Lower Cedar River Side Channel
Fry Production from 1999 Spawners
Data Report

-FINAL-

Prepared for:

U.S. Army Corps of Engineers, Seattle District
4735 E. Marginal Way
Seattle, Washington 98124-2255

Prepared by:

Eric D. Jeanes
Phil J. Hilgert
R2 Resource Consultants, Inc.
15250 NE 95th St.
Redmond, Washington 98052-2518

Subconsultant to:

HDR Engineering
500 108th Avenue N.E.
Bellevue, Washington 98004-5538

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1. INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (USACE) and the City of Renton (the City) constructed a groundwater-fed spawning channel (USACE Groundwater Side Channel) in the lower Cedar River, King County, Washington during 1998 as one element of mitigation for the Cedar River Flood Control Project. The monitoring plan for the project included conducting fall spawner surveys in the channel and estimating the number of salmon fry produced from the channel in the spring. In September 1999, the USACE contracted with R2 Resource Consultants (R2), as a subconsultant to HDR Engineering, to conduct biological monitoring in the USACE Groundwater Side Channel. Specifically, the scope of work identified five tasks:

- Attend a site reconnaissance;
- Conduct adult spawner surveys;
- Prepare a spawning summary report;
- Conduct fry emergence timing and production surveys; and
- Prepare a fry production summary report.

This report summarizes fry production from the constructed channel as a result of the 1999 fall spawners. The 1999 spawning survey data report was submitted to the USACE in February 2000, but is also attached to this document (see Appendix A). In addition, for comparison between brood years (i.e., 1998 vs. 1999), we have attached copies of the 1998 spawning and fry production data reports prepared by the USACE (see Appendix B and Appendix C, respectively).

The Cedar River is the largest tributary to Lake Washington, and drains approximately 182 mi^2 of forested, industrial, and urban lands (Chrzastowski 1983; City of Seattle 1998). The Cedar has an average discharge of 670 ft^3 (range = 374-1,016 ft^3; period of record = 1946 through 1997; USGS Gage No. 12119000). The Cedar River, one of the most productive salmon streams in the Puget Sound region, is home to the largest naturally-reproducing sockeye (*Oncorhynchus nerka*) run south of British Columbia. Anadromous populations of chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon, and rainbow trout (*O. mykiss*) are also present in the system, but their numbers are at least an order of magnitude lower than sockeye salmon (Table 1).

As in other basins throughout the Pacific Northwest, the hydrology of the Cedar River watershed has undergone significant changes since European settlement. Before 1916, the

Cedar River flowed into the Black River, the original outlet located on the southern shoreline of Lake Washington. The Black River then drained into the Green River, forming the Duwamish River, which emptied to Puget Sound. Near the time of the construction of the Lake Washington Ship Canal in 1916, the Cedar River was diverted away from the Black River and into Lake Washington (Chrzastowski 1983; City of Seattle 1998). In addition, the Landsburg Diversion, constructed at RM 21.8 by the City of Seattle, has been used to divert water for municipal use since 1901 (Miller 1976). Since construction of the Landsburg Diversion, approximately 27% of the mean annual flow at Landsburg is diverted out of the basin for municipal use (Fresh and Lucchetti 2000). Regulation of flood flows in the Cedar River occurs through a series of flood control facilities (i.e., levees and revetments). The control of flood flows along with floodplain development has combined to reduce the floodplain surface area and lateral habitat available to juvenile salmonids below Landsburg Diversion by more than 50% (Lucchetti 1998).

Table 1. Population parameters of anadromous salmonids occurring in the Lake Washington basin, Washington (adapted from Fresh and Lucchetti 2000).

	Fish Species			
Parameter	**Sockeye**	**Chinook**	**Coho**	**Steelhead**
Mean Escapement (1987-1996)	166,500	901	3,450	598
Lowest Escapement on Record	26,000	245	200	70
Escapement Goal	350,000	1,500	15,000	1,600
Status	depressed	depressed	depressed	depressed

The Elliot Levee is one flood control measure constructed on the Cedar River that disrupts the natural connectivity of floodplain habitats available to juvenile salmonids in the lower river. Constructed near RM 6 in the mid-1970s, the levee has failed at least twice in the past twenty years, including during the 1990 flood of record (Lucchetti 1998). Following the 1990 flood, one option was to abandon the levee; however, due to concerns over continued future flood damage to Maplewood Golf Course, the City and King County agreed upon a levee setback project. Construction of the levee setback project occurred in 1995. The project created a “floodplain” between the face of the set-back levee and the mainstem Cedar River channel. A notch was constructed to allow the Cedar River to overtop the levee and dissipate energy during high flow events. A groundwater-fed side channel (Elliot Groundwater Channel) near the downstream end of the Elliot Levee near RM 4 was also constructed in 1995. The Elliot Groundwater Channel (approximately 700-ft-long and 15-ft-wide) was designed to provide additional spawning and rearing habitat for anadromous salmonids inhabiting the lower Cedar River (Lucchetti 1998).

The lower Cedar River near RM 1 has been periodically dredged to increase channel capacity and reduce the deleterious effects of flood events in the City of Renton. Due to difficulties encountered in obtaining regulatory permits, dredging of the lower Cedar River was reduced in the 1970s and discontinued during the 1980s (West Consultants 1999). During the flood of 1990, the Cedar River inundated portions of the City of Renton. Subsequently, the City of Renton requested the USACE to evaluate flood control alternatives. The USACE developed a flood control program that included dredging the Cedar River downstream from Williams Avenue to the mouth, and construction of levees and/or floodwalls in 1994-1997 (M. Martz, USACE, *pers. comm*). The program called for the Cedar River to be dredged to a depth of four (4) ft below the 1995 bed profile from the mouth of the Cedar River upstream to RM 1 (West Consultants 1999). From that point (near Logan Avenue Bridge) dredging would gradually taper at a slope of 0.0056 ft per ft to meet the existing channel gradient near Williams Avenue (RM 1.25). The gradual change in channel slope was considered necessary to reduce the risk of significant channel change caused by mobilization of bed particles during flood events. Additional floodwalls and levees were also constructed in the City of Renton to provide protection during a 100-year flood.

Dredging occurred during the summer of 1998. To mitigate for the potential effects of the Cedar River Flood Control Project on salmonids in the Cedar River, the USACE and the City constructed a rearing and spawning side channel, approximately 2,000 ft upstream from King County's Elliot Groundwater Channel (Figures 1 through 3). Construction of the channel was completed in August 1998. The side channel was expected to provide off-channel spawning and rearing habitats for primarily sockeye and coho salmon; however, chinook and steelhead fry would also potentially benefit from creation of additional rearing habitat in the lower Cedar River (M. Martz, USACE, *pers. comm*).

