective, identification of the detection method used in the fishery, and identification of the related group ID.

[1] Coded Wire Tag release and recovery data are maintained by the Pacific States Marine Fisheries Commission on the Regional Mark Information System or RMIS.

Estimates of mortalities of unmarked tagged fish in mark-selective fisheries

Estimates of unmarked mortalities were made using three of the methods described in SFEC-AWG (2002). All of the methods use the information provided by the unmarked-to-marked ratio for the tag groups in the DIT groups. Two of the methods were designed to estimate total unmarked mortalities summed over all mark-selective fisheries. Those methods were applied and resulted in imprecise and often biased estimates. Imprecision was due to the small number of mortalities being estimated. The bias was due to violation of the assumption that all fishery mortalities and all escapements were sampled and reported.

The third method, paired-ratio, was designed for pairing of non-selective and selective fisheries (SFEC-AWG 2002). However, the number of tag recoveries in the non-selective fishery component of the non-selective|selective fishery pairs was insufficient for a precise estimate of the unmarked-to-marked ratio of the DIT groups in the non-selective fishery for extrapolation to the subsequent selective fishery. Consequently, two alternative estimates were calculated using ratios from release and escapement.

The group was unable to determine which source of the unmarked-to-marked ratio, at release or at escapement, was preferred so estimates are reported for both. The estimates using release ratios are expected to yield underestimates of unmarked mortalities and the method using escapement ratios are expected to yield overestimates of unmarked mortalities. Therefore, reporting both provided a bounded range for the estimates.

Uncertainty in estimates of unmarked mortalities in mark-selective fisheries is due to bias as well as to sampling error (imprecision). Bias, unlike uncertainty due to imprecision, cannot be quantified using sampled data from unmarked fish in that fishery. The potential bias in estimates was evaluated using a range of unmarked-to-marked ratios and release mortality rates. The range of the ratio was bounded by the ratios at release and at escapement, although the differences between the two were not significant for the individual brood years and hatcheries. The range of release mortalities chosen by the authors was based on the release mortality rates currently used in pre-season management models.

Differences between marked and unmarked tag groups

Tests were conducted that compared the escapement return ratios of unmarked to marked DIT fish to the ratio at release. If mark-selective fisheries significantly impacted a stock, one would expect the ratio observed at escapement to favor unmarked fish. When the tests were conducted separately for each release group, 12 out of 37 were significant at the 0.05 level with 10 of the 12 favoring unmarked fish in the observed escapements. Most of the significant results were observed in coastal stocks.

When averaged over all DIT releases and all return years there was a detectable impact of mark-selective fisheries on exploitation rates. It is likely that the mortalities were too small to be detected using individual release groups, but combining release groups improved the power so that the impact was detected.

Recommendations

These recommendations from the workgroup are not listed in priority order.

- The impact to managers of conducting a mark-selective fishery is that the indirect estimation of unmarked, mark-selective mortalities adds additional uncertainty that cannot be directly quantified. As with drop-off mortality, catch-and-release mortality, and sub-legal mortality, these mortalities are indirectly estimated and unlike landed mortality, the uncertainties cannot be estimated from direct observation of tags in landed catch by samplers. Managers should consider these uncertainties and their implications regarding stock management objectives and the precision and accuracy of fishery evaluation tools.
- Whenever a mark-selective fishery is proposed managers should consider the source of data for estimating the unmarked-to-marked ratio (λ). The analyses for this report illustrated the importance of the unmarked-to-marked ratio of the DIT group, which is used to estimate encounters and cohort size for unmarked coho salmon. The bias and precision in the estimate of this ratio is critical for all of the methods for estimating unmarked mortalities in mark-selective fisheries.
- The assumptions required to obtain unbiased estimates of unmarked mortalities (using the methods developed by the SFEC-AWG) were often difficult to satisfy. Many of these situations could have been avoided, however, if the assumptions of the analytical methods were considered during the preseason planning process. With better communication between technical support staff and fisheries managers many of these problems could be avoided or minimized in the future.
- All fisheries and escapements should be sampled. Priority should be given to larger fisheries and to spawning grounds where there may be significant straying from indicator hatchery stocks.
- Evaluation of the impacts of mark-selective fisheries by comparison of the escapement of marked and unmarked groups in the DIT pairs relies on sufficient numbers of tags being released. Future tag group sizes should be evaluated with this objective in mind.
- Hatchery release and recovery programs for CWT groups in general and DIT groups in particular should be reviewed. Release programs should be mindful that tagged fish are randomly allocated to a mark status and that after tagging|marking, both groups are treated similarly (i.e., preferably are reared together). Hatchery programs for recovering CWTs from returning adults should also be reviewed to identify facility limitations and to ensure that sampling|handling practices are not mark-dependent (e.g., different detection devices used for unmarked and marked fish).
- Communication with hatchery managers and enhancement biologists on the goals and requirements of the DIT program is important and must be maintained.
- Training programs for samplers and hatchery staff should be continued and improved where necessary.
- Indicator stocks should be reviewed for their utility as indicator stocks. Hatchery stocks where returning tagged fish cannot be sampled in the escapement (e.g., net pens, or hatcheries with significant unsampled straying or annual flooding) should not serve as candidates for the exploitation rate indicator stock program.

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1 INTRODUCTION

Coded-wire tagged (CWT) groups of hatchery salmon are used to represent naturally-spawning stocks of salmon originating within the same basin and region. The intent of this indicator stock program is to derive information on fishery distribution and exploitation rates in ocean fisheries using cohort analysis methods (ASFEC 1997) under the assumption that the hatchery fish will exhibit the same migrational timing and ocean distribution patterns as the natural-origin fish they represent once they have left the watershed. The CWT recoveries from sampled fisheries and escapements are used to estimate landed and non-landed mortalities (e.g., shaker mortality and catch-and-release mortality in species-selective fisheries) which are used as inputs to cohort analysis. Mass-marking of hatchery production using an adipose fin clip has provided management with the option of using mark-selective fisheries to allow the release of unmarked fish while marked hatchery fish can be exploited. However, the mortality due to the release of the unmarked fish is a new type of non-landed mortality that previous methods in cohort analysis do not address (ASFEC 1997, SFEC-AWG 2002). Therefore, it was necessary to develop new methods to estimate the unmarked mortalities in mark-selective fisheries. The indicator stock program was changed to include double indexed tag (DIT) groups. Double indexed tag groups are indicator tag pairs intended to allow estimation of unmarked mortalities in mark-selective fisheries. The pair of tag groups is treated in an identical manner in rearing, tagging, and release with the only difference being that one tag group is marked (adipose fin clipped) and the other is unmarked.

Mark-selective fisheries have been directed at coho since 1998 and coded-wire tag data from double indexed stocks impacted by these fisheries are now available for brood years 1995-1997. ***In this report "marked" refers to adipose fin-clipped and tagged fish in the DIT pair, while "unmarked" refers to the unclipped and tagged fish in the pair.*** Methods for estimating unmarked mortalities due to catch and release in mark-selective fisheries using DIT groups have been developed by the Selective Fisheries Evaluation Committee – Analysis Work Group (SFEC-AWG 2002). Recognizing the need to analyze the coho tag data to estimate unmarked release mortalities in mark-selective fisheries and to evaluate the DIT program in general, a workgroup consisting of tribal and state biologists, as well as members of the SFEC-AWG was formed and charged with the task.

The analysis of the DIT data was used to answer two general categories of questions:

1. Are the analytical methods developed for estimating the mortality of unmarked salmon in mark-selective fisheries by the SFEC-AWG (2002) applicable to the coho data? Is it possible to verify the assumptions of the methods? Given the assumptions, how precise are the estimates?
2. Have the mark-selective fisheries resulted in lower mortalities on unmarked fish than marked fish as evidenced by a higher escapement rate of unmarked and tagged fish?

This workgroup focused its efforts on estimating unmarked mortalities in mark-selective fisheries using the analytical methods recently developed by the SFEC-AWG (2002). While assessing the effectiveness of mark-selective fisheries (category 2) was not the primary goal of this workgroup, some preliminary analyses were undertaken to examine the relative impacts on marked and unmarked fish as well as their relative contribution to escapement.

2 METHODS

2.1 Data Compilation

Data were pulled from the Pacific States Marine Fishery Commission (PSMFC) regional mark informational system (RMIS, http://www.rmis.org/) in October of 2002 for each DIT group (Table 1). In this database, DIT releases are identified by a "D" in the *related_group_type* field. Tag codes belonging to the same DIT release group are linked by a unique identifier in the *related_group_id* field. Release information from the RMIS was used to estimate unmarked-to-marked ratios at release (referred to as λ in this report) for each DIT group. Table 1 shows these estimates as well as the estimated unmarked-to-marked ratios of DIT groups at escapement (from samples at hatchery racks and natural spawning grounds). Only recoveries listed as sample type = 1 ("in-sample recoveries from a sampled fishery with known catch") in the PSMFC database were included in the analyses which estimated tagged harvest and escapement.

Several data quality control checks resulted in the discovery of a number of errors in the database. Some of these errors were related to a recent update in the format of the data to PSC version 4.0 (e.g., new reporting requirements regarding whether recoveries occurred in a mark-selective fishery and whether or not electronic tag detection was in place) or to new fields identifying DIT groups. A cross-tabulation for each DIT release group of tag codes by mark-status identified several coding errors (e.g., mislabeled *related_group_id*). The *detection_method* field was examined to determine the extent of visual sampling recorded in the database (this field was often incorrectly reported). Finally, the release mark (*cwt_1st_mark* in release database) was compared to the mark status recorded by the sampler (*recorded_mark* in the recovery database) to determine problems with either marking individuals or identifying the mark status (see Section 3.2.1). Errors were reconciled by working with appropriate agency staff and corrected in the PSMFC database whenever possible.

RMIS provided estimates of tagged fish harvested or in escapement. These are based on tag recoveries expanded to account for sampling fractions. Approximate estimates of the sampling variances associated with each recovery record were calculated using:

$$Var(\hat{X}) \approx \frac{O(1-s)}{s^2} \qquad (1)$$

where $\hat{X}$ is the estimated number of tags recovered (i.e., after expansion for sampling), O is the observed number of tag recoveries in the sample, and s is the expansion rate to account for catch sampling as well as lost or unreadable tags (Bernard and Clark 1996). The variance of a group of recoveries (e.g., all those recoveries making up a fishery) was estimated by summing the variances of the individual tag recoveries under the assumption that the recoveries were all mutually independent. This estimate of variance assumes that the catch is known and does not include the covariance component for combined tag codes and fisheries (which is usually relatively small).

Table 1. Hatchery release groups, showing unmarked-to-marked ratio (λ) at release and escapement

Hatchery|Sea Pen	Brood Year	Related Group ID	No. Unmarked Released	No. Marked Released	λ^{Rel}	λ^{Esc}
Bingham Creek	1995	419972203	74,919	72,016	1.04	4.66
Bingham Creek	1995	419972204	72,340	71,971	1.01	1.67
Bingham Creek	1996	419981011	61,023	59,913	1.02	1.14
Bingham Creek	1996	419981012	65,229	63,980	1.02	1.08
Bingham Creek	1997	419991009	74,744	75,449	0.99	0.85
Forks Creek	1995	419972401	75,497	75,294	1.00	1.34
George Adams	1995	419971601	45,243	45,068	1.00	0.93
George Adams	1997	419991020	21,728	20,817	1.04	1.18
George Adams	1997	419991021	22,312	22,280	1.00	1.08
Humptulips	1995	419972201	79,143	79,073	1.00	1.22
Humptulips	1996	419981001	74,509	79,321	0.94	1.09
Kalama Creek	1996	1419989001	48,782	44,078	1.11	0.00
Kendall Creek	1996	419981002	44,889	88,332	0.51	0.55
Kendall Creek	1997	419991010	33,824	35,209	0.96	0.94
Lower Elwha	1995	1419979001	72,909	78,150	0.93	1.03
Lower Elwha	1996	1419989002	75,203	78,862	0.95	0.89
Lower Elwha	1997	141999DI03	77,378	74,940	1.03	1.11
Makah NFH	1996	071998WM43	38,133	49,196	0.78	0.75
Makah NFH	1997	071999WM55	37,980	39,657	0.96	0.83
Marblemount	1995	419970301	42,567	42,489	1.00	0.93
Marblemount	1996	419981003	45,090	43,347	1.04	1.29
Marblemount	1997	419991007	41,907	42,298	0.99	
Port Gamble Bay Pens	1996	1419989004	49,500	50,017	0.99	
Port Gamble Bay Pens	1997	141999DI05	52,593	49,420	1.06	
Quilcene Bay Pens	1996	1419989006	44,859	42,377	1.06	
Quilcene Bay Pens	1997	141999DI02	45,788	48,875	0.94	1.09
Quilcene NFH	1996	071998WC15	40,861	45,411	0.90	0.84
Quilcene NFH	1997	071999WC35	46,235	48,413	0.96	0.98
Quinault NFH	1996	071998WT50	82,697	83,318	0.99	0.76
Quinault NFH	1997	071999WT85	78,347	80,935	0.97	0.96
Salmon River	1995	1419979002	71,285	98,028	0.73	1.27
Salmon River	1996	1419989003	98,473	73,928	1.33	1.34
Salmon River	1997	141999DI04	68,234	72,236	0.94	1.50
Solduc	1996	419981009	73,698	71,336	1.03	1.12
Solduc	1997	419991005	69,987	73,132	0.96	1.10
Soos Creek	1996	419981005	41,127	44,781	0.92	0.74
Soos Creek	1997	419991004	41,879	42,430	0.99	1.29
Voights Creek	1996	419981007	20,761	19,927	1.04	0.89
Voights Creek	1996	419981008	20,077	20,106	1.00	1.29
Wallace River	1996	419981004	45,718	46,253	0.99	1.11
Wallace River	1997	419991002	45,091	45,005	1.00	1.06

Individual recovery records were mapped to fisheries using the Coded-wire tag Retrieval and Analysis System (CRAS) fishery definitions (CRAS is a program maintained by the NWIFC in Olympia, WA for the purpose of summarizing CWT data). CRAS fisheries are defined by PSMFC recovery location codes and fishery gear codes (see Appendix 1). In two instances, the CRAS fisheries grouped recoveries made in a non-selective fishery with those from a mark-selective fishery:

1. In 1998, the CRAS fishery labeled "WA Area 2 Sport" consisted of recoveries in Willapa Bay|Grays Harbor mark-selective fisheries as well as recoveries from non-selective fishing in Ocean Area 2.
2. In 1999, the opposite occurred. The CRAS fishery labeled "WA Area 2 Sport" consisted of recoveries in Willapa Bay|Grays Harbor non-selective fishery as well as recoveries from a mark-selective fishery in Ocean Area 2.

In both cases, the WA Area 2 sport fishery was split into two fishery strata, "WA Area 2 SF Sport" and "WA Area 2 NSF Sport."

2.2 Key Assumptions

All fisheries and spawning areas must be sampled in order to obtain unbiased estimates of exploitation rates using indicator tag groups (with or without DIT). In addition, comprehensive sampling programs are necessary for obtaining unbiased estimates of unmarked mortalities using two of the DIT methods developed by the SFEC (SFEC-AWG 2002). Finally, all of the SFEC methods for estimating unmarked mortalities assume that marked and unmarked fish are treated identically during rearing and that they are sampled identically (e.g., using the same electronic tag detection equipment) in fisheries and escapement. Violations of these assumptions can bias estimates of unmarked mortalities. Therefore, the first step in analyzing the DIT data was to evaluate the rearing and sampling history for each DIT group. This step was accomplished by contacting hatchery personnel; a checklist of questions regarding potential concerns was used to facilitate this inquiry (Appendix 2).

2.3 Methods for Estimating Unmarked Mortalities in Mark-Selective Fisheries

Four methods for estimating unmarked mortalities in mark-selective fisheries were developed by the SFEC-AWG. The assumptions of the methods, the equations required to implement the methods, and the properties of the methods are described in their report (SFEC-AWG 2002). All of these methods depend on the relationship between the unmarked and marked DIT groups, measured by the ratio of unmarked to marked fish (λ).

These methods can be categorized into two groups: total methods and fishery-specific methods. The total methods estimate the total impact on unmarked fish summed over all mark-selective fisheries by subtracting the number of fish accounted for (in either escapement or in non-selective fisheries) from an initial abundance estimate. The total methods do not produce fishery-specific estimates of mortalities. In contrast, the fishery-specific methods work by estimating the number of encounters of unmarked fish in a specific mark-selective fishery. Estimates of unmarked mortalities in this fishery are then estimated by applying a

selective fishery catch-and-release mortality rate, *sfm*, to the estimated number of encounters. Required assumptions for these methods are given in Table 2 and Table 3.

Table 2. Assumptions of the total methods (require λ but not *sfm*).

Equal Marine Survival (EMS) Method	
Key Assumptions	• There are no differential sources of mortality between unmarked and marked fish before the first mark-selective fishery. • All fisheries and escapement of both unmarked and marked fish are adequately sampled. • There are no non-fishing sources of mortality (i.e., natural mortality) on three year old fish. • Effects of multiple mark-selective fisheries do not need to be separable by fishery.
Equal Exploitation Rate (EER) Method	
Key Assumptions	• An appropriate non-selective fishery is available to estimate the λ at large (for each DIT group) in pre-terminal areas before any mark-selective fisheries have occurred. • All fisheries and escapement of both unmarked and marked fish are adequately sampled. • There are no non-fishing sources of mortality (i.e., natural mortality) on three year old fish. • Effects of multiple mark-selective fisheries do not need to be separable by fishery.

Table 3. Assumptions of the fishery-specific methods (require λ and *sfm*).

Terminal (TERM) Method	
Key Assumptions	• The λ feeding into the terminal area is constant for the duration of the terminal area fisheries and escapement. • One can accurately estimate the abundance of marked and unmarked fish after the mark-selective fishery has occurred or one can estimate the number of marked and unmarked fish that were vulnerable to the fishery. • Fish do not encounter gear on multiple occasions. • The selective fishery mortality rate of unmarked fish released in the mark-selective fishery (*sfm*) is accurate.
Paired-Ratio (PR) Method	
Key Assumptions	• The λ in the mark-selective fishery can be estimated accurately for each DIT group (e.g., using a paired non-selective fishery). • The selective fishery mortality rate of unmarked fish released in the mark-selective fishery (*sfm*) is accurate. • Fish do not encounter gear on multiple occasions.

Workgroup members attempted to apply all four methods to the data for each release group. Problems with meeting the assumptions were noted, and results were reported for each method for which the assumptions were thought to be reasonably met (Appendix 3).

2.4 Methods to Test for Differences Between Marked and Unmarked Mortalities due to Mark-Selective Fisheries

Return rates of age three marked fish to escapement (i.e., the estimated proportion of the marked fish at release that escape to spawning grounds or hatchery racks, $\hat{p}_m$) were compared to the return rates of age three unmarked fish ($\hat{p}_u$) to ascertain whether mark-selective fisheries resulted in lower total mortalities of unmarked fish compared to marked fish. A z-test was used to assess statistical significance:

$$z = \frac{\hat{p}_u - \hat{p}_m}{\sqrt{\hat{Var}(\hat{p}_u) + \hat{Var}(\hat{p}_m)}} \ . \qquad (2)$$

$\hat{Var}(\hat{p}_u)$ and $\hat{Var}(\hat{p}_m)$ were calculated so as 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 escapement for tags. We illustrate the derivation of $\hat{Var}(\hat{p}_u)$ below:

$$Var(\hat{p}_u) = Var\left(\frac{\hat{E}^U}{N^U}\right) = \frac{Var(\hat{E}^U)}{[N^U]^2} \qquad (3)$$

where $\hat{E}^U$ is the estimated escapement of age three unmarked but tagged fish and N^U is the number of unmarked and tagged fish released (assumed to be known without error). To calculate the variance of $\hat{E}^U$ we condition on the true escapement and use the conditional variance formula, Var(X) = Var[E($X|Y$)] + E[Var($X|Y$)] (Casella and Berger 1990, pp.158-159) that can be described as measuring the process error and sampling error, respectively:

$$Var(\hat{E}^U) = \underset{\textbf{process error}}{Var[E(\hat{E}^U \mid E^U)]} + \underset{\textbf{sampling error}}{E[Var(\hat{E}^U \mid E^U)]} \qquad (4)$$

$$\approx N^U p_u(1-p_u) + E^U \frac{(1-s)}{s}$$

where s is the expansion rate for observed tags in escapement. The first term accounts for random variation due to chance survival events while the second term accounts for variation due to sampling escapement for tags. Replacing E^U with its estimate and combining (3) and (4), we get:

$$Var(\hat{p}_u) \approx \frac{\hat{p}_u(1-\hat{p}_u)}{N_u} + \frac{\hat{E}^U(1-s)}{s \cdot (N_u)^2} \ . \qquad (5)$$

In addition, the difference in the average return rate (across all *n* release groups) of marked and unmarked fish was estimated:

$$(\bar{p}_u \hat{-} \bar{p}_m) = \frac{\sum_{i=1}^{n} \hat{p}_u}{n} - \frac{\sum_{i=1}^{n} \hat{p}_m}{n}. \quad (6)$$

The variance of $(\bar{p}_u \hat{-} \bar{p}_m)$ was estimated assuming independence among release groups and using the individual variance estimates from equation (5):

$$\hat{Var}(\bar{p}_u \hat{-} \bar{p}_m) = \frac{\sum_{i=1}^{n} \left(\hat{Var}(\hat{p}_u) + \hat{Var}(\hat{p}_m)\right)}{n^2}. \quad (7)$$

We also examined relative differences in return rates, $\frac{(\hat{p}_u - \hat{p}_m)}{\hat{p}_m}$. We calculated 95% confidence intervals for the relative differences in return rates assuming the differences are normally distributed. We used the delta method to calculate the approximate variance of the differences:

$$Var\left[\frac{(\hat{p}_u - \hat{p}_m)}{\hat{p}_m}\right] \approx \left[\frac{1}{\hat{p}_m}\right]^2 Var(\hat{p}_u) + \left[\frac{\hat{p}_u}{\hat{p}_m^2}\right]^2 Var(\hat{p}_m). \quad (8)$$

3 RESULTS

3.1 General Concerns with Incomplete Sampling

Workgroup members encountered several problems when attempting to analyze the CWT data. In particular, the group had difficulty obtaining reliable estimates of escapement and total catch of tagged fish in all fisheries impacting the DIT groups. These problems are not specific to whether or not a fishery is mark-selective or to DIT groups, but arise when attempting to complete a cohort analysis to estimate exploitation rates for any tagged group of fish[2]. If escapement is not fully sampled, or if there are fisheries that are not sampled, then cohort sizes estimated from CWT recoveries will be biased low as tagged fish from the unsampled locations will not be accounted for in the total cohort size. It will be as if these fish did not exist. There will be a zero exploitation rate for an unsampled fishery and all other fishery-specific exploitation rates will be biased high because the cohort size will be too low.

When a mark-selective fishery is prosecuted, there will be biases due to non-sampled fisheries or escapement in addition to those described above. For the two total methods (EMS and EER) and the TERM method, unsampled escapement and fisheries will lead to bias in the estimated mark-selective fishery mortality (see methods in SFEC-AWG 2002). For the total methods, the cohort size of the marked group will be biased as will the total expanded unmarked tags from sampled fisheries and escapement. For the TERM method, the reconstruction of harvest rates of marked fish in the terminal fishery will be biased.

In addition to the problems related to incomplete sampling, the group discovered that the assumptions required to obtain unbiased estimates of unmarked mortalities using the methods developed by the SFEC-AWG (2002) were often difficult to satisfy. Many of these situations could have been avoided, however, if the assumptions of the analytical methods were considered during the preseason planning process. We hope that a benefit of the analyses presented here will be increased awareness of the requirements necessary to implement the analysis methods. With better communication between technical support staff and fisheries managers many of these problems could be avoided in the future.

3.1.1 Incomplete Escapement Estimation

Problem:

In many cases, a large proportion of the hatchery return was not sampled due to fish straying from the hatchery, fish being released above the hatchery to spawn naturally, or fish passing over hatchery racks during extreme flood events. Net pens potentially offer the most extreme case of unsampled escapement since there is no central location where returns can be sampled.

[2] An exploitation rate for an individual fishery is calculated as the total fishery mortality in that fishery divided by the total cohort size (which is the sum of all fishery mortalities plus escapement).

Consequences:

Three of the analytical methods available for estimating unmarked mortalities in mark-selective fisheries, the Equal Marine Survival Method (EMS), the Equal Exploitation Rate (EER) method, and the Terminal (TERM) method assume that a full accounting of escapement of tagged fish is available. When a proportion of the escapement is not sampled or accounted for, these methods will result in biased estimates of unmarked mortalities (SFEC-AWG 2002).

If expansion rates of hatchery returns do not account for non-sampled fish (e.g., fish released above the rack), then escapement estimates will be biased low for both marked and unmarked fish. Furthermore, estimates of the initial cohort size obtained from cohort analysis will be too small which results in biased estimates of exploitation rates.

Potential Solutions:

The solution is to obtain a complete estimate of the number of fish that escape to the hatchery and natural spawning areas. There are several problems that may make this goal difficult to achieve. Some of these difficulties are discussed below along with potential solutions.

There are not enough resources available to sample all fish that return to the hatchery. All fish entering the hatchery should be electronically sampled. If complete sampling (100%) is not possible due to logistics (e.g., personnel not available), then all fish that are handled should be sampled systematically. For instance, if 50% are to be sampled then every other fish should be sampled. Samplers should always record when 100% sampling is not possible. In addition to tag recovery information, the following information should be recorded: sampling period (month|week|day), number of fish sampled (s), number of fish handled (N), and the sampling rate (s/N).

Fish must be passed upstream for spawning. Fish passed upstream should be sampled electronically first. If this is not possible, then these fish should be counted and this count should be used to estimate the number of tagged fish passed upstream. Both marked and unmarked fish should be sampled in the same manner (e.g., do not use wands for unmarked fish and tube detectors for marked fish).

If both marked and unmarked fish are passed upstream, then the expansion rates should be adjusted for both sets of fish as in the following example:

Data:

Total number of hatchery returns:	6,000
Number of fish passed upstream and not sampled:	2,000
Number of fish sampled in hatchery	6,000
Sampling rate in the hatchery:	100%
Number of marked and tagged fish sampled in the hatchery:	182
Number of unmarked and tagged fish sampled in the hatchery:	220

Adjustment:

Estimated "sampling rate" $75\% \left(= \frac{6{,}000}{6{,}000 + 2{,}000} \times 100 \right)$

Estimated (expanded) number of marked fish to the hatchery[3]: 243 (= 182/0.75)
Estimated (expanded) number of unmarked fish to the hatchery[3]: 293 (= 220/0.75)

One can also estimate the uncertainty of the resulting estimates of marked and unmarked fish returning to the hatchery using equation (1) from section 2. The adjusted estimate of the number of hatchery recoveries and its estimated sampling variance will not constitute statistically valid estimates if the fish passed above the hatchery were not a random sample from the total number of fish entering the hatchery. Nonetheless, the adjusted estimates are preferable to the unadjusted numbers.

If only one group (e.g., unmarked fish) are passed upstream, use the example above but only for that group. Similarly, if marked and unmarked fish are passed upstream at different rates then the two groups will have different "sampling rates".

There is flooding and fish escape. If the number escaping can be recorded, then the method described above should be used. If the number escaping cannot be recorded, or a good estimate cannot be made, then this is a bias that cannot be estimated. Estimates of fish escaping upstream during a flooding event usually assume that fish do not move or are unable to move upstream through the system during a high flooding event, i.e., the number of fish counted in holding ponds from the evening prior to the flood event accurately reflects the number of fish passing upstream. If this assumption is incorrect (e.g., if fish pass upstream and are not observed or fish are swept downstream of the hatchery and are later double counted when they re-enter the hatchery) then estimates of escapement will be biased.

Hatchery fish stray onto the spawning grounds. Sampling spawners in the wild is difficult and time consuming and therefore sampling rates are often low (e.g., under 5-10%) leading to imprecise estimates. Run reconstruction methods might be used to estimate the number of hatchery strays in cases where an estimate of the total terminal run size is available (e.g., see the Voights Creek and Soos Creek analyses in Appendix 3.15 and Appendix 3.16). The specifics of the approach will depend on the spatial location of the hatchery, terminal area fisheries, and natural spawning grounds as well as the types of information available. Using run reconstruction methods, an estimate of hatchery strays is derived by subtracting individual components (e.g., terminal fishery mortalities or escapement components) from this estimate of the total terminal run. The variance of the estimate will be the sum of the variances of the individual components as well as the variance of the terminal run size estimate. Therefore, estimates of hatchery strays obtained from run reconstruction methods will typically be very imprecise. Although, estimates of total escapement to spawning grounds are often very uncertain, sampling spawning grounds offers a direct method of estimating hatchery strays and is generally preferable to run reconstruction methods.

[3] Estimate expanded for fish passed upstream and not sampled.

If there is no method available to estimate tagged strays, but straying is known to occur, then a sensitivity analysis can be conducted to determine how these non-sampled fish may influence the estimated exploitation rates. Conclusions regarding the resulting exploitation rates may be reduced to statements such as, "if there are *x* number of unsampled fish that escaped, then the exploitation rate is *y*." This type of result is less satisfactory than a statistically valid estimate of the exploitation rate. However, it is better to recognize that the estimates are uncertain because of unsampled escapement than to use the data as is, assuming that they are accurate. In addition, there may be situations where data can guide the sensitivity analysis. For example, if straying is due to a flood event, a comparison of escapements from flood years and non-flood years may allow one to determine a likely range for the non-sampled escapement.

Finally, if there are consistent problems with estimating escapement, then one may want to reconsider whether or not the stock should continue to serve as a DIT indicator stock.

3.1.2 Non-Sampled Fisheries and|or Non-Reported Catch

Problem:

Fisheries may not be sampled and in some cases harvest may not be reported at all. For example, in-river sport fisheries are often not sampled. However, generally an estimate of the total catch is available from catch record cards. Appendix 4 lists the freshwater sport fisheries that are likely to have exploited DIT groups on their return migration as adults. If total catch is known and an estimate of the proportion of tags is available from another source, the number of tagged fish harvested can be estimated. In some cases harvest is not reported or sampled, for example due to sales not reported on commercial fish tickets or sport catch record cards, or due to poaching. If a fishery harvest is not reported, the number of tagged fish cannot be estimated directly by any means.

Consequences:

Tagged harvest that is not accounted for has the same effect on estimated cohort sizes and exploitation rates as non-sampled escapement (cohort sizes are underestimated and individual exploitation rates are overestimated). Similarly, estimates of unmarked mortalities using the EMS or EER methods will be biased in the same manner as that due to non-sampled escapement. And, if the fisheries occur in terminal areas, they may bias estimates of unmarked mortalities using the TERM method.

Possible Solutions:

The best solution is to sample all fisheries (i.e., freshwater fisheries should be planned with the intent of sampling them). Estimates of CWT recoveries in freshwater sport fisheries are most easily obtained by combining estimates of catch (from catch record cards) with estimates of the tag rate of marked and unmarked fish from a sample of fish caught in the fishery. For fisheries with recorded catch but no sampling, one might choose to apply the tag rates estimated from a fishery in a similar area|time stratum (see for example Voights Creek in Appendix 3.15). Estimates will be biased to the extent that the catch composition differs between the sampled and unsampled fisheries. When catch is not reported it is not possible to estimate mortalities.

In those cases where it is not feasible to sample a significant freshwater fishery or where non-reporting occurs, then one can conduct a sensitivity analysis to determine the significance of the problem. If the estimates of exploitation rates appear to be highly sensitive to assumed levels of non-reporting and non-sampled fishery mortalities, and the problem cannot be alleviated, then the hatchery stock may not be an appropriate exploitation rate indicator.

3.2 Data Quality Checks and New Data Needs

Significant modifications to sampling programs and to fisher behavior have been necessary since the implementation of mass marking, double index tagging, and mark-selective fisheries for coho salmon. Electronic detection is required in order to obtain unmarked CWT recoveries. In addition, mark-selective fisheries require fishers to be knowledgeable of mark-selective fishery regulations and to be able to recognize the mark status of fish. Finally, these modifications have led to additional data requests and reporting requirements.

3.2.1 Electronic Tag Detection

All of the methods developed by the SFEC-AWG assume that electronic tag detection is being used in all fisheries and that the detectors are working effectively. Currently, Alaskan fisheries are not sampled electronically. Unmarked recoveries in these fisheries were estimated using the PR method with the selective fishery release mortality rate, *sfm*, set equal to 1 (all unmarked fish that are encountered in these fisheries are kept and therefore die) and λ estimated at release (under the assumption that these fisheries have not been influenced by prior mark-selective fisheries). In addition, several other recoveries in the database were listed as being detected using "visual" detection (i.e., by searching for a missing adipose fin). Most of these recoveries appear to have been misreported. For example, all CWT recoveries by Oregon Department of Fish and Wildlife (ODFW) were reported as having been visually detected when in fact they were electronically detected (John Leppink *ODFW, personal communication*). ODFW staff has been made aware of this problem and plan to correct the data as time permits. Other (non-Alaskan and non-Oregon) recoveries that were recorded as having been detected using visual sampling are listed in Table 4.

Table 4. Recoveries recorded as detected using "visual" sampling, i.e., using the presence of an adipose fin clip as a CWT identifier.

Fishery Name	Recovery Location Code	Location Name	Return Year	Mark Type	Frequency
Escapement	2FS99GSVIH0100	H-BIG QUALICUM R	1999	M	1
Escapement	3F10107 010406 H	KENDALL CR HATCHERY	1998	M	1
Escapement	3F10308 070943 H	WALLACE R HATCHERY	1998	M	1
Escapement	3F10412 170012 H	QUILCENE NFH	1998	M	1
Escapement	3F10412 170012 H	QUILCENE NFH	1998	U	2
Escapement	3F21702 210429 H	QUINAULT NFH -COOK C	1998	M	2
Freshwater Net	3F21702 210398 R	QUINAULT R 21.0398	1999	U	1

3.2.2 Identification of Mark-Selective Fisheries

Another new field, *adclip_selective_fishery*, was added to the PSMFC database in order to identify mark-selective fisheries. We found that this information was not always correctly reported. In particular, all coho fisheries in Oregon were mark-selective but none of these were identified as such in the database. ODFW staff has been made aware of the problem and plans to correct the data as time permits (John Leppink *ODFW, personal communication*). Similarly, Washington sport recoveries in areas 5, 6, and 13 in year 2000 were reported as non-selective when these fisheries were mark-selective.

3.2.3 Non-Retention of Legal Fish

Traditionally estimates of exploitation rates in fisheries have accounted for non-landed mortalities due to fish "drop off" as well as catch-and-release mortalities of non-legal fish (e.g., due to size or species restrictions), but have ignored mortalities associated with the release of legal-sized (i.e., retainable) fish. Similarly, the methods developed by the SFEC assume that all encountered marked fish are kept and all encountered unmarked fish are released in mark-selective fisheries. However, retainable fish (in mark-selective or non-selective fisheries) may be released because anglers have already reached their bag limit, because they hope that they will catch larger fish before reaching their bag limit, or because they are simply not interested in retaining any fish.

Estimating mortalities from non-retention of legal-sized fish can be problematic because it requires assumptions or additional information regarding angler behavior (e.g., an estimate of the non-retention rate of legal-sized fish = number of legal-sized fish that are released / number of legal-sized fish that are encountered). And, although it may be possible to estimate the non-retention rate of legal-sized fish in a fishery, apportioning these mortalities to tag group requires additional assumptions. These estimation problems are compounded by increasingly complex fishery regulations (e.g., an overall bag limit of two fish of which only one can be unmarked). This type of fishery regulation will likely result in different non-retention rates for marked and unmarked fish. Workgroup members also expressed concern that anglers may choose to release unmarked fish in non-selective fisheries. Therefore, estimation of mortalities due to non-retention of legal fish will likely require separate estimates of non-retention rates for marked and unmarked fish in both mark-selective and non-selective fisheries.

3.2.4 Unmarked-Retention Error

In some of the mark-selective fisheries, unmarked and tagged fish were observed in the sample of landed fish. In these fisheries, any recoveries for tag codes representing unmarked fish represent either: (1) non-compliance with fishery regulations (purposeful or non-purposeful) or (2) fish tagged with a tag code indicating an unclipped fish, but that lacked an adipose fin. Either they were mistakenly marked before release or naturally lost their adipose fin. Regardless, mortalities due to the retention of unmarked fish can be estimated by directly sampling landed catch if both marked and unmarked fish are sampled in all fisheries using electronic tag detection equipment.

3.2.5 Comparison of Sample Mark versus Release Mark – Mark Error

With the advent of mass marking both the release mark (in the release database) and the mark recorded by the sampler (in the recovery database) are available. This provides an opportunity to evaluate quality control by comparing the release mark to the sample mark. This type of analysis can help flag fisheries or release groups with error rates that are larger than average. Table 5 and Table 6 provide information regarding these mark error rates by DIT group. A high mark error rate for a particular DIT group may be indicative of:

- a problem at the hatchery when fish were marked (e.g., fish that should be unmarked were marked, or vice versa); or
- a high error rate by the samplers at the hatchery or in a fishery that has a high exploitation rate on that stock (e.g., samplers accustomed to historic CWT indicator groups where all tagged fish were marked might have initially been prone to recording all tagged fish as marked regardless of their true mark status); or
- a release group of unmarked fish with an abnormally high rate of natural adipose fin loss; or
- a release of marked fish with a larger than normal regeneration rate of the adipose fin.

A large proportion of the hatchery returns for the U. S. Fish and Wildlife Service release groups from the Makah and Quinault National Fish Hatchery (NFH) were recorded as having an "unknown" mark status when sampled.

Table 5. Percent of marked fish that were recorded by sampler as unmarked, marked, and unknown by hatchery and brood year.

Release Mark Type	Hatchery	Brood Year	Sample Mark Type			Number observed tags
			Unmarked (%)	Marked (%)	Unknown (%)	
M	Bingham Creek	1995	3	96	1	974
M	Bingham Creek	1996	2	98	0	1,316
M	Bingham Creek	1997	2	98	0	589
M	Forks Creek	1995	6	93	1	245
M	George Adams	1995	1	99	0	221
M	George Adams	1997	1	99	0	777
M	Humptulips	1995	1	96	3	349
M	Humptulips	1996	16	84	0	966
M	Kalama Creek	1996	50	50	0	4
M	Kendall Creek	1996	4	96	0	677
M	Kendall Creek	1997	3	97	0	366
M	Lower Elwha	1995	1	99	1	143
M	Lower Elwha	1996	7	92	1	370
M	Lower Elwha	1997	6	93	1	311
M	Makah NFH	1996	2	37	61	503
M	Makah NFH	1997	1	68	31	188
M	Marblemount	1995	1	99	0	1,344
M	Marblemount	1996	3	97	0	441
M	Marblemount	1997	2	97	1	2,135
M	Port Gamble Bay Pens	1996	2	98	0	201
M	Port Gamble Bay Pens	1997	4	96	0	56
M	Quilcene Bay Pens	1996	1	96	3	224
M	Quilcene Bay Pens	1997	2	98	0	505
M	Quilcene NFH	1996	0	96	4	242
M	Quilcene NFH	1997	4	96	0	481
M	Quinault NFH	1996	2	75	23	708
M	Quinault NFH	1997	3	92	5	1,005
M	Salmon River	1995	3	97	0	604
M	Salmon River	1996	1	99	0	465
M	Salmon River	1997	2	98	0	339
M	Solduc	1996	2	98	0	1,595
M	Solduc	1997	5	95	0	1,638
M	Soos Creek	1996	2	98	0	280
M	Soos Creek	1997	9	87	4	1,161
M	Voights Creek	1996	1	99	0	204
M	Wallace River	1996	2	98	0	981
M	Wallace River	1997	3	96	1	3,266

Table 6. Percent of unmarked fish that were recorded by sampler as unmarked, marked, and unknown by hatchery and brood year.

Release Mark Type	Hatchery	Brood Year	Sample Mark Type			Number observed tags
			Unmarked (%)	Marked (%)	Unknown (%)	
U	Bingham Creek	1995	95	5	0	1,018
U	Bingham Creek	1996	98	2	0	1,465
U	Bingham Creek	1997	95	5	0	496
U	Forks Creek	1995	95	4	1	314
U	George Adams	1995	95	5	0	204
U	George Adams	1997	85	13	2	852
U	Humptulips	1995	96	3	1	397
U	Humptulips	1996	80	20	0	1,013
U	Kalama Creek	1996	20	80	0	5
U	Kendall Creek	1996	95	5	0	356
U	Kendall Creek	1997	95	5	0	361
U	Lower Elwha	1995	98	1	1	151
U	Lower Elwha	1996	86	2	12	323
U	Lower Elwha	1997	89	9	2	347
U	Makah NFH	1996	30	2	68	336
U	Makah NFH	1997	56	4	40	136
U	Marblemount	1995	90	10	0	1,264
U	Marblemount	1996	97	3	0	518
U	Marblemount	1997	94	4	2	1,996
U	Port Gamble Bay Pens	1996	95	5	0	159
U	Port Gamble Bay Pens	1997	87	9	4	70
U	Quilcene Bay Pens	1996	91	6	3	220
U	Quilcene Bay Pens	1997	96	4	0	476
U	Quilcene NFH	1996	92	3	5	193
U	Quilcene NFH	1997	95	5	0	452
U	Quinault NFH	1996	87	1	12	634
U	Quinault NFH	1997	95	1	4	848
U	Salmon River	1995	96	4	0	461
U	Salmon River	1996	99	1	0	428
U	Salmon River	1997	98	2	0	305
U	Solduc	1996	97	3	0	1,732
U	Solduc	1997	95	5	0	1,643
U	Soos Creek	1996	88	10	2	224
U	Soos Creek	1997	84	11	5	1,462
U	Voights Creek	1996	93	7	0	217
U	Wallace River	1996	91	9	0	1,051
U	Wallace River	1997	94	5	1	3,385

Table 7 and Table 8 list the error rates by fishery for all DIT groups combined. Large error rates over all DIT groups encountered in a single fishery may be indicative of unusually high sampler error rates. In these cases sampler training should address the problem.

