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The Integrated Status and Effectiveness Monitoring Program

Expansion of Existing Smolt Trapping Program and Steelhead Spawner Surveys

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INTRODUCTION

The Integrated Status and Effectiveness Monitoring Program (ISEMP – BPA project #2003-0017) has been created as a cost effective means of developing protocols and new technologies, novel indicators, sample designs, analytical, data management and communication tools and skills, and restoration experiments that support the development of a region-wide Research, Monitoring and Evaluation (RME) program to assess the status of anadromous salmonid populations, their tributary habitat and restoration and management actions.

The most straightforward approach to developing a regional-scale monitoring and evaluation program would be to increase standardization among status and trend monitoring programs. However, the diversity of species and their habitat, as well as the overwhelming uncertainty surrounding indicators, metrics, and data interpretation methods, requires the testing of multiple approaches. Thus, the approach ISEMP has adopted is to develop a broad template that may differ in the details among subbasins, but one that will ultimately lead to the formation of a unified RME process for the management of anadromous salmonid populations and habitat across the Columbia River Basin.

ISEMP has been initiated in three pilot subbasins, the Wenatchee/Entiat, John Day, and Salmon. To balance replicating experimental approaches with the goal of developing monitoring and evaluation tools that apply as broadly as possible across the Pacific Northwest, these subbasins were chosen as representative of a wide range of potential challenges and conditions, e.g., differing fish species composition and life histories, ecoregions, institutional settings, and existing data.

ISEMP has constructed a framework that builds on current status and trend monitoring infrastructures in these pilot subbasins, but challenges current programs by testing alternative monitoring approaches. In addition, the ISEMP is:

1) Collecting information over a hierarchy of spatial scales, allowing for a greater flexibility of data aggregation for multi-scale recovery planning assessments, and;

2) Designing methods that:
   - a) Identify factors limiting fish production in watersheds;
   - b) Determine restoration actions to address these problems;
   - c) Implement actions as a large-scale experiment (e.g., Before After Control Impact, or BACI design), and
   - d) Implement intensive monitoring and research to evaluate the action's success.

The intent of the ISEMP project is to design monitoring programs that can efficiently collect information to address multiple management objectives over a broad range of scales. This includes:

- Evaluating the status of anadromous salmonids and their habitat;
- Identifying opportunities to restore habitat function and fish performance, and
- Evaluating the benefits of the actions to the fish populations across the Columbia River Basin.

The multi-scale nature of this goal requires the standardization of protocols and sampling designs that are statistically valid and powerful, properties that are currently inconsistent across the multiple monitoring programs in the region. Other aspects of the program will aid in the ability to extrapolate information beyond the study area, such as research to elucidate causal mechanisms, and a classification of watersheds throughout the Columbia River Basin. Obviously, the scale of the problem is immense and the ISEMP does not claim to be the only program working towards this goal. As such, ISEMP relies heavily on the basin's current monitoring infrastructure to test and develop monitoring strategies, while acting as a coordinating body and providing support for key elements such as data management and technical analyses. The ISEMP also ensures that monitoring programs can address large-scale management objectives (resulting largely from the ESA) through these local efforts. While the ISEMP maintains a regional focus it also returns the necessary information to aid in management at the smaller spatial scales (individual projects) where manipulations (e.g., habitat restoration actions) actually occur.

The work captured in this report is a component of the overall Integrated Status and Effectiveness Monitoring Program, and while it stands alone as an important contribution to the management of anadromous salmonids and their habitat, it also plays a key role within ISEMP. Each component of work within ISEMP is reported on individually, as is done so here, and in annual and triennial summary reports that present all of the overall project components in their programmatic context and shows how the data and tools developed can be applied to the development of regionally consistent, efficient and effective Research, Monitoring, and Evaluation.

PURPOSE OF THIS PROJECT

This report covers the activities conducted by the Washington Department of Fish and Wildlife (WDFW) as part of a larger project (#2003-017-00), to develop monitoring and evaluation programs in the Wenatchee, John Day, and South Fork Salmon River. These programs are intended to be pilot subbasin-scale programs for status and trend monitoring for anadromous salmonids and their habitat and effectiveness monitoring for habitat restoration projects. Specifically, WDFW was contracted to 1) estimate the total number of steelhead *Oncorhynchus mykiss* redds in selected streams within the Wenatchee subbasin by conducting index spawning ground counts, and 2) estimate the annual smolt production of spring Chinook salmon *O. tshawytscha* and steelhead within the Wenatchee subbasin. Current status and trend monitoring of steelhead and spring Chinook populations in the Wenatchee subbasin has been focused on hatchery supplementation programs and their efficacy in increasing the number of naturally spawning adults. An objective of this project was to increase the scope of this monitoring, and the accuracy and precision of steelhead redd counts and smolt production estimates within the Wenatchee subbasin.

In 2000, WDFW began limited steelhead spawning surveys in the Wenatchee subbasin funded by Chelan County Public Utility District (CCPUD). Spawning ground surveys were conducted in streams selected for supplementation to determine the efficacy of a supplementation program in increasing the number of natural spawners. This project was intended to expand the scope of the surveys to include all tributaries in the Wenatchee subbasin with a significant steelhead spawning population and ensure surveys are conducted on a weekly basis.

The Wenatchee subbasin smolt-monitoring program was initiated in 1993, and has been increasing in scope since initiation (Table 1). These programs were also conducted in selected streams and focused on supplementation programs of varying species. Chelan County Public Utility District (CCPUD) funds a smolt monitoring project on the Chiwawa River targeting spring Chinook and on the upper Wenatchee River (0.5 km below Lake Wenatchee) targeting sockeye *O. nerka* salmon. More recently, the Washington State Salmon Recovery Funding Board (SRFB) and CCPUD funded a smolt monitoring program on the lower Wenatchee River (rkm 16) targeting spring Chinook and steelhead that began in 2000.

The limited scope of the upper Wenatchee smolt-monitoring program (i.e., sockeye) prohibits estimating smolt production of other species (e.g. spring Chinook and steelhead) that spawn in the Little Wenatchee and White River watersheds (tributaries of Lake Wenatchee). Furthermore, the trap efficiency at both the upper and lower Wenatchee River locations has been determined to be inadequate to provide smolt production estimates of steelhead and spring Chinook with the desired level of precision. The ISEMP project was intended to increase the trapping period of the upper Wenatchee smolt monitoring program to encompass the entire spring Chinook emigration period and provide an additional smolt trap and personnel (beginning in 2005) at each location to increase the capture efficiency and provide a higher level of precision.

Table 1. Smolt trap locations within the Wenatchee subbasin in 2008.

Trap location	Rkm	Year started	Funding agency
Lower Wenatchee – 2 traps	16	2000 & 2005[a]	CCPUD; BPA
Upper Wenatchee – 2 traps	90	1997 & 2005[a]	CCPUD; BPA
Chiwawa River	1	1993	CCPUD
Nason Creek	1	2001[b]	BPA
White River	2	2005[c]	GCPUD

[a] Funded under this contact.

[b] Funded under this project but different contracts.

[c] Operated by WDFW during fall of 2005, currently operated by Yakama Nation.

STUDY AREA

The Wenatchee subbasin is located in north central Washington and drains a portion of the east slope of the Cascade Mountains. The river flows in a generally southeasterly direction and flows into the Columbia River at rkm 781 (Andonaegui 2001). The subbasin covers approximately 3,550 km^2 with 383 km of major rivers and stream (Andonaegui 2001). The Little Wenatchee and White Rivers flow into Lake Wenatchee, the source of the Wenatchee River. The Wenatchee River flows 90 km from Lake Wenatchee to the Columbia River. Other major tributaries of the Wenatchee River include the Chiwawa River, and Nason, Icicle, and Peshastin Creeks.

The Wenatchee subbasin supports several runs of anadromous fish including spring Chinook, summer Chinook, sockeye, and summer steelhead. Coho salmon *O. kisutch* were recently reintroduced into the Wenatchee subbasin, but abundance of this species is still heavily dependent on hatchery releases. All anadromous fish must migrate through seven hydroelectric projects located in the Columbia River. Sockeye salmon only spawn in the White and Little Wenatchee rivers and summer Chinook only spawn in the mainstem Wenatchee River (Mosey and Murphy 2002). Both steelhead and spring Chinook spawn in all the major tributaries of the Wenatchee River including the mainstem (Mosey and Murphy 2002). Both spring Chinook (endangered) and steelhead (endangered) are listed under the Endangered Species Act. Sockeye and summer Chinook populations are considered healthy and support commercial, tribal, and sport fisheries when abundance is expected to exceed spawning escapement requirements.

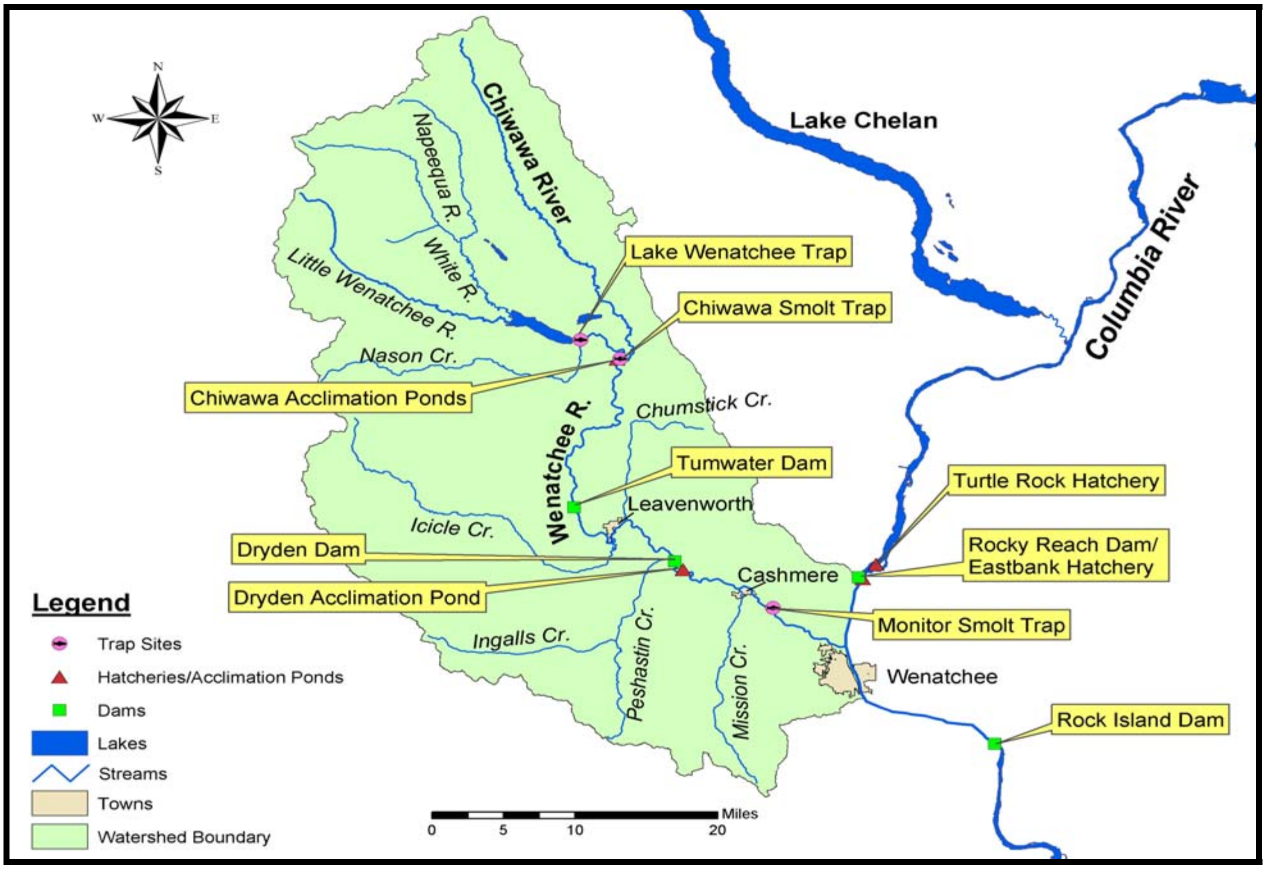

Figure 1. Location of the upper Wenatchee (Lake Wenatchee Trap) and lower Wenatchee River (Monitor Smolt Trap) smolt traps.

METHODS

STEELHEAD SPAWNER SURVEYS

Steelhead spawning escapement in selected tributaries were estimated using index area redd counts within known core-spawning areas as described in Hillman (2004). Surveys were performed weekly within index reaches, and a single survey was performed on the larger historical reaches, which may be comprised of one or more index and non-index reaches (Table 2). Support for this monitoring beyond 2004 is conditioned, in part, upon BPA receiving an acceptable plan that clearly identifies the monitoring and analytical framework, timeframes (i.e., expected schedules across years), and collaborative contributions for data collection and analyses by partner entities.

Secondary sexual characteristics (i.e., maxillary length) was used to calculate sex ratios for the entire run at Tumwater Dam. The sex ratio of the run was subsequently used to estimate the number fish per redd (i.e., assuming each female constructed one redd). Spawning escapement was estimated by multiplying the estimated total number of redds by the number of fish per redd. Linear regression analysis was used to examine the relationship between run escapement, index redd counts, and total redd counts upstream of Tumwater Dam.

