IMPROVING MONITORING METHODS FOR ESTIMATION OF NON-RETAINED SALMONIDS ENCOUNTERED IN SUMMER AND FALL COLUMBIA RIVER COMMERCIAL FISHERIES

FINAL REPORT

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Columbia River Management Program

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INTRODUCTION

Fisheries in the Columbia River harvest hatchery and wild salmonids. Hatchery fish are primarily provided for harvest as mitigation for significant losses of natural production throughout the Columbia Basin. Wild salmon stocks harvested by these fisheries include healthy runs of summer and fall Chinook. Steelhead are incidentally caught and released in commercial fisheries downstream of Bonneville Dam, but retention of steelhead in these fisheries is prohibited. Detailed descriptions of Columbia River fisheries may be found in a series of annual reports produced jointly by the Oregon and Washington Departments of Fish and Wildlife (ODFW/WDFW 2010 and 2011).

Columbia River fisheries generate millions of dollars in economic inputs annually and are high-profile. Their management comes under intense annual scrutiny, particularly in light of intensive efforts to recover 15 stocks and species listed as threatened or endangered under the federal Endangered Species Act (ESA). In addition to in-river fisheries, production of salmon from the Columbia River contributes substantially to large ocean fisheries from California to Alaska.

Two primary factors drive the management of salmon fisheries in the Columbia River. First and foremost is the conservation and recovery of ESA-listed stocks and the protection of healthy wild stocks in the basin. Thirteen stocks of salmon and steelhead in the Columbia River basin are listed under the ESA, and all of these migrate through fisheries in the lower Columbia River below Bonneville Dam (Figure 1). Fisheries impacting listed stocks are reviewed in consultation with NOAA Fisheries to determine if they are consistent with conservation and recovery goals under the ESA. Healthy wild stocks are managed to provide necessary escapement to perpetuate the runs.

In addition, fisheries are managed to harvest hatchery-produced salmon and steelhead provided by various mitigation agreements. These agreements are primarily intended to offset significant losses of naturally-produced fish caused by hydro-electric development throughout the Columbia Basin.

Management of Columbia River salmon fisheries is a balancing act between keeping harvest-related mortality of ESA-listed stocks at or below levels needed to promote conservation and recovery while providing reasonable opportunities to harvest abundant hatchery stocks and healthy wild stocks. Management is further complicated by uncertainties in estimates of handling, harvest, and total mortalities in these fisheries. Fishery managers account for this uncertainty by adopting conservative fisheries plans – an approach that may result in lost opportunities and under-utilization of healthy fish stocks. Greater certainty in estimates of handling and harvest in fisheries would allow for more efficient utilization of the fishery resources in the Columbia River.

Steelhead are classified as a game fish in the Columbia River, rather than a food fish, and non-Treaty commercial fishers are not allowed to retain steelhead. Currently, summer and fall commercial salmon fisheries are full-retention fisheries in which all Chinook and coho salmon encountered may be landed. However, all steelhead must be released immediately. Commercial fisheries are structured with extensive time, area, and gear limitations to allow harvest of abundant stocks while minimizing impacts to steelhead and other sensitive stocks.

As in any fishery that includes encounters of non-retained fish, estimating the total catch of steelhead in these fisheries is challenging, and requires different methodologies than those used to estimate retained catch. The Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) currently rely on estimates of steelhead-to-Chinook ratios from historic test fisheries to estimate encounters of steelhead in summer and fall commercial fisheries. Total mortalities of steelhead are estimated by multiplying estimated total encounters by fishery-specific mortality rates. Under the ESA, non-Treaty fisheries are limited in the percentage of the total wild steelhead run that are killed as a result of fisheries.

Because this information has not been collected for several years and to increase the amount of available data, there is a need to update the historic information used in evaluating these fisheries, and to include it as part of the permanent monitoring of these fisheries. In the absence of real-time monitoring, fishery managers must accept more uncertainty in estimates of the total mortality of wild steelhead encountered in commercial fisheries.

OBJECTIVES

1. Determine if encounter rates of steelhead, Chinook, and coho salmon caught by individual commercial fishers in summer/fall seasons are independent of one another.
2. Estimate the relative encounter rates of steelhead in lower Columbia River summer/fall commercial fisheries through direct observations of catch independent of port or dockside sampling.
3. Identify the best method(s) for estimating and indexing encounter rates of steelhead in summer/fall commercial fisheries.
4. Recommend a suitable design for long-term monitoring of steelhead encounter rates in summer/fall commercial fisheries.

STUDY AREA

Non-Treaty commercial fisheries in the Columbia River are limited to the area from Buoy 10, at the river's mouth, upstream to the fishing boundary at Beacon Rock which is approximately four miles downstream of Bonneville Dam (RM 146). This area is subdivided into five geographic zones for purposes of monitoring catch in the fishery. In addition to fisheries in the mainstem Columbia River, commercial fisheries also occur in off-channel areas, referred to as Select Areas. These areas include Youngs Bay, Deep River, Blind Slough/Knappa Slough, and Tongue Point/South Channel. Aside from these Select Areas, non-Treaty commercial fisheries are prohibited in tributaries of the Columbia.

