

Wind River Winter and Summer Steelhead Adult and Smolt Population  
Estimates from Trapping Data, 2006

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**Abstract**

In 2006, wild steelhead smolt production was estimated for the Wind River and key subwatersheds using a stratified Petersen/Darroch estimator. A total of 19,125 smolts were estimated to emigrate from the Wind River subbasin, 1,428 from the Trout Creek subwatershed, 961 from the Panther Creek subwatershed, and 2,044 from the Upper Wind River. Smolts emigrating from Trout Creek, Panther Creek, and the Upper Wind River accounted for 7%, 5%, and 11% of the total smolt production from the Wind River. The remaining 77% of the smolts originated from the middle and lower mainstem of the Wind River. Adult summer steelhead escapement was estimated using four different mark-recapture methods. The wild summer steelhead abundance was estimated to be 648 fish based on the “Jumper” method. The wild winter steelhead escapement was estimated 38 adults based on expanded trap counts and redd surveys below Shipherd Falls.

## **Introduction**

Abundance of wild summer steelhead (*Oncorhynchus mykiss*) spawning in the Wind River declined from the 1980s through the 1990s (Busby et al. 1996, WDFW 1997). By the early 1990's a multi-agency technical advisory committee (TAC) was formed to investigate the cause of the decline and recommend actions that would lead to improved wild summer steelhead abundance. The TAC was originally composed of members from the United States Fish and Wildlife Service (USFWS), United States Forest Service (USFS), Washington Department of Fish and Wildlife (WDFW), and Yakama Nation (YN). In the late 1990s, the USFWS provided funding to the Underwood Conservation District (UCD) to establish a watershed council. The UCD and United States Geologic Survey – Columbia River Research Laboratory (USGS-CRRL) were added to the original TAC, which was renamed the Technical Advisory Group (TAG) to support the Wind River Watershed Council. The Bonneville Power Administration (BPA) agreed to fund a collaborative monitoring and restoration effort on the Wind River in 1997 (Rawding et al. 1999). In this partnership, WDFW was responsible for Wind River smolt and adult steelhead population estimates. The objectives for WDFW were to: 1) develop annual estimates of adult and smolt abundance for the Wind River basin, 2) determine smolt yield from key production areas within the basin, and 3) to collect juvenile steelhead life history information during the smolt outmigration.

These monitoring data are being used to help determine factors affecting steelhead production in key subwatersheds in the Wind River basin (Rawding 2004). They are also being used to develop a science-based steelhead and watershed recovery plan (Rawding et al. 2004, Rawding 2004, LCFRB 2004, McElhaney et al. 2004), and to determine if watershed restoration activities are effective at increasing the productivity and abundance of steelhead (Rawding 2004). A complete description of the methodology for adult and smolt production estimates can be found in Rawding and Cochran (2005). This report provides an estimate of the wild adult summer and winter steelhead run in 2006 at Shipherd Falls, and an estimate of the number of wild winter steelhead spawning below Shipherd Falls. In addition, the 2006 smolt abundance at four trapping locations in the Wind River basin is also provided. Population estimates for adult spring Chinook salmon spawning in 2005 are presented in Appendix 1.

## **Methods**

### **Study Site**

The Wind River is located near Carson, Washington. This fifth order stream drains 362 square kilometers (km) and enters the Columbia River in the Bonneville Pool at river kilometer (rkm) 250. The watershed provides habitat for summer and winter steelhead, rainbow trout, spring and fall Chinook (*O. tshawytscha*), and coho salmon (*O. kisutch*), mountain whitefish (*Prosopium williamsoni*), lamprey (*Lampetra spp*), suckers (*Catostomas spp*), sculpins (*Cottus spp*), stickleback (*Gasterosteus aculeatus*), peamouth (*Mylocheils caurins*), reidside shiner (*Richardsoniustius balteatus*) and leopard dace (*Rhinichthys falcatus*). Prior to the construction of the Shipherd Falls fish ladder in 1956 at rkm 3, the only anadromous salmon accessing the upper watershed were steelhead. The primary purpose of the fishway is to provide passage for spring Chinook, which return to Carson National Fish Hatchery at rkm 29. The upper portion of the watershed lies within the Gifford Pinchot National Forest. The President's Forest Plan

categorizes this basin as a “Tier 1, key watershed” that provides important habitat for anadromous salmonids. The USFS manages 77% of the watershed for multi-use benefits. The lower portion of the Wind River basin consists of non-federal lands primarily managed for timber harvest.

Adult steelhead are tagged and released at the Shipherd Falls trapping facility and recovered at the Hemlock Dam trapping facility (Figure 1) and “recaptured” through snorkeling which is termed resight. Mid-summer and fall snorkel surveys occur in the mainstem Wind River from Dry Creek to Shipherd Falls, a distance of approximately 26 km. If resources were available and river conditions allowed, then snorkel surveys were also conducted in the winter from just above Dry Creek to the Stabler Bridge, a distance of approximately 11 km. The area from the Stabler Bridge to Shipherd Falls is rated as class 4-5 whitewater in the winter and is only used by advanced whitewater boaters. Therefore, this area was not snorkel surveyed during the winter due to safety concerns and a low probability of observing adult steelhead.

Some winter steelhead spawning takes place in the 2 km reach below Shipherd Falls and in the Little Wind River (Figure 1). Spawning below Shipherd Falls is not accounted for in the adult trapping data or snorkel surveys. To quantify spawning in this area, redd surveys were conducted bi-weekly in 2006 from Shipherd Falls to the screw trap site, and in the lower 1.8 km of the Little Wind River, from mid-March through May. The redd count in the surveyed reaches was expanded by 1.62 fish/redd to estimate winter steelhead escapement, which assumes 0.81 females per redd and a sex ratio of 1:1 (Freymond and Foley 1985).

Four rotary screw traps were strategically located to monitor juvenile outmigration in important subwatersheds and for the basin as a whole. The upper Wind River and Trout Creek sites are located on USFS property just downstream of proposed or ongoing habitat restoration projects. The Trout Creek, Panther Creek, and Lower Wind River sites are located near the lowest portions of these basins to determine smolt yield by key subwatershed. Site selection was based on access, presence of suitable juvenile trap anchor sites, and stream channel characteristics that would produce acceptable trap efficiencies. Traps with 1.5-meter diameter cones were located in the upper Wind River at rkm 29, in lower Trout Creek at rkm 3, and in lower Panther Creek at rkm 3. The trap located in the lower Wind River, at rkm 2, had a larger 2.4-meter diameter cone (Figure 1).

### **Mark-recapture study design**

**Adults.** --- A detailed description of the mark-recapture study design can be found in Rawding and Cochran (2005) and is briefly repeated here. Salmon and steelhead were captured in Shipherd Falls fish ladder adult trap at rkm 3. All wild steelhead were anesthetized, bio-sampled, double Floy tagged and released upstream. Wild summer steelhead trapped between June and mid-November were tagged with bright, fluorescent tags. Summer steelhead captured from mid-November to April were tagged with white tags and winter steelhead were tagged with light blue tags. Steelhead were able to jump Shipherd Falls from the start of trapping on June 5, 2005 through October 18, 2005. The adult trap was left open during the month of May, when few adult steelhead were present and because limited resources did not allow for sampling the large return of hatchery spring Chinook salmon.

A combination of mark-recapture and mark-resight methods were used to estimate the summer steelhead population (Rawding and Cochran 2005). The recapture events occurred at the Trout Creek fish trap and resight occurred through snorkeling. Following the methods of Thurow (1994), snorkelers worked downstream in groups of two to four to cover the 3 to 8 km in each section. Snorkelers tried to keep equi-distant from each other and in a straight line perpendicular to the flow. Each person was responsible for a field of vision, usually from their right shoulder to the adjacent snorkeler's right shoulder or right bank. The left most snorkeler was also responsible from their right shoulder to the left bank. Groups stopped at the beginning and end of each pool, where most steelhead were observed, to record their counts. Each snorkel team recorded the number of tagged and untagged fish that were observed.

**Smolts.** --- A detailed description of the mark-recapture study design used to estimate smolt abundance can be found in Rawding and Cochran (2005) and is briefly described here. Steelhead smolts were captured in four rotary screw traps, three of which were located near the mouth of key subwatersheds with a fourth located near the mouth of the Wind River subbasin. Traps were installed prior to smolt outmigration usually in late March or early April and were fished through June. Traps were fished at least one week after the last smolt was captured. Captured smolts were anesthetized, bio-sampled, and examined for tags or marks. Unmarked smolts were batch marked with a Panjet inoculator using alcian blue dye (Hart and Pitcher 1969; Thedinga and Johnson 1995). Marks were unique to each location and rotated weekly. Every three weeks the same marks were used. The marking schedule used in 2006 is shown in Table 1. The use of marks that could be linked to individual traps allowed all marks to be pooled for analysis at the lower Wind trap. Since the lower Wind trap has much lower trap efficiency than the other sites, pooling of marks allowed desired levels of precision to occur when population estimates were made. Mark retention is high for this type of mark (Thedinga and Johnson 1995) and we assumed that no marks were lost during the outmigration period. In 2006, all steelhead smolts were Panjet marked and approximately 50% were tagged with coded-wire-tags (CWT) in the right cheek and the remaining 50% received Passive Integrated Transponder (PIT) tags. Thus every smolt received a alcian blue mark and was also tagged with either a CWT or PIT tag.