Comprehensive spawning ground surveys of index areas were conducted weekly. All redds within an index area were individually flagged, georeferenced by GPS, and numbered sequentially. A final survey was conducted of the entire reach(s) at the end or after peak spawning if poor water conditions were expected. All redds in each reach were counted. Marking redds was not required during the final survey. A different surveyor surveyed within the index area and counted only redds that were visible. An index expansion factor (*IF*) was calculated by dividing the number of visible redds in the index by the total number of redds in the index area.

$$IF = n_{visible} / n_{total}$$

The reach total (*RT*) was calculated by expanding the number of redds in the non-index area by the proportion of visible redds in the index (i.e., index expansion factor) and adding the total number of redds found in the index area.

$$RT = n_{non-index} / IF + N_{Index-total}$$

An estimate of the total number of redds (*TR*) in a selected stream was calculated by summing the reach totals.

$$TR = \sum RT$$

Table 2. Wenatchee subbasin spawning ground survey reaches and corresponding index areas.

Reach	Index area
	Wenatchee River
Sleepy Hollow Br. to Lower Cashmere Br. (W2)	Monitor boat ramp to Cashmere boat ramp
Leavenworth Bridge to Icicle Road Bridge (W6)	Leavenworth boat ramp to Icicle River
Tumwater Dam to Tumwater Bridge (W8)	Swiftwater boat ramp to Tumwater Bridge
Tumwater Bridge to Plain (W9)	Tumwater Bridge to Plain
Plain to Lake Wenatchee (W10)	Chiwawa pump station to Lake Wenatchee
	Peshastin Creek
Mouth to Camas Creek (P1)	Kings Bridge to Camas Creek
Camas Creek to mouth of Scotty Creek (P2A)	Ingalls Creek to Ruby Creek
Camas Creek to mouth of Scotty Creek (P2)	FR7320 to mouth of Shaser Cr.
	Ingalls Creek
Mouth to Trailhead rm 1.0 (D1)	Mouth to Trailhead rm 1.0
Trailhead to Wilderness Boundary rm 1.5 (D2)	Trailhead to Wilderness Boundary rm 1.5
	Chiwawa River
Mouth to Grouse Creek (C1)	Mouth to Road 62 Bridge rm 6.4
Grouse Creek to Rock Creek (C2)	Chikamin Creek to Log jam
	Clear Creek
Mouth to HWY 22 (V1)	Mouth to HWY 22
HWY 22 to Lower culvert rm 2.0 (V2)	HWY 22 to Lower culvert
	Nason Creek
Mouth to Kahler Creek Bridge (N1)	Mouth to Swamp Creek
HWY 2 Bridge to Lower R.R. Bridge (N3)	Highway 2 Bridge to Merrit Bridge
Lower R.R. Bridge to Whitepine Creek (N4)	Rayrock to Church camp
	Icicle River
Mouth to Hatchery (I1)	Mouth to Hatchery
	Little Wenatchee River
Mouth to Lost Creek (L2)	Fish Weir to Lost Creek
Lost Creek to Rainy Creek Bridge (L3)	Lost Creek to Rainy Creek Bridge
	White River
Sears Cr. Bridge to Napeequa River (H2)	Riprap bank to Napeequa River
Napeequa River to mouth of Panther Creek (H3)	Napeequa River to Grasshopper Meadows.
	Napeequa River
Mouth to rm 1.0 (Q1)	Mouth to rm 1.0

SMOLT PRODUCTION ESTIMATES

Smolt production was estimated for spring Chinook salmon and steelhead from data collected at rotary smolt traps operated at two trapping locations (Figure 1). Population estimates were generated at subbasin (i.e., Wenatchee) and watershed scales (i.e., White and Little Wenatchee rivers). These traps were part of a comprehensive trapping program consisting of six traps located throughout the Wenatchee subbasin operated within the project and/or by cooperating agencies funded outside of this project.

Fish were removed from the trap at a minimum every morning and placed in an anesthetic solution of MS-222. Fish were identified to species and counted. Non-target species were allowed to fully recover in fresh water prior to being released in an area of calm water downstream from the smolt trap. Target species were held in separate live boxes for use during mark/recapture efficiency trials.

Fork length was measured to the nearest millimeter and weight to the nearest 0.1 g. A Fulton type condition factor ($WH10^5/FL^3$) was calculated for all target species. The degree of smoltification (parr, transitional, or smolt) was assessed by visual examination. Juvenile spring Chinook and steelhead were classified as parr if parr marks were distinct, transitional if parr marks were not distinct, and smolts if parr marks were not visible and the fish exhibited a silvery appearance.

Mark/recapture efficiency trials were conducted throughout the trapping season. The frequency of mark/recapture trials was dependent on the number of fish captured (no less than 100) and the river discharge. These trials were conducted over the widest range of discharge possible (interval depends on trap location). Fish for the mark/recapture trials were marked, by clipping the tip of either the upper or lower lobe of the caudal fin. Fish were placed in a live pen to recover for at least 8 h before being transported to a release site at least 1 km upstream of the trap. Marked fish were distributed across the width of the river and along approximately 100 m of the bank in pools or in calm pockets of water around boulders. In the case of the upper Wenatchee River trap, marked fish were transported and released into Lake Wenatchee. Fish were released between 1800 h and 2000 h. Recaptures of marked fish typically occur within 48 h after each trial.

The number of fish that could be marked and released may limit the frequency with which trap efficiency trials can be conducted. Emigration estimates were calculated using estimated daily trap efficiency derived from the regression formula using trap efficiency (dependent variable) and discharge (independent variable).

Trap efficiency was calculated using the following formula:

$$\text{Trap efficiency, } E_i = R_i / M_I,$$

*w*here E_i is the trap efficiency during time period i; M_i is the number of marked fish released during time period i; and R_i is the number of marked fish recaptured during time period i.

The number of fish captured was expanded by the estimated daily trap efficiency (e) to estimate the daily number of fish migrating past the trap (N_i) using the following formula:

$$\text{Estimated daily migration } = \hat{N}_i = C_i / \hat{e}_i$$

where N_i is the estimated number of fish passing the trap during time period i; C_i is the number of unmarked fish captured during time period i; and e_i is the estimated trap efficiency for time period i based on the regression equation.

The variance for the total daily number of fish migrating past the trap was calculated using the following formulas:

Variance of daily migration estimate = $$\mathrm{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{\mathrm{MSE}\left(1 + \frac{1}{n} + \frac{\left(X_i - \overline{X}\right)^2}{(n-1)s_X^2}\right)}{\hat{e}_i^2}$$

where X_i is the discharge for time period i, and n is the sample size. If a relationship between discharge and trap efficiency was not present (i.e. P < 0.05; r^2 . 0.5), a pooled trap efficiency was used to estimate daily emigration:

Pooled trap efficiency = $$E_p = \sum R / \sum M$$

The daily emigration estimate was calculated using the formula:

Daily emigration estimate = $$\hat{N}_i = C_i / E_p$$

The variance for daily emigration estimates using the pooled trap efficiency was calculated using the formula:

Variance for daily emigration estimate = $$\mathrm{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{E_p(1 - E_p) / \sum M}{E_p^2}$$

The total emigration estimate and confidence interval was calculated using the following formulas:

Total emigration estimate = $$\sum \hat{N}_i$$

95% confidence interval = $$1.96 \times \sqrt{\sum \mathrm{var}\left[\hat{N}_i\right]}$$

RESULTS

STEELHEAD SPAWNER SURVEYS

The estimated steelhead run escapement upstream of Tumwater Dam was 1,328 fish that included 5 fish detected on videotape, 11 surplus hatchery broodstock, and 1,312 fish trapped and released upstream of the dam. Run escapement in 2008 was 202% greater than 2007, but was 17% lower than the previous 5-year average of 1,609 fish (Table 3). A greater proportion of male than female steelhead were observed at Tumwater Dam resulting in a fish per redd value of 2.81. Of those steelhead released upstream of Tumwater Dam, 36 % (N = 480) were determined to be naturally produced.

Table 3. Total number, gender, and sex ratio of steelhead migrating upstream of Tumwater Dam between 2001 and 2008. Sex ratio in 2001 was determined by the number of fish passed and collected during broodstock collection at Tumwater and Dryden dams. For 2002-2008, gender was determined visually at Tumwater Dam.

Year	Number of steelhead above Tumwater Dam			Male to female ratio	Number of fish per redd
	Total	Female	Male		
2001	820	394	426	1.08	2.08
2002	1,720	641	1,079	1.68	2.68
2003	1,813	1,137	676	0.59	1.59
2004	1,918	869	1,049	1.21	2.21
2005	2,598	1,620	978	0.60	1.60
2006	1,057	505	552	1.09	2.09
2007	657	339	318	0.94	1.94
2008	1,328	473	855	1.81	2.81

In 2008, a large snow pack coupled with cool temperatures delayed runoff and river conditions during the survey period were similar to those observed in 2003 and 2006. After the second week of May, air temperatures increased such that snowmelt resulted in elevated water conditions for the remainder of the spawning period. Steelhead began spawning during the fourth week of March in the Wenatchee River and the third week of March in Nason Creek and progressed upstream as water temperatures increased. Spawning was observed in water temperatures ranging from 3.2–9.9 ^oC. Based on preliminary data, most spawning activity appeared to begin once a mean daily stream temperature reached ~4.3^{o}C. Steelhead spawning peaked in Peshastin Creek the third week of April. Peak spawning in the Wenatchee River and Nason Creek occurred during the fourth week of April (Table 5). As indicated above, spawning ground surveys were limited after the second week of May due to poor river conditions. A single survey was conducted the first week of June to determine if any late spawning could be detected and found that all previously constructed redds were erased and no new redds were located.

The estimated number of redds in the Wenatchee Basin increased 80% between 2007 (*N* = 159) and 2008 (*N* = 286) but the 2008 count was 26% below the 4-year average of 388 redds (Table 4). High river discharge occurring during, and following the peak of spawning decreased observer efficiency and may have resulted in an underestimate of redd abundance. For the above Tumwater Dam spawning aggregate, the decrease in the proportion of redds (29%) was slightly below the observed decrease in the estimated number of spawners (25%) between 2007 and 2008. The proportion of redds in tributaries upstream of Tumwater Dam generally decreased and increased in tributaries downstream of Tumwater Dam as well as in the Wenatchee River. The increase in redd abundance in spawning areas below Tumwater Dam was likely the function of poor survey conditions during peak and post peak spawn periods in areas above Tumwater Dam.

In 2008, the proportion of redds in Nason Creek (31%) was slightly less than the 4-year mean (34%; Table 4). This slight decrease was likely due to poor survey conditions (i.e., high flows and low water clarity), which persisted beyond the second week of May. Redd distribution in Nason Creek continues to be primarily occurring in the middle two reaches (68%; Figure 2). Steelhead redds observed in the Chiwawa River were also found in locations consistent with previous years (Figure 3). The proportion of redds found in all streams upstream of Tumwater Dam decreased from a high of 96% in 2006 to 59% in 2008 (Figure 4). While Peshastin Creek experienced only a small increase in the proportion of redds, the overall abundance of redds in 2008 was 288% greater than 2007 (Figure 5). The number of steelhead redds in Icicle Creek, another major spawning tributary downstream of Tumwater Dam, increased 617% of that observed in 2007 however they only represented 12.9% of the redds in the basin.

Table 4. Comparison of the number and distribution of steelhead redds in 2008 and the four year geometric mean (2004-2007).

Stream	2008		Geo. mean (2004-2007)	
	Number of redds	Distribution (%)	Number of redds	Distribution (%)
Nason Creek	88	30.9	133	34.3
Chiwawa River	11	3.8	38	9.8
White River	1	0.3	1	0.3
L. Wenatchee River	0	0.0	0	0.0
Peshastin Creek	49	17.1	44	11.3
Icicle Creek	37	12.9	15	3.8
Wenatchee River	100	35.0	157	40.5
Above Tumwater	59	59.0	136	91.3
Below Tumwater	41	41.0	13	8.7
Total	286		388	

Table 5. Summary of steelhead spawning ground index surveys in the Wenatchee River basin in 2008.

Reach	Survey Week of index Area														Index Total	Reach Total	Expanded # of redds
	2 Mar	9 Mar	16 Mar	23 Mar	30 Mar	6 Apr	13 Apr	20 Apr	27 Apr	4 May	11 May	18 May	25 May	1 Jun			
Wenatchee River																	
W1																1	3
W2	0	0	0	0	0	0	0	3	0	0	0				3	4	7
W3																5	15
W4																0	0
W5																2	2
W6	0	0	0	1	1	0	0	2	0	0					4	14	14
W7															-	-	-
W8	0	0	0	0	0	0	1	1	4						6	6	6
W9		0	0	0	0	0	0	1	3	0	2				6	6	6
W10		0	0	0	0	0	2	9	15	7	13				46	47	47
Total	0	0	0	1	1	0	3	16	22	7	15				65	85	100
Peshastin Creek																	
P1		0	0		2	2	2	16	8	5					35	35	35
P2		0	0		0	2	0	5	0	1					8	11	13
Total		0	0		2	4	2	21	8	6					43	46	48
Chiwawa River																	
C1							0	6	3						9	9	9
C2															-	-	-
Total							0	6	3						9	9	9

Table 5. Continued.

