STATE OF WASHINGTON June 2010

Migration of Hatchery and Wild Steelhead Smolts from the Kalama River in 2009

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Fish Program
Fish Science Division

FPT 10-04

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Introduction

Genetic and ecological interactions between hatchery and wild salmonids have been widely debated and studies are numerous (Leider et al. 1984, Chilcote et al. 1986, Leider et al. 1986, Leider et al. 1990, McMichael et al. 1997, Kostow et al. 2003, Kostow and Zhou 2006, Sharpe et al. 2007). A long-term investigation of steelhead interactions on the Kalama River was initiated in 1975 by the Washington Department of Fish and Wildlife (then Department of Game: Chilcote et al. 1980).

A juvenile outmigrant monitoring component of those investigations in the Kalama River basin began in 1978 as part of a seven-year study by Loch et al. (1985). Use of the traversing fyke net methods developed by Loch et al. outmigrant studies resumed from 1992 to 1994 (Hulett et al. 1995). Juvenile outmigrant trapping was again resumed in the Kalama River in 1998, this time using rotary screw trap gear. This document describes and summarizes the results of rotary screw trapping operations conducted in 2009. This trapping operation provides important baseline data on wild steelhead production and hatchery steelhead outmigration for ongoing studies. The freshwater productivity data will also be used, along with adult return data, to assess steelhead population status and trends in the Lower Columbia ESU. Further, wild-broodstock hatchery programs in the Kalama release winter- and summer-run steelhead and smolt trap operation was a critical tool for evaluation of success of those programs. Specifically the objective of this study was to monitor hatchery and wild juvenile steelhead outmigrants in the Kalama River above Kalama Falls Hatchery (KFH).

Methods

Study Site

The Kalama River, situated in southwest Washington, flows westerly from its headwaters at Kalama Springs, located on the flanks of Mount St. Helens, to its confluence with the Columbia River at river kilometer (rkm) 117. The Kalama is a moderate-sized drainage approximately 113 km in length draining approximately 531 km^2. A fishway and trapping facility at KFH (rkm 17) is adjacent to a falls (Figure 1) that restricts salmon and steelhead passage at some flows Bradford et al. (1996).

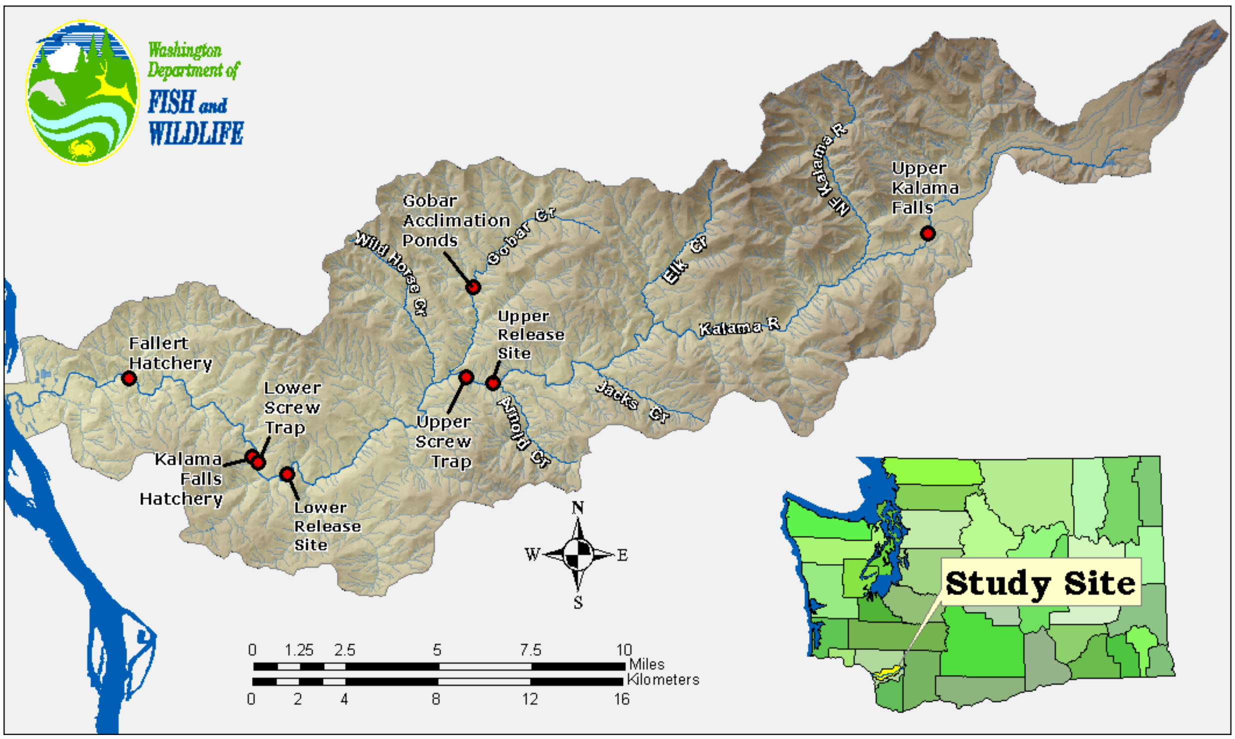


Figure 1. Location of the Kalama River basin with the lower and upper trap and release sites, Gobar Pond, and the Kalama Falls –Hatchery. The upper screw trap site was not used in 2009 (see text).