Juvenile PIT tagging was initiated in 2003 because these tags allow for individual identification of smolts and adults. Adult and juvenile PIT tag detection takes place at Bonneville Dam, the Columbia River estuary (Ledgerwood et al. 2004), Wind River and Trout Creek adult traps, and all Wind River juvenile traps. Recently, the USGS installed two PIT tag detectors in the Hemlock Dam fishway, further increasing the opportunity to detect PIT tagged fish in the system. This combination of detection sites allows for estimates of wild steelhead timing at Wind and Columbia River sites, and travel time between these sites. The timing of adult steelhead between Bonneville Dam and Wind River will improve the accuracy of steelhead race determinations at Shipherd Falls. In addition, the survival of smolts can also be estimated using the Cormack-Jolly-Seber model (Burnham et al. 1987). Although PIT tags provide additional information required for more comprehensive analyses, PIT application is more invasive than CWT application and may cause additional mortality, which would bias smolt outmigration estimates. To address this concern, analyses will be conducted over the next few years to determine if there are significant differences in survival between fish receiving the two tag types.

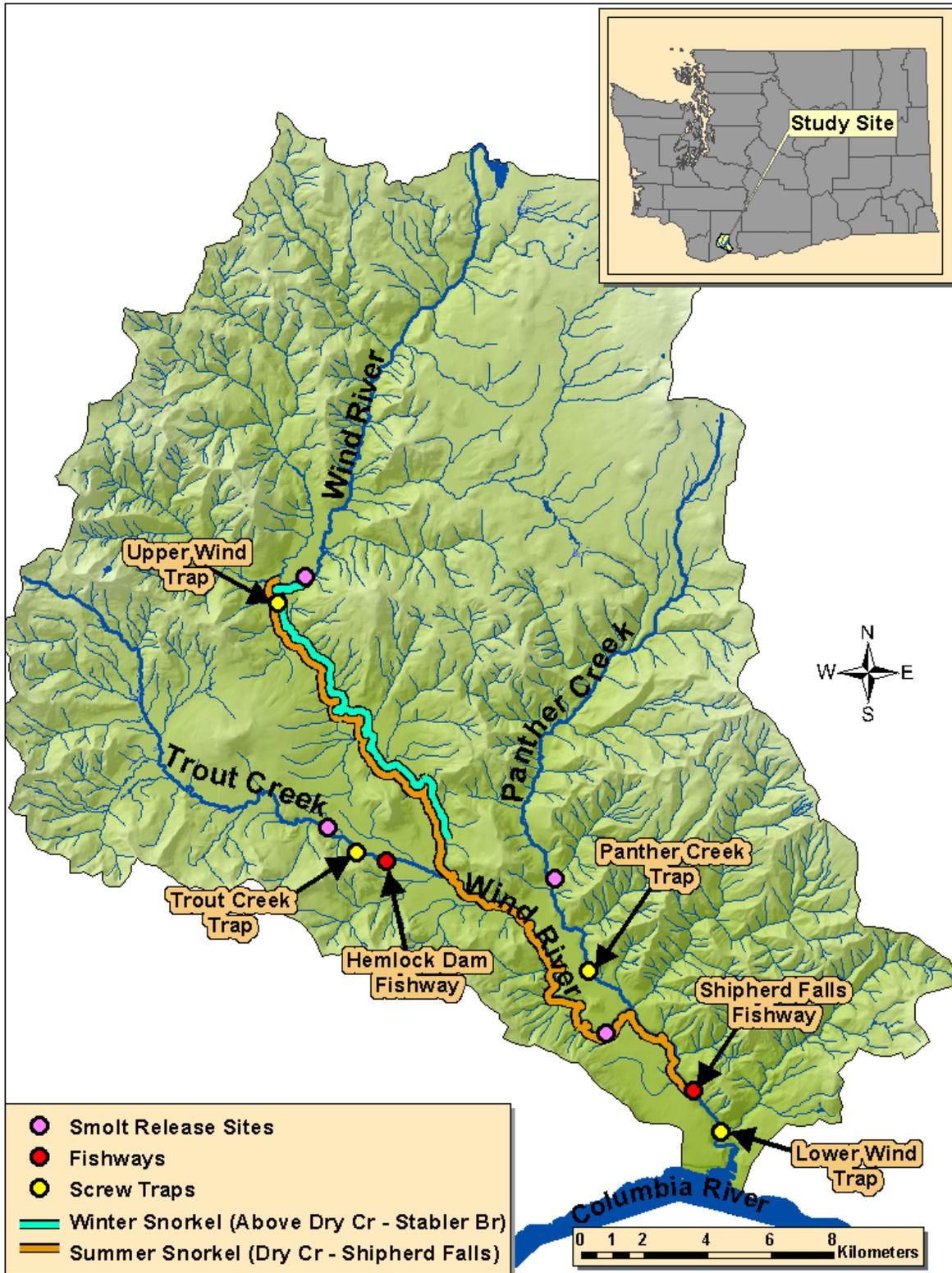


Figure 1. Wind River subbasin with adult and juvenile trapping sites, juvenile release sites, and snorkel survey sections.

Table 1. Mark schedule for steelhead smolts by trap location during the 2006 outmigration.

Statistical Week	Trap Site			
	Lower Wind	Trout Creek	Panther Creek	Upper Wind
13	LV+RV	AN+UC	LP+UC	RP+UC
14	LV	AN	LP	RP
15	RV	AN+LC	LP+LC	RP+LC
16	LV+RV	AN+UC	LP+UC	RP+UC
17	LV	AN	LP	RP
18	RV	AN+LC	LP+LC	RP+LC
19	LV+RV	AN+UC	LP+UC	RP+UC
20	LV	AN	LP	RP
21	RV	AN+LC	LP+LC	RP+LC
22	LV+RV	AN+UC	LP+UC	RP+UC
23	LV	AN	LP	RP
24	RV	AN+LC	LP+LC	RP+LC
25	LV+RV	AN+UC	LP+UC	RP+UC

- Mark codes refer to fins as follows: LV=left ventral, RV=right ventral, AN=anal, LP=left pectoral, RP=right pectoral, LC=lower caudal lobe, UC=upper caudal lobe.

### Data Analysis

The Lincoln-Petersen estimate is often used to estimate salmon and steelhead abundance. One extension to the simple Lincoln-Petersen estimator was developed by Darroch (1961) for temporally or geographically stratified experiments and this approach is often used to estimate smolt outmigration (Dempson and Stansbury 1991, Thedinga et al. 1994, Carlson et al. 1998, Bjorkstedt 2000). Another extension was developed by White (1996) for multiple mark-resight experiments and this method is used to estimate adult summer steelhead abundance in the Wind River.

**Adults.** --- Four methods were used for estimating adult summer steelhead abundance labeled as “Trout Creek”, “Trout Creek Early”, “Winter Snorkel & Trap”, and “Jumpers” (Rawding and Cochran 2005). The Trout Creek method was a mark-recapture estimate of all summer steelhead passing Shipherd Falls and recovered in Trout Creek. The Trout Creek early method was a mark-recapture estimate for all summer steelhead passing June through November 15 plus the count of summer steelhead using the ladder for the remainder of the season. Winter snorkel surveys and adult trapping were combined in the third method, which was a mark-recapture estimate of summer steelhead tagged from the start of trapping in June through mid-November, added to the count of steelhead using the ladder after this date.

The fourth method was termed the Jumper method, because it depends on the ratio of fish successfully jumping Shipherd Falls to those observed in the trap (Bradford et al. 1996). In early August, snorkel surveys from Dry Creek to Shipherd Falls were used to resight tagged and untagged steelhead. In most years, few steelhead have entered Trout Creek by this date but if fish were captured they were included in the estimates. A second snorkel survey was conducted

in September or October. By subtracting the August population estimate from the September estimate, the number fish passing Shipherd Falls during this period was estimated. The population estimate in this period was divided by the number of fish using the ladder to obtain a ladder multiplier. This ladder multiplier was used to expand for the number of steelhead passing after the last snorkel period through the remainder of the period where steelhead were able to jump the falls. The trap count after this date was then added to this estimate.