Sockeye salmon exhibit the greatest variety of life history patterns of all the Pacific salmon, and characteristically use lacustrine (lake) habitat more than other salmon species. Lake-rearing sockeye juveniles typically spend 1 to 3 years in lacustrine habitats, before migrating to sea (Burgner 1991). Lake rearing stocks represent the most common and typical life history. Sockeye that rear in rivers for 1 to 2 years (river-type sockeye) are less common than the lake-type sockeye, and little is known about them.

Adult Cedar River sockeye, in general, enter freshwater in June, July, and August (WDFW et al. 1994; Gustafson et al. 1997). Spawning occurs from September through January in the lower Cedar River (WDFW et al. 1994) in gravel areas containing upwelling of oxygenated water. Length of sockeye egg incubation is temperature dependent, but is generally longer

than for other salmon species (Burgner 1991). In general, spawning occurs during periods of declining temperatures, incubation occurs at the lowest winter temperatures, and hatching is associated with rising water temperatures in late winter or early spring (Burgner 1991).

After emergence, juvenile sockeye typically migrate to nursery lakes for rearing (Burgner 1991). Initially, upon emergence, juvenile sockeye exhibit photonegative response, moving primarily at night, which is believed to be an anti-predator adaptation (Burgner 1991). Smolt outmigration to the ocean usually occurs during darkness, beginning in late April and extending through early July (Gustafson et al. 1997). Juvenile sockeye entering the Lake Washington Ship Canal appear to maintain nocturnal behavior, however, when entering the locks, juvenile sockeye become more diurnal in their movements (F. Goetz, USACE, *pers. comm*).

Adult coho are also found in the Lake Washington system and generally return to their natal streams to spawn at age 3, after spending 18 to 24 months (up to 3 years) in the marine environment. Coho spawning takes place in the Cedar River from late October through late February (WDFW et al. 1994). Coho spawn in the upper mainstem reaches below Landsburg and in the many tributaries to the mainstem Cedar River. Incubation periods for coho salmon last from 35 to 101 days (Laufle et al. 1986; Sandercock 1991).

After hatching, the coho alevins typically spend 3 to 4 weeks (depending on depth of egg pocket, percentage of fine sediments, and water temperatures) absorbing the yolk sac in gravels before they emerge in early March to mid-May (McMahon 1983; Laufle et al. 1986; Sandercock 1991). Juvenile coho salmon remain in freshwater for approximately 15 to 18 months prior to migrating downstream to the ocean, but may extend their freshwater rearing period for up to 2 years (Sandercock 1991). Newly-emerged fry usually congregate in schools in pools of their natal stream. As juveniles grow, they move into more riffle habitat and aggressively defend their territory, resulting in displacement of excess juveniles to downstream habitats (Lister and Genoe 1970). Aggressive behavior may be an important factor maintaining the density of juvenile coho within the carrying capacity of the stream, and distributing juveniles more widely downstream (Chapman 1966; Sabo 1995). Once territories are established, individuals may rear in selected areas of the stream feeding on drifting benthic organisms and terrestrial insects until the following spring (Hart 1973; Cederholm and Scarlett 1981). Complex woody debris structures and side channels are important habitat elements for juvenile coho salmon, particularly during the summer low-flow period (Grette and Salo 1986; Hilgert and Jeanes 1999), suggesting that the abundance

of juvenile coho is often determined by the combination of space, food, and water temperature (Chapman 1966; Sandercock 1991).

The objective of this study was to evaluate fry production from a groundwater side channel constructed as a mitigation measure for dredging that occurred on the lower Cedar River during the summer of 1998. Specifically, using a fyke net, we wanted to quantify the number of salmonid fry recruited to the Cedar River as a result of this mitigation project to help guide the design and development of similar projects. In addition, emergence nets monitored the success of individual redds within the side channel. Limited monitoring of the Elliot Groundwater Channel was also conducted to provide a comparison with the newly constructed USACE Groundwater Side Channel.