Smolt Trap Operation

We used a single 8 ft rotary screw trap operated adjacent to KFH at rkm 17. The trap was installed where the river was constricted with a defined thalweg to increase trapping efficiencies. The trap was anchored to large trees with 3/8" steel cable at opposite stream banks and positioned parallel to the stream bank so that flow entered the cone in a straight line. Water velocity produced between 5 and 9 cone revolutions per minute (CRPM). Trap position was adjusted as needed to accommodate varying flows to maximize capture probability without unnecessarily risking loss of the equipment and safety of personnel.

The trap was fished only during nighttime hours because of safety concerns for recreational rafters passing the trap location. Historic data convincingly demonstrated that outmigrant movement during daylight hours is negligible and any outmigrants missed during the day will be accounted for with decreased capture probabilities (Loch 1985). Trap operation was interrupted for brief intervals because of equipment failure, debris loading, or dangerously high flows. In most cases migrant estimates should not be affected by the interruptions because, again, capture probabilities during those intervals will decrease. In some cases when, by chance, the interruption occurred when no marked fish were available for recapture, our final estimates may be biased low.

Hatchery Fish Releases

Wild-broodstock winter- and summer-run steelhead (WBWR and WBSR, respectively) were released from Gobar Acclimation Pond (Figure 1) beginning on 4/24/2009. Release from the pond was accomplished by pulling the outlet screen and removing approximately three 6" dam boards each week. All the dam boards were removed by 5/15/2009 and essentially all the fish left the pond by 5/16/2009. Juveniles emigrating from the pond were counted using a Smith-Root (Vancouver, WA, USA) fish counter.

On 4/29/2009, after the pond screen was removed but before an appreciable number of fish had left Gobar Pond (N = 77 fish), we sampled 218 juveniles by cast net from the pond and recorded length, weight, presence or absence of a CWT, and presence or absence of a fin clip.

Fish Handling

The trap was checked and emptied of fish at least once daily in the morning. When large numbers of fish were captured the livebox was emptied continuously. Fish removed from the livebox onboard the trap were placed in 19 L buckets and anaesthetized approximately 20 at a time in MS-222 solution (~ 60 mg/l). For each specimen, we noted species, presence or absence of fin clips, CWT, and other marks (described below), and recorded the fork length (FL) to the nearest mm from a subset of the migrants. Steelhead and cutthroat juveniles were classified as parr, pre-smolts, or smolts (Rawding et al. 1999). The criteria for steelhead parr included well-developed parr marks and heavy spotting across the dorsal surface; pre-smolts were those fish that measured greater than 120mm FL, had faint parr marks, less prominent dorsal spotting, silvery appearance, and no dark caudal fin margin; smolts measured greater than 120mm FL, had deciduous scales, silver appearance, and a dark pigmentation on the outer margin of the caudal fin. Since smoltification is a process that salmon, steelhead, and cutthroat undergo along their downstream migration, and these salmonids are more than 120 km from the ocean, captures of smolts and presmolts were pooled for the outmigration analysis. Parr captures were excluded from the analyses.

Fish were sampled as quickly as possible and were allowed to recover fully before being either released back into the river downstream of the trap in rapidly flowing water or marked and transported upstream of the trapping location for use in estimating trap efficiency (described below).

Fish Marking

Marks were administered with a Micro-Ject portable jet injector (NewWest Technologies, Santa Rosa, CA, USA) and colored ("photonic") marking formulation injected into the anal fin. Hatchery fish were marked prior to release from the hatcheries with adipose clips (wild-broodstock winter-run) or adipose clips plus coded wire tags (snout tags: wild-broodstock summer-run). The release location of fish captured and marked at the trap was approximately 4 km upstream. All marked fish were allowed to recover fully from anesthesia prior to release.

Abundance Estimation

Mark-recapture estimates and standard deviations (SD) for steelhead outmigrants (wild and hatchery) were generated using the software program DARR (Darroch Analysis with Rank Reduction; Bjorkstedt 2005). DARR calculates a Petersen maximum likelihood estimate for stratified populations as described by Darroch (1961) and illustrated in Seber (1982). We stratified mark-recapture sample periods into approximately seven-day intervals. DARR aggregated the data as needed to prevent estimator failure due to small sample size, while still maintaining as much of the original structure as possible (Bjorkstedt 2005).

Murphy et al. (1994) listed the standard assumptions of the Petersen method that apply in trap efficiency 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. During the smolt trapping season, we took steps to reduce the possibility that these assumptions were violated. Assumption 1 is that of closure, which assumes that no fish leave or enter between sampling occasions. Since smolts are actively emigrating this assumption cannot be met. However, the Petersen estimate is still consistent if the loss rate of tagged and untagged smolts is the same (Arnason et al. 1996). Therefore, the closure assumption is treated as if it were met in this study.