In the first three methods variance was estimated for the entire season. In the Jumper method, variance was calculated through the fall snorkel survey. However, variance has not been calculated for the period between the fall snorkel survey and the end of the jumping period. Therefore, the 95% confidence interval (CI) for the jumper method is not complete. Adult steelhead population and precision estimates were calculated using NOREMARK software (White 1996). Individual population estimates for each sampling occasion (k) are estimated using a modification of the simple Petersen estimate (Chapman 1951), which is corrected for small sample size:

$$N = \frac{(M_i + 1)(n_i + 1)}{(m_i + 1)} - 1 \quad (1)$$

where N = population estimate,  $M_i$  = the number of tagged steelhead in the population that are in the survey area surveyed at the time of the  $i^{th}$  sighting survey. For all  $M_i$  constant, define  $M = M_i$ ,  $n_i$  = number of steelhead seen during the  $i^{th}$  sighting survey, consisting of  $m_i$  marked steelhead and  $u_i$  unmarked steelhead, so that  $n_i = m_i + u_i$ ,  $m.$  = total number of sightings of wild steelhead, so that  $m. = \sum m_i$ , and  $u.$  = the total number of sightings of unmarked steelhead, so that  $u. = \sum u_i$ , where  $i = 1, \dots, N - T$ .

Seber (1982) provides an approximate unbiased estimate of the variance:

$$\text{Var} = \frac{(M_i + 1)(n_i + 1)(M_i - m_i)(n_i - m_i)}{(m_i + 1)(m_i + 1)(m_i + 2)} \quad (2)$$

and normal confidence limits were calculated from the equation:

$$95\% \text{ CI} = 1.96 * \sqrt{\text{Var}}. \quad (3)$$

The sample size for the Trout Creek and Trout Creek Early estimates included only one recapture occasion. Therefore the population estimate, variance, and 95% CI were calculated using equations 1 through 3. Since there was more than one sampling occasion, adult steelhead population estimates for the jumper and winter snorkel methods were calculated using the joint hypergeometric maximum likelihood estimator (JHE; Bartmann et al. 1987) in NOREMARK software (White 1996).

$$\mathcal{P}(N | M, n_i, m_i) = \prod_{i=1}^k \frac{\binom{M}{m_i} \binom{N-M}{n_i - m_i}}{\binom{N}{n_i}} \quad (4)$$

White (1996) indicates this estimator assumes that the marked animals are a representative sample from the population and each animal in the population has the same sighting probability on an occasion as every other animal, but sighting probabilities can vary across occasions. The population estimate is found by iterative numerical methods, and confidence intervals are determined with the profile likelihood method (Hudson 1971, Venzon and Moolgavkar 1988). Furthermore, this estimator assumes that the population is geographically closed. The number of marked animals is the same for each survey in the above equation, although the probability of sighting animals is not assumed to be the same for each survey.

Winter steelhead passed Shipherd Falls during a period when jumping was not successful, so the trap count was the population estimate through the period of trap operation. Since few winter steelhead may pass during May when the trap is not operated, the percentage of wild winter steelhead passing in May is based on trap data from other basins. Winter steelhead spawning below the trap were estimated using redd surveys as described above.

**Smolts.** --- Smolt abundance was estimated using a pooled or stratified Petersen estimator (Rawding and Cochran 2005). Outmigration data were analyzed using the maximum likelihood estimator for stratified populations developed by Darroch (1961) as illustrated by Seber (1982). This is a standard method for estimating salmonid smolt population abundance (Dempson and Stansbury 1991, Rawding and Groesbeck 2004). The software used for this analysis is a program called DARR (Darroch Analysis with Rank Reduction) developed by Bjorkstedt (2000). DARR 2.0 was used and it is an improved version of the original program (Bjorkstedt 2005). In a temporally stratified study design, fish are marked and released in  $s$  tagging strata, and tagged and untagged fish are recovered in  $t$  recovery strata. The number of smolts captured in recovery stratum  $j$  is  $u_j$ ,  $m_i$  is the number of marked individuals released in tagging stratum  $i$ , and  $r_{ij}$  is the number of marked fish released in tagging stratum  $i$  that are recaptured in recovery stratum  $j$ . The probability that a fish tagged in the  $i^{\text{th}}$  period, will be captured in the  $j^{\text{th}}$  period, is the joint probability ( $\pi_{ij}$ ) that an individual released in period  $i$  will resume migration and is susceptible to capture during period  $j$  (migration probability  $\theta_{ij}$ ) and is captured during period  $j$  (capture probability  $p_j$ ). The joint probability is  $\pi_{ij} = \theta_{ij} p_j$ . Darroch (1961) provided a maximum likelihood estimator for obtaining  $n_j$  where  $s = t$  and the rows of  $R, \{r_i\}$ , are mutually independent and

$$\begin{aligned} r_i &\sim \text{multinomial}(m_i, \pi_{ij}) \\ u_j &\sim \text{binomial}(n_j, p_j) \end{aligned}$$

where  $i = 1, 2, 3, \dots, s$ , and  $j = 1, 2, 3, \dots, t$ .

Data are arranged in matrices as

$$\mathbf{u} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix}, \quad \mathbf{m} = \begin{pmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{pmatrix}, \quad \mathbf{R} = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1t} \\ 0 & r_{22} & \dots & r_{2t} \\ \dots & \dots & \dots & \dots \\ 0 & \dots & 0 & r_{st} \end{pmatrix}$$

The capture probability or the trap efficiency for each period is estimated as the proportion of marked fish that are recaptured from the matrices:

$$\mathbf{P} = \mathbf{p}^{-1} \quad (5)$$

Counts of smolts are expanded to estimates of abundance

$$\mathbf{n} = \mathbf{D}_u \mathbf{P} \quad (6)$$

where  $\mathbf{p} = \mathbf{R}^{-1} \mathbf{m}$ ,  $\mathbf{R}^{-1}$  is the inverse of the recapture matrix,  $n_j$  is the estimated number of smolts migrating past the trap in the  $j^{\text{th}}$  recovery period,  $\mathbf{D}_u$  is a matrix with elements  $\mathbf{u}$  arranged along the diagonal with zeros elsewhere, and  $\mathbf{u}$  is the number of unmarked fish passing the trap during recovery stratum. The total abundance is estimated by summing the estimated number of unmarked individuals.

$$N = \sum n_j \quad (7)$$

The variance-covariance matrix for  $\mathbf{n}$  is approximated by:

$$\text{cov}(\mathbf{n}) \sim \mathbf{D}_n \boldsymbol{\theta}^{-1} \mathbf{D}_u \mathbf{D}_m^{-1} (\boldsymbol{\theta}')^{-1} \mathbf{D}_n + \mathbf{D}_n (\mathbf{D}_n - \mathbf{I}) \quad (8)$$

where  $\mathbf{D}$  is the diagonal matrix,  $\mathbf{I}$  is an identity matrix, elements of the vector  $\mathbf{u}$  are calculated  $u_i = \sum_j (\theta_{ij} / p_j) - 1$ , and  $\boldsymbol{\theta} = \mathbf{D}_m^{-1} \mathbf{R} \mathbf{D}_p$ . The estimated variance for the total population estimate is obtained by summing the elements of the variance-covariance matrix for the stratum estimates. Normal confidence limits were calculated from equation (4).

To increase the precision of the smolt estimate, the partial pooling option in DARR 2.0 was implemented. Guidance on appropriate methods of pooling mark and recovery strata are not always clear (Schwarz and Taylor 1998). Two diagnostic chi-square tests were used to determine if pooling adjacent strata was valid (Darroch 1961, Arnason et al. 1996, Schwarz and Taylor 1998). The equal proportions test determines if the ratio of marked to unmarked fish is constant across all strata and the complete mixing test determines if recovery probabilities are constant across all strata. If either test yields p-values greater than 0.05, strata were pooled.

Schwarz and Taylor (1998) indicated that recovery strata may be arbitrarily pooled without affecting the consistency of the Petersen estimate. Since the Darroch estimate is only valid when the number of tagging and recovery strata are equal, a DARR algorithm pools the recovery strata to match the tagging strata. The purpose of this pooling was to develop homogeneous periods for the population estimate and to increase the precision of the seasonal migration estimate. Estimates in the results section are reported as pooled, initial, and final. The pooled estimate was obtained by pooling all marks, recaptures, and captures into a Petersen estimate using equation 1. The initial estimate was obtained by entering the stratified weekly data into DARR and allowing the algorithms in the program to pool strata as needed for convergence. The final estimate included full or partial pooling based on the chi-squared tests for equal proportions and complete mixing as described above.

