ANNUAL REPORT

1998 CEDAR RIVER SOCKEYE SALMON FRY PRODUCTION EVALUATION

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The success of this project relies on the hard work of a number of dedicated permanent and temporary WDFW personnel. The Hatcheries Program successfully collected adult broodstock and incubated eggs, releasing over 9.8 million sockeye fry. Eric Volk and Gene Sanborn designed and implemented the otolith-marking program at Landsburg Hatchery. Eric and his staff at the Otolith Lab extracted and analyzed otoliths from the fry sampled at the trap. Scientific Technicians Paul Lorenz, Chuck Ridley and Tim Eichler worked long hours at night operating and maintaining the trap, marking and releasing fry, and enumerating catches. WDFW Wild Salmon Production & Survival Evaluation Unit biologists Mike Ackley and Pete Topping provided valuable logistical support.

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Introduction

Adult sockeye salmon returns to the Lake Washington system have declined from peak runs in excess of 600,000 fish as recently as 1988, to under 100,000 fish in subsequent years. In 1991, a broad-based group comprised of representatives of local governments, the Muckleshoot Indian Tribe, state and federal fisheries agencies, academic institutions, and concerned citizens was formed to address this decline. Resource managers developed a program to investigate the cause(s) of the sockeye decline through research and population monitoring in combination with an artificial production program. Information generated by these efforts will be used to devise a restoration plan for Lake Washington sockeye salmon.

Existing management information indicated that marine survival has averaged 13.1%, varying eight-fold (2.6% to 21.4%) with no apparent decline over the data set, which begins with the 1967 brood. In contrast, however, survival during the freshwater phase has declined in recent years. For the 1985 through 1992 broods, freshwater survival (as indicated by the estimated numbers of presmolts produced/spawner) has averaged only 4.8. This rate is only one third of the average production rate of 14.1 presmolts per spawner for the previous 18 broods (1967-1984).

The majority of sockeye production involves two freshwater habitats: the stream, where spawning, egg incubation, fry emergence, and migration to the lake occurs; and the lake, where the juveniles rear for one year before emigrating to the ocean as smolts. Measuring survival rates in both of these habitats requires quantifying the numbers of hatchery and naturally-produced sockeye fry entering Lake Washington as well as estimating the population as spawners and as smolts.

Production at the Landsburg Hatchery began with the 1991 brood. This brood, released in 1992, and all subsequent sockeye incubated at this hatchery, have been identified with thermally-induced otolith-marks (*Volk et al. 1990*). We developed the trapping gear and methodology to estimate sockeye fry production from the Cedar River in 1992.

During the first three years of this evaluation, we determined that survival of hatchery fry from Landsburg to the trap was very low, often less than 10%. In these three seasons, however, flows during most upriver releases were at or near minimum levels. To avoid this high in-river mortality, beginning in the second year (1993), the majority of the hatchery production was transported and released in the lower river just upstream of Highway I-405. In 1995, we evaluated the effect of flow on survival using ten groups released over a range of flows. Results corroborated the earlier estimates, demonstrating that in-river fry survival is largely a function of flow.

Over the first five brood years of this evaluation, we have also determined that the survival from egg deposition to fry emigration is a function of the severity of peak flows in the Cedar River during the time that the eggs are incubating in the gravel. Therefore, over the range of spawning population levels we have thus far evaluated, the numbers of naturally produced fry entering Lake Washington are the product of the number of eggs deposited and the flow-effected survival rate. In 1996, an estimated 230,000 sockeye spawned in the Cedar River, over twice as many as in any of the previous five years. In 1997, WDFW biologists estimated that 104,000 adult sockeye spawned in the Cedar River.

This report documents the ***1998 Cedar River Sockeye Salmon Fry Production Evaluation***. This trapping project estimated the numbers of 1997 brood Cedar River wild and hatchery-produced fry that entered Lake Washington during 1998.