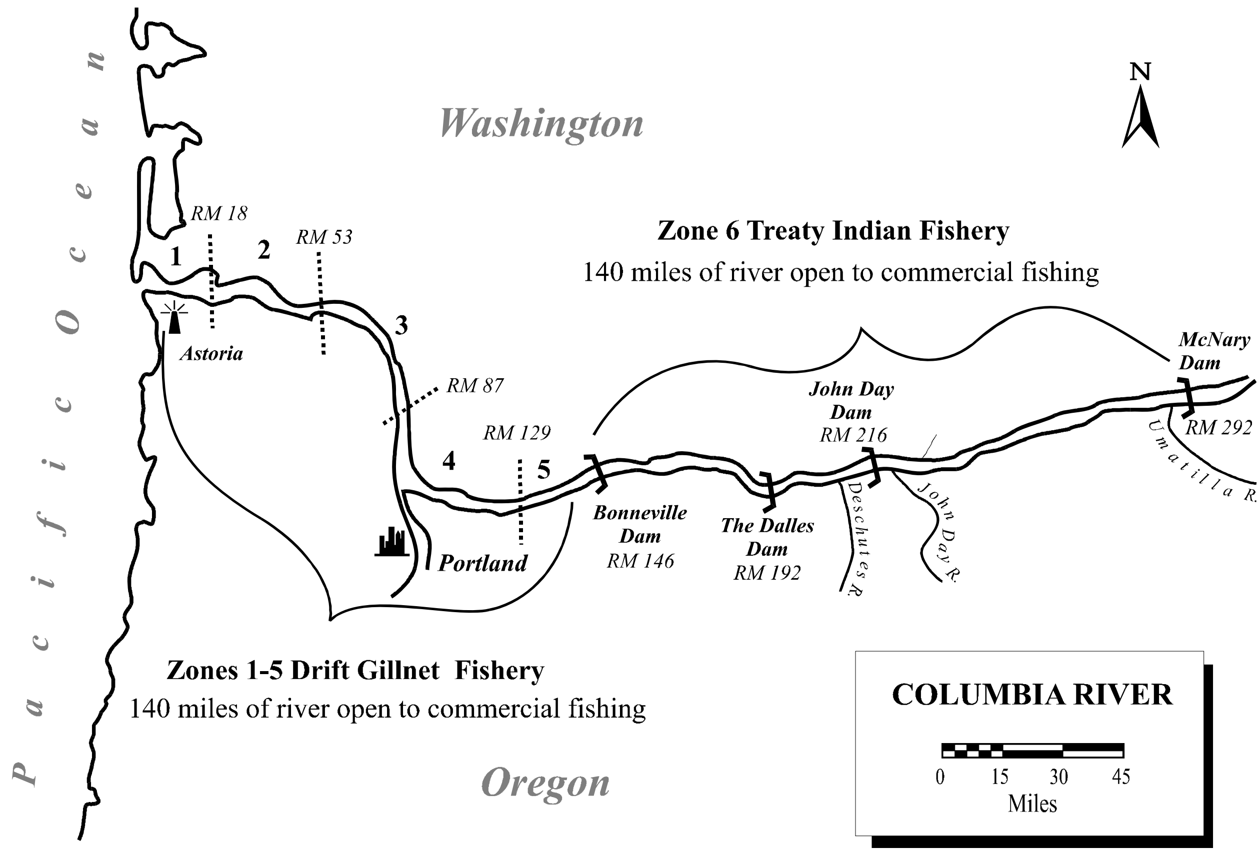

Figure 1. Columbia River commercial fishing zones.

BACKGROUND

Substantial background information on current Columbia River fisheries is available in a series of annual reports produced by the Oregon and Washington Departments of Fish and Wildlife (ODFW/WDFW 2010 and 2011). Information on fisheries prior to recent years is available in Columbia River status reports (ODFW/WDFW 2002) produced annually or bi-annually through 2002. Readers are encouraged to review these documents for full discussions of current and historic Columbia River fisheries.

Since 1992, fall season commercial gillnet fisheries downstream of Bonneville Dam have been reduced in response to federal ESA listings. Time, area, and gear (mesh size as well as net structure, i.e. floater or diver, etc.) restrictions have been implemented during the fall commercial fishery to reduce the incidental catch of non-target species. Since 2002, August fisheries have expanded in time and area with increased emphasis placed on targeting Chinook. Late fall seasons typically occur from mid- to late September through the end of October.

Historically, the majority of September-October fisheries targeted coho in the lower river downstream of the mouth of the Lewis River. Some target Chinook seasons have also occurred during late September and October, including Zones 4-5 (upstream of the I-205 Bridge in some years). During 1995-1998, extremely low coho abundance curtailed nearly all commercial fishing opportunities during the late fall period. Since 2006, the ESA listing of lower river wild coho has reduced coho fishing opportunities compared to past years.

Prior to 2005, no commercial summer Chinook season had occurred downstream of Bonneville Dam since a two-day season in 1964. By 2005 the upper Columbia River summer Chinook run had increased to the point that commercial harvest was again viable. Since 2005, the number of annual commercial openers has ranged from two to thirteen. Harvests have ranged from 1,100 to 4,800 Chinook. Participation is variable in this timeframe, with total deliveries ranging from 20 to 128 per opener. Participation typically wanes if the season extends into July, due to reduced catches and the departure of many fishers who also participate in Alaska fisheries.

In summer and fall commercial fisheries, on-board observations have only been conducted sporadically, largely due to budget constraints. ODFW and WDFW currently rely on encounter rate information collected in fall fisheries from the 1980s and early 1990s to estimate encounters of steelhead in summer and fall fisheries.

Commercial fish landings are reported to the states of Oregon or Washington on fish landing tickets completed at the point of sale. Portions of landed fish are sampled for biological data and coded-wire tags (CWTs) at buying stations; these data are combined with landing reports to determine total landings by species and stock.

The commercial fishery currently utilizes a variety of mesh sizes and fishery structures in order to maximize harvest of target species and stocks while minimizing impacts on co-occurring ESA-listed non-target species and stocks. Steelhead are encountered in large mesh gear less frequently than in small mesh gear and large mesh gear is often used to reduce steelhead encounters.

During an open period, an individual boat will make multiple fishing efforts, or "drifts". In most cases, fishers concentrate their efforts on familiar areas in specific sections of the river, and over the course of time, certain areas have developed "drift rights" whereby an individual fisher is given priority to a fishing area by other fishers, due to their level of historic participation and use of the area. Depending on the fishers' preferred fishing area and which areas are open, a fisher may choose to fish only a portion of the open period, in order to ensure their fishing effort coincides with the most productive portion of the tidal cycle in that area.

Given the structure of Columbia River commercial salmon fisheries, the sampling units for observation of fishing activities will be referred to in this report as follows:

- "Drift" is a single fishing effort consisting of the deployment and retrieval of gear in a specific fishing location by a single fishing boat.
- "Trip" is a series of drifts within a specific open fishing period by a single boat, although the boat may fish in multiple areas within a fishery. Individual landings (deliveries) of fish on commercial fish landing tickets are the most accurate available estimate of the total number of trips made in a fishery.
- "Opener" or "Fishery" is the sum of all trips made by all fishers participating in a given fishing period.
- "Season" is the sum of all open periods for a given species and/or run type conducted during a specific timeframe of the year.

Following each fishing period, fishers are required to report their landings to the states of Oregon or Washington on fish landing tickets. Fishers are not required to report their fishing effort (drifts) in a given period. This limits the ability to use effort-based expansions for estimating non-retained catch given the current available data. Currently, the only available record of fleet-wide fishing effort is the number of individual deliveries, that are typically composed of several drifts for each fisher, and do not include fishing trips with no landed catch. Fishers are required to submit all catches of kept fish on a fish ticket, including any fish that may be retained for personal use. Thus, for our purposes, landings are taken to represent a known quantity.

METHODS

Field work for this project was initiated in late August of 2009. Several fall Chinook fisheries were adopted for late August and early October; additionally, coho and white sturgeon fisheries occurred in late September and October. Table 1 presents details about the commercial periods in which observations were conducted. The majority of observer effort during the fall commercial fisheries was conducted via "ride-alongs" where ODFW observers met a specified fisher at a previously arranged time and location and remained on the vessel for the entire fishing trip. In this method, the data collected represent a complete fishing trip for the specific period. During Zone 3 coho fishery observations a strategy of "on-the-water" randomly selected samples was used, whereby ODFW staff were deployed from an agency boat onto randomly selected commercial vessels during the fishery. In this technique, since the amount of time spent observing onboard any one vessel was shorter (typically 2-3 hours) a greater proportion of total vessels could be observed, and observations on each vessel are a subsample rather than a complete trip.

Two summer commercial fishing seasons were adopted in 2010, occurring on June 17 and June 22 (Table 1). The June 17 fishery occurred in fishing Zones 1-4 (up to I-205 Bridge only) and the June 22 fishery occurred in all of Zones 1-5; however, observations were focused on Zones 1-2 because the majority of fishing effort was expected to occur in these zones. Most of the observer effort was conducted as "on-the-water" observations, where samplers were shuttled around the river by boat, randomly selecting vessels to board for observations. Samplers generally remained on the vessel for one to two fishing drifts (occasionally as many as seven) before moving to another vessel. Additional drifts were also observed by the boat drivers while waiting to pick up observers.

Four 12-hour early-August commercial fishing periods were adopted for 2010, occurring on August 3rd, 5th, 8th, and 10th. The first three occurred in fishing Zones 1-5 while the final period was restricted to Zones 2-4. ODFW staff conducted observation activities only during the August 8th period (Table 1). The observer effort was conducted as "ride-along" observations, where samplers were assigned to one commercial vessel for the duration of the fishing period.