## Results

**Adults.** --- The results of the four different adult summer steelhead population estimates are shown in Table 2. The Jumper estimate was calculated using an average summer steelhead jumper rate from return years 2000-2006. The timing of the August 2006 snorkel survey was late, which narrowed the timeframe between the August and September estimates. Fish passage during this narrow window was not representative of the entire period that steelhead are able to jump Shipherd Falls, therefore an average from all years was used to expand the trap count between September and the end of the jumper period.

Table 2. Abundance and precision estimates of Wild summer steelhead in the Wind River during spawn year 2006 using four methods.

Method	Estimate	95% CL	CV
Trout Creek	560	429-690	12%
Trout Ck Early	546	422-669	12%
Winter Snorkel	607	512-743	10%
Jumper	648	620-683	2%

Winter steelhead passed Shipherd Falls during a period when jumping was not successful, so the trap count was the population estimate through the period of trap operation (Table 3).

Approximately 92% of the adult wild winter steelhead pass the adult trap on the nearby North Fork (NF) Toutle River by May 1 (WDFW unpublished data). There were 21 winter steelhead trapped at Shipherd Falls through the end of April, which expands to an estimate of 23 using timing data. Three winter steelhead redds were observed in the Wind River between Shipherd Falls and the screw trap site. Six redds were counted in the lower 1.76 km of the Little Wind River. Total escapement for the Wind River below Shipherd Falls and the Little Wind River was estimated to be 15 adult winter steelhead. Final estimates of winter steelhead returns above Shipherd Falls, below Shipherd Falls, and in the Little Wind River are in Table 3.

Table 3. Winter steelhead escapement estimates in the Wind River based on expanded trap data and redd surveys.

Section	Counted Redds	Total Redds*	Fish Count	Expansion	Total Escapement
Little Wind River	6	6	NA	1.62 fish/redd	10
Wind R. below Shipherd	3	3	NA	1.62 fish/redd	5
Wind R. above Shipherd	NA	NA	21	Count/0.92	23
Total estimated winter steelhead escapement:					38

**Smolts.** --- Smolt yield was calculated for all four trap locations. The estimated smolt yield ranged from 961 in Panther Creek to 19,125 for the lower Wind River (Table 4). The lower Wind River screw trap is located ~2 km upstream from the Columbia River and in 2006 over 99% of the steelhead spawning occurred above this site. The steelhead smolt composition is composed of both summer and winter steelhead but it is not possible to distinguish between these two races using visual inspection. The smolt yield from Panther Creek, Trout Creek, and the Upper Wind River was 5%, 7%, and 11% of the total yield. The estimated smolt production from the area above the Lower Wind River trap and below the three upper traps was 77% of the smolt yield.

Table 4. Catch and population estimates for naturally produced steelhead smolts emigrating past the all traps, 2006 (**final estimates in bold**).

Trap Location	Petersen Estimate	Periods	Catch	Migration Estimate	SE	Lower 95% CI	Upper 95% CI	CV
Panther	Pooled	1-11	470	961	40	883	1038	4%
	Initial Strata	1-2,3,4,5,6,7,8,9-11		965	42	884	1047	4%
	<b>Final Strata</b>	<b>1-11</b>		<b>961</b>	<b>40</b>	<b>883</b>	<b>1038</b>	<b>4%</b>
Trout	Pooled	1-12	529	1428	75	1280	1575	5%
	Initial Strata	1-5,6,7,8,9,10-12		1451	82	1291	1612	6%
	<b>Final Strata</b>	<b>1-12</b>		<b>1428</b>	<b>75</b>	<b>1280</b>	<b>1575</b>	<b>5%</b>
Upper Wind	Pooled	1-12	613	1908	106	1699	2116	6%
	Initial Strata	1-3,4,5,6,7,8,9,10-12		2127	173	1788	2467	8%
	<b>Final Strata</b>	<b>1-5, 6-12</b>		<b>2044</b>	<b>143</b>	<b>1765</b>	<b>2325</b>	<b>7%</b>
Lower Wind	Pooled	1-14	1441	19125	1253	16669	21581	7%
	Initial Strata	1-5,6,7,8,9,10, 11-14		18497	1423	15707	21287	8%
	<b>Final Strata</b>	<b>1-14</b>		<b>19125</b>	<b>1253</b>	<b>16669</b>	<b>21581</b>	<b>7%</b>
Area between traps	Pooled			14829	1260	12359	17300	8%
	Initial strata			13953	1437	11137	16769	10%
	<b>Final Strata</b>			<b>14692</b>	<b>1264</b>	<b>12216</b>	<b>17170</b>	<b>9%</b>

## Discussion

**Assumptions.** --- Seber (1982) listed the standard assumptions of the Petersen method that apply to mark-recapture experiments: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (4) marking does not affect catchability; (5) fish do not lose their marks; and (6) all recaptured marks are recognized. Although these assumptions have not been rigorously tested, preliminary analysis suggests that no major violations have occurred. However, until they can be rigorously evaluated our adult and smolt wild steelhead estimates should be considered preliminary (Rawding and Cochran 2005).

Using the jumper method, adult summer steelhead population estimates have improved from a low of 193 in 2000 to a high of 1,067 in 2003 (Figure 2). The 2006 estimate is the fourth highest since trapping began at Shipherd Falls in 1999, and is a 19% increase over 2005. All methods over the seven-year period yielded similar adult population estimates. The Trout Creek and Trout Creek Early estimates were the least precise (Table 5) because they had the lowest recovery rate for marks of all the methods used. Trout Creek represented less than 10% of the annual Wind River adult summer steelhead population, and limiting analysis to the Trout Creek groups assumes that they are fully representative of all steelhead passing Shipherd Falls, which may or may not be the case. Potentially the most precise population methodology with the least likelihood for major violations of mark-recapture assumptions was the Winter Snorkel & Trap method. This approach uses winter snorkel surveys plus the Trout Creek trap numbers to estimate abundance of steelhead passing through mid-November and also adds steelhead passing after this date to the estimate.

As stated above, the precision of the Jumper estimate does not include a variance from the fall snorkel survey to the end of jumping in late October and early November. Only the Trout Creek and Jumper methods provided estimates for all years. Due to few recoveries in the Trout Creek method, this estimate is not precise. All methods yielded similar estimates but for consistency, we recommend that Jumper estimates be used as preliminary estimates for stock status. Since fewer assumptions are involved in calculating the winter snorkel and trap methods, and it is more precise than the Trout Creek methods, this method is preferred whenever environmental conditions allow. However, due to this uncertainty the jumper method will continue to provide estimates in most years.

Table 5. Four estimates of Wind River wild adult summer steelhead escapement above Shipherd Falls for spawning years 2000 - 2006.

Spawn Year	Trout Creek		Trout Creek Early		Winter Snorkel & Trap		Jumpers <sup>a</sup>	
	Pop. Est.	95% CI	Pop. Est.	95% CI	Pop. Est.	95% CI	Pop. Est.	95% CI
2000	200	53-346	NA	NA	NA	NA	193	163-253
2001	479	318-640	462	303-621	478	393-609	416	389-454
2002	581	442-720	526	419-633	600	517-726	669	724-624
2003	1435	1041-1830	1210	911-1509	NA	NA	1067	1013-1133
2004	807	617-967	767	633-1034	NA	NA	816	776-860
2005	540	438-718	514	423-673	552	489-642	542	479-636
2006	560	429-690	546	422-669	607	512-743	648	620-683

a) Jumper ratio was less than 1 in 2000 and 2001, and 13.8 in 2004. Average jumper ratio (3.7) from 2002, 2003 and 2005 was used for estimates in 2000, 2001, and 2004. Average jumper ratio (5.1) from all years (2000-2006) was used in 2006. Represents a minimum variance estimate for the Jumper method because variances were not calculated after the fall snorkel survey.

Shipherd Falls historically segregated winter and summer steelhead by acting as a barrier to most winter steelhead. Therefore, wild winter steelhead abundance above Shipherd Falls is low compared to summer steelhead in the Wind River. Winter steelhead accounted for 2% to 11% of the steelhead run above Shipherd Falls from 2000 to 2006 (Table 6). Wild, adult winter steelhead escapements have ranged from 20 to 53 adults since 2000 (Figure 3).

Table 6. Wild winter steelhead trap counts at Shipherd Falls with expanded estimates for the periods following trap removal for spawn years 2000-2006; expansion based on average wild winter steelhead timing at the NF Toutle River trap.