Reach	Survey Week of index Area														Index Total	Reach Total	Expanded # of redds
	2 Mar	9 Mar	16 Mar	23 Mar	30 Mar	6 Apr	13 Apr	20 Apr	27 Apr	4 May	11 May	18 May	25 May	1 Jun			
									Clear Creek								
V1	0	0	0	0	0	0	0		0	0	0		2	0	2	2	2
V2											0		0	0	0	0	0
Total	0	0	0	0	0	0	0		0	0	0		2	0	2	2	2
									Nason Creek								
N1	0	0	0	0	0	0	1	7	2	0	3				13	13	13
N2																22	24
N3	0	0	1	0	0	0	1	4	6	7	8				27	31	35
N4	0	0	0	0	0	0	0	3	6	1	4				14	15	15
Total	0	0	1	0	0	0	2	14	14	8	15				54	81	87
									Icicle River								
Total	0	0	0	0	2	1	8	5	16	5					37	37	37
									White River								
H2							0	0	0						0	0	0
H3							0	0	0	0					0	0	0
Total							0	0	0	0					0	0	0
									Napeequa River								
Total							0	0	1						1	1	1
									Little Wenatchee River								
L2															-	-	-
L3															-	-	-
Total															-	-	-
									Wenatchee River Basin								
Total	0	0	1	1	5	5	15	62	63	26	30		2	0	210	260	284

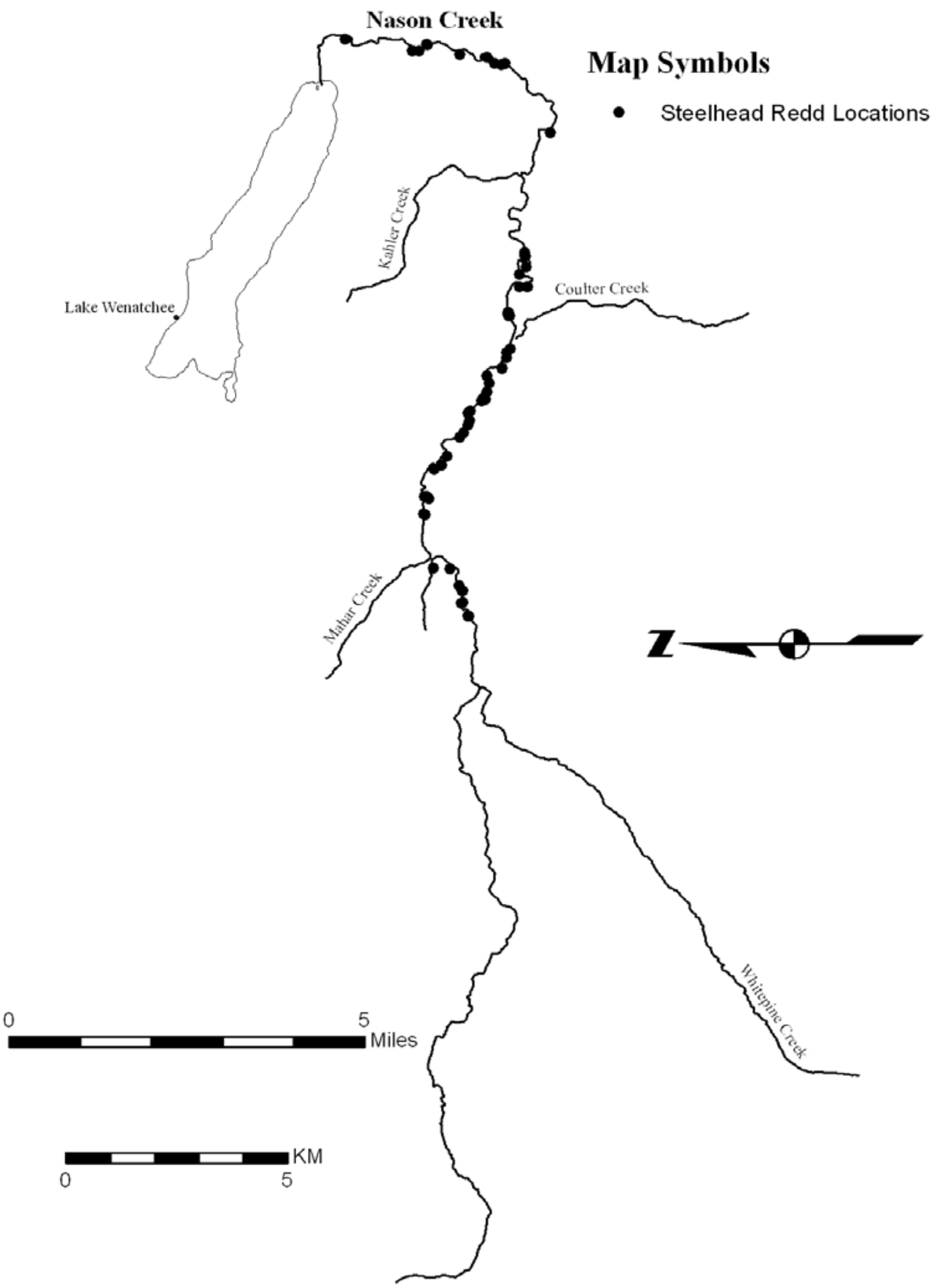

Figure 2. Steelhead spawning distribution in the Nason Creek Basin in 2008.

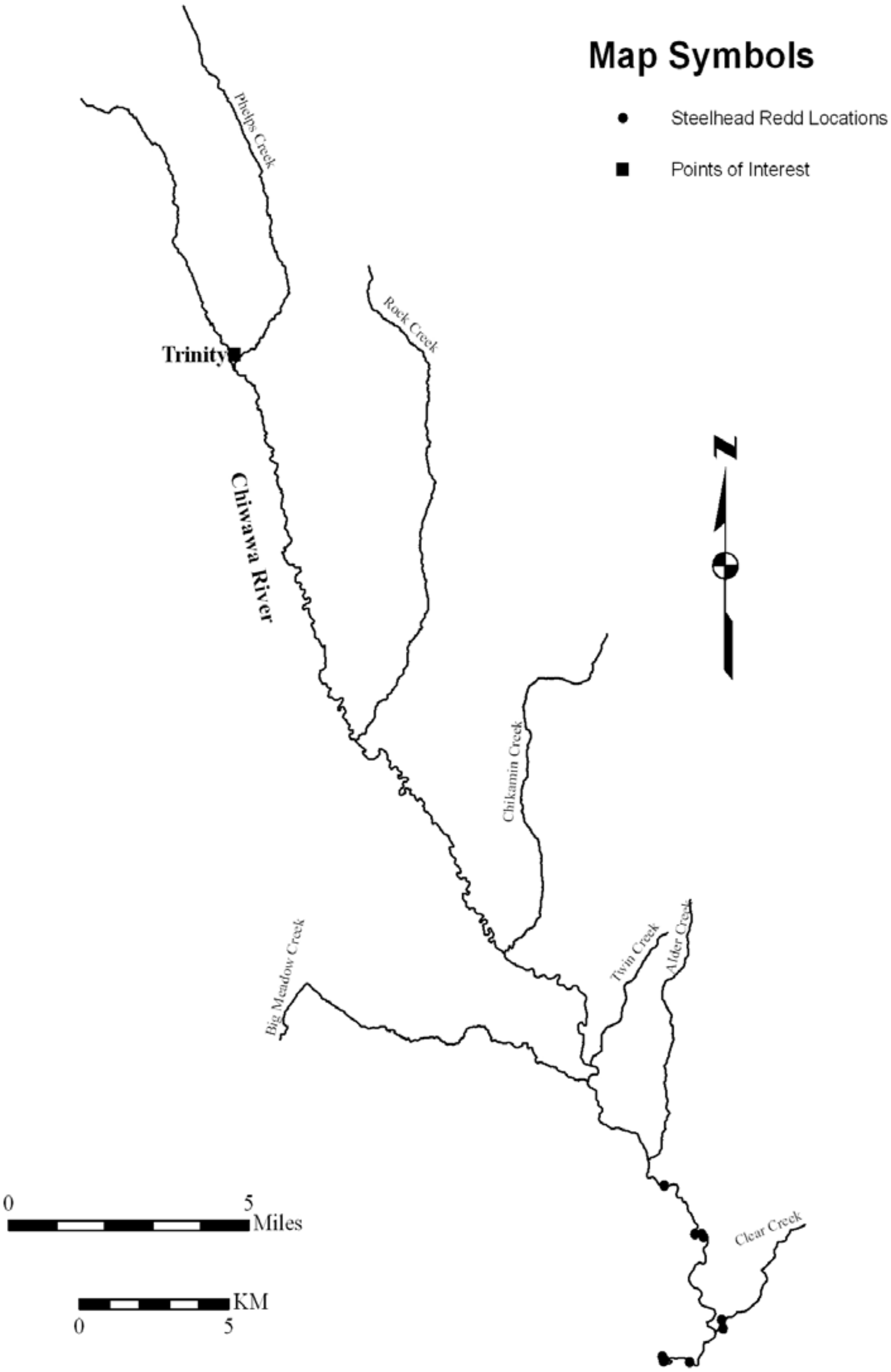

Figure 3. Steelhead spawning distribution in the Chiwawa River Basin in 2008.

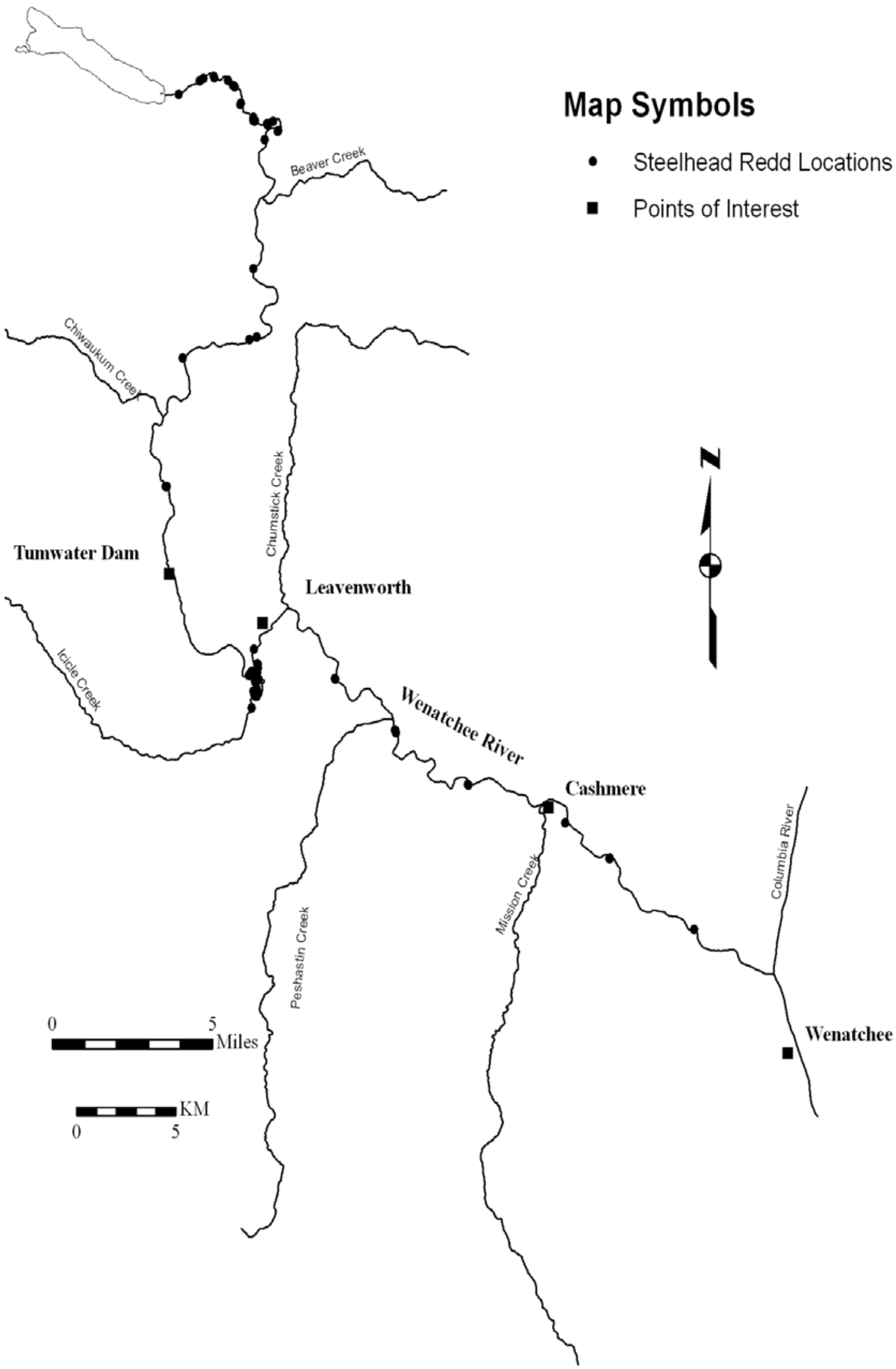

Figure 4. Steelhead spawning distribution in the Wenatchee River in 2008.