We also collected information on mortality of steelhead during our observations. Steelhead were classified as "live", "dead", or "unknown" by samplers depending on the condition they were in when examined. These were immediate mortalities, and do not consider any delayed mortality effects.

Table 1. 2009 and 2010 fisheries during which observations were conducted.

Year	Date	Allowed Mesh Size	Open Fishing Zones
2009	Aug 18-19	9”–9¾”	3 – 5
	Aug 20-21	9”–9¾”	3 – 5
	Aug 25-26	9”–9¾”	5
	Sept 24-25	8”–9¾”	4 – 5
	Sept 28	6” max	1 – 3
	Sept 29	9”–9¾”	1 – 5
	Sept 30	6” max	1 – 3
	Oct 4-5	8”–9¾”	4 – 5
	Oct 7-8	8”–9¾”	4 – 5
	Oct 8	9”–9¾”	1 – 5
	Oct 21	6” max	1 – 3
2010	Jun 17-18	8”–9¾”	1 – 4
	Jun 22-23	8”–9¾”	1 – 5
	Aug 8-9	9”–9¾”	1 – 5

In order to use observation information to estimate catches of steelhead, we employed a ratio-based estimator (Cochran 1977), that is functionally identical to the mathematics used for past estimates. This method expands the number of released fish according to the total landings of an auxiliary variable, which in this case is most commonly landed catch of Chinook. In addition to testing the performance of the ratio of steelhead-to-Chinook, we also tested the utility of using coho landings as an auxiliary variable in late fall coho fisheries, which has not been done historically. Due to incomplete sampling of certain zones and fishing dates, the estimates of steelhead catch we generated from the observation data are limited to fisheries and fishing zones that were sampled. These estimates cannot be applied to the full fleet fisheries for the entire season(s), but provide a basis for examining the relationship between sampling effort and variance that can be used to inform development of future sampling protocols.

In the ratio estimator, the number of landed fish (Chinook or coho) is treated as the auxiliary variable and is used to estimate the total catch of steelhead using the formula:

$$\hat{Y}_R = \frac{y}{x} X \quad \text{eq 1.1}$$

where $\hat{Y}_R$ is the estimated catch of steelhead, y is the observed catch of steelhead in all drifts sampled, x is the observed catch of fish retained in all drifts sampled, and X is the landed catch for the fishery opener.

This estimator will have a variance:

$$v(\hat{Y}_R) = \frac{N(N-n)}{n(n-1)} \left(\sum y_i^2 + \hat{R}^2 \sum x_i^2 - 2\hat{R} \sum y_i x_i \right) \quad \text{eq 1.2}$$

where N is the total number of landed fish, n is the number of landed fish observed, $\hat{R}$ is the ratio $\frac{y}{x}$, and y_i and x_i are the number of observed steelhead and landed fish in observed drift i.

Although all steelhead must be released in non-Treaty commercial fisheries, ESA impact limitations on the fishery are based on the percentage of wild steelhead returns that are killed in the fisheries. For this study, in order to simplify calculation of variances for wild steelhead catch estimates, we used only wild-origin steelhead observed, rather than estimating total steelhead encounters and then adjusting the total for the estimated percentage of wild fish. Some observations categorized steelhead as "unknown" with regard to hatchery/wild origin. This was most often a case of fish removed from the net quickly (as is encouraged) before they could be positively identified. There were also occasions where observations were conducted from a nearby Agency boat and fish could not be closely examined. We apportioned unknown origin fish into hatchery/wild categories according to the ratio of known hatchery and wild fish in all observations. As a result, some values for wild steelhead encounters are presented as fractions of fish, reflecting the apportionment of whole numbers into wild and hatchery categories.

An alternative to the ratio-based method of expanding observation data to a full-fleet estimate would be simple expansion based on fishing effort. However, effort-based expansion would require an accurate estimate of total number of fishing efforts N, in this case number of drifts, that is currently unavailable. Accordingly, our analysis focuses on the ratio-based methodology but this is not intended to preclude future examination or use of effort-based methods.

Historic Catch Ratios

Estimated catch of steelhead in fall fisheries has been derived using ratios of steelhead-to-Chinook from some historic test fishery sampling conducted during fall seasons. This sampling was conducted in several years, but has not been repeated since 1992. The average ratio of steelhead to Chinook in large mesh (8" or larger stretched measure) from observations that is currently used is 0.052 steelhead per Chinook. This rate is currently applied to all summer and fall season fisheries using large mesh nets (ranging from 8" to 9"+) by multiplying the ratio by the total landings of Chinook in large mesh fisheries. The average ratio of steelhead-to-Chinook in small mesh (6" or smaller stretched measure) from observations that is currently used is 0.060 steelhead-per-Chinook. This rate is currently applied to all fall fisheries using small mesh nets by multiplying the ratio by the total landings of Chinook in small mesh fisheries.

Following estimation of total steelhead catch, the catch is apportioned into hatchery- and wild-origin components using the proportions of hatchery and wild fish observed at Bonneville Dam. Steelhead handled downstream of Bonneville Dam in May and June are assumed to be Skamania stock fish. Steelhead encountered after July 1 are assumed to belong to either the A-run or B-run components of the summer steelhead run originating from tributaries upstream of Bonneville Dam. Estimated encounters of steelhead during this timeframe are apportioned by group using the estimated passage of each component at Bonneville Dam. Finally, the total estimated catch of wild-origin steelhead of each stock is multiplied by gear-specific total mortality rates derived from the historic studies (59% for large mesh gear and 66% for small mesh gear) to determine total mortality. These mortality rates were intended to account for both immediate and delayed mortality by adding a delayed mortality estimate of 10% to the immediate mortality estimates for both gears (49% for large mesh and 56% for small mesh).

Correlations

As noted by Cochran (1977), a ratio-based estimator would generally be expected to be more precise than an effort-based estimator if the correlation between the variables is strong. For large random samples, a ratio-based estimator $\hat{Y}_R$ will generally be more precise than a means-based (effort-based) estimator $\hat{Y}$ if the correlation between y and x is greater than $\left(\frac{1}{2}\right)\left(\frac{CVx}{CVy}\right)$.

If the variability of the auxiliary variable *x*, as measured by its coefficient of variation (CV; standard deviation divided by mean), is more than twice as large as the coefficient of variation of the variable *y* to be estimated, the ratio-based estimator will always be less precise than the effort-based estimator. Similarly, if the two variables are poorly correlated, the auxiliary variable would not be expected to represent the variable to be estimated as precisely. In order to test this assumption for these fisheries, we calculated the correlation between observed steelhead and the observed numbers of kept Chinook or coho for each sampled fishery.

Although strong correlation is likely indicative of a situation in which a ratio-based estimator is more precise than an effort-based estimator, poor correlation may not imply that the ratio-based estimator is not applicable. Correlation between two variables is also not necessarily indicative of interdependence between the variables. Instead, variables may co-vary together with some other driving force. This is likely the case for Chinook, coho, and steelhead encounters in these fisheries.