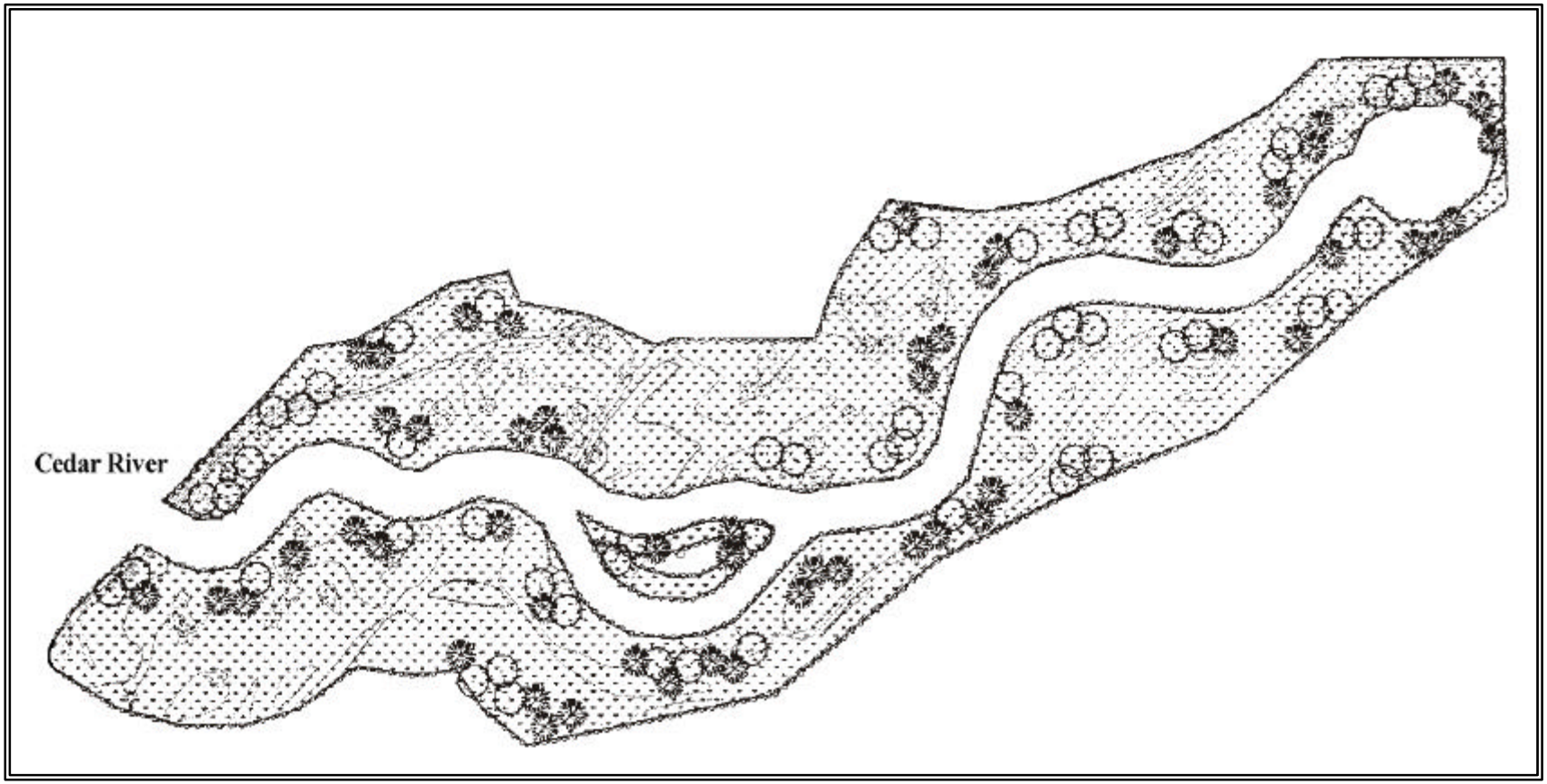

Figure 1. Groundwater side channel created by USACE as mitigation for dredging impacts, lower Cedar River, Washington, 2000 (base map adapted from USACE by R2 Resource Consultants).

Figure 2. Upstream (inlet) end of USACE Groundwater Side Channel (looking downstream), lower Cedar River, Washington, 2000.

Figure 3. Downstream (outlet) end of USACE Groundwater Side Channel (looking upstream), lower Cedar River, Washington, 2000.

2. METHODS

2.1 JUVENILE SALMONID MOVEMENT

Juvenile salmonid production and emigration timing was assessed by fyke netting the downstream end of the USACE Groundwater Side Channel from 10 March through 6 June 2000. The fyke net was fished twice a week during the peak of juvenile outmigration (19 March through 27 May) and once a week during the tails of the migration window (5 March through 18 March and 28 May through 12 June). On each survey, the fyke net was installed approximately two hours before sunset and fished until approximately sunrise of the following morning. On most occasions, the fyke net was checked every hour beginning at sunset and continuing until 0300 hrs of the next morning, or until the catch appeared to subside. The fyke net was checked for the final time at sunrise of the next morning after it was installed.

The fyke net, 1.2 m (4.0 ft) wide by 1.2 m (4.0 ft) deep, had 9.8 m (32 ft) wings constructed from 3-mm nylon mesh that spanned the entire channel (Figures 4 and 5). The mouth of the net funnels down to a 30.5 cm (1.0 ft) throat containing three velocity shelters and empties into a 0.61 m (2 ft) wide, 0.61 m (2 ft) deep, 1.2 m- (4 ft) long floating live car constructed of 3-mm nylon mesh. Frames of the net and live car were constructed out of aluminum aircraft tubing (38 mm [1.5 in] diameter). The mouth of the fyke net was positioned in the thalweg of the channel and held in place, along with the wings, by metal fence posts. The fyke net was positioned about 33 m (100 ft) upstream of the mouth of the channel to maintain water velocity at the mouth of the fyke net during periods of backwatering from mainstem Cedar River high flows. Although seven redds were identified downstream of the trap placement location during the fall spawner survey, based on visual observation, we assumed that little production occurred from these because the backwater effect from the Cedar River caused high sediment loading in that portion of the channel.

All species were removed from the live car, placed into darkened recovery containers, anesthetized with MS-222 (75 mg/l), identified to species, measured to nearest mm fork length (FL), and released downstream of the fyke net upon recovery. All fish data, duration of fishing, and photographs were recorded on field data sheets. All data were entered electronically using MS Excel and cross-referenced with original field data forms for quality control purposes. Weekly estimated fry production was calculated using the mean number of sockeye fry captured from the two survey events and multiplied by seven. Total production

was summed from individual survey weeks. Based on snorkel surveys conducted downstream of the fyke net, we assumed that we captured 100% of the sockeye fry emigrating from the side channel on each survey occasion. Based on spot sampling during daylight periods, we assumed that sockeye fry would not emigrate from the channel during daylight hours. Statistical analysis was conducted using Jandel Scientific SigmaStat.

2.2 SOCKEYE EMERGENCE

In addition to estimating fry production, we also checked the reliability of predicting fry emergence timing by first estimating peak fry emergence and then comparing direct measurements of fry emergence. The timing of two peaks of sockeye spawning observed during the fall spawning survey were used to estimate peak emergence of both "early" and "late" spawning sockeye (see Appendix A). By noting the date of redd construction and collecting mean daily water temperature data, we were able to compute the approximate date of emergence using the following equation that summed temperature units over the period from redd deposition to emergence:

$$(1) \qquad \textit{Degree day} = \textit{number of days} \cdot {}^{\circ}C \textit{ above } 0^{\circ}C$$

Secondly, we directly sampled several sockeye redds (in both USACE Groundwater Side Channel and the Elliot Levee Groundwater Channel) to measure emergence directly from individual redds using traps that were based on a modified design of Porter (1973). The emergence traps were teardrop-shaped (128 cm long by 99 cm wide by 10 cm high), and covered with 3-mm nylon mesh that spanned the entire metal frame (Figure 6). The mesh was detachable to facilitate installation and anchoring of the traps. A cordura apron was attached to the perimeter of the metal frame and buried to a depth of 0.3 m during installation to prevent loss of fry from lateral migration (Reiser et al. 1998). The collection bottle (3.7 cm long by 1.15 cm-diameter PVC pipe) was located at the posterior end and fitted with baffles to reduce water velocities and provide shelter for fry. The collection bottle had holes covered with 500μ Nitex™ mesh to allow for flow through and aeration for the fry.

Installation, including burial of the apron and anchoring the traps, occurred on 10 March 2000. Two traps (Traps 1 and 2) were installed in the USACE Groundwater Side Channel (Figure 7), while one trap (Trap 3) was placed in the Elliot Levee Groundwater Channel. Traps 1 and 3 were positioned over redds constructed on 15 November 1999, and Trap 2 was positioned over a redd deposited on 7 January 2000. The selection of redds allowed for

comparison of emergence between side channels and redd deposition dates. Traps were checked in conjunction with fyke net surveys and removed on 7 June 2000.

All data were entered electronically using MS Excel and cross-referenced with original field data forms for QA/QC purposes. Statistical analysis was conducted using Jandel Scientific SigmaStat.