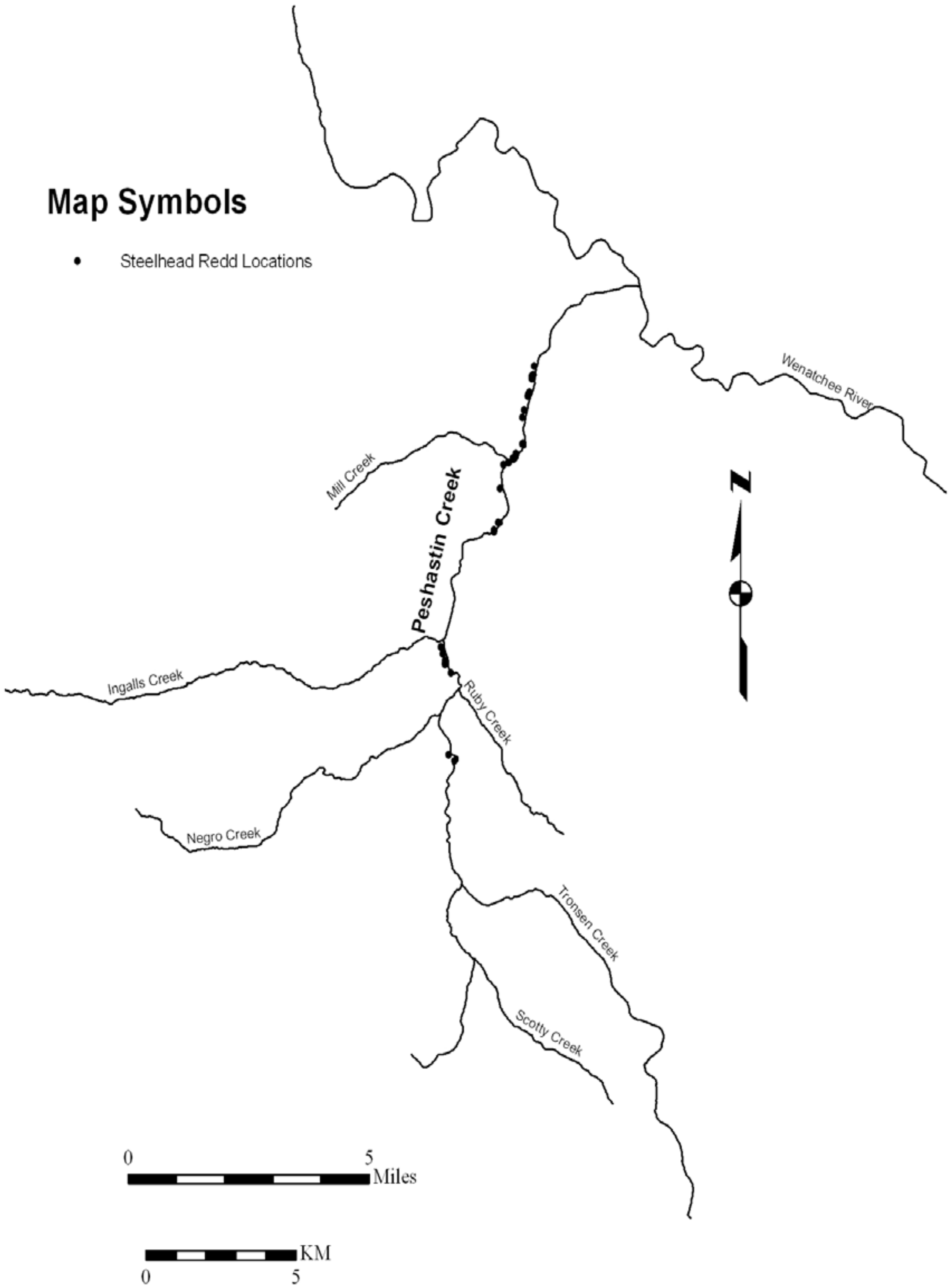

Figure 5. Steelhead spawning distribution in the Peshastin Creek Basin in 2008.

As a result of poor survey conditions during the peak and post peak spawning periods, observer efficiency was reduced resulting in fewer visible redds and subsequent lower expansion rates for non-index areas. However, the proportion of redds found within index areas upstream of Tumwater Dam in 2008 was only slightly lower the 4-year average of 83% (2004-2007, Table 3).

Table 3. Comparison of the number of redds found within index areas and the estimated number of redds in non-index areas upstream of Tumwater Dam between 2001 and 2008.

Year	Index area	Non-index area	Estimated total	Within index area (%)
2001	118	19	137	86
2002	296	179	475	62
2003	353	88	441	80
2004	277	92	369	75
2005	828	136	964	86
2006	192	34	226	85
2007	105	29	134	78
2008	124	35	159	78

Female escapement explained a slightly greater proportion of the variation in the estimated total number of redds than the total number of steelhead (Figure 6). Given the variation in sex ratios and that only female steelhead construct redds, we would expect female escapement to highly correlated to the number of redds. The high correlation (r = 0.88) between female escapement and the number of redds, despite a large variation in the number of females, suggests that prespawn mortality may be less variable and redd superimposition may not be of concern at the observed escapement levels. However, total run escapement explained a greater proportion of the variation in index redd counts than total redd counts suggesting that redd detection rates or observer efficiency in non-index areas may be highly variable (Figure 7).

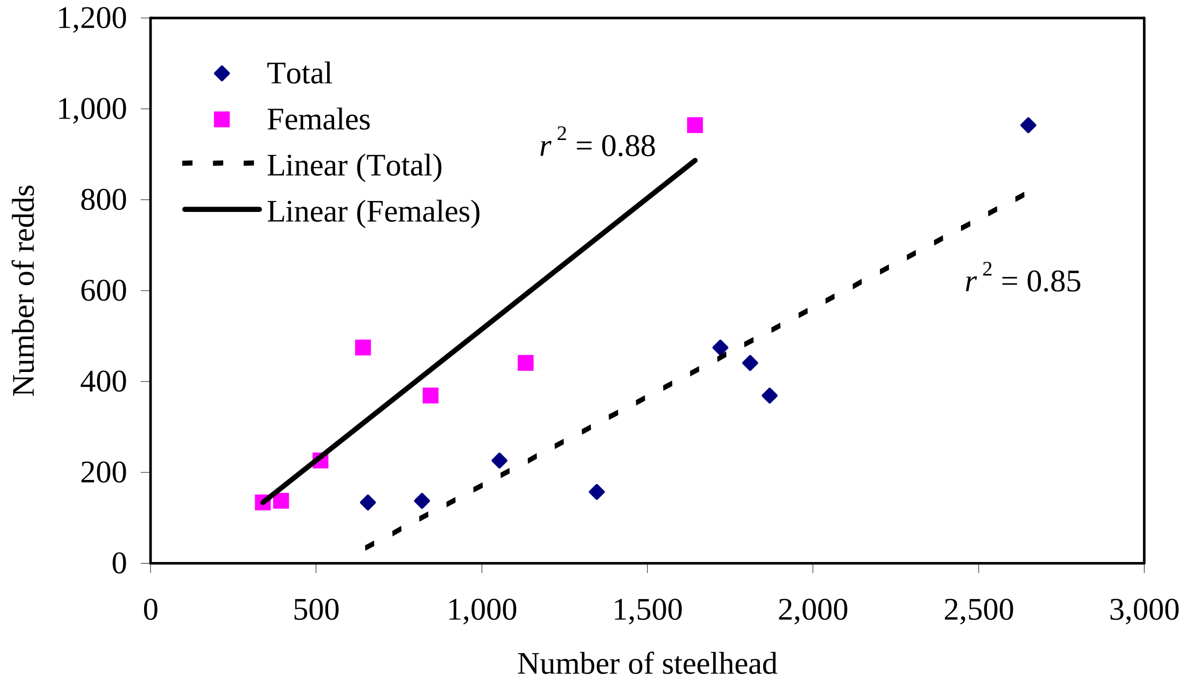

Figure 6. Relationship between steelhead run escapement (total and female) upstream of Tumwater Dam and total redd counts.

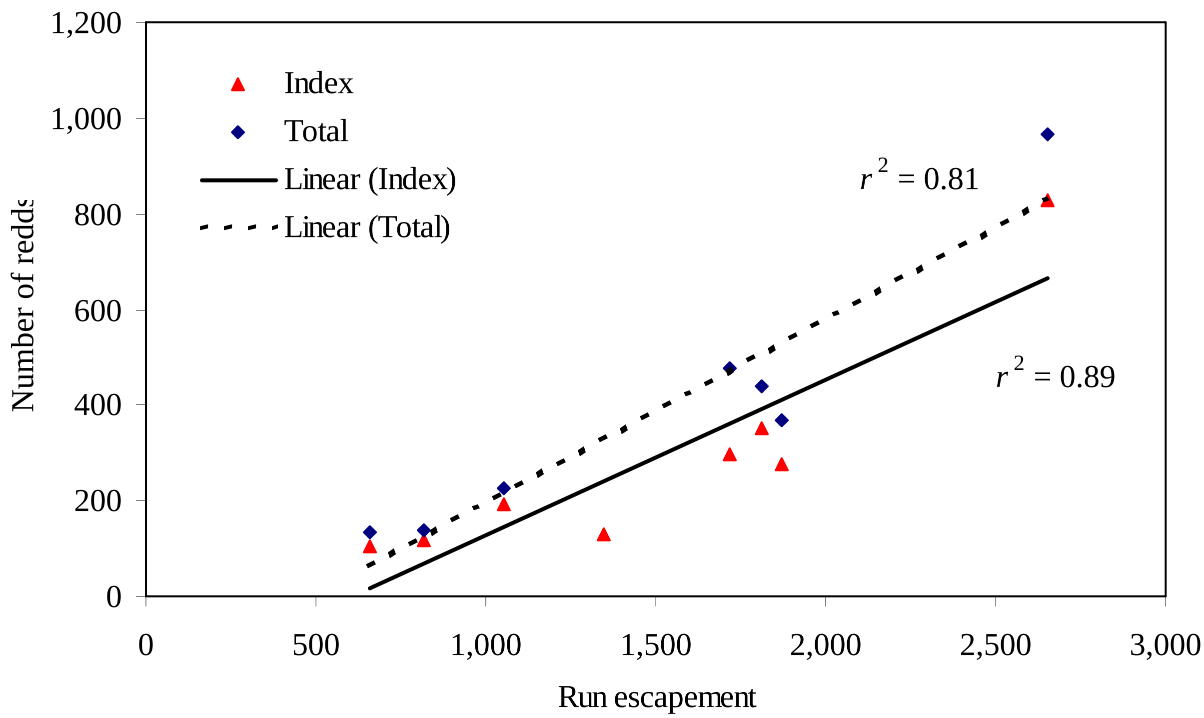

Figure 7. Relationship between steelhead run escapement upstream of Tumwater Dam and total and index area redd counts.

In 2008, only 34% of the steelhead migrating above Tumwater Dam were accounted for on spawning ground surveys compared to the 4-year average (2004-2007) of 50% (Table 4). Difficult survey conditions during and after the peak spawning period resulted in poor redd detection rates. While environmental conditions do affect the accuracy of our estimates, other factors may contribute to the difference between run and spawning escapement estimates that are quantifiable. Ongoing studies address some of these factors, while new studies will be required for those not currently being addressed.

Table 4. Comparison of run and estimated spawning escapement for steelhead upstream of Tumwater Dam between 2001 and 2008.

Year	Run escapement (A)	Number of redds (B)	Number of fish per redd (C)	Estimated spawning escapement (D = B x C)	Proportion of run escapement (E = D/A)
2001	820	137	2.08	285	0.35
2002	1,720	475	2.68	1,273	0.74
2003	1,813	441	1.59	701	0.39
2004	1,918	369	2.21	815	0.42
2005	2,598	964	1.60	1,542	0.59
2006	1,057	226	2.09	472	0.45
2007	657	134	1.94	260	0.40
2008	1,328	159	2.81	447	0.34

SMOLT PRODUCTION ESTIMATES

Upper Wenatchee River Smolt Trap

The upper Wenatchee River smolt trap (two-1.5 m diameter) was located approximately 0.5 km below the outlet of Lake Wenatchee. The trap operated nightly between 22 March and 30 June 2008. We captured 194 yearling spring Chinook smolts (Figure 8) and 28 steelhead juveniles (Figure 9) during the sampling period. One steelhead fry was also captured. We conducted two mark/recapture efficiency trials with wild and hatchery fish during the sampling period. A total of 1,063 wild and hatchery sockeye were marked (i.e., caudal fin clip) and released into Lake Wenatchee. Recapture of wild and hatchery fish totaled 18 (Table 8). The smolt production estimate (95% C.I.) for spring Chinook was 12,711 (± 1,163; Appendix B). The steelhead parr and smolt estimate was 1,201 (±158) and 1,140 (±146), respectively (Appendix C).