Spawn year	Trap count	Final day of trap operation	Percent of passage prior to trap removal	Population estimate	Percent of adult steelhead population
2000	13	April 5	65%	20	9%
2001	49	April 30	92%	53	11%
2002	47	May 12	92%	51	7%
2003	25	April 30	92%	27	2%
2004	26	April 30	92%	27	3%
2005	20	May 4	92%	22	4%
2006	21	May 1	92%	23	3%

The escapement of winter steelhead spawning below Shipherd Falls and in the Little Wind River has not been estimated prior to 2006. Redd surveys were conducted in 2001 through 2004, but the surveys were incomplete due to limited resources and flow conditions. Spawning in these

reaches contributes an unknown percentage to the juvenile steelhead production at the lower Wind River trap site. Production models for the basin are incomplete without this escapement data. Verification of the upper limit of steelhead distribution in the Little Wind River, expanding the bi-weekly survey to include a higher percentage of the stream, and/or conducting a peak count survey that covers most or all of the anadromous accessible stream would improve the precision and accuracy of the winter steelhead estimate.

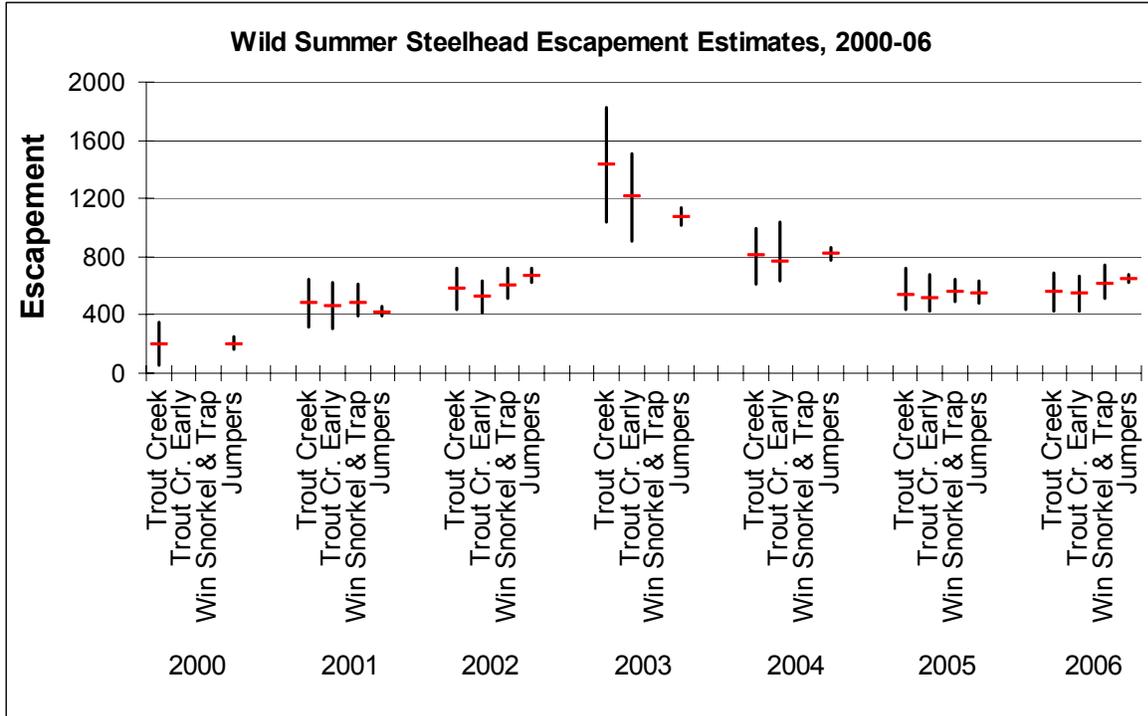


Figure 2. Four estimates of wild summer steelhead escapement at Shipherd Falls with 95% confidence limits for spawning years 2000 - 2006.

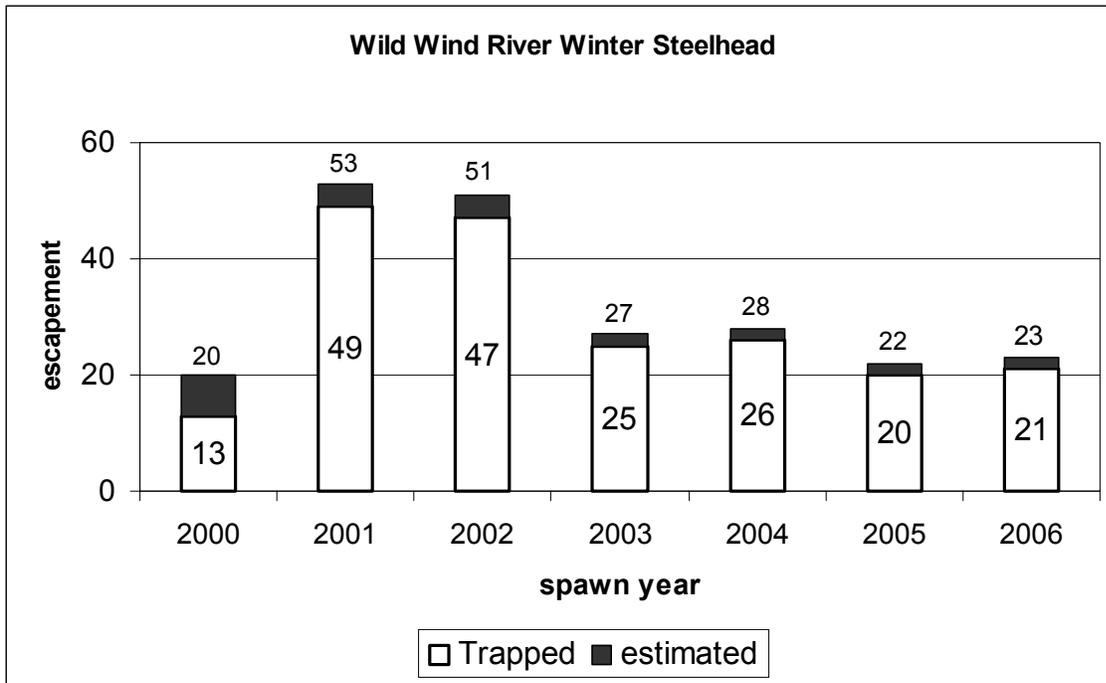


Figure 3. Wild winter steelhead adult counts at Shipherd Falls, 2000 - 2006.

Steelhead smolt production peaked in 2005 and declined by over 50% in 2006 (Figure 4). The 2005 outmigration was the highest since monitoring began in 1995, and was the result of the largest wild, summer steelhead return on record. The sharp decline in smolt production in 2006 cannot be explained by adult population data. The 2003 and 2004 summer steelhead populations, which produced 95% of the outmigrating smolts in 2006, were the two largest since the current monitoring program began in 2000. Volkhardt et al. (2007) suggested that coho smolt abundance is correlated with environmental conditions during spawning and rearing. Future analysis investigating the connection between environmental variables (stream flow and temperature) and smolt production should be explored.