Stratification

In order to evaluate whether stratification was necessary in estimating encounters of steelhead, we conducted an extensive series of contingency table analyses to test for differences among strata (date and fishing zone) in catch of steelhead. We did not subdivide steelhead into only wild fish, as we did for generating estimates and variances of wild steelhead encounters and mortalities. This helped to increase sample sizes, allowing for inclusion of some samples that would otherwise be lost due to the need to exclude expected encounters below a critical threshold in the contingency table tests. Following recommendations by Snedacor and Cochran (1967), we considered an expected encounter of one or more to be sufficient for inclusion in the analyses, whereas strata with expected values of less than one were excluded. Zar (1974) and other authors have cited expected values of five or more as minimums, but other authors, including Snedacor and Cochran, have since stated that this threshold has often been found to be unnecessarily conservative.

We tested for differences in steelhead catch across zones within each specific date sampled in each year and fishery type to determine if observed catches of steelhead among zones on a specific date differed from what would be expected if observed catches of steelhead in each zone on each date were consistently proportional to observed kept catches of Chinook or coho on that date across zones. Expected values for observed steelhead were generated from the observed kept catch of Chinook or coho for each zone on each date. The same test was performed using the total number of drifts sampled in each zone and date to generate expected values for observed steelhead to determine if observed catches of steelhead differed from what would be expected if observed catches of steelhead were consistently proportional to sampling effort on each date and across zones.

Results of the contingency table analyses indicated that differences in steelhead catch among strata were often significant and that a stratified estimation was preferable. Accordingly, we calculated estimated catch of wild steelhead using date and fishing zone as strata. Estimates and variances were calculated for each stratum and then summed to generate estimates from the sampling data.

Precision

A key consideration in assessing a sampling program is an evaluation of the precision of the estimates generated versus the sampling effort expended. Sampling effort was evaluated as the fraction of total landed catch (either Chinook or coho) observed. We calculated the 95% confidence intervals (CI's) of the estimated catch of wild steelhead for each zone and fishery sampled in the course of this study.

Example Sampling Design

In order to use estimates of precision in the development of a proposed observation sampling program, we compared the CI's and sampling rates (fraction of landed catch observed) observed to a hypothetical set of fisheries. We used the fishing dates for seasons that occurred in the summer and fall of 2010 as an example season. In order to simulate how an observation plan would likely be developed, we then used deliveries by zone for similar data from 2009 to approximate expected effort by area for the 2010 seasons. This was intended to replicate the kind of information a researcher would have available in developing a pre-season plan for conducting observations. There were no late fall all-zone Chinook fisheries conducted in 2009, so to estimate effort by fishing zone for late fall all-zone Chinook fisheries in 2009, we used actual 2010 deliveries by zone. Because fisheries are highly variable from one year to the next, and often vary considerably during the season from pre-season planning, a precise estimation of sampling effort needed to cover all fisheries and strata is difficult. We used these seasons as a base case to demonstrate a potential method for applying our results to developing a sampling plan for future efforts. We constructed the example under the assumption that sampling would be conducted under a stratified-random design, with fishing zone making up the strata. Within each stratum, fishers would be randomly selected for observations.

We set a precision goal to produce a point estimate for wild steelhead mortalities that was within 50% of the true value 95% of the time. We averaged the number of deliveries by fishing zone in each grouping of fisheries. Fisheries were grouped according to date and zones open to fishing. We assumed that landings of fish per delivery would be constant across fishers, and that to achieve a sampling rate of a specific proportion of the landed catch, we would need to sample the same proportion of all fishers. The use of deliveries as a measure of fisher effort allowed us to approximate the expected distribution of landings by zone to ensure that sampling effort would be distributed proportionally by zone. The landings of fish per delivery is generally not equivalent across fishers, however, random selection of fishers for sampling within each zone was assumed to prevent any biases that might result from this factor.

RESULTS

Over the course of the fall 2009 and summer and early August 2010 fishing seasons, ODFW staff observed 240 drifts onboard commercial fishing vessels (Table 2). Seventy observer-days of effort were expended to collect this information.

In 2009, observations were conducted during all three of the late August fall Chinook fisheries and 74 individual fishing drifts were observed. Observations were conducted during only three of the thirteen late fall (September/October) fall Chinook fisheries in 2009; however, these fisheries accounted for 2,600 landed Chinook and 113 deliveries out of the total 5,700 landed Chinook and 225 deliveries that occurred in all of the late fall Chinook fisheries. A total of 40 drifts were observed during these fisheries.

Observations were conducted during three of the four late fall coho fishing periods that occurred in Zones 1-3 in 2009; however, we were only able to observe one zone during each of these fisheries. Observations were conducted in Zone 1 on the first fishery, Zone 2 on the second, and Zone 3 on the third. A total of 45 drifts were observed.

Observations were conducted during two of the four 2009 late fall white sturgeon target fishing periods. A total of 9 drifts were observed and no Chinook or steelhead were observed; a total of 41 Chinook were landed by the fleet in these two fisheries.

Two summer commercial fishing seasons were adopted in 2010. During these fisheries, ODFW staff observed 55 total drifts onboard commercial fishing vessels (Table 2). However, observations were only conducted in Zones 1 and 2, because the majority of catch and effort was expected to occur in these zones.

Seventeen fishing drifts were observed during an August 8-9 Chinook fishery in 2010 conducted in Zones 2-5. A total of 141 Chinook and no steelhead were observed.

We observed a total of 94 steelhead during all observations conducted as part of this study. Of the 94 fish, one had a live/dead status listed as “unknown”. Of the remaining 93 fish, 11 were listed as “dead” and the remaining 82 as “live” at time of release. The steelhead mortalities observed are summarized by gear type and fishery in Table 3.

Table 2. Observation results, 2009 and 2010 summer and fall commercial fishing periods.

				Adult Salmonids					White Sturgeon			
Year	Date	Zones observed	N drifts observed	Chinook	Coho	Steelhead	Chum	Sockeye	Sublegal	Legal	Over-legal	Green sturgeon
2009	Aug 18-19	4,5	9	198	0	13	0	0	31	17	14	0
	Aug 20-21	4,5	40	246	15	31	0	0	7	9	7	0
	Aug 25-26	5	25	425	20	13	0	0	45	18	31	1
	Sept 24-25	4,5	31	141	135	6	0	0	57	11	4	2
	Sept 28	1	10	0	17	1	0	0	0	0	0	1
	Sept 29	2	3	0	0	0	0	0	101	96	33	6
	Sept 30	2	18	8	834	17	1	0	5	1	0	0
	Oct 4-5	4	1	1	1	0	0	0	0	9	2	0
	Oct 7-8	5	8	101	5	0	0	0	17	9	6	0
	Oct 8	2	6	0	1	0	0	0	3	1	1	0
	Oct 21	3	17	3	97	2	1	0	14	0	0	0
2010	Jun 17-18	1,2	28	77	0	6	0	7	109	50	17	4
	Jun 22-23	1,2	27	65	0	5	0	13	34	11	3	3
	Aug 8-9	1	17	141	3	0	0	0	1	0	3	2

Table 3. Summary of steelhead immediate mortalities observed in 2009 and 2010 commercial fishery observations and estimated total mortality rate (in parentheses) assuming a 10% delayed mortality rate.

	Small Mesh	Large Mesh	
	Fall	Fall	June
Dead	2	5	4
Alive	18	57	7
Immediate mortality rate	10%	8%	36%
(estimated total mortality rate)	(20%)	(18%)	(46%)

Historic Catch Ratios

We summarized the observation data and calculated the ratios of steelhead-to-Chinook for our observations and compared them to the historic ratios currently used (Table 4). The observed ratio for the combined August Chinook samples was slightly higher than the historic ratio; however, a two sample t-test demonstrated that the difference was not statistically significant ($\alpha=0.05$, $p=0.455$). The observed ratio for the combined late fall Chinook samples was only one-half of the historic ratio. When all fall Chinook season ratios were combined as a weighted average ratio, the ratio of observed steelhead-to-Chinook was 0.049, nearly identical to the historic ratio of 0.052.