2.3 PHYSICAL HABITAT PARAMETERS

One transect was established upstream of the fyke net near the staff gage to record discharge. Discharge measurements were collected using a Swoffer Model 2100 velocity throughout the study period. Discharge was calculated using the wadable stream discharge measurement method of Pleus (1999). Daily water temperatures (to the nearest 0.05°C) were recorded in both channels using digital Onset Optic StowAway continuous recorders (Onset Computer Corp., Pocasset, MA). Water temperature recorders were installed on 29 September 1999 (USACE Groundwater Side Channel) and on 7 October 1999 (Elliot Groundwater Channel); both were removed on 7 June 2000. Water temperature was also recorded in each channel and in the Cedar River using a handheld thermometer to the nearest 0.5°C on each survey date. Minimum, mean, and maximum daily water temperatures were calculated using an in-house program. Provisional discharge data (mean daily flows) were obtained from the U.S. Geological Survey for the Cedar River at Renton, Washington (USGS Gage 12119000). All data were entered electronically using MS Excel and cross-referenced with original field data forms for quality control purposes.

Figure 4. Upstream end (inlet) of fyke net installed in USACE Groundwater Side Channel (looking downstream), lower Cedar River, Washington, 2000.

Figure 5. Downstream end (outlet) of fyke net installed in USACE Groundwater Side Channel (looking upstream), lower Cedar River, Washington, 2000.

Figure 6. Emergence trap installed in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

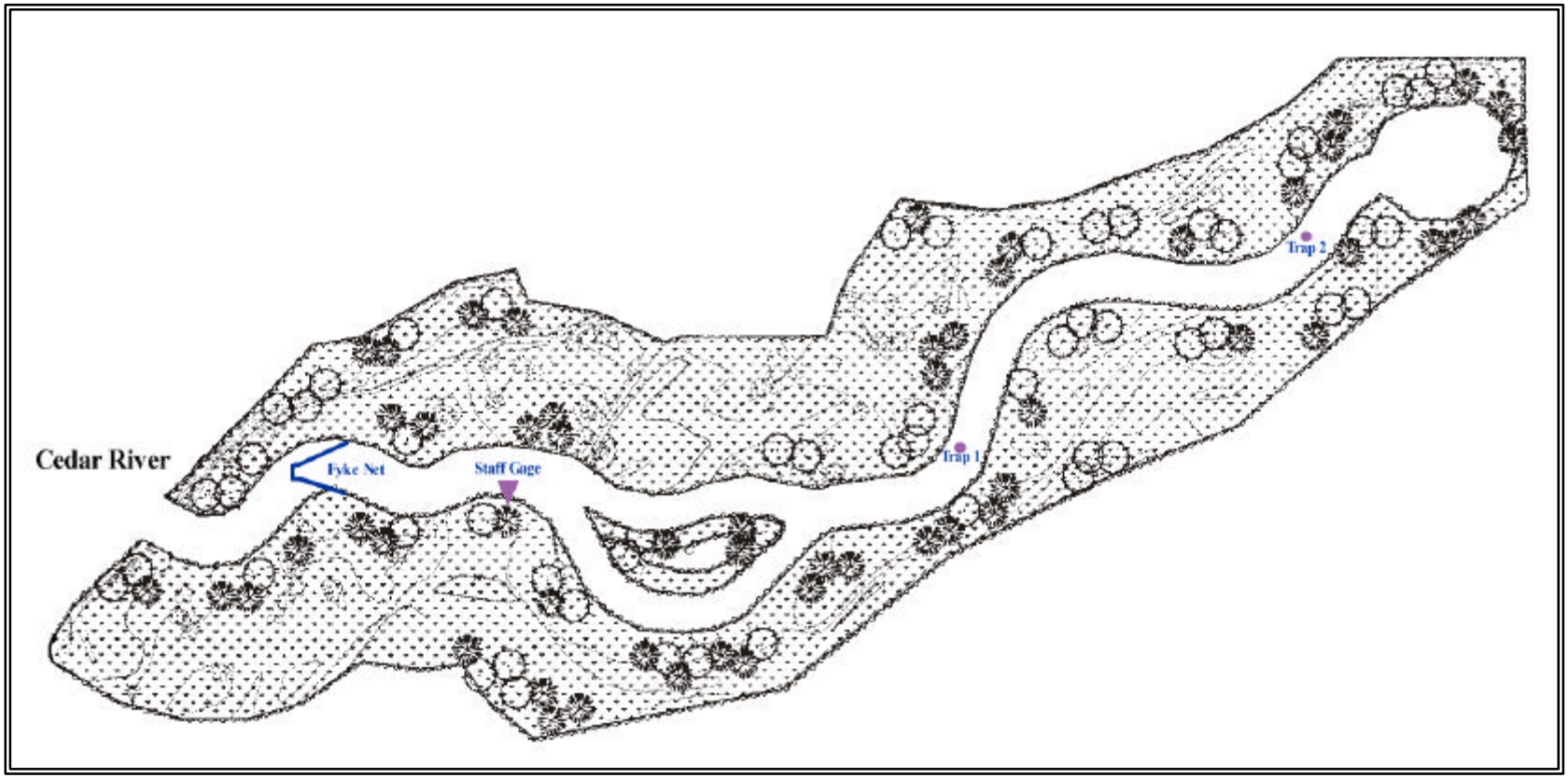

Figure 7. Fyke net and emergent trap (Traps 1 and 2) locations in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000 (base map adapted from USACE by R2 Resource Consultants).

3. RESULTS AND DISCUSSION

3.1 SALMONID OUTMIGRATION

A total of 12,378 sockeye were captured at the mouth of the USACE Groundwater Side Channel from 10 March through 6 June (Table 2). Total sockeye production from the 1999 brood was estimated at 44,090 for an overall density (based on a wetted area upstream of the trap of 15,000 ft^2) of 2.94 sockeye produced per ft^2 in the USACE Groundwater Side Channel (Figure 8). A single sockeye fry was captured on the initial survey date (10 March); while six sockeye were captured on the final survey (6 June) (Figure 8). We assumed that we adequately captured the majority of the sockeye emigration periods. Snorkel surveys conducted on the nights of 10 March and 9 June observed less than 10 sockeye fry in the entire channel on both occasions.

Sockeye outmigration peaked from 26 April through 10 May during which an estimated 1,338 sockeye moved from the USACE Groundwater Side Channel into the Cedar River, nightly. This two-week window represented approximately 50% (20,070) of the total estimated sockeye outmigration during the study period. Sockeye fry ranged from 20-73 mm in FL (mean = 30.7; SD = 6.1 mm) throughout the study period. Most sockeye (~80%) ranged from 26-32 mm in FL, indicating that they spent little time rearing in the USACE Groundwater Side Channel after emergence (Figure 9). This fact was corroborated by the large percentage (>14%) of fry that did not have their yolk-sack completely absorbed (termed button-up fry).