Goals and Objectives

The primary goal of this project is to measure total sockeye salmon fry production from the Cedar River. Additional goals include estimating the hatchery and wild composition of the nightly fry emigration throughout the season. Accomplishing these goals enables the following estimates, which are critical for understanding the components of this stock's survival decline and the carrying capacity of Lake Washington for rearing sockeye.

1. **The season total of wild and hatchery fry entering the lake**. Relating the pre-smolt population the following spring to this estimate measures rearing survival in the lake.

2. **Survival of natural production**. Relating the estimate of wild fry produced to the estimated egg deposition measures the overall average success of natural spawning. Significant variation in this rate among broods, as a function of spawner abundance and flows, will be assessed through correlation analysis. Analysis of wild emigration timing will also provide insight into survival among certain components of natural spawners.

3. **Survival of hatchery fry by release group.** Correlating in-river survival of hatchery fry with release location, timing, flow and total fry density will help explain the interannual variation in survival rates estimated for wild fry. It will also provide guidance for release location decisions.

4. **Incidence of hatchery fry in the population at lake entry**. Comparing this estimate with the incidence of hatchery fish in the population at later life stages (presmolts and adults) will assess relative hatchery and wild survival rates.

Methods

We estimated the numbers of sockeye fry migrating from the lower Cedar River by operating a trap throughout the season and calibrating the capture efficiency of this gear. During the first four years of this program, we estimated the hatchery and wild composition of nightly and seasonal migrations based on the proportion of marked otoliths in samples taken each night. Beginning in 1996, we reduced the numbers of fry sampled for otoliths for several reasons: natural fry production from the 1995 brood was so low that large catches following hatchery releases were obviously hatchery fish; 80% of the hatchery production was released in the lower river just upstream of I-405; and the budget for otolith analysis was limited. In 1997, although natural production was high, given the budget limitations and the differences in timing between hatchery and wild fry, which became even more apparent in 1996, a hatchery release plan was developed that minimized the need to sample catches for otoliths. The major element of this plan, releasing a portion of the production below the trap, continued in 1998.

Trapping Gear and Operation

The trap is a low angle inclined-plane screen device (3x2x9 ft.), suspended from a 40x15 ft. steel pontoon barge. This structure resembles the larger traps we use to capture smolts throughout the state (*Seiler et al. 1981*). Each night, we fished the traps at a constant depth, from the surface down 16 in. At this depth, the cross-sectional area trapped is 4 ft^2. At a velocity of 4 ft/second, we are trapping 16 cfs.

In previous years, we positioned the trap at R.M. 0.4, approximately 30 ft. off the left bank, and marked the cables at each anchor winch to ensure that we maintained exactly the same trap position in the channel throughout the season. Lateral positioning is critical, as fry distribution is not uniform or random across the channel. In Spring 1997, however, it became apparent that the high flows following the "ice storm" in January 1997, created a gravel bar in front of the trap, which shifted the thalweg towards the opposite bank, directing flow and fish away from the trap at lower flow levels. In early-April 1997, we moved the trap into a new position, off the right bank. By January 1998, the river had formed an even more distinct channel near the right bank, through the extensive gravel beds, which had formed in the lower river. At high flows, this channel was "drowned-out," but as flows decreased, virtually all the water was contained in this discreet channel. In 1998, we placed the trap in this channel, which provided higher velocities at low flows than we have observed in any of the previous years.

We began trap operation on the night of January 18, and fished every night, through April 24, except on January 22, when the heavy debris load prevented trap operation. From April 24 through June 27, we trapped every other night except for a period between May 10-19, when we trapped every third night, and June 2-3, when we fished every night. After June 27, through the end of trapping (July 5), we fished three more nights.

On virtually every date fished, we began trapping before dusk and continued past dawn. To assess the extent of migration during the day, we also operated the trap during some daylight hours on two dates (May 16 and 19).