This pattern did not hold for the coho fishery observations. The observed steelhead-to-Chinook ratio in these observations was substantially higher than the historic ratio. It is unclear whether this was an artifact of our sampling (such as selection of fishers for observation) or whether the ratio we observed is accurate for the fishery. This finding points out a need for further data collection in this fishery.

The ratio of steelhead-to-Chinook in the 2010 summer Chinook observations was slightly higher than the historic ratio. The historic ratios were derived from fall season sampling, and were not conducted during the same time frame as the current summer fishery. Thus it is perhaps not surprising that the ratios differ, and the need to collect information on this fishery was a key consideration in developing this study.

Table 4. Comparison of 2009-2010 observations of steelhead-to-Chinook ratios and historic steelhead-to-Chinook ratios.

Date	Drifts Observed	Kept Chinook Observed	Total Steelhead Observed	Observed Steelhead:Chinook Ratio	Historic Steelhead:Chinook Ratio
August Chinook Season (9" Large Mesh)					
8/19/09	9	198	13	0.066	
8/21/09	40	246	31	0.126	
8/26/09	25	425	13	0.031	
8/9/10	17	141	0	0.000	
Total	91	1,010	57	0.056	0.052
Late Fall Chinook Season (8" Large Mesh)					
9/25/09	31	141	6	0.043	
10/5/09	1	1	0	0.000	
10/7/09	8	101	0	0.000	
Total	40	243	6	0.025	0.052
All Fall Large Mesh		**1,253**	**63**	**0.049**	**0.052**
Coho Season (6" small mesh)					
9/28/09	10	0	1		
9/30/09	18	8	17	2.125	
10/21/09	17	3	2	0.667	
Total	45	11	20	1.818	0.060
Summer Chinook Season (8" Large Mesh)					
6/18/10	28	77	6	0.078	
6/23/10	27	65	5	0.077	
Total	55	142	11	0.077	0.052

Correlations

Correlations were strongest for Chinook versus steelhead in August 9" mesh gear, Chinook versus steelhead in summer 8" mesh gear for Zone 1, and for coho versus steelhead during late-September and October in small mesh gear (Table 5). Correlations were poor for Chinook versus steelhead in September and October large mesh gears and for steelhead versus Chinook in summer in Zone 2. The poor correlations are likely attributable to low frequency of encounters of steelhead in many of the observations.

Table 5. Correlation coefficients of wild steelhead versus Chinook or coho in observation samples.

August 2009 Chinook Observations		September 2009 Chinook Observations		2009 Coho Observations			Summer 2010 Chinook Observations	
Zone	Ch/St Correlation	Zone	Ch/St Correlation	Zone	Co/St Correlation	Ch/St Correlation	Zone	Ch/St Correlation
		Zone 2	--	Zone 1	0.34	--	Zone 1	0.59
Zone 4	0.68	Zone 4	-0.03	Zone 2	0.71	-0.18	Zone 2	0.02
Zone 5	0.28	Zone 5	--	Zone 3	0.44	0.54		
4-5	0.33	2,4,5	-0.04	1-3	0.74	0.00	1-2	0.16

Comparisons of CV and correlation coefficients show that a ratio-based estimator would be expected to result in more precise estimates than an effort-based estimator for the observations with the strongest correlation-CV results. This is the case for August Chinook with Chinook as the auxiliary variable and late fall coho with coho as the auxiliary variable (Table 6). The correlation between steelhead and Chinook in the summer samples is nearly equal to, but slightly below the test statistic.

Table 6. Correlation test statistics of wild steelhead versus landed species. Summer/Fall commercial fishery observations, 2009-2010. **Bold** text indicates samples in which correlations exceed the Cochran CV ratio test statistic.

		Correlation		Coefficient of Variation of number observed			Cochran
Season	Zone	Chinook	Coho	Chinook	Coho	Steelhead	Statistic
Summer Chinook	1-2	0.162	--	1.173	--	3.584	0.164
August Chinook	**4-5**	**0.329**	--	1.053	--	1.836	**0.287**
September Chinook	4-5	-0.044	--	1.967	--	7.000	0.140
Late fall coho v coho	**1-3**		**0.737**		1.697	2.675	**0.317**
Late fall coho v Ch	2-3	0.069	--	2.491	--	2.675	0.466

Stratification

Results from the tests conducted for stratification are shown in Appendix Tables 1-3. For August and September steelhead catches in Zone 4, no significant differences were detected between observed steelhead and expected steelhead across dates sampled. However, significant differences were detected across dates for the same fisheries in Zone 5. These results were consistent whether the expected values were derived from observed kept Chinook or number of drifts sampled. When observation data were pooled across the two zones for individual fishing dates, significant differences between expected and observed steelhead were detected in the majority of tests, and this result was consistent regardless of the method used to calculate expected observations. These results indicate that stratification of observation data by date and fishing zone is necessary for ratio-based estimates of these fisheries. During the timeframe we conducted observations in 2009, no all zone Chinook fisheries occurred, therefore, our results only apply to Zones 4 and 5. This might be expected to demonstrate less difference in encounters of steelhead between these two adjacent zones than might occur over all five zones.

No differences between expected observations of steelhead and actual observations were detected in the coho fishery samples. This may be due to relatively low numbers of steelhead observed, and the likelihood that steelhead numbers were relatively consistent across the fisheries due to run timing; late fall encompasses a period when the summer steelhead return is nearly complete.

Differences between expected observed steelhead and actual observed steelhead were insignificant for the summer Chinook fisheries regardless of the method used to calculate the expected values. However, one test for the second fishery date had to be eliminated due to an expected value of less than one. All samples were collected from adjacent fishing zones (1 and 2); therefore we were unable to determine if differences in observed steelhead are present in fishing Zones 3-5.

The frequency of differences among zones and dates for some fisheries indicates that stratification of observation data by dates and zones would likely be necessary. Accordingly, we calculated all subsequent estimates and variances of wild steelhead catch stratified by zone and date.

In some cases, observations data were not available for specific fisheries or fishing zones. Because this study is the first to conduct onboard observations, the data collected represent the only onboard information collected in the full fleet fishery. Other sampling information has been periodically collected, but it has typically come from test fisheries or limited sampling of individual fishers. Because of the paucity of background information, we felt it was inappropriate to attempt to apply sampling information from one zone or fishery to other zones or fisheries where sampling was not conducted. Accordingly, estimates of wild steelhead encounters and mortalities, as well as variance and precision estimates, apply only to the specific zones and fisheries sampled.

In conducting stratified estimates, we calculated estimates and variances (equations 1.1 and 1.2) of wild steelhead using the ratio estimator with landed Chinook or coho as the auxiliary variables for expansions. Estimates were conducted for each date, fishery type, and fishing zone observed. For each fishery date, the individual estimates and variances of wild steelhead for each fishing zone were summed to generate the total estimates and variances for the observed portions of the fishery.