Approximately 137 sockeye redds were deposited in the USACE Groundwater Side Channel upstream of the trap (144 total) during the 1999 spawning season, a year in which escapement to the Cedar River was less than 50,000 adult sockeye (D. Seiler, WDFW, *pers. comm.*). Based upon parameters used to estimate sockeye production (i.e., 3,230 eggs deposited per redd; 8.38% egg-to-fry survival) for a new side channel on the lower Cedar River in Jeanes and Hilgert (2000), hypothetically, 37,000 sockeye fry could be produced from the 137 redds deposited during the 1999 season. Our estimated production of 44,090 was 19% greater than the hypothetical value; however if a higher value of egg-to-fry survival were used (i.e., 10%), our estimate of production and the hypothetical production would be virtually identical. Higher egg-to-fry survival values (i.e., >10%) often occur when sockeye spawn in off-channel habitats (Foerster 1968; Chapman et al. 1995).

Along with sockeye, juvenile chinook and coho salmon, rainbow trout were captured during surveys conducted in the USACE Groundwater Side Channel (Figures 10 and 11). Combined, the latter three species represented less than 1% of the total catch (Table 3). Juvenile coho salmon were the largest salmonid sub-yearling captured (mean = 55.2 mm FL), followed by chinook (mean = 47.8 mm FL), rainbow trout (mean = 46.0 mm FL), and sockeye salmon (mean = 30.7 mm FL) (Table 4; Figure 12).

In addition to salmonids, other species captured in the fyke net were (in decreasing order of abundance); threespine stickleback (*Gasterosteus aculeatus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*C. asper*), torrent sculpin (*C. rotheus*), longnose dace (*Rhynichthys cataractae*), and largescale sucker (*Catostomus macrocheilus*). In total, 51 sculpins (*Cottus* spp.) were captured in the USACE Groundwater Side Channel. Each sculpin stomach was flushed using the methods modified from Sheng et al. (1990). Combined, the 51 sculpins consumed 134 sockeye fry for an average of 2.63 sockeye per sculpin in the USACE Groundwater Side Channel. In general, larger sculpin consumed the most sockeye fry (Table 5). However, there were two sculpin (81-90 mm FL) that were particularly gluttonous, consuming 13 sockeye fry each. Overall, sockeye consumption rate by sculpin in the USACE Groundwater Side Channel was almost one fish greater than that reported by Tabor and Chan (1996) in the lower Cedar River (Table 6). Our capture gear (i.e., fyke net) may have positively biased the sockeye consumption rate by increasing the density of sockeye fry over natural levels of mainstem habitats sampled by Tabor and Chan (1996). Conversely, much of the predation by sculpin noted by Tabor and Chan on the lower Cedar River in 1995 occurred shortly after a hatchery release of 382,000 sockeye fry.

A total of 12,596 fish were captured, handled, and released at the USACE Groundwater Side Channel fyke net during 2000. Visible injuries occurred to 24 sockeye and resulted in 23 immediate mortalities for an overall injury rate of <0.2%. Undoubtedly, delayed injury and/or mortality occurred after fish were released, however the combination of physical conditions (i.e., low water velocities and extended trap wings) and checking the trap on an hourly time interval helped to decrease the overall impacts to salmonids. All of the observed injuries/mortalities occurred to sockeye <30 mm FL and in button-up condition, a stage at which juvenile salmonids are particularly fragile (Becker et al. 1983).

3.2 PHYSICAL HABITAT PARAMETERS

Mean daily discharge in the Cedar River at Renton, Washington during the outmigration period ranged from 1,200 cfs (4 January) to 480 cfs (4 June) (Figure 13). The stage in the

USACE Groundwater Side Channel mirrored that of the Cedar River, increasing during March and mid-April, peaking on 22 April, and decreasing in May and June (Figure 14). Maximum discharge recorded in the USACE Groundwater Side Channel (4.1 cfs) peaked on 22 April and was positively related to stage of the USACE Groundwater Side Channel (R^2 = 0.8053) (Figure 15).

Water temperatures measured in the USACE Groundwater Side Channel were slightly cooler during the fall than those measured in the Elliot Levee Groundwater Channel (Figures 16 and 17, respectively), however water temperatures in the USACE Groundwater Side Channel increased more rapidly in the spring compared to the Elliot Levee Groundwater Channel (Figure 18). Mean daily water temperatures were significantly greater in the USASCE Groundwater Side Channel when compared to the Elliot Levee Groundwater Channel for the period of record 7 October 1999 through 7 June 2000 (Man-Whitney Rank Sum Test; p = 0.0231). The USACE Groundwater Side Channel receives water that infiltrates directly from the Cedar River through the levee and from nearby Madson Creek, while the Elliot Levee Groundwater Side Channel is fed from a pipe that transmits groundwater to the channel. Both side channels are shaded by canopy of mature cottonwoods (*Populus spp.*), thus the daily and seasonal water temperature fluctuations observed in both channels are apparently controlled by the temperature of their water source.

3.3 ESTIMATED FRY EMERGENCE

The timing of fry emergence in the USACE Groundwater Side Channel was initially forecast to allow field-sampling efforts to be scheduled to increase the likelihood of capturing the majority of fry emigrants. Based on fall spawning surveys, average incubation requirements obtained in Foerster (1968) and Burgner (1991), and predictions of side channel water temperatures, peak sockeye fry emergence was predicted to occur in late March. A description of the process used to calculate degree-day requirements during incubation is provided in Burgner (1991). Our first observations of sockeye fry emergence in the USACE Groundwater Side Channel occurred on 22 April, and fry emergence in the Elliot Levee Groundwater Channel commenced on 1 April, three weeks earlier than the USACE Groundwater Side Channel. Peak emergence (based on the emergent traps) occurred from 17 May through 23 May in the Elliot Levee Groundwater Channel.

Our forecast of peak fry emergence assumed water temperatures in the side channels would be 8.5°C throughout the late winter and early spring months. Analyses of recorded water temperatures for that same time period revealed that actual water temperatures were

considerably lower than the assumed value of 8.5°C (Figure 18). Based on a peak spawning date of 15 November and peak emergence observed in the fry traps, sockeye embryos accumulated more than 1,200-degree days during the incubation period. The length of incubation observed in the side channels is more than 20% greater than the value reported in Burgner (1991). Neither trap placed in the USACE Groundwater Side Channel captured enough sockeye to compute a peak emergence time, however. Thus, based on a limited sample size, emergence of sockeye from the redds appears to be somewhat protracted. The first sockeye was captured in an emergent net on 1 April, while the last one was captured on 25 May.