We tested for bias caused by violations of the remaining principle assumptions. We reasoned that the most likely violations of assumptions 2 and 3 would be because of a relationship between trap avoidance and size of the juveniles, especially with steelhead, where large steelhead might avoid the trap more readily. We addressed this issue by testing for differences in recovery rates by length. Although Seber (1982) recommends a comparison of recaptured fish with those not seen again, this is not possible with the batch mark we used for smolt trapping. For batch marked fish, we followed the recommendation of Thedinga et al. (1994) and compared recaptured fish with all marked fish. Assumptions 4, 5, and 6 were tested by holding marked fish to assess tag loss, tag readability, and handling mortality. Properly applied Micro-Ject marks were easily identified and retention consistently exceeded 99% (Sharpe and Glaser 2007). Field staff were trained to properly apply marks and identify marked fish. Also, we intentionally marked only those fish that were not obviously injured or descaled during trapping or handling. Taken together, by marking only healthy fish and testing for delayed negative effects of handling and marking, we increased the likelihood that we were releasing groups of marked fish that were representative of the populations we were assessing.

Results

Wild Migrants

We captured 919 smolt and pre-smolt steelhead between 4/6/09 and 6/18/09, the dates that the first and last wild fish were captured, respectively. Micro-Ject marks were applied to 803 specimens and we recaptured 36 over the course of the season. Because of the small number of recaptures DARR automatically pooled captures and recaptures for intervals 1 through 5 (4/6/09 – 5/10/09) and intervals 8 through 11 (5/25/09 – 6/21/09). The final abundance estimate for wild steelhead emigrating from the Kalama River in 2009 was 27,300 ± 6,783 (Estimate ± SD). Details on trapping of wild steelhead are provided in Appendix Table 1.

Hatchery Migrants

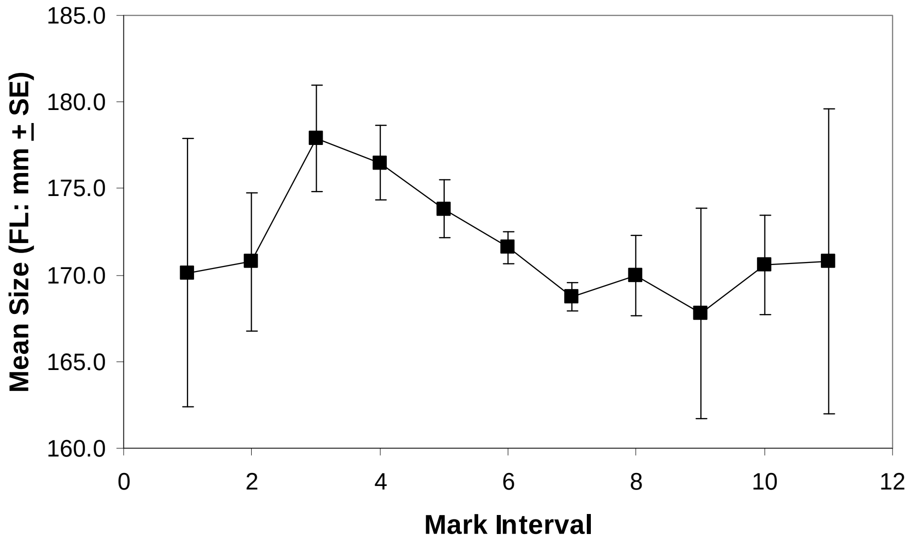
We captured 9,426 hatchery smolt and pre-smolt steelhead between 4/15/09 and 6/18/09, the dates that the first and last hatchery fish were captured, respectively (5,471 wild-broodstock summer-run and 3,955 wild brood winter-run). We made no corrections for loss of CWTs. MicroJect marks were applied to 731 specimens and we recaptured 55 over the course of the season. Because of the small number of recaptures we pooled marks and recaptures of hatchery winter- and summer-run steelhead. Initially, DARR attempted to automatically pool the first 8 trapping intervals. Because of the very low capture probabilities in intervals 2 through 5 and 7 through 8, the effect was to artificially decrease the capture probability applied to captures in interval 6 when the majority of hatchery migrants were captured. The result was an unrealistic abundance estimate for migrants in interval 6 and, consequently, a gross overestimate of total migrants (see Discussion section). We decided to pool intervals 2 through 5 and 7 through 8 *a priori*, and assumed that we would obtain a more accurate estimate of abundance in interval 6.

The final abundance estimate for wild-broodstock summer-run steelhead emigrating from the Kalama River in 2009 was 37,892 ± 15,194 (Estimate ± SD). WDFW hatchery records indicate that 56,583 WBSR were planted out of Gobar Pond so approximately two-thirds (67%) of the WBSR planted in 2009 apparently migrated. The final abundance estimate for wild-broodstock winter-run steelhead emigrating from the Kalama River in 2009 was 41,397 ± 8,231 (Estimate ± SD). Details on trapping of hatchery steelhead are provided in Appendix Table 2. WDFW hatchery records indicate that 64,990 WBWR were planted out of Gobar Pond so, as with the WBSR, approximately two-thirds (64%) of the WBSR planted in 2009 apparently migrated.