Table 7. Percent of marked fish that were recorded by sampler as unmarked, marked, or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
M	Buoy 10 Sport	N	1998	0	100	0	2
M	Buoy 10 Sport	N	2000	0	100	0	2
M	Coos Bay Sport	Y	1999	0	100	0	4
M	Coos Bay Sport	Y	2000	0	100	0	3
M	Escapement	N	1998	2	98	0	3,443
M	Escapement	N	1999	4	89	7	7,550
M	Escapement	N	2000	3	96	1	10,050
M	Freshwater Net	N	1998	2	98	0	567
M	Freshwater Net	N	1999	2	98	0	746
M	Freshwater Net	N	2000	4	94	2	851
M	Freshwater Sport	Y	1998	0	100	0	14
M	Georgia|Juan de Fuca|Johnstone	Y	2000	0	100	0	1
M	Grays Harbor Net	N	1998	0	37	63	27
M	Grays Harbor Net	N	1999	0	100	0	9
M	Grays Harbor Net	N	2000	8	92	0	12
M	Newport Sport	Y	1999	0	100	0	10
M	Newport Sport	Y	2000	0	100	0	30
M	Southeast Alaska Net[3]	N	1998	0	100	0	3
M	Southeast Alaska Net[3]	N	1999	0	100	0	3
M	Southeast Alaska Troll[3]	N	1998	0	100	0	26
M	Southeast Alaska Troll[3]	N	1999	0	100	0	15
M	Southeast Alaska Troll[3]	N	2000	0	100	0	7
M	Tillamook Sport	Y	1999	0	100	0	11
M	Tillamook Sport	Y	2000	0	100	0	6
M	WA Area 1 Sport	Y	1998	0	100	0	13
M	WA Area 1 Sport	Y	1999	0	100	0	62
M	WA Area 1 Sport	Y	2000	0	100	0	73
M	WA Area 1 Sport	N	2001	0	100	0	1
M	WA Area 1 Troll	Y	2000	0	100	0	52
M	WA Area 10 Net	N	1999	0	100	0	3
M	WA Area 10 Net	N	2000	10	90	0	10
M	WA Area 10 Sport	N	1998	0	100	0	6
M	WA Area 10 Sport	N	1999	29	71	0	7
M	WA Area 10 Sport	N	2000	3	97	0	35
M	WA Area 10A Net	N	2000	13	87	0	8
M	WA Area 10E Net	N	1998	0	100	0	1

- continued -

Table 7. Percent of marked fish that were recorded by sampler as unmarked, marked, or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
M	WA Area 10E Net	N	1999	0	100	0	1
M	WA Area 10E Net	N	2000	0	100	0	1
M	WA Area 11 Sport	N	1998	0	100	0	1
M	WA Area 11 Sport	N	1999	0	100	0	2
M	WA Area 11 Sport	N	2000	0	100	0	8
M	WA Area 12 Sport	N	2000	14	86	0	7
M	WA Area 12, 12B, 12C, 12D Net	N	1998	0	100	0	6
M	WA Area 12, 12B, 12C, 12D Net	N	1999	0	100	0	6
M	WA Area 12, 12B, 12C, 12D Net	N	2000	7	93	0	14
M	WA Area 12A Net	N	1998	0	100	0	2
M	WA Area 12A Net	N	1999	0	86	14	7
M	WA Area 12A Net	N	2000	5	93	2	96
M	WA Area 13 Sport	N	1998	0	100	0	1
M	WA Area 13 Sport	Y	2000	0	100	0	1
M	WA Area 13A Net	N	1998	0	100	0	1
M	WA Area 13A Net	N	2000	0	100	0	2
M	WA Area 13D Net	N	1998	0	100	0	1
M	WA Area 13D Net	N	2000	0	100	0	3
M	WA Area 2 NSF Sport	N	1998	6	94	0	35
M	WA Area 2 NSF Sport	N	1999	0	100	0	1
M	WA Area 2 SF Sport	Y	1998	0	100	0	10
M	WA Area 2 SF Sport	Y	1999	0	100	0	95
M	WA Area 2 Sport	Y	2000	0	100	0	187
M	WA Area 2 Troll	Y	2000	0	100	0	26
M	WA Area 3 Sport	N	1998	0	100	0	2
M	WA Area 3 Sport	Y	1999	0	100	0	97
M	WA Area 3 Sport	Y	2000	0	100	0	37
M	WA Area 3 Troll	N	1999	7	93	0	46
M	WA Area 4 Sport	N	1998	0	100	0	13
M	WA Area 4 Sport	Y	1999	0	100	0	84
M	WA Area 4 Sport	Y	2000	0	100	0	119
M	WA Area 4, 4B Troll	N	1998	0	90	10	20
M	WA Area 4, 4B Troll	N	1999	6	94	0	174
M	WA Area 4, 4B Troll	N	2000	0	100	0	24
M	WA Area 5 Sport	N	1998	0	100	0	25
M	WA Area 5 Sport	Y	1999	0	100	0	47
M	WA Area 5 Sport	Y	2000	0	100	0	97
M	WA Area 6 Sport	N	1998	10	90	0	10
M	WA Area 6 Sport	Y	1999	0	100	0	4
M	WA Area 6 Sport	Y	2000	0	100	0	26

- continued -

Table 7. Percent of marked fish that were recorded by sampler as unmarked, marked, or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
M	WA Area 6D Net	N	1998	0	100	0	1
M	WA Area 6D Net	N	1999	0	100	0	4
M	WA Area 6D Net	N	2000	0	100	0	1
M	WA Area 7 Sport	N	1998	0	100	0	1
M	WA Area 7 Sport	N	1999	33	33	33	3
M	WA Area 7B, 7C, 7E Net	N	1999	5	95	0	276
M	WA Area 7B, 7C, 7E Net	N	2000	3	97	0	77
M	WA Area 8 Net	N	1999	0	100	0	2
M	WA Area 8 Net	N	2000	0	100	0	5
M	WA Area 8 Sport	N	1998	0	100	0	1
M	WA Area 8 Sport	N	1999	0	100	0	4
M	WA Area 8 Sport	N	2000	0	100	0	2
M	WA Area 8-2 Sport	N	1998	0	100	0	19
M	WA Area 8-2 Sport	N	1999	0	100	0	8
M	WA Area 8-2 Sport	N	2000	2	89	9	46
M	WA Area 8A Net	N	1998	0	100	0	3
M	WA Area 8A Net	N	2000	0	100	0	7
M	WA Area 8D Net	N	1998	0	100	0	9
M	WA Area 8D Net	N	1999	0	100	0	24
M	WA Area 8D Net	N	2000	3	97	0	33
M	WA Area 9 Sport	N	1998	0	100	0	12
M	WA Area 9 Sport	N	1999	0	100	0	4
M	WA Area 9 Sport	N	2000	5	95	0	21
M	WA Area 9A Net	N	1999	1	99	0	157
M	WA Area 9A Net	N	2000	2	98	0	62
M	WA Areas 4B, 5, 6, 6A, 6C Net	N	1999	0	100	0	9
M	WA Areas 4B, 5, 6, 6A, 6C Net	N	2000	0	100	0	8
M	Willapa Bay Net	N	1998	8	88	4	48
M	Willapa Bay Net	N	1999	0	100	0	18
M	Willapa Bay Net	N	2000	0	100	0	7

[1] Alaskan fisheries were not electronically sampled.

Table 8. Percent of unmarked fish that were recorded by sampler as unmarked, marked or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
U	Buoy 10 Sport	Y	2000	0	100	0	1
U	Escapement	N	1998	94	6	0	3,548
U	Escapement	N	1999	89	6	5	7,707
U	Escapement	N	2000	92	6	2	10,587
U	Freshwater Net	N	1998	97	3	0	533
U	Freshwater Net	N	1999	98	1	1	737
U	Freshwater Net	N	2000	97	2	1	943
U	Freshwater Sport	Y	1998	75	25	0	8
U	Grays Harbor Net	N	1998	61	0	39	18
U	Grays Harbor Net	N	1999	100	0	0	6
U	Grays Harbor Net	N	2000	100	0	0	27
U	Tillamook Sport	Y	1999	0	100	0	1
U	WA Area 1 Sport	Y	1999	50	50	0	2
U	WA Area 1 Sport	Y	2000	0	100	0	2
U	WA Area 1 Troll	Y	2000	0	100	0	2
U	WA Area 10 Net	N	1998	100	0	0	1
U	WA Area 10 Net	N	1999	100	0	0	2
U	WA Area 10 Net	N	2000	100	0	0	11
U	WA Area 10 Sport	N	1998	100	0	0	5
U	WA Area 10 Sport	N	1999	100	0	0	12
U	WA Area 10 Sport	N	2000	96	4	0	46
U	WA Area 10A Net	N	2000	100	0	0	9
U	WA Area 10E Net	N	1999	100	0	0	2
U	WA Area 10E Net	N	2000	100	0	0	1
U	WA Area 11 Sport	N	1998	100	0	0	1
U	WA Area 11 Sport	N	1999	67	33	0	3
U	WA Area 11 Sport	N	2000	100	0	0	7
U	WA Area 12 Sport	N	1998	100	0	0	1
U	WA Area 12 Sport	N	2000	100	0	0	1
U	WA Area 12, 12B, 12C, 12D Net	N	1998	100	0	0	3
U	WA Area 12, 12B, 12C, 12D Net	N	1999	100	0	0	7
U	WA Area 12, 12B, 12C, 12D Net	N	2000	92	8	0	24
U	WA Area 12A Net	N	1998	100	0	0	2
U	WA Area 12A Net	N	1999	100	0	0	6
U	WA Area 12A Net	N	2000	95	5	0	113
U	WA Area 13 Sport	Y	2000	100	0	0	3
U	WA Area 13C Net	N	1999	0	100	0	1
U	WA Area 13D Net	N	1998	100	0	0	1
U	WA Area 2 NSF Sport	N	1998	77	23	0	30

- continued -

Table 8. Percent of unmarked fish that were recorded by sampler as unmarked, marked or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
U	WA Area 2 NSF Sport	N	1999	0	100	0	1
U	WA Area 2 SF Sport	Y	1998	50	50	0	2
U	WA Area 2 Sport	Y	2000	25	75	0	4
U	WA Area 2 Troll	N	1999	100	0	0	1
U	WA Area 2 Troll	Y	2000	0	100	0	1
U	WA Area 3 Sport	N	1998	100	0	0	3
U	WA Area 3 Sport	Y	1999	100	0	0	1
U	WA Area 3 Troll	N	1999	85	15	0	48
U	WA Area 4 Sport	N	1998	60	40	0	10
U	WA Area 4 Sport	Y	1999	0	100	0	1
U	WA Area 4 Sport	Y	2000	25	75	0	4
U	WA Area 4, 4B Troll	N	1998	93	7	0	15
U	WA Area 4, 4B Troll	N	1999	95	5	0	164
U	WA Area 4, 4B Troll	N	2000	97	3	0	30
U	WA Area 5 Sport	N	1998	90	10	0	21
U	WA Area 5 Sport	Y	1999	50	50	0	2
U	WA Area 5 Sport	Y	2000	0	100	0	4
U	WA Area 6 Sport	N	1998	100	0	0	9
U	WA Area 6 Sport	Y	2000	0	100	0	1
U	WA Area 6D Net	N	1998	100	0	0	2
U	WA Area 7 Sport	N	2000	100	0	0	3
U	WA Area 7, 7A Net	N	1998	100	0	0	1
U	WA Area 7B, 7C, 7E Net	N	1998	100	0	0	1
U	WA Area 7B, 7C, 7E Net	N	1999	97	3	0	158
U	WA Area 7B, 7C, 7E Net	N	2000	97	3	0	95
U	WA Area 8 Net	N	1999	100	0	0	2
U	WA Area 8 Net	N	2000	100	0	0	8
U	WA Area 8 Sport	N	1998	100	0	0	3
U	WA Area 8 Sport	N	1999	100	0	0	4
U	WA Area 8 Sport	N	2000	100	0	0	1
U	WA Area 8-2 Sport	N	1998	71	29	0	7
U	WA Area 8-2 Sport	N	1999	82	18	0	11
U	WA Area 8-2 Sport	N	2000	100	0	0	24
U	WA Area 8A Net	N	1998	100	0	0	2
U	WA Area 8A Net	N	2000	100	0	0	5
U	WA Area 8D Net	N	1998	50	50	0	6
U	WA Area 8D Net	N	1999	96	0	4	26
U	WA Area 8D Net	N	2000	96	4	0	50
U	WA Area 9 Sport	N	1998	79	21	0	14
U	WA Area 9 Sport	N	1999	71	29	0	7
U	WA Area 9 Sport	N	2000	81	19	0	16
U	WA Area 9A Net	N	1999	96	4	0	133
U	WA Area 9A Net	N	2000	92	4	4	73

- continued -

Table 8. Percent of unmarked fish that were recorded by sampler as unmarked, marked or unknown for all DIT groups combined within a fishery.

Mark Type	Fishery[1]	MSF (Y|N)	Return Year	Sample Mark Type			Number observed tags
				Unmarked (%)	Marked (%)	Unknown (%)	
U	WA Areas 4B, 5, 6, 6A, 6C Net	N	1998	100	0	0	5
U	WA Areas 4B, 5, 6, 6A, 6C Net	N	1999	100	0	0	16
U	WA Areas 4B, 5, 6, 6A, 6C Net	N	2000	86	14	0	7
U	WA Areas 6B, 9 Net	N	2000	80	20	0	5
U	West Coast Vancouver Island	N	1999	100	0	0	1
U	Willapa Bay Net	N	1998	96	3	1	71
U	Willapa Bay Net	N	1999	100	0	0	15
U	Willapa Bay Net	N	2000	100	0	0	4

[1] Alaskan fisheries were not electronically sampled.

Few unmarked fish were found in CWT samples from mark-selective fisheries, but they were often recorded as marked and so the error rate is high for unmarked fish (Table 8). These errors are due to either natural loss of the adipose fin or sampler error. Tagged and unmarked coho with natural adipose fin loss will show up as errors for unmarked fish as the sample mark status will be "marked" while the release mark status will be recorded as "unmarked". A second source of error may be due to samplers' assumption that any landed fish in mark-selective fisheries are marked since unmarked fish are not legal. Given the few unmarked fish landed in mark-selective fisheries, it is not surprising to see high error rates for unmarked fish in mark-selective fisheries (Table 8).

3.2.6 Rearing and Sampling of DIT Groups

A fundamental assumption required for valid inference regarding DIT groups is that the two groups of tagged fish (marked and unmarked DIT pair) have been treated identically during rearing. In addition, the two groups should be treated the same in non-selective fisheries and escapement, and they should be sampled using identical methods (e.g., either both groups should be sampled using wands or both should be sampled using tube detectors). This equal treatment is necessary to meet the assumptions that any significant differences noted between the two groups (e.g., differences in return rates) are due to mark-selective fisheries rather than some other confounding factor. In reality, however, differences could also result from the act of marking the fish (e.g., there may be delayed mark mortality).

In talking to hatchery managers, we found that marked and unmarked DIT pairs were, in general, treated similarly during rearing and tagging and during the adult return. However, some exceptions were found.

At Marblemount Hatchery it was discovered that unmarked fish were sampled using wands while marked fish were passed through tube detectors. This procedure was used so that unmarked fish (which were potentially of natural origin) could be passed upstream with minimal impact to these fish. When electronic tag detection is used properly for coho salmon both methods have been shown to have greater than 98% detection rates (ASFEC 1997). However, if the wands are used incorrectly or if the sensitivity of the tube detector is not set properly, detection rates can be degraded [e.g., dropping the detection rate to ~85%] (ASFEC 1997). Therefore, the use of different detection methods for unmarked and marked fish could bias comparisons of the number of expanded tags in these groups if there is sampler error associated with one of the two methods. We recommend that the same CWT detection methods be used for both unmarked and marked fish whenever fish are sampled.

We also discovered that while all marked fish were sampled at the weir on Bingham Creek, only 25% of unmarked males were sampled and no unmarked females were sampled at the weir. Again, this procedure was done in order to have minimal impact on the unmarked population. While expansion rates can adjust for differential sampling intensities, if males and female fish have different probabilities of having a tag then estimated recoveries of unmarked fish will be biased. We recommend that unmarked and marked tagged fish should always be treated, and sampled, in the same manner.

Another problem was noted with the release groups from George Adams Hatchery in 1997. Two DIT groups were used and the total release sizes for each of these DIT groups were half the normal size. One of the groups was released as an experimental group with an elastomer jaw tag. Since the two DIT groups had half the normal release size, less information is available to estimate unmarked mortalities and|or to detect differences in return rates between marked and unmarked groups. One alternative is to combine the two release groups, but in doing so, one must assume that there is no effect due to the elastomer jaw tag. In general, we recommend experimental groups be treated separately from DIT groups.

3.3 Problems Implementing the DIT Analytical Methods

The group discovered that in many cases there were problems with meeting the assumptions of the DIT methods. The methods will produce biased estimates of unmarked mortalities when the assumptions are not met. See SFEC-AWG (2002) for a detailed description of the equations and associated assumptions for all methods in this report.

3.3.1 Total Methods (EMS and EER)

These methods provide estimates of total mark-selective fishery mortality for the unmarked DIT tag group. They do not estimate fishery-specific exploitation rates of unmarked fish in multiple mark-selective fisheries. The methods use the estimates of total tagged harvest and escapement for marked and unmarked tag groups in the DIT pair. For the marked fish this represents the cohort size. The unmarked-to-marked ratio for the DIT group at the time prior to any fishery exploitation, or at time of recruitment, applied to the estimated marked cohort size estimates the unmarked cohort size. The total methods depend on two different methods for estimating this ratio. The difference between this unmarked cohort size and the total

tagged and unmarked harvest and escapement is an estimate of the unmarked mortalities in mark-selective fisheries.

Both total methods assume that all fisheries and escapement of both unmarked and marked fish are adequately sampled. This assumption was often not satisfied (see section 3.1). In addition, both methods produced estimates that were very imprecise. Typically, confidence intervals were extremely large and several of the estimates of unmarked mortalities were either negative or much larger than one would intuitively expect. These methods result in imprecise estimates of unmarked mortalities (SFEC-AWG 2002) because they require taking the difference between two quantities, both of which are estimated with error, and the variance of the estimate of unmarked mortalities is calculated by summing the variance of the two sub-components. When the difference being measured is small relative to the values being subtracted the resulting variances for the differences will be large. In the case of the mark-selective fisheries, the total recoveries being subtracted (and variances being summed) are very large relative to the smaller mark-selective fishery mortalities.

An example shown in Table 9 illustrates the imprecision of the estimates of unmarked mark-selective fishery mortalities. This example uses the Makah NFH data for 1996 (Appendix Tables 3.4.1 and 3.4.2) and the Equal Marine Survival method (EMS, see below).

Total tagged mortalities and escapement are estimated from sampled fisheries and escapement. The marked tag group cohort size is equal to the total tagged mortalities plus escapement or 2,088 fish (assuming all fisheries and escapement locations are sampled), with a variance of 8,457 and a CV of 4% (Table 9).

As the summed mortality and escapement for unmarked fish from sampled tagged fish represents an incomplete accounting, the unmarked group total cohort size is estimated by using the marked cohort size multiplied by the release unmarked-to-marked ratio for the DIT group (λ=0.775), giving 1,618 fish with a variance of 5,079 and a CV of 4% (Table 9).

The unmarked selective fishery release mortalities are estimated by subtracting the sum of unmarked mortalities and escapement estimated from tagged recoveries (1,551 fish) from the estimated cohort size (1,618) giving 68 fish (Table 9).

The variances for the unmarked mark-selective fishery mortalities are estimated by adding the variances for the two components in the above calculation (6,917+5,079 = 11,997). The result is a very large variance (11,997) for the unmarked mortalities in the mark-selective fisheries relative to the small number estimated of 68 fish; the CV is 162% which indicates a very imprecise estimate which will not be useful. The 95% confidence interval also illustrate the imprecision of the estimate, the confidence interval for the unmarked mortalities in the selective fishery goes from -147 to 282 fish.

Table 9. An example of estimation of total unmarked mortality in mark-selective fisheries using the Equal Marine Survival (EMS) method. Data from Makah NFH 1996 (Appendix 3.4) are used for this illustration.

	Marked	Unmarked
Total tagged mortalities and escapement	2,088	1,551
Variance	8,457	6,917
CV[4]	4%	5%
Cohort Size	2,088	1,618
Variance	8,457	5,079
CV	4%	4%
Estimated mark-selective fishery mortalities	117	68
Variance	159	11,997
CV	11%	162%
95% confidence interval[5]		
Lower	92	-147
Upper	149	282

By comparison, the estimate of marked mortalities in mark-selective fisheries is derived from tags recovered in samples and has a much smaller CV of 11% (Table 9). The Equal Exploitation Rate (EER) method similarly uses a differencing approach and is similarly imprecise.

3.3.1.1 EMS Method

The main assumption of the EMS method is that the survival from release to the first fishery is the same for both the unmarked and marked fish of a DIT group. Therefore, the assumption is that the unmarked-to-marked ratio, λ, is the same at the time of recruitment as it was at release. This assumption will be of concern only if there is a delayed (post-release) mortality associated with marking. In addition, the assumption that all fisheries and escapement are adequately sampled is of primary concern.

3.3.1.2 EER Method

This method does not require the assumption of equal survival from release to the first fishery, which may not be the case if there is any delayed mark-mortality. Instead, if the first fishery is a non-selective fishery, samples from that fishery will provide estimates of the unmarked-to-marked ratio at that point in time. The EER method requires a non-selective fishery from which one can estimate the ratio of unmarked to marked fish, λ, before any mark-selective fisheries have occurred. In 1999 and 2000, mark-selective fisheries were prosecuted before there were any non-selective fisheries. As mark-selective fisheries are prosecuted and unmarked fish are released, the λ of the DIT group should increase.

[4] $CV = \frac{standard\ error\ of\ estimate}{estimate}$

[5] 95% confidence interval = estimate ±1.96 *x* standard error.

Therefore, estimates of λ from non-selective fisheries that occur after mark-selective fisheries will be biased high. This precludes being able to use this method.

3.3.2 Fishery-Specific Methods (TERM and PR)

Both of the fishery-specific methods require an estimate of the catch and release mortality, *sfm*, in mark-selective fisheries. Currently, values of *sfm* used in preseason fishery assessment models range from 7 to 16%. Release mortality for adult coho salmon caught recreationally in Puget Sound is modeled preseason at 7% (coho less than 13" are modeled at 15%). The release mortality for recreational fisheries in the ocean is modeled at 14% (Larrie Lavoy *WDFW, personal communication*). These values could also be used for post-season analyses.

3.3.2.1 Paired-Ratio (PR) Method

The paired-ratio method uses estimated mortalities of marked fish for a DIT group in mark-selective fisheries (M^{SF}), and applies the unmarked-to-marked ratio for the DIT group (λ) to estimate the unmarked encounters in the fishery. The mortalities of unmarked fish (U^{SF}) are estimated by multiplying the encounters by a release mortality rate (*sfm*).

$$\hat{U}^{SF} = \hat{M}^{SF}\hat{\lambda}^{SF}\hat{sfm}$$

The ratio of unmarked to marked fish in the mark-selective fishery (λ^{SF}) that is required to estimate unmarked mortalities using the PR method is DIT group specific (i.e., λ^{SF} = the λ for a specific DIT group). The ratio λ^{SF} is not equivalent to the overall mark rate encountered by the fishery, since the fish that are encountered will include both tagged and untagged fish and fish from multiple stocks. For any specific mark-selective fishery, there are three potential sources that may provide an estimate of the λ in that fishery for any given DIT group, the λ at release (λ^{Rel}), the λ observed in one or more non-selective fisheries (λ^{NSF}), and the λ in escapement (λ^{Esc}).

Choosing Between λ^{NSF}, λ^{Rel}, and λ^{Esc}:

If the unmarked and marked DIT groups are treated identically until release and, assuming no delayed mark mortality, on average the λ for each DIT group should initially be the same in all locations and should be equal to λ^{Rel} (i.e., λ^{Rel} is an unbiased estimate of the fishery λ).

Mark-selective fisheries will result in a change in this ratio, and λ will increase since only marked fish are retained in these fisheries. However, this change in λ will be limited to regions impacted by the mark-selective fishery (either directly or through migration of fish that have escaped the fishery). The λs in geographical areas that are separated by a large distance from any mark-selective fishery should remain close to λ^{Rel}:

Region A impacted by the SF:	$E(\lambda^{Rel}) < E(\lambda^{A})$,
Region B not impacted by the SF:	$E(\lambda^{Rel}) = E(\lambda^{B})$.

Figure 1 illustrates the value of the unmarked-to-marked ratio throughout the migration of salmon returning within a single year under several scenarios. Each path ending with an arrow into escapement represents a different scenario. Starting with $\lambda^{Rel} = 1.0$ for simplicity, if there are no mark-selective fisheries, the expected λ^{Esc} is also 1.0 (Path A). If there are mark-selective fisheries the λ will change depending on the timing of the fisheries and the distribution of the tagged stock (Paths C and D). If there is delayed mark mortality, λ will increase even if there are no mark-selective fisheries (Path B).

Because coho salmon return predominately at age 3, with fisheries occurring on these stocks as they migrate towards terminal areas, one would expect that $\lambda^{Rel} \leq \lambda^{SF} \leq \lambda^{Esc}$ as in Path D. The SFEC suggested that an unbiased estimate of λ in any region could be obtained by "pairing" each mark-selective fishery with a non-selective fishery in the same time|area strata (SFEC-AWG 2002). If the non-selective fishery exploits fish with the same λ as the mark-selective fishery:

$$E(\lambda^{NSF}) = E(\lambda^{SF}) = E(\lambda).$$

The problem with estimating λ from a non-selective fishery is that it is difficult to obtain enough tags to insure that the estimate ($\hat{\lambda}^{NSF}$) will be close to λ^{SF}. In other words, $\hat{\lambda}^{NSF}$ is not a very precise estimator of λ^{SF}. In contrast, $\hat{\lambda}^{Rel}$ and $\hat{\lambda}^{Esc}$, which are based on large numbers of tagged fish will typically be very precise, but may be biased once mark-selective fisheries have already occurred. Hence, there is a bias versus precision tradeoff to using $\hat{\lambda}^{Rel}$ or $\hat{\lambda}^{Esc}$ versus $\hat{\lambda}^{NSF}$.

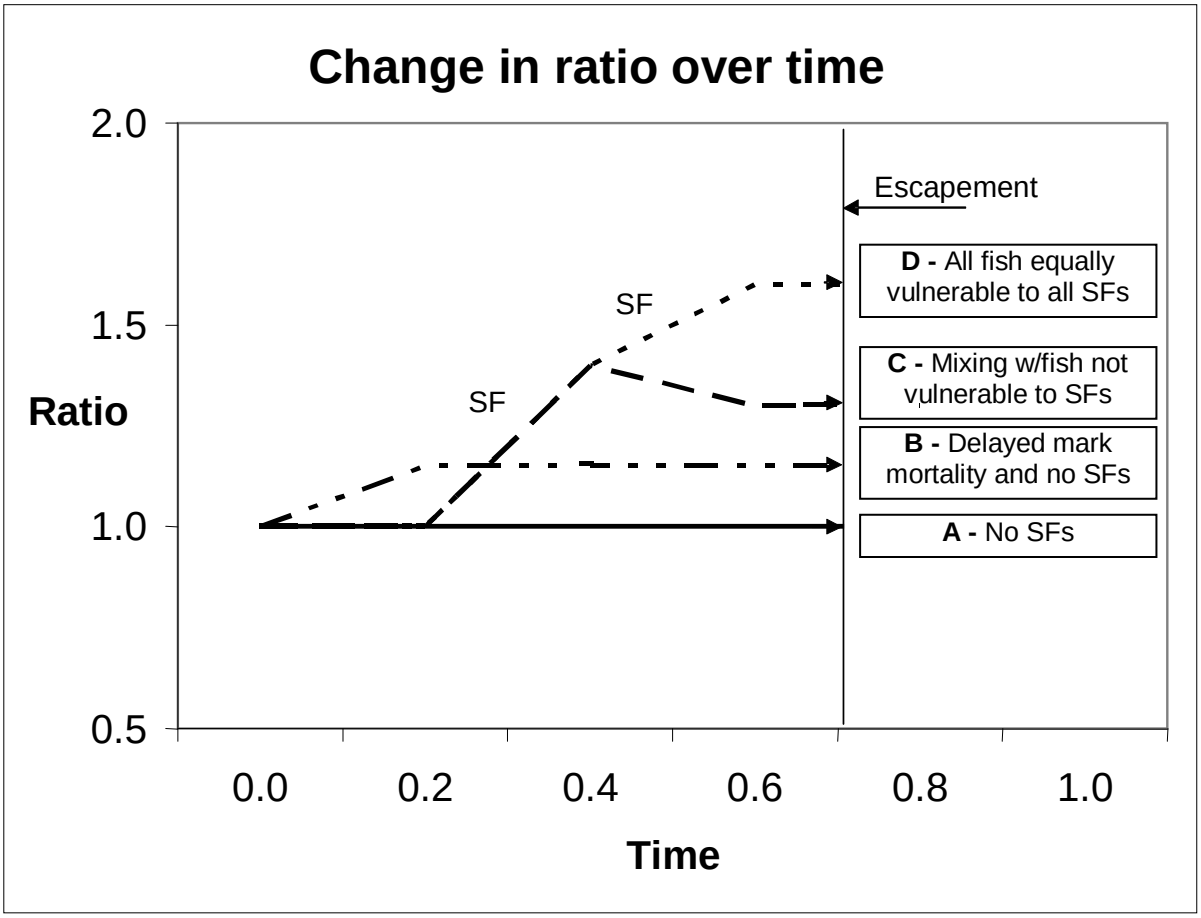

Figure 1. General schematic illustrating the potential change in the unmarked-to-marked ratio (λ) over time (starting with $\lambda^{Rel} = 1$) for a migration occurring within a single year (e.g., age 3 coho salmon) under several scenarios (with and without mark-selective fisheries and with no selective fishery but with delayed mark mortality). λ will increase with each new mark-selective fishery (SF) that impacts the stock. λ will increase if there is a delayed mark mortality effect. Furthermore, λ can decrease locally if fish from a DIT group that were not subjected to mark-selective fisheries enter the area and thereby "dilute" λ.

Statistically, estimators are evaluated in terms of their accuracy and precision. The best estimators are unbiased (on average, across all possible samples, the estimator is equal to the parameter that it is trying to estimate) and precise (the estimates do not vary much from sample to sample). Biased estimators systematically over- or under- estimate the true parameter; therefore, it is often preferable to consider unbiased estimators alone. In other cases, a biased estimator that is very precise may be preferable to a highly imprecise but unbiased estimator (Figure 2).

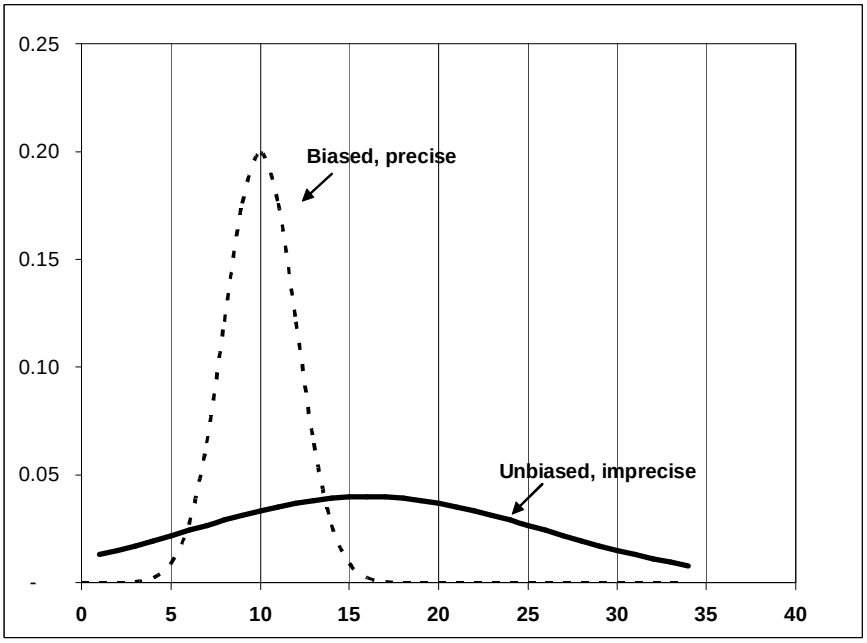

Figure 2. The sampling distribution of two estimates of unmarked mortality in a mark-selective fishery (SF) using different estimates of λ^{SF}. The estimates using λ^{Rel} is biased but precise due to the large number of tags. The estimate using recoveries from a paired non-selective fishery to estimate λ^{SF} is unbiased but very imprecise due to small numbers of tags recovered.

In general, estimates using λ^{Rel} and λ^{Esc} will be much more precise than those using λ^{NSF} as their estimation is based on larger numbers of sampled fish in the hatchery, but more prone to bias (Figure 2). The unmarked-to-marked ratio at release (λ^{Rel}) will always be biased low after the first mark-selective fishery (Figure 1). The ratio from escapement ($\hat{\lambda}^{Esc}$) will also be a biased estimator of λ in mark-selective fisheries. The direction of the bias, however, will be more difficult to infer than in the case with $\hat{\lambda}^{Rel}$. The relationship between λ^{Esc} and λ^{SF} will depend on the timing of the mark-selective fishery and its location relative to other later fisheries and escapement. If all of the stock is not equally vulnerable to all mark-selective fisheries, then λ^{Esc} can be lower or higher than the λ^{SF} it is estimating as seen in Path C in Figure 1. A simple example illustrating the problem is given below and in Table 10.

As shown in Table 10, initially equal numbers of marked and unmarked (but tagged) fish are released, λ^{Rel} =1. These fish distribute themselves into two distinct regions, A and B, with twice as many fish in region B than region A (Table 10). There are two distinct fishery time periods. In the first time period, there is a mark-selective fishery in region A (λ^{SF} = 4,000/4,000 = 1) and a non-selective fishery in region B. The harvest rate of both fisheries is 0.4. In the mark-selective fishery, the catch-and-release mortality rate, *sfm*, is 0.1. In the second fishery time period, there is a mark-selective fishery in Region A (λ^{SF} = 3,840/2,400 = 1.6) and a mark-selective fishery in region B (λ^{SF} = 4,800/4,800 = 1). In both of these fisheries, the harvest rate = 0.2 and the *sfm* = 0.1. All fish that are not caught in the second fishery time period escape.

Table 10. Example of the change in the unmarked-to-marked ratio, λ, during migration to escapement in two regions as mark-selective fisheries are executed.

	Region A		Region B		Combined	
	Number	λ	Number	λ	Number	λ
After Release						
Marked	4,000	1.00	8,000	1.00	12,000	1.00
Unmarked	4,000		8,000		12,000	
After first fishery time period						
Marked	2,400	1.60	4,800	1.00	7,200	1.20
Unmarked	3,840		4,800		8,640	
After second fishery time period						
Marked	1,920	1.96	3,840	1.22	5,760	1.47
Unmarked	3,763		4,704		8,467	
Escapement						
Marked					5,760	1.47
Unmarked					8,467	

λ^{Esc} is biased high for both the mark-selective fishery in Region B and the first mark-selective fishery in Region A (where $\lambda^{SF} = \lambda^{Rel} = 1$). In contrast, λ^{Esc} is biased low for the mark-selective fishery in the second time period in Region A ($\lambda^{SF} = 1.6$).

But, while the direction of the bias for λ^{Esc} is more difficult to infer, in general the ratio will always be greater than the λ^{Rel}, or:

$$E(\lambda^{Esc}) > E(\lambda^{Rel}).$$

The above examples illustrate the potential biases associated with estimating λ^{SF} using $\hat{\lambda}^{Rel}$ and|or $\hat{\lambda}^{Esc}$. These potential biases need to be assessed simultaneously with the precision of the estimators in order to determine which is most appropriate in any given situation.

For the coho salmon DIT data for brood years 1995-1997, it was generally not possible to find a non-selective fishery that would provide an unbiased estimate of the λ in a mark-selective fishery. Many of the non-selective fisheries occurred after mark-selective fisheries had occurred. Therefore, the λ in the non-selective fisheries would be expected to be biased high relative to the mark-selective fishery preceding it. In addition to the potential bias associated with the λ estimated from one or more non-selective fisheries, the precision of these estimates was poor due to the small number of recovered tags. The estimates of λ were highly variable from fishery to fishery, reflecting imprecision and possibly bias, and it was difficult to determine which λ should be used.

Given the imprecision and potential for bias when using λ from a non-selective fishery, we felt that $\hat{\lambda}^{Rel}$ and $\hat{\lambda}^{Esc}$ were more appropriate for the coho DIT release groups in the database. The degree of bias associated with these λs will depend on the extent to which prior mark-selective fisheries have altered the λ in the fishery of interest. The ratio $\hat{\lambda}^{Rel}$ is likely to be most appropriate for mark-selective fisheries that take place in the earlier part (in time and

location) of the migration, whereas $\hat{\lambda}^{Esc}$ may be more appropriate for mark-selective fisheries occurring later in the migration and closer to, or in, terminal areas.

The types of information needed to assess the potential bias and precision of the three estimators are listed below.

Precision of the estimates:

- λ^{Rel}: requires knowledge regarding the techniques used to estimate the number of DIT fish released from the hatchery ("No. Released with CWT" field in the PSMFC data base). Several different counting methods are used to estimate this quantity ("Counting Method" field in the PSMFC database). Methods that rely on a statistical sample (e.g., Petersen estimates) will allow one to estimate the precision of the estimate of the number of fish released.
- λ^{NSF}: requires estimates of the number of marked and unmarked DIT fish landed in the non-selective fishery(ies) along with their estimated precision.
- λ^{Esc}: requires estimates of the number of marked and unmarked DIT fish in escapement sampling along with their estimated precision.

Bias of the estimates:

- λ^{Rel}: requires knowledge regarding the extent of delayed mark mortality as well as the impact of prior mark-selective fisheries.
- λ^{NSF}: requires knowledge regarding the degree to which the λs in the paired fishery are likely to be representative of the λs in the mark-selective fishery of interest.
- λ^{Esc}: requires knowledge regarding the degree to which the λs in escapement samples are likely to be representative of the λs in the mark-selective fishery of interest.

3.3.2.2 TERM Method

Very few of the DIT groups were harvested in terminal mark-selective fisheries, so the TERM method was rarely applicable. However, the terminal method will produce biased estimates of unmarked mortalities if escapement is not fully sampled. This problem was pervasive (see section 3.1).

3.4 Estimates of Unmarked Mortalities Using the PR Method

The PR method was used to estimate unmarked mortalities due to catch and release in mark-selective fisheries. The *sfm* for each fishery (Table 11) was used along with the release and escapement unmarked-to-marked ratios.

Mark-selective fishery mortalities of unmarked tagged fish were calculated using λ at release and at escapement (Table 12). This provides a range of values for unmarked tagged fish mortalities. The totals shown for the mark-selective fisheries include mortalities due to catch and release and mortalities due to unmarked recognition error, i.e., mortalities estimated from unmarked tagged coho landed in mark-selective fisheries, but does not adjust for other non-landed mortalities such as drop-off mortalities. A simple exploitation rate (SER) was calculated as the estimated fishery mortalities divided by the total mortalities plus escapement (Table 13 and Figure 3). This rate is not calculated for the net pen hatchery programs in Hood

Canal, as these do not have adequate escapement estimates nor are these included in the total for estimation of total SER for Hood Canal stocks.

Table 11. Release mortality rates used as defaults for each mark-selective fishery. These rates are those used for coho salmon pre-season management models.

Mark Selective Fishery	Release Mortality Rate (*sfm)*
Buoy 10 Sport	0.16
Coos Bay Sport	0.14
Freshwater Sport	0.14
Georgia|Juan de Fuca|Johnstone Straits Sport	0.00
Newport Sport	0.14
Tillamook Sport	0.14
WA Area 1 Sport	0.14
WA Area 1 Troll	0.26
WA Area 13 Sport	0.07
WA Area 2 SF Sport	0.14
WA Area 2 Sport	0.14
WA Area 2 Troll	0.26
WA Area 3 Sport	0.14
WA Area 4 Sport	0.14
WA Area 5 Sport	0.07
WA Area 6 Sport	0.07

Table 12. Estimates of marked and unmarked mortalities, and escapement, by hatchery release group and brood year. SF = mark-selective fishery, NSF = non-selective fishery.