Precision

We calculated 95% CI's for each fishery sampled. As expected, calculated CI's are much larger for fisheries with small numbers of observed fish, as well as for those with low sample rates. For fisheries such as Columbia River commercial fisheries, where catch of steelhead is purposely minimized, this interaction makes achieving high precision difficult. One main goal of the management of these fisheries is to minimize encounters of steelhead, which simultaneously decreases precision of estimates. However, it must also be pointed out that a less precise measure of a small estimate results in a low number of encounters and mortalities compared to a more precise measure of a large estimate.

The precision results only apply to observations conducted as part of the present study, and are not intended to be applied to the historic dataset currently used to account for steelhead encounters in these fisheries. As such, they should be interpreted as starting points for developing an in-season onboard observation program for purposes of estimating steelhead encounters, but cannot be used to assess the precision of the methods used historically.

We provide two sets of estimates for wild steelhead mortalities in the strata we observed, one using the historic total mortality rate that is currently used in management of these fisheries (Table 7), and one using the immediate mortality rates we observed in our sampling with an adjustment for historic estimates of delayed mortality rates (Table 8). Although the immediate mortality we observed is less than the historically-used values, we assumed that there was no proportional difference in delayed mortality. In the calculations using the observed mortality rates, the total mortality rate applied to small mesh fishery samples was 20%. A total mortality of 18% was applied to the fall large mesh fishery samples, and a total mortality of 46% was applied to June large mesh fishery samples. The selection of mortality rate obviously has a large effect on the calculated total mortality of wild steelhead, with estimates using the observed mortality rate being 30% of the currently used estimates for fall large mesh and small mesh fishery samples and 79% of the currently used estimate for the 2010 June large mesh fishery samples. It is important to note that studies to empirically estimate delayed mortality have not been conducted for any Columbia River fisheries (recreational or commercial) except for the spring commercial salmon fishery. We include the 10% assumption of delayed mortality in our calculations of total mortality from observations so that they can be compared to the historically-used total mortality using the same currency.

Table 7. Observed wild steelhead, estimated wild steelhead catch in observed strata, and estimated mortality and 95% CI ranges in observed strata using historic mortality rates.

Date	Zone	Observed Wild Steelhead	Estimated Wild Steelhead Catch	Estimated Wild Steelhead Mortality	95% CI	95% CI Range
2009 August Chinook Fishery						
8/19/2009	4	0.4	40	24	47	0-71
8/19/2009	5	5.2	90	53	50	3-103
	4+5	5.6	130	77	69	8-146
8/21/2009	4	2.0	85	50	70	0-120
8/21/2009	5	14.7	261	154	95	59-249
	4+5	16.7	346	204	118	87-322
8/26/2009	5	6.4	62	37	32	5-69
2009 Late Fall Chinook Fishery						
9/25/2009	4	0.4	17	10	20	0-30
9/25/2009	5	0.0	0			
	4+5	0.4	17	10	20	0-30
10/5/2009	4		No steelhead observed			
10/8/2009	5		No steelhead observed			
2009 Coho Fishery, using steelhead:Chinook ratio						
9/28/2009	1	0.44		No Chinook observed		
9/30/2009	2	5.00	183	121	117	3-238
10/21/2009	3	0.44	4	3	6	0-9
2009 Coho Fishery, using steelhead:coho ratio						
9/28/2009	1	0.4	116	77	155	0-232
9/30/2009	2	6.0	109	72	71	1-143
10/21/2009	3	0.4	5	3	7	0-10
2009 Late Fall Sturgeon Fishery						
9/29/2009	2		No steelhead observed			
10/8/2009	2					
2010 Summer Chinook Fishery						
6/18/2010	1	0.9	14	9	12	0-21
6/18/2010	2	2.9	66	39	56	0-95
	1+2	3.8	80	48	57	0-105

Table 7. Continued.

Date	Zone	Observed Wild Steelhead	Estimated Wild Steelhead Catch	Estimated Wild Steelhead Mortality	95% CI	95% CI Range
6/23/2010	1	0.0	0			
6/23/2010	2	0.9	18	11	15	0-26
	1+2	0.9	18	11	15	0-26
6/18+6/23	1+2	4.7	98	59	59	0-118
2010 August Chinook Fishery						
8/9/2010	1	0.0	No steelhead observed			

Table 8. Observed wild steelhead, estimated wild steelhead catch in observed strata, and estimated mortality and 95% CI ranges in observed strata using observed mortality rates.

Date	Zone	Observed Wild Steelhead	Estimated Wild Steelhead Catch	Estimated Wild Steelhead Mortality	95% CI	95% CI Range
2009 August Chinook Fishery						
8/19/2009	4	0.4	40	7	14	0-21
8/19/2009	5	5.2	90	16	15	1-31
	4+5	5.6	130	23	21	2-44
8/21/2009	4	2.0	85	15	21	0-36
8/21/2009	5	14.7	261	47	29	18-76
	4+5	16.7	346	63	36	27-99
8/26/2009	5	6.4	62	11	10	1-21
2009 Late Fall Chinook Fishery						
9/25/2009	4	0.4	17	3	6	0-9
9/25/2009	5	0.0	0	0		
	4+5	0.4	17	3	6	0-9
10/5/2009	4		No steelhead observed			
10/8/2009	5		No steelhead observed			
2009 Coho Fishery, using steelhead:Chinook ratio						
9/28/2009	1	0.44		No Chinook observed		
9/30/2009	2	5.00	183	37	36	1-73
10/21/2009	3	0.44	4	1	2	0-3
2009 Coho Fishery, using steelhead:coho ratio						
9/28/2009	1	0.4	116	23	47	0-70
9/30/2009	2	6.0	109	22	22	0-44
10/21/2009	3	0.4	5	1	2	0-3
2009 Late Fall Sturgeon Fishery						
9/29/2009	2		No steelhead observed			
10/8/2009	2					
2010 Summer Chinook Fishery						
6/18/2010	1	0.9	14	7	9	0-16
6/18/2010	2	2.9	66	31	44	0-75
	1+2	3.8	80	38	45	0-83

Table 8. Continued.

Date	Zone	Observed Wild Steelhead	Estimated Wild Steelhead Catch	Estimated Wild Steelhead Mortality	95% CI	95% CI Range
6/23/2010	1	0.0	0	0		
6/23/2010	2	0.9	18	8	12	0-20
	1+2	0.9	18	8	12	0-20
6/18+6/23	1+2	4.7	98	46	46	0-92
2010 August Chinook Fishery						
8/9/2010	1	0.0	No steelhead observed			

From the precision estimates we estimated levels of sampling effort that would be needed to achieve varying levels of precision in estimates of wild steelhead encounters. These results are most applicable to fisheries that are similar to those in which the observations were conducted. Further, expected inter-annual variability will alter the performance of these estimates in subsequent years. More consistent annual sampling would be needed to improve the estimates of sampling efforts needed in the future.

We focused on using the proportion of landed catch observed to express total sampling effort. We used the average CV for a given fishery and the average sampling effort during that fishery and estimated the change in CV that would occur under different levels of sampling effort using the equation:

$$CV_{projected} = CV_{observed} \bullet \frac{1}{\sqrt{n_{relative}}} \quad \text{where} \quad n_{relative} = \frac{n_{projected}}{n_{observed}}$$

eq. 1.3, (Rossman 2007) and *n* is the measure of sampling effort, in this case, fraction of landed catch observed. Because we were ultimately interested in expressing precision as 95% CI's rather than CV's, we converted the CV versus sampling rate calculations to CI versus sampling rate.