Biological Characteristics of Migrants

Wild Migrants: Active migration commenced in approximately trapping interval 3 (4/27-5/03), peaked in Trapping interval 6 (5/11-5/17), and ended in trapping interval 11 (6/15-6/21) (see Appendix Table 1). Mean size was high in the migrants captured in trapping interval 3 and generally decreased thereafter (Figure 2, top). Overall, FL of wild steelhead smolts and presmolts was 172 mm ± 0.55 mm (Mean ± SE; Figure 2, bottom).

Hatchery Migrants: Small numbers of hatchery steelhead were captured immediately after the screens were pulled at Gobar Pond, peak migration occurred in trapping interval 6 (5/11-5/17), coincident with peak migration of wild steelhead, and the migration was essentially over by trapping interval 11 (6/15-6/21) (see Appendix Table 2). The size distribution of WBSR sampled from Gobar Pond closely matched the size distribution of WBSR captured in the smolt trap (Figure 3). However, the size distribution of WBWR hatchery smolts and presmolts captured in the trap differed markedly from the size distribution of juveniles sampled from Gobar Pond just before migration commenced (Figure 3). The WBWR in Gobar Pond were small and bi-modally distributed by size but trapped smolts and presmolts were larger and mono-modally distributed by size. We infer by inspection of Figure 3 that approximately half of the WBWR in Gobar Pond did not attain a size large enough to undergo the parr-smolt transformation.



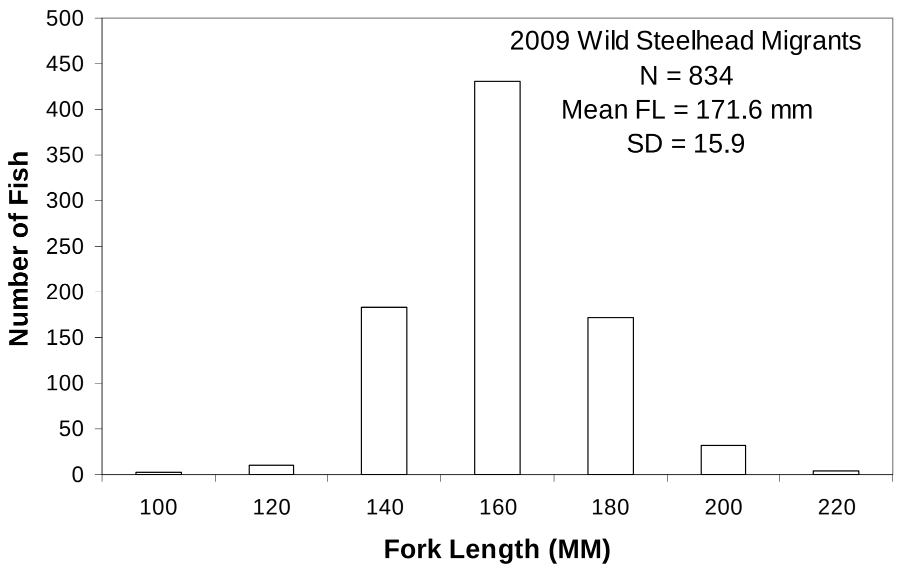


Figure 2. Size over time (top) and size distribution (bottom) of wild steelhead migrants.