Each hour, on the hour, captured fish were removed from the trap and enumerated. Large fry catches were counted with an electronic fish counter. In 1997 we calibrated this counter again by passing known numbers of fry through it. In these trials the electronic counter counted 96.6% of the actual number of fish passed through it. In previous years, we estimated the proportion counted at 96.5%.

Trap Calibration

Two assumptions critical for accurate trap calibration involve a known number of fry passing the trap and their capture susceptibility. The first assumption is that all of the marked fry released pass the gear within a certain recovery period. This requirement argues for releasing fish immediately upstream of the trap to minimize their exposure to predation. Marked fry, however, must also be captured at the same rate as unmarked fry. As fry have little ability to avoid the gear in the fast current where we positioned the trap, satisfying this assumption primarily involves achieving the same lateral distribution with marked fry as that of unmarked fry. The further upstream fry are released, the more likely they become distributed as unmarked fry because they are subjected to the same currents.

As in previous years, we estimated capture rate by releasing marked fry at the Logan Street bridge. Fry captured the previous night were marked in a solution of Bismarck brown dye (0.014 g/ℝ for 1.5 hours). The bridge is approximately one mile upstream from the trap, and was selected as a compromise between the opposing needs of releasing fish close enough to avoid predation loss and distant enough to insure natural distribution. To assess whether the calibration groups were distributed naturally, we released fry in three groups, from three locations: right bank, left bank, and mid-channel. Early in the season, as in previous years, release times were separated by an hour or more to enable analysis of capture rates as a function of release location while using only one mark. This year, on several nights (March 31, and April 6-7), we released all the marked fry at one time.

Over the season, from January 24 to April 13, we released groups of dye-marked fry on 40 nights. Recovery rates were correlated with mean nightly discharge to assess the effect of flow on instantaneous capture efficiency.

Hatchery Releases

Over the season, 9,799,300 hatchery-produced fry were released into the Cedar River. Eighty percent of this production (7,748,300) was transported to the lower river, while the balance (2,051,000) was released directly from the hatchery at Landsburg. Fry were released to the lower river above Highway I-405 (Riviera) on 29 nights between February 9 and April 15, and downstream of the trap at the Renton Municipal Airport (Cedar Park) on eight nights between February 4 and March 5. Upper river releases occurred on eight nights, between February 2 and March 13. Group sizes ranged from 11,000 to 570,000 fry (Table 1). Hatchery fry were identified by nine otolith codes, representing early, middle, and late releases at the three different release sites.

Table 1. Hatchery-produced sockeye fry released at three locations, Cedar River 1998.

Release	NUMBER RELEASED			
Date	Landsburg	Riviera	Airport	Total
02/02	**263,000**			**263,000**
02/03	**556,000**			**556,000**
02/04			**570,000**	**570,000**
02/09		279,000	272,000	551,000
02/10		504,000		504,000
02/11		254,000		254,000
02/12		555,000		555,000
02/17		510,000		510,000
02/18	**486,000**			**486,000**
02/19	**298,000**		266,000	**564,000**
02/20			270,000	270,000
02/23		262,000	258,000	520,000
02/24		343,000		343,000
02/25		542,000		542,000
03/02		536,000		536,000
03/03		245,000		245,000
03/04	**516,000**			**516,000**
03/05			415,000	415,000
03/06		379,000		379,000
03/10[a]		421,000		421,000
03/11		161,000		161,000
03/12	**360,000**			**360,000**
03/17		88,000		88,000
03/23		11,800		11,800
03/27		79,000		79,000
03/31		45,500		45,500
04/07		23,000		23,000
04/10		20,000		20,000
04/15		11,000		11,000
Total	2,479,000	5,269,300	2,051,000	9,799,300

[a] On March 10, a portion of the Riviera group was inadvertently released at Landsburg (pers comm Charlotte).