The estimated egg deposition for spring Chinook was calculated based on the total number of redds counted in the White, Napeequa, Panther, and Little Wenatchee rivers ($N = 69$) in 2006 (2006 brood yearling smolt migrated in 2008) multiplied by an average fecundity of 4,324 eggs derived from broodstock (C. Herring, WDFW, personal communication). The egg-to-smolt survival rate for spring Chinook was calculated at 4.3%. The average number of spring Chinook smolts per redd was calculated at 184. Egg to smolt survival for steelhead was not calculated because basin total steelhead redds counts were not available for time period required (2003-2006).

Individual length and weight measurements were recorded from a sample of the daily catch. Mean fork length (SD) of spring Chinook and steelhead was 108.7 (12.01) mm and 94.9 (27.9) mm, respectively (Table 9).

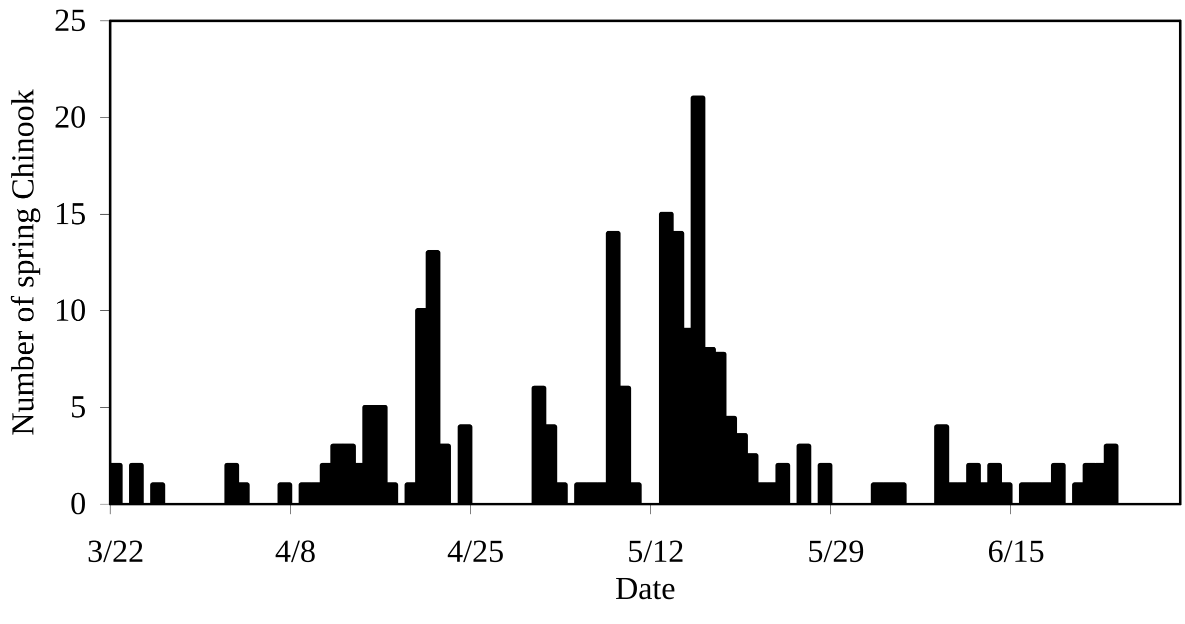

Figure 8. Daily capture of wild spring Chinook at the upper Wenatchee River trap in 2008.

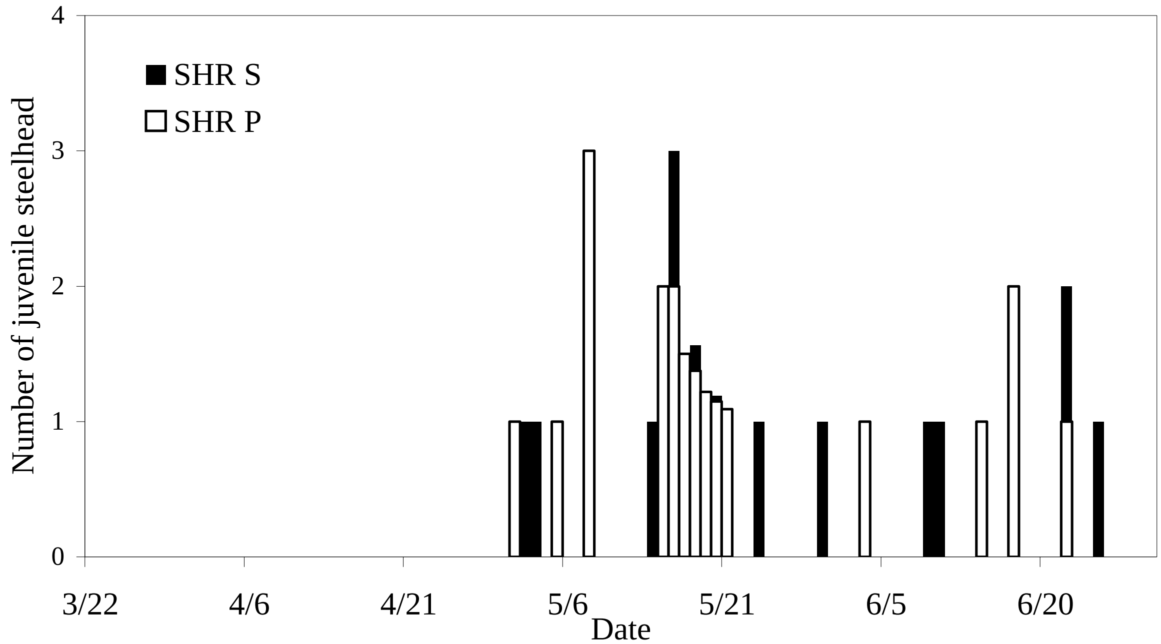

Figure 9. Daily capture of wild juvenile steelhead at the upper Wenatchee smolt trap in 2008 (SHR S = steelhead smolt, SHR P = steelhead parr).

Table 8. Mark/recapture efficiency trials conducted at the upper Wenatchee River smolt trap in 2008 (wild and hatchery sockeye smolts used as surrogates).

Date	Number of fish marked	Number of recaptured fish	Percent efficiency
5/2/2008	548	0	0.0
5/7/2008	515	18	3.5

Table 9. Mean fork lengths (mm), weights (g), and body condition factor of spring Chinook and juvenile steelhead captured in the Lake Wenatchee smolt trap during 2008.

	Spring Chinook			Juvenile steelhead		
	Mean	SD	*N*	Mean	SD	*N*
Fork length	108.8	12.01	*192*	94.9	27.95	*29*
Weight	14.7	4.74	*190*	12.4	12.19	*28*
K factor	1.12	0.14	*190*	1.20	0.19	*28*

Lower Wenatchee River Smolt Trap.

The lower Wenatchee River smolt trap (two-2.4 m diameter) was located at the West Monitor Bridge (rkm 9.6). The trap operated nightly between 14 February and 15 August. We captured 612 wild spring Chinook (Figure 10) and 319 parr and smolt steelhead (Figure 11). A total of 70 steelhead fry were also captured. Mortality during the trapping period consisted of three yearling Chinook (0.5%) and two parr and a smolt steelhead (0.6%). Two of the yearling Chinook mortalities were post-handling while the cause of the remaining three mortalities could not be determined (i.e., fish were found dead in the trap). We conducted 9 mark/recapture efficiency trials during the sampling period and released 5,519 marked yearling salmon (i.e., hatchery Chinook, hatchery coho, and wild and hatchery sockeye), of which 31 were recaptured (Table 10).

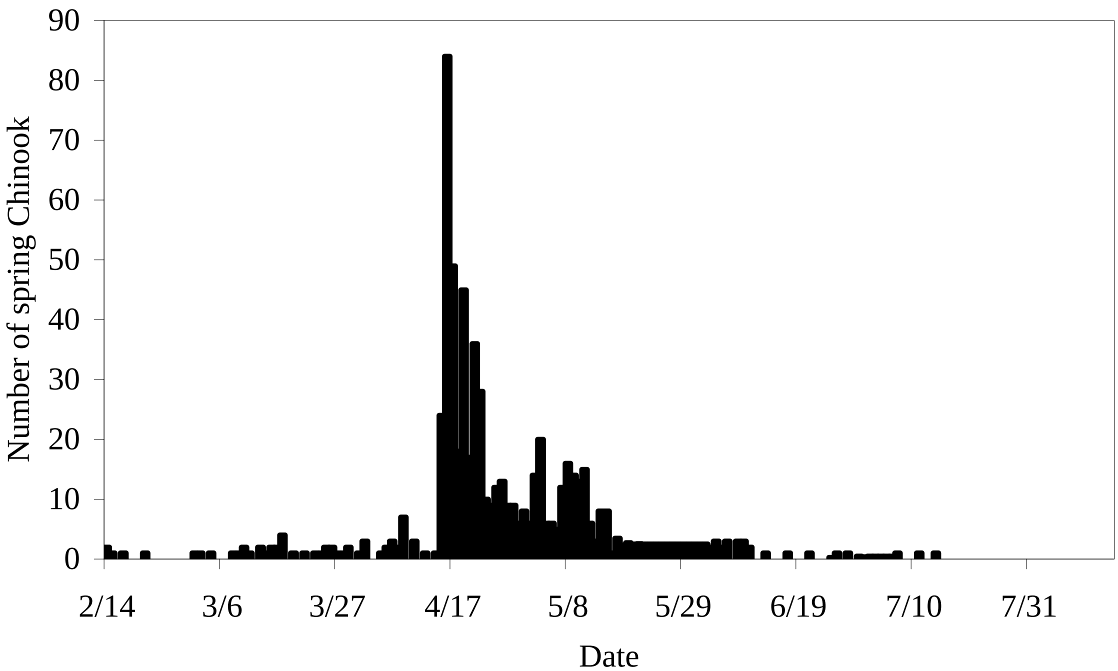

Figure 10. Daily capture of wild spring Chinook at the lower Wenatchee River trap in 2008.

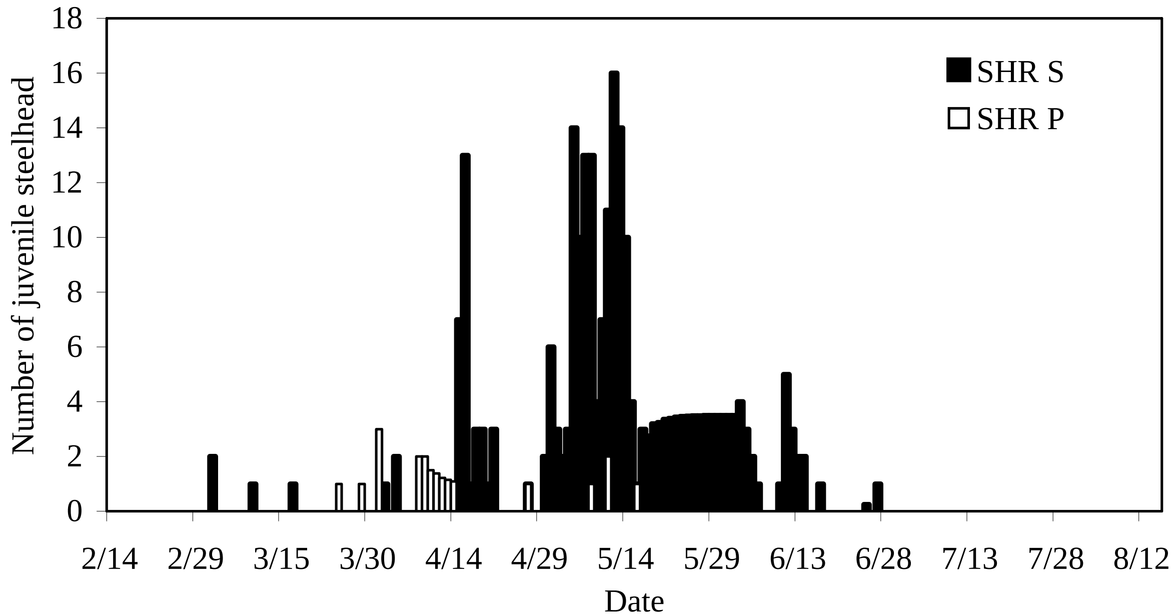

Figure 11. Daily capture of wild juvenile steelhead at the lower Wenatchee smolt trap in 2008 (SHR S = steelhead smolt, SHR P = steelhead parr).

Table 10. Mark/recapture efficiency trials conducted at the lower Wenatchee River smolt trap, 2008.

Date	Position	Number of fish marked	Number of recaptured fish	Percent efficiency
26 April	Out	423	3	0.7
1 May	Out	955	0	0.0
2 May	Out	482	4	0.8
2 May	Out	498	4	0.8
7 May	In	508	0	0.0
9 May	Out	755	9	1.2
9 May	Out	401	9	2.2
14 May	In	506	1	0.2
14 May	In	991	1	0.1
Total		5,519	31	0.6

The smolt production estimate (95% C.I.) for spring Chinook was 85,588 (± 9,262; Appendix D). The steelhead smolt estimate was 31,902 (±8,979). Egg deposition for spring Chinook was calculated based on the number of redds (N = 588) counted in the Wenatchee River basin multiplied by an average fecundity of 4,324 eggs based on broodstock collected (C. Herring, WDFW, personal communication). An egg-to-smolt survival rate for spring Chinook was calculated at 3.37%. The average number of spring Chinook smolts per redd was calculated at 146 smolts.