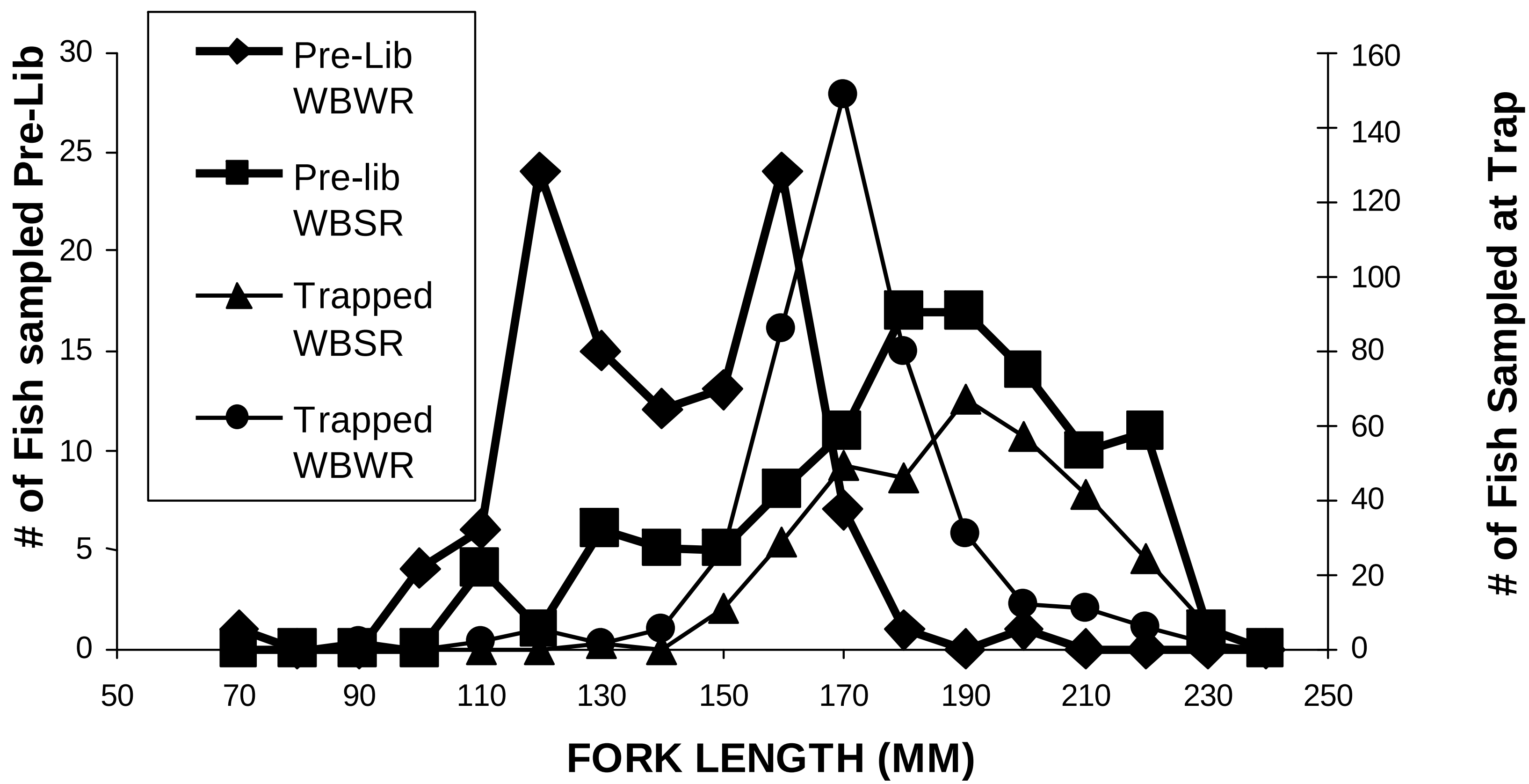


Figure 3. Size distributions of hatchery steelhead in Gobar Pond ("Pre-Lib") and upon capture in the smolt trap ("Trapped").

Tests for Size Selectivity

In K-S tests for bias due to size selectivity of the trapping operation we found no statistically significant differences in the size of either hatchery or wild steelhead marked (Figure 4). We conclude that our estimates were not biased due to size selectivity.