Region	Hatchery	Brood Year	Marked			Unmarked					
			SF	NSF	Escap.	λ^{Rel}	SF(rel)	λ^{Esc}	SF(esc)	NSF	Escape.
Coastal	Bingham Creek	1995 Late		16.8	101.0					15.1	470.9
		1995 Normal	71.2	199.0	781.0	1.005	10.0	1.674	16.7	149.3	1,307.5
		1996 Normal	43.1	105.3	1,075.1	1.019	6.2	1.140	6.9	92.1	1,219.0
		1996 Late		20.1	192.2					21.5	207.1
		1997	55.3	220.8	535.7	0.991	11.0	0.847	9.4	192.3	466.3
	Forks Creek	1995	10.6	273.9	198.1	1.003	1.5	1.336	2.0	324.6	264.7
	Humptulips	1995	18.7	340.2	219.0	1.001	2.6	1.224	3.2	375.6	268.0
		1996	35.9	330.5	823.0	0.939	4.7	1.088	5.5	268.6	899.0
	Makah NFH	1996	117.1	319.0	1,652.3	0.775	12.5	0.751	12.1	318.9	1,227.0
		1997	72.4	15.2	746.6	0.958	9.7	0.831	8.4	21.7	661.6
	Quinault NFH	1996	109.1	1,156.9	1,149.9	0.993	15.2	0.765	11.7	1,056.0	942.9
		1997	296.9	1,341.8	1,390.7	0.968	45.2	0.958	44.8	1,397.4	1,279.8
	Salmon River	1995	3.2	998.1	706.2	0.727	0.3	1.270	0.6	793.9	896.7
		1996	144.8	618.1	833.8	1.332	24.6	1.339	24.7	727.2	1,115.4
		1997	131.7	334.8	431.3	0.945	17.9	1.503	28.5	362.8	645.1
	Solduc	1996	135.9	176.9	1,483.8	1.033	19.7	1.116	21.2	178.4	1,679.2
		1997	196.4	15.0	1,541.1	0.957	31.1	1.095	35.6	2.9	1,640.1
Coastal Total			1,442.3	6,482.4	13,860.8		212.2		231.3	6,298.3	15,190.3
Hood Canal	George Adams	1995		104.4	199.2					82.7	185.8
		1997	18.9	13.6	362.0	1.044	1.3	1.179	1.5	51.5	424.0
		1997	60.6	36.3	381.0	1.001	5.9	1.075	6.3	35.4	408.0
	Port Gamble Bay Pens	1996	27.4	389.7	19.4	0.990	2.5	0.200		373.5	3.0
		1997	12.9	101.8		1.064	1.1			121.0	1.0

- continued -

Table 12. Estimates of marked and unmarked mortalities, and escapement, by hatchery release group and brood year. SF = mark-selective fishery, NSF = non-selective fishery.

Region	Hatchery	Brood Year	Marked			Unmarked					
			SF	NSF	Escap.	λ^{Rel}	SF(rel)	λ^{Esc}	SF(esc)	NSF	Escape.
Hood Canal	Quilcene Bay Pens	1996	24.3	10.5	443.4	1.059	2.8	0.842	2.3	52.4	434.4
		1997	154.9	694.6	1,205.9	0.937	15.5	0.983	17.9	673.8	1,275.8
	Quilcene NFH	1996	49.0	25.1	469.8	0.900	4.1	0.896	3.8	9.4	410.8
		1997	161.2	416.5	1,260.1	0.956	14.3	1.086	14.7	650.3	1,228.0
Hood Canal Total			509.2	1,792.5	4,340.8		47.5		46.5	2,050.0	4,370.8
North Puget Sound	Kendall Creek	1996	92.1	714.3	381.3	0.508	5.4	0.551	5.8	381.1	208.8
		1997	34.2	241.8	275.5	0.961	2.6	0.942	2.6	255.6	261.8
	Marblemount	1995	2.4	427.9	1,206.2	1.002	0.4	0.933	0.4	407.3	1,126.2
		1996	70.3	192.3	335.3	1.040	8.6	1.286	10.6	175.5	429.4
		1997	279.7	663.3	1,908.3	0.991	31.5	0.964	30.6	714.2	1,839.0
	Wallace River	1996	73.0	134.9	919.0	0.988	9.0	1.108	10.1	228.2	1,010.0
		1997	137.2	305.9	3,195.3	1.002	14.0	1.062	14.9	248.2	3,372.3
North Puget Sound Total			688.9	2,680.4	8,220.9		71.5		75.0	2,410.1	8,247.5
South Puget Sound	Kalama Creek	1996		1.6	3.0					4.4	3.0
	Soos Creek	1996	21.5	180.7	272.3	0.918	2.3	0.743	1.8	165.0	206.3
		1997	111.9	679.8	896.8	0.987	11.3	1.292	14.8	868.7	1,152.8
	Voights Creek	1996	19.4	25.1	84.7	1.042	2.0	0.895	1.7	26.3	68.0
		1996	21.0	50.0	92.0	0.999	1.6	1.293	2.1	82.5	119.0
South Puget Sound Total			173.8	937.2	1,348.8	0.977	17.2	1.078	20.4	1,146.9	1,549.1
Strait of Juan de Fuca	Lower Elwha	1995	3.2	146.3	114.0	0.933	0.4	1.026	0.5	152.6	117.0
		1996	30.0	168.5	327.8	0.954	3.2	0.890	3.0	169.6	298.8
		1997	20.1	142.7	273.0	1.033	2.4	1.115	2.6	126.2	319.0
Strait of Juan de Fuca Total			53.3	457.5	714.8		6.0		6.1	448.4	734.8

Table 13. Estimated simple exploitation rate (SER) for the unmarked tagged group from estimation using ratio at release (λ^{Rel}) and ratio at escapement (λ^{Esc}), and for marked fish in mark-selective fisheries. RE is the relative error which is calculated as half the length of the 95% confidence interval divided by the estimate.

Region	Hatchery	Brood Year	Unmarked					Marked	
			SF(λ^{Rel})	RE	SF(λ^{Esc})	RE	Difference	SF	RE
Coastal	Bingham Creek	1995	0.68%	72%	1.13%	78%	0.45%	6.77%	58%
		1996	0.47%	41%	0.52%	41%	0.06%	3.53%	41%
		1996	0.00%		0.00%		0.00%	0.00%	
		1997	1.64%	31%	1.40%	31%	-0.23%	6.81%	30%
	Forks Creek	1995	0.26%	86%	0.35%	86%	0.09%	2.20%	87%
	Humptulips	1995	0.40%	65%	0.49%	65%	0.09%	3.23%	65%
		1996	0.40%	40%	0.47%	40%	0.06%	3.02%	40%
	Makah NFH	1996	0.80%	23%	0.78%	24%	-0.02%	5.61%	23%
		1997	1.40%	31%	1.22%	33%	-0.18%	8.67%	32%
	Quinault NFH	1996	0.75%	24%	0.58%	25%	-0.17%	4.52%	24%
		1997	1.66%	15%	1.65%	16%	-0.02%	9.80%	14%
	Salmon River	1995	0.02%	164%	0.03%	174%	0.01%	0.19%	163%
		1996	1.44%	28%	1.45%	39%	0.01%	9.07%	28%
		1997	1.88%	35%	2.96%	50%	1.08%	14.67%	32%
	Solduc	1996	1.05%	19%	1.13%	19%	0.08%	7.57%	20%
		1997	1.86%	17%	2.12%	17%	0.26%	11.21%	16%
Coastal Total			1.00%	8%	1.09%	11%	0.09%	6.62%	7%
Hood Canal	George Adams	1995	0.00%		0.00%		0.00%	0.00%	
		1997	0.28%	90%	0.31%	90%	0.04%	4.80%	86%
		1997	1.30%	39%	1.40%	39%	0.09%	12.67%	43%
	Quilcene NFH	1996	0.96%	41%	0.90%	42%	-0.06%	9.01%	44%
		1997	0.77%	26%	0.79%	27%	0.02%	8.77%	28%
Hood Canal Total			0.79%	19%	0.82%	19%	0.02%	8.90%	20%
North Puget Sound	Kendall Creek	1996	0.90%	31%	0.97%	31%	0.07%	7.75%	31%
		1997	0.50%	59%	0.49%	59%	-0.01%	6.20%	65%
	Marblemount	1995	0.02%	149%	0.02%	149%	0.00%	0.14%	149%
		1996	1.40%	33%	1.73%	33%	0.33%	11.77%	34%
		1997	1.22%	18%	1.18%	18%	-0.03%	9.81%	19%

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Table 13. Estimated simple exploitation rate (SER) for the unmarked tagged group from estimation using ratio at release (λ^{Rel}) and ratio at escapement (λ^{Esc}), and for marked fish in mark-selective fisheries. RE is the relative error which is calculated as half the length of the 95% confidence interval divided by the estimate.

Region	Hatchery	Brood Year	Unmarked					Marked	
			SF(λ^{Rel})	RE	SF(λ^{Esc})	RE	Difference	SF	RE
N. Puget Sound	Wallace River	1996	0.72%	30%	0.81%	30%	0.09%	6.48%	31%
		1997	0.39%	25%	0.41%	25%	0.02%	3.77%	28%
North Puget Sound Total			0.67%	11%	0.70%	11%	0.03%	5.94%	12%
South Puget Sound	Kalama Creek	1996	0.00%		0.00%		0.00%	0.00%	
	Soos Creek	1996	0.61%	56%	0.49%	57%	-0.12%	4.52%	59%
		1997	0.56%	28%	0.73%	28%	0.17%	6.63%	31%
	Voights Creek	1996	2.08%	69%	1.79%	69%	-0.29%	14.88%	71%
			0.78%	69%	1.01%	69%	0.23%	12.86%	72%
South Puget Sound Total			0.63%	22%	0.75%	23%	0.12%	7.06%	24%
Strait of Juan de Fuca	Lower Elwha	1995	0.15%	163%	0.17%	163%	0.02%	1.20%	164%
		1996	0.68%	50%	0.64%	50%	-0.05%	5.70%	52%
		1997	0.54%	59%	0.58%	59%	0.04%	4.62%	69%
Strait of Juan de Fuca Total			0.51%	37%	0.51%	37%	0.00%	4.35%	41%

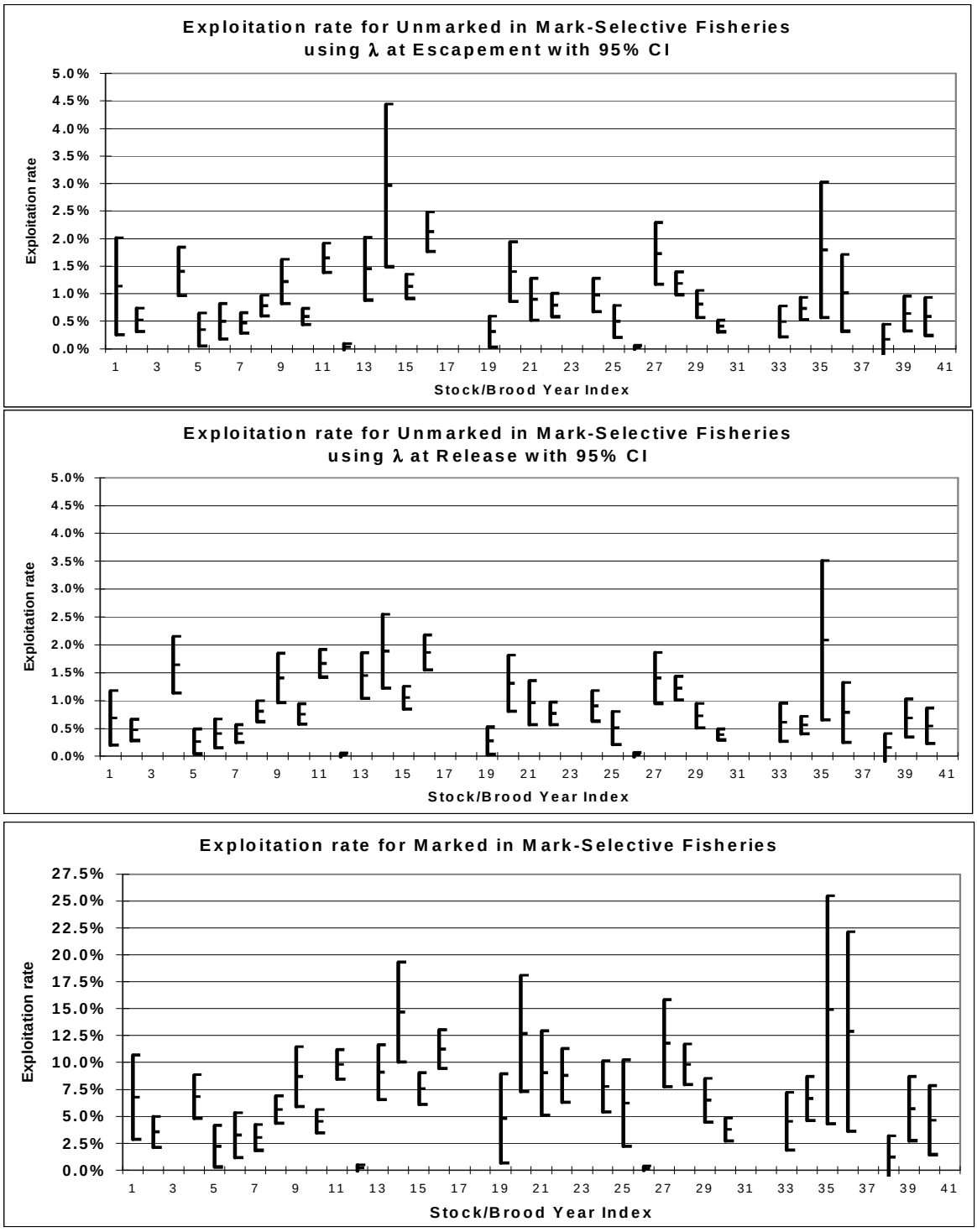

Figure 3. Estimated Simple Exploitation Rate (SER) for marked and unmarked coho salmon in mark-selective fisheries with 95% confidence intervals (CI). Unmarked exploitation rates are estimated using both λ at release and escapement.

The regional SER for the unmarked fish (Table 13) ranged from 0.5% for the Strait of Juan de Fuca region to 1.1% for the Coastal region. The estimated SERs for the individual stocks ranged from 0.02% to 2.96% (Table 13) depending on the λ used (Figure 3). In comparison, the regional SER for marked fish in mark-selective fisheries ranged from 4.3% for the Elwha DIT group to 8.9% for the Hood Canal DIT groups (Table 13), and ranged from 0.14% to 14.88% for the individual stocks (Figure 3). The differences between the SER estimated for unmarked fish in mark-selective fisheries using the ratio at release and at escapement ranged from 0 to 1%, which represents 20% or less of the estimate using the ratio at release (Table 13 and Figure 4). This difference was not significantly different from zero for any stock.

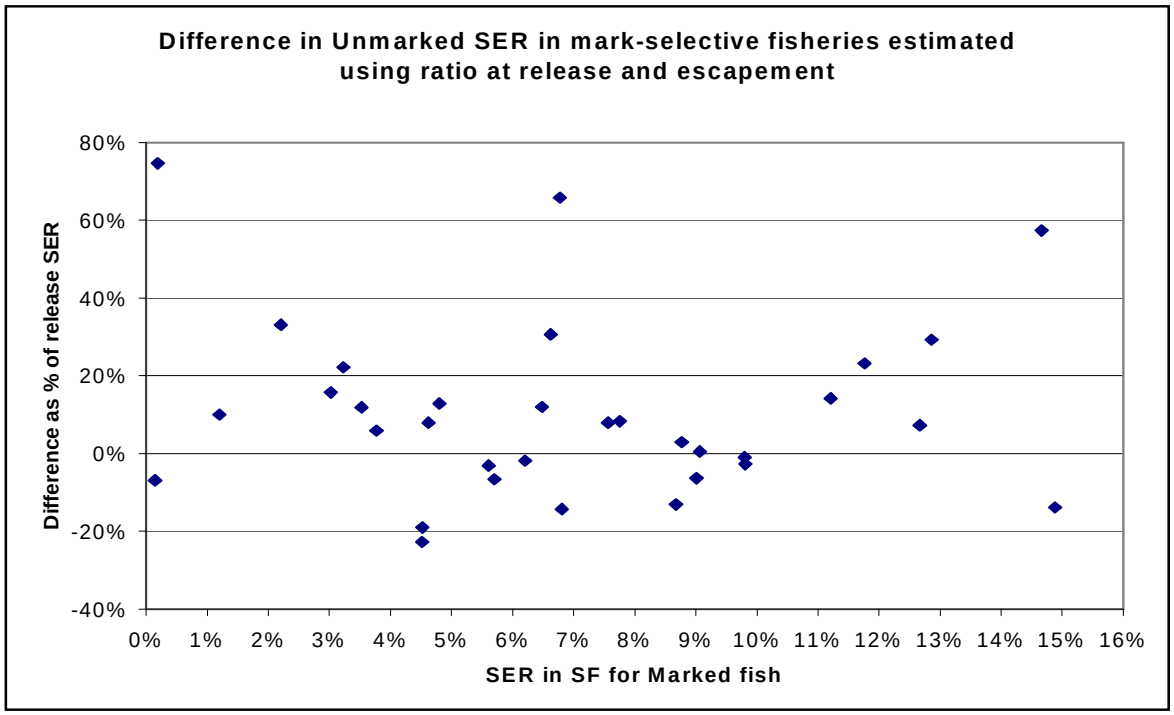

Figure 4. Difference between SER for unmarked fish in mark-selective fisheries estimated using λ^{Rel} and λ^{Esc} as a function of the SER for marked fish in mark-selective fisheries.

The precision of the estimates of SER is measured by the 95% confidence intervals (Figure 3) and by the relative error, which is half of the confidence interval divided by the estimate of SER. The relative errors range from 15% to 174% for the unmarked stocks and 14% to 164% for the marked stocks (Table 13). There is a general trend of decreasing relative error with increasing estimates of SER (Figure 5); however, there is considerable variability in this trend. The estimates of unmarked SER in mark-selective fisheries have the same level of precision as those of marked SER (Figure 5). For both estimates the relative error, or width of the half of the 95% confidence interval, ranges from 8 to 80% for most estimates. However, the relative error does not measure bias, and so underestimates the true uncertainty in the estimates of unmarked mortalities in mark-selective fisheries.

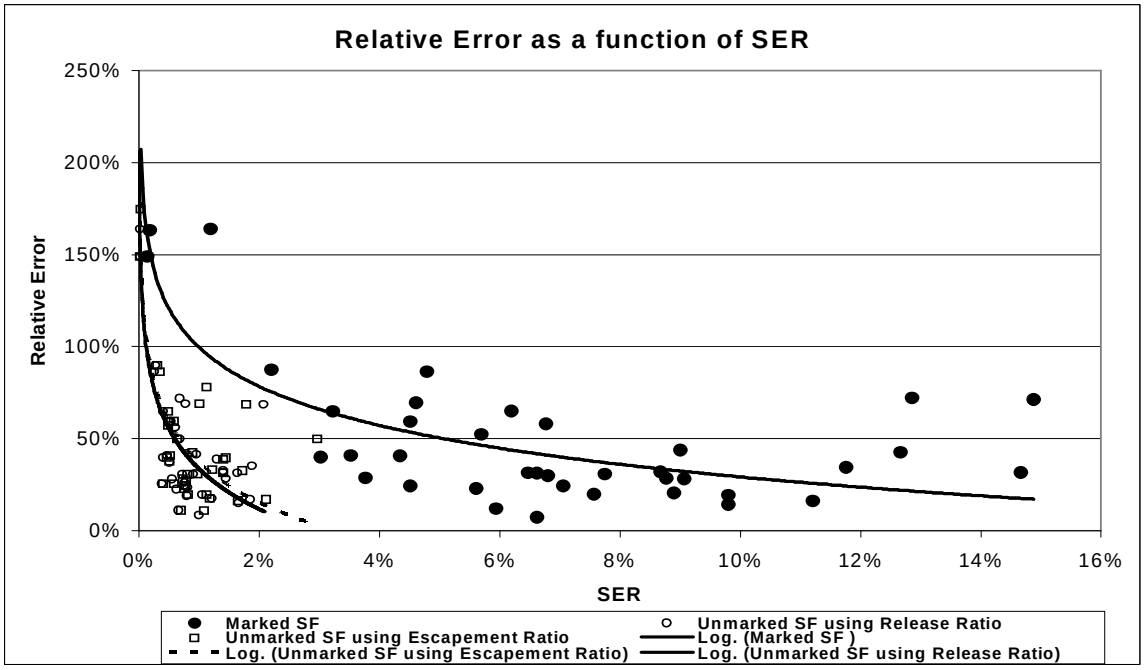

Figure 5. Precision of estimates of SER as a function of the SER. Precision is measured as the relative error, which is half of the 95% confidence interval divided by the estimate of SER.

The value of the release mortality (*sfm*) was varied from the default (Table 11), with one value half of the default and the other twice the default. Obviously the range of the estimates of unmarked SER will vary similarly (Table 14), and this variation is more than the difference between the estimates made using either the ratio at release (λ^{Rel}) or escapement (λ^{Esc}).

Table 14. Estimates of non-selective (NSF) and selective (SF) fishery mortalities as a proportion of total estimated fishery mortalities and escapement (or simple exploitation rates – SER) for marked and unmarked DIT groups. Unmarked mortalities in mark-selective fisheries are estimated using λ^{Rel}. SF mortalities for unmarked fish include landed unmarked mortalities (e.g., due to unmarked retention error) as well as catch and release mortalities estimated using landed marked and tagged fish using the default *sfm* and λ^{rel}.

Region	Hatchery	Brood Year	Marked		Unmarked			
			NSF	SF	NSF	SF		
						Half Default SFM	Default SFM	Twice Default SFM
Coastal	Bingham Creek							
	Late	1995	14.3%	0.0%	3.1%	0.0%	0.0%	0.0%
	Normal	1995	18.9%	6.8%	10.1%	0.7%	1.0%	1.7%
	Normal	1996	8.6%	3.5%	6.9%	2.1%	2.4%	2.8%
	Late	1996	9.4%	0.0%	9.4%	0.0%	0.0%	0.0%
	Normal	1997	27.2%	6.8%	28.5%	1.6%	2.4%	3.9%
	Forks Creek	1995	56.7%	2.2%	54.9%	0.1%	0.3%	0.5%
	Humptulips	1995	58.9%	3.2%	58.1%	0.2%	0.4%	0.8%
		1996	27.8%	3.0%	22.9%	0.2%	0.4%	0.8%
	Makah NFH	1996	15.3%	5.6%	20.4%	0.7%	1.1%	1.9%
		1997	1.8%	8.7%	3.1%	1.1%	1.7%	3.1%
	Quinault NFH	1995	58.5%	0.2%	46.9%	0.0%	0.0%	0.0%
		1996	47.9%	4.5%	52.4%	0.5%	0.8%	1.6%
		1997	44.3%	9.8%	51.1%	1.1%	1.9%	3.5%
	Salmon River	1996	38.7%	9.1%	38.8%	0.7%	1.4%	2.8%
		1997	37.3%	14.7%	34.9%	1.2%	2.1%	3.9%
	Solduc	1996	9.8%	7.6%	9.5%	0.6%	1.1%	2.1%
		1997	0.9%	11.2%	0.2%	1.1%	2.0%	3.8%
Coastal Total			29.8%	6.6%	28.9%	0.8%	1.3%	2.2%

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Table 14. Estimates of non-selective (NSF) and selective (SF) fishery mortalities as a proportion of total estimated fishery mortalities and escapement (or simple exploitation rates – SER) for marked and unmarked DIT groups. Unmarked mortalities in mark-selective fisheries are estimated using λ^{Rel}. SF mortalities for unmarked fish include landed unmarked mortalities (e.g., due to unmarked retention error) as well as catch and release mortalities estimated using landed marked and tagged fish using the default *sfm* and λ^{rel}.

Region	Hatchery	Brood Year	Marked		Unmarked			
			NSF	SF	NSF	SF		
						Half Default SFM	Default SFM	Twice Default SFM
Hood Canal	Port Gamble Bay Pens	1996						
		1997						
	Quilcene NFH	1996	4.6%	9.0%	2.2%	1.4%	1.8%	2.8%
		1997	22.7%	8.8%	34.2%	0.8%	1.2%	1.9%
	George Adams	1995	34.4%	0.0%	30.8%	0.0%	0.0%	0.0%
		1997	3.4%	4.8%	10.6%	2.2%	2.3%	2.6%
		1997	7.6%	12.7%	7.8%	0.7%	1.3%	2.6%
	Quilcene Bay Pens	1996						
		1997						
Hood Canal Total			27.0%	7.7%	31.5%	0.8%	1.2%	1.9%
North Puget Sound	Kendall Creek	1996	60.1%	7.8%	63.9%	0.5%	0.9%	1.8%
		1997	43.8%	6.2%	48.9%	0.8%	1.0%	1.5%
	Marblemount	1995	26.1%	0.1%	26.6%	0.0%	0.0%	0.0%
		1996	32.2%	11.8%	28.5%	0.7%	1.4%	2.8%
		1997	23.3%	9.8%	27.4%	1.3%	1.9%	3.0%
	Wallace River	1996	12.0%	6.5%	18.2%	0.5%	0.8%	1.5%
		1997	8.4%	3.8%	6.8%	0.2%	0.4%	0.8%
North Puget Sound Total			23.1%	5.9%	22.4%	0.5%	0.9%	1.5%

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Table 14. Estimates of non-selective (NSF) and selective (SF) fishery mortalities as a proportion of total estimated fishery mortalities and escapement (or simple exploitation rates – SER) for marked and unmarked DIT groups. Unmarked mortalities in mark-selective fisheries are estimated using λ^{Rel}. SF mortalities for unmarked fish include landed unmarked mortalities (e.g., due to unmarked retention error) as well as catch and release mortalities estimated using landed marked and tagged fish using the default *sfm* and λ^{rel}.

Region	Hatchery	Brood Year	Marked		Unmarked			
			NSF	SF	NSF	SF		
						Half Default SFM	Default SFM	Twice Default SFM
South Puget Sound	Kalama Creek	1996	34.4%	0.0%	59.3%	0.0%	0.0%	0.0%
	Soos Creek	1996	38.1%	4.5%	44.2%	0.3%	0.6%	1.2%
		1997	40.3%	6.6%	42.6%	0.4%	0.7%	1.3%
	Voights Creek	1996	19.2%	14.9%	27.3%	1.1%	2.1%	4.1%
		1996	30.7%	12.9%	40.5%	0.4%	0.8%	1.6%
South Puget Sound Total			38.1%	7.1%	42.2%	0.4%	0.7%	1.4%
Strait J.D.F	Lower Elwha	1995	55.5%	1.2%	56.5%	0.1%	0.2%	0.3%
		1996	32.0%	5.7%	35.9%	0.3%	0.7%	1.4%
		1997	32.7%	4.6%	28.2%	0.3%	0.5%	1.1%
Strait of Juan de Fuca Total			37.3%	4.3%	37.7%	0.3%	0.5%	1.0%

3.5 Comparing Differences in the Escapement Rate of Unmarked and Marked Fish

Age 3 return rates for unmarked and marked fish, p_u and p_m respectively, are given in Table 15. The $\hat{p}_m$ is the estimated proportion of the marked fish at release that escape to spawning grounds and hatchery racks and the $\hat{p}_u$ is the estimated proportion for the unmarked tagged fish. Also shown are z-statistics calculated using equation (2) in section 2 along with the associated *P*-value for the test. Positive values of the z-statistic indicate that proportionally more unmarked than marked tagged fish have returned ($p_u > p_m$), as one would expect if mark-selective fisheries result in lower mortalities on unmarked fish. A *P*-value less than 0.05 is significant at $\alpha = 0.05$. The *P*-values in Table 15 do not account for multiple comparisons and therefore should be interpreted with caution, as in multiple comparisons some tests are expected to be significant due to random chance.

For most release groups we did not detect a significant difference in the escapement rates of marked and unmarked fish (Table 16). Confidence intervals for the relative difference in return rates were wide and included 0 in most cases (Figure 6). Other measures of the difference in return rates [e.g., $\hat{p}_u / \hat{p}_m$, $\hat{p}_u - \hat{p}_m$, $\log(\hat{p}_u) - \log(\hat{p}_m)$] gave very similar results.

Table 15. Comparison of escapement return rates for unmarked and marked fish. The p_u and p_m are the proportions of the total unmarked and marked release returning to escapement. The z-statistic tests the null hypothesis that unmarked and marked fish are returning at equal rates. A * in the *P*-value column indicates a test significant at $\alpha \leq 0.05$. SF_1 = the number of marked and tagged fish that were harvested in mark-selective fisheries divided by the total number of marked and tagged fish in fisheries and escapement.

Hatchery|Location	Return Year	SF_1	p_u (%)	p_m (%)	z-statistic	*P*-value
Coastal						
Bingham Creek	1998	0.00	0.20	0.14	1.74	0.08
Bingham Creek	1998	0.07	1.81	1.09	1.61	0.11
Bingham Creek	1999	0.04	2.00	1.79	2.59	0.01*
Bingham Creek	1999	0.00	0.32	0.30	0.55	0.58
Bingham Creek	2000	0.07	0.62	0.71	-1.97	0.05
Forks Creek	1998	0.02	0.35	0.26	2.90	0.00*
Humptulips	1998	0.03	0.34	0.28	2.17	0.03*
Humptulips	1999	0.03	1.21	1.04	3.17	0.00*
Makah NFH	1999	0.06	3.22	3.36	-0.52	0.61
Makah NFH	2000	0.09	1.74	1.88	-0.65	0.51
Quinault NFH	1999	0.05	1.14	1.38	-2.47	0.01*
Quinault NFH	2000	0.10	1.63	1.72	-0.77	0.44
Salmon River	1998	0.00	1.26	0.72	1.69	0.09
Salmon River	1999	0.09	1.13	1.13	0.02	0.99
Salmon River	2000	0.15	0.95	0.60	1.30	0.19
Solduc	1999	0.08	2.28	2.08	2.57	0.01*
Solduc	2000	0.11	2.34	2.11	3.03	0.00*
Hood Canal						
George Adams	1998	0.00	0.41	0.44	-0.72	0.47
George Adams	2000	0.04	1.95	1.74	1.59	0.11
George Adams	2000	0.13	1.82	1.71	0.95	0.34
Port Gamble Bay Pens	1999	0.06	NA	NA	NA	NA
Port Gamble Bay Pens	2000	0.12	NA	NA	NA	NA
Quilcene Bay Pens	1999	0.05	NA	NA	NA	NA
Quilcene Bay Pens	2000	0.08	NA	NA	NA	NA
Quilcene NFH	1999	0.09	1.00	1.03	-0.25	0.80
Quilcene NFH	2000	0.09	2.65	2.60	0.24	0.81
North Puget Sound						
Kendall Creek	1999	0.08	0.47	0.43	0.81	0.42
Kendall Creek	2000	0.06	0.77	0.78	-0.12	0.90
Marblemount	1998	0.00	2.65	2.84	-1.72	0.08
Marblemount	1999	0.12	0.95	0.77	2.88	0.00*
Marblemount	2000	0.10	4.39	4.51	-0.86	0.39
Wallace River	1999	0.07	2.21	1.98	2.35	0.02*
Wallace River	2000	0.04	7.48	7.10	2.16	0.03*

- continued -

Table 15. Comparison of escapement return rates for unmarked and marked fish. The p_u and p_m are the proportions of the total unmarked and marked release returning to escapement. The z-statistic tests the null hypothesis that unmarked and marked fish are returning at equal rates. A * in the *P*-value column indicates a test significant at $\alpha \leq 0.05$. SF_1 = the number of marked and tagged fish that were harvested in mark-selective fisheries divided by the total number of marked and tagged fish in fisheries and escapement.

Hatchery|Location	Return Year	SF_1	p_u (%)	p_m (%)	z-statistic	*P*-value
South Puget Sound						
Kalama Creek	1999	0.00	0.00	0.00	-0.10	0.92
Soos Creek	1999	0.05	0.50	0.61	-1.59	0.11
Soos Creek	2000	0.07	2.75	2.11	6.02	0.00*
Voights Creek	1999	0.15	0.33	0.43	-1.41	0.16
Voights Creek	1999	0.13	0.59	0.46	1.87	0.06
Strait of Juan de Fuca						
Lower Elwha	1998	0.01	0.16	0.15	0.72	0.47
Lower Elwha	1999	0.06	0.40	0.42	-0.56	0.57
Lower Elwha	2000	0.05	0.41	0.36	1.51	0.13

Table 16. Summary of escapement return rate tests by brood year summarized from Table 15.

Run Year	$p_m > p_u$ ($P < 0.05$)	$p_u > p_m$ ($P < 0.05$)	Non-significant
1998	0	2	6
1999	1	5	10
2000	1	3	9

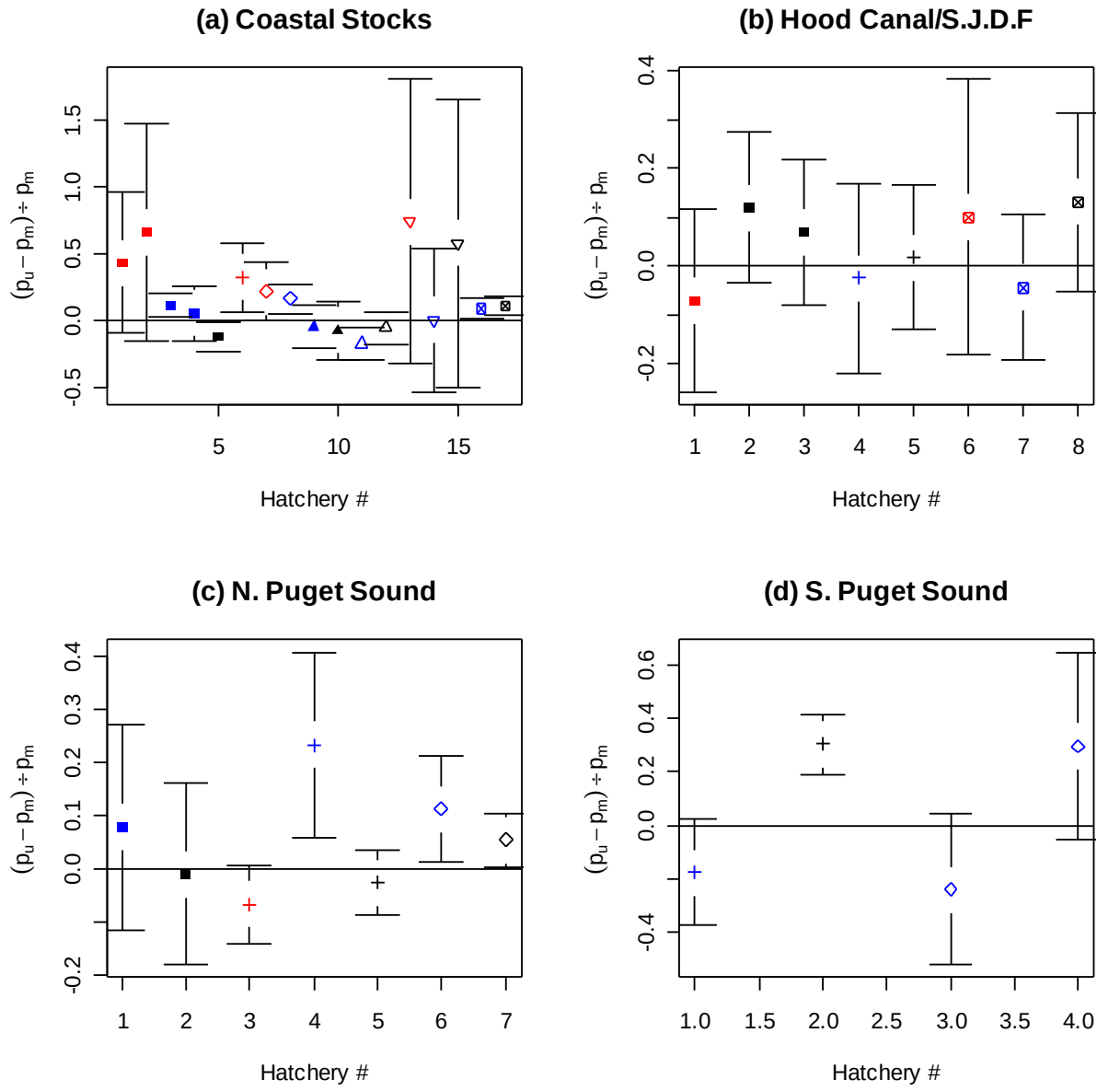

Figure 6. Relative differences in return rates for marked and unmarked release groups plotted along with 95% confidence intervals for these differences. (a) Coastal stocks: 1-5 = Bingham Creek, 6 = Forks Creek, 7-8 = Humptulips, 9-10 = Makah NFH, 11-12 = Quinault NFH, 13-15 = Salmon River, 16-17 = Solduc; (b) Hood Canal and Strait of Juan de Fuca (S.J.D.F.) stocks: 1-3 = George Adams, 4-5 = Quilcene NFH, 6-9 = Lower Elwha (S.J.D.F.); (c) North Puget Sound stocks: 1-2 = Kendall Creek, 3-5 = Marblemount, 6-7 = Wallace River; (d) South Puget Sound stocks: 1-2 = Soos Creek, 3-4 = Voights Creek.

The DIT release groups can be expected to have different migration pathways and therefore should be encountered in mark-selective fisheries at varying levels. Those groups that are encountered at higher rates in mark-selective fisheries should, in theory, have larger differences in their return rates. We estimated a measure of mark-selective fishing pressure for each DIT group (SF_1) as the number of marked recoveries that occur in mark-selective fisheries divided by the total number of marked recoveries in all fisheries and escapement.

Somewhat surprisingly, there appeared to be no strong relationship between this measure and the difference in return rates (Figure 7), despite a detectable difference in the average return rate (across various release groups) shown in Table 17 and Table 18.

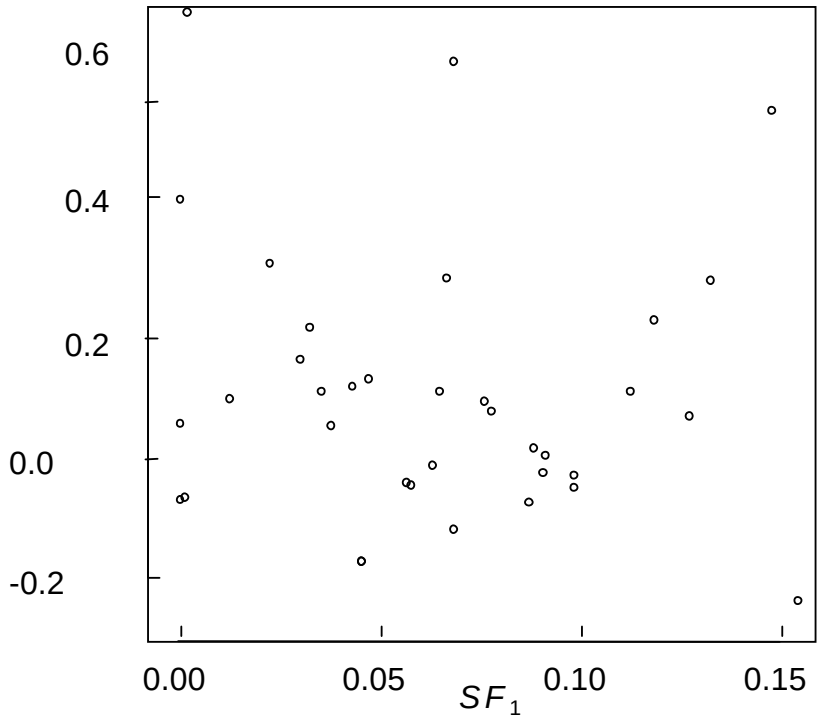

Figure 7. Plot of the relative difference in return rates between unmarked and marked fish versus mark-selective fishing pressure: (a) SF_1 = the number of marked recoveries in mark-selective fisheries divided by the total number of marked recoveries in all fisheries and escapement

There are several potential explanations for the observed results:

1. The measure of mark-selective fishing pressure (SF_1) we examined has too much error associated with it to detect a signal. In general, when there is measurement error in the explanatory variable, the slope of a regression line will be biased towards showing no significant relationship (Rawlings 1988).
2. Unmarked fish have slightly higher return rates than marked fish, but the differences in return rates may be due to other factors, e.g., delayed mark mortality, or additional

"savings" in non-selective fisheries if anglers are more likely to release unmarked fish in these fisheries. The ASFEC reviewed studies examining mark-induced mortalities in their 1997 report (ASFEC 1997). Few studies have been conducted to determine the potential effects of adipose fin-clipping. Examination of DIT groups that have not been subjected to mark-selective fishing pressure would allow one to examine this effect. However, tagging and sampling rates may need to be increased in order to ensure that the comparisons will have sufficient power to detect an effect of marking.