Example Sampling Design

Sampling goals for an example set of fishing seasons based on the 2010 fisheries are shown in Table 9. Sample sizes reflect the variance in samples we collected during this study. Because many of these sample rates and variances were not available for all zones and dates, we applied the values we felt were most comparable to the fishery in question. For summer fisheries, we applied the sample rate and variances we observed in the 2010 Zone 1 and 2 samples. For August fisheries, we applied the sample rate and variances observed in the 2009 August samples, which were all conducted in Zones 4 and 5. No late fall Chinook fishing was conducted in all zones in 2009, so we applied the average sample rate and variance that were observed in Zones 4 and 5 in September-October of 2009 to any projected September-October Chinook fisheries, regardless of zone. For coho fisheries, we applied the average sample rate and variance from the 2009 coho fishery samples.

Table 9. Example of estimated observation effort (number of boat trips observed) during a hypothetical fishing season (based on 2010 actual seasons) needed to produce a point estimate for wild steelhead mortalities that is within 50% of the true value 95% of the time. Zones not open for fishing are indicated with dashes.

Date	Zones	Hours	Mesh	Deliveries	Boats Sampled by Zone 1	2	3	4	5	Sum
Summer Chinook										
6/17/2010	1-4	10	8	124	8	20	12	2	--	42
6/23/2010	1-5	10	8	128	8	19	11	2	2	42
August Chinook										
8/3/2010	1-5	12	9	140	14	3	1	1	1	20
8/5/2010	1-5	12	9	145	15	4	1	1	1	22
8/8/2010	1-5	12	9	184	19	4	1	1	1	26
8/10/2010	2-5	12	9	143	--	15	2	2	1	20
8/19/2010	4-5	10	9	91	--	--	--	6	6	12
8/22/2010	4-5	9	9	108	--	--	--	7	7	14
8/24/2010	4-5	9	9	123	--	--	--	8	8	16
Late Fall Chinook										
10/5/2010	1-5	12	8	100	14	21	8	5	6	54
10/7/2010	1-5	12	8	101	14	21	8	5	6	54
10/11/2010	1-5	12	8	89	12	18	7	4	6	47
9/22/2010	4-5	10	8	101	--	--	--	26	27	53
10/14/2010	4-5	12	8	13	--	--	--	4	4	8
10/17/2010	4-5	12	8	14	--	--	--	4	4	8
10/19/2010	4-5	12	8	6	--	--	--	2	2	4
10/21/2010	4-5	12	8	5	--	--	--	2	2	4
Coho										
10/12/2010	1-3	12	6	116	24	33	11	--	--	68
10/14/2010	1-3	12	6	88	18	25	8	--	--	51
10/20/2010	1-3	12	6	79	17	22	8	--	--	47

DISCUSSION

We were able to effectively sample several of the fisheries described in this report, however, sampling rates in some fisheries were fairly low, and some strata (zone and date) were missed. This was a factor of the condensed nature of these fisheries, staffing levels, and the amount of participation in some of the fisheries. We anticipated that this study would collect results that would allow us to compare new observation data with the currently used data, and would allow us to collect data necessary to calculate variances for differing levels of sampling effort. Collection of drift-by-drift information was necessary to accomplish this.

During some fisheries, we noted some clustering of our observations occurred over a narrow portion of the fishing zone being sampled. This appears to have been a result of our practice of conducting observations as “ride-alongs”. With this method, while fishers may be selected at random, determining specifically where they are likely to fish in order to maintain a representative sample by area within each zone is problematic. Fishers may not be entirely certain where they will fish, and selection of fishers by where they specifically intend to fish may violate assumptions of randomness. As an example, in observations conducted during the September 30, 2009 coho fishery, three observers were assigned to three separate boats. These three boats all ended up fishing in close proximity to one another, with all of them operating within about a 3 mile section of Zone 2. As a result, we cannot be sure whether observations conducted during that fishery are representative of the full-fleet within the full fishing zone. Boat-based random selection, stratified by zone and spread across areas within zones may help avoid this issue.

The results of this study can be used to explore options and methodologies for more robust future sampling, and we have presented one example of this (Table 9). Our example observation plan based on 2010 fisheries is intended to demonstrate the approximate level of effort that our data indicate might be necessary to produce a point estimate for wild steelhead mortalities that is within 50% of the true value 95% of the time. While this is the best information available for drafting such a plan, results following implementation of such a plan will almost certainly differ from our estimates. This planning should be interpreted as a starting point. Upon completion of further sampling, the exercise of evaluating sample size and precision should be repeated, to further refine these estimates and to modify sampling plans accordingly.

Managers will need to weigh the needs for precision in these estimates against the cost of implementing specific levels of sampling needed to achieve that precision. Based on our results, some fisheries would need to have substantial levels of sampling in order to achieve the level of precision that was specified (Table 10). However, in most cases, this is due to low overall catches of steelhead in the fishery. Managers will need to decide how important a precise estimate of a relatively small number is in the context of specific fisheries. Our example observation plan can be easily modified for different target precision for individual fisheries to provide an estimate of what the effects of such changes might be.

We recommend that, if an in-season observation program is instituted, it be formed around the basic outline we have presented. Development of an annual sampling plan, that allocates observer effort based on expected fisheries by strata and uses recent past or other similar information on effort and catch by those same strata, would be the most appropriate procedure. Annual planning of summer and fall fisheries is completed by April of each year during the

North of Falcon (NOF) process. While the planning developed during NOF is extensive, in general, season dates, zones, and fishing hours often cannot be set until just before a series of fisheries begins. Thus, the development of specific sampling plans cannot begin until then. However, information on how many fisheries of each type are expected, the weeks they are expected to be conducted in, and past participation in similar fisheries is available prior to the onset of the fishing seasons, and could be used to create a draft observation plan. Due to the prevalence of in-season changes, these observation plans must remain flexible and adaptive.

In samples collected during 2009 coho fisheries, the ratio of steelhead-to-Chinook was substantially higher than the historic ratio currently used. This may be a result of changing fisheries, i.e., the fishery currently operates differently than it did historically and expected catches have been altered as a result. It may also be due to some artifact of our sample selection, i.e., selection of fishers to observe or areas to observe may have somehow been biased. The 2009 summer steelhead return was one of the largest on record, with a total passage of 601,000 fish at Bonneville Dam; however abundance was declining by late-fall as expected, as indicated by Bonneville Dam passage counts. The average passage over the prior 10 years was 357,000 fish, including the record of 630,000 in 2001. Our observations of the coho fisheries were conducted in only a single zone on each of three fishing dates in 2009. Although we observed 20 steelhead in our samples, we also observed only 11 Chinook, far fewer than expected, which affected the steelhead-to-Chinook ratio. The ratio of Chinook-to-coho we observed was about 63% of the ratio of Chinook-to-coho in landings from the same strata. The low encounter of Chinook may also have been due to a relatively low abundance of Chinook during the timeframe these fisheries were conducted, due to run timing. The average daily passage of Chinook at Bonneville Dam in the five days following this fishery was only 900 fish. The information we collected does not allow for a robust determination of whether the rate we observed in the coho fisheries is reflective of the current full-fleet fishery, and we urge caution in interpreting these results, but it does indicate the possibility of a large difference between the historic rate and the current rate in the fishery. We recommend that more information be collected during future small mesh coho fisheries.