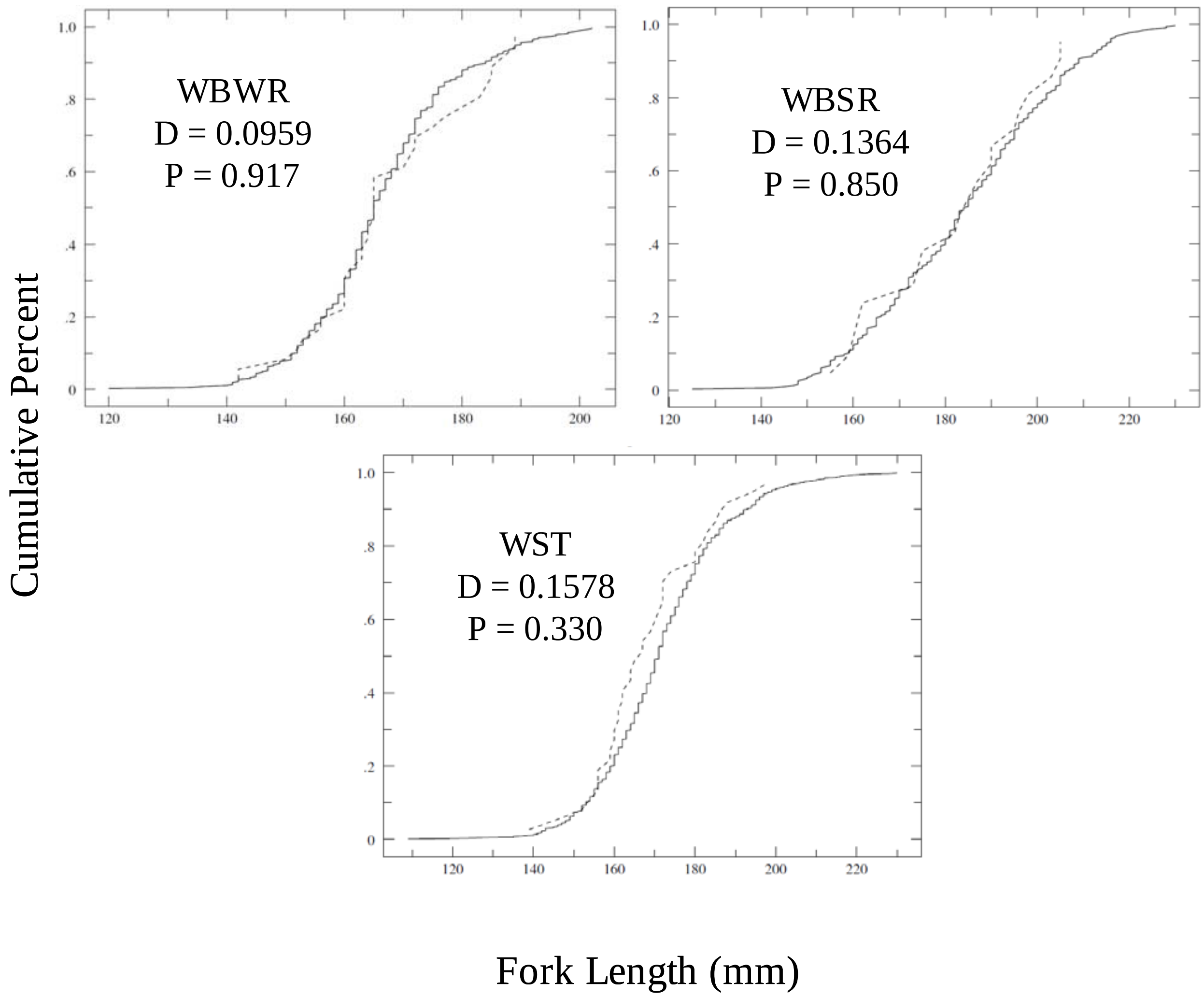


Figure 4.KS-tests for size differences between marked and recaptured steelhead. WST refers to wild steelhead. WBWR and WBSR refer to winter- and summer-run hatchery steelhead, respectively.

Discussion

Wild Migrants

Wild migrants from the Kalama in 2009 were well within the expected range. Recent reliable estimates (Sharpe et al. 2009) showed abundance of smolt and presmolt migrants in the range of approximately 20,000 – 40,000 fish/ year and we estimated that approximately 27,000 fish migrated in 2009. Obtaining an understanding of natural production by steelhead in the Kalama is complex because of the diversity of steelhead types spawning in any year. Production of emigrants are from spawners which can include winter- and summer-run fish, hatchery summer-run steelhead passed upstream as part of an ongoing reproductive success study in the watershed (Hulett et al. 2004; Sharpe et al. 2000), other hatchery steelhead evading our adult trap in the lower watershed, and residual hatchery or resident wild fish. The relative abundance of spawner types will vary year to year and it is unclear how the ability to produce smolts varies among different spawner types.

In the future, tissue samples from emigrants could be used in a mixed stock fisheries analyses based on DNA profiles that could partition smolts to stock origins, similar to the approach used by Sharpe et al. (2000) based on allozyme genetics data. The value of obtaining stock specific production estimates would have to be weighed against the cost of obtaining the required DNA profiles of the adult parents and smolt offspring. Summer-run DNA data will be available for adults that spawned in 2003, 2004, and 2005 from the summer-run reproductive success study being completed on the Kalama. Tissue samples are available for the corresponding adult winter-run and for their smolt offspring captured in 2005, 2006, and 2007.

Hatchery Migrants

A large proportion of the hatchery fish, WBSR and WBWR, failed to successfully migrate from the watershed, becoming either residuals or perishing. The observation that many hatchery steelhead didn’t actually migrate is troubling because the likelihood of negative ecological interactions with native conspecifics and other fish with overlapping ecological requirements is high (McMichael et al. 1997, Sharpe et al. 2007, Viola and Schuck 1995).

However, the proportion of WBWR and WBSR that did appear to migrate in 2009 is an improvement on performance of some earlier cohorts (see Sharpe et al. 2009). Data from those years showed that less than 50-percent of the WBWR appeared to migrate in 2001, 2002, 2004, and 2005. We estimated that more than 60-percent of WBSR migrated for most releases but, in 2005, we estimated that only 40-percent might have migrated past the smolt trap.

Assumption Testing for Abundance Estimation

Perhaps the most important task for successfully conducting a smolt trapping operation is deriving accurate and precise estimates of capture probabilities so that catch can be expanded to yield accurate and precise estimates of abundance. We are not convinced that we fully achieved this task in our 2009 smolt trapping operation. In previous work (Sharpe et al 2009) we showed that it was beneficial to use a 2-trap design in the Kalama where a small trap in the upper watershed was used to provide marked fish for eventual recapture at our main trap near KFH. Fish marked at the lower trap, trucked upstream approximately 1 km and then released were recaptured at a rate lower than the true capture probability of the trapping operation with the consequence of biasing the abundance estimates high. In later work Klungle et al. (In prep.) showed that accurate and precise capture probabilities could be obtained with a 1-trap design if the release location was more than 1 km above the trap. Because of severe funding shortfalls we were not able to use a 2-trap design in 2009 and decided to use a 1-trap design and adopt the recommendation of Klungle et al. (In prep.) to move the release location to a point 4 km above the trap. Lacking the 2-trap operation for comparison we are not able independently test to see if our estimates of capture probabilities might have been biased low. However, we made some observations suggesting that that might have been the case.