The limited use of emergent fry traps, which was initiated as a test procedure during the 1999 field season, was marginally successful. We suggest that a more rigorous fry emergence survey be planned for future monitoring efforts. With little additional effort, 4 to 6 emergent traps could be monitored in each channel to obtain more accurate descriptions of the peak and duration of emergence timing between the two study sites.

Table 2. Date, number of sockeye captured, week ending date, and estimated number of sockeye produced in the USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

Date	Number Sockeye Captured	Week Ending	Estimated Number of Sockeye Outmigrants
10-Mar	1	11-Mar	7
16-Mar	9	18-Mar	63
22-Mar	344	25-Mar	1,239
27-Mar	346		
30-Mar	271	1-Apr	2,163
5-Apr	632		
6-Apr	556	8-Apr	4,158
12-Apr	264		
13-Apr	269	15-Apr	1,869
17-Apr	436		
19-Apr	465	22-Apr	3,052
26-Apr	1,038		
27-Apr	2,259	29-Apr	11,540
2-May	831		
5-May	1,414	6-May	7,858
9-May	879		
10-May	1,607	13-May	8,701
17-May	58		
19-May	138	20-May	686
23-May	80		
24-May	255	27-May	1,173
30-May	220	3-Jun	1,540
6-Jun	6	10-Jun	42
Total	***12,378***		***44,090***

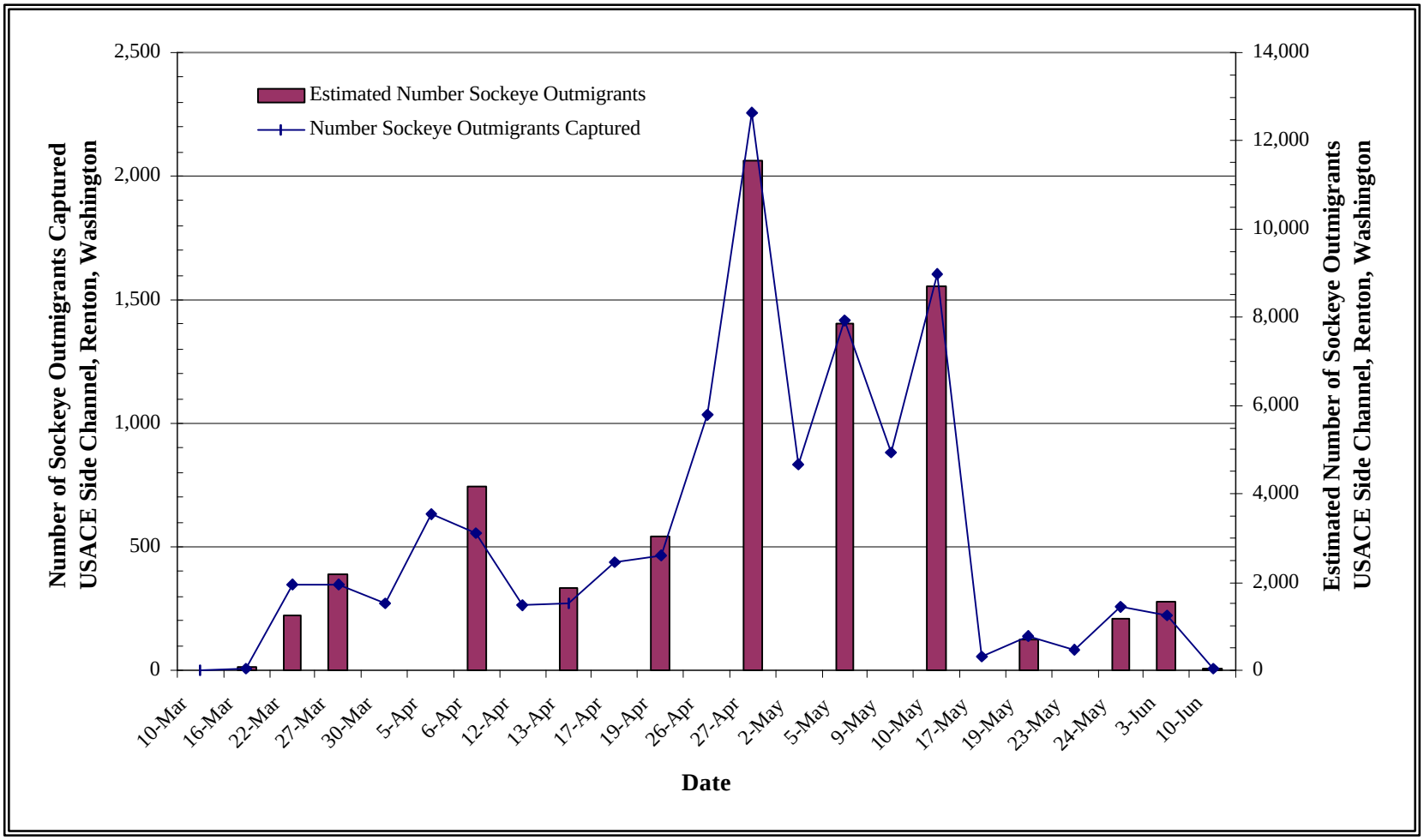

Figure 8. Number of sockeye captured on each survey date and estimated number of sockeye outmigrants in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