Individual length and weight measurements were recorded from a sample of the daily catch. Mean fork length (SD) of spring Chinook and steelhead was 97.2 (9.35) mm and 139.4 (41.07) mm, respectively (Table 11).

Table 11. Mean fork lengths (mm), weights (g), and body condition factor of spring Chinook and juvenile steelhead captured in the Lower Wenatchee smolt trap during 2008.

	Spring Chinook			Juvenile steelhead		
	Mean	SD	*N*	Mean	SD	*N*
Fork length	97.2	9.35	*615*	139.4	41.07	*304*
Weight	10.5	3.07	*615*	34.3	24.48	*301*
K factor	1.12	0.13	*615*	1.05	0.14	*301*

BUDGET

Smolt trapping at Lower Wenatchee and Upper Wenatchee sites

Salaries				
Position	Name	Months	$/Month	Total
Fish and Wildlife Biologist 3	Contract and Meetings	0.25	4676	$1,169
Scientific Technician 2	Smolt Trapping	13	3074	$39,962
Scientific Technician 3	Data QA/QC	0.35	3560	$1,246
Total		14.5		$42,377
Benefits				
State OASI and Retirement	(13.58% of salaries)			$5,755
Medical Aid	($103.08/month)	14.5		$1,495
Health and Industrial Insurance	($707/month)	14.5		$10,252
Benefit subtotal:				$17,501
Personnel subtotal:				$59,878
Goods and Services				
Personnel service overhead	(0.6722705% of salaries and benefits)			$403
Repair and Maintenance (smolt traps)				$2,000
G & S and Travel subtotal:				$2,403
Subtotal				**$62,280**
Indirect (28.74% of subtotal)				**$17,899**
Subtotal smolt trapping				**$80,180**

Steelhead spawning ground surveys

Salaries				
Position	Name	Months	$/Month	Total
Scientific Technician 2	Steelhead Spawning Surveys	4	3074	$12,296
Total		4		$12,296
Benefits				
State OASI and Retirement	(13.58% of salaries)			$1,670
Medical Aid	($103.08/month)	4		$412
Health and Industrial Insurance	($707/month)	4		$2,828
Benefit subtotal:				$4,910
Personnel subtotal:				$17,206
Goods and Services				
Personnel service overhead	(0.6722705% of salaries and benefits)			$116
Misc Equipment (waders, boots, nets)				$350
Explorer ($0.35/mile, lease $335/month)	(3500 miles; 3.6 months)			$2,431
G & S and Travel subtotal:				$2,897
Subtotal				**$20,103**
Indirect (28.74% of subtotal)				**$5,778**
Subtotal for spawning ground surveys				**$25,880**
Contract Total				**$106,060**

DISCUSSION

STEELHEAD SPAWNER SURVEYS

The high correlation between the expanded total redd counts and run escapement (r = 0.89) suggest that the methodology used to estimate the number of steelhead can be very robust in estimating trends in spawning escapement. It also suggests that factors responsible for the observed difference in run and estimated spawning escapement are relatively constant with respect to escapement levels and time. Given the large differences between run and spawn escapement upstream of Tumwater Dam, it is evident that multiple factors are contributing to the difference in the escapement estimates.

Tumwater Dam offers a unique opportunity to examine all the possible factors that may influence the size of the spawning population. Furthermore, it is not unreasonable to apply results of studies designed to answer these critical uncertainties to all populations in the upper Columbia River Basin. In the following section, we discuss these factors in more detail.

Estimates of the number of redds

The current methodology does not involve conducting weekly surveys of the entire available spawning habitat (e.g., spring Chinook, summer Chinook, and sockeye). Steelhead are thought to have a greater range of spawning habitats than other anadromous species making a total redd census logistically impractical and costly. In the Wenatchee Basin, the ISEMP has been conducting probabilistic sampling (e.g., EMAP) of those areas not covered under the current methodology. When available, annual estimates of redd abundance outside of the current survey area should provide some indication regarding the extent of steelhead spawning habitat.

Within the current survey area, a majority of the steelhead redds are consistently found within index areas, which may simply be a result of inadequacies in the methodology. Studies planned for the Twisp River in 2009 to compare the estimated redd abundance in non-index areas to the actual count should also be conducted in the Entiat and Wenatchee Basins. Furthermore, observer efficiency is a potentially large source of error in conducting redd counts (Dunham et al. 2001; Muhlfeld et al. 2006). The current methodology should be modified to incorporate estimates of observer efficiency and not only identify, but also quantify sources of error (redd omission or false identification).

Run escapement estimates

Current methodology allows for the direct enumeration of steelhead upstream of Tumwater Dam. However, it may not be appropriate to assume that all steelhead that migrate upstream of Tumwater Dam spawn upstream of Tumwater Dam (i.e., fallback and prespawn mortality). Using PIT tag recapture data, we were able to calculate a minimum fallback rate of steelhead at Tumwater Dam in 2008. Nearly all the steelhead (99.6%) that migrated past Tumwater Dam were implanted with a PIT tag in the pelvic girdle. PIT tag detection at all Columbia and Snake River hydroelectric projects and some major spawning tributaries downstream of Tumwater Dam (e.g., Peshastin Creek, Prosser Dam in the Yakima Basin) provided recapture data. Because some steelhead may have spawned in areas downstream of Tumwater Dam with no PIT tag antenna array (e.g., lower Wenatchee, Icicle, Mission, and Chumstick) or simply lost their tag, fallback rates were considered minimum values. Of the PIT tagged steelhead that were passed upstream of Tumwater Dam (*N* = 1,353), 3.0% (*N* = 41) were detected prior to spawning downstream of Tumwater Dam. While most steelhead (78%, *N* = 32) were detected upstream of the Wenatchee River, fish were also detected in Peshastin Creek (*N* = 8) and the Yakima River (*N* = 1).

Because no estimate of survival to spawning is available for steelhead in the Wenatchee Basin, we assumed that survival to spawning was at a minimum similar to that of steelhead overwintering in lower Columbia River tributaries (i.e., Deschutes and John Day) reported by Keefer et al (2008). Actual survival in the Wenatchee River may be considerably lower than that reported by Keefer et al. (2008) as a result of colder water temperatures and depleted energy reserves. Studies should be designed and implemented to estimate survival to spawning for all tributaries in the Upper Columbia Basin. We used estimates of fallback and prespawn mortality to adjust run escapement estimates upstream of Tumwater Dam (Table 12). After adjustment, the mean proportion of the run escapement accounted for on the spawning grounds increased from 46% to 58%.

Table 12. Comparison of steelhead run escapement estimates at Tumwater Dam to the estimate spawning escapement derived from redd counts after adjusting for fallback and prespawn mortality.

Year	Tumwater Dam count	Adjusted Tumwater Dam counts		Number of redds	Number of fish per redd	Estimated spawning escapement	Proportion of run escapement
		Fallback	Prespawn mortality				
	(A)	(B = A - 3.0%)	(C = B - 18.9%)	(D)	(E)	(F = D x E)	(G = F/C)
2001	820	795	645	137	2.08	285	0.44
2002	1,720	1,668	1,353	475	2.68	1,273	0.94
2003	1,810	1,756	1,424	441	1.60	706	0.50
2004	1,869	1,813	1,470	369	2.21	815	0.55
2005	2,650	2,571	2,085	964	1.61	1,552	0.74
2006	1,053	1,021	828	226	2.05	463	0.56
2007	657	637	517	134	1.94	260	0.50
2008	1,358	1,317	1,068	159	2.81	447	0.42

Spawning escapement estimates

Monitoring and evaluation plans require estimates of the spawning population in order to evaluate hatchery program effectiveness and determine appropriate escapement levels (i.e., carrying capacity). Steelhead exhibit a diverse life history and complex migration patterns reducing the reliability that run escapement estimates (i.e., dam counts) accurately reflect the size of the spawning population. Steelhead spawning ground surveys are currently conducted in every major steelhead population in the Upper Columbia Basin. However, uncertainty in using these data to estimate the size of the spawning population lies in some factors previously discussed (i.e., redd omission and observer efficiency), but also in the manner in which redd counts are expanded to estimate the population.

The conversion of redd counts to an estimate of the spawning population requires knowledge of the average number of redds constructed per female and the number of fish per redd (Gallagher et al. 2007). In some populations, female steelhead were reported to construct multiple redds. If steelhead in the Wenatchee do construct multiple redds, differences in run and escapement estimates would increase as a result of a lower spawning escapement estimate. For example, if female steelhead construct an average of 1.5 redds, the difference in run and spawning escapement estimates would increase 9%.

Redd abundance estimates are used to estimate the female escapement, which are then expanded by the sex ratio to estimate the male population on the spawning grounds. The number of fish per redd is based on the sex ratio of the population. Error associated with observer accuracy (i.e., gender misassignments) could be corrected using portable ultrasound devices. This approach assumes 1) equal survival to spawning and 2) every male spawns on average at one redd location. A tagging study is needed to test these assumptions.

Hatchery effectiveness monitoring

The timing and distribution of natural spawning hatchery and naturally produced steelhead in the Wenatchee River is unknown. Differences in spawn timing have been observed in Wenatchee summer steelhead broodstock, but fish are held in a controlled environment on well water. Based on the differences observed in the hatchery, it is possible that a considerable portion of hatchery origin steelhead spawn prior to initiation of spawning ground surveys. Spawning ground surveys start in early March and typically no redds have been found until April suggesting that hatchery steelhead are spawning within the current survey period. A bi-modal spawning distribution has not been detectable under the current survey protocols, but may be masked by the large proportion of hatchery fish on the spawning grounds. The inability to discern hatchery and naturally produced fish on the spawning grounds precludes determining the spawning distribution and timing of hatchery steelhead relative to naturally produced steelhead. Murdoch et al. (2008) reported that spawning location of both male and female spring Chinook salmon was a significant factor influencing reproductive success. Studies developed and implemented to examine the factors previously discussed, should also incorporate an assessment of the temporal and spatial distribution of hatchery and wild steelhead.

Recommendations

Of all the factors that are contributing to the difference between run and spawning escapement estimates, redds constructed in streams not included in the survey area have the potential to account for a significant portion of the difference. The reported number of redds upstream of Tumwater Dam underestimate the total number of redds because all available spawning habitat (i.e., low order streams) is not surveyed. Studies have been ongoing in the Wenatchee Basin designed to estimate the number of redds in areas not covered under the current survey design. Data from these studies (ISEMP) must be analyzed and incorporated into spawning escapement estimates.

The accuracy and precision of the current methodology used in estimating the redd abundance should be evaluated. Studies focused on the testing assumptions used in estimating the size of the spawning population (number of redds per female and number of fish per redd) should also incorporate an assessment of 1) fallback 2) survival to spawning 3) the spawning distribution of the hatchery and wild steelhead. Information from these studies is required to ensure spawning escapement estimates have sufficient accuracy and precision, such that inferences regarding the efficacy of naturally spawning hatchery steelhead can be made in a timely manner.

SMOLT PRODUCTION ESTIMATES

Upper Wenatchee River Smolt Trap

Due to low numbers of spring Chinook and steelhead caught, sockeye were used as surrogates in mark/recapture efficiency trials. However only two mark/recapture efficiency trials were performed this year due to the low number of wild and hatchery sockeye available. Tagging activities of sockeye and their sensitivities to tagging and handling precluded their use in performing more mark/recapture efficiency trials. Of the two efficiency trials, only one resulted in recaptured fish. Because numbers of spring Chinook captured were less than in 2007, wild and hatchery sockeye smolts were again used as surrogates for mark/recapture efficiency trials. A delay in migration and subsequent recapture of the marked fish from Lake Wenatchee negatively affected the relationship between discharge and trap efficiency (i.e., unequal probability of recapture). Therefore, the pooled trap efficiency (3.5%) was used to calculate spring Chinook and steelhead smolt production estimates. If captures of wild spring Chinook do in fact increase at the trap, individual mark/recapture trials will be conducted in the future using wild spring Chinook.

Lower Wenatchee River Smolt Trap.

Low abundance of spring Chinook and steelhead precluded their use for mark/recapture trials. Hatchery Chinook and coho were used as surrogates for mark/recaptures trials, which were conducted at various levels of river discharge or if the trap position had changed. Smolt production estimates were calculated using separate regression models (independent variable = river discharge; dependent variable = trap efficiency) for each of the two trap positions. In some cases, efficiency trials from previous years (i.e., 2001-2007) were used in the regression model to increase the sample size used in the model. Hatchery Chinook and coho will continue to be used as surrogates in trap efficiency trials until the relative abundance of wild spring Chinook and steelhead increases sufficiently to allow species-specific efficiency trials.

In 2008, accuracy of smolt production estimates based on estimated trap efficiencies should be high because the regression models used to estimate trap efficiency were significant and discharge accounted for a large proportion of the variability in observed trap efficiencies for both trap positions ($r^2 = 0.76$, $P < 0.001$; $r^2 = 0.99$, $P < 0.05$).