First, capture probability estimates in 2009 were consistently and significantly lower for wild fish than for hatchery fish. That has not been routinely apparent in earlier years of trapping. Generally, we have been able to pool recaptures of wild and hatchery steelhead migrants but we were not able to do so in 2009. It may simply be the case that changes in the channel morphology at the trap site in the winter of 2008-2009 decreased the suitability of the site for smolt trapping to the point where, perhaps, increased condition or swimming ability by wild fish was manifested by increased trap avoidance. It was apparent that the trap was not spinning as fast in 2009 as in prior years (2009 range: 5 – 9 RPM; 1999 through 2005 range 6 – 10 RPM).

Second, our pre-liberation sampling of WBWR at Gobar Pond suggested that only about 50% of those fish had attained a size adequate for them to undergo the parr-smolt transformation. Our past experience with these stocks in this watershed has suggested that approximately 60 to 80% of the fish that get large enough during rearing successfully migrate. This past average suggests that only about 30 to 40% of the WBWR should have passed the lower trap and yet we estimated 67% passed the smolt trap.

Finally, our estimate that a total of 79,289 hatchery steelhead migrated from the watershed in 2009 was obtained less objectively than desired. We manipulated the DARR analysis so that the sixth capture interval, when we obtained the highest apparent capture probability during the peak of the migration, was not pooled with earlier capture intervals. Had we allowed the DARR software to pool intervals according to its own algorithm then the abundance estimate exceeded the total number of fish planted in 2009.

Future analyses of these data are warranted. For example, as time and funding become available it might be useful to relate outmigration rates of the hatchery fish to variables such as size of the fish at release, growth trajectories of the fish exhibited during rearing or disease incidence within particular stocks. Such *a posteriori* analyses might prove fruitful because we have noted a great deal of variability both within and between years in these parameters and, especially, a tendency for higher survival and larger smolt sizes in earlier years and higher mortality and smaller more variable smolt sizes in later years.

Acknowledgements

We thank personnel working for the Washington Department Fish and Wildlife at the Kalama Falls Hatchery for their continued cooperation in our research efforts and especially for providing housing for research staff during the smolt trapping seasons. We also thank the smolt trappers Jacquelyn Bouchard (Tribal Technician) and Andrew Perry (Volunteer) for their field support and assistance with data management. We also extend our gratitude to Andrew Murdoch who reviewed this report. Funding was provided by NOAA-Fisheries through the Mitchell Act, WDFW through the Statewide Monitoring Program, and the Cowlitz Indian Tribe.

Literature Cited

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapement and other populations. Canadian Tech. Report of Fisheries and Aquatic Science 2106. 37p.

Bradford, R.H., S.A. Leider, P.L. Hulett, and C.W. Wagemann. 1996. Differential leaping success by adult summer and winter steelhead at Kalama Falls: implications for estimation of steelhead spawner escapement. Washington Department of Fish and Wildlife, Fish Management Technical Report RAD 96-02, Olympia. 56pp.

Bjorkstedt, E.P. 2005. DARR 2.0: Updated software for estimating abundance from stratified mark-recapture data. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-368. 21pp.

Chilcote, M. W., B. A. Crawford, and S. A. Leider. 1980. A genetic comparison of sympatric populations of summer and winter steelheads. Transactions of the American Fisheries Society 109:203-206.

Chilcote, M. W., S. A. Leider, and J. J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society 115:726-735.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Hulett, P.L., C. S. Sharpe, C. W. Wagemann. 2004. Critical need for rigorous evaluation of salmonid propagation programs using local wild broodstock. Pages 253-262 in M.J. Nickum, P.M. Mazik, J.G. Nickum, and D.D. MacKinlay, editors. Propagated Fish in Resource Management. American Fisheries Society, Symposium 44. American Fisheries Society, Bethesda, Maryland.

Hulett, P.L., R.H. Bradford, C.W. Wagemann, and S.A. Leider. 1993. Studies of hatchery and wild steelhead in the lower Columbia region. Progress report for fiscal year 1992. Washington Department of Fish and Wildlife, Fisheries Management Division Report 93-12, Olympia. 70pp.

Hulett, P.L., C.W. Wagemann, R.H. Bradford, and S.A. Leider. 1994. Studies of hatchery and wild steelhead in the lower Columbia region. Progress report for fiscal year 1993. Washington Department of Fish and Wildlife, Fisheries Management Division Report 94-03, Olympia. 52pp.

Hulett, P.L., C.W. Wagemann, C.S. Sharpe, and S.A. Leider. 1995. Studies of hatchery and wild steelhead in the lower Columbia basin. Progress report for fiscal year 1994. Washington Department of Fish and Wildlife, Fish Management Program Report RAD 95-03, Olympia. 44pp.

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society 132:780-790.

Kostow, K. E. and S. Zhou. 2006. The effect of an introduced summer steelhead hatchery stock on the productivity of a wild winter steelhead population. Transactions of the American Fisheries Society 135:825-841.

Leider, S. A., M. W. Chilcote, and J. J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout (*Salmo gairdneri*): evidence for partial reproductive isolation. Canadian Journal of Fisheries and Aquatic Sciences 41:1454-1462.

Leider, S. A., M. W. Chilcote, and J. J. Loch. 1986. Comparative life history characteristics of hatchery and wild steelhead trout (*Salmo gairdneri*) of summer and winter races in the Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences 43:1398-1409.