3. If unmarked and marked fish are reared differently, or if they are sampled using different equipment, then estimates of the difference in return rates could be biased. While this could be a problem for one or two release groups (e.g., Bingham Creek – see section 3.2.4), it is doubtful that these types of biases are responsible for the lack of a detectable relationship between differences in return rates and mark-selective fishing pressure.

The relative differences in return rates ($100 \times (\overline{p}_u - \hat{\overline{p}}_m)$) are averaged locations and years in Table 17 and Table 18, respectively. The relative difference should be greater than zero due to the impact of mark-selective fisheries.

Table 17. Mean differences in escapement return rates averaged across release locations by year.

Year	$100 \times (\overline{p}_u - \hat{\overline{p}}_m)$	95% Confidence Interval
1998	0.157%	-0.016% - 0.330%
1999	0.035%	-0.035% - 0.105%
2000	0.121%	0.032% - 0.210%
Total	0.093%	0.042% - 0.145%

Table 18. Mean differences in escapement return rates averaged across years by release location.

Location	$100 \times (\overline{p}_u - \hat{\overline{p}}_m)$	95% Confidence Interval
Coastal	0.115%	0.015% - 0.215%
Hood Canal	0.063%	-0.120% - 0.246%
North Puget Sound	0.069%	-0.036% - 0.175%
South Puget Sound	0.141%	-0.034% - 0.316%
Strait of Juan de Fuca	0.015%	-0.196% - 0.226%
Total	0.093%	0.042% - 0.145%

The average of the differences in return rates is positive for all years and all release groups. However, only the confidence intervals for return year 2000 and for the Coastal group exclude 0 (which indicates the average is significantly different from zero). The Coastal group had the largest number of release groups and year 2000 had the highest overall return rate. Therefore, the non-significance (statistically) of the other sub-categories in Table 17 and Table 18 is likely due to low power.

4 DISCUSSION

The double index tag (DIT) system was instituted as part of the indicator stock program for the purposes of estimating exploitation rates in fisheries and survival for tagged stocks. Exploitation rate analysis requires estimates of total fishery mortalities in all fisheries, of escapement to hatcheries and spawning grounds, and of any other mortalities to which the tag group may be vulnerable. The implementation of mass marking and mark-selective fisheries requires the development of a method for estimating the mortalities of unmarked fish in mark-selective fisheries. The intent of the DIT groups is to use the recoveries of marked and tagged fish in the mark-selective fisheries, in conjunction with information on the unmarked-to-marked ratios of the DIT group, to estimate these mortalities (SFEC-AWG 2002).

A second use for the DIT groups is to compare the total mortalities of mark-selective fisheries on the marked and unmarked groups by comparing the proportions of each group returning to the hatchery and|or escapement to the spawning grounds. Assuming that there is no differential mortality related to marking other than that resulting from mark-selective fisheries, the expectation would be that a lower proportion of marked fish would return to the hatchery.

This report has looked at both of these uses of the DIT groups for coho salmon of brood years 1995, 1996, and 1997. The report also evaluated and made recommendations regarding the quality of the tagging, sampling, and data available for the tag groups.

4.1 Estimation of Unmarked Mortalities in Mark-Selective Fisheries

Mark-selective fisheries for coho salmon have been implemented since 1998. Although four methods were proposed by the SFEC-AWG (2002) for estimating unmarked mortalities in mark-selective fisheries the workgroup concluded that only one method, the paired-ratio (PR) method, provided useful estimates. Two of the methods, referred to as the Total Methods, were found to be unreliable due to the imprecision of the estimates. These two methods are unlikely to be useful for estimation of unmarked mortalities in mark-selective fisheries for coho salmon unless selective fishery mortalities comprise a much larger percentage of the total fishing mortalities than observed in our analyses.

The paired-ratio method uses a ratio of unmarked to marked tagged fish (λ) for each DIT group to estimate encounters of unmarked tagged fish from landed mortalities of marked tagged fish. As originally described, the λ used would be estimated from DIT recoveries in a non-selective fishery if one occurred in the same area|time stratum as the mark-selective fishery or immediately prior to the mark-selective fishery in time or space (SFEC-AWG 2002). When the λ in a non-selective fishery provides an unbiased estimate of the λ in the selective fishery, the estimate of unmarked encounters is unbiased. However, no appropriate fishery pairs were available for the coho data from 1998-2000 and so no fishery ratios could be used.

The unmarked-to-marked ratio is well known and precise at two points in the life history of the DIT group, upon release and at escapement at the hatchery. In the analyses reported, the ratios measured at release and escapement of age-3 DIT coho salmon were used to provide bounds for the estimates of encounters. The assumption made was that prior to the first mark-selective fishery, the λ^{Rel} provides an unbiased estimate of λs in all fisheries and a lower bound for all fisheries after the first mark-selective fishery. Once a mark-selective fishery occurs the λ of the vulnerable DIT pairs will change, increasing as marked fish are removed in the selective fisheries. The final estimate of λ at escapement would provide an upper bound on the fishery λ for the DIT group.

In addition to choosing a λ for the PR method, it is also necessary to choose a value for the release mortality rate (*sfm*). In our analyses we chose three values of *sfm,* the values currently used for pre-season management models for each fishery (the default value) and a value half of the default and twice the default. Again this provides a range of values for unmarked mortalities in selective fisheries.

4.1.1 Estimates Using λ^{Rel} and λ^{Esc}

Recoveries of double index tagged coho salmon are available for the years 1998-2000 and were used to estimate unmarked mortalities in the mark-selective fisheries. Estimates were made of simple exploitation rates (SER = fishery mortality divided by mortalities plus escapement). The estimates made using the two ratios represent a bounded range of exploitation rates for unmarked fish in mark-selective fisheries. For the return years 1998-2000 the differences between these two estimates generally ranged between ±20% of the estimates, but this was not a significant difference. The precision of the estimates was comparable to the precision of estimates of marked fish in mark-selective fisheries.

We report a range of estimates of unmarked mortalities in mark-selective fisheries, each with one of two values of λ and one of three values of *sfm.* In choosing which of the estimates to use the analyst or manager must consider the reasonableness of the input values for λ and *sfm*. In these analyses there was little difference between λ^{Rel} and λ^{Esc}, but the differences that result from using a *sfm* half or twice that of the default values are more substantial.

4.2 Comparison of Escapement Rates of Unmarked and Marked Fish

Comparisons of the proportion of DIT marked and unmarked tag groups returning to the escapement found that in 10 out of 37 cases (hatchery|year combinations) significantly more unmarked fish returned, while in 25 cases there were no significant differences. Six of the significant differences were found for coastal groups, while the remaining significant tests were for Northern and Southern Puget Sound stocks. When averaged by region the differences in return rates were positive for all regions. However, only the coastal stock group showed a significant average difference, i.e., the 95% confidence interval for the mean difference did not include zero.

In order to use DIT pairs to evaluate the impact of selective fisheries by comparing the return rate of unmarked and marked tagged fish, the number of tagged fish sampled in the hatchery is extremely important. The larger the number of tagged fish returning to the hatchery the

smaller the difference in return rates that can be detected. In the case of the 1995-1997 brood years for coho, most of the comparisons were not significant. In order to detect small impacts it is necessary to sample larger numbers of tagged fish, either by increasing the size of the tag group or sampling at higher rates. As most hatcheries attempt to sample at or close to 100%, tag group sizes would have to be increased.

4.3 Quality of Tagging, Sampling, and Data

Several issues were raised during the evaluation of the tag data by the workgroup including fisheries that were not sampled for tags, harvest that was not reported, escapement that was not sampled, and concerns with sampling methods in hatcheries and the escapement to the spawning grounds.

Many of these concerns are not unique to the DIT system, but introduce potential bias to the general use of tagged hatchery stocks for estimation of exploitation rates and survival. When fisheries and escapement are not sampled for tags, total cohort size will be biased which results in biased estimates of exploitation rates and survival. In addition, exploitation rates cannot be estimated for unsampled fisheries. These are issues which need to be assessed for each watershed to evaluate and improve the quality of the present indicator stock system.

Methods of rearing, tagging, and sampling the marked and unmarked fish must be conducted in an identical manner for the major assumption of the DIT system to be valid. The assumption is that the only difference between the DIT pair is the mark and their differential exploitation in mark-selective fisheries. If marked and unmarked fish are not treated identically when reared, tagged, and sampled, the effect of the mark-selective fishery will be confounded.

4.4 Implications

The impact to managers of conducting a mark-selective fishery is that the indirect estimation of unmarked, mark-selective mortalities adds additional uncertainty that cannot be directly quantified. A value of the unmarked-to-marked ratio must be chosen in order to estimate the encounters of unmarked fish in mark-selective fisheries, although for coho salmon estimates using the release and escapement ratio represent a bounded range. Estimating mark-selective mortalities of unmarked fish also requires input values for release mortality rates. Both of these input values represent assumptions and sources of bias which increases the uncertainty in the estimates.

The sources of bias may be evaluated to some extent, e.g., coho salmon encounter rates can be evaluated by comparing the unmarked-to-marked ratio at release and at escapement, or for release mortality rates by examining studies in the literature or carrying out research to independently estimate the rates. The effect of the additional unknown bias is reflected in this report in that the estimated mortalities are reported as ranges rather than as single values. Given this range, managers can consider the impact of the bias with reference to the numbers of mortalities and the exploitation rates being estimated.

5 RECOMMENDATIONS

The recommendations of the workgroup are summarized below. These are not listed in priority order. They can be put into two groups, recommendations that pertain only to estimation of mortalities of unmarked fish in mark-selective fisheries, and recommendations that are relevant for the CWT indicator stock programs for all estimation using cohort or exploitation rate analysis.

Recommendations:

- The impact to managers of conducting a mark-selective fishery is that the indirect estimation of unmarked, mark-selective mortalities adds additional uncertainty that cannot be directly quantified. As with drop-off mortality, catch-and-release mortality, and sub-legal mortality, these mortalities are indirectly estimated and unlike landed mortality, the uncertainties cannot be estimated from direct observation of tags in landed catch by samplers. Managers should consider these uncertainties and their implications regarding stock management objectives and the precision and accuracy of fishery evaluation tools.
- Whenever a mark-selective fishery is proposed managers should consider the source of data for estimating the unmarked-to-marked ratio (λ). The analyses for this report illustrated the importance of the unmarked-to-marked ratio of the DIT group, which is used to estimate encounters and cohort size for unmarked coho salmon. The bias and precision in the estimate of this ratio is critical for all of the methods for estimating unmarked mortalities in mark-selective fisheries.
- The assumptions required to obtain unbiased estimates of unmarked mortalities (using the methods developed by the SFEC-AWG) were often difficult to satisfy. Many of these situations could have been avoided, however, if the assumptions of the analytical methods were considered during the preseason planning process. With better communication between technical support staff and fisheries managers many of these problems could be avoided or minimized in the future.
- All fisheries and escapements should be sampled. Priority should be given to larger fisheries and to spawning grounds where there may be significant straying from indicator hatchery stocks.
- Evaluation of the impacts of mark-selective fisheries by comparison of the escapement of marked and unmarked groups in the DIT pairs relies on sufficient numbers of tags being released. Future tag group sizes should be evaluated with this objective in mind.
- Hatchery release and recovery programs for CWT groups in general and DIT groups in particular should be reviewed. Release programs should be mindful that tagged fish are randomly allocated to a mark status and that after tagging|marking, both groups are treated similarly (i.e., preferably are reared together). Hatchery programs for recovering CWTs from returning adults should also be reviewed to identify facility limitations and to ensure that sampling|handling practices are not mark-dependent (e.g., different detection devices used for unmarked and marked fish).
- Communication with hatchery managers and enhancement biologists on the goals and requirements of the DIT program is important and must be maintained.

- Training programs for samplers and hatchery staff should be continued and improved where necessary.
- Indicator stocks should be reviewed for their utility as indicator stocks. Hatchery stocks where returning tagged fish cannot be sampled in the escapement (e.g., net pens, or hatcheries with significant unsampled straying or annual flooding) should not serve as candidates for the exploitation rate indicator stock program.

6 LITERATURE CITED

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7 APPENDICES

APPENDIX 1. CRAS FISHERY DEFINITIONS

Individual recovery records were mapped to fisheries using the Coded-wire tag Retrieval and Analysis System (CRAS) fishery definitions (CRAS is a program maintained by the NWIFC in Olympia, WA for the purpose of summarizing CWT data). CRAS fisheries are defined by PSMFC recovery location codes and fishery gear codes. Appendix Table 1.1 was used to assign recoveries to CRAS fisheries. The mapping works by taking each recovery record's fishery code and recovery site location code and comparing it, row by row, to the columns 3, 5, and 6 in Appendix Table 1.1. The recovery is mapped to the first fishery in the table where the following criterion are met:

1. The first *N* characters of the recovery's recovery site location code is exactly equal to the PSC recovery site location code, where *N* is equal to the number in the 4th column of the table.
2. The recovery's fishery code is between the lower and upper fishery gear codes in columns 5 and 6 of the table.

Appendix Table 1.1. PSC location codes sorted by number (3) of characters, PSC recovery site location code, and fishery gear code

Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
30	Tillamook Troll	5M22202 O2 10	18	10	19
24	WA Area 1 Troll	5M22202 O2 19	18	10	19
24	WA Area 1 Troll	5M22202 O2 37	18	10	19
29	Buoy 10 Sport	5F33201 R1 32	18	40	49
31	Tillamook Sport	5M22202 O2 11	18	40	49
25	WA Area 1 Sport	5M22202 O2 19	18	40	49
25	WA Area 1 Sport	5M22202 O2 37	18	40	49
68	WA Area 10E Net	3M10510 888101	15	20	29
68	WA Area 10E Net	3M10510 888105	15	20	29
68	WA Area 10E Net	3M10510 888106	15	20	29
66	WA Area 10A Net	3M10510X2 X10A	15	20	29
68	WA Area 10E Net	3M10510X5 X10E	15	20	29
78	WA Area 13D Net	3M10513 888130	15	20	29
78	WA Area 13D Net	3M10513 888131	15	20	29
18	WA Area 4, 4B Troll	3M364 X1 X6C	14	10	19
59	WA Area 8D Net	3M10308X1 X8D	14	20	29
69	WA Area 11 Net	3M105 X1 X11	14	20	29
65	WA Area 10 Net	3M165 X1 X10	14	20	29
61	WA Areas 6B, 9 Net	3M167 X1 X6B	14	20	29
90	California General Troll	3M* CAL	13	10	19
87	Canada General Troll	3M* CAN	13	10	19
89	Oregon-California General Troll	3M* OR-	13	10	19
88	Oregon General Troll	3M* ORE	13	10	19
22	WA Area 2 Troll	3M32101 8601	13	10	19
24	WA Area 1 Troll	3M32202 8602	13	10	19

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
18	WA Area 4, 4B Troll	3M32303 8603	13	10	19
18	WA Area 4, 4B Troll	3M354 X1 X4	13	10	19
18	WA Area 4, 4B Troll	3M354 X2 X4	13	10	19
42	Fort Bragg Troll	6MO NHFR	13	10	19
42	Fort Bragg Troll	6MO NHPP	13	10	19
44	Southern California Troll	6MO NHPS	13	10	19
38	Crescent City Troll	6MO OBBG	13	10	19
38	Crescent City Troll	6MO OBFK	13	10	19
26	WA North Coast Net	3M10745X2 X4	13	20	29
47	WA Area 7, 7A Net	3M10767X1 X7	13	20	29
61	WA Areas 6B, 9 Net	3M164 X2 X9	13	20	29
47	WA Area 7, 7A Net	3M167 X1 X7	13	20	29
61	WA Areas 6B, 9 Net	3M167 X1 X9	13	20	29
23	WA Area 2 Sport	3M32101 8601	13	40	49
25	WA Area 1 Sport	3M32202 8602	13	40	49
19	WA Area 4 Sport	3M32303 8603	13	40	49
43	Fort Bragg Sport	6MO NHFR	13	40	49
43	Fort Bragg Sport	6MO NHPP	13	40	49
45	Southern California Sport	6MO NHPS	13	40	49
39	Crescent City Sport	6MO OBBG	13	40	49
39	Crescent City Sport	6MO OBFK	13	40	49
38	Crescent City Troll	6MO FKB	12	10	19
40	Eureka Troll	6MO FKC	12	10	19
40	Eureka Troll	6MO FKS	12	10	19
40	Eureka Troll	6MO OBC	12	10	19
39	Crescent City Sport	6MO FKB	12	40	49
41	Eureka Sport	6MO FKC	12	40	49
41	Eureka Sport	6MO FKS	12	40	49
41	Eureka Sport	6MO OBC	12	40	49
24	WA Area 1 Troll	5M22202 O0	11	10	19
44	Southern California Troll	6MO FR	11	10	19
25	WA Area 1 Sport	5M22202 O0	11	40	49
45	Southern California Sport	6MO FR	11	40	49
40	Eureka Troll	6MO B	10	10	19
42	Fort Bragg Troll	6MO C	10	10	19
44	Southern California Troll	6MO P	10	10	19
44	Southern California Troll	6MO S	10	10	19
32	Newport Troll	6MO W	10	10	19
49	WA Area 7D Net	3M10107 8	10	20	29
49	WA Area 7D Net	3M10107 D	10	20	29
59	WA Area 8D Net	3M10308 D	10	20	29
73	WA Area 12A Net	3M10412 1	10	20	29
73	WA Area 12A Net	3M10412 8	10	20	29
73	WA Area 12A Net	3M10412 A	10	20	29
66	WA Area 10A Net	3M10510 A	10	20	29
67	WA Area 10B Net	3M10510 B	10	20	29

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
68	WA Area 10E Net	3M10510 E	10	20	29
70	WA Area 11A Net	3M10511 A	10	20	29
76	WA Area 13A Net	3M10513 A	10	20	29
78	WA Area 13D Net	3M10513 B	10	20	29
77	WA Area 13C Net	3M10513 C	10	20	29
78	WA Area 13D Net	3M10513 D	10	20	29
79	WA Area 13E-K Net	3M10513 E	10	20	29
79	WA Area 13E-K Net	3M10513 F	10	20	29
79	WA Area 13E-K Net	3M10513 G	10	20	29
79	WA Area 13E-K Net	3M10513 H	10	20	29
79	WA Area 13E-K Net	3M10513 I	10	20	29
79	WA Area 13E-K Net	3M10513 J	10	20	29
79	WA Area 13E-K Net	3M10513 K	10	20	29
48	WA Area 7B, 7C, 7E Net	3M10707 E	10	20	29
41	Eureka Sport	6MO B	10	40	49
43	Fort Bragg Sport	6MO C	10	40	49
45	Southern California Sport	6MO P	10	40	49
45	Southern California Sport	6MO S	10	40	49
33	Newport Sport	6MO W	10	40	49
34	Coos Bay Troll	5F2220505	9	10	19
34	Coos Bay Troll	5F2221605	9	10	19
24	WA Area 1 Troll	5F2223002	9	10	19
24	WA Area 1 Troll	5M2220201	9	10	19
24	WA Area 1 Troll	5M2220202	9	10	19
30	Tillamook Troll	5M2220203	9	10	19
32	Newport Troll	5M2220204	9	10	19
24	WA Area 1 Troll	5M2220502	9	10	19
30	Tillamook Troll	5M2220503	9	10	19
34	Coos Bay Troll	5M2220505	9	10	19
24	WA Area 1 Troll	5M2220602	9	10	19
30	Tillamook Troll	5M2220603	9	10	19
30	Tillamook Troll	5M2220803	9	10	19
24	WA Area 1 Troll	5M2221001	9	10	19
24	WA Area 1 Troll	5M2221002	9	10	19
30	Tillamook Troll	5M2221003	9	10	19
32	Newport Troll	5M2221004	9	10	19
34	Coos Bay Troll	5M2221005	9	10	19
36	Brookings Troll	5M2221006	9	10	19
38	Crescent City Troll	5M2221007	9	10	19
30	Tillamook Troll	5M2221203	9	10	19
32	Newport Troll	5M2221204	9	10	19
24	WA Area 1 Troll	5M2221601	9	10	19
24	WA Area 1 Troll	5M2221602	9	10	19
30	Tillamook Troll	5M2221603	9	10	19
32	Newport Troll	5M2221604	9	10	19
34	Coos Bay Troll	5M2221605	9	10	19

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
30	Tillamook Troll	5M2221803	9	10	19
32	Newport Troll	5M2221804	9	10	19
24	WA Area 1 Troll	5M2222201	9	10	19
24	WA Area 1 Troll	5M2222202	9	10	19
30	Tillamook Troll	5M2222203	9	10	19
32	Newport Troll	5M2222204	9	10	19
34	Coos Bay Troll	5M2222205	9	10	19
36	Brookings Troll	5M2222206	9	10	19
24	WA Area 1 Troll	5M2222401	9	10	19
24	WA Area 1 Troll	5M2222402	9	10	19
30	Tillamook Troll	5M2222403	9	10	19
32	Newport Troll	5M2222404	9	10	19
34	Coos Bay Troll	5M2222405	9	10	19
36	Brookings Troll	5M2222406	9	10	19
38	Crescent City Troll	5M2222407	9	10	19
24	WA Area 1 Troll	5M2223001	9	10	19
24	WA Area 1 Troll	5M2223002	9	10	19
30	Tillamook Troll	5M2223003	9	10	19
32	Newport Troll	5M2223004	9	10	19
34	Coos Bay Troll	5M2223005	9	10	19
36	Brookings Troll	5M2223006	9	10	19
38	Crescent City Troll	5M2223007	9	10	19
24	WA Area 1 Troll	5M2223202	9	10	19
30	Tillamook Troll	5M2223203	9	10	19
32	Newport Troll	5M2223204	9	10	19
34	Coos Bay Troll	5M2223205	9	10	19
36	Brookings Troll	5M2223206	9	10	19
38	Crescent City Troll	5M2223207	9	10	19
24	WA Area 1 Troll	5M2223401	9	10	19
24	WA Area 1 Troll	5M2223402	9	10	19
30	Tillamook Troll	5M2223403	9	10	19
32	Newport Troll	5M2223404	9	10	19
34	Coos Bay Troll	5M2223405	9	10	19
36	Brookings Troll	5M2223406	9	10	19
38	Crescent City Troll	5M2223407	9	10	19
32	Newport Troll	5M2223604	9	10	19
34	Coos Bay Troll	5M2223605	9	10	19
36	Brookings Troll	5M2223606	9	10	19
38	Crescent City Troll	5M2223607	9	10	19
30	Tillamook Troll	5M2223803	9	10	19
32	Newport Troll	5M2223804	9	10	19
34	Coos Bay Troll	5M2223805	9	10	19
36	Brookings Troll	5M2223806	9	10	19
38	Crescent City Troll	5M2223807	9	10	19
24	WA Area 1 Troll	5M2224002	9	10	19
32	Newport Troll	5M2224004	9	10	19

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
34	Coos Bay Troll	5M2224005	9	10	19
36	Brookings Troll	5M2224006	9	10	19
38	Crescent City Troll	5M2224007	9	10	19
24	WA Area 1 Troll	5M2224202	9	10	19
30	Tillamook Troll	5M2224203	9	10	19
32	Newport Troll	5M2224204	9	10	19
34	Coos Bay Troll	5M2224205	9	10	19
36	Brookings Troll	5M2224206	9	10	19
38	Crescent City Troll	5M2224207	9	10	19
67	WA Area 10B Net	3M10510X1	9	20	29
65	WA Area 10 Net	3M10510X2	9	20	29
67	WA Area 10B Net	3M10510X3	9	20	29
67	WA Area 10B Net	3M10510X4	9	20	29
65	WA Area 10 Net	3M10510X5	9	20	29
79	WA Area 13E-K Net	3M10513X1	9	20	29
79	WA Area 13E-K Net	3M10513X2	9	20	29
25	WA Area 1 Sport	5M2220201	9	40	49
25	WA Area 1 Sport	5M2220202	9	40	49
31	Tillamook Sport	5M2220203	9	40	49
33	Newport Sport	5M2220204	9	40	49
31	Tillamook Sport	5M2220803	9	40	49
25	WA Area 1 Sport	5M2221001	9	40	49
25	WA Area 1 Sport	5M2221002	9	40	49
31	Tillamook Sport	5M2221003	9	40	49
33	Newport Sport	5M2221004	9	40	49
35	Coos Bay Sport	5M2221005	9	40	49
37	Brookings Sport	5M2221006	9	40	49
39	Crescent City Sport	5M2221007	9	40	49
31	Tillamook Sport	5M2221203	9	40	49
33	Newport Sport	5M2221204	9	40	49
25	WA Area 1 Sport	5M2221601	9	40	49
25	WA Area 1 Sport	5M2221602	9	40	49
31	Tillamook Sport	5M2221603	9	40	49
33	Newport Sport	5M2221604	9	40	49
35	Coos Bay Sport	5M2221605	9	40	49
25	WA Area 1 Sport	5M2222201	9	40	49
25	WA Area 1 Sport	5M2222202	9	40	49
31	Tillamook Sport	5M2222203	9	40	49
33	Newport Sport	5M2222204	9	40	49
35	Coos Bay Sport	5M2222205	9	40	49
37	Brookings Sport	5M2222206	9	40	49
25	WA Area 1 Sport	5M2222401	9	40	49
25	WA Area 1 Sport	5M2222402	9	40	49
31	Tillamook Sport	5M2222403	9	40	49
33	Newport Sport	5M2222404	9	40	49
35	Coos Bay Sport	5M2222405	9	40	49

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
37	Brookings Sport	5M2222406	9	40	49
39	Crescent City Sport	5M2222407	9	40	49
25	WA Area 1 Sport	5M2223001	9	40	49
25	WA Area 1 Sport	5M2223002	9	40	49
31	Tillamook Sport	5M2223003	9	40	49
33	Newport Sport	5M2223004	9	40	49
35	Coos Bay Sport	5M2223005	9	40	49
37	Brookings Sport	5M2223006	9	40	49
39	Crescent City Sport	5M2223007	9	40	49
25	WA Area 1 Sport	5M2223202	9	40	49
31	Tillamook Sport	5M2223203	9	40	49
33	Newport Sport	5M2223204	9	40	49
35	Coos Bay Sport	5M2223205	9	40	49
37	Brookings Sport	5M2223206	9	40	49
39	Crescent City Sport	5M2223207	9	40	49
25	WA Area 1 Sport	5M2223401	9	40	49
25	WA Area 1 Sport	5M2223402	9	40	49
31	Tillamook Sport	5M2223403	9	40	49
33	Newport Sport	5M2223404	9	40	49
35	Coos Bay Sport	5M2223405	9	40	49
37	Brookings Sport	5M2223406	9	40	49
39	Crescent City Sport	5M2223407	9	40	49
25	WA Area 1 Sport	5M2224002	9	40	49
33	Newport Sport	5M2224004	9	40	49
35	Coos Bay Sport	5M2224005	9	40	49
37	Brookings Sport	5M2224006	9	40	49
39	Crescent City Sport	5M2224007	9	40	49
25	WA Area 1 Sport	5M2224202	9	40	49
31	Tillamook Sport	5M2224203	9	40	49
33	Newport Sport	5M2224204	9	40	49
35	Coos Bay Sport	5M2224205	9	40	49
37	Brookings Sport	5M2224206	9	40	49
39	Crescent City Sport	5M2224207	9	40	49
42	Fort Bragg Troll	6MOSFBOD	8	10	19
78	WA Area 13D Net	3M10513X	8	20	29
81	Freshwater Net	6MOSFCMA	8	20	29
57	WA Area 8-2 Sport	3M112082	8	40	49
43	Fort Bragg Sport	6MOSFBOD	8	40	49
80	Freshwater Sport	6MOSFCMA	8	40	49
84	Escapement	6MOSFCMA	8	50	59
10	SW Vancouver Island Troll	5M*2215	7	10	19
40	Eureka Troll	5M*2216	7	10	19
24	WA Area 1 Troll	5M22201	7	10	19
30	Tillamook Troll	5M22203	7	10	19
30	Tillamook Troll	5M22204	7	10	19
32	Newport Troll	5M22205	7	10	19

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
32	Newport Troll	5M22206	7	10	19
34	Coos Bay Troll	5M22207	7	10	19
34	Coos Bay Troll	5M22208	7	10	19
34	Coos Bay Troll	5M22209	7	10	19
34	Coos Bay Troll	5M22210	7	10	19
36	Brookings Troll	5M22211	7	10	19
36	Brookings Troll	5M22212	7	10	19
36	Brookings Troll	5M22213	7	10	19
24	WA Area 1 Troll	5M2221A	7	10	19
24	WA Area 1 Troll	5M2221B	7	10	19
32	Newport Troll	5M22220	7	10	19
32	Newport Troll	5M22226	7	10	19
30	Tillamook Troll	5M2223A	7	10	19
32	Newport Troll	5M2224A	7	10	19
32	Newport Troll	5M2224B	7	10	19
32	Newport Troll	5M2226A	7	10	19
62	WA Area 9A Net	3M10409	7	20	29
69	WA Area 11 Net	3M10511	7	20	29
75	WA Area 13 Net	3M10513	7	20	29
26	WA North Coast Net	3M10704	7	20	29
47	WA Area 7, 7A Net	3M10707	7	20	29
26	WA North Coast Net	3M10744	7	20	29
51	WA Area 5 Sport	3M11105	7	40	49
52	WA Area 6 Sport	3M11106	7	40	49
46	WA Area 7 Sport	3M11107	7	40	49
55	WA Area 8 Sport	3M11208	7	40	49
60	WA Area 9 Sport	3M11309	7	40	49
63	WA Area 10 Sport	3M11410	7	40	49
64	WA Area 11 Sport	3M11411	7	40	49
74	WA Area 13 Sport	3M11413	7	40	49
71	WA Area 12 Sport	3M11512	7	40	49
23	WA Area 2 Sport	5M*2214	7	40	49
41	Eureka Sport	5M*2216	7	40	49
25	WA Area 1 Sport	5M22201	7	40	49
31	Tillamook Sport	5M22203	7	40	49
31	Tillamook Sport	5M22204	7	40	49
33	Newport Sport	5M22205	7	40	49
33	Newport Sport	5M22206	7	40	49
35	Coos Bay Sport	5M22207	7	40	49
35	Coos Bay Sport	5M22208	7	40	49
35	Coos Bay Sport	5M22209	7	40	49
35	Coos Bay Sport	5M22210	7	40	49
37	Brookings Sport	5M22211	7	40	49
37	Brookings Sport	5M22212	7	40	49
37	Brookings Sport	5M22213	7	40	49
25	WA Area 1 Sport	5M2221A	7	40	49

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
25	WA Area 1 Sport	5M2221B	7	40	49
33	Newport Sport	5M22220	7	40	49
31	Tillamook Sport	5M2223A	7	40	49
33	Newport Sport	5M2224A	7	40	49
33	Newport Sport	5M2224B	7	40	49
33	Newport Sport	5M2226A	7	40	49
92	Oregon-Unknown or Mixed Gear	5M22206	7	60	69
74	WA Area 13 Sport	3M1114	6	40	49
5	Central British Columbia Troll	2MN05	5	10	19
4	North British Columbia Troll	2MN06	5	10	19
1	Southeast Alaska Troll	2MN07	5	10	19
9	NW Vancouver Island Troll	2MS01	5	10	19
10	SW Vancouver Island Troll	2MS02	5	10	19
18	WA Area 4, 4B Troll	2MS03	5	10	19
13	Georgia/Juan de Fuca/Johnstone Straits Troll	2MS04	5	10	19
10	SW Vancouver Island Troll	2MS14	5	10	19
87	Canada General Troll	2MS16	5	10	19
24	WA Area 1 Troll	3M321	5	10	19
22	WA Area 2 Troll	3M322	5	10	19
20	WA Area 3 Troll	3M323	5	10	19
18	WA Area 4, 4B Troll	3M324	5	10	19
50	WA Area 5, 6, 6C, 7, 7A Troll	3M325	5	10	19
50	WA Area 5, 6, 6C, 7, 7A Troll	3M326	5	10	19
50	WA Area 5, 6, 6C, 7, 7A Troll	3M327	5	10	19
50	WA Area 5, 6, 6C, 7, 7A Troll	3M354	5	10	19
50	WA Area 5, 6, 6C, 7, 7A Troll	3M364	5	10	19
34	Coos Bay Troll	5M221	5	10	19
38	Crescent City Troll	6MOCR	5	10	19
40	Eureka Troll	6MOEU	5	10	19
42	Fort Bragg Troll	6MOFB	5	10	19
44	Southern California Troll	6MOSF	5	10	19
2	Southeast Alaska Net	2M*47	5	20	29
7	North British Columbia Net	2MN09	5	20	29
8	Central British Columbia Net	2MN12	5	20	29
16	Fraser River Net	2MS08	5	20	29
15	Georgia/Johnstone Straits Net	2MS10	5	20	29
15	Georgia/Johnstone Straits Net	2MS11	5	20	29
17	Strait of Juan de Fuca Net (Canadian Area 20)	2MS13	5	20	29
12	West Coast Vancouver Island Net	2MS20	5	20	29
12	West Coast Vancouver Island Net	2MS21	5	20	29
15	Georgia/Johnstone Straits Net	2MS45	5	20	29
16	Fraser River Net	2MS58	5	20	29

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
12	West Coast Vancouver Island Net	2MS70	5	20	29
48	WA Area 7B, 7C, 7E Net	3M101	5	20	29
56	WA Area 8 Net	3M102	5	20	29
58	WA Area 8A Net	3M103	5	20	29
72	WA Area 12, 12B, 12C, 12D Net	3M104	5	20	29
65	WA Area 10 Net	3M105	5	20	29
61	WA Areas 6B, 9 Net	3M106	5	20	29
53	WA Areas 4B, 5, 6, 6A, 6C Net	3M107	5	20	29
54	WA Area 6D Net	3M108	5	20	29
62	WA Area 9A Net	3M164	5	20	29
61	WA Areas 6B, 9 Net	3M165	5	20	29
53	WA Areas 4B, 5, 6, 6A, 6C Net	3M167	5	20	29
27	Grays Harbor Net	3M218	5	20	29
28	Willapa Bay Net	3M219	5	20	29
14	Georgia/Juan de Fuca/Johnstone Straits Sport	2MS22	5	40	49
14	Georgia/Juan de Fuca/Johnstone Straits Sport	2MS23	5	40	49
14	Georgia/Juan de Fuca/Johnstone Straits Sport	2MS24	5	40	49
11	West Coast Vancouver Island Sport	2MS27	5	40	49
14	Georgia/Juan de Fuca/Johnstone Straits Sport	2MS28	5	40	49
23	WA Area 2 Sport	3M218	5	40	49
23	WA Area 2 Sport	3M219	5	40	49
25	WA Area 1 Sport	3M321	5	40	49
23	WA Area 2 Sport	3M322	5	40	49
21	WA Area 3 Sport	3M323	5	40	49
19	WA Area 4 Sport	3M324	5	40	49
35	Coos Bay Sport	5M221	5	40	49
39	Crescent City Sport	6MOCR	5	40	49
41	Eureka Sport	6MOEU	5	40	49
43	Fort Bragg Sport	6MOFB	5	40	49
45	Southern California Sport	6MOSF	5	40	49
5	Central British Columbia Troll	2MN5	4	10	19
44	Southern California Troll	6MOM	4	10	19
6	North/Central British Columbia Sport	2MN2	4	40	49
29	Buoy 10 Sport	3M42	4	40	49
45	Southern California Sport	6MOM	4	40	49
1	Southeast Alaska Troll	1M	2	10	19
1	Southeast Alaska Troll	1F	2	10	19
81	Freshwater Net	1F	2	20	29
2	Southeast Alaska Net	1M	2	20	29
81	Freshwater Net	3F	2	20	29

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Fishery Number	Fishery Name	PSC recovery site location code	# Char	Fishery gear code lower	Fishery gear code upper
95	Washington-General Net	3M	2	20	29
81	Freshwater Net	4F	2	20	29
81	Freshwater Net	5F	2	20	29
81	Freshwater Net	6F	2	20	29
80	Freshwater Sport	1F	2	40	49
3	Southeast Alaska Sport	1M	2	40	49
80	Freshwater Sport	2F	2	40	49
80	Freshwater Sport	3F	2	40	49
80	Freshwater Sport	4F	2	40	49
80	Freshwater Sport	5F	2	40	49
80	Freshwater Sport	6F	2	40	49
84	Escapement	1F	2	50	59
84	Escapement	2F	2	50	59
84	Escapement	3F	2	50	59
84	Escapement	4F	2	50	59
84	Escapement	5F	2	50	59
84	Escapement	6F	2	50	59
94	Cal FW-Unknown or Mixed Gear	6F	2	99	99
85	Alaska Cost Recovery	1	1	94	94
91	Alaska-Unknown or Mixed Gear	1	1	61	61
91	Alaska-Unknown or Mixed Gear	1	1	64	64
91	Alaska-Unknown or Mixed Gear	1	1	90	90
91	Alaska-Unknown or Mixed Gear	1	1	94	94
92	Oregon-Unknown or Mixed Gear	5	1	61	61

APPENDIX 2. CHECK LIST FOR ANALYSIS WITH DIT GROUPS

Hatchery	
Brood Year	
Related Group Id	
Hatchery Issues:	
Unmarked Group Size	
Marked Group Size	
"Good" DIT group	
Release Ratio	
Method of estimating Release Ratio	
Pre-terminal Fishery Issues:	
Are there Alaska or Canadian fisheries not electronically sampled?	
Are all pre-terminal fisheries sampled?	
Terminal and in-river fishery issues (hatchery and fishery bios):	
Location and size of terminal and in-river net	
Are all net fisheries sampled?	
Location and size of freshwater sport fishery	
Is freshwater sport fishery sampled?	
If fisheries not sampled, what method can be used to "estimate" harvest of DIT tags?	
Questions for hatchery managers:	
Are 100% of the fish entering the hatchery sampled?	
Are all jacks counted and sampled?	
Are any fish passed above the hatchery? • If so, are they included in the total hatchery count reported and sampled at 100? • If not included in total hatchery count, how are they reported and how sampled?	
Does 100% of the adult hatchery return enter the hatchery?	
Is there any spawning ground sampling for hatchery tags?	
OTHER:	

APPENDIX 3. RESULTS OF INDIVIDUAL ANALYSES

The results are organized by hatchery. A few caveats apply. The confidence intervals that are included are all approximate (SFEC 2002). Furthermore, the confidence intervals do not incorporate the uncertainty in the estimates of the selective fishery mortality[6] (*sfm*) and uncertainty due to biases that result from process error (Appendix Table 3.1).

In this appendix, "marked" refers to adipose fin-clipped and coded-wire tagged fish in the DIT pair, while "unmarked" refers to the unclipped and coded-wire tagged fish in the pair.

Appendix Table 3.1. Potential biases of the double index tag methods.

Method	Reason for bias
EMS	*λ^{Rel} is not equal to λ at large (due to delayed mark-induced mortality or differential survival of marked and unmarked fish due to process error).* *Unsampled fisheries or escapement.*
EER	*λ^{NSF} is not equal to the λ at large (due to process error or because of previous mark-selective fisheries).* *Unsampled fisheries or escapement.*
PR	*λ^{NSF} is not equal to the λ at large (due to process error or because of previous mark-selective fisheries make the non-selective fishery an inadequate pair).* *Assumed sfm is incorrect.*
TERM	*Abundance used to estimate encounter rate is incorrect.* *Assumed sfm is incorrect.*

[6] The selective fishery mortality is the mortality that occurs as a result of a fish harvested by a selective fishery being released.

APPENDIX 3

Appendix 3.1. Bingham Creek Hatchery

Jeff Haymes, WDFW
Annette Hoffmann, WDFW
Laurie Peterson, WDFW

Brood Year	Stock	Related Group ID	Unmarked	Marked	λ^{Rel}
1995	Normal-timed	419972204	72,340	71,971	1.0051
	Late-timed	419972203	74,919	72,016	1.0403
1996	Normal-timed	419981011	61,023	59,913	1.0185
	Late-timed	419981012	65,229	63,980	1.0195
1997	Normal-timed	419991009	74,744	75,449	0.9907

Bingham Creek Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on Bingham Creek, a major tributary to the East Fork Satsop River (Appendix Figure 3.1.1). A trap operated by WDFW is operated on Bingham Creek at river mile 0.8. The East Fork Satsop and Bingham Creek intersect at approximately the hatchery location.