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APPENDICES

Appendix A. Steelhead spawning surveys in the Wenatchee River basin, 2001 – 2008. Redd counts are expanded values derived from sample rates within index areas.

Basin/subbasin	2001	2002	2003	2004	2005	2006	2007	2008
Chiwawa River Basin								
Chiwawa River	25	27	26	17	118	8	3	9
Rock Creek	--	1	0	0	0	0	--	--
Chikamin creek	--	0	0	1	2	1	0	--
Meadow Creek	--	5	1	5	16	3	0	0
Twin Creek	--	4	0	--	0	--	--	--
Goose Creek	--	0	--	--	--	--	--	--
Alder Creek	--	0	5	2	14	0	0	0
Deep Creek	--	0	--	--	--	--	--	--
Clear Creek	--	43	32	37	12	7	8	2
Subtotal	25	80	64	62	162	19	11	11
Nason Creek Basin								
Nason Creek	27	80	121	124	410	74	78	87
White Pine Creek	--	--	--	0	0	0	0	--
Un-named Creek	--	--	--	3	0	3	0	1
Roaring Creek	--	--	--	--	2	0	0	0
Subtotal	27	80	121	127	412	77	78	88
White River Basin								
White River	--	0	1	0	2	0	1	0
Panther Creek	--	--	0	0	0	0	0	0
Napeequa River	--	0	2	0	0	0	0	1
Subtotal		0	3	0	2	0	1	1
Little Wenatchee River								
Mainstem	--	1	5	0	0	--	0	0
Icicle Creek								
Mainstem	19	27	16	23	8	41	6	37
Peshastin Creek Basin								
Peshastin Creek	--	--	15	32	91	67	17	48
Mill Creek	--	--	--	--	1	0	0	1
Ingalls Creek	--	--	0	0	0	0	--	--
Ruby Creek	--	--	0	0	0	--	--	--
Tronsen Creek	--	--	0	2	5	0	0	0
Scotty Creek	--	--	0	0	0	0	0	0
Shaser Creek	--	--	0	0	0	0	0	0
Schafer Creek	--	--	--	0	0	0	0	0
Subtotal	--	--	15	34	97	67	17	49
Wenatchee River								
Mainstem	116	315	248	136	456	191	46	100
Beaver Creek	--	0	0	* 15	3	0	0	0
Chiwaukum Creek	--	--	0	--	0	0	--	0
Subtotal	116	315	248	151	459	191	46	100
Wenatchee Basin Total	187	503	472	397	1,140	395	159	286

*Redds were enumerated by USFS

Appendix B. Actual daily and estimated captures and emigration estimates for wild spring Chinook, Upper Wenatchee River smolt trap 2008.

Date	Average Trapping Flow (M^3/S)	Wild Spring Chinook		
		Catch		Migration estimate
		Actual	Estimated	
28-Mar	16.7	0	--	0
29-Mar	16.4	0	--	0
30-Mar	15.8	0	--	0
31-Mar	15.5	0	--	0
1-Apr	15.1	0	--	0
2-Apr	14.9	2	--	118
3-Apr	14.9	1	--	59
4-Apr	15.0	0	--	0
5-Apr	15.2	0	--	0
6-Apr	15.2	0	--	0
7-Apr	15.4	1	--	59
8-Apr	15.7	0	--	0
9-Apr	15.6	1	--	59
10-Apr	15.7	1	--	59
11-Apr	16.0	2	--	118
12-Apr	17.3	3	--	177
13-Apr	20.7	3	--	177
14-Apr	27.6	2	--	118
15-Apr	31.7	5	--	295
16-Apr	32.6	5	--	295
17-Apr	33.1	1	--	59
18-Apr	34.0	0	--	0
19-Apr	34.0	1	--	59
20-Apr	32.9	10	--	591
21-Apr	31.4	13	--	768
22-Apr	29.7	3	--	177
23-Apr	29.2	0	--	0
24-Apr	28.3	4	--	236
25-Apr	27.6	0	--	0
26-Apr	26.5	0	--	0
27-Apr	27.6	0	--	0
28-Apr	30.6	0	--	0
29-Apr	38.0	0	--	0
30-Apr	41.1	0	--	0
1-May	40.8	6	--	354
2-May	40.5	4	--	236
3-May	41.4	1	--	59
4-May	43.9	0	--	0
5-May	53.8	1	--	59
6-May	70.5	1	--	59
7-May	83.6	1	--	59
8-May	89.2	14	--	827
9-May	84.4	6	--	354
10-May	81.3	1	--	59
11-May	80.7	0	--	0
12-May	78.2	0	--	0
13-May	76.8	15	--	886
14-May	80.7	14	--	827
15-May	107.9	9	--	532
16-May	153.8	21	--	1240
17-May	230.6	--	8	472
18-May	317.3	--	8	458

19-May	354.1	--	4	262
20-May	342.8	--	4	209
21-May	308.8	--	2	147
22-May	236.8	1	--	59
23-May	185.0	1	--	59
24-May	158.6	2	--	118
25-May	165.4	0	--	0
26-May	187.5	3	--	177
27-May	204.8	0	--	0
28-May	217.8	2	--	118
29-May	225.8	0	--	0
30-May	220.4	0	--	0
31-May	200.6	0	--	0
01-Jun	189.5	0	--	0
02-Jun	174.2	1	--	59
03-Jun	154.4	1	--	59
04-Jun	144.2	1	--	59
05-Jun	130.9	0	--	0
06-Jun	123.5	0	--	0
07-Jun	114.4	0	--	0
08-Jun	105.7	4	--	236
09-Jun	101.7	1	--	59
10-Jun	101.7	1	--	59
11-Jun	95.5	2	--	118
12-Jun	91.2	1	--	59
13-Jun	97.7	2	--	118
14-Jun	110.8	1	--	59
15-Jun	117.3	0	--	0
16-Jun	122.1	1	--	59
17-Jun	127.8	1	--	59
18-Jun	122.4	1	--	59
19-Jun	113.6	2	--	118
20-Jun	107.1	0	--	0
21-Jun	119.8	1	--	59
22-Jun	130.3	2	--	118
23-Jun	129.7	2	--	118
24-Jun	122.4	3	--	177
25-Jun	117.6	0	--	0
26-Jun	117.6	0	--	0
27-Jun	119.3	0	--	0
28-Jun	137.7	0	--	0
29-Jun	167.7	0	--	0
30-Jun	194.9	0	--	0
Totals		**189**	**26**	**12,711**

Appendix C. Actual daily and estimated captures and emigration estimates for steelhead parr and smolts, Upper Wenatchee River smolts trap 2008.

Date	Average Trapping Flow (M^3/S)	Steelhead parr			Steelhead smolts		
		Catch		Migration estimate	Catch		Migration estimate
		Actual	Estimated		Actual	Estimated	
28-Mar	16.7	0	--	0	0	--	0
29-Mar	16.4	0	--	0	0	--	0
30-Mar	15.8	0	--	0	0	--	0
31-Mar	15.5	0	--	0	0	--	0
1-Apr	15.1	0	--	0	0	--	0
2-Apr	14.9	0	--	0	0	--	0
3-Apr	14.9	0	--	0	0	--	0
4-Apr	15.0	0	--	0	0	--	0
5-Apr	15.2	0	--	0	0	--	0
6-Apr	15.2	0	--	0	0	--	0
7-Apr	15.4	0	--	0	0	--	0
8-Apr	15.7	0	--	0	0	--	0
9-Apr	15.6	0	--	0	0	--	0
10-Apr	15.7	0	--	0	0	--	0
11-Apr	16.0	0	--	0	0	--	0
12-Apr	17.3	0	--	0	0	--	0
13-Apr	20.7	0	--	0	0	--	0
14-Apr	27.6	0	--	0	0	--	0
15-Apr	31.7	0	--	0	0	--	0
16-Apr	32.6	0	--	0	0	--	0
17-Apr	33.1	0	--	0	0	--	0
18-Apr	34.0	0	--	0	0	--	0
19-Apr	34.0	0	--	0	0	--	0
20-Apr	32.9	0	--	0	0	--	0
21-Apr	31.4	0	--	0	0	--	0
22-Apr	29.7	0	--	0	0	--	0
23-Apr	29.2	0	--	0	0	--	0
24-Apr	28.3	0	--	0	0	--	0
25-Apr	27.6	0	--	0	0	--	0
26-Apr	26.5	0	--	0	0	--	0
27-Apr	27.6	0	--	0	0	--	0
28-Apr	30.6	0	--	0	0	--	0
29-Apr	38.0	0	--	0	0	--	0
30-Apr	41.1	0	--	0	0	--	0
1-May	40.8	1	--	59	0	--	0
2-May	40.5	0	--	0	1	--	59
3-May	41.4	0	--	0	1	--	59
4-May	43.9	0	--	0	0	--	0
5-May	53.8	1	--	59	0	--	0
6-May	70.5	0	--	0	0	--	0
7-May	83.6	0	--	0	0	--	0
8-May	89.2	3	--	177	0	--	0
9-May	84.4	0	--	0	0	--	0
10-May	81.3	0	--	0	0	--	0
11-May	80.7	0	--	0	0	--	0
12-May	78.2	0	--	0	0	--	0
13-May	76.8	0	--	0	0	--	0
14-May	80.7	0	--	0	1	--	59
15-May	107.9	2	--	118	0	--	0
16-May	153.8	2	--	118	3	--	177
17-May	230.6	--	2	89	--	1	74
18-May	317.3	--	1	81	--	2	92

19-May	354.1	--	1	72	--	1	71
20-May	342.8	--	1	68	--	1	70
21-May	308.8	--	1	64	--	1	65
22-May	236.8	0	--	0	0	--	0
23-May	185.0	0	--	0	0	--	0
24-May	158.6	0	--	0	1	--	59
25-May	165.4	0	--	0	0	--	0
26-May	187.5	0	--	0	0	--	0
27-May	204.8	0	--	0	0	--	0
28-May	217.8	0	--	0	0	--	0
29-May	225.8	0	--	0	0	--	0
30-May	220.4	0	--	0	1	--	59
31-May	200.6	0	--	0	0	--	0
01-Jun	189.5	0	--	0	0	--	0
02-Jun	174.2	0	--	0	0	--	0
03-Jun	154.4	1	--	59	0	--	0
04-Jun	144.2	0	--	0	0	--	0
05-Jun	130.9	0	--	0	0	--	0
06-Jun	123.5	0	--	0	0	--	0
07-Jun	114.4	0	--	0	0	--	0
08-Jun	105.7	0	--	0	0	--	0
09-Jun	101.7	0	--	0	1	--	59
10-Jun	101.7	0	--	0	1	--	59
11-Jun	95.5	0	--	0	0	--	0
12-Jun	91.2	0	--	0	0	--	0
13-Jun	97.7	0	--	0	0	--	0
14-Jun	110.8	1	--	59	0	--	0
15-Jun	117.3	0	--	0	0	--	0
16-Jun	122.1	0	--	0	0	--	0
17-Jun	127.8	2	--	118	0	--	0
18-Jun	122.4	0	--	0	0	--	0
19-Jun	113.6	0	--	0	0	--	0
20-Jun	107.1	0	--	0	0	--	0
21-Jun	119.8	0	--	0	0	--	0
22-Jun	130.3	1	--	59	2	--	118
23-Jun	129.7	0	--	0	0	--	0
24-Jun	122.4	0	--	0	0	--	0
25-Jun	117.6	0	--	0	1	--	59
26-Jun	117.6	0	--	0	0	--	0
27-Jun	119.3	0	--	0	0	--	0
28-Jun	137.7	0	--	0	0	--	0
29-Jun	167.7	0	--	0	0	--	0
30-Jun	194.9	0	--	0	0	--	0
Totals		**14**	**6**	**1,201**	**13**	**6**	**1,140**

Appendix D. Actual daily and estimated captures and emigration estimates for wild spring Chinook and Steelhead smolts, lower Wenatchee River trap 2008.