Leider, S. A., P. L. Hulett, J. J. Loch, and M. W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage. Aquaculture 88:239-252.

Loch, J. J., M. W. Chilcote, and S. A. Leider. 1985. Kalama River studies final report. Part II. Juvenile downstream migrant studies. Washington Department of Game, Fisheries Management Division Report 85-12, Olympia. 63pp.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring Chinook salmon. Transactions of the American Fisheries Society 126:230-239.

Murphy, M. L., J. F. Thedinga, and J. J. Pella. 1994. Bootstrap confidence intervals for trap efficiency estimates of migrating fish. Unpublished manuscript, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, Alaska, 99801-8626.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin and Company, London. 506 pp.

Sharpe, C.S. 2007. Physiological stress responses to automated and manual vaccine injection procedures in yearling coho salmon. North American Journal of Aquaculture. 69:180–184.

Sharpe, C.S., B. Beckman, K. Cooper, and P.L. Hulett. 2007. Growth modulation during juvenile rearing can reduce rates of residualism in the progeny of wild steelhead broodstock. North American Journal of Fish Management. 27:1355–1368.

Sharpe, C.S. and B.G. Glaser. 2007. 2005 Coweeman River juvenile salmonid production evaluation. WDFW Report FPA07-07, Olympia. 32 pp.

Sharpe, C.S., D.A. Thompson, H.L. Blankenship, C.B. Schreck. 1998. Effects of routine handling and tagging procedures on physiological stress responses in juvenile Chinook salmon. Progressive Fish-Culturist. 60:81-87

Sharpe, C.S., P.L Hulett, C.W. Wagemann. 2000. Studies of hatchery and wild steelhead in the lower Columbia Basin. Progress Report for FY 1998, WDFW FPA 00–10, Olympia. 51 pp.

Thedinga, J. F., S. W. Johnson, K V. Koski, J. M. Lorenz, and M. L. Murphy. 1994. Determination of salmonid smolt yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Viola, A.E. and Schuck, M.L. 1995. A method to reduce the abundance of residual hatchery steelhead in rivers. North American Journal of Fisheries Management 15: 488-493.

Appendices

Appendix Table 1. Wild steelhead (WST) catch, mark, and recapture data from Kalama smolt trapping operations in 2009.

Mark Interval	Dates & Marks	WST Catch	WST Marks Out	Recaptures by Recapture Interval 1	2	3	4	5	6	7	8	9	10	11
1	04/06-04/12 Red	7	6	0	0	0	0	0	0	0	0	0	0	0
2	04/13-04/19 Blue	21	20	0	0	0	0	0	0	0	0	0	0	0
3	04/20-04/26 Green	28	26	0	0	0	2	0	0	0	0	0	0	0
4	04/27-05/03 Orange	98	95	0	0	0	1	1	0	0	0	0	0	0
5	05/04-05/10 Pink	107	104	0	0	0	0	1	1	0	0	0	0	0
6	05/11-05/17 Purple	332	245	0	0	0	0	0	17	1	0	0	0	0
7	05/18-05/24 Blue and Green	251	238	0	0	0	0	0	0	6	0	0	0	0
8	05/25-05/31 Orange	39	38	0	0	0	0	0	0	0	1	0	0	0
9	06/01-06/07 Pink	9	9	0	0	0	0	0	0	0	0	0	1	0
10	06/08-06/14 Purple	19	17	0	0	0	0	0	0	0	0	0	1	0
11	06/15-06/21 Red & Green	8	5	0	0	0	0	0	0	0	0	0	0	3

Appendix Table 2. Hatchery steelhead mark, recapture, and catch data from Kalama smolt trapping operations in 2009. WBWR and WBSR indicate wild brood winter-run and wild brood summer-run, respectively. Marks Out and Recaptures are pooled for WBSR and WBWR.

Mark Interval	Dates & Marks	WBSR Catch	WBWR Catch	HST Marks Out	Recaptures by Recapture Interval									
					2	3	4	5	6	7	8	9	10	11
2	04/13-04/19 Blue	1	2	3	0	0	0	0	0	0	0	0	0	0
3	04/20-04/26 Green	1	4	5	0	0	0	0	0	0	0	0	0	0
4	04/27-05/03 Orange	14	1	12	0	0	0	0	0	0	0	0	0	0
5	05/04-05/10 Pink	329	295	179	0	0	0	6	3	0	1	0	0	0
6	05/11-05/17 Purple	4562	2496	167	0	0	0	0	16	5	0	0	0	0
7	05/18-05/24 Blue and Green	465	873	130	0	0	0	0	0	4	0	0	0	0
8	05/25-05/31 Orange	65	180	133	0	0	0	0	0	0	8	0	0	0
9	06/01-06/07 Pink	17	45	51	0	0	0	0	0	0	0	1	0	0
10	06/08-06/14 Purple	15	46	44	0	0	0	0	0	0	0	0	8	0
11	06/15-06/21 Red & Green	2	13	7	0	0	0	0	0	0	0	0	0	3