Hatchery practices that are relevant to these analyses

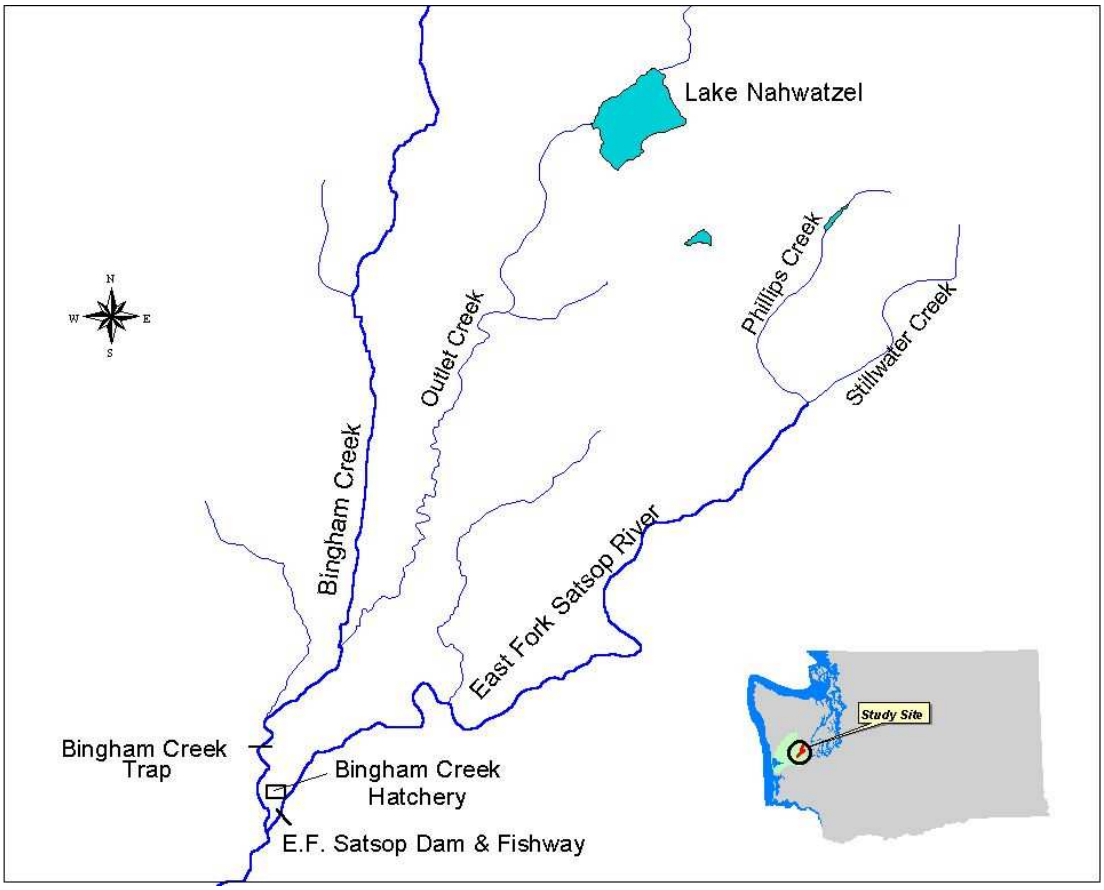
Marked and unmarked fish were reared in similar conditions prior to release. At return, all coho (including jacks) entering the hatchery are electronically sampled (primarily with wands). Untagged and unclipped fish are released upstream of the hatchery. When flows are high enough, some returning adults may jump over the East Fork Satsop Dam (and escape being counted at the hatchery). However, this is unlikely because a concrete splash apron was constructed at the base of the dam in 1996 which limits the ability of fish to jump the dam.

Sampling practices at the hatchery|trap

All hatchery fish may not enter the hatchery. Periodically, when the hatchery holding pond is full, the fish ladder that provides access to the pond is closed temporarily to returning adults. During these times, some fish destined for the hatchery stray into Bingham Creek. These fish are 100% electronically sampled (with wands or "V" detectors) by WDFW crew operating the fishway|trap on Bingham Creek. After electronic sampling, fish are classified as tagged or untagged and then processed as follows:

- All ***marked and tagged*** fish are sacrificed, their heads are taken for tag recovery, and their carcasses returned to the stream. Of the ***unmarked and tagged*** fish, only males are sacrificed for tag recovery at a rate of 20-25%, while 100% of the females are released upstream. All ***unmarked and tagged*** jacks are sacrificed.
- All ***marked but untagged*** fish are sacrificed and their carcasses are returned to the stream. All ***unmarked and untagged*** fish are released upstream to spawn.

APPENDIX 3



Appendix Figure 3.1.1. Map of the East Fork Satsop River, Bingham Creek, and tributaries, showing WDFW trapping facilities.

Spawning ground sampling

The Quinault Indian Nation and WDFW have conducted spawning ground surveys below and above the hatchery. Electronic sampling was conducted on all coho salmon surveyed and heads were taken if tags were detected. The mark status of fish sampled and other data were also recorded.

Preliminary tag recovery data from spawning ground surveys conducted in Grays Harbor and Willapa Bay basins for return years 1998, 1999, and 2000 (Appendix Table 3.1.1) were obtained from WDFW. That tag recovery data had not yet been entered into the RMIS system. For return year 1998, there were two jack recoveries (1996 brood year) on the spawning grounds of the Satsop River, one unmarked (tag code 636212) and one marked (tag code 636213). For return year 1999, there were two adult recoveries (1996 brood year) on the spawning grounds of the Satsop River, one unmarked (tag code 636212) and one marked (tag code 636213). These numbers were added to the escapement tag recovery data on the appropriate data sheets. For return year 2000, there were no reported recoveries of the Bingham Creek Hatchery DIT group on the spawning grounds.

APPENDIX 3

General comments for all brood years 1995-1997

For brood years 1995 and 1996, two different DIT groups were released – one that was from "normal-timed" stock and one that was from "late-timed" stock. Late-timed coho typically return in late fall|early winter, while normal-timed fish usually return in mid-fall.

General notes and concerns

In-river mark-selective sport fisheries existed in the Chehalis and Satsop rivers during all three return years 1998, 1999, and 2000. However, these fisheries were not sampled for CWTs. An additional difficulty arises because the catch is expected to consist of marked fish from more than one hatchery. In addition to the Bingham Creek Hatchery, the Satsop Springs rearing facility has also released adipose fin-clipped hatchery coho over several years, including brood years 1995, 1996, and 1997. Satsop Springs is located downstream of Bingham Hatchery on the Satsop River at river mile 14.8. This facility is operated by a co-op and receives its stock from the Bingham Creek Hatchery.

Number of marked fish released from Satsop Springs rearing facility.

Brood Year	Ad-Clipped but not CWT	Ad-Clipped and CWT
1995	517,500	
1996	401,709	38,868 (tag code 636161)
1997	520,000	

Adult return information to the Satsop Springs facility is incomplete making it difficult to apportion escapement or to assess straying rates. However, it is believed that most adults return to the Bingham Creek Hatchery (Stan Hammer *WDFW, personal communication*). Because the catch in the mark-selective fishery is expected to consist of marked fish from both Bingham Creek Hatchery and Satsop Springs Hatchery, it would be difficult to apportion the catch to each, a necessary step for indirectly estimating the number of tags in the catch (see Appendix 3.13 for detailed method). An alternative would be to combine the two facilities under the assumption that they represent one stock.

In fishery year 2000, unmarked fish were recovered in two marine mark-selective fisheries. These recoveries were recorded by the sampler as unmarked and therefore likely represent an error on the angler's part (i.e., these fish should have been released).

There were no recoveries of the 1995 brood "late-timed" hatchery coho in 1998 mark selective fisheries, nor were there recoveries of 1996 brood "late-timed" stock in 1999 mark-selective fisheries. It appears that selective fisheries occurred too early to capture late-timed hatchery fish during these fishery years.

Appendix Table 3.1.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Bingham Creek Hatchery DIT groups for brood years 1995, 1996, and 1997.

				1995				1996				1997	
				Late timed		Normal timed		Late timed		Normal timed		Normal timed	
Age	Fishery	Type	Data	M	U	M	U	M	U	M	U	M	U
2	Escapement	NSF	Observed						1	84	90	76	77
			Estimated						1.00	84.00	90.00	76.00	77.00
			SE						0.00	0.00	0.00	0.00	0.00
	Freshwater Sport	SF	Observed							5	8		
			Estimated							15.90	25.44		
			SE							5.89	7.45		
	WA Area 2 SF Sport	SF	Observed									1	
			Estimated									2.60	
			SE									2.04	
3	Buoy 10 Sport	SF	Observed									1	
			Estimated									2.13	
			SE									1.55	
	Escapement	NSF	Observed	101	104	781	853	190	205	990	1,129	418	354
			Estimated	101.00	470.89	781.00	1,307.45	190.00	205.00	990.00	1,129.00	459.71	389.28
			SE	0.00	320.30	0.00	321.52	0.00	0.00	0.00	0.00	6.77	6.23
	Freshwater Net	NSF	Observed	1	2	52	42	4	6	16	12	46	33
			Estimated	4.55	8.27	177.78	128.97	10.64	21.51	48.56	37.31	147.85	106.54
			SE	4.02	5.13	21.45	17.27	5.07	7.98	11.04	9.73	18.26	15.50
	Freshwater Sport	SF	Observed			9							
			Estimated			28.62							
			SE			7.90							
	Grays Harbor Net	NSF	Observed			7	9			3	4	12	26
			Estimated			8.39	13.09			16.80	22.40	37.68	71.32
			SE			1.43	2.52			8.79	10.15	8.98	11.75
	Newport Sport	SF	Observed									1	
			Estimated									1.96	
			SE									1.37	

Appendix Table 3.1.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Bingham Creek Hatchery DIT groups for brood years 1995, 1996, and 1997.

				1995				1996				1997	
				Late timed		Normal timed		Late timed		Normal timed		Normal timed	
Age	Fishery	Type	Data	M	U	M	U	M	U	M	U	M	U
	Southeast Alaska Troll	NSF	Observed	3		1		1					
			Estimated	9.74		3.76		3.86					
			SE	4.73		3.22		3.32					
	WA Area 1 Sport	SF	Observed			5				6		3	
			Estimated			9.15				17.76		7.80	
			SE			3.25				6.01		3.55	
	WA Area 1 Troll	SF	Observed									11	
			Estimated									20.48	
			SE									5.01	
	WA Area 13D Net	NSF	Observed			1						1	
			Estimated			1.56						2.88	
			SE			0.93						2.33	
	WA Area 2 NSF Sport	NSF	Observed		1	2	2			1	1		
			Estimated		1.55	3.33	3.10			15.23	15.23		
			SE		0.92	1.50	1.31			14.72	14.72		
	WA Area 2 SF Sport	SF	Observed			6	2			2			
			Estimated			33.41	5.32			4.46			
			SE			19.05	2.97			2.43			
	WA Area 2 Sport	SF	Observed									3	1
			Estimated									7.20	2.79
			SE									3.31	2.23
	WA Area 2 Troll	SF	Observed									3	1
			Estimated									6.87	2.19
			SE									2.99	1.61
	WA Area 3 Sport	SF	Observed							3		5	
			Estimated							5.02		6.23	
			SE							1.84		1.24	

Appendix Table 3.1.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Bingham Creek Hatchery DIT groups for brood years 1995, 1996, and 1997.

				1995				1996				1997	
				Late timed		Normal timed		Late timed		Normal timed		Normal timed	
Age	Fishery	Type	Data	M	U	M	U	M	U	M	U	M	U
	WA Area 4, 4B Troll	NSF	Observed	2	1	3		1		2	2		
			Estimated	2.52	1.14	4.20		5.55		12.38	4.36		
			SE		0.40	1.36		5.03		10.34	2.43		
	Willapa Bay Net	NSF	Observed		1		1			4	6	7	4
			Estimated		4.11		4.11			8.45	12.84	27.90	14.44
			SE		3.58		3.58			3.08	3.84	9.97	7.15
4	Escapement	NSF	Observed					2	1	1			
			Estimated					2.20	1.10	1.10			
			SE					0.47	0.33	0.33			
	Freshwater Net	NSF	Observed							1			
			Estimated							3.92			
			SE							3.38			
	WA Area 1 Sport	NSF	Observed									1	
			Estimated									4.46	
			SE									3.93	
Total Observed				27	22	87	152	40	53	86	157	39	71
Total Estimated				117.81	485.96	1,051.20	1,462.04	212.25	228.61	1,223.58	1,336.58	811.75	663.56
Total Standard Error				6.21	320.36	30.22	322.03	7.89	7.99	24.98	22.15	25.45	21.81

APPENDIX 3

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Bingham Creek Hatchery DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.1.1).

Equal Marine Survival (EMS) Method

Using λ Rel the EMS estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.1.2.

Appendix Table 3.1.2. Estimated numbers of unmarked mortalities of Bingham Creek DIT groups in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1995	1.005	-768	-2028	492
1996	1.019	-77	-155	1
1997	0.991	146	81	211

The mark-selective fisheries in return years 1998 and 1999 appeared small relative to other fishery mortalities. For both years, the EMS method was unable to detect such a small impact and yielded negative and imprecise estimates (brood years 1995 and 1996). In contrast, there were six mark-selective fisheries in 2000. In this year, the EMS method detected a selective fishery impact (brood year 1997). Considering the hatchery practices discussed above, it seems reasonable to assume that there is no delayed marked mortality, and that the post-release tag loss rate was identical for the marked and unmarked groups, both critical assumptions of the EMS method.

Equal Exploitation Rate (EER) Method

For the EER method, all non-selective fisheries were combined to yield an unmarked-to-marked ratio. Using all non-selective fisheries, the EER estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.1.3. In all three years, there were no non-selective fisheries that occurred prior (in time and area) to the mark-selective fisheries (although WA Area 2 Sport and WA Area 4/4B Troll occurred somewhat concurrently with the WA Area 1 Sport selective fishery). Therefore, this method is expected to yield biased estimates of unmarked mortalities.

Appendix Table 3.1.3. Estimated numbers of unmarked mortalities of Bingham Creek DIT groups in all mark-selective fisheries using the EER method.

Brood Year	λ^{NSF}	SE(λ^{NSF})	Estimate	95% Confidence Interval	
				Lower	Upper
1995	0.76	0.145	-1,055	-2,343	232
1996	0.91	0.293	-230	-982	521
1997	0.87	0.131	46	-106	199

APPENDIX 3

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.1.4). Three values of the selective fishery mortality (*sfm*) were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Terminal (TERM) Method

The terminal fisheries for this hatchery are not selective and|or are not sampled, therefore, this method was not applied.

Appendix Table 3.1.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Bingham Creek Hatchery for brood years 1995, 1996, and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement for normal timed-releases.

Age	Fishery	1995						1996						1997					
		50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
								λ^{Rel}											
2	Freshwater Sport							1.13	0.42	2.27	0.84	4.53	1.68						
	WA Area 2 SF Sport													0.18	0.14	0.36	0.28	0.72	0.57
2 Total								1.13	0.42	2.27	0.84	4.53	1.68	0.18	0.14	0.36	0.28	0.72	0.57
3	Freshwater Sport	2.01	0.56	4.03	1.11	8.05	2.22												
	Newport Sport													0.14	0.10	0.27	0.19	0.54	0.38
	WA Area 1 Sport	0.64	0.23	1.29	0.46	2.58	0.91	1.27	0.43	2.53	0.86	5.06	1.71	0.54	0.25	1.08	0.49	2.16	0.99
	WA Area 1 Troll													2.64	0.65	5.28	1.29	10.55	2.58
	WA Area 2 SF Sport	2.35	1.34	4.70	2.68	9.40	5.36	0.32	0.17	0.64	0.35	1.27	0.69						
	WA Area 2 Sport													0.50	0.23	1.00	0.46	2.00	0.92
	WA Area 2 Troll													0.88	0.38	1.77	0.77	3.54	1.54
	WA Area 3 Sport							0.36	0.13	0.72	0.26	1.43	0.53	0.43	0.09	0.86	0.17	1.73	0.34
	Buoy 10 Sport													0.17	0.12	0.34	0.25	0.68	0.49
3 Total		5.01	2.12	10.02	4.25	20.03	8.50	1.94	0.73	3.88	1.47	7.77	2.93	5.30	1.81	10.60	3.62	21.20	7.24
								λ^{Esc}											
2	Freshwater Sport							1.27	0.47	2.54	0.94	5.08	1.88						
	WA Area 2 SF Sport													0.15	0.12	0.31	0.24	0.62	0.48
2 Total								1.27	0.47	2.54	0.94	5.08	1.88	0.15	0.12	0.31	0.24	0.62	0.48
3	Freshwater Sport	3.35	1.24	6.71	2.48	13.42	4.96												
	Newport Sport													0.12	0.08	0.23	0.16	0.46	0.33
	WA Area 1 Sport	1.07	0.46	2.14	0.93	4.29	1.85	1.42	0.48	2.84	0.96	5.67	1.92	0.46	0.21	0.92	0.42	1.85	0.84
	WA Area 1 Troll													2.25	0.55	4.51	1.11	9.02	2.22
	WA Area 2 SF Sport	3.92	2.43	7.83	4.86	15.66	9.72	0.36	0.19	0.71	0.39	1.42	0.78						
	WA Area 2 Sport													0.43	0.20	0.85	0.39	1.71	0.78
	WA Area 2 Troll													0.76	0.33	1.51	0.66	3.03	1.32
	WA Area 3 Sport							0.40	0.15	0.80	0.29	1.60	0.59	0.37	0.07	0.74	0.15	1.48	0.30
	Buoy 10 Sport													0.14	0.11	0.29	0.21	0.58	0.42
3 Total		8.34	4.13	16.68	8.27	33.37	16.54	2.17	0.82	4.35	1.64	8.70	3.28	4.53	1.55	9.06	3.10	18.12	6.20

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Appendix 3.2. Forks Creek Hatchery

Annette Hoffmann, WDFW
Laurie Peterson, WDFW

Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
1995	419972401	75,497	75,294	1.0027

Forks Creek Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on Forks Creek, a tributary to the Willapa River.

Hatchery practices that are relevant to this analysis

All coho salmon, including jacks, entering the hatchery are counted and electronically sampled using wands. Wild fish that are sampled as untagged and unclipped are released upstream of the hatchery. When flows are high (if the river comes up 2-3 feet) fish could jump over the barrier at the hatchery so that some returning adults could pass above the hatchery unsampled. For the 1995 brood, the marked and unmarked fish were reared in similar conditions prior to release.

Spawning ground sampling

Spawning ground surveys were conducted below and above the hatchery. Electronic sampling was conducted on all coho surveyed. The mark status of fish sampled and other data were also recorded. Preliminary data from spawning ground surveys (Susan Markey *WDFW, personal communication*) in years 1998, 1999, and 2000 showed no recoveries of Forks Creek Hatchery tags on the spawning grounds.

General notes and concerns

A selective sport fishery existed in the Willapa River in 1998, possibly intercepting Forks Creek hatchery fish. However, this fishery was not sampled.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries were made of Forks Creek Hatchery DIT fish largely in Washington ocean and Puget Sound fisheries (Appendix Table 3.2.1).

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Appendix Table 3.2.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Forks Creek Hatchery DIT groups for brood year 1995.

Age	Fishery	Type	Data	M	U
3	Buoy 10 Sport	SF	Observed	1.00	
			Estimated	2.22	
			SE	1.65	
	Escapement	NSF	Observed	182.00	243.00
			Estimated	198.11	264.69
			SE	4.19	4.86
	Freshwater Net	NSF	Observed	1.00	
			Estimated	2.19	
			SE	1.61	
	Grays Harbor Net	NSF	Observed		1.00
			Estimated		1.05
			SE		0.23
	Southeast Alaska Troll	NSF	Observed	1.00	
			Estimated	1.64	
			SE	1.02	
	WA Area 1 Sport	SF	Observed	2.00	
			Estimated	4.41	
			SE	2.67	
	WA Area 11 Sport	NSF	Observed	1.00	
			Estimated	4.15	
			SE	3.62	
	WA Area 13A Net	NSF	Observed	1.00	
			Estimated	1.00	
			SE	0.00	
	WA Area 2 NSF Sport	NSF	Observed	3.00	1.00
			Estimated	6.13	1.55
			SE	2.61	0.92
	WA Area 2 SF Sport	SF	Observed	1.00	
			Estimated	4.01	
			SE	3.47	
	WA Area 4, 4B Troll	NSF	Observed	2.00	2.00
			Estimated	3.45	2.40
			SE	1.58	0.70
	WA Area 5 Sport	NSF	Observed	1.00	
			Estimated	4.29	
			SE	3.76	
	WA Area 8-2 Sport	NSF	Observed	1.00	
			Estimated	2.35	
			SE	1.78	
	Willapa Bay Net	NSF	Observed	48.00	67.00
			Estimated	248.68	319.59
			SE	33.70	36.88
Total Observed				245.00	314.00
Total Estimated				482.63	589.28
Total Standard Error				34.34	37.21

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Equal Marine Survival (EMS) Method

Using λ^{Rel} the EMS estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.2.2.

Appendix Table 3.2.2. Estimated number of mortalities of unmarked fish for Forks Creek DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1995	1.0027	–104.24	-245.93	37.46

Only two selective fisheries occurred in return year 1998 (WA Area 1 Sport and Buoy 10 Sport) and there were minimal tag recoveries (6.63 expanded marked recoveries total). This method was unable to detect impacts from selective fisheries which resulted in a negative and imprecise total estimate of unmarked mortalities in mark-selective fisheries.

Equal Exploitation Rate (EER) Method

For the EER method, all non-selective fisheries were combined to yield an unmarked-to-marked ratio (λ^{NSF}). Using all non-selective fisheries, the EER estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.2.3.

Appendix Table 3.2.3. Estimated number of mortalities of unmarked fish for Forks Creek DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	λ^{NSF}	SE(λ^{NSF})	Estimate	95% Confidence Interval	
				Lower	Upper
1995	0.76	0.145	-17.28	-162.15	127.57

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.2.4.) Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Terminal (TERM) Method

The terminal fisheries for this hatchery are not selective and|or are not sampled, therefore, this method was not appropriate.

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Appendix Table 3.2.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Forks Creek Hatchery for brood year 1995 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}					
3	WA Area 1 Sport	0.14	0.31	0.19	0.62	0.38	1.24	0.75
	WA Area 2 SF Sport	0.14	0.28	0.24	0.56	0.49	1.13	0.98
	Buoy 10 Sport	0.16	0.18	0.13	0.36	0.26	0.71	0.53
3 Total			0.77	0.56	1.54	1.13	3.08	2.25
			λ^{Esc}					
3	WA Area 1 Sport	0.14	0.41	0.25	0.82	0.50	1.65	1.00
	WA Area 2 SF Sport	0.14	0.38	0.33	0.75	0.65	1.50	1.30
	Buoy 10 Sport	0.16	0.24	0.18	0.47	0.35	0.95	0.70
3 Total			1.02	0.75	2.05	1.50	4.10	3.01

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Appendix 3.3. Humptulips Hatchery

Annette Hoffmann, WDFW
Laurie Peterson, WDFW

Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
1995	419972201	79,143	79,073	1.0009
1996	419981001	74,509	79,321	0.9393

Humptulips Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on Stevens Creek, a tributary of the Humptulips River.

Hatchery practices that are relevant to this analysis

All of the fish entering the hatchery were electronically sampled during return years 1998 and 1999, primarily with tubes. All jacks were counted and sampled with wands. However, the majority of returning coho salmon do not enter the hatchery. Returns to the hatchery are voluntary with most of the escapement going up the mainstem Humptulips River and passing the hatchery. In a typical year, about 28,000 fish will return to the hatchery while about 40,000 will head up the mainstem Humptulips River to spawn (*WDFW, personal communication*). The Humptulips Hatchery is no longer a DIT release site.

Concerns

There was a mark-selective sport fishery in the river that was not sampled (Appendix Table 4).

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Humptulips Hatchery DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.3.1).

Appendix Table 3.3.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Humptulips Hatchery DIT groups for brood years 1995 and 1996.

				1995		1996	
Age	Fishery	Type	Data	M	U	M	U
2	Escapement	NSF	Observed			13	18
			Estimated			13.00	18.00
			SE			0.00	0.00
3	Escapement	NSF	Observed	219	268	810	881
			Estimated	219.00	268.00	810.00	881.00
			SE	0.00	0.00	0.00	0.00
	Freshwater Net	NSF	Observed	89	106	100	96
			Estimated	281.74	331.52	238.01	219.20
			SE	26.23	28.11	20.11	18.35
	Grays Harbor Net	NSF	Observed	19	8	5	2
			Estimated	24.11	10.48	28.00	11.20
			SE	2.78	1.95	11.35	7.18

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Appendix Table 3.3.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Humptulips Hatchery DIT groups for brood years 1995 and 1996.

				1995		1996	
Age	Fishery	Type	Data	M	U	M	U
	Newport Sport	SF	Observed			1	
			Estimated			2.29	
			SE			1.72	
	Southeast Alaska Net	NSF	Observed	1			
			Estimated	5.51			
			SE	4.98			
	Southeast Alaska Troll	NSF	Observed	7			
			Estimated	16.10			
			SE	4.93			
	Tillamook Sport	SF	Observed			1	
			Estimated			1.13	
			SE			0.38	
	WA Area 1 Sport	SF	Observed	4		8	
			Estimated	7.97		17.13	
			SE	2.94		5.25	
	WA Area 2 NSF Sport	NSF	Observed	4	7		
			Estimated	8.28	13.62		
			SE	3.24	3.83		
	WA Area 2 SF Sport	SF	Observed	3		4	
			Estimated	10.68		10.60	
			SE	5.34		4.32	
	WA Area 3 Sport	NSF	Observed		1		
			Estimated		1.06		
			SE		0.25		
		SF	Observed			2	
			Estimated			3.50	
			SE			1.70	
	WA Area 3 Troll	NSF	Observed			1	4
			Estimated			1.17	4.52
			SE			0.45	0.78
	WA Area 4 Sport	SF	Observed			1	
			Estimated			1.28	
			SE			0.60	
	WA Area 4, 4B Troll	NSF	Observed	2	5	7	4
			Estimated	2.52	6.62	35.89	16.74
			SE	0.81	1.53	15.78	10.62
	WA Area 8D Net	NSF	Observed	1			
			Estimated	1.90			
			SE	1.31			
	Willapa Bay Net	NSF	Observed		2	13	8
			Estimated		12.26	27.38	16.90
			SE		7.93	5.53	4.35
Total Observed				349	397	966	1,013
Total Estimated				577.81	643.56	1,189.38	1,167.56
Total Standard Error				28.19	29.56	29.42	22.82

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Equal Marine Survival (EMS) Method

A key assumption of this method is that adequate sampling is conducted at escapement and in fisheries, but this assumption was clearly violated in the case of the Humptulips Hatchery DIT groups because of inadequate sampling of the escapement.

Equal Exploitation Rate (EER) Method

A key assumption of this method is that adequate sampling is conducted at escapement and in fisheries, but this assumption was clearly violated in the case of the Humptulips Hatchery DIT groups because of inadequate sampling of the escapement.

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.3.2). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.3.2. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Humptulips Hatchery for brood years 1995 and 1996 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1995 50% *sfm*	SE	1995 Default *sfm*	SE	1995 200% *sfm*	SE	1996 50% *sfm*	SE	1996 Default *sfm*	SE	1996 200% *sfm*	SE
						λ^{Rel}								
3	Newport Sport	0.14							0.15	0.11	0.30	0.23	0.60	0.45
	Tillamook Sport	0.14							0.07	0.03	0.15	0.05	0.30	0.10
	WA Area 1 Sport	0.14	0.56	0.21	1.12	0.41	2.23	0.82	1.13	0.35	2.25	0.69	4.51	1.38
	WA Area 2 SF Sport	0.14	0.75	0.37	1.50	0.75	2.99	1.50	0.70	0.28	1.39	0.57	2.79	1.14
	WA Area 3 Sport	0.14							0.23	0.11	0.46	0.22	0.92	0.45
	WA Area 4 Sport	0.14							0.08	0.04	0.17	0.08	0.34	0.16
3 Total			1.31	0.58	2.61	1.16	5.23	2.32	2.36	0.92	4.73	1.84	9.45	3.67
						λ^{Esc}								
3	Newport Sport	0.14							0.17	0.13	0.35	0.26	0.70	0.52
	Tillamook Sport	0.14							0.09	0.03	0.17	0.06	0.34	0.12
	WA Area 1 Sport	0.14	0.68	0.25	1.37	0.50	2.73	1.01	1.30	0.40	2.61	0.80	5.22	1.60
	WA Area 2 SF Sport	0.14	0.91	0.46	1.83	0.92	3.66	1.83	0.81	0.33	1.61	0.66	3.23	1.31
	WA Area 3 Sport	0.14							0.27	0.13	0.53	0.26	1.07	0.52
	WA Area 4 Sport	0.14							0.10	0.05	0.19	0.09	0.39	0.18
3 Total			1.60	0.71	3.20	1.42	6.39	2.84	2.74	1.06	5.47	2.13	10.94	4.25

Appendix 3.4. Makah NFH

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Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Makah NFH	1996	071998WM43	38,133	49,196	0.7751
	1997	071999WM55	37,980	39,657	0.9577

The Makah National Fish Hatchery (NFH) is operated by the U.S. Fish and Wildlife Service (USFWS) on the Soos River.

DIT rearing strategy

Marked and unmarked DIT groups are tagged on the same day or consecutive days and are reared together in the same pond (four separate replicated groups are used for DIT tagging). The initial number of fish in each DIT group is estimated using an inventory method. Release numbers are then determined by subtracting estimated mortalities occurring between this initial abundance estimate and the release date. These mortalities are estimated by hand counts and are allocated to tag|mark group in relative proportion to initial abundance estimates for each group.

General comments

The location of the hatchery is three miles from the mouth of the Soos River. The hatchery is on the mainstem and runs a completely spanning|blocking electrified weir with an associated fish ladder. There are no tributaries downstream of the hatchery and it is expected that very few fish spawn in-river downstream of the hatchery (David Zajack, *USFWS personal communication*). The location of the weir makes it subject to tidal influence and high water occurrences swamp the weir and allow fish to pass. An estimate of the number of fish that pass above the hatchery is made during these times. The hatchery return is sampled at less than 100% and some fish are passed above the hatchery. However, fish that are passed above the hatchery are counted so that expansion rates account for these fish. Jacks are treated no differently from other fish when sampling.

General concerns for all brood years

These release groups were caught in the southeast Alaskan Troll fishery which is not electronically sampled. Therefore, unmarked recoveries will not be observed in this fishery. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}. In addition, these recoveries were ignored when applying the EMS and EER methods.

APPENDIX 3

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Makah DIT groups largely occurred in Washington and Oregon ocean fisheries (Appendix Table 3.4.1). For the 1996 brood year, unmarked recoveries were observed in the Area 3 and Area 4 sport selective fisheries. In Area 3 there was 1 observed recovery (1.77 expanded recoveries) which was recorded as unmarked by the sampler. In Area 4 there was 1 observed recovery (2.94 expanded recoveries) which was recorded as marked by the sampler. For the 1997 brood year, there was 1 observed unmarked recovery in the WA Area 1 Sport fishery which was mark-selective. It was recorded by the sampler as a marked fish. A single unmarked tag was observed in the Area 2 sport selective fishery.

Appendix Table 3.4.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Makah NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
2	Escapement	NSF	Observed	70	41	6	12
			Estimated	86.61	51.47	27.90	64.56
			SE	5.32	4.24	10.85	16.82
	Freshwater Net	NSF	Observed				1
			Estimated				3.54
			SE				3.00
3	Escapement	NSF	Observed	308	231	147	119
			Estimated	1,565.68	1,175.55	718.67	597.06
			SE	80.17	69.45	53.18	48.98
	Freshwater Net	NSF	Observed	19	21	1	1
			Estimated	153.61	161.62	4.14	3.19
			SE	33.27	34.06	3.61	2.64
	Newport Sport	SF	Observed	3		3	
			Estimated	5.86		5.84	
			SE	2.40		2.37	
	Southeast Alaska Troll	NSF	Observed	5		1	
			Estimated	14.77	*11.45*	3.58	*3.43*
			SE	5.68	*4.40*	3.04	*2.91*
	Tillamook Sport	SF	Observed	1			
			Estimated	1.52			
			SE	0.89			
	WA Area 1 Sport	SF	Observed	10		5	1
			Estimated	22.21		14.66	2.45
			SE	5.59		5.64	1.88
	WA Area 1 Troll	SF	Observed			2	
			Estimated			3.06	
			SE			1.38	

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Appendix Table 3.4.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Makah NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996 M	1996 U	1997 M	1997 U
	WA Area 2 SF Sport	SF	Observed	9			
			Estimated	22.98			
			SE	6.11			
	WA Area 2 Sport	SF	Observed			10	
			Estimated			25.02	
			SE			6.31	
	WA Area 2 Troll	NSF	Observed		1		
			Estimated		5.85		
			SE		5.33		
	WA Area 3 Sport	SF	Observed	18	1	5	
			Estimated	32.23	1.77	6.58	
			SE	5.11	1.17	1.46	
	WA Area 3 Troll	NSF	Observed	7	9		
			Estimated	8.03	11.92		
			SE	1.10	2.47		
	WA Area 4 Sport	SF	Observed	11	1	6	
			Estimated	28.55	2.94	12.18	
			SE	6.85	2.39	3.72	
	WA Area 4, 4B Troll	NSF	Observed	41	30	1	2
			Estimated	142.55	137.73	7.48	14.96
			SE	26.49	29.55	6.96	9.85
	WA Area 5 Sport	SF	Observed	1		1	
			Estimated	3.78		5.02	
			SE	3.24		4.49	
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed		1		
			Estimated		1.81		
			SE		1.21		
Total Observed				39	37	16	23
Total Estimated				2,088.38	1,550.66	834.13	685.76
Total Standard Error				91.96	83.17	55.96	52.90

Equal Marine Survival (EMS) Method

For the 1996 brood year using λ^{Rel} = 0.775, the estimate for the total unmarked mortality summed across all mark-selective fisheries is 68 fish (Appendix Table 3.4.2). For the 1997 brood year using λ^{Rel} = 0.958, the estimate for the total unmarked mortality summed across all mark-selective fisheries is 113 fish.

Appendix Table 3.4.2. Estimated number of mortalities of unmarked fish for Makah NFH DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
1996	0.7751	68	-147	283
1997	0.9577	113	-35	261

Equal Exploitation Rate (EER) Method

For the 1996 brood year, there were no non-selective fisheries that occurred prior (in time and area) to mark-selective fisheries. Therefore, it may not be possible to obtain an unbiased estimate of λ from any of the non-selective fisheries. The λ combined in all significant marine non-selective fisheries (WA Area 2 Troll, WA Area 4, 4B Troll, WA Area 3 Troll) was 1.04 (95% confidence interval = 0.5, 2.05). The estimate of the total number of unmarked mortalities in mark-selective fisheries using the EER method with the above λ is 631 (Appendix Table 3.4.3). Comparing this estimate to the EMS estimate illustrates how λ impacts the estimate of unmarked mortalities. In addition, the EER method is extremely imprecise since it accounts for the uncertainty in the estimated λ due to sampling error. For the 1997 brood year, the only non-selective fishery that might be considered for the EER method would be the WA Area 4, 4B Troll fishery. There were very few recoveries in this fishery and it occurred after several non-selective fisheries had already begun. Therefore, a reliable estimate could not be obtained using the EER method.

Appendix Table 3.4.3. Estimated number of mortalities of unmarked fish for Makah NFH DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	λ^{NSF}	SE(λ^{NSF})	Estimate	95% Confidence Interval	
1996	1.04	0.27	631.06	-428.21	1,690.32
1997	2.00	2.28	982.50	-2,719.26	4,684.26

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.4.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.4.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Makah NFH for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
3	Newport Sport	14%	0.32	0.13	0.64	0.26	1.27	0.52	0.39	0.16	0.78	0.32	1.57	0.64
	Tillamook Sport	14%	0.08	0.05	0.16	0.10	0.33	0.19						
	WA Area 1 Sport	14%	1.21	0.30	2.41	0.61	4.82	1.21	0.98	0.38	1.97	0.76	3.93	1.51
	WA Area 1 Troll	26%							0.38	0.17	0.76	0.34	1.52	0.69
	WA Area 2 SF Sport	14%	1.25	0.33	2.49	0.66	4.99	1.33						
	WA Area 2 Sport	14%							1.68	0.42	3.35	0.85	6.71	1.69
	WA Area 3 Sport	14%	1.75	0.28	3.50	0.55	7.00	1.11	0.44	0.10	0.88	0.20	1.76	0.39
	WA Area 4 Sport	14%	1.55	0.37	3.10	0.74	6.20	1.49	0.82	0.25	1.63	0.50	3.27	1.00
	WA Area 5 Sport	7%	0.10	0.09	0.21	0.18	0.41	0.35	0.17	0.15	0.34	0.30	0.67	0.60
3 Total			6.25	0.44	12.51	1.78	25.01	7.10	4.86	0.47	9.72	1.89	19.43	7.54
			λ^{Esc}											
3	Newport Sport	14%	0.31	0.13	0.62	0.26	1.23	0.51	0.34	0.14	0.68	0.29	1.36	0.57
	Tillamook Sport	14%	0.08	0.05	0.16	0.09	0.32	0.19						
	WA Area 1 Sport	14%	1.17	0.31	2.33	0.62	4.67	1.23	0.85	0.34	1.71	0.68	3.41	1.37
	WA Area 1 Troll	26%							0.33	0.15	0.66	0.31	1.32	0.61
	WA Area 2 SF Sport	14%	1.21	0.33	2.42	0.67	4.83	1.34						
	WA Area 2 Sport	14%							1.46	0.40	2.91	0.80	5.82	1.60
	WA Area 3 Sport	14%	1.69	0.30	3.39	0.60	6.78	1.20	0.38	0.10	0.77	0.19	1.53	0.38
	WA Area 4 Sport	14%	1.50	0.38	3.00	0.76	6.00	1.51	0.71	0.23	1.42	0.46	2.83	0.92
	WA Area 5 Sport	7%	0.10	0.09	0.20	0.17	0.40	0.34	0.15	0.13	0.29	0.26	0.58	0.53
3 Total			6.06	2.97	12.11	11.87	24.23	47.47	4.21	2.64	8.43	10.55	16.86	42.19

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Appendix 3.5. Quinault National Fish Hatchery

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Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Quinault NFH	1996	071998WT50	82,697	83,318	0.9925
	1997	071999WT85	78,347	80,935	0.9680

Hatchery practices that are relevant to these analyses

The Quinault National Fish Hatchery (NFH) is operated by the U.S. Fish and Wildlife Service (USFWS) and is located on Cook Creek, a tributary to the Quinault River. All, or close to all, returning adults enter the hatchery where the sample rate is approximately 30%. There is a very small sport fishery with limited access which may harvest a few fish.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries were made of Quinault NFH DIT coho salmon largely in Washington and Oregon ocean and terminal net fisheries (Appendix Table 3.5.1). Marked recoveries occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}. Several unmarked and tagged fish were observed in mark-selective fisheries, including Tillamook sport, Washington Area 1 sport and troll, and Washington Area 2 sport.

Appendix Table 3.5.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quinault NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
2	Escapement	NSF	Observed	48	99	153	130
			Estimated	48.96	100.98	453.08	381.37
			SE	0.99	1.42	30.00	27.30
3	Buoy 10 Sport	SF	Observed			1	
			Estimated			2.49	
			SE			1.93	
	Escapement	NSF	Observed	334	273	329	320
			Estimated	1,100.90	841.87	937.65	898.47
			SE	51.33	42.66	41.77	40.46
	Freshwater Net	NSF	Observed	250	238	380	387
			Estimated	1,079.12	1,008.28	1,317.35	1,346.12
			SE	61.02	58.38	58.33	59.16
	Grays Harbor Net	NSF	Observed				1
			Estimated				3.14
			SE				2.59

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Appendix Table 3.5.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quinault NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
	Newport Sport	SF	Observed	2		12	
			Estimated	2.67		22.88	
			SE	0.99		4.59	
	Southeast Alaska	NSF	Observed	1			
	Troll		Estimated	2.62	*2.60*		
			SE	2.06	*2.04*		
	Tillamook Sport	SF	Observed	2	1	1	
			Estimated	2.52	1.52	1.32	
			SE	0.89	0.89	0.65	
	WA Area 1 Sport	SF	Observed	7		24	1
			Estimated	19.08		51.56	2.26
			SE	5.95		8.66	1.69
	WA Area 1 Troll	SF	Observed			12	1
			Estimated			24.70	1.83
			SE			5.66	1.23
	WA Area 13D Net	NSF	Observed			1	
			Estimated			1.98	
			SE			1.39	
	WA Area 2 SF Sport	SF	Observed	21			
			Estimated	53.64			
			SE	9.56			
	WA Area 2 Sport	SF	Observed			68	1
			Estimated			153.70	3.24
			SE			14.42	2.69
	WA Area 2 Troll	SF	Observed			7	
			Estimated			17.90	
			SE			5.57	
	WA Area 3 Sport	SF	Observed	10		11	
			Estimated	16.69		14.37	
			SE	3.37		2.22	
	WA Area 3 Troll	NSF	Observed	8	6		
			Estimated	10.92	6.86		
			SE	2.47	1.00		
	WA Area 4 Sport	SF	Observed	5		3	
			Estimated	14.54		8.00	
			SE	5.29		3.78	
	WA Area 4, 4B Troll	NSF	Observed	18	16	3	6
			Estimated	54.31	38.82	22.44	44.88
			SE	14.63	8.96	12.06	17.05

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Appendix Table 3.5.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quinault NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
	WA Area 9 Sport	NSF	Observed	1			
			Estimated	7.89			
			SE	7.37			
	WA Areas 4B, 5, 6,	NSF	Observed				1
			Estimated				3.29
			SE				2.74
	Willapa Bay Net	NSF	Observed	1	1		
			Estimated	2.03	2.03		
			SE	1.45	1.45		
Total Observed				708	634	1,005	848
Total Estimated				2,415.89	2,002.96	3,029.42	2,684.60
Total Standard Error				72.93	72.90	81.15	78.73

Equal Marine Survival (EMS) Method

The estimates made using the EMS method were 395 coho for brood year 1996 and 1,239 for brood year 1997 (Appendix Table 3.5.2).