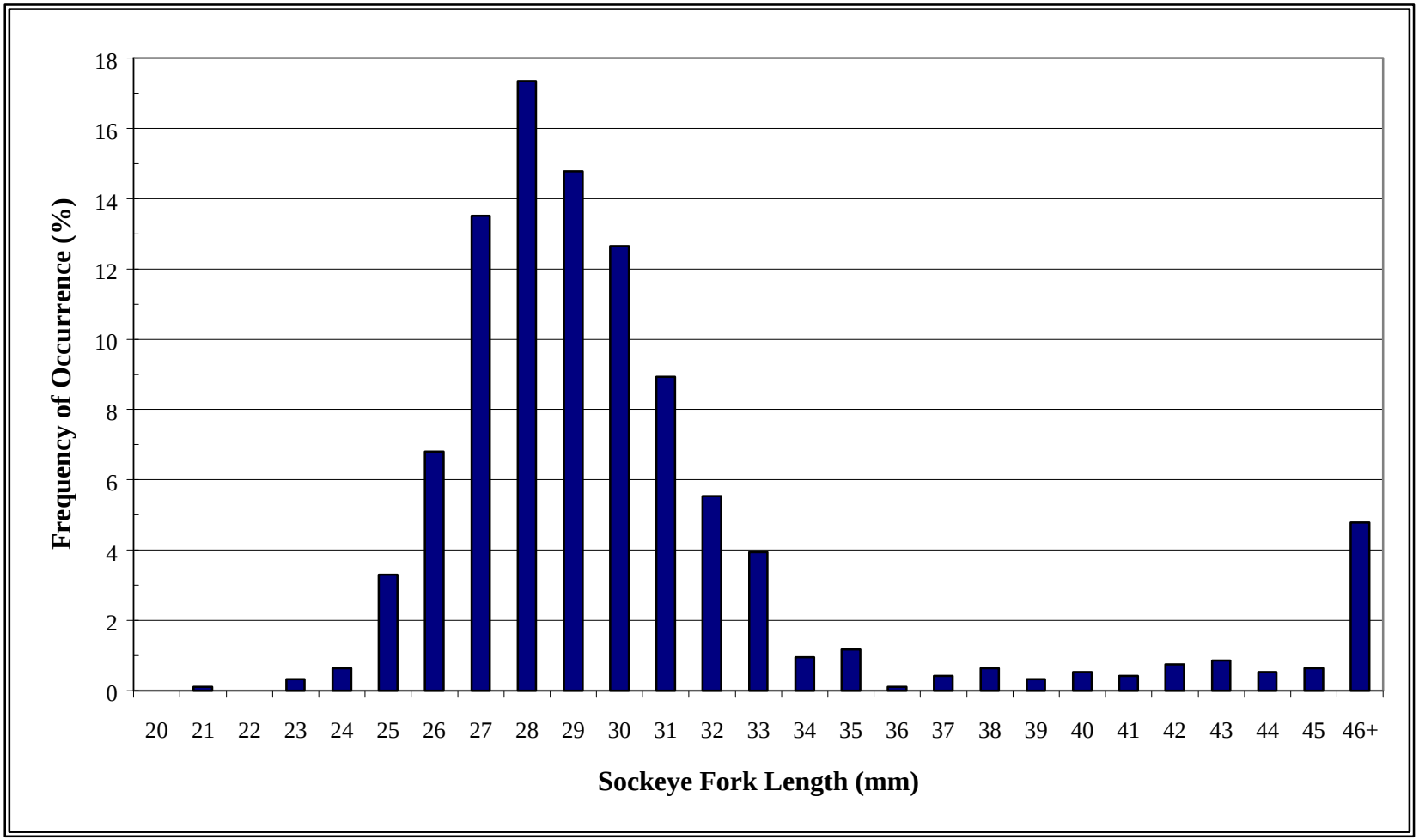

Figure 9. Length frequency of sockeye outmigrants in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000 (N=940).

Table 3. Species, number, and percentage of salmonid fry captured by month in the USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

	Number Captured by Month					Percent Captured by Month				
Species	**March**	**April**	**May**	**June**	**Grand Total**	**March**	**April**	**May**	**June**	**Grand Total**
Chinook salmon	16	13	13	0	42	38	31	31	0	100
Coho salmon	3	5	23	6	37	8	14	62	16	100
Sockeye salmon	971	5,919	5,482	6	12,378	8	48	44	0	100
Rainbow trout	0	1	0	1	2	0	50	0	50	100
Total	***990***	***5,938***	***5,518***	***13***	***12,459***	***8***	***48***	***44***	***0***	***100***

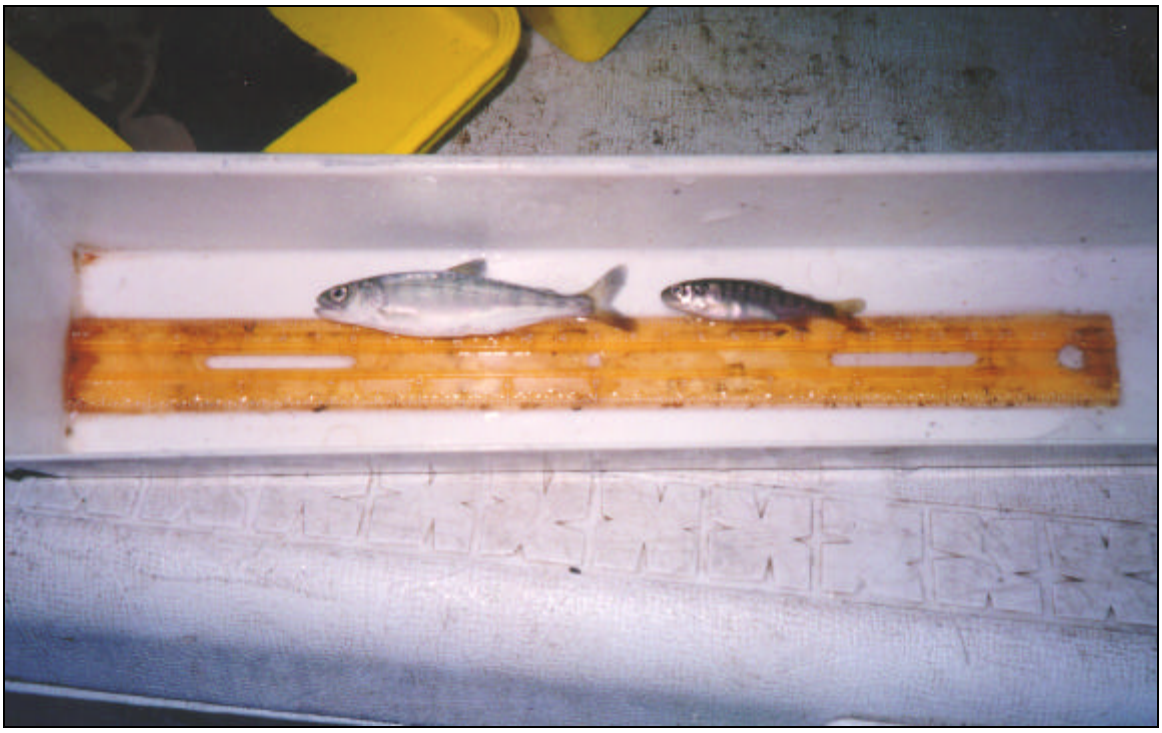

Figure 10. Coho salmon juveniles captured in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

Figure 11. Chinook (top) and sockeye (bottom) salmon juveniles captured in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

Table 4. Species, number, and fork length (FL) statistics of salmonid fry captured in the USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