Date	Average Trapping Flow (M^3/S)	Wild Spring Chinook			Steelhead smolts		
		Catch		Migration estimate	Catch		Migration estimate
		Actual	Estimated		Actual	Estimated	
14-Feb	26.8	2	--	281	0	--	0
15-Feb	26.0	1	--	141	0	--	0
16-Feb	25.5	0	--	0	0	--	0
17-Feb	25.7	1	--	141	0	--	0
18-Feb	25.6	0	--	0	0	--	0
19-Feb	25.2	0	--	0	0	--	0
20-Feb	24.9	0	--	0	0	--	0
21-Feb	24.8	1	--	141	0	--	0
22-Feb	24.8	0	--	0	0	--	0
23-Feb	24.8	--	0	0	--	0	0
24-Feb	24.9	--	0	0	--	0	0
25-Feb	25.4	0	--	0	0	--	0
26-Feb	25.4	0	--	0	0	--	0
27-Feb	25.8	0	--	0	0	--	0
28-Feb	26.7	0	--	0	0	--	0
29-Feb	28.9	0	--	0	0	--	0
01-Mar	31.9	1	--	141	0	--	0
02-Mar	34.5	1	--	141	0	--	0
03-Mar	35.1	0	--	0	2	--	281
04-Mar	35.1	1	--	141	0	--	0
05-Mar	34.9	0	--	0	0	--	0
06-Mar	33.9	0	--	0	0	--	0
07-Mar	33.8	0	--	0	0	--	0
08-Mar	34.0	1	--	141	0	--	0
09-Mar	34.7	1	--	141	0	--	0
10-Mar	36.2	2	--	281	1	--	141
11-Mar	37.8	1	--	141	0	--	0
12-Mar	40.2	0	--	0	0	--	0
13-Mar	41.5	2	--	281	0	--	0
14-Mar	41.8	1	--	141	0	--	0
15-Mar	41.7	2	--	281	0	--	0
16-Mar	41.1	2	--	281	0	--	0
17-Mar	40.5	4	--	563	1	--	141
18-Mar	40.0	0	--	0	0	--	0
19-Mar	40.1	1	--	141	0	--	0
20-Mar	39.9	0	--	0	0	--	0
21-Mar	39.6	1	--	141	0	--	0
22-Mar	38.4	0	--	0	0	--	0
23-Mar	37.4	1	--	141	0	--	0
24-Mar	37.4	1	--	141	0	--	0
25-Mar	37.3	2	--	281	0	--	0
26-Mar	35.9	2	--	281	0	--	0
27-Mar	35.4	1	--	141	0	--	0
28-Mar	34.7	1	--	141	0	--	0
29-Mar	34.4	2	--	281	0	--	0
30-Mar	33.4	0	--	0	0	--	0
31-Mar	32.5	1	--	141	0	--	0
01-Apr	31.5	3	--	422	0	--	0
02-Apr	30.9	0	--	0	1	--	141
03-Apr	30.6	0	--	0	0	--	0
04-Apr	30.8	1	--	141	2	--	281
05-Apr	31.2	2	--	281	0	--	0

06-Apr	31.4	3	--	422	0	--	0
07-Apr	31.9	2	--	281	0	--	0
08-Apr	30.5	7	--	985	0	--	0
09-Apr	30.9	0	--	0	0	--	0
10-Apr	30.8	3	--	422	1	--	141
11-Apr	31.0	0	--	0	0	--	0
12-Apr	32.3	1	--	141	1	--	141
13-Apr	36.6	0	--	0	0	--	0
14-Apr	46.8	1	--	141	0	--	0
15-Apr	61.3	24	--	3113	7	--	908
16-Apr	62.1	84	--	10842	13	--	1678
17-Apr	60.8	49	--	6372	1	--	130
18-Apr	61.7	18	--	2329	3	--	388
19-Apr	62.6	45	--	5791	3	--	386
20-Apr	60.7	17	--	2212	1	--	130
21-Apr	57.9	36	--	4762	3	--	397
22-Apr	54.4	28	--	3783	0	--	0
23-Apr	51.4	10	--	1376	0	--	0
24-Apr	51.5	9	--	1238	0	--	0
25-Apr	49.7	12	--	1668	0	--	0
26-Apr	48.4	13	--	1822	0	--	0
27-Apr	47.7	9	--	1267	1	--	141
28-Apr	50.0	9	--	1249	0	--	0
29-Apr	57.5	6	--	796	0	--	0
30-Apr	70.0	8	--	986	2	--	246
01-May	73.2	6	--	726	6	--	726
02-May	70.8	14	--	1718	3	--	368
03-May	70.6	20	--	2457	2	--	246
04-May	72.8	6	--	728	3	--	364
05-May	82.8	6	--	688	14	--	1605
06-May	108.8	5	--	393	10	--	889
07-May	135.8	12	--	960	13	--	1134
08-May	154.2	16	--	1395	13	--	1039
09-May	155.3	14	--	1227	4	--	318
10-May	144.7	13	--	1093	7	--	588
11-May	141.5	15	--	1273	11	--	934
12-May	143.2	6	--	505	16	--	1346
13-May	137.0	3	--	260	14	--	1214
14-May	138.2	8	--	690	10	--	862
15-May	169.3	8	--	751	4	--	299
16-May	253.2	1	--	150	1	--	53
17-May	333.6	--	4	560	--	3	153
18-May	472.0	--	2	380	--	3	140
19-May	598.3	--	3	435	--	3	163
20-May	622.5	--	3	403	--	3	165
21-May	595.6	--	3	409	--	3	171
22-May	522.0	--	3	403	--	3	173
23-May	417.8	--	3	403	--	3	175
24-May	352.8	--	3	401	--	3	176
25-May	340.8	--	3	401	--	3	177
26-May	359.3	--	3	400	--	3	178
27-May	385.9	--	3	400	--	3	178
28-May	407.4	--	3	400	--	3	178
29-May	413.6	--	3	400	--	3	178
30-May	418.1	--	3	400	--	3	178
31-May	411.1	--	3	400	--	3	178
01-Jun	377.3	--	3	400	--	3	178
02-Jun	358.3	--	3	400	--	3	178
03-Jun	326.9	2	--	320	4	--	204

04-Jun	300.2	3	--	480	3	--	153
05-Jun	271.7	2	--	320	2	--	102
06-Jun	242.0	3	--	419	1	--	55
07-Jun	223.6	0	--	0	0	--	0
08-Jun	202.0	3	--	333	0	--	0
09-Jun	187.4	3	--	309	0	--	0
10-Jun	181.5	2	--	200	1	--	71
11-Jun	178.5	0	--	0	5	--	358
12-Jun	166.5	0	--	0	3	--	227
13-Jun	162.2	1	--	84	2	--	168
14-Jun	184.9	0	--	0	2	--	168
15-Jun	207.1	0	--	0	0	--	0
16-Jun	220.3	0	--	0	0	--	0
17-Jun	225.2	1	--	126	1	--	59
18-Jun	232.1	0	--	0	0	--	0
19-Jun	216.1	0	--	0	0	--	0
20-Jun	200.1	0	--	0	0	--	0
21-Jun	196.5	1	--	108	0	--	0
22-Jun	226.9	0	--	0	0	--	0
23-Jun	238.9	0	--	0	0	--	0
24-Jun	227.4	0	--	0	0	--	0
25-Jun	210.4	--	0	16	--	0	16
26-Jun	202.1	1	--	65	0	--	0
27-Jun	202.8	0	--	0	1	--	65
28-Jun	217.7	1	--	61	0	--	0
29-Jun	261.7	0	--	0	0	--	0
30-Jun	304.2	--	1	22	--	0	0
01-Jul	338.4	--	0	15	--	0	0
02-Jul	342.8	--	0	18	--	0	0
03-Jul	322.4	--	0	19	--	0	0
04-Jul	318.2	--	0	20	--	0	0
05-Jul	281.4	--	0	23	--	0	0
06-Jul	231.5	--	0	28	--	0	0
07-Jul	202.3	1	--	65	0	--	0
08-Jul	176.4	0	--	0	0	--	0
09-Jul	165.0	0	--	0	0	--	0
10-Jul	162.2	0	--	0	0	--	0
11-Jul	155.7	1	--	79	0	--	0
12-Jul	136.4	0	--	0	0	--	0
13-Jul	121.1	0	--	0	0	--	0
14-Jul	115.8	1	--	96	0	--	0
15-Jul	112.1	0	--	0	0	--	0
16-Jul	107.5	0	--	0	0	--	0
17-Jul	101.4	0	--	0	0	--	0
18-Jul	95.3	0	--	0	0	--	0
19-Jul	90.3	0	--	0	0	--	0
20-Jul	84.2	0	--	0	0	--	0
21-Jul	76.2	0	--	0	0	--	0
22-Jul	76.2	0	--	0	0	--	0
23-Jul	76.4	0	--	0	0	--	0
24-Jul	73.0	0	--	0	0	--	0
25-Jul	68.6	0	--	0	0	--	0
26-Jul	64.5	0	--	0	0	--	0
27-Jul	62.2	0	--	0	0	--	0
28-Jul	60.5	0	--	0	0	--	0
29-Jul	57.1	0	--	0	0	--	0
30-Jul	54.7	0	--	0	0	--	0
31-Jul	53.5	0	--	0	0	--	0
1-Aug	49.6	0	--	0	0	--	0

2-Aug	47.3	--	0	0	--	0	0
3-Aug	47.6	0	--	0	0	--	0
4-Aug	44.0	0	--	0	0	--	0
5-Aug	39.5	0	--	0	0	--	0
6-Aug	41.2	0	--	0	0	--	0
7-Aug	38.2	0	--	0	0	--	0
8-Aug	37.7	0	--	0	0	--	0
9-Aug	38.3	0	--	0	0	--	0
10-Aug	44.1	0	--	0	0	--	0
11-Aug	39.9	0	--	0	0	--	0
12-Aug	36.6	0	--	0	0	--	0
13-Aug	33.6	0	--	0	0	--	0
14-Aug	33.6	--	0	0	--	0	0
15-Aug	33.3	0	--	0	0	--	0
Totals		**611**	**52**	***83,282**	**206**	**51**	***22,222**

*Totals deviate due to rounding issues.

Appendix E. Yearly and monthly total juvenile capture information for the upper Wenatchee River smolts trap 2008.

	2008										
Species/Origin	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chinook											
Wild yearling	5	58	103	28	--	--	--	--	--	--	194
Wild subyearling	19	39	7	6	--	--	--	--	--	--	71
Hatchery yearling	0	33	227	138	--	--	--	--	--	--	398
Steelhead											
Wild	0	0	17	11	--	--	--	--	--	--	28
Smolt	0	0	8	6	--	--	--	--	--	--	14
Parr	0	0	9	5	--	--	--	--	--	--	14
Hatchery	0	0	60	1	--	--	--	--	--	--	61
Sockeye											
Wild	0	2,739	6,388	6	--	--	--	--	--	--	9,133
Hatchery	0	17	1,317	33	--	--	--	--	--	--	1,367
Coho											
Wild yearling	0	1	4	1	--	--	--	--	--	--	6
Wild subyearling	0	7	2	7	--	--	--	--	--	--	16
Hatchery yearling	0	5	91	24	--	--	--	--	--	--	120
Bull trout											
Juvenile	0	2	1	0	--	--	--	--	--	--	3
Adult	0	0	0	0	--	--	--	--	--	--	0
Cutthroat	0	1	0	1	--	--	--	--	--	--	2
White fish	0	25	9	1	--	--	--	--	--	--	35
Northern pikeminnow	0	3	70	33	--	--	--	--	--	--	106
Longnose dace	0	3	4	1	--	--	--	--	--	--	8
Sucker spp.	0	1	1	1	--	--	--	--	--	--	3
Redside shiner	0	4	14	3	--	--	--	--	--	--	21
Yellow perch	0	0	0	0	--	--	--	--	--	--	0
Sculpin spp.	7	61	94	89	--	--	--	--	--	--	251

Appendix F. Yearly and monthly total juvenile capture information for the lower Wenatchee River trap 2008.

	2008											
Species/Origin	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chinook												
Wild yearling	5	32	396	153	23	3	0	--	--	--	--	612
Wild subyearling	1	216	1418	3049	21635	4091	137	--	--	--	--	30,547
Hatchery yearling	0	0	13446	5947	39	7	1	--	--	--	--	19,440
Steelhead												
Wild	0	8	103	147	58	1	2	--	--	--	--	319
Smolt	0	4	45	131	40	0	0	--	--	--	--	220
Parr	0	4	58	16	18	1	2	--	--	--	--	99
Hatchery	0	0	0	1864	242	0	0	--	--	--	--	2,106
Sockeye												
Wild	0	0	34	179	3	0	0	--	--	--	--	216
Hatchery	0	0	2	200	5	0	0	--	--	--	--	207
Coho												
Wild yearling	0	2	62	27	14	6	0	--	--	--	--	111
Wild subyearling	0	1	96	74	308	513	23	--	--	--	--	1,013
Hatchery yearling	0	0	1091	2773	432	0	0	--	--	--	--	4,296
Bull trout												
Juvenile	0	0	0	1	0	0	0	--	--	--	--	1
Adult	0	0	0	0	0	0	0	--	--	--	--	0
Cutthroat	0	0	0	1	0	0	0	--	--	--	--	1
White fish	0	0	0	0	5	60	2	--	--	--	--	67
Northern pikeminnow	0	0	10	25	9	8	5	--	--	--	--	57
Longnose dace	3	78	180	114	106	72	15	--	--	--	--	568
Speckled dace	0	0	0	0	1	0	0	--	--	--	--	1
Umatilla dace	0	0	0	0	0	0	2	--	--	--	--	2
Sucker spp.	2	27	186	292	74	28	3	--	--	--	--	612
Peamouth	0	0	1	1	0	0	0	--	--	--	--	2
Chiselmouth	0	0	0	0	0	0	0	--	--	--	--	0
Redside shiner	1	7	6	11	8	18	18	--	--	--	--	69
Yellow bullhead	0	0	0	0	0	0	0	--	--	--	--	0
Pacific lamprey	10	161	157	424	556	120	3	--	--	--	--	1,431
River lamprey	0	0	0	0	0	0	0	--	--	--	--	0
Sculpin spp.	0	6	17	4	8	11	3	--	--	--	--	49
Stickleback (3 spined)	0	1	0	1	0	1	1	--	--	--	--	4