Sampling Fry for Thermal Marks

As otolith-marks are internal, their detection requires killing fish. In previous years, we collected a sample of fry from the catch each night that hatchery-produced fry were released or may have been present in the lower river (post-release nights). In 1998, we collected otolith samples on 15 nights, on and following the six releases at Landsburg Hatchery. Landsburg releases began on February 2, and ended on March 12. To insure that the samples were not biased by differences in migration timing between hatchery and wild fry, we retained a constant proportion of each hours' catch over the entire night. Each morning, we gently stirred the retention tank to thoroughly mix the fry, then we collected 155 fry for the sample, of which 150 were analyzed.

Fry Estimation

As in previous years, on most nights in 1998 we calculated the sockeye fry migration past the trap by applying an estimate of trap efficiency to the catch. To apportion the migration estimate into hatchery and wild components, we applied the following methodology and assumptions.

1. On the nights that hatchery fish were released above the trap and otolith samples were not samples taken, we estimated wild migration by interpolating from the preceding and following nights on which hatchery fish were not released. Hatchery production was estimated by subtracting the wild estimates from the total estimated fry production.

2. On the nights when we sampled for otoliths, we used the sample results to calculate the composition of hatchery and wild fry in the catch.

3. To estimate wild migration during the periods late in the season, when we trapped every other night, we also interpolated migration from that estimated on preceding and following nights.

4. The numbers of wild fry migrating before the trapping period were estimated by straight line extrapolation of initial migration estimates based on trapping to January 1, which we selected as the migration start date.

5. Based on the limited daylight trapping it was evident that some level of migration was occurring during the daytime. To estimate the proportion of this migration, we expanded the daytime catch data to estimate the daylight catch on these dates. Relating these estimates to respective nightly catches estimates the proportion of the migration occurring during the night. We used this rate to compute 24-hour migration estimates for wild fish and the hatchery fry released at Landsburg.

Results

Catch

Nightly catches of sockeye fry increased from 816 sockeye on January 21, our first night of trapping, to peak at 133,000 fry on March 11, when large numbers of hatchery fish were released to the lower river. By July 5, our last night of trapping, we caught only 12 sockeye fry. Over the season, our combined catch of hatchery and wild sockeye fry totaled 2,731,309 for the 130 nights we trapped (Appendix A).

Efficiency and Flow

Recapture rates of the 40 calibration tests using dye-marked sockeye fry, conducted between January 24 and April 13, ranged from 3.6% to 14.2%, and averaged 9.3% (Table 2). As in previous seasons, flow explained much of the variation (68%) in capture rates (Figure 3). On the nights that we ran calibration tests, flows ranged between 1,620 and 481 cfs. Over the season, flows exceeded this range on only one night (1,790 cfs on January 23). After April 15, however, flows were less than 481 cfs on all but eight nights.

Table 2. Trap efficiency estimates from catches of dye-marked sockeye fry released above the fry trap, and flow, Cedar River 1998.

Date	Flow	Eff.	Date	Flow	Eff.	Date	Flow	Eff.	Date	Flow	Eff.
01/24	1,620	3.63%	02/01	646	9.15%	03/01	713	10.13%	04/02	887	7.79%
01/27	1,400	4.89%	02/03	560	10.16%	03/03	689	11.54%	04/04	848	6.81%
01/29	1,100	8.91%	02/05	511	11.18%	03/05	509	14.16%	04/06	734	7.68%
01/30	900	9.20%	02/07	481	10.48%	03/07	497	11.06%	04/09	550	9.96%
			02/09	486	11.38%	03/09	571	7.90%	04/11	533	11.87%
			02/11	495	11.25%	03/11	617	12.64%	04/13	517	12.35%
			02/13	602	10.28%	03/13	732	8.52%			
			02/15	549	13.48%	03/15	856	7.65%			
			02/17	503	12.07%	03/17	867	9.76%			
			02/19	551	8.73%	03/19	791	9.36%			
			02/21	678	10.70%	03/21	805	6.67%			
			02/23	629	11.30%	03/23	973	4.50%			
			02/25	631	11.92%	03/25	882	8.16%			
			02/28	593	8.78%	03/27	1,140	6.08%			
						03/29	1,090	5.27%			
						03/31	1,130	6.13%			
								Minimum			3.6%
								Maximum			14.2%
								Average			9.3

Otolith Sampling

Hatchery-produced fry comprised 28% of the 2,250 sockeye sampled for otoliths over 15 nights (Table 3). The incidence of fry released at Landsburg Hatchery in samples taken on the release nights ranged from 87% in early-February, to less than 10% in mid-March.