From our 2009 samples, it appears that the ratio of steelhead-to-coho catch may be a more applicable ratio for conducting a ratio-based encounter estimate for steelhead during coho fisheries. Correlations between coho and steelhead observed were much stronger than those between Chinook and steelhead. However, we observed relatively few Chinook, and if this is not representative of full-fleet results, may not be applicable. Collection of more information would allow for a re-examination of correlations and ratios among these three species.

The steelhead-to-Chinook ratio for the observations we conducted during the summer Chinook fishery in 2010 was slightly higher than the historic fall ratios that have been applied in the past, although only 11 steelhead were observed. However, because we were only able to sample in Zones 1-2, we cannot determine if the ratio we calculated can be applied across all zones. Given the small difference between the two ratios, it is possible that the addition of the remaining zones would alter the overall ratio. The 2010 summer steelhead run was 410,400 fish, compared to an average return of 297,000 per year in the years when the historic ratios for fall fisheries were developed, and the higher relative abundance of steelhead versus Chinook would be expected to alter the catch ratio somewhat. We recommend that more sampling be conducted during these fisheries to collect additional information.

Catches of salmon and steelhead in these fisheries are primarily driven by the vulnerability of individual fish to the different gears and their total abundance at the times and in the areas where the fisheries occur. Therefore, catches reflect the relative abundance of each species at the location where the gear is deployed, and should be useful in projecting catches. This information, in combination with run timing information, would enable managers to estimate abundance of fish in fishing areas throughout the duration of the fisheries. It may be possible to construct a model that utilizes run timing, abundance, and historic catch information to estimate steelhead catches in the various fisheries.

Much more data regarding catches during the fisheries is needed to contribute to this effort. Sampling would need to occur over several run size, date, and fishery combinations to incorporate sufficient contrasts in variability to define strong relationships. We intend to work with staff from WDFW to pursue this potential technique.

For fall fisheries, monitoring is complicated by the condensed nature of some of the openers. Different fisheries can occur in immediate succession to one another. For instance a white sturgeon fishery may end at 7 AM, and be followed by a Chinook fishery that begins at 7 AM on the same day. Such rapid succession is not common, but does occur. These kinds of fishery structures would require multiple crews of observers to ensure adequate coverage. Similarly, observation staffs may run up against work-hour limitations, also necessitating multiple crews. These aspects will need to be examined on an individual basis for each specific set of fisheries.

Special attention should be paid to achieving representative samples across fishers and areas. If crew sizes are small, the practice of ride-along observations may make this more difficult. A program of boat-based observations may be more appropriate. In either case, we recommend that sampling be conducted under a stratified-random design, with fishing zones as the strata, and with effort in each strata deployed proportionally to expected fishing effort. Fishers should be randomly selected within each zone, whether sampling is conducted as ride-alongs or as boat-based sampling.

Steelhead mortality rates based on our observations of immediate mortality in the samples we observed combined with the assumed delayed mortality rates that have been used historically were far lower than prior estimates of total mortality. The difference between rates points to a need for more information. Mortality rates may vary by year or season, and in-season observation programs would allow for better accounting of varying rates. In addition, empirically-derived estimates of total mortality rates from field studies in Columbia River fisheries (recreational or commercial) are unavailable for any fishery other than the spring commercial salmon fishery. There is a need to provide empirical estimates of these rates for the remaining Columbia River fisheries.

Our work focused on examination of a ratio-based estimator due to the types of information currently available, but there are some indications that an effort-based estimator may be useful, particularly for fisheries with poor correlations between steelhead and landed catch. These tend to occur in fisheries with relatively low numbers of encountered steelhead. We cannot evaluate the potential for an effort-based estimate at this time, but if future observation data are collected, over time enough information may be collected to allow for some evaluation of this technique.

Although estimating catches of other species, such as sockeye and white sturgeon, was not among our objectives for this study, such estimates may be deemed important by managers. We collected information on these catches during our study that can be combined with future efforts if desired. However, due to incomplete strata coverage in our sampling, we urge caution in interpretation of the data collected on these species. While we have examined and estimated catches of wild steelhead in sampled strata, and have compared steelhead catch ratios to historic data, we have not been able to make similar calculations for other species, and were not able to compare our data to past information for these other species. Encounters of sockeye in this study were likely uncharacteristically high during the timeframe we sampled. The 2010 return of sockeye salmon was 388,000 fish, which was the largest return since the creation of Bonneville Dam allowed accurate enumeration of returns. In comparison, the 10-year average return of sockeye salmon through 2009 was 97,000 fish, including 2008 and 2009 returns of 214,000 and 179,000 fish, respectively. The large abundance of sockeye during 2010 undoubtedly increased the number of encounters of sockeye in our samples compared to what would likely be seen in an "average" year, despite the use of large mesh nets to reduce encounters of sockeye and steelhead. Even so, we observed only 20 sockeye during our sampling.

If an in-season observation program is implemented, we recommend continued collection of encounters of other species be included. Further research on methods for expansion of other species will be necessary if estimates of full-fleet catch are desired. An additional aspect that should be examined once more information is available is an examination of whether a ratio-based estimate based on landed catch or an effort-based estimate based on fishing drifts is more appropriate for estimates of these species.

Because these fisheries are jointly managed by the states of Oregon and Washington, final decisions on how our findings may be implemented will need to be made jointly by the managing agencies from both states.

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APPENDICES

Appendix Table 1. Chi-square contingency results by zone and fishery sample.

Observed steelhead versus expected from kept Chinook

Zone	1			2			4			5		
	x2	test	p	x2	test	p	x2	test	p	x2	test	p
August	--	--	--	--	--	--	0.040	3.841	0.841	29.298	5.991	0.000
September	--	--	--	--	--	--	0.167	3.841	0.683	3.132	3.841	0.077
Summer 10	1.083	3.841	0.298	0.143	3.841	0.705	--	--	--	--	--	--

Observed steelhead versus expected from drifts

Zone	1			2			4			5		
	x2	test	p	x2	test	p	x2	test	p	x2	test	p
August	--	--	--	--	--	--	0.111	3.841	0.739	16.455	5.991	0.000
September	--	--	--	--	--	--	0.754	3.841	0.385	53.111	3.841	0.000
Summer 10	0.005	3.841	0.941	0.036	3.841	0.850	--	--	--	--	--	--

Appendix Table 2. Chi-square contingency results by date and fishery sample.

		Observed steelhead versus expected from observed Chinook			Observed steelhead versus expected from drifts		
	Zones	x2	test	p	x2	test	p
8/19/09	4-5	1.184	3.841	0.276	7.112	3.841	0.008
8/21/09	4-5	5.595	3.841	0.018	8.186	3.841	0.004
9/25/09	4-5	4.748	3.841	0.029	1.313	3.841	0.252
9/28/09 9/30/09	1-2	2.602	5.991	0.272	16.879	5.991	0.000
6/18/10	1-2	0.242	3.841	0.623	0.414	3.841	0.520
6/23/10	1-2	4.446	3.841	0.035	0.281	3.841	0.596

Appendix Table 3. Chi-square contingency results by date and fishery sample, coho fishery samples only.

	Observed steelhead versus expected from landed coho			Observed steelhead versus expected from drifts		
	x2	test	p	x2	test	p
9/28/09 9/30/09 10/21/09	4.104	5.991	0.128	16.879	5.99146	0.00022

	Observed steelhead versus expected from observed coho					
	x2	test	p			
9/28/09 9/30/09 10/21/09	1.168	5.991	0.558	--	--	--