	Chinook Salmon				Coho Salmon				Sockeye Salmon				Rainbow Trout				
Date	**No.**	**Mean FL (mm)**	**Max FL (mm)**	**Min FL (mm)**	**No.**	**Mean FL (mm)**	**Max FL (mm)**	**Min FL (mm)**	**No.**	**Mean FL (mm)**	**Max FL (mm)**	**Min FL (mm)**	**No.**	**Mean FL (mm)**	**Max FL (mm)**	**Min FL (mm)**	**Total**
10-Mar									1	35.0	35	35					***1***
16-Mar									9	30.0	33	25					***9***
22-Mar	8	50.4	54	48	2	45.0	45	45	344	28.8	48	20					***354***
27-Mar	6	51.2	54	47	1	41.0	41	41	346	31.3	45	24					***353***
30-Mar	2								271								***273***
5-Apr	1	47.0	47	47					632	30.7	35	25					***633***
6-Apr	1								556								***557***
12-Apr	1	62.0	62	62					264	31.0	33	29					***265***
13-Apr									269								***269***
17-Apr	4	49.3	52	45					436	28.3	32	25					***440***
19-Apr	1	67.0	67	67	2	40.0	40	40	465	30.4	34	29					***468***
26-Apr	1	51.0	51	51					1,038	30.1	32	27	1	38.0	38	38	***1,040***
27-Apr	4	57.0	70	47	3	50.7	55	43	2,259	32.7	44	26					***2,266***
2-May	4	33.0	33	33					831	28.5	34	25					***835***
5-May	5	40.0	57	33	2	60.5	63	58	1,414	28.0	32	25					***1,421***
9-May	1	62.0	62	62					879	30.1	46	27					***880***
10-May	1	32.0	32	32					1,607	27.2	30	25					***1,608***
17-May									58	30.8	33	29					***58***
19-May									138	28.8	33	26					***138***
23-May									80	30.1	43	27					***80***
24-May	2	39.0	43	35					255	26.8	29	25					***257***
30-May					21	57.5	66	35	220	43.9	73	27					***241***
6-Jun					6	56.2	65	52	6	41.0	53	30	1	54.0	54	54	***13***
Total	***42***	***47.8***	***70***	***32***	***37***	***55.2***	***66***	***35***	***12,378***	***30.7***	***73***	***20***	***2***	***46.0***	***54***	***38***	***12,459***

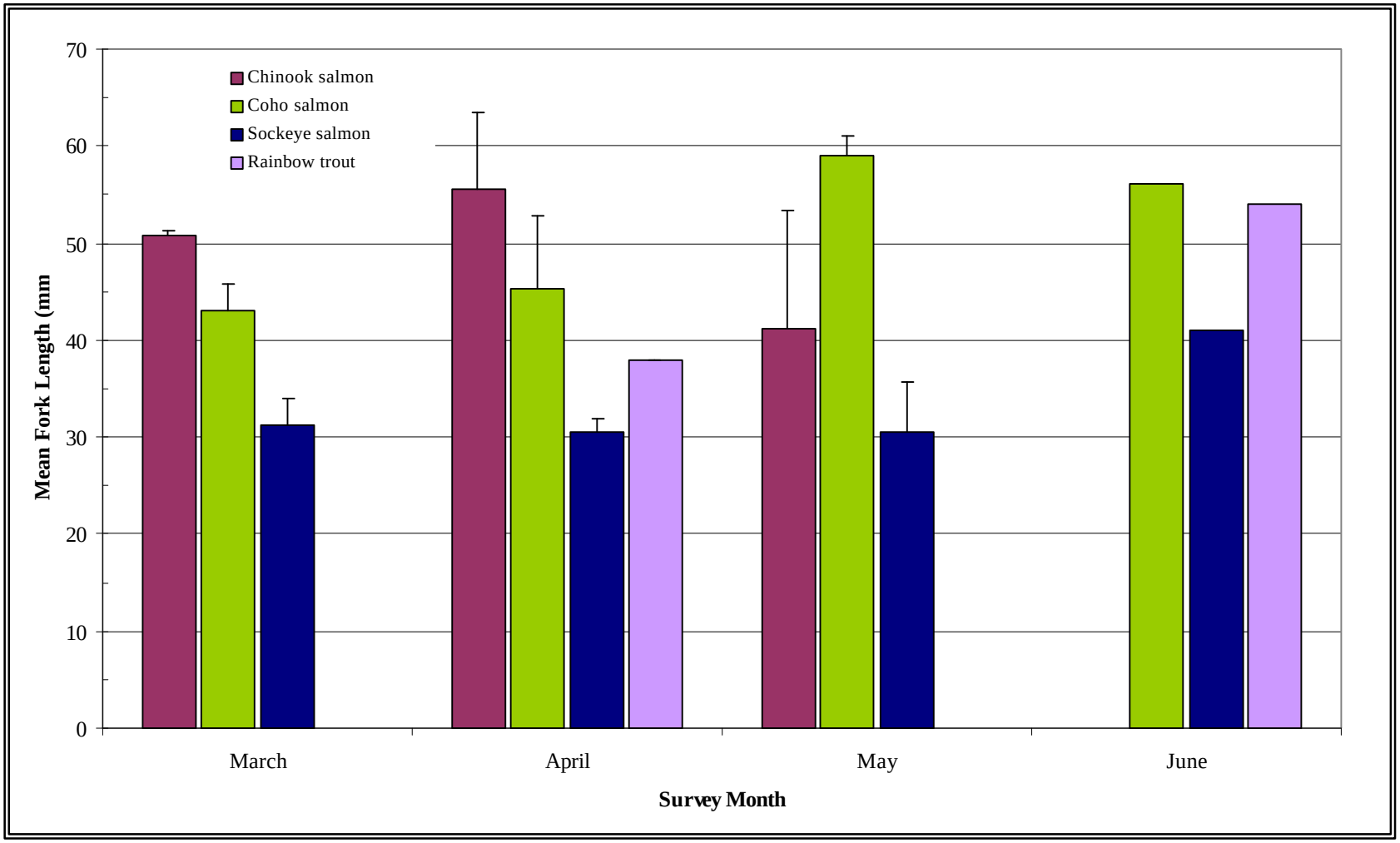

Figure 12. Mean size (mm) and standard deviation (error bars) of juvenile salmonids captured in USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

Table 5. Length category, number captured, number of sockeye consumed, and sockeye consumption rate by sculpin captured in the USACE Groundwater Side Channel, lower Cedar River, Washington, 2000.

Sculpin Length Category (mm)	No. Captured	Sockeye Consumed	Sockeye Predation Rate
41-50	2	0	0.00
51-60	2	0	0.00
61-70	11	5	0.45
71-80	10	22	2.20
81-90	15	66	4.40
91-100	7	23	3.29
101-110	4	18	4.50
Total	***51***	***134***	***2.63***

Table 6. Survey month, number captured, mean length (mm), number of sockeye consumed, sockeye consumption rate, and maximum