Appendix Table 3.5.2. Estimated number of mortalities of unmarked fish for Quinault NFH DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1996	0.9925	395	180	610
1997	0.9680	1,239	982	1,497

Equal Exploitation Rate (EER) Method

There were no non-selective fisheries that occurred prior (in time and area) to mark-selective fisheries. Therefore, it may not be possible to obtain an unbiased estimate of λ from any of the non-selective fisheries. The λ combined in all significant marine non-selective fisheries (WA Area 4, 4B Troll, WA Area 3 Troll) was 0.70 for the 1996 brood year and 2.00 for the 1997 brood year (Appendix Table 3.5.3). These estimates were extremely imprecise. The EER method is unreliable when the estimate of λ is imprecise.

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Appendix Table 3.5.3. Estimated number of mortalities of unmarked fish for Quinault NFH DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	$\lambda^{Fishery}$	SE($\lambda^{Fishery}$)	Estimate	95% Confidence Interval	
				Lower	Upper
1996	0.70	0.24	-311.13	-1,426.42	804.15
1997	2.00	1.32	3,374.24	-4,391.39	11,139.87

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.5.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.5.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Quinault NFH for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
3	Newport Sport	0.14	0.19	0.07	0.37	0.14	0.74	0.27	1.55	0.31	3.10	0.62	6.20	1.24
	Tillamook Sport	0.14	0.18	0.06	0.35	0.12	0.70	0.25	0.09	0.04	0.18	0.09	0.36	0.18
	WA Area 1 Sport	0.14	1.33	0.41	2.65	0.83	5.30	1.65	3.49	0.59	6.99	1.17	13.98	2.35
	WA Area 1 Troll	0.26							3.11	0.71	6.22	1.42	12.43	2.85
	WA Area 2 SF Sport	0.14	3.73	0.66	7.45	1.33	14.91	2.66						
	WA Area 2 Sport	0.14							10.42	0.98	20.83	1.95	41.66	3.91
	WA Area 2 Troll	0.26							2.25	0.70	4.51	1.40	9.01	2.80
	WA Area 3 Sport	0.14	1.16	0.23	2.32	0.47	4.64	0.94	0.97	0.15	1.95	0.30	3.89	0.60
	WA Area 4 Sport	0.14	1.01	0.37	2.02	0.73	4.04	1.47	0.54	0.26	1.08	0.51	2.17	1.02
	Buoy 10 Sport	0.16							0.19	0.15	0.39	0.30	0.77	0.60
3 Total			7.58	1.81	15.17	3.62	30.33	7.24	22.62	3.89	45.24	7.78	90.47	15.55
			λ^{Esc}											
3	Newport Sport	0.14	0.14	0.05	0.29	0.11	0.57	0.21	1.53	0.32	3.07	0.65	6.14	1.29
	Tillamook Sport	0.14	0.13	0.05	0.27	0.10	0.54	0.19	0.09	0.04	0.18	0.09	0.35	0.18
	WA Area 1 Sport	0.14	1.02	0.33	2.04	0.65	4.09	1.31	3.46	0.62	6.92	1.24	13.83	2.48
	WA Area 1 Troll	0.26							3.08	0.73	6.15	1.46	12.31	2.93
	WA Area 2 SF Sport	0.14	2.87	0.55	5.74	1.10	11.49	2.19						
	WA Area 2 Sport	0.14							10.31	1.17	20.62	2.33	41.24	4.67
	WA Area 2 Troll	0.26							2.23	0.71	4.46	1.42	8.92	2.83
	WA Area 3 Sport	0.14	0.89	0.19	1.79	0.38	3.57	0.76	0.96	0.16	1.93	0.32	3.86	0.64
	WA Area 4 Sport	0.14	0.78	0.29	1.56	0.58	3.11	1.15	0.54	0.26	1.07	0.51	2.15	1.02
	Buoy 10 Sport	0.16							0.19	0.15	0.38	0.30	0.76	0.59
3 Total			5.84	1.46	11.68	2.91	23.37	5.82	22.39	4.16	44.78	8.32	89.56	16.64

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Appendix 3.6. Salmon River Hatchery

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Marianna Alexandersdottir, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Salmon River	1995	1419979002	71,285	98,028	0.7272
	1996	1419989003	98,473	73,928	1.3320
	1997	141999DI04	68,234	72,236	0.9446

Hatchery practices that are relevant to these analyses

The Salmon River Fish Hatchery is operated by the Quinault Indian Nation and is located on the Salmon River, a tributary to the Queets River. The hatchery allows 1,700-1,800 coho salmon to enter the hatchery for brood stock purposes before closing the rack. The remainder of the run moves up the river. All fish entering the hatchery are sampled for marks and CWTs. There is sampling for CWTs on the spawning grounds at 4-8% of the spawning abundance. There is a sport fishery in the Queets and Salmon Rivers, but it is relatively small due to the combination of National Park regulations and isolated location. There is a guided sport fishery on the Quinault Indian Reservation for which recoveries are not available.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Salmon River DIT groups largely occurred in Washington and Oregon ocean fisheries (Appendix Table 3.6.1). Marked recoveries occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}. A single unmarked tag was observed in the Area 2 sport selective fishery.

Appendix Table 3.6.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Salmon River Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
2	Hatchery Escapement		Observed			2	2	4	3
			Estimated			2.38	2.38	4.12	3.09
			SE			0.67	0.67	0.35	0.30
	WA Area 4 Sport	SF	Observed					1	
			Estimated					2.27	
			SE					1.70	
3	Coos Bay Sport	SF	Observed			3		1	
			Estimated			3.87		1.74	
			SE			1.06		1.13	

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Appendix Table 3.6.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Salmon River Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
	Hatchery Escapement		Observed	208	154	209	226	179	199
			Estimated	706.2	896.70	831.41	1,113.0	427.17	642.01
			SE	155.09	193.33	166.66	199.19	109.79	147.28
	Spawning Grounds		Estimated	265.54	398.32	202.94	266.36	184.47	214.53
			SE	82.38	100.89	48.69	55.79	100.15	70.00
	Freshwater Net	NSF	Observed	352	287	143	163	93	101
			Estimated	903.04	748.56	510.21	591.90	327.29	355.28
			SE	38.10	35.17	36.63	39.72	29.53	30.69
	Grays Harbor Net	NSF	Observed	1		1			
			Estimated	1.05		5.60			
			SE	0.23		5.08			
	Newport Sport	SF	Observed			2		3	
			Estimated			3.82		5.62	
			SE			1.94		2.25	
	Southeast Alaska Net	NSF	Observed			1			
			Estimated			5.47	*7.29*		
			SE			4.94	*8.77*		
	Southeast Alaska Troll	NSF	Observed	9		1			
			Estimated	24.63	*17.91*	2.57	*3.42*		
			SE	6.72	*3.56*	2.01	*3.56*		
	Tillamook Sport	SF	Observed			3		1	
			Estimated			4.82		1.20	
			SE			1.72		0.49	
	WA Area 1 Sport	SF	Observed	1		12		13	
			Estimated	3.16		22.84		25.33	
			SE	2.61		4.97		5.31	
	WA Area 1 Troll	SF	Observed					6	
			Estimated					14.52	
			SE					4.79	
	WA Area 2 NSF Sport	NSF	Observed	21	15				
			Estimated	45.02	30.62				
			SE	7.63	6.03				
	WA Area 2 SF Sport	SF	Observed			23			
			Estimated			59.54			
			SE			10.14			
	WA Area 2 Sport	SF	Observed					30	1
			Estimated					66.25	2.19
			SE					9.24	1.61
	WA Area 2 Troll	SF	Observed					1	
			Estimated					2.49	
			SE					1.93	

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Appendix Table 3.6.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Salmon River Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
	WA Area 3 Sport	NSF	Observed	2	1				
			Estimated	2.12	1.06				
			SE	0.36	0.25				
		SF	Observed			21		3	
			Estimated			37.09		3.58	
			SE			5.40		0.84	
	WA Area 3 Troll	NSF	Observed			12	8		
			Estimated			15.28	9.04		
			SE			2.56	1.10		
	WA Area 4 Sport	NSF	Observed	2					
			Estimated	3.55					
			SE	1.99					
		SF	Observed			5		3	
			Estimated			12.83		8.65	
			SE			4.67		4.04	
	WA Area 4, 4B Troll	NSF	Observed	5	1	26	28	1	1
			Estimated	7.38	1.14	75.88	124.97	7.48	7.48
			SE	1.97	0.40	17.74	27.90	6.96	6.96
	WA Area 5 Sport	NSF	Observed	2	2				
			Estimated	9.42	10.26				
			SE	5.94	6.51				
	WA Area 6 Sport	NSF	Observed		1				
			Estimated		2.22				
			SE		1.65				
	WA Area 8D Net	NSF	Observed	1					
			Estimated	1.90					
			SE	1.31					
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed				1		
			Estimated				1.25		
			SE				0.56		
4	Freshwater Net	NSF	Observed			1			
			Estimated			3.10			
			SE			2.55			
Total Observed				604	461	465	428	339	305
Total Estimated				1,972.9	2,106.7	1,799.6	2,119.5	1,082.1	1,224.5
Total Standard Error				180.12	221.10	179.04	212.69	152.22	166.09

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Equal Marine Survival (EMS) Method

The estimates made using the EMS method were imprecise (Appendix Table 3.6.2). For the 1995 and 1997 brood years the estimates were negative and for the 1996 brood year not significantly different from zero (95% confidence interval included zero).

Appendix Table 3.6.2. Estimated number of mortalities of unmarked fish for Salmon River Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1995	0.7272	-654	-1,158	-151
1996	1.3320	288	-338	914
1997	0.9446	-202	-633	228

Equal Exploitation Rate (EER) Method

There were no non-selective fisheries that occurred prior (in time and area) to mark-selective fisheries. Therefore, it may not be possible to obtain an unbiased estimate of λ from any of the non-selective fisheries. The λ combined in all significant marine non-selective fisheries (WA Area 4, 4B Troll, WA Area 3 Troll) was 0.15 for the 1995 brood year, 1.47 for the 1996 brood year, and 1.00 for the 1997 brood year (Appendix Table 3.6.3). These estimates were extremely imprecise and the EER method is unreliable when the estimate of λ is imprecise.

Appendix Table 3.6.3. Estimated number of mortalities of unmarked fish for Salmon River Hatchery DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	$\lambda^{Fishery}$	SE($\lambda^{Fishery}$)	Estimate	95% Confidence Interval	
				Lower	Upper
1995	0.15	0.08	-1,784.11	-2,328.19	-1,240.04
1996	1.47	10.00	536.70	-32,904.70	33,978.10
1997	1.00	9.16	-142.40	-19,450.36	19,165.56

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.6.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.6.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Salmon River Hatchery for brood years 1995, 1996, and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1995						1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
									λ^{Rel}											
2	WA Area 4 Sport	0.14													0.15	0.11	0.30	0.22	0.60	0.45
	2 Total														0.15	0.11	0.30	0.22	0.60	0.45
3	Coos Bay Sport	0.14							0.36	0.10	0.72	0.20	1.44	0.40	0.12	0.08	0.23	0.15	0.46	0.30
	Newport Sport	0.14							0.36	0.18	0.71	0.36	1.42	0.72	0.37	0.15	0.74	0.30	1.49	0.59
	Tillamook Sport	0.14							0.45	0.16	0.90	0.32	1.80	0.64	0.08	0.03	0.16	0.06	0.32	0.13
	WA Area 1 Sport	0.14	0.16	0.13	0.32	0.27	0.64	0.53	2.13	0.46	4.26	0.93	8.52	1.85	1.67	0.35	3.35	0.70	6.70	1.40
	WA Area 1 Troll	0.26													1.78	0.59	3.57	1.18	7.13	2.35
	WA Area 2 Sport	0.14							5.55	0.95	11.10	1.89	22.21	3.78						
	WA Area 2 Troll	0.26													4.38	0.61	8.76	1.22	17.52	2.44
	WA Area 3 Sport	0.14													0.31	0.24	0.61	0.47	1.22	0.95
	WA Area 4 Sport	0.14							3.46	0.50	6.92	1.01	13.83	2.01	0.24	0.06	0.47	0.11	0.95	0.22
	3 Total		0.16	0.13	0.32	0.27	0.64	0.53	12.31	1.20	24.61	2.39	49.22	4.78	8.95	0.97	17.89	1.93	35.79	3.85
									λ^{Esc}											
2	WA Area 4 Sport	0.14													0.24	0.20	0.48	0.39	0.96	0.79
	2 Total														0.24	0.20	0.48	0.39	0.96	0.79
3	Coos Bay Sport	0.14							0.36	0.14	0.73	0.28	1.45	0.56	0.18	0.14	0.37	0.27	0.73	0.54
	Newport Sport	0.14							0.36	0.21	0.72	0.41	1.43	0.82	0.59	0.31	1.18	0.62	2.37	1.25
	Tillamook Sport	0.14							0.45	0.20	0.90	0.40	1.81	0.81	0.13	0.07	0.25	0.13	0.51	0.27
	WA Area 1 Sport	0.14	0.28	0.25	0.56	0.50	1.12	0.99	2.14	0.74	4.28	1.48	8.56	2.96	2.66	1.07	5.33	2.15	10.66	4.30
	WA Area 1 Troll	0.26													2.84	1.35	5.67	2.71	11.35	5.41
	WA Area 2 Sport	0.14							5.58	1.77	11.16	3.55	22.32	7.10						
	WA Area 2 Troll	0.26													6.97	2.59	13.94	5.18	27.88	10.36
	WA Area 3 Sport	0.14													0.49	0.41	0.97	0.82	1.95	1.65
	WA Area 4 Sport	0.14							3.48	1.06	6.95	2.12	13.90	4.25	0.38	0.16	0.75	0.31	1.51	0.63
	3 Total		0.28	0.25	0.56	0.50	1.12	0.99	12.37	2.22	24.74	4.44	49.47	8.88	14.24	3.16	28.46	6.33	56.96	12.65

Appendix 3.7. Solduc Hatchery

Marianna Alexandersdottir, NWIFC
Andy Rankis, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Solduc Hatchery	1996	419981009	73,698	71,336	1.0331
	1997	419991005	69,987	73,132	0.9570

The Solduc Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located is on the Quillayute River system.

Terminal fishery considerations

Returning coho salmon are harvested in river sport fisheries in the Quillayute River system and its tributaries. Numbers of coho salmon harvested by year are summarized below:

System	1999		2000	
	Adult	Jacks	Adults	Jacks
Bogachiel	109	6	248	35
Calawah	22	3	28	7
Dickey	23		21	21
Quillayute	283	42	310	41
Solduc	997	238	709	62

Issues of concern

There are spawning ground surveys conducted by the tribal agency. However, hatchery carcasses are returned to the river for nutrient supplementation. Due to the large number of these carcasses, the spawning survey crews have been unable to sample the naturally spawning fish for tags. There is also a sport fishery in the system that is not sampled.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Solduc Hatchery DIT groups largely occurred in Washington and Oregon ocean fisheries and Strait of Juan de Fuca fisheries (Appendix Table 3.7.1). Tag recoveries from the Quillayute River net fishery were provided by tribal biologists.

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Appendix Table 3.7.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Solduc Hatchery DIT groups for brood years 1996 and 1997.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
2	Escapement	NSF	Observed	79	111	295	275
			Estimated	79.84	112.16	295.00	275.00
			SE	0.93	1.10	0.00	0.00
	WA Area 4, 4B Troll	NSF	Observed				1
			Estimated				2.92
			SE				2.37
3	Buoy 10 Sport	SF	Observed				1
			Estimated				1.37
			SE				0.71
	Coos Bay Sport	SF	Observed	1		2	
			Estimated	1.29		3.16	
			SE	0.61		1.52	
	Escapement	NSF	Observed	1,404	1,567	1,246	1,365
			Estimated	1,404.00	1,567.0	1,246.0	1,365.0
			SE	0.00	0.00	0.25	0.22
	Freshwater Net	NSF	Observed	2	1		
			Estimated	1,382.57	1,410.2	281.60	281.60
			SE	4.13	3.18		
	Newport Sport	SF	Observed	2		9	
			Estimated	2.74		17.58	
			SE	1.06		4.11	
	Tillamook Sport	SF	Observed	4		4	
			Estimated	5.82		5.33	
			SE	1.72		1.35	
	WA Area 1 Sport	SF	Observed	13	1	22	
			Estimated	26.73	1.28	48.91	
			SE	5.95	0.60	8.59	
	WA Area 1 Troll	SF	Observed			16	1
			Estimated			30.64	1.18
			SE			6.04	0.46
	WA Area 2 SF Sport	SF	Observed	22			
			Estimated	57.91			
			SE	9.99			
	WA Area 2 Sport	SF	Observed			25	
			Estimated			56.02	
			SE			8.72	
	WA Area 2 Troll	SF	Observed			4	
			Estimated			11.03	
			SE			4.70	
	WA Area 3 Sport	SF	Observed	21		4	
			Estimated	35.46		5.19	
			SE	4.98		1.25	

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Appendix Table 3.7.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Solduc Hatchery DIT groups for brood years 1996 and 1997.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 3 Troll	NSF	Observed	11	13		
			Estimated	15.99	14.57		
			SE	3.35	1.35		
	WA Area 4 Sport	SF	Observed	2		9	
			Estimated	5.97		18.55	
			SE	3.44		4.84	
	WA Area 4, 4B Troll	NSF	Observed	32	36	2	
			Estimated	151.26	154.71	14.96	
			SE	31.64	32.31	9.85	
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed	2	3		
			Estimated	2.81	5.43		
			SE	1.21	2.10		
Total Observed				1,595	1,732	1,638	1,643
Total Estimated				3,172.3	3,265.7	2,034.3	1,927.2
Total SE				34.76	32.58	18.74	2.53

Equal Marine Survival (EMS) Method

The estimates made using the EMS method were imprecise (Appendix Table 3.7.2). For the 1996 brood year the estimate was negative. For both brood years the estimate were not significantly different from zero (95% confidence interval included zero).

Appendix Table 3.7.2. Estimated number of mortalities of unmarked fish for Solduc Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1996	1.0331	-22	-116	73
1997	0.9570	19	-16	55

Equal Exploitation Rate (EER) Method

There were no non-selective fisheries that occurred prior (in time and area) to mark-selective fisheries. The λ combined in all significant marine non-selective fisheries (WA Area 4, 4B Troll, WA Area 3 Troll) was 1.01 for the 1996 brood year in 1998. However, no unmarked and tagged fish were recovered in these fisheries for brood year 1997 in 2000. The estimate of the total number of unmarked mortalities in mark-selective fisheries using the EER method was a negative 55 coho salmon for the 1996 brood (Appendix Table 3.7.3).

Appendix Table 3.7.3. Estimated number of mortalities of unmarked fish for Solduc Hatchery DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	$\lambda^{Fishery}$	SE($\lambda^{Fishery}$)	Estimate	95% Confidence Interval	
				Lower	Upper
1996	1.01	0.29	-55	-1,775.64	1,665.50
1997	NA				

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.7.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.7.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Solduc Hatchery for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996 50% *sfm*	SE	1996 Default *sfm*	SE	1996 200% *sfm*	SE	1997 50% *sfm*	SE	1997 Default *sfm*	SE	1997 200% *sfm*	SE
						λ^{Rel}								
3	Coos Bay Sport	0.14	0.09	0.04	0.19	0.09	0.37	0.18	0.21	0.10	0.42	0.20	0.85	0.41
	Newport Sport	0.14	0.20	0.08	0.40	0.15	0.79	0.31	1.18	0.28	2.36	0.55	4.71	1.10
	Tillamook Sport	0.14	0.42	0.12	0.84	0.25	1.68	0.50	0.36	0.09	0.71	0.18	1.43	0.36
	WA Area 1 Sport	0.14	1.93	0.43	3.87	0.86	7.73	1.72	3.28	0.58	6.55	1.15	13.11	2.30
	WA Area 1 Troll	0.26							3.81	0.75	7.62	1.50	15.25	3.01
	WA Area 2 SF Sport	0.14	4.19	0.72	8.38	1.44	16.75	2.89						
	WA Area 2 Sport	0.14							3.75	0.58	7.51	1.17	15.01	2.34
	WA Area 2 Troll	0.26							1.37	0.58	2.74	1.17	5.49	2.34
	WA Area 3 Sport	0.14	2.56	0.36	5.13	0.72	10.26	1.44	0.35	0.08	0.70	0.17	1.39	0.33
	WA Area 4 Sport	0.14	0.43	0.25	0.86	0.50	1.73	1.00	1.24	0.32	2.49	0.65	4.97	1.30
3 Total			9.83	2.01	19.66	4.02	39.32	8.03	15.55	3.37	31.10	6.74	62.20	13.48
						λ^{Esc}								
3	Coos Bay Sport	0.14	0.10	0.05	0.20	0.10	0.40	0.19	0.24	0.12	0.48	0.23	0.97	0.47
	Newport Sport	0.14	0.21	0.08	0.43	0.17	0.86	0.33	1.35	0.31	2.70	0.63	5.39	1.26
	Tillamook Sport	0.14	0.45	0.13	0.91	0.27	1.82	0.54	0.41	0.10	0.82	0.21	1.63	0.41
	WA Area 1 Sport	0.14	2.09	0.47	4.18	0.93	8.35	1.86	3.75	0.66	7.50	1.32	15.00	2.63
	WA Area 1 Troll	0.26							4.36	0.86	8.73	1.72	17.45	3.44
	WA Area 2 SF Sport	0.14	4.52	0.78	9.05	1.56	18.10	3.12						
	WA Area 2 Sport	0.14							4.30	0.67	8.59	1.34	17.18	2.67
	WA Area 2 Troll	0.26							1.57	0.67	3.14	1.34	6.28	2.68
	WA Area 3 Sport	0.14	2.77	0.39	5.54	0.78	11.08	1.56	0.40	0.10	0.80	0.19	1.59	0.38
	WA Area 4 Sport	0.14	0.47	0.27	0.93	0.54	1.87	1.08	1.42	0.37	2.85	0.74	5.69	1.48
3 Total			10.62	2.17	21.24	4.34	42.48	8.68	17.80	3.86	35.60	7.72	71.20	15.43

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Appendix 3.8. Port Gamble Sea Pens

Aimee Keller, Port Gamble
Cindy Gray, PNPTC
Amy Seiders, NWIFC
John Fieberg, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Port Gamble Sea Pens	1996	1419989004	49,500	50,017	0.9897
	1997	141999DI05	52,593	49,420	1.0642

The Port Gamble Sea Pens are operated by the Port Gamble S'Klallam Tribe and are located in Port Gamble Bay in northern Hood Canal.

General concerns

Since the DIT groups are released from sea pens, there is no centralized location to collect returning fish. Estimates of escapement are very poor and any escapement recoveries would be strays into hatcheries or onto spawning grounds; therefore, no exploitation rates can be estimated for this tag group. In addition, Hood Canal fisheries are typically difficult to sample. Concern exists that catch may also be under-reported. Marked recoveries occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Port Gamble Sea Pen fish were made in Alaska, but the majority were recovered in Puget Sound fisheries (Appendix Table 3.8.1).

Appendix Table 3.8.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Port Gamble Sea Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
2	Escapement	NSF	Observed	14	2		
			Estimated	14.42	2.00		
			SE	0.71	0.00		
	WA Area 12, 12B, 12C, 12D Net	NSF	Observed	1			
			Estimated	1.36			
			SE	0.70			
	WA Area 5 Sport	NSF	Observed	1			
			Estimated	4.29			
			SE	3.76			

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Appendix Table 3.8.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Port Gamble Sea Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 6 Sport	NSF	Observed	1			
			Estimated	2.22			
			SE	1.65			
	WA Area 9 Sport	NSF	Observed		1		
			Estimated		7.06		
			SE		6.54		
3	Escapement	NSF	Observed	5	1		1
			Estimated	5.00	1.00		1.00
			SE	0.00	0.00		0.00
	Freshwater Net	NSF	Observed	1	1		
			Estimated	1.00	1.23		
			SE	0.00	0.53		
	Southeast Alaska Troll	NSF	Observed	2		1	
			Estimated	5.14	*5.09*	3.58	*3.81*
			SE	2.84	*7.90*	3.04	*10.46*
	WA Area 10 Sport	NSF	Observed		2		
			Estimated		4.50		
			SE		2.37		
	WA Area 10E Net	NSF	Observed	1	2	1	
			Estimated	1.00	3.40	1.56	
			SE	0.00	1.55	0.93	
	WA Area 11 Sport	NSF	Observed		2		
			Estimated		14.58		
			SE		9.58		
	WA Area 12 Sport	NSF	Observed			1	
			Estimated			12.29	
			SE			11.78	
	WA Area 12, 12B, 12C, 12D Net	NSF	Observed	6	7	1	2
			Estimated	10.38	10.16	8.10	11.32
			SE	3.18	2.65	7.58	8.04
	WA Area 2 SF Sport	SF	Observed	1			
			Estimated	2.29			
			SE	1.72			
	WA Area 3 Sport	SF	Observed	1			
			Estimated	1.77			
			SE	1.17			
	WA Area 3 Troll	NSF	Observed		1		
			Estimated		1.17		
			SE		0.45		
	WA Area 4 Sport	SF	Observed	2		1	
			Estimated	4.78		2.25	
			SE	2.73		1.68	

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Appendix Table 3.8.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Port Gamble Sea Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 4, 4B Troll	NSF	Observed	4	4		
			Estimated	11.17	18.05		
			SE	5.54	10.98		
	WA Area 5 Sport	SF	Observed	4		2	
			Estimated	15.42		10.66	
			SE	6.64		6.81	
	WA Area 6 Sport	SF	Observed	1			
			Estimated	3.10			
			SE	2.55			
	WA Area 8-2 Sport	NSF	Observed		2		
			Estimated		9.56		
			SE		6.01		
	WA Area 8D Net	NSF	Observed		1		
			Estimated		2.50		
			SE		1.94		
	WA Area 9 Sport	NSF	Observed	1			2
			Estimated	10.67			14.90
			SE	10.16			9.80
	WA Area 9A Net	NSF	Observed	155	131	48	62
			Estimated	342.46	298.38	72.93	89.47
			SE	23.08	21.90	8.63	7.40
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed		2	1	1
			Estimated		2.90	3.29	3.29
			SE		1.18	2.74	2.74
	WA Areas 6B, 9 Net	NSF	Observed				2
			Estimated				2.00
			SE				0.00
Total Observed				201	159	56	70
Total Estimated				436.47	376.49	114.66	121.98
Total SE				27.66	29.22	18.37	18.24

Neither the EMS nor the EER method can be used for this DIT group as no estimates of escapements are available.

Paired-Ratio (PR) Method

The only non-selective fishery of any significance for this DIT group was the WA Area 9A Net fishery. This fishery occurred late in the season after several other mark-selective fisheries had occurred. Therefore, one would expect the λ estimated from this fishery to be biased high. So λ^{Rel} was used to estimate the unmarked mortalities in mark-selective fisheries (Appendix Table 3.8.2). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.8.2. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Port Gamble Sea Pens for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release.

			1996						1997					
		Default	50%		Default		200%		50%		Default		200%	
Age	Fishery	*sfm*	*sfm*	SE	*sfm*	SE	*sfm*	SE	*sfm*	SE	*sfm*	SE	*sfm*	SE
3	WA Area 2 SF Sport	0.14	0.159	0.119	0.317	0.238	0.635	0.476						
	WA Area 3 Sport	0.14	0.123	0.081	0.245	0.162	0.491	0.324						
	WA Area 4 Sport	0.14	0.331	0.189	0.662	0.379	1.325	0.757	0.168	0.125	0.335	0.25	0.67	0.5
	WA Area 5 Sport	0.07	0.534	0.230	1.068	0.460	2.137	0.920	0.397	0.254	0.794	0.507	1.588	1.014
	WA Area 6 Sport	0.07	0.107	0.088	0.215	0.177	0.430	0.354						
3 Total			1.254	0.12	2.508	0.470	5.016	1.88	0.565	0.080	1.129	0.32	2.259	1.280

Appendix 3.9. Quilcene NFH

Aimee Keller, Port Gamble
Cindy Gray, PNPTC
Amy Seiders, NWIFC
John Fieberg, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Quilcene NFH	1996	071998WC15	40,861	45,411	0.8998
	1997	071999WC35	46,235	48,413	0.9550

The Quilcene National Fish Hatchery (NFH) is operated by the U.S. Fish and Wildlife Service (USFWS) and is located on the Quilcene River.

DIT rearing strategy

Marked and unmarked DIT groups are tagged on the same day or consecutive days and are reared together in the same pond (four separate replicated groups are used for DIT tagging). The initial number of fish of each DIT group is estimated using an inventory method. Release numbers are then determined by subtracting estimated mortalities occurring between this initial abundance estimate and the release date. These mortalities are estimated by hand counts. All mortalities are scanned so that the mortalities can be accurately apportioned into the appropriate tag|mark groups.

General comments

The location of the hatchery is 2.8 miles from the mouth of the Quilcene River. The hatchery is on the mainstem of the river. There is a completely spanning|blocking electrified weir with an associated fish ladder. The electricity is turned off on January 1 in order for steelhead to pass and not turned on again until late summer. There are no tributaries downstream of the hatchery and mangers believe that few fish spawn downstream from the hatchery (David Zajack, *USFWS personal communication*). The hatchery return is sampled at less than 100% and some fish are passed above the hatchery. However, fish that are passed above the hatchery are counted so that expansion rates account for these fish. Jacks are treated no differently from other fish when sampling. There is no sampling on spawning grounds for tags. However, since all fish must pass over through the weir, escapement estimates obtained from the hatchery should be fairly accurate.

General concerns

Marked recoveries of the 1997 DIT group occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. There were few marked recoveries, however, in these fisheries (3.06 expanded recoveries). The number of unmarked recoveries was estimated using the PR method with *sfm* = 1 and using λ^{Rel}. One unmarked tagged fish was sampled in the Area 2 mark-selective fishery and 1 in the Area 5 mark-selective fishery. There is a sport fishery in the river that is not sampled (Appendix Table 4).

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Estimation of unmarked mortalities in mark-selective fisheries

Quilcene NFH DIT coho salmon were recovered mainly in Puget Sound fisheries (Appendix Table 3.9.1). Two recoveries were made in Alaska.

Appendix Table 3.9.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
2	Escapement	NSF	Observed	14	19	11	6
			Estimated	28.01	38.83	25.63	14.02
			SE	5.85	7.63	5.84	4.33
	Freshwater Net	NSF	Observed				1
			Estimated				3.85
			SE				3.31
	WA Area 5 Sport	SF	Observed			1	
			Estimated			3.78	
			SE			3.24	
3	Escapement	NSF	Observed	201	167	362	356
			Estimated	441.78	371.95	1,234.42	1,213.96
			SE	23.86	21.93	54.54	54.09
	Freshwater Net	NSF	Observed			8	10
			Estimated			96.00	112.20
			SE			32.50	34.66
	Newport Sport	SF	Observed			1	
			Estimated			1.87	
			SE			1.28	
	Southeast Alaska Troll	NSF	Observed			2	
			Estimated			4.20	*4.47*
			SE			2.38	*6.44*
	WA Area 1 Sport	SF	Observed	1		1	
			Estimated	1.38		2.22	
			SE	0.72		1.65	
	WA Area 1 Troll	SF	Observed			1	
			Estimated			1.83	
			SE			1.23	
	WA Area 10 Sport	NSF	Observed		1	1	2
			Estimated		2.25	3.97	7.05
			SE		1.68	3.43	4.27
	WA Area 10E Net	NSF	Observed				1
			Estimated				1.56
			SE				0.93

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Appendix Table 3.9.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 12 Sport	NSF	Observed			1	
			Estimated			8.39	
			SE			7.87	
	WA Area 12, 12B, 12C, 12D Net	NSF	Observed			3	9
			Estimated			24.78	52.10
			SE			14.76	19.88
	WA Area 12A Net	NSF	Observed	2		32	55
			Estimated	2.00		238.40	432.35
			SE	0.00		41.53	57.54
	WA Area 13A Net	NSF	Observed			1	
			Estimated			2.72	
			SE			2.16	
	WA Area 2 Sport	SF	Observed			6	1
			Estimated			12.58	1.97
			SE			3.75	1.38
	WA Area 3 Sport	SF	Observed	2		2	
			Estimated	3.85		2.46	
			SE	1.91		0.78	
	WA Area 3 Troll	NSF	Observed		1		
			Estimated		1.17		
			SE		0.45		
	WA Area 4 Sport	SF	Observed	4		12	
			Estimated	10.15		31.75	
			SE	3.95		7.29	
	WA Area 4, 4B Troll	NSF	Observed	5	2	1	4
			Estimated	13.82	3.09	7.48	29.92
			SE	5.50	1.30	6.96	13.92
	WA Area 5 Sport	SF	Observed	8	1	18	1
			Estimated	30.54	3.78	92.22	5.64
			SE	9.28	3.24	19.52	5.12
	WA Area 6 Sport	SF	Observed	1		4	
			Estimated	3.10		12.48	
			SE	2.55		5.14	
	WA Area 8D Net	NSF	Observed				1
			Estimated				5.14
			SE				4.61
	WA Area 9 Sport	NSF	Observed			2	
			Estimated			14.90	
			SE			9.80	

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Appendix Table 3.9.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene NFH DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 9A Net	NSF	Observed	2		10	4
			Estimated	5.98		12.34	5.14
			SE	3.45		1.91	1.34
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed	2	2	1	
			Estimated	3.30	2.90	3.29	
			SE	1.46	1.18	2.74	
	WA Areas 6B, 9 Net	NSF	Observed				1
			Estimated				1.00
			SE				0.00
Total Observed				242	193	481	452
Total Estimated				543.91	423.97	1,837.71	1,885.90
Total SE				27.57	23.57	82.09	90.15

Equal Marine Survival (EMS) Method

Using λ^{Rel} = 0.900 for brood year 1996, the estimate for the total unmarked mortality summed across all mark-selective fisheries is 65 and using 0.955 for brood 1997 the estimate is –131 (Appendix Table 3.9.2).

Appendix Table 3.9.2. Estimated number of mortalities of unmarked fish for Quilcene NFH DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
1996	0.8998	65	-2	133
1997	0.9550	-131	-365	104

Equal Exploitation Rate (EER) Method

There were very few recoveries in non-selective fisheries. In addition, these fisheries took place after several mark-selective fisheries had already begun. Therefore, the EER method was not applied to this data set.

Paired-Ratio (PR) Method

Again, there were no fisheries that could serve as obvious non-selective pairs. The λ estimated in the non-selective fisheries was highly variable and typically higher than that at release, perhaps because these fisheries occurred after several mark-selective fisheries (Appendix Table 3.9.3). Most of the mark-selective fisheries occurred early in the season in

marine waters. Unmarked mortalities in mark-selective fisheries were estimated using the λ at release and escapement and for three values of *sfm*. Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM). The estimates ranged from 2 fish to 29 fish depending on the values used (Appendix Table 3.9.4).

Appendix Table 3.9.3. Unmarked-to-marked ratio (λ) in non-selective fisheries for Quilcene NFH coho salmon from the 1997 brood year.

Fishery	λ^{NSF}	95% Confidence Interval	
WA Area 12A Net	1.81	1.03	2.59
WA Area 4,4B Troll	4.00	-4.16	12.16
WA Area 9A Net	0.42	0.17	0.66
WA Area 12, 12B, 12C, 12D Net	2.10	-0.35	4.55
Freshwater Net	1.13	0.10	2.15

Appendix Table 3.9.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Quilcene NFH for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
2	WA Area 5 Sport	0.07							0.126	0.108	0.253	0.217	0.505	0.433
2 Total									0.126	0.108	0.253	0.217	0.505	0.433
3	Newport Sport	0.14							0.125	0.085	0.25	0.171	0.5	0.341
	WA Area 1 Sport	0.14	0.087	0.046	0.174	0.091	0.348	0.182	0.148	0.11	0.297	0.22	0.594	0.44
	WA Area 1 Troll	0.26							0.227	0.153	0.454	0.306	0.909	0.612
	WA Area 2 Sport	0.14							0.841	0.251	1.682	0.502	3.364	1.004
	WA Area 3 Sport	0.14	0.243	0.12	0.485	0.24	0.97	0.48	0.165	0.052	0.329	0.105	0.658	0.209
	WA Area 4 Sport	0.14	0.639	0.249	1.279	0.498	2.557	0.996	2.123	0.487	4.245	0.974	8.49	1.949
	WA Area 5 Sport	0.07	0.962	0.292	1.924	0.584	3.847	1.169	3.083	0.653	6.165	1.305	12.33	2.611
	WA Area 6 Sport	0.07	0.098	0.08	0.195	0.161	0.391	0.321	0.417	0.172	0.834	0.344	1.669	0.688
3 Total			2.028	0.17	4.056	0.68	8.113	2.73	7.128	0.80	14.26	3.21	28.51	12.82
			λ^{Esc}											
2	WA Area 5 Sport	0.07							0.13	0.112	0.26	0.224	0.52	0.448
2 Total									0.13	0.112	0.26	0.224	0.52	0.448
3	Newport Sport	0.14							0.129	0.088	0.258	0.176	0.515	0.353
	WA Area 1 Sport	0.14	0.081	0.043	0.163	0.086	0.325	0.173	0.153	0.114	0.306	0.227	0.611	0.455
	WA Area 1 Troll	0.26							0.234	0.158	0.468	0.317	0.936	0.633
	WA Area 2 Sport	0.14							0.866	0.264	1.732	0.528	3.464	1.056
	WA Area 3 Sport	0.14	0.227	0.114	0.454	0.228	0.908	0.455	0.169	0.055	0.339	0.11	0.677	0.219
	WA Area 4 Sport	0.14	0.598	0.238	1.196	0.476	2.393	0.952	2.186	0.52	4.371	1.04	8.743	2.081
	WA Area 5 Sport	0.07	0.9	0.283	1.8	0.565	3.6	1.131	3.174	0.701	6.348	1.402	12.7	2.804
	WA Area 6 Sport	0.07	0.091	0.076	0.183	0.151	0.365	0.302	0.43	0.179	0.859	0.358	1.718	0.716
3 Total			1.898	0.16	3.796	0.63	7.591	2.51	7.34	0.91	14.68	3.65	29.36	14.60

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Appendix 3.10. George Adams Hatchery

Aimee Keller, Port Gamble
Cindy Gray, PNPTC
Amy Seiders, NWIFC
John Fieberg, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
George Adams	1995	419971601	45,243	45,068	1.004
	1997	419991020	21,728	20,817	1.044
		419991021	22,312	22,280	1.001
	1997 Combined		44,040	43,097	1.022

George Adams Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on Purdy Creek, a tributary to the Skokomish River.

DIT rearing strategy

Marked and unmarked DIT groups are tagged on the same day and are reared together in the same pond. Mortalities are counted daily and are allocated to tag|mark group in relative proportion to initial abundance estimates for each group. Release numbers are determined by subtracting these mortalities from the initial number of tagged fish in each DIT group.

General comments

The hatchery is located on Purdy Creek, a small tributary of the Skokomish River. Fish may bypass the hatchery and go further up the Skokomish River to spawn naturally. The extent of hatchery straying and natural spawning in the Skokomish River is unknown. WDFW samples the river for tags (using wands), but high water levels often make it difficult to sample reliably. Returns to the hatchery are sampled at 100% (including jacks) using tube detectors and there is little opportunity for fish to pass above the hatchery to spawn (the creek is blocked by the intake valves). There is a sport fishery for coho salmon in the river that is not sampled. The wild coho salmon population in the river is small and thought to return later in time than the hatchery stock.

General concerns

In 1997 one half of the DIT releases were marked with an additional mark in the form of a red elastomer jaw tag as a separate experiment. Because of this experiment, the brood was split into four groups (two DIT groups). The release size of each DIT group was half of the normal recommended level and, therefore, there were not enough recoveries to analyze the two DIT groups separately (even after combining the two DIT groups there were only 34 marked and 20 unmarked fishery recoveries spread among 15 fisheries). Thus, we were forced to assume that the elastomer jaw tag had no effect on the fish (i.e., that the two release groups have identical exploitation patterns). A test of the differences in the exploitation pattern among the two DIT groups was not significant (Fisher's Exact Test $P = 0.29$), although the power of the test is suspect due to the small sample size.

APPENDIX 3

Estimation of unmarked mortalities in mark-selective fisheries

Estimates of unmarked mortalities will be biased if there is any interaction between mark-status and the elastomer jaw tag. It is preferable to not use an experimental release as an indicator stock. Therefore, in the future the number of releases should be doubled if experimental releases are conducted.

There were no recoveries of the George Adams DIT group for the 1995 brood year in selective fisheries. Recoveries of the 1996 brood year largely occurred in Washington ocean fisheries and Puget Sound (Appendix Table 3.10.1). There were 2 observed (10.04 expanded) recoveries of unmarked fish in the WA Area 5 Sport fishery. These fish were both recorded as marked by the sampler.

Appendix Table 3.10.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from George Adams Hatchery DIT groups for brood years 1995 and 1997.