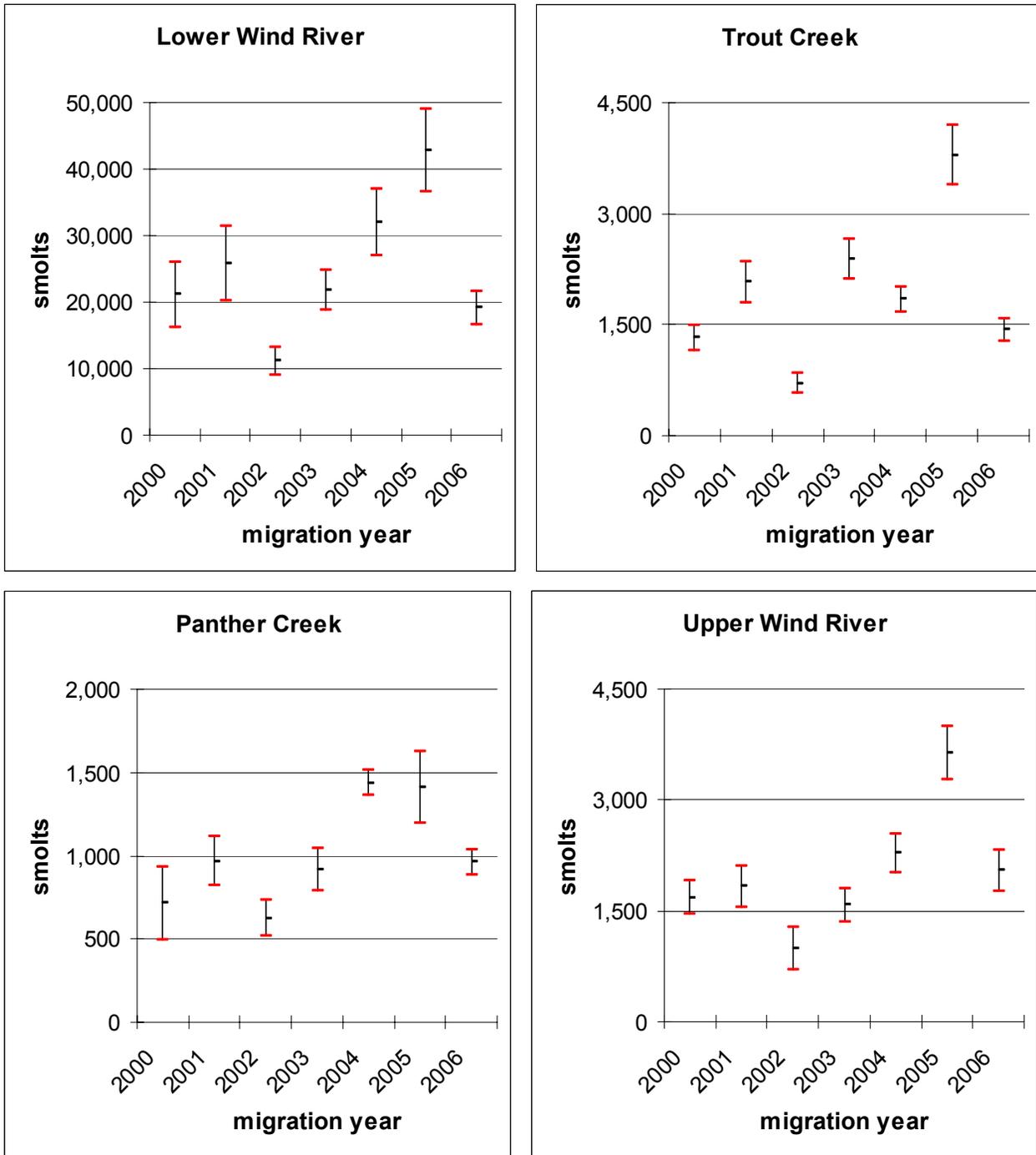


Figure 4 Steelhead smolt outmigration estimates with 95% confidence limits at the four screw trap sites in the Wind River basin, 2000-2006.

**Precision.** --- For small steelhead and salmon populations, it can be difficult to obtain precise abundance estimates. This occurs because it may be difficult to tag sufficient numbers of smolts or to recapture a sufficient number of tagged fish (Bjorkstedt 2000). Robson and Regier (1964) suggested 95% CI of  $\pm 10\%$  for research and  $\pm 25\%$  for management. Cousens et al. (1982) indicated that the International Pacific Salmon Fisheries Commission considered estimates with 95% CI of less than  $\pm 20\%$  to be good. Rawding (1997) conducted simulations based on Wind River trap locations, expected smolt abundance, and expected trap efficiency to establish levels of precision that could be achieved with current funding. These results indicated that for this study a 95% CI of  $\pm 20\%$  of the estimate should be achievable in most years. An alternate expression for precision goals is that the coefficient of variation (CV) should not exceed 10%. For 2006 the precision goal was met at all locations (Table 4). Since 2000 the precision goal has been met 83% (20/24) of the time. Precision is a function of the number of recaptures (Seber 1982), and record low smolt abundance in 2002 and poor site selection in Panther Creek in 2000 were the major factors for not meeting our precision goals (Figure 5). The level of precision at the lower Wind River site is problematic due to a poor site location and we rely upon pooled marks from all traps to reach precision goals.

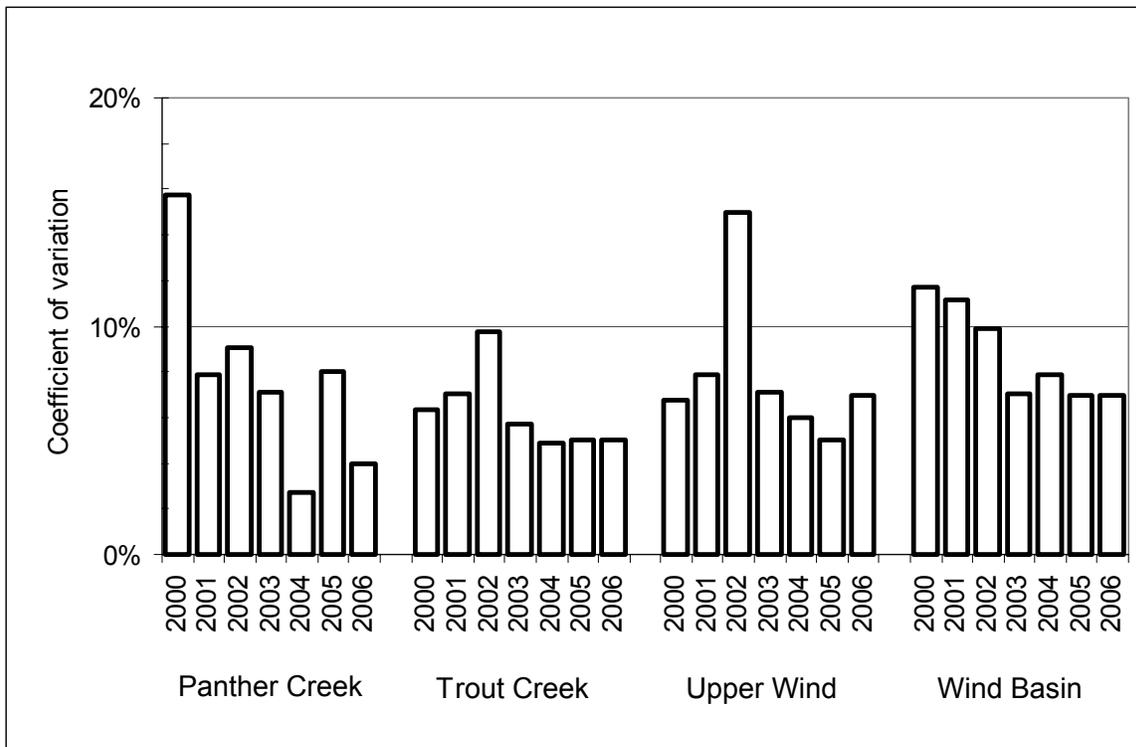


Figure 5 Estimates coefficients of variation for smolt yield by trap site in the Wind River basin, 2000-2006.

No precision goals have been developed for the adult monitoring program. However, we recommend a level of precision similar to the those recommended for smolt estimates, which is

that the 95% CI should be less than  $\pm 20\%$  of the estimate or a CV of less than 10%. The coefficient of variation ranged from 10% to 13% in 2006 depending on the method. During this study, the most precise estimates are made using the winter snorkel and trap or the jumper methods (Figure 6). Complete estimates of precision are not currently available for the Jumper method for summer steelhead or for the expanded trap counts of winter steelhead but are available with caveats in Table 2 and Figure 6.

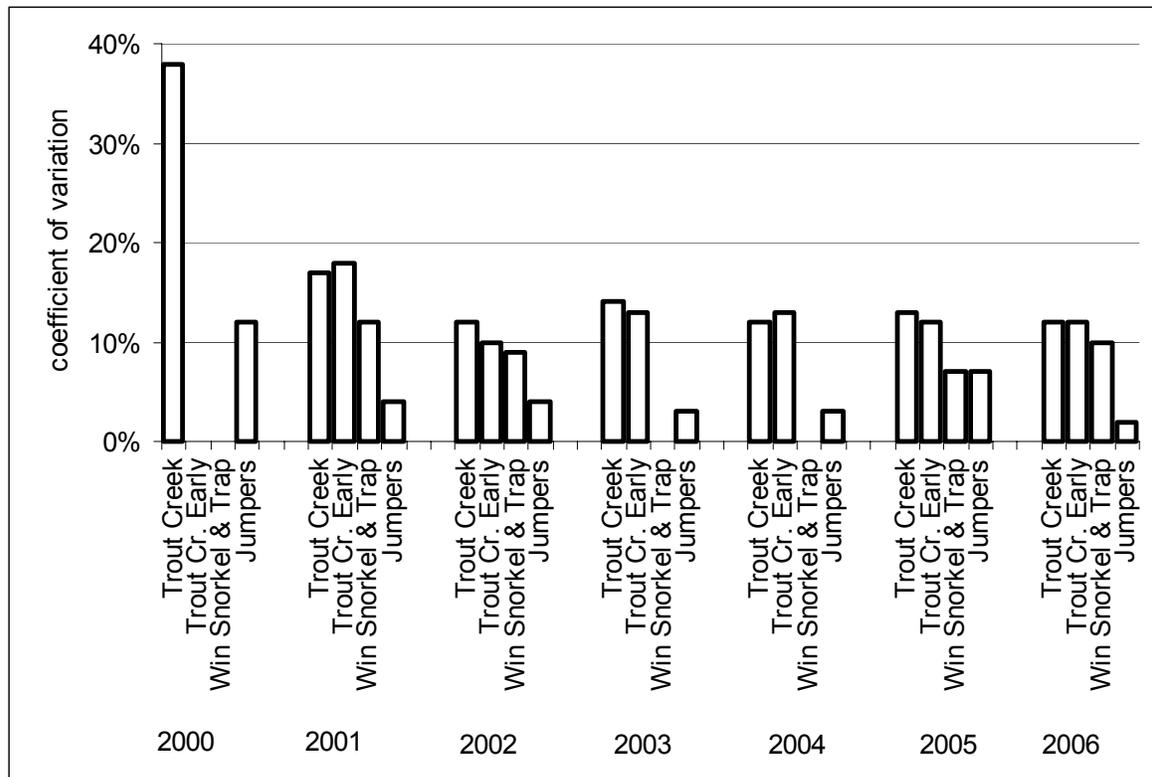


Figure 6. Estimates of the coefficient of variation for the four methods used to estimate adult escapement in the Wind River basin, spawn years 2000-2006.