As we directed otolith sampling on and following the nights that sockeye were released from Landsburg Hatchery, these releases accounted for all but four of the 630 hatchery fry in the analysis. Three of these fry, which originated from the Riviera release on February 17, were found in the sample taken on February 18. The other fry, which was identified as an Airport release (below the trap), probably originated from a portion of the group destined for release at Riviera, but which escaped from the Landsburg Hatchery on March 10. The only other anomaly in this data was the one fry on February 19, which originated from the first releases at Landsburg February 2-3. This fry, which spent over two weeks migrating downstream, indicates protracted migration does occur, at least for a portion of the releases when flows are relatively low (500-600 cfs).

Table 3. Otolith sampling results, Cedar River sockeye fry, 1998.

Trap Date	Sample	Number Marked	Percent Marked	RELEASE	
				Strategy	Location
02/02	150	125	83.33%	E1	Landsburg
02/03	150	131	87.33%	E1	Landsburg
02/04	150	100	66.67%	E1	Landsburg
02/05	150	11	7.33%	E1	Landsburg
02/06	150	8	5.33%	E1	Landsburg
02/07	150	3	2.00%	E1	Landsburg
02/18	150	30	20.00%	M1	Landsburg
		3	2.00%	E3	Riviera
		33	22.00%	**Total**	
02/19	150	1	0.67%	E1	Landsburg
		40	26.67%	M1	Landsburg
		41	27.33%	**Total**	
02/20	150	12	8.00%	M1	Landsburg
02/21	150	4	2.67%	M1	Landsburg
03/04	150	46	30.67%	L1	Landsburg
03/05	150	18	12.00%	L1	Landsburg
03/12	150	13	8.67%	L1	Landsburg
03/13	150	1	0.67%	L2	Airport
		4	2.67%	L1	Landsburg
		5	3.33%	**Total**	
03/14	150	1	0.67%	L1	Landsburg
Total	2,250	630	28.00%		

Diel Migration

In most years, trapping during daylight intervals indicated that very few sockeye fry migrate during daytime hours. We therefore concentrated all our trapping effort during the hours of darkness. In 1997, however, we observed a higher daytime migration rate (~10%), which we attributed to higher flows (in excess of 1,000 cfs throughout most of the season, compared to around 350 cfs in other years) and associated turbidity. Flows in 1998 were considerably lower, however, similar to those of previous years, averaging around 600 cfs (Figure 4).

During continuous trap operation on May 16 and 19, 5.9% and 8.6%, respectively, of our sockeye fry catches occurred during the daylight (Table 4). These rates were observed at minimum flows (around 385 cfs), when the turbidity was very low. For 1998, we selected an average day:night rate of 8.0% to approximate the numbers of sockeye fry emigrating during daylight hours.

Table 4. Day vs. Night catch rates, Cedar River 1998.

Date	TIME FISHED			CATCH		HOURS		TOTAL EST		PERCENT	
	Start	End	Interval	No.	Rate	Day	Night	Day	Night	Day	Night
05/16	08:00	20:00	12.0	182	15.2	15.2		231		8.15%	
	20:00	06:00	10.0	2,959	295.9		8.8		2,604		91.85%
05/19	05:00	20:00	15.0	149	9.9	15.4		153		13.20%	
	20:00	06:00	10.0	1,170	117.0		8.6		1,006		86.80%
Average										10.67%	89.33%

Fry Production

We estimated 32.4 million sockeye fry entered Lake Washington from the Cedar River (Table 5, Figure 5). Wild fry production accounts for 77% (25.1 million) of this total, and hatchery production the balance (7.3 million fry).