Age	Fishery	Type	Data	1995		1997	
				M	U	M	U
2	Escapement	NSF	Observed			37	37
			Estimated			37.00	37.00
			SE			0.00	0.00
	WA Area 8-2 Sport	NSF	Observed				1
			Estimated				4.78
			SE				4.25
3	Escapement	NSF	Observed	197	184	706	795
			Estimated	199.16	185.83	706.00	795.00
			SE	1.49	1.36	0.00	0.00
	Georgia/Juan de Fuca/ Johnstone Straits Sport	SF	Observed			1	
			Estimated			2.10	
			SE			1.52	
	WA Area 10 Net	NSF	Observed			1	3
			Estimated			1.02	5.25
			SE			0.14	1.43
	WA Area 10 Sport	NSF	Observed	1	1		2
			Estimated	2.72	2.72		22.58
			SE	2.16	2.16		10.78
	WA Area 10A Net	NSF	Observed			1	
			Estimated			3.51	
			SE			2.97	
	WA Area 11 Sport	NSF	Observed		1		
			Estimated		4.15		
			SE		3.62		
	WA Area 12 Sport	NSF	Observed		1		
			Estimated		9.18		
			SE		8.67		
	WA Area 12, 12B, 12C, 12D Net	NSF	Observed	5	3	2	6
			Estimated	12.20	7.08	21.56	35.34
			SE	4.74	3.10	14.52	12.39

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Appendix Table 3.10.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from George Adams Hatchery DIT groups for brood years 1995 and 1997.

Age	Fishery	Type	Data	1995		1997	
				M	U	M	U
	WA Area 12A Net	NSF	Observed	2			
			Estimated	6.62			
			SE	3.94			
	WA Area 13D Net	NSF	Observed		1		
			Estimated		2.72		
			SE		2.16		
	WA Area 2 NSF Sport	NSF	Observed	1			
			Estimated	3.17			
			SE	2.62			
	WA Area 2 Sport	SF	Observed			1	
			Estimated			1.65	
			SE			1.04	
	WA Area 3 Sport	SF	Observed			1	
			Estimated			1.38	
			SE			0.72	
	WA Area 4 Sport	NSF	Observed	2	2		
			Estimated	3.91	3.92		
			SE	1.93	1.94		
		SF	Observed			9	
			Estimated			21.08	
			SE			2.98	
	WA Area 4, 4B Troll	NSF	Observed			1	
			Estimated			7.48	
			SE			6.96	
	WA Area 5 Sport	NSF	Observed	3	5		
			Estimated	12.87	21.45		
			SE	6.51	8.40		
		SF	Observed			8	2
			Estimated			42.02	10.04
			SE			9.39	6.35
	WA Area 6 Sport	NSF	Observed	4	2		
			Estimated	12.04	6.02		
			SE	5.17	3.65		
		SF	Observed			4	
			Estimated			11.26	
			SE			4.56	
	WA Area 7 Sport	NSF	Observed	1			
			Estimated	13.82			
			SE	13.31			
	WA Area 8-2 Sport	NSF	Observed		1		1
			Estimated		3.95		5.13
			SE		3.41		4.60
	WA Area 9 Sport	NSF	Observed	5	3	1	1
			Estimated	37.05	21.53	7.45	7.45
			SE	15.41	11.54	6.93	6.93

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Appendix Table 3.10.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from George Adams Hatchery DIT groups for brood years 1995 and 1997.

Age	Fishery	Type	Data	1995 M	1995 U	1997 M	1997 U
	WA Area 9A Net	NSF	Observed			4	3
			Estimated			8.88	3.00
			SE			2.63	0.00
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed				1
			Estimated				3.29
			SE				2.74
Total Observed				221	204	777	852
Total Estimated				303.56	268.55	872.39	928.86
Total SE				23.22	18.48	21.09	20.18

Equal Marine Survival (EMS) Method

For the 1997 brood year using λ^{Rel} = 1.022 (from the two combined DIT groups), the estimate for the total unmarked mortality summed across all mark-selective fisheries is –37 and not statistically different from zero (Appendix Table 3.10.2). The width of the confidence interval is underestimated, however, as it ignores uncertainty in the estimate of λ^{Rel}.

Appendix Table 3.10.2. Estimated number of mortalities of unmarked fish for George Adams Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
1997	1.022	-37	-95	21

Equal Exploitation Rate (EER) Method

There were no non-selective fisheries that occurred prior (in time and area) to selective fisheries, so this method may not be able to provide an unbiased estimate of unmarked mortalities. The λ for all non-selective fisheries combined (WA Area 4, 4B Troll, WA 10 sport, WA 9 Sport, WA Area 12, 12B, 12C, 12D Net, WA Area 10A Net, WA Area 10 Net, WA Area 9 Net, and WA Areas 4B, 5, 6, 6A, 6C Net) was 1.64 (95% confidence interval: 1.24 - 4.07). Given the uncertainty in the estimate of λ and the potential for bias in this estimate, the EER method was not used to estimate the unmarked mortalities in mark-selective fisheries.

Paired-Ratio (PR) Method

There were no non-selective fisheries to serve as pairs for the mark-selective fisheries since the selective fisheries occurred prior to the non-selective fisheries in time and space. Furthermore, there were few tags recovered in the non-selective fisheries, so the λs estimated from the non-selective fisheries are highly imprecise. Therefore, the λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries. Three values of *sfm* were used for the estimates: a default value, 50% of the default

value, and 200% of the default value (Appendix Table 3.10.3). The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.10.3. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from George Adams Hatchery for brood year 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}					
3	WA Area 2 Sport	0.14	0.12	0.07	0.23	0.15	0.46	0.29
	WA Area 3 Sport	0.14	0.10	0.05	0.19	0.10	0.39	0.20
	WA Area 4 Sport	0.14	1.48	0.42	2.96	0.84	5.92	1.68
	WA Area 5 Sport	0.07	1.50	0.67	2.99	1.34	5.98	2.68
	WA Area 6 Sport	0.07	0.39	0.16	0.79	0.32	1.58	0.64
3 Total			3.58	0.81	7.17	1.62	14.34	3.25
			λ^{Esc}					
3	WA Area 2 Sport	0.14	0.12	0.08	0.25	0.16	0.50	0.31
	WA Area 3 Sport	0.14	0.10	0.05	0.21	0.11	0.42	0.22
	WA Area 4 Sport	0.14	1.59	0.45	3.19	0.90	6.38	1.81
	WA Area 5 Sport	0.07	1.64	0.74	3.28	1.47	6.55	2.95
	WA Area 6 Sport	0.07	0.42	0.17	0.85	0.34	1.70	0.69
3 Total			3.88	0.89	7.77	1.77	15.54	3.54

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Appendix 3.11. Quilcene Bay Net Pens

Aimee Keller, Port Gamble
Cindy Gray, PNPTC
Amy Seiders, NWIFC
John Fieberg, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Quilcene Bay Net Pens	1996	1419989006	44,859	42,377	1.0586
	1997	141999DI02	45,788	48,875	0.9368

The Quilcene Bay Net Pens are operated by the Skokomish Indian Tribe and are located in Quilcene Bay on the western side of Hood Canal.

General concerns

Since the DIT groups are released from sea (net) pens, there is no centralized location to collect returning fish. Therefore, estimates of escapement are not possible, nor are estimates of exploitation rates. Any escapement recoveries are from hatchery and spawning ground strays. In addition, Hood Canal fisheries are typically difficult to sample and catch may be underreported.

Estimation of unmarked mortalities in mark-selective fisheries

Approximately 500 marked and unmarked fish released from Quilcene Bay Net Pens were estimated to be harvested or to be strays into escapements from the 1996 brood year and 2,000 marked and unmarked fish from the 1997 brood year (Appendix Table 3.11.1). There were recoveries of marked fish from the 1997 brood year in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}. For the 1997 brood year there were two observed (5.18 expanded) recoveries of unmarked fish in the WA Area 4 sport fishery; both recoveries were recorded as marked by the sampler.

Appendix Table 3.11.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene Bay Net Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996 M	1996 U	1997 M	1997 U
2	Escapement	NSF	Observed	36	47	39	28
			Estimated	61.37	92.11	90.87	65.24
			SE	7.97	10.80	10.99	9.31
	WA Area 10 Sport	NSF	Observed				1
			Estimated				5.46
			SE				4.93

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Appendix Table 3.11.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene Bay Net Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 12A Net	NSF	Observed		2		
			Estimated		6.62		
			SE		3.94		
	WA Area 5 Sport	NSF	Observed		1		
			Estimated		4.29		
			SE		3.76		
	WA Area 9 Sport	NSF	Observed		1		
			Estimated		7.41		
			SE		6.89		
3	Escapement	NSF	Observed	170	154	327	355
			Estimated	382.04	342.27	1,115.07	1,210.55
			SE	22.40	21.04	51.84	54.01
	Freshwater Net	NSF	Observed			3	6
			Estimated			36.00	72.00
			SE			19.90	28.14
	Newport Sport	SF	Observed			1	
			Estimated			1.96	
			SE			1.37	
	Southeast Alaska Troll	NSF	Observed			1	
			Estimated			1.37	*1.28*
			SE			0.71	*0.67*
	WA Area 1 Sport	SF	Observed	1		2	
			Estimated	1.28		5.50	
			SE	0.60		3.19	
	WA Area 10 Net	NSF	Observed				2
			Estimated				2.12
			SE				0.36
	WA Area 10 Sport	NSF	Observed			3	1
			Estimated			11.91	3.08
			SE			5.95	2.53
	WA Area 11 Sport	NSF	Observed		1		
			Estimated		7.29		
			SE		6.77		
	WA Area 12 Sport	NSF	Observed			5	1
			Estimated			41.95	8.39
			SE			17.61	7.87
	WA Area 12, 12B, 12C, 12D Net	NSF	Observed			8	7
			Estimated			56.00	65.22
			SE			21.22	24.33
	WA Area 12A Net	NSF	Observed	5	6	64	58
			Estimated	5.00	6.00	500.66	457.10
			SE	0.00	0.00	61.96	58.53

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Appendix Table 3.11.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Quilcene Bay Net Pen DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1996		1997	
				M	U	M	U
	WA Area 13A Net	NSF	Observed			1	
			Estimated			2.72	
			SE			2.16	
	WA Area 2 SF Sport	SF	Observed	1			
			Estimated	3.27			
			SE	2.72			
	WA Area 2 Sport	SF	Observed			8	
			Estimated			19.64	
			SE			5.61	
	WA Area 2 Troll	SF	Observed			2	
			Estimated			4.98	
			SE			2.72	
	WA Area 3 Sport	SF	Observed	3		1	
			Estimated	5.96		1.27	
			SE	2.44		0.59	
	WA Area 3 Troll	NSF	Observed	2	1		
			Estimated	2.18	1.17		
			SE	0.46	0.45		
	WA Area 4 Sport	SF	Observed	1		16	2
			Estimated	2.49		39.39	5.18
			SE	1.93		7.82	2.87
	WA Area 4, 4B Troll	NSF	Observed		3	4	4
			Estimated		13.91	29.92	29.92
			SE		7.46	13.92	13.92
	WA Area 5 Sport	SF	Observed	3	1	14	
			Estimated	11.34	3.78	72.76	
			SE	5.61	3.24	17.51	
	WA Area 6 Sport	SF	Observed			3	
			Estimated			9.36	
			SE			4.45	
	WA Area 9 Sport	NSF	Observed			1	2
			Estimated			7.45	14.90
			SE			6.93	9.80
	WA Area 9A Net	NSF	Observed		2		3
			Estimated		4.07		3.00
			SE		2.46		0.00
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed	2	1	2	4
			Estimated	3.30	1.65	6.58	10.56
			SE	1.46	1.04	3.88	4.36
	WA Areas 6B, 9 Net	NSF	Observed				2
			Estimated				2.00
			SE				0.00
Total Observed				224	220	505	476
Total Estimated				478.23	490.57	2,055.36	1,954.72
Total Standard Error				24.83	27.49	92.41	90.69

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As the EMS and EER methods depend on complete fishery and escapement recoveries, and no escapement recoveries can be made with net pen fish, these methods were not applied.

Paired-Ratio (PR) Method

The λs estimated in the non-selective fisheries was highly variable, and imprecise (Appendix Table 3.11.2) and were not used. The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.11.3). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.11.2. Unmarked-to-marked ratio (λ) in non-selective fisheries for Quilcene Bay DIT coho salmon groups from the 1997 brood year.

Fishery	λ^{NSF}	95% Confidence Interval	
WA Area 4, 4B Troll	1.00	-0.28	2.29
WA Area 12A Net	0.91	0.59	1.23
WA Area 12, 12B, 12C, 12D Net	1.16	0.0	2.38
Freshwater Net	2.00	-0.65	4.65

Appendix Table 3.11.3. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Quilcene Bay Net Pens for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
3	Newport Sport	0.14							0.129	0.09	0.257	0.18	0.514	0.36
	WA Area 1 Sport	0.14	0.095	0.044	0.19	0.089	0.379	0.177	0.361	0.209	0.721	0.419	1.443	0.837
	WA Area 2 SF Sport	0.14	0.242	0.202	0.485	0.404	0.969	0.808						
	WA Area 2 Sport	0.14							1.288	0.368	2.576	0.736	5.152	1.472
	WA Area 2 Troll	0.26							0.607	0.332	1.213	0.664	2.426	1.327
	WA Area 3 Sport	0.14	0.442	0.181	0.883	0.362	1.767	0.724	0.083	0.038	0.167	0.077	0.333	0.154
	WA Area 4 Sport	0.14	0.185	0.143	0.369	0.286	0.738	0.571	2.583	0.513	5.166	1.026	10.33	2.053
	WA Area 5 Sport	0.07	0.42	0.208	0.84	0.416	1.681	0.832	2.386	0.574	4.772	1.148	9.543	2.296
	WA Area 6 Sport	0.07							0.307	0.146	0.614	0.292	1.228	0.584
3 Total			1.383	0.14	2.767	0.56	5.534	2.23	7.743	0.91	15.49	3.65	30.97	14.61
			λ^{Esc}											
3	Newport Sport	0.14							0.149	0.105	0.298	0.209	0.596	0.419
	WA Area 1 Sport	0.14	0.08	0.038	0.161	0.076	0.321	0.153	0.418	0.244	0.836	0.488	1.672	0.976
	WA Area 2 SF Sport	0.14	0.205	0.172	0.41	0.344	0.82	0.687						
	WA Area 2 Sport	0.14							1,493	0.437	2.985	0.874	5.97	1.748
	WA Area 2 Troll	0.26							0.703	0.387	1.406	0.774	2.811	1.548
	WA Area 3 Sport	0.14	0.374	0.157	0.748	0.313	1.495	0.626	0.097	0.045	0.193	0.09	0.386	0.18
	WA Area 4 Sport	0.14	0.156	0.122	0.312	0.243	0.625	0.486	2.993	0.625	5.987	1.25	11.97	2.501
	WA Area 5 Sport	0.07	0.356	0.179	0.711	0.357	1.422	0.715	2.765	0.689	5.529	1.377	11.06	2.755
	WA Area 6 Sport	0.07							0.356	0.171	0.711	0.342	1.423	0.683
3 Total			1.171	0.10	2.342	0.41	4.683	1.63	8.973	1.31	17.94	5.23	35.89	20.92

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Appendix 3.12. Kendall Creek Hatchery

Rebecca Bernard, Skagit System Cooperative
Annette Hoffmann, WDFW
Don Noviello, WDFW

Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
1996	419981002	44,889	88,332	0.5082
1997	419991010	33,824	35,209	0.9607

Kendall Creek Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on Kendall Creek, a tributary of the North Fork Nooksack River.

Hatchery practices relevant to this analysis

Except for a small amount of spawning that occurs just outside the hatchery, all adult hatchery returns enter the hatchery. Unfortunately, there were flooding events in 1999 and an estimated 1,015 unsampled fish escaped the hatchery (presumably upstream) during these floods. Also, approximately 520 fish were passed above the dam but were not electronically sampled. There was no electronic sampling of the upstream spawning ground in 1999 or in 2000. Approximately, 500 adult fish were transported above the hatchery in 2000; these fish were electronically sampled prior to transport.

General concerns

There is an in-river sport fishery (Nooksack River) that is not sampled (Appendix Table 4).

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Kendall Creek Hatchery DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.12.1). Three marked and tagged fish were recovered in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}. One unmarked fish was recovered in the Area 4 mark-selective fishery.

Appendix Table 3.12.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Kendall Creek Hatchery DIT groups for brood years 1996 and 1997.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
2	Escapement	NSF	Observed	6.00	2.00	5.00	7.00
			Estimated	6.00	2.00	5.13	7.00
			SE	0.00	0.00	0.38	0.00
3	Escapement	NSF	Observed	332.00	183.00	260.00	245.00
			Estimated	375.32	206.79	270.37	254.80
			SE	7.00	5.18	3.28	3.19

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Appendix Table 3.12.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Kendall Creek Hatchery DIT groups for brood years 1996 and 1997.

				1996		1997	
Age	Fishery	Type	Data	M	U	M	U
	Freshwater Net	NSF	Observed	14.00	5.00	16.00	11.00
			Estimated	62.48	6.22	75.72	45.76
			SE	18.05	1.23	17.28	12.13
	Southeast Alaska Troll	NSF	Observed	3.00			
			Estimated	6.34	*3.22*		
			SE	2.73	*1.39*		
	WA Area 1 Sport	SF	Observed	2.00			
			Estimated	6.63			
			SE	3.93			
	WA Area 2 SF Sport	SF	Observed	1.00			
			Estimated	3.40			
			SE	2.86			
	WA Area 3 Sport	SF	Observed	3.00			
			Estimated	4.95			
			SE	1.81			
	WA Area 3 Troll	NSF	Observed	2.00			
			Estimated	2.34			
			SE	0.63			
	WA Area 4 Sport	SF	Observed	16.00		3.00	1.00
			Estimated	43.33		4.74	2.78
			SE	8.80		1.71	2.22
	WA Area 4, 4B Troll	NSF	Observed	11.00	7.00		2.00
			Estimated	34.18	20.69		14.96
			SE	12.02	6.43		9.85
	WA Area 5 Sport	SF	Observed	8.00		5.00	
			Estimated	30.69		26.96	
			SE	9.33		10.90	
	WA Area 6 Sport	SF	Observed	1.00		1.00	
			Estimated	3.10		2.51	
			SE	2.55		1.95	
	WA Area 7 Sport	NSF	Observed	3.00			1.00
			Estimated	12.13			4.72
			SE	6.11			4.19
	WA Area 7B, 7C, 7E Net	NSF	Observed	274.00	158.00	75.00	94.00
			Estimated	595.16	349.10	162.80	190.16
			SE	29.77	23.20	15.71	16.10
	WA Area 8 Sport	NSF	Observed		1.00		
			Estimated		5.13		
			SE		4.60		
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed	1.00		1.00	
			Estimated	1.65		3.29	
			SE	1.04		2.74	
Total Observed				677.00	356.00	366.00	361.00
Total Estimated				1187.70	589.93	551.52	520.18
Total Standard Error				40.62	25.08	26.26	23.15

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Equal Marine Survival (EMS) Method

Using λ^{Rel}, the EMS estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.12.2.

Appendix Table 3.12.2. Estimated number of mortalities of unmarked fish for Kendall Creek Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1996	0.5082	5	-58	68
1997	0.9607	10	-57	77

Equal Exploitation Rate (EER) Method

For the EER method, all non-selective fisheries were combined to yield an unmarked-to-marked ratio. Using all non-selective fisheries, the EER estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.12.3.

Appendix Table 3.12.3. Estimated number of mortalities of unmarked fish for Kendall Creek Hatchery DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	λ^{NSF}	SE(λ^{NSF})	Estimate	95% Confidence Interval	
				Lower	Upper
1996	0.53	0.04	43	-2	89
1997	1.05	0.14	64	-24	152

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.12.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Terminal (TERM) Method

The terminal fisheries for this hatchery are not selective, nor are they well sampled. Given the required assumptions, this method was not appropriate.

Appendix Table 3.12.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Kendall Creek Hatchery for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996 50% *sfm*	SE	1996 Default *sfm*	SE	1996 200% *sfm*	SE	1997 50% *sfm*	SE	1997 Default *sfm*	SE	1997 200% *sfm*	SE
						λ^{Rel}								
3	WA Area 1 Sport	0.14	0.24	0.14	0.47	0.28	0.94	0.56						
	WA Area 2 SF Sport	0.14	0.12	0.10	0.24	0.20	0.48	0.41						
	WA Area 3 Sport	0.14	0.18	0.06	0.35	0.13	0.70	0.26						
	WA Area 4 Sport	0.14	1.54	0.31	3.08	0.63	6.17	1.25	0.32	0.12	0.64	0.23	1.28	0.46
	WA Area 5 Sport	0.07	0.55	0.17	1.09	0.33	2.18	0.66	0.91	0.37	1.81	0.73	3.63	1.47
	WA Area 6 Sport	0.07	0.06	0.05	0.11	0.09	0.22	0.18	0.08	0.07	0.17	0.13	0.34	0.26
3 Total			2.68	0.83	5.35	1.66	10.70	3.32	1.31	0.55	2.62	1.09	5.24	2.19
						λ^{Esc}								
3	WA Area 1 Sport	0.14	0.26	0.15	0.51	0.30	1.02	0.61						
	WA Area 2 SF Sport	0.14	0.13	0.11	0.26	0.22	0.52	0.44						
	WA Area 3 Sport	0.14	0.19	0.07	0.38	0.14	0.76	0.28						
	WA Area 4 Sport	0.14	1.67	0.34	3.34	0.69	6.68	1.37	0.31	0.11	0.63	0.23	1.25	0.45
	WA Area 5 Sport	0.07	0.59	0.18	1.18	0.36	2.37	0.72	0.89	0.36	1.78	0.72	3.56	1.44
	WA Area 6 Sport	0.07	0.06	0.05	0.12	0.10	0.24	0.20	0.08	0.06	0.17	0.13	0.33	0.26
3 Total			2.90	0.91	5.80	1.81	11.60	3.62	1.28	0.54	2.57	1.07	5.14	2.15

Appendix 3.13. Marblemount Hatchery

Rebecca Bernard, Skagit System Cooperative
Angelika Hagen-Breaux, WDFW
Annette Hoffmann, WDFW
Don Noviello, WDFW
Colleen MacDonald, WDFW

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Marblemount Hatchery	1995	419970301	42,567	42,489	1.0018
	1996	419981003	45,090	43,347	1.0402
	1997	419991007	41,907	42,298	0.9908

Marblemount Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located at the confluence of the Cascade River and Clark Creek. The Cascade River is a tributary of the Skagit River.

Hatchery practices that are relevant to these analyses

At the hatchery, 100% of the returning coho salmon, including jacks, were sampled. However, there are anecdotal reports of hatchery fish straying to natural spawning areas. There is no electronic sampling for coded-wire tags in the natural spawning areas, so this straying is unsampled. The hatchery practice is to release unmarked and untagged fish upstream. All unmarked fish are electronically sampled with a hand-held wand. If no tag is detected with the wand, the fish is released upstream. If a tag is detected the fish is sampled with an R-detector. All marked fish are electronically sampled with an R-detector. Because the marked and unmarked fish are handled differently there is a potential for spurious results. If the hand-held wand has a greater false negative rate (where an instrument does not detect an embedded tag) than the R-detector, then proportionally more unmarked and tagged fish will have been missed than marked and tagged fish. This would cause a negative bias in the proportion of unmarked-to-marked DIT fish reported to have returned to the hatchery, a result that could mask a mark-selective fishing impact.

General comments for all brood years 1995-1997

For all three brood years, a mark-selective sport fishery occurred in the Cascade River. This fishery was sampled to obtain a catch estimate, but was not sampled for tags. Therefore, tag recoveries for marked fish were estimated by multiplying the estimated catch (expected to be exclusively of marked fish) by the tag rate of the marked hatchery stock and the variance was calculated using the estimated variance of the total catch (see below). There was also sport harvest in the Skagit River that was not sampled.

Tags from the marked DIT fish were recovered in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with $sfm = 1$ and using λ^{Rel}.

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Let	C	=	estimate of total catch (from catch record cards),
	V(C)	=	variance estimate of C,
	M	=	estimated number of marked DIT recoveries, and
	p	=	proportion of marked fish that were CWT tagged at release.
Then	M	=	Cp
	V(M)	=	$p^2V(C)$

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Marblemount Hatchery DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.13.1).

Appendix Table 3.13.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Marblemount Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
2	Escapement	NSF	Observed			3.00	2.00	3.00	3.00
			Estimated			3.20	2.40	3.00	3.00
			SE			0.49	0.69	0.00	0.00
3	Buoy 10 Sport	SF	Observed	1.00					
			Estimated	2.36					
			SE	1.79					
	Escapement	NSF	Observed	1,206.0	1,125.0	332.00	427.00	1,868.0	1,800.0
			Estimated	1,206.2	1,125.2	332.06	427.00	1,905.3	1,836.0
			SE	0.49	0.49	0.25	0.00	6.17	6.06
	Freshwater Net	NSF	Observed	54.00	68.00	50.00	53.00	68.00	85.00
			Estimated	102.58	135.29	68.18	73.15	156.75	192.81
			SE	10.34	12.81	5.12	5.44	29.97	33.39
	Southeast Alaska Troll	NSF	Observed					1.00	
			Estimated					1.37	*1.36*
			SE					0.71	*0.70*
	WA Area 1 Sport	SF	Observed					2.00	
			Estimated					4.79	
			SE					2.87	
	WA Area 1 Troll	SF	Observed					1.00	
			Estimated					2.45	
			SE					1.88	
	WA Area 10 Net	NSF	Observed					4.00	1.00
			Estimated					4.08	1.02
			SE					0.29	0.14

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Appendix Table 3.13.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Marblemount Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
	WA Area 10 Sport	NSF	Observed	5.00	3.00	3.00	2.00	25.00	32.00
			Estimated	28.27	11.16	6.75	7.71	130.71	157.81
			SE	13.48	6.03	2.90	5.21	29.08	31.37
	WA Area 10A Net	NSF	Observed						1.00
			Estimated						3.51
			SE						2.97
	WA Area 10E Net	NSF	Observed	1.00					
			Estimated	1.38					
			SE	0.72					
	WA Area 11 Sport	NSF	Observed			1.00		7.00	7.00
			Estimated			6.46		38.89	39.80
			SE			5.94		13.34	13.66
	WA Area 13 Sport	SF	Observed					1.00	3.00
			Estimated					3.44	10.32
			SE					2.90	5.02
	WA Area 2 NSF Sport	NSF	Observed	4.00	4.00				
			Estimated	7.91	8.51				
			SE	2.86	3.32				
	WA Area 2 SF Sport	SF	Observed			2.00			
			Estimated			5.67			
			SE			3.24			
	WA Area 2 Sport	SF	Observed					23.00	
			Estimated					48.96	
			SE					7.75	
	WA Area 2 Troll	SF	Observed					6.00	
			Estimated					14.34	
			SE					4.48	
	WA Area 3 Sport	NSF	Observed		1.00				
			Estimated		1.06				
			SE		0.25				
		SF	Observed			2.00		2.00	
			Estimated			3.36		2.71	
			SE			1.51		0.98	
	WA Area 3 Troll	NSF	Observed			1.00	2.00		
			Estimated			1.17	2.18		
			SE			0.45	0.46		
	WA Area 4 Sport	NSF	Observed	8.00	8.00				
			Estimated	17.07	17.45				
			SE	4.63	4.61				
		SF	Observed			15.00		31.00	1.00
			Estimated			38.71		71.83	2.02
			SE			8.02		10.22	1.44

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Appendix Table 3.13.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Marblemount Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
	WA Area 4, 4B Troll	NSF	Observed	5.00	5.00	9.00	13.00	4.00	2.00
			Estimated	7.56	6.18	43.22	28.00	29.92	14.96
			SE	2.02	1.21	16.62	6.94	13.92	9.85
	WA Area 5 Sport	NSF	Observed	18.00	12.00				
			Estimated	80.58	51.48				
			SE	16.80	13.01				
		SF	Observed			5.00		23.00	1.00
			Estimated			19.50		115.58	5.02
			SE			7.52		21.62	4.49
	WA Area 6 Sport	NSF	Observed	5.00	6.00				
			Estimated	11.10	14.90				
			SE	3.68	4.92				
		SF	Observed			1.00		5.00	
			Estimated			3.10		15.60	
			SE			2.55		5.75	
	WA Area 7 Sport	NSF	Observed						1.00
			Estimated						9.06
			SE						8.55
	WA Area 7B, 7C, 7E Net	NSF	Observed		1.00	2.00		1.00	1.00
			Estimated		2.04	5.58		2.11	2.19
			SE		1.46	3.16		1.53	1.61
	WA Area 8 Net	NSF	Observed			1.00	2.00	5.00	8.00
			Estimated			2.80	5.60	11.90	19.04
			SE			2.24	3.17	4.05	5.13
	WA Area 8 Sport	NSF	Observed	1.00	3.00	4.00	3.00	2.00	1.00
			Estimated	8.79	14.32	21.96	16.83	10.80	5.40
			SE	8.27	7.39	9.94	8.81	6.89	4.87
	WA Area 8-2 Sport	NSF	Observed	18.00	6.00	1.00	1.00	28.00	17.00
			Estimated	75.42	22.10	4.78	4.78	138.79	82.36
			SE	15.84	7.84	4.25	4.25	23.52	17.89
	WA Area 8A Net	NSF	Observed	3.00	2.00			2.00	3.00
			Estimated	4.83	29.05			10.87	19.62
			SE	1.72	26.95			6.96	10.43
	WA Area 8D Net	NSF	Observed	7.00	6.00	9.00	12.00	15.00	21.00
			Estimated	26.10	22.17	31.35	35.61	75.85	111.09
			SE	9.42	9.19	12.70	12.80	18.15	22.91
	WA Area 9 Sport	NSF	Observed	7.00	9.00			6.00	7.00
			Estimated	54.70	64.24			44.70	53.99
			SE	19.67	19.86			16.98	19.11
	WA Area 9A Net	NSF	Observed						1.00
			Estimated						1.57
			SE						0.95

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Appendix Table 3.13.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Marblemount Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1995		1996		1997	
Age	Fishery	Type	Data	M	U	M	U	M	U
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed		3.00		1.00	2.00	
			Estimated		3.03		1.65	6.58	
			SE		0.17		1.04	3.88	
	WA Area 7, 7A Net	NSF	Observed		1.00				
			Estimated		4.33				
			SE		3.80				
4	Escapement	NSF	Observed		1.00				
			Estimated		1.00				
			SE		0.00				
	Freshwater Net	NSF	Observed	1.00					
			Estimated	1.58					
			SE	0.96					
Total Observed				1,344	1,264	441	518	2,135	1,996
Total Estimated				1,636	1,534	598	605	2,851	2,571
Total Standard Error				112.71	123.32	86.92	48.81	233.89	199.83

The sport catch from the Cascade River was not sampled electronically. The number of tags was estimated as the estimated marked catch multiplied by the proportion of marked fish that were tagged.

Equal Marine Survival (EMS) Method

Using λ^{Rel}, the EMS estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.13.2.

Appendix Table 3.13.2. Estimated number of mortalities of unmarked fish for Marblemount Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1995	1.0018	105	-6	216
1996	1.0152	2	-65	69
1997	1.0088	323	147	500

Equal Exploitation Rate (EER) Method

For the EER method, all non-selective fisheries were combined to yield an unmarked-to-marked ratio. Using all non-selective fisheries, the EER estimates for the total unmarked mortality summed across all mark-selective fisheries are given in Appendix Table 3.13.3.

Appendix Table 3.13.4. Estimated number of mortalities of unmarked fish for Marblemount Hatchery DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	λ^{NSF}	SE(λ^{NSF})	Estimate	95% Confidence Interval	
				Lower	Upper
1995	0.95	0.129	22	-284	327
1996	0.92	0.157	-57	-184	70
1997	1.08	0.133	517	-57	1092

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.13.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

*Terminal (*TERM*) Method*

The terminal fisheries in the Cascade River were mark-selective. However, the fishery was not sampled for CWTs.

Appendix Table 3.13.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Marblemount Hatchery for brood years 1995, 1996, and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Def. *sfm*	1995 50% *sfm*		1995 Default *sfm*	SE	1995 200% *sfm*	SE	1996 50% *sfm*		1996 Default *sfm*	SE	1996 200% *sfm*	SE	1997 50% *sfm*	SE	1997 Default *sfm*	SE	1997 200% *sfm*	SE
									λ^{Rel}											
3	WA Area 1 Sport	0.14													0.33	0.20	0.66	0.40	1.33	0.80
	WA Area 1 Troll	0.26													0.32	0.24	0.63	0.49	1.26	0.97
	WA Area 2 Sport	0.14							0.41	0.24	0.83	0.47	1.65	0.94						
	WA Area 2 Sport	0.14													3.40	0.54	6.79	1.07	13.58	2.15
	WA Area 2 Troll	0.26													1.85	0.58	3.69	1.15	7.39	2.31
	WA Area 3 Sport	0.14							0.24	0.11	0.49	0.22	0.98	0.44	0.19	0.07	0.38	0.14	0.75	0.27
	WA Area 4 Sport	0.14							2.82	0.58	5.64	1.17	11.28	2.34	4.98	0.71	9.96	1.42	19.93	2.83
	WA Area 5 Sport	0.07							0.71	0.27	1.42	0.55	2.84	1.10	4.01	0.75	8.02	1.50	16.03	3.00
	WA Area 6 Sport	0.07							0.11	0.09	0.23	0.19	0.45	0.37	0.54	0.20	1.08	0.40	2.16	0.80
	Buoy 10 Sport	0.16	0.19	0.14	0.38	0.29	0.76	0.57												
	WA Area 13 Sport	0.07													0.12	0.10	0.24	0.20	0.48	0.40
	3 Total		0.19	0.14	0.38	0.29	0.76	0.57	4.30	1.30	8.60	2.59	17.20	5.19	15.73	3.38	31.46	6.76	62.91	13.53
									λ^{Esc}											
3	WA Area 1 Sport	0.14													0.32	0.19	0.65	0.39	1.29	0.77
	WA Area 1 Troll	0.26													0.31	0.24	0.61	0.47	1.23	0.94
	WA Area 2 Sport	0.14							0.51	0.29	1.02	0.58	2.04	1.17						
	WA Area 2 Sport	0.14													3.30	0.52	6.61	1.05	13.21	2.09
	WA Area 2 Troll	0.26													1.80	0.56	3.59	1.12	7.19	2.24
	WA Area 3 Sport	0.14							0.30	0.14	0.60	0.27	1.21	0.55	0.18	0.07	0.37	0.13	0.73	0.26
	WA Area 4 Sport	0.14							3.48	0.72	6.97	1.44	13.94	2.89	4.85	0.69	9.69	1.38	19.38	2.76
	WA Area 5 Sport	0.07							0.88	0.34	1.76	0.68	3.51	1.35	3.90	0.73	7.80	1.46	15.59	2.92
	WA Area 6 Sport	0.07							0.14	0.11	0.28	0.23	0.56	0.46	0.53	0.19	1.05	0.39	2.10	0.78
	Buoy 10 Sport	0.16	0.18	0.13	0.35	0.27	0.70	0.53												
	WA Area 13 Sport	0.07													0.12	0.10	0.23	0.20	0.46	0.39
	3 Total		0.18	0.13	0.35	0.27	0.70	0.53	5.31	1.60	10.63	3.21	21.26	6.41	15.30	3.29	30.59	6.58	61.19	13.16

Appendix 3.14. Wallace River Hatchery

Marla Maxwell, Tulalip
Marianna Alexandersdottir, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Wallace River	1996	419981004	45,718	46,253	0.9884
	1997	419991002	45,091	45,005	1.0019

Hatchery practices that are relevant to these analyses

The Wallace River hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on the Wallace River, a tributary to the Skykomish River. Coho salmon smolts sufficient to sustain the brood stock at the hatchery are released into the Wallace River. These fish are also used as the indicator tag group. The adult fish voluntarily return to a hatchery trap and all fish entering the trap are sampled electronically.

General concerns for all brood years

Marked recoveries of the DIT groups from Wallace River Hatchery occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. There is a sport fishery in the river that is not sampled.

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Wallace River DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.14.1).

Appendix Table 3.14.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Wallace River Hatchery DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	Marked	Unmarked	Marked	Unmarked
2	Escapement		Observed	19	13	31	13
			Estimated	19.00	13.00	31.00	13.00
			SE	0.00	0.00	0.00	0.00
	WA Area 13 Sport	NSF	Observed	1			
			Estimated	4.75			
			SE	4.22			
3	Escapement		Observed	900	997	3,133	3,326
			Estimated	900.00	997.00	3,164.32	3,359.25
			SE	0.00	0.00	5.62	5.80

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Appendix Table 3.14.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Wallace River Hatchery DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	Marked	Unmarked	Marked	Unmarked
	Southeast Alaska Troll	NSF	Observed			1	
			Estimated			1.37	*1.37*
			SE			0.71	*0.71*
	WA Area 1 Sport	SF	Observed	2	1		
			Estimated	5.41	1.31		
			SE	3.04	0.64		
	WA Area 1 Troll	SF	Observed			2	
			Estimated			2.33	
			SE			0.62	
	WA Area 10 Net	NSF	Observed			1	
			Estimated			1.06	
			SE			0.25	
	WA Area 10 Sport	NSF	Observed		1	5	3
			Estimated		2.25	18.07	19.23
			SE		1.68	6.94	11.82
	WA Area 2 SF Sport	SF	Observed	3			
			Estimated	8.59			
			SE	4.07			
	WA Area 2 Sport	SF	Observed			7	
			Estimated			16.97	
			SE			5.14	
	WA Area 2 Troll	SF	Observed			2	
			Estimated			4.68	
			SE			2.51	
	WA Area 3 Sport	SF	Observed	6		2	
			Estimated	11.19		2.35	
			SE	3.14		0.66	
	WA Area 3 Troll	NSF	Observed	1	1		
			Estimated	1.17	1.17		
			SE	0.45	0.45		
	WA Area 4 Sport	SF	Observed	13		10	
			Estimated	32.12		24.38	
			SE	7.08		6.15	
	WA Area 4, 4B Troll	NSF	Observed	6	13	4	6
			Estimated	22.03	51.61	29.92	44.88
			SE	11.03	16.80	13.92	17.05
	WA Area 5 Sport	SF	Observed	4		14	
			Estimated	15.72		70.90	
			SE	6.79		16.99	

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Appendix Table 3.14.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Wallace River Hatchery DIT groups for brood years 1996 and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

				1996		1997	
Age	Fishery	Type	Data	Marked	Unmarked	Marked	Unmarked
	WA Area 6 Sport	SF	Observed			5	
			Estimated			15.60	
			SE			5.75	
	WA Area 7 Sport	NSF	Observed				1
			Estimated				4.72
			SE				4.19
	WA Area 8 Net	NSF	Observed	1			
			Estimated	2.80			
			SE	2.24			
	WA Area 8-2 Sport	NSF	Observed	7	7	16	4
			Estimated	29.10	31.28	79.17	20.52
			SE	9.93	10.61	17.74	9.21
	WA Area 8A Net	NSF	Observed			5	2
			Estimated			31.89	11.68
			SE			13.12	7.58
	WA Area 8D Net	NSF	Observed	15	13	18	28
			Estimated	52.03	106.56	74.10	132.28
			SE	17.39	32.84	16.66	23.39
	WA Area 9 Sport	NSF	Observed	2	3	9	2
			Estimated	21.34	32.01	67.05	14.90
			SE	14.37	17.59	20.80	9.80
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed	1	2	1	
			Estimated	1.65	3.30	3.29	
			SE	1.04	1.46	2.74	
Total Observed				981	1,051	3,266	3,385
Total Estimated				1,126.90	1,239.49	3,638.45	3,620.46
Total SE				29.75	42.29	43.26	35.60

One unmarked recovery from the 1996 brood year was observed in the Area 1 selective fishery in 1999. This was a single tag recovery which was recorded as unmarked by the sampler. There were recoveries of age 2 fish in the hatchery escapement and a single tagged age 2 fish was recovered in the Area 13 sport fishery in 1998. One recovery from the 1997 brood year was made of a marked and tagged fish in the southeast Alaska troll fishery which was not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with *sfm* = 1 and using λ^{Rel}.

APPENDIX 3

Equal Marine Survival (EMS) Method

The estimates made using the EMS method were imprecise (Appendix Table 3.14.2). For the 1996 brood year the estimate was negative and for the 1997 brood year the estimate was not significantly different from zero (95% confidence interval included zero).

Appendix Table 3.14.2. Estimated number of mortalities of unmarked fish for Wallace River Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1996	0.9884	-135	-235	-34
1997	1.0019	25	-85	135

Equal Exploitation Rate (EER) Method

There were no non-selective fisheries that occurred prior (in time and area) to mark-selective fisheries. Therefore, it may not be possible to obtain an unbiased estimate of λ from any of the non-selective fisheries. The λ combined in all significant marine non-selective fisheries (WA Area 4, 4B Troll, WA Area 3 Troll) was 2.28 for the 1996 brood year in 1998 and 1.5 for the 1997 brood year in fishery year 2000 (Appendix Table 3.14.3). The estimate of the total number of unmarked mortalities in mark-selective fisheries using the EER method with the above λ is 1,324 for the 1996 brood year and 1,837 for the 1997 brood year. In both years the estimate of λ is based on fewer than 10 tags in the fisheries and is very imprecise. The EER method is unreliable when the estimate of λ is so imprecise.