**Recommendations.** --- Current smolt and adult population estimates do not address all of the uncertainty associated with adult and juvenile estimates and were identified in Rawding and Cochran (2005). For adult steelhead, the variance of the jumper method has not been calculated. Uncertainties identified by Seber (1982), Murphy et al. (1996), Carlson et al. (1998), Schwarz and Dempson (1994), Thedinga et al. (1994), Rawjani and Schwarz (1997), Schwarz et al. (2000), and Schwarz and Taylor (1998) include: tag loss, tagging effects, misidentification of tags, delayed migration, missed days of juvenile trapping, and adult fallback and re-ascension. Over the last 11 seasons the use of PIT tags, double Floy tagging, and holding experiments have allowed measurement of some of these factors but it may be impossible to measure others such as the number of fish migrating when traps are not fished. We strongly recommend analysis of mark-recapture assumptions. The initial analysis should include simulations based on Wind River data and the literature to assess possible bias in population estimates. Specifically, we

recommend a Bayesian approach to extend the work of Rivot and Prevost (2002), Mäntyniemi and Romakkaniemi (2002) for mark-recapture estimates by incorporating uncertainty in the above factors using WinBugs (Spiegelhalter et al. 2003).

The purpose of WDFW adult and juvenile trapping is to monitor population status of ESA listed steelhead in the Wind River and assess the effectiveness of habitat restoration actions. For the last 11 years, adult and smolt abundance have been monitored in the watershed. Reports to date have been smolt and adult steelhead abundance summary reports. The database is now sufficient enough for a technical analysis of population status and we recommend that such an analysis be funded in 2007. After addressing the uncertainty in the mark-recapture estimates as identified above, we recommend developing estimates of freshwater productivity for baseline habitat conditions using a spawner-recruit analysis. The first step would be to extend the Bayesian mark-recapture approach to the August adult snorkel surveys conducted from 1988 to 1999 by modifying the methods of Parken et al. (2003) to obtain population estimates from 1989 to 1998. The Bayesian mark-recapture approach identified above would be extended to spawner-recruit analysis using a state-space modeling approach (Rivot et al. 2004), which includes measurement error in the parameter estimation procedure. This approach would have wide applications for adult and juvenile population estimates in the Columbia Basin. Furthermore, the Columbia River Technical Recovery Teams have included measurement error in developing and assessing recovery goals, partitioning error into process and measurement could lead to different recovery goals and/or estimates of extinction.

The Ecosystem Diagnosis and Treatment (EDT) model (Lestelle et al. 1996) was used extensively for subbasin plans in the Wind River and other Columbia River tributaries. One of the key assumptions in the EDT model for Columbia River steelhead is that steelhead parr successfully rear in the mainstem Columbia River for one year before emigrating as smolts. Although the Columbia River has a large habitat capacity this type of low gradient habitat is not preferred by juvenile steelhead (Gibbons et al. 1985). USGS-CRRL is PIT tagging steelhead parr in the upper Wind River and its tributaries, and this has proved to be successful at assessing survival by site (Pat Connolly USGS, pers. comm.). We recommend that up to 2,000 steelhead parr be tagged at the Lower Wind River screw trap and that USGS-CRRL and WDFW collaboratively assess differences in survival between the Lower Wind site and upriver sites. The results of this experiment would address one of the key uncertainties in the EDT model for steelhead in the Columbia basin.

In general, Wind River steelhead spawn in the upper mainstem or in tributaries. Their offspring rear in these locations for a short period before emigrating to higher gradient reaches in the lower sections of their tributaries or to the Wind River canyon. Based on smolt yields, those parr that emigrate downstream apparently have good survival over the next year and may disproportionately contribute to the total smolt production from the Wind River subbasin. One caveat was the lack of information concerning the relatively low gradient reach from the upper Wind River smolt trap to the Stabler Bridge (rkm 30 to rkm 19). We recommend that an additional smolt-trapping site be added at the top of the Wind River canyon to determine if this area is used by juvenile steelhead for rearing. This trap should be operated through the summer to capture all the parr leaving this part of the basin.

One purpose of PIT tagging was to determine steelhead timing by race at Bonneville Dam to help with race classification at Shipherd Falls. However, the Shipherd Falls adult trap is left open from early May through early June because the size of the trap is too small to hold the large numbers of hatchery spring Chinook salmon passing at this time of the year. An alternative to trapping is to install a PIT tag detector at the trap exit. PIT tag detection would provide information needed for steelhead but would also help with assessment of hatchery spring Chinook salmon returns to CNFH and provide an in-season evaluation of adult returns for fisheries management.

The USFS has recommended Hemlock Dam on Trout Creek be removed to improve the status of wild steelhead populations in the Wind River (USFS 2004). The total count of wild adult steelhead at Hemlock Dam, along with an estimate of smolt production above Hemlock Lake, is a unique wild steelhead dataset. In addition to Trout Creek and Wind River, only two other comparable high quality datasets currently exist for steelhead in the state of Washington and only six over the entire Pacific Rim, respectively (Rawding 2004b). These datasets are priceless because adult counts, rather than estimates, of wild adult steelhead allow a rare opportunity to study the population dynamics and estimate extinction risk of wild steelhead due to environmental variability with small or no measurement error. If the USFS does remove Hemlock dam, WDFW recommends support for adult and smolt monitoring be continued to evaluate the effectiveness of dam removal and restoration efforts in Trout Creek.

Subbasin planning used the EDT model to assess habitat under current, properly functioning conditions (PFC), and historical conditions in the Wind River (LCFRB 2004). Using spawner-recruit analysis Rawding (2004a) demonstrated that the EDT model's prediction of performance under current habitat conditions was reasonable. We recommend the EDT Scenario Builder be used to assess steelhead and salmon performance to prioritize passive and active restoration actions and to assess the sufficiency of actions identified for salmon and steelhead recovery (LCFRB 2004).

## **Acknowledgments**

We would like to thank the following people who assisted with this project: Brian McNamara (WDFW) took part in all aspects of juvenile and adult trap operation and the collection of adult and juvenile data during this study. WDFW employees Bryce Glaser, Todd Hillson, Steve VanderPloeg and Ann Stephenson assisted with trap installation and removal. Tom Burns (WDFW) coordinated fish trapping and maintenance activities in the Shipherd Falls fish ladder. The USFS – Mt. Adams District staff including Steve Ohnemus, Jennifer DeShong and Sean McGroarty provided assistance in adult and juvenile data collection and smolt trap installation and removal. Tim Cummings (USFWS) provided screw traps, trap anchoring systems, and fish sampling equipment that were used in this study. John Hitron and Jeff Blaisdell, at Carson National Fish Hatchery (USFWS), assisted with trap repairs and provided trap storage. Ian Jezorek, Jodi Charrier and Carrie Munz, from (USGS-CRRL) provided assistance in trap installation and PIT tagging. Garfield Klinger allowed us to locate the Panther Creek trap on his property. Jordan Kim, manager of Carson Hot Springs Resort, provided an anchor point for the lower Wind River trap. A crew of dedicated individuals from WDFW, USFS, YN, USGS-CRRL, USFWS and other volunteers snorkeled the Wind River and recorded the number of tagged and untagged steelhead used in the population estimates. We thank John Baugher (BPA), Roy Beaty (BPA) Bryce Glaser (WDFW), Steve Schroder (WDFW), and Jim Scott (WDFW) for review of this report. The majority of this study was funded by BPA and we would like to thank John Baugher for his support of this project.

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## **Appendix 1**

Abundance, Origin, and Age of Spring Chinook Salmon Spawning  
in the Wind River, 2005.

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January, 2007

Project No. 199801900  
Contract No. 19617  
Contract Period: September 1, 2005 to August 31, 2006  
For The Bonneville Power Administration  
Portland, Oregon

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**Abstract**

The spawning escapement of spring Chinook salmon in the Wind River was estimated using a pooled Petersen estimator in 2005. Escapement was estimated to be 237 spawners (95%CI 61 to 413). A total of 69 fish were sampled to determine their origin and all of these individuals were identified as hatchery fish based on fin marks or scale pattern analysis. The age structure of spring Chinook spawning in the river was 1% age 3<sub>2</sub>, 91% age 4<sub>2</sub> and 7% age 5<sub>2</sub>, which was not significantly different than the age structure of the adults that returned to the hatchery. The sex composition of hatchery and in-river spawners was also not significantly different and equaled of 1% jacks, 67% females, and 32% adult males. A total of 3 tags, or less than 5% of the tagged fish, were recovered as carcasses, which led to an imprecise abundance estimate. Mark-resight sampling should be incorporated into the recapture event to improve the precision of the estimate. Similarly, scales should be taken from all seined fish to better define the age structure of in-river spawners.

## **Introduction**

Spring Chinook salmon (*Oncorhynchus tshawytscha*) are not native to the Wind River and were first introduced in the 1950's. Adult escapement to the Wind River is maintained by the Carson National Fish Hatchery (CNFH) operated by the United States Fish and Wildlife Service (USFWS). This program is funded through the Mitchell Act to mitigate salmon losses caused by the operation of the Columbia River hydrosystem. The goal for CNFH is to produce 1.25 million spring Chinook salmon smolts for eventual harvest (USFWS 2002). While providing harvest benefits hatchery spring Chinook salmon may cause negative ecological interactions with native salmonids (USFWS 2002). In the Wind River, possible negative interactions include competition, predation, and disease transfer between hatchery Spring Chinook and native summer steelhead (*O. mykiss*), which are listed for protection under the Endangered Species Act (ESA). Possible positive benefits to native steelhead from hatchery spring Chinook salmon include nutrients from salmon carcasses (Bilby et al. 1998) and juvenile Chinook salmon may serve as a food source for juvenile salmonids (Pearsons and Fritts 1999). The purpose of this study was to estimate the number of spring Chinook salmon escaping to the Wind River, and to determine their origin and age structure.

## **Methods**

### *Fish Sampling*

Prior to spawning, spring Chinook hold in a pool just upstream of CNFH (RM 18). On August 2, 2005, a beach seine (200 ft long, 12 ft high, with ½ inch mesh) was used to capture schooled salmon. A total of 60 were captured (37 females and 23 males). Chick tags were attached to the right opercle of fish in good condition (Maselko et al. 2003). A secondary mark, a left opercle punch was used to assess tag loss. Biological sampling was conducted on all salmon. Data collected included fork length, fin clips, and classification as female, males, and jack. A total of two sampled fish had an adipose fin, and scales were collected from them to determine their origin. All captured salmon were in good condition and were subsequently tagged and released.

Recaptures of marked spring Chinook occurred during carcass surveys that took place from Paradise Creek (RM 23) to Beaver Camp (RM 17). A total of 6 weekly carcass surveys were conducted from the beginning until the end of spawning from August 4 to September 15. All carcasses were examined for marks, tags, and fin clips. In addition, biological data were collected from each carcass including sex, length, and scales.

### *Statistical Analysis*

The origin of spring Chinook salmon spawning in the Wind River was based primarily on adipose fin clips, since all spring Chinook salmon released from CNFH are adipose fin clipped. Scales were collected from fish with intact adipose fins and their origin was identified based on scale pattern analysis. The age and sex composition for spring Chinook salmon spawning in the river was compared to those returning to the hatchery using Chi-square tests.

A pooled Petersen estimator was used to determine the number of spring Chinook that had spawned in the Wind River basin. The estimate is valid if standard assumptions of mark-recapture experiments are met. These assumptions include tagging effects, closure, and equal catchability (Arnason et al. 1996). Possible tagging effects include tag loss (Seber and Felton 1981), mortality due to tagging, and not reporting of all tags (Rajwani and Schwarz 1997). Tags loss was assessed through a double tagging experiment (Seber 1982). In addition to the chick tag, a left opercle punch was applied to serve as permanent mark. Tag loss was assessed from recovered carcasses that possessed a punch hole in their left opercle.

Adult spring Chinook population and precision estimates were calculated using the SPAS software (Arnason et al. 1996). Abundance was estimated using a modification to the simple Petersen estimate (Chapman 1951), which is corrected for small sample size:

$$N = \frac{(M+1)(n+1)}{(m+1)} - 1 \quad (1)$$

where  $N$  = population estimate,  $M$  = the number of tagged Chinook in the population that are in the survey area surveyed,  $n$  = number of Chinook seen during the survey, consisting of  $m$  marked Chinook.

Seber (1982) provides an approximate unbiased estimate of the variance:

$$\text{Var} = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)(m+1)(m+2)} \quad (2)$$

and normal confidence limits were calculated from the equation:

$$95\% \text{ CI} = 1.96 * \sqrt{\text{Var}}. \quad (3)$$

## Results

### *Assumptions*

The closure assumption means that no migration of salmon has occurred in the study area. This assumption was not met as there was both immigration and emigration from the study area. A total of 24 spring Chinook salmon were enumerated at the Shipherd Falls ladder after tagging on August 2, 2005. However, it is likely that most of these fish remained near the fish ladder since only 15 and 18 were observed downstream of the study area during the August 19<sup>th</sup> and 20<sup>th</sup> snorkel surveys, respectively. A total of five tagged fish emigrated from the study area into the hatchery from the time of tagging through the end of trap operations. The Petersen estimate, however, can still be used if the number of tags released is adjusted for migration.

Tag loss was evaluated from 3 recovered carcasses and 5 recovered fish at the hatchery. All fish displayed both the permanent mark and the tag, indicating that tag loss was zero. Both hatchery personnel and surveyors carefully examined fish and it is not likely that tags were missed especially given the visibility of the chick tags. Salmon were observed spawning immediately after tagging and typically die shortly after spawning. Surveys were initiated two days after tagging and even if tagging effects occurred as long as carcasses were recovered, the tagging effects would not effect the population estimate,

It was difficult to asses equal catchability of tagged and untagged fish because there were only three recoveries to assess mixing of tagged and untagged fish between sections. However, the majority of carcasses and recoveries came from the same section adjacent to the hatchery.

#### *Abundance, Origin, and Age Structure*

A total of 65 fish were sampled to determine the origin of spring Chinook spawning in the Wind River. A total of 63 fish were identified as hatchery fish based on fin marks and an additional two fish were identified as hatchery fish based on scale patterns analysis. The age structure of fish spawning in the river was 1% age 3<sub>2</sub>, 91% age 4<sub>2</sub> and 7% age 5<sub>2</sub>, based on a sample of 65 salmon from seining and carcass recoveries, which was not significantly different than the age structure of 592 fish sampled in the hatchery ( $\chi^2 = 0.935$ , df=2, p-value = 0.626). The sex composition of hatchery and in-river spawners based on 63 spawners was also not significant ( $\chi^2 = 0.966$ , df=2, p-value = 0.616) and was composed of 1% jacks, 67% females, and 32% adult males. The abundance estimate for spring Chinook salmon was 237 spawners (95%CI 61 to 413).

#### **Discussion**

Robson and Regier (1964) recommend that 7 recaptures occur in order for a population estimate to have negligible bias. In this experiment a total of three tagged fish were recovered, which indicates that our estimate may be biased. To improve the precision of an adult steelhead abundance estimate, Rawding and Cochran (2006) used mark-resight in conjunction with mark-recapture to increase the number of “recovered” tags. The use of Petersen Disc tags (Lister 1969) would allow surveyors to resight tags from live fish during carcass surveys. We recommend that a visible tag be applied to tagged fish and mark-resight be included in abundance survey designs.

All naturally spawning spring Chinook salmon sampled were identified as hatchery origin fish by adipose fin clips or scale pattern analysis. This suggests that the reproductive success of Carson stock in the Wind River was zero for brood years 2000 through 2002, with the caveat that this is based on few recoveries. Furthermore, the age structure and sex ratios of naturally spawning spring Chinook salmon were not significantly different than those returning to the hatchery. Further supporting that hatchery and in-river spawners were similar.

Naturally spawning hatchery spring Chinook appear to provide few or no adult returns to the Wind River. Thus, there appears to be little fisheries benefit derived from the natural production of this species. Hatchery fish spawning in the Wind River, however, are an ecological risk to ESA listed summer steelhead (USFWS 2002). Consequently, we recommend that in-river spring Chinook salmon population estimates and hatchery/wild origin determinations continue into the future to see if the reproductive success of these fish remains low. These data will be incorporated into a hatchery risk analysis (Pearsons and Hopley 1999) to evaluate any impacts spawning spring Chinook may pose to native salmonids in the Wind River.

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