Table 5. Estimated wild and hatchery sockeye fry migrations entering Lake Washington from the Cedar River, 1998.

Period	Dates	ESTIMATED MIGRATION TO LAKE ENTRY					
		Wild	Hatchery				Total
			Landsburg	Riviera	Airport	Total	
Before trapping	January 1-20	107,650	0	0	0	0	107,650
During trapping	January 21-July 5	24,947,085	1,256,196	4,037,481	2,051,000	7,344,677	32,291,762
	Total	25,054,735	1,256,196	4,037,481	2,051,000	7,344,677	32,399,412
	Proportion of Total	77.3%	3.9%	12.5%	6.3%	22.7%	

Wild and Hatchery Migration Timing

Releases of hatchery-produced fry began on January 13 and continued through April 11 (Figure 5). The wild fry migration was under way when we began trapping on January 24, peaked during March and April, and was essentially over when we quit trapping in early-June. The median migration date for hatchery fry occurred on February 20, while the median date for the wild migration occurred on March 11, three weeks later (Figure 6). This difference results from at least three factors:

1. Proportionally higher egg takes from the early and middle parts of the run than the later segment.

2. Incubating eggs at slightly elevated water temperatures relative to river water.

3. Any eggs deposited after the peak flow event on January 2 experienced higher survival than those from earlier spawners.

Wild timing in 1997 was similar to that observed in 1996 which was later than all of the five preceding broods. Timing of hatchery fry in 1997 was the earliest of the six broods assessed thus far with a median migration date of February 20. Combined migration timing in 1997, however, is just two days earlier than the average of the previous five broods (Table 6).

Table 6. Median migration dates of wild, hatchery, and total (combined) sockeye fry populations, Cedar River.

Brood Year i	Trap Year i+1	MEDIAN DATE			Difference (days) W-H
		Wild	Hatchery	Combined	
1991	1992	03/18	02/28	03/12	18
1992	1993	03/27	03/07	03/25	20
1993	1994	03/29	03/21	03/26	8
1994	1995	04/05	03/17	03/29	19
1995	1996	04/07	02/26	02/28	40
1996	1997	04/07	02/20	03/16	46
1997	1998	03/11	02/20	03/06	19
Average		03/28	03/03	03/16	24
Avg. previous 6 yrs		03/31	03/05	03/18	25

Egg-to-Migrant Survival of Naturally-Produced Fry

The severity of peak flow during egg incubation explains virtually all of the interannual variation in egg-to-migrant fry survival that we have measured in the Cedar River over five broods (Table 7, Figure 7). The curve in Figure 7 was derived using the estimates from the previous five brood years.

Table 7. Estimated egg-to-migrant survival of naturally-produced sockeye fry in the Cedar River, brood years 1991-1996.

Brood Year	Estimated Escapement	Females (@50%)	P.E.D. @3,000x	Fry Production	Survival Rate	Flow (cfs)
1991	77,000	38,500	115,500,000	9,800,000	8.48%	2,060
1992	100,000	50,000	150,000,000	27,100,000	18.07%	1,570
1993	76,000	38,000	114,000,000	18,100,000	15.88%	927
1994	109,000	54,500	163,500,000	8,700,000	5.32%	2,730
1995	22,000	11,000	33,000,000	730,000	2.21%	7,310
1996	230,000	115,000	345,000,000	24,390,000	7.07%	2,830
1997	104,000	52,000	156,000,000	25,055,000	16.06%	1,590

Survival-to-lake-entry of fry produced from the potential egg deposition (PED) of natural spawners is estimated at 16.1% (Table 7). This rate represents an overall average value which is the ratio of 24.4 million fry to an estimated PED of 345 million. This PED is based on the following estimates, assumptions, and counts:

1. an estimated natural spawning population of 230,000 adults in 1996;
2. an even sex ratio;
3. an average fecundity of 3,000 eggs per female.