Appendix Table 3.14.3. Estimated number of mortalities of unmarked fish for Wallace River Hatchery DIT coho salmon in all mark-selective fisheries using the EER method.

Brood Year	$\lambda^{Fishery}$	SE	Estimate	95% Confidence Interval	
				Lower	Upper
1996	2.28	1.35	1,324	-1,596	4,245
1997	1.50	0.90	1,837	-4,538	8,213

Paired-Ratio (PR) Method

The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries (Appendix Table 3.14.4). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.14.4 Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Wallace River Hatchery for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996 50% *sfm*	SE	1996 Default *sfm*	SE	1996 200% *sfm*	SE	1997 50% *sfm*	SE	1997 Default *sfm*	SE	1997 200% *sfm*	SE
						λ^{Rel}								
3	WA Area 1 Sport	0.14	0.37	0.21	0.75	0.42	1.50	0.84						
	WA Area 1 Troll	0.26							0.30	0.08	0.61	0.16	1.21	0.32
	WA Area 2 SF Sport	0.14	0.59	0.28	1.19	0.56	2.38	1.13						
	WA Area 2 Sport	0.14							1.19	0.36	2.38	0.72	4.76	1.44
	WA Area 2 Troll	0.26							0.61	0.33	1.22	0.65	2.44	1.31
	WA Area 3 Sport	0.14	0.77	0.22	1.55	0.43	3.10	0.87	0.16	0.05	0.33	0.09	0.66	0.18
	WA Area 4 Sport	0.14	2.22	0.49	4.44	0.98	8.89	1.96	1.71	0.43	3.42	0.86	6.84	1.72
	WA Area 5 Sport	0.07	0.54	0.23	1.09	0.47	2.18	0.94	2.49	0.60	4.97	1.19	9.95	2.38
	WA Area 6 Sport	0.07							0.55	0.20	1.09	0.40	2.19	0.81
	Total		4.51	0.47	9.02	1.86	18.04	7.45	7.01	0.83	14.02	3.31	28.04	13.24
						λ^{Esc}								
3	WA Area 1 Sport	0.14	0.42	0.24	0.84	0.47	1.68	0.94						
	WA Area 1 Troll	0.26							0.32	0.09	0.64	0.17	1.29	0.34
	WA Area 2 SF Sport	0.14	0.67	0.32	1.33	0.63	2.66	1.26						
	WA Area 2 Sport	0.14							1.26	0.38	2.52	0.76	5.04	1.53
	WA Area 2 Troll	0.26							0.65	0.35	1.29	0.69	2.58	1.39
	WA Area 3 Sport	0.14	0.87	0.24	1.74	0.49	3.47	0.97	0.17	0.05	0.35	0.10	0.70	0.19
	WA Area 4 Sport	0.14	2.49	0.55	4.98	1.10	9.96	2.20	1.81	0.46	3.62	0.91	7.25	1.83
	WA Area 5 Sport	0.07	0.61	0.26	1.22	0.53	2.44	1.05	2.63	0.63	5.27	1.26	10.54	2.52
	WA Area 6 Sport	0.07							0.58	0.21	1.16	0.43	2.32	0.85
	Total			5.05	1.61	10.11	3.21	20.21	6.43	7.43	2.17	14.86	4.33	29.71

Appendix 3.15. Voights Creek Hatchery

Jay Zischke, Suquamish Tribe
Marianna Alexandersdottir, NWIFC

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Voights Creek	1996	419981007	20,761	19,927	1.0418
	1996	419981008	20,077	20,106	0.9986
	Combined		40,838	40,033	1.0201

The Voights Creek Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on the Puyallup River (Voights Creek is 22 river miles from saltwater, on a tributary to the Carbon River).

DIT rearing strategy

For brood years 1995 through 1998, all coho salmon juveniles were reared with the same culture techniques. Delayed mortality|tag retention is estimated three weeks after tagging. All cultured fish are released together.

General comments

The facility manager is knowledgeable about the objectives of the DIT program. All adults returning to the rack were sampled for marks. Flood conditions compromise the capture of adults. In 1996 the weir was damaged by flood waters. The existing weir status will let fish swim around the structure and pass upstream at medium to high river discharges. While the facility managers observe the majority of the coho salmon return to the hatchery, an unknown percentage of fish pass upstream. Some upstream sampling of carcasses is done by WDFW and Puyallup Tribal fisheries staff in South Prairie Creek.

Terminal fishery considerations

A Treaty net fishery occurs primarily in the lower Puyallup River. This fishery is sampled at a target 20% of the total catch each week. A freshwater (in-river) recreational fishery opens in October and is concentrated at the confluence of Voights creek and the Carbon River. This fishery is not sampled. According to the preliminary sport catch reports, 1,078 coho salmon and 454 jack coho were harvested in the Carbon River and Puyallup River during 1999 (Terrie Manning, *WDFW memo 11/22/2000*). In 1998, 3,388 coho salmon were reported harvested in these two locations with 2,480 jack coho taken (Manning and Smith 2001)[7].

Issues of concerns

- Flood damage in 1996 has left the weir across Voights Creek compromised. This condition lets and unknown number of adults migrate beyond the facility. This issue needs to be addressed.
- Unsampled harvest by the recreational fishery may be significant.

[7] Manning, T. and S. Smith. 2001. Washington State Sport Catch Report 1998. WDFW February 2001.

- Limited sampling of carcasses on the spawning grounds identifies that some level of straying to other areas of the system is occurring. Presently, the level of sampling is not adequate to expand throughout the system.

In 1999, a total of 2,851 coho were harvested in the Puyallup River freshwater commercial fishery. In addition, 9,005 coho salmon entered the hatchery (plus 40 jacks) and were sampled. Of these, 6,888 were retained in the hatchery and 2,117 released from the rack (Jeff Haymes, *WDFW personal communication*) and 4,165 "wild" coho salmon adults were estimated to spawn naturally. These numbers plus the sport fishery estimates (1,078 non-jack coho salmon) result in a total age 3 run size of 17,099 in 1999.

Estimation of sport and natural escapement recoveries

The hatchery is located on Voights Creek, a tributary to the Carbon River. The freshwater net fishery is in the lower river and, under the assumption that the proportion of each tagged group in the net fishery is representative of the total run entering the river, the total number of tagged coho salmon in the run can be estimated as shown in the Appendix Table 3.15.1. Under the assumption that the proportion tagged in the freshwater net harvest can also be applied to the freshwater sport fishery, the tagged sport harvest can also be estimated. However, given that the fishery largely takes place in the Carbon River this assumption may not be valid if tagged hatchery fish are more likely to be present in the Carbon River in-route to the hatchery than in the total run. Given these two assumptions, then the tagged fish straying to natural spawning areas can be estimated by subtraction (Appendix Table 3.15.1). This method results in imprecise estimates of natural spawners and there is the potential for bias in both the sport and spawner estimate if the assumptions are invalid.

Appendix Table 3.15.1. Estimated catch, hatchery return, and natural spawners, and estimated tagged contribution to these components of the total run, for the 1996 brood year of DIT coho salmon from Voights Creek Hatchery.

Location	Total # fish		Marked			Unmarked		
			419981008	419981007	Total	419981008	419981007	Total
Freshwater net catch	2,851	Tagged	33.2	25.1	58.2	64.6	24.1	88.7
		Var	92.1	71.5	163.7	191.7	64.7	256.5
		CV	29%	34%	22%	21%	33%	18%
Freshwater sport catch	1,078	Tagged	12.5	9.5	22.0	24.4	9.1	33.5
		Var	13.2	10.2	23.4	27.4	9.3	36.7
		CV	29%	34%	22%	21%	33%	18%
Hatchery return	9,005	Tagged	92.0	76.0	168.0	119.0	68.0	187.0
		Var	-	-	-	-	-	-
		CV	0%	0%	0%	0%	0%	0%
Natural spawners	4,165	Tagged	61.1	39.9	101.0	179.5	43.2	222.7
		Var	3,419.8	2,654.1	6,074.0	7,116.2	2,402.0	9,518.2
		CV	96%	129%	77%	47%	113%	44%
Total Run	17,099	Tagged	198.8	150.5	349.3	387.6	144.4	531.9
		Var	3,314.5	2,572.4	5,886.9	6,897.0	2,328.1	9,225.1
		CV	29%	34%	22%	21%	33%	18%

APPENDIX 3

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Voights Creek DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.15.2). There were two DIT groups in the release database, but no obvious difference between these groups is identified. The hatchery manager has stated that all coho are reared with the same culture techniques. The rate of return to escapement is not significantly different between the groups. In the following estimation of unmarked mortalities due to release in selective fisheries both groups are combined and treated as a single release.

Appendix Table 3.15.2. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Voights Creek Hatchery DIT coho salmon for brood year 1996.

				Marked			Unmarked		
Age	Fishery	Type	Data	419981007	419981008	Total	419981007	419981008	Total
2	Escapement	NSF	Observed	1.00		1.00			
			Estimated	8.69		8.69			
			SE	8.17		8.17			
3	Escapement	NSF	Observed	76.00	92.00	168.00	68.00	119.00	187.00
			Estimated	76.00	92.00	168.00	68.00	119.00	187.00
			SE	-	-	-	-	-	-
	Freshwater Net	NSF	Observed	7.00	9.00	16.00	7.00	17.00	24.00
			Estimated	25.09	33.15	58.24	24.07	64.62	88.69
			SE	8.46	9.60	18.06	8.04	13.85	21.89
	WA Area 10 Net	NSF	Observed		1.00	1.00			
			Estimated		2.64	2.64			
			SE		2.08	2.08			
	WA Area 10 Sport	NSF	Observed		1.00	1.00	1.00	2.00	3.00
			Estimated		2.25	2.25	2.25	4.50	6.75
			SE		1.68	1.68	1.68	2.37	4.05
	WA Area 11 Sport	NSF	Observed		1.00	1.00			
			Estimated		7.29	7.29			
			SE		6.77	6.77			
	WA Area 3 Sport	SF	Observed		1.00	1.00			
			Estimated		1.77	1.77			
			SE		1.17	1.17			
	WA Area 3 Troll	NSF	Observed					1.00	1.00
			Estimated					1.17	1.17
			SE					0.45	0.45
	WA Area 4 Sport	SF	Observed	3.00		3.00			
			Estimated	8.06		8.06			
			SE	3.73		3.73			
	WA Area 4, 4B Troll	NSF	Observed		3.00	3.00		1.00	1.00
			Estimated		4.71	4.71		1.57	1.57
			SE		1.64	1.64		0.95	0.95

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Appendix Table 3.15.2. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Voights Creek Hatchery DIT coho salmon for brood year 1996.

				Marked			Unmarked		
Age	Fishery	Type	Data	419981007	419981008	Total	419981007	419981008	Total
	WA Area 5 Sport	SF	Observed	3.00	5.00	8.00			
			Estimated	11.34	19.20	30.54			
			SE	5.61	7.39	13.00			
	WA Area 9 Sport	NSF	Observed					1.00	1.00
			Estimated					10.67	10.67
			SE					10.16	10.16
4	Escapement	NSF	Observed	1.00		1.00			
			Estimated	1.18		1.18			
			SE	0.46		0.46			
Total Observed				91.00	113.00	204.00	76.00	141.00	217.00
Total Estimated				130.36	163.01	293.37	94.32	201.53	295.85
Total Standard Error				13.56	14.27	25.16	8.22	17.37	24.49
Estimated (from Appendix Table 3.15.1)									
	Freshwater Sport	NSF	Estimated	9.50	12.50	22.00	9.10	24.40	33.50
			SE	3.19	3.63	4.84	3.05	5.23	6.06
	Natural Escapement	NSF	Estimated	39.90	61.10	101.00	43.20	179.50	222.70
			SE	51.52	58.48	77.94	49.01	84.36	97.56
	Total		Estimated	179.76	236.61	416.37	146.62	405.43	552.05
			SE	53.37	60.31	82.04	49.79	86.29	100.77

Equal Marine Survival (EMS) Method.

The estimate of unmarked mortalities is 3.41 fish when only estimates derived from tags sampled in fisheries or hatchery escapement are used. However, this estimate was not based on an unbiased cohort size, as no samples were taken in the freshwater sport and natural escapement. If the recoveries that are estimated for these components are included, the estimate is –127.32 (Appendix Table 3.15.3).

Appendix Table 3.15.3. Estimated number of mortalities of unmarked fish for Voights Creek Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Estimate	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
Without freshwater sport and escapement	1.020	3.41	-131.77	138.59
With freshwater sport and escapement	1.020	-127.32	-09.01	154.38

APPENDIX 3

Equal Exploitation Rate (EER) Method

The numbers of recoveries available in any non-selective fishery were not sufficient for this method.

Paired-Ratio (PR) Method

As with the EER method, there is no "good" non-selective fishery for estimating a λ for the paired ratio method and the λ^{Rel} and λ^{Esc} were used. Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM). (Appendix Table 3.15.4).

Appendix Table 3.15.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Voights Creek Hatchery for brood year 1996 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
				λ^{Rel}				
3	WA Area 3 Sport	0.14	0.12	0.08	0.25	0.16	0.49	0.33
	WA Area 4 Sport	0.14	0.59	0.27	1.18	0.54	2.35	1.09
	WA Area 5 Sport	0.07	1.08	0.46	2.17	0.93	4.34	1.85
3 Total			1.80	0.82	3.59	1.63	7.18	3.27
				λ^{Esc}				
3	WA Area 3 Sport	0.14	0.16	0.11	0.32	0.21	0.64	0.42
	WA Area 4 Sport	0.14	0.50	0.23	1.01	0.47	2.02	0.93
	WA Area 5 Sport	0.07	1.22	0.51	2.45	1.02	4.90	2.04
3 Total			1.89	0.85	3.78	1.70	7.56	3.40

Appendix 3.16. Soos Creek Hatchery

Jay Zischke, Suquamish Tribe
Mike Mahovlich, Muckleshoot Tribe
Marianna Alexandersdottir, NWIFC.

Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Soos Creek	1996	419981005	41,127	44,781	0.9184
	1997	419991004	41,879	42,430	0.9870

Soos Creek Hatchery is operated by the Washington Dept. of Fish and Wildlife (WDFW) and is located on the Green River.

DIT rearing strategy

The DIT groups for brood years 1996 and 1997 were reared in same type of ponds with the same culture techniques as non-DITs. Delayed mortality|tag retention of DIT fish was estimated three weeks after tagging. The DIT groups were released together with other coho groups.

General comments

The facility manager is knowledgeable about the objectives of the DIT program and attempts to keep rearing similar for all coho releases. Facility staff attempt to mark sample 100% of the returning adults at the rack. Flooding problems exist during the return of the adult coho salmon. The rack overtopped during 1996 and again in 2001. There was no overtop during 1998-2000, although a beaver chewed a hole in the rack during the 1998 return, resulting in an estimated upstream escapement of 4,000 fish (facility staff rough estimate). In 2001 the rough estimate of upstream flood escapees was 18,000 fish.

Terminal fishery considerations

Commercial: There are treaty net fisheries in Elliott Bay and the Duwamish|Green River that are directed at coho salmon throughout the coho adult return. These fisheries were mark sampled at a high rate (50-75%). Fisheries occurred in all return years for DIT group adults (1998-2001). The commercial freshwater harvest was 12,787 coho salmon in 1999 and 48,708 coho salmon in 2000 (PSMFC Catch Sample Database).

Recreational: Recreational fisheries occurred in all years of DIT returns. Fisheries occurred in both Elliott Bay (recreational area 10) and within the Green River system. Marine catch is mark sampled at a target of 10%, although typically this area has been sampled at a higher rate. The freshwater fishery is not sampled and may be of significant magnitude. There is a directed fishery for coho salmon limited to younger anglers in Soos Creek (just downstream of the facility) which occurs for approximately one month annually – this fishery is not sampled. The sport harvest is estimated using catch record cards (CRCs). In 1999 the adult (non-jack) harvest was 753 coho and 364 jack coho were reported (preliminary estimates: Terrie Manning, WDFW memo 11/22/2000). In 2000 the harvest estimate from the CRC

system was 2,155 adults and 378 jacks (preliminary estimates: Terrie Manning, WDFW memo 11/27/2001).

Issues of concern

- Rack flooding – this can happen in any return year – a back-up protocol should be developed to sample fish and an abundance estimate above the rack should be developed for when flooding occurs.
- Commercial fishery – while well sampled, there is concern that due to very low value in recent years (1999-2001) some catch is not being reported. For 1998-2000 tribal managers estimated the unreported catch at 10%.
- Recreational fishery – the lack of freshwater sampling may be significant. Regional managers may be able to provide an estimate of catch across the geography of the river to estimate potential composition differences due to location in the river.

In 1999 a total of 8,200 (plus 17 jacks) coho entered the hatchery and were sampled at a rate of 57.3%. Of these 3,144 were retained in the hatchery and 5,056 released from the rack (Jeff Haymes, *WDFW personal communication*) and 1,244 coho salmon were estimated to spawn naturally. These numbers plus the sport fishery estimates (1,078 non-jack coho salmon) result in a total age 3 run size of 22,984 in 1999.

Estimation of sport and natural escapement recoveries

The hatchery is on Soos Creek. The freshwater net fishery is in the lower river and under the assumption that the proportion of each tagged group in the net fishery is representative of the total run entering the river, then the total number of tagged in the run can be estimated, as shown in (Appendix Table 3.16.1). Under the assumption that the freshwater net proportion tagged can also be applied to the freshwater fishery, the tagged sport harvest can also be estimated.

Given the two above assumptions, then the tagged fish straying to natural spawning areas can be estimated by subtraction (Appendix Table 3.16.1). This method results in imprecise estimates for the estimate of natural spawners, and there is the potential for bias in both the sport and spawner estimate if the assumptions made are invalid. The major assumption here is the freshwater net fishery provides an unbiased estimate of the % tagged in the sport fishery and the run. This requires either that the fishery extend throughout the run and operates as a proportional sampler of the total run, or that the proportion tagged is constant throughout the run so a sample taken by the fishery at any time will be unbiased. It also requires that the fish pass through the sport fishery before the hatchery fish have left the run for the hatchery thus changing the proportion tagged. In fact for Soos Creek the numbers of spawners are negative both for brood years 1996 and 1997, and so should not be used.

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Appendix Table 3.16.1. Estimation of age 3 tagged fish in sport harvest and "wild" spawners using method of subtraction for Soos Creek coho salmon, brood years 1996 and 1997.

Location	Data	1996			1997		
		Total in catch or spawners	Tagged catch or spawners		Total in catch or spawners	Tagged catch or spawners	
			Marked	Unmarked		Marked	Unmarked
Freshwater net	Tagged	12,787	136.53	120.65	48,708	581.73	780.21
	Var.		41.49	36.41		1,274.86	1,636.8
	CV		5%	5%		6%	5%
	% tagged		1.07%	0.94%		1.19%	1.60%
	SE		0.05%	0.05%		0.07%	0.08%
	CV		5%	5%		6%	5%
Freshwater sport	Tagged	902	9.631	8.51	2,155	25.74	34.52
	Var.		0.2	0.2		2.50	3.20
	CV		5%	5%		6%	5%
Hatchery total	Tagged	8,200	272.25	202.25	43,721	888	1146
	Var.		203.43	150.93		0	0
	CV		5%	6%		0%	0%
"Wild Spawners"	Tagged	1,244	-171.4	-113.1	2,745	-1,219.2	-1,590.2
	Var.		380.9	306.7		1,564.9	2,009.3
	CV		11%	15%		3%	3%
Total	Tagged	23,133	247.0	218.3	97,329	276.3	370.5
	Var		135.8	119.2		287.6	369.2
	CV		5%	5%		6%	5%

Estimation of unmarked mortalities in mark-selective fisheries

Recoveries of Soos Creek DIT groups largely occurred in Washington ocean and Puget Sound fisheries (Appendix Table 3.16.2).

Appendix Table 3.16.2. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Soos Creek Hatchery DIT groups for brood years 1996 and 1997.

Age	Fishery	Type	Data	1996		1997	
				Marked	Unmarked	Marked	Unmarked
2	Escapement		Observed		4	8	5
			Estimated		4.00	8.75	5.75
			SE		0.00	1.15	1.15
	Freshwater Net	NSF	Observed		1	4	2
			Estimated		1.09	4.95	2.46
			SE		0.31	1.09	0.75

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Appendix Table 3.16.2. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Soos Creek Hatchery DIT groups for brood years 1996 and 1997.

Age	Fishery	Type	Data	1996		1997	
				Marked	Unmarked	Marked	Unmarked
	WA Area 10 Sport	NSF	Observed		1		
			Estimated		2.72		
			SE		2.16		
3	Escapement		Observed	156	116	888	1,147
			Estimated	272.25	202.25	888.00	1,147.00
			SE	14.26	12.29	0.00	0.00
	Freshwater Net	NSF	Observed	105	93	205	283
			Estimated	136.53	120.65	582.65	781.61
			SE	6.44	6.03	35.75	40.52
	WA Area 1 Sport	SF	Observed			1	
			Estimated			1.47	
			SE			0.83	
	WA Area 10 Net	NSF	Observed	2	2	4	5
			Estimated	5.62	2.06	5.90	6.90
			SE	3.19	0.25	1.91	1.91
	WA Area 10 Sport	NSF	Observed	3		1	6
			Estimated	6.75		3.97	22.04
			SE	2.90		3.43	7.74
	WA Area 10A Net	NSF	Observed			7	8
			Estimated			22.80	23.06
			SE			7.36	7.27
	WA Area 11 Sport	NSF	Observed			1	
			Estimated			6.27	
			SE			5.75	
	WA Area 13D Net	NSF	Observed			1	
			Estimated			1.98	
			SE			1.39	
	WA Area 2 SF Sport	SF	Observed	1			
			Estimated	2.29			
			SE	1.72			
	WA Area 2 Sport	SF	Observed			5	
			Estimated			11.16	
			SE			3.77	
	WA Area 3 Sport	SF	Observed	2		1	
			Estimated	3.54		1.23	
			SE	1.65		0.53	
	WA Area 3 Troll	NSF	Observed		1		
			Estimated		1.17		
			SE		0.45		

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Appendix Table 3.16.2. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Soos Creek Hatchery DIT groups for brood years 1996 and 1997.

Age	Fishery	Type	Data	1996		1997	
				Marked	Unmarked	Marked	Unmarked
	WA Area 4 Sport	SF	Observed	3		15	
			Estimated	7.92		37.83	
			SE	3.64		7.85	
	WA Area 4, 4B Troll	NSF	Observed	6	2	3	1
			Estimated	31.77	7.12	22.44	7.48
			SE	15.14	5.11	12.06	6.96
	WA Area 5 Sport	SF	Observed	2		10	
			Estimated	7.71		50.82	
			SE	4.69		14.42	
	WA Area 6 Sport	SF	Observed			3	1
			Estimated			9.36	3.12
			SE			4.45	2.57
	WA Area 8-2 Sport	NSF	Observed			2	2
			Estimated			10.26	10.26
			SE			6.51	6.51
	WA Area 9 Sport	NSF	Observed		3	2	2
			Estimated		29.23	18.58	14.90
			SE		16.15	12.41	9.80
	West Coast Vancouver	NSF	Observed		1		
			Estimated		1.00		
			SE		0.00		
Total Observed				280	224	1,161	1,462
Total Estimated				474.38	371.29	1,688.42	2,024.58
Total Standard Error				23.10	21.89	45.07	44.20

Equal Marine Survival (EMS) Method.

The estimate of unmarked mortalities is 63.1 for the 1996 brood year and a negative 209 coho salmon for the 1997 brood year (Appendix Table 3.16.3).

Appendix Table 3.16.3. Estimated number of mortalities of unmarked fish for Soos Creek Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
			Lower	Upper
1996	0.9184	63.08	3.42	122.74
1997	0.9870	-209.03	-337.59	-80.47

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Equal Exploitation Rate (EER) Method

The numbers of recoveries available in any non-selective fishery were not sufficient to use this method.

Paired-Ratio (PR) Method

As with the EER method there is no "good" non-selective fishery for estimating a λ for the paired-ratio method, therefore, the λ^{Rel} and λ^{Esc} were used. Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value (Appendix Table 3.16.4). The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.16.4. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Soos Creek Hatchery for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Total *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
3	WA Area 1 Sport	0.14							0.10	0.06	0.20	0.11	0.41	0.23
	WA Area 2 SF Sport	0.14	0.15	0.11	0.29	0.22	0.59	0.44						
	WA Area 2 Sport	0.14							0.77	0.26	1.54	0.52	3.08	1.04
	WA Area 3 Sport	0.14	0.23	0.11	0.46	0.21	0.91	0.42	0.09	0.04	0.17	0.07	0.34	0.15
	WA Area 4 Sport	0.14	0.51	0.23	1.02	0.47	2.04	0.94	2.61	0.54	5.23	1.08	10.46	2.17
	WA Area 5 Sport	0.07	0.25	0.15	0.50	0.30	0.99	0.60	1.76	0.50	3.51	1.00	7.02	1.99
	WA Area 6 Sport	0.07							0.32	0.15	0.65	0.31	1.29	0.62
3 Total			1.13	0.10	2.26	0.40	4.53	1.61	5.65	0.64	11.30	2.55	22.60	10.21
			λ^{Esc}											
3	WA Area 1 Sport	0.14							0.13	0.08	0.27	0.15	0.53	0.30
	WA Area 2 SF Sport	0.14	0.12	0.09	0.24	0.18	0.48	0.36						
	WA Area 2 Sport	0.14							1.01	0.34	2.02	0.68	4.04	1.36
	WA Area 3 Sport	0.14	0.18	0.09	0.37	0.17	0.74	0.35	0.11	0.05	0.22	0.10	0.44	0.19
	WA Area 4 Sport	0.14	0.41	0.19	0.82	0.38	1.65	0.77	3.42	0.71	6.84	1.42	13.68	2.84
	WA Area 5 Sport	0.07	0.20	0.12	0.40	0.25	0.80	0.49	2.30	0.65	4.60	1.30	9.19	2.61
	WA Area 6 Sport	0.07							0.42	0.20	0.85	0.40	1.69	0.81
3 Total			0.92	0.49	1.83	0.98	3.66	1.97	7.39	2.03	14.79	4.05	29.58	8.11

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Appendix 3.17. Lower Elwha Hatchery

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Amy Seiders, NWIFC
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Hatchery	Brood Year	Related Group ID	Unmarked	Marked	λ^{Rel}
Lower Elwha	1995	1419979001	72,909	78,150	0.9329
	1996	1419989002	75,203	78,862	0.9536
	1997	141999DI03	77,378	74,940	1.0325

The Lower Elwha Hatchery is operated by the Elwha Tribes and is located on a side tributary of the Elwha River.

DIT rearing strategy

Marked and unmarked DIT groups are tagged on the same day and are reared together in the same pond. Total release numbers are determined using counters that count fish as they are released. Before release, a sample of 600 fish is wanded to check for CWTs. The total number of tagged fish at release is calculated by multiplying the total release size (from the counters) by the proportion of tagged fish in the sample. The number of marked and unmarked fish in each DIT group is determined by allocating the total number of tagged fish to marked and unmarked groups in proportion to their initial tagging rates.

General comments

The hatchery is on a small tributary (~0.25 miles long) which enters the Elwha River ~0.5 miles from its mouth. Fish may bypass the hatchery and choose to spawn naturally in the river. The extent of hatchery straying is unknown. The turbidity of the river makes it nearly impossible to sample for carcasses during the time when coho salmon are spawning. Returns to the hatchery are sampled at 100% (including jacks).

General concerns for all brood years

Marked recoveries from the 1996 brood year occurred in southeast Alaska fisheries which were not electronically sampled. Therefore, unmarked recoveries will not be observed. These recoveries were estimated using the PR method with $sfm = 1$ and using λ^{Rel}.

Estimation of unmarked selective fishery mortalities

Brood year 1995 year was not significantly impacted by mark-selective fisheries, therefore no analyses were conducted for this group. There was only one observed recovery (3.16 expanded recoveries) in mark-selective fisheries. This observed recovery corresponded to a marked fish (Appendix Table 3.17.1).

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Appendix Table 3.17.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Lower Elwha Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1995		1996		1997	
				M	U	M	U	M	U
2	Escapement	NSF	Observed			44	46	90	115
			Estimated			45.76	47.80	90.00	115.00
			SE			1.35	1.37	0.00	0.00
3	Escapement	NSF	Observed	114	117	282	251	183	204
			Estimated	114.01	117.00	282.00	251.00	183.00	204.00
			SE	0.10	0.00	0.00	0.00	0.00	0.00
	Freshwater Net	NSF	Observed	18	27	21	20	29	26
			Estimated	112.48	138.50	143.49	159.52	138.14	111.28
			SE	28.42	27.51	33.87	37.73	23.80	20.33
	Southeast Alaska Net	NSF	Observed	2		2			
			Estimated	14.11	*13.16*	7.82	*7.46*		
			SE	9.62	*80.55*	5.03	*22.97*		
	Southeast Alaska Troll	NSF	Observed	5		2			
			Estimated	14.56	*13.58*	4.43	*4.22*		
			SE	5.51	*26.45*	2.37	*5.12*		
	WA Area 1 Sport	SF	Observed	1					
			Estimated	3.16					
			SE	2.61					
	WA Area 1 Troll	SF	Observed					1	
			Estimated					1.15	
			SE					0.42	
	WA Area 10 Net	NSF	Observed		1				
			Estimated		1.00				
			SE		0.00				
	WA Area 10 Sport	NSF	Observed				1		
			Estimated				2.25		
			SE				1.68		
	WA Area 2 SF Sport	SF	Observed			4			
			Estimated			10.22			
			SE			4.10			
	WA Area 2 Sport	SF	Observed					1	
			Estimated					1.97	
			SE					1.38	
	WA Area 2 Troll	SF	Observed					1	
			Estimated					2.19	
			SE					1.61	
	WA Area 3 Sport	SF	Observed			2			
			Estimated			3.88			
			SE			1.92			
	WA Area 3 Troll	NSF	Observed			1			
			Estimated			1.17			
			SE			0.45			

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Appendix Table 3.17.1. Number of observed tags and estimates of mortalities of tagged fish in fisheries and escapement for marked (M) and unmarked (U) coho salmon from Lower Elwha Hatchery DIT groups for brood years 1995, 1996, and 1997. Numbers in italics are for fisheries with visual sampling where estimates were made using the PR method and *sfm* = 1.

Age	Fishery	Type	Data	1995		1996		1997	
				M	U	M	U	M	U
	WA Area 4 Sport	NSF	Observed	1					
			Estimated	2.55					
			SE	1.99					
		SF	Observed			2		1	
			Estimated			4.11		2.25	
			SE			2.17		1.68	
	WA Area 4, 4B Troll	NSF	Observed	1	1	2	2		2
			Estimated	1.14	1.70	3.09	3.14		14.96
			SE	0.40	1.09	1.30	1.34		9.85
	WA Area 5 Sport	NSF	Observed		1				
			Estimated		4.29				
			SE		3.76				
		SF	Observed			3		2	
			Estimated			11.79		9.46	
			SE			5.88		5.95	
	WA Area 6 Sport	SF	Observed					1	
			Estimated					3.12	
			SE					2.57	
	WA Area 6D Net	NSF	Observed	1	2	4		1	
			Estimated	1.49	3.52	7.40		2.36	
			SE	0.85	1.64	2.53		1.79	
	WA Area 7B, 7C, 7E Net	NSF	Observed					1	
			Estimated					2.19	
			SE					1.61	
	WA Areas 4B, 5, 6, 6A, 6C Net	NSF	Observed		2	1	3		
			Estimated		3.59	1.05	4.71		
			SE		1.78	0.23	1.69		
Total Observed				143	151	370	323	311	347
Total Estimated				263.50	269.60	526.21	468.42	435.83	445.24
Total Standard Error				30.69	27.90	35.33	37.86	24.94	22.58

Equal Marine Survival (EMS) Method

Using λ^{Rel} = 0.9536 for brood year 1996, the estimate for the total unmarked mortality summed across all mark-selective fisheries is 33 fish and using λ^{Rel} = 1.033 for brood year 1997, the estimate for the total unmarked mortality summed across all mark-selective fisheries is 5 fish (Appendix Table 3.17.2).

Appendix Table 3.17.2. Estimated number of mortalities of unmarked fish for Lower Elwha Hatchery DIT coho salmon in all mark-selective fisheries using the EMS method.

Brood Year	λ^{Rel}	Estimate	95% Confidence Interval	
1996	0.9536	33	-76	143
1997	1.0325	5	-62	72

Equal Exploitation Rate (EER) Method

The only significant non-selective fishery for brood years 1996 and 1997 was the freshwater net fishery. The λ in this fishery is likely to be higher than the λ in the mark-selective fisheries since it occured much later in time. Therefore, the EER method was not applied.

Paired-Ratio (PR) Method

There were no non-selective fisheries that could serve as adequate pairs for the mark-selective fisheries. The λs at release and escapement were used to estimate the number of mortalities of unmarked fish in all selective fisheries used (Appendix Table 3.17.3). Three values of *sfm* were used for the estimates: a default value, 50% of the default value, and 200% of the default value. The default value varied by fishery and depended on whether the fishery was located in marine or fresh water. The default values used were the same as those used by the Fishery Regulation Assessment Model (FRAM).

Appendix Table 3.17.3. Estimated number of mortalities in mark-selective fisheries for unmarked DIT coho salmon from Lower Elwha Hatchery for brood years 1996 and 1997 using the PR method and the unmarked-to-marked ratio (λ) at release and in the escapement.

Age	Fishery	Default *sfm*	1996						1997					
			50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE	50% *sfm*	SE	Default *sfm*	SE	200% *sfm*	SE
			λ^{Rel}											
3	WA Area 1 Sport	0.14												
	WA Area 1 Troll	0.26							0.15	0.06	0.31	0.11	0.62	0.22
	WA Area 2 SF Sport	0.14	0.68	0.27	1.36	0.55	2.73	1.09						
	WA Area 2 Sport	0.14							0.14	0.10	0.28	0.20	0.57	0.40
	WA Area 2 Troll	0.26							0.29	0.22	0.59	0.43	1.18	0.87
	WA Area 3 Sport	0.14	0.26	0.13	0.52	0.26	1.04	0.51						
	WA Area 4 Sport	0.14	0.27	0.14	0.55	0.29	1.10	0.58	0.16	0.12	0.33	0.24	0.65	0.48
	WA Area 5 Sport	0.07	0.39	0.20	0.79	0.39	1.57	0.78	0.34	0.22	0.68	0.43	1.37	0.86
	WA Area 6 Sport	0.07							0.11	0.09	0.23	0.19	0.45	0.37
3 Total			1.61	0.15	3.22	0.60	6.44	2.41	1.21	0.13	2.42	0.52	4.83	2.07
			λ^{Esc}											
3	WA Area 1 Sport	0.14												
	WA Area 1 Troll	0.26							0.17	0.06	0.33	0.12	0.67	0.24
	WA Area 2 SF Sport	0.14	0.64	0.26	1.27	0.51	2.55	1.02						
	WA Area 2 Sport	0.14							0.15	0.11	0.31	0.22	0.61	0.43
	WA Area 2 Troll	0.26							0.32	0.23	0.63	0.47	1.27	0.94
	WA Area 3 Sport	0.14	0.24	0.12	0.48	0.24	0.97	0.48						
	WA Area 4 Sport	0.14	0.26	0.14	0.51	0.27	1.02	0.54	0.18	0.13	0.35	0.26	0.70	0.52
	WA Area 5 Sport	0.07	0.37	0.18	0.73	0.37	1.47	0.73	0.37	0.23	0.74	0.46	1.48	0.93
	WA Area 6 Sport	0.07							0.12	0.10	0.24	0.20	0.49	0.40
3 Total			1.50	0.13	3.00	0.53	6.01	2.10	1.30	0.15	2.61	0.60	5.22	2.42

Appendix Table 4. Summary of freshwater recreational fisheries impacting DIT groups in return years 1998 through 2000.

DIT Group Affected	Report Appendix	River Fishery	Year	Estimated Catch[a]	Sampled	Relevant coho salmon regulations
Bingham Creek Hatchery	3.1	Chehalis	1998	287	lower	MSF[b], 1 adult
			1999	1,979	river	Oct. 1 - Nov. 15: NSF, 2 adults; Nov. 15 – Jan. 31: MSF, 2 adults
			2000	1,541	only	partial MSF, 2 adults, only 1 wild
		Satsop	1998	365	NO	MSF, 2 adults
			1999	832	NO	Oct. 1 – Nov. 15: NSF, 2 adults; Nov. 15 – Jan. 31: MSF, 2 adults
			2000	509	NO	MSF, 2 adults
Forks Creek Hatchery	3.2	Willapa	1998	270	NO	MSF, 2 adults
			1999	829	NO	MSF, 2 adults
			2000	468	NO	MSF, 2 adults
Humptulips Hatchery	3.3	Humptulips	1998	218	NO	MSF, 2 adults
			1999	635	NO	MSF, 2 adults
			2000	1,434	NO	MSF, 2 adults
Makah NFH	3.4	Soos	1998	0		closed
			1999	0		closed
			2000	118	?	closed
Quinault NFH	3.5	Quinault and Cook Creek	1998	NA[c]	?	Quinault Tribal Regulations
			1999	NA	?	Quinault Tribal Regulations
			2000	NA	?	Quinault Tribal Regulations
Salmon River Hatchery	3.6	Queets	1998	85	NO	Olympic National Park Regulations
			1999	39	NO	Olympic National Park Regulations
			2000	21	NO	Olympic National Park Regulations
		Salmon	1998	38	NO	NSF[d], 2 adults
			1999	70	NO	NSF, 2 adults
			2000	181	NO	NSF, 2 adults

Appendix Table 4. Summary of freshwater recreational fisheries impacting DIT groups in return years 1998 through 2000.

DIT Group Affected	Report Appendix	River Fishery	Year	Estimated Catch[a]	Sampled	Relevant coho salmon regulations
Solduc Hatchery	3.7	Quillayute	1998	419	NO	NSF, 2 adults
			1999	283	NO	NSF, 2 adults
			2000	310	NO	NSF, 2 adults
		Sol Duc	1998	645	NO	NSF, 2 adults
			1999	997	NO	NSF, 2 adults
			2000	723	NO	NSF, 2 adults
Port Gamble Sea Pens	3.8	none				
Quilcene NFH	3.9	Quilcene	1998	0		closed
			1999	206	NO	NSF, 2 adults
			2000	1,912	NO	NSF, 2 adults
George Adams Hatchery	3.10	Skokomish	1998	494	NO	NSF, 4 adults
			1999	387	NO	NSF, 4 adults
			2000	440	NO	NSF, 2 adults
Quilcene Bay Net Pens	3.11	Quilcene	1998	0		closed
			1999	206	NO	NSF, 2 adults
			2000	1,912	NO	NSF, 2 adults
Kendall Creek Hatchery	3.12	Nooksack	1998	2,311	NO	NSF, 4 adults
			1999	2,602	NO	NSF, 2 adults
			2000	3,464	NO	NSF, 2 adults
Marblemount Hatchery	3.13	Cascade	1998			MSF, 2 adults
			1999	89		MSF, 2 adults
			2000			MSF, 2 adults
		Skagit	1998	2,203	NO	**release all coho**
			1999	1,222	NO	NSF, 2 adults
			2000	1,671	NO	**Chum only**

Appendix Table 4. Summary of freshwater recreational fisheries impacting DIT groups in return years 1998 through 2000.

DIT Group Affected	Report Appendix	River Fishery	Year	Estimated Catch[a]	Sampled	Relevant coho salmon regulations
Wallace River Hatchery	3.14	Wallace	1998		NO	NSF, 2 adults
			1999		NO	NSF, 2 adults
			2000		NO	NSF, 2 adults
Wallace River Hatchery	3.14	Skykomish	1998	644	NO	NSF, 2 adults
			1999	502	NO	NSF, 2 adults
			2000	722	NO	Chum only
		Snohomish	1998	2,166	NO	NSF, 2 adults
			1999	1,947	NO	NSF, 2 adults
			2000	2,043	NO	Chum only
Voights Creek Hatchery	3.15	Carbon	1998	1,515	NO	NSF, up to 4 adults
			1999	430	NO	NSF, up to 4 adults
			2000	2,476	NO	NSF, up to 4 adults
		Puyallup	1998	1,873	NO	NSF, 2 adults
			1999	649	NO	NSF, 2 adults
			2000	1,097	NO	NSF, 2 adults
Soos Creek Hatchery	3.16	Green	1998	1,426	NO	NSF, 2 adults
			1999	902	NO	NSF, 2 adults
			2000	2,155	NO	NSF, 2 adults
Lower Elwha Hatchery	3.17	Elwha	1998	865	NO	NSF, up to 4 adults
			1999	648	NO	NSF, up to 4 adults
			2000	258	NO	NSF, up to 4 adults

[a] Catch Record System estimate of the number of coho salmon harvested by the recreational fishery.

[b] MSF = recreational fishery was a mark-selective fishery.

[c] NA = estimate not available.

APPENDIX 4