This survival rate is higher than the rate (5.3%) that we estimated for the 1994 brood which experienced an even lower peak flow level of 2,730 cfs. The difference between these two estimates results from a combination of the following factors.

1. **Changes in the streambed and resultant spawner distribution**. During the two extreme high flow events (over 7,000 cfs) in November 1995 and February 1996, the stream bed was altered by channel movements, gravel scour, and gravel recruitment. These processes transported tremendous quantities of gravel to the lower river. In 1996, sockeye made intensive use of these gravels spawning throughout the lower river all the way down to the lake. Gradient in the lower river is less, so gravels are not as easily scoured; it takes a higher flow to cause

the same mortality, and at an equivalent flow, survival is higher. Post-emergent fry survival is also higher because exposure to predation is minimal with the short distance to travel.

2. **Spawning flows**. Flows during October and November of 1994 (278 and 452 cfs, respectively) averaged around half of the flows during October and November of 1996 (498 and 1,105 cfs, respectively). Spawning at lower flows places eggs closer to the thalweg, the zone of highest energy where eggs are more susceptible to scour. In contrast, the 1996 brood spawned in higher flows, thereby depositing their eggs over a broader area, including lower energy zones.

3. **Timing difference of the peak flows**. Peak flows for the 1994 brood occurred on December 27 (2,730 cfs), and again on February 19, 1995 (2,690 cfs). Peak flow for the 1996 brood occurred on January 2 (2,830 cfs -- USGS provisional estimate), and again on March 19 (2,730 cfs). Although the peak flows affecting the 1994 brood were slightly lower, occurrence of the second one in February 1995, a month earlier than the second peak in 1997, impacted a higher proportion of that brood's P.E.D.

4. **Flows during fry migration**. We have determined that flow has a strong positive affect on in-river sockeye fry survival in the Cedar River. As flows during fry migration were higher in 1997 than in 1995, survival from emergence to the lake was higher for the 1996 brood.

5. **Underestimating 1996 Cedar River escapement**. As the denominator in the survival ratio (P.E.D.) is determined by the escapement estimate, error or bias in this estimate is reflected in the survival rate. In previous years the majority of sockeye spawned further upstream, therefore, escapements have been estimated based on spawning ground surveys upstream of R.M. 4.2. In 1996, however, substantial numbers of sockeye spawned downstream of this point. Escapement upstream of R.M. 4.2 was estimated at 124,000 sockeye, based on seven surveys. From R.M. 4.2 to 1.4, 62,000 sockeye were estimated based on four surveys. Three surveys were conducted in the lower 1.4 to 0.0 river miles, estimating 44,000 sockeye (*Egan and Ames, WDFW memo 1997*). Considering that the lower 4.2 R.M. was surveyed half as intensively as the upper, it is wider and flows were much higher later in the season, coinciding with spawner timing in the lower river, it is likely that escapement in the lower river was underestimated. Therefore, the actual egg deposition is higher than the 345 million calculated from the estimate of 230,000 spawners, and survival-to-fry is commensurately lower.

If we attribute all of the difference between these two survival estimates to the underestimate of spawning escapement in 1996, then the actual escapement is calculable. Back-calculating from our 1997 wild fry estimate using the 1994 brood survival rate of 5.3%, estimates a spawning escapement in 1996 of 306,000 adults. We believe this estimate is high, however, due to the first four reasons listed above. A more realistic escapement estimate might be something less than 300,000 but higher than 230,000. At a median value of 270,000 adult sockeye, for example, P.E.D. is estimated at 405 million, and survival to lake entry as fry is 6%.

In-river Survival of Hatchery-Produced Fry

We assumed that the flow survival relationship derived in 1995 estimated in-river survival from release at Landsburg to the trap in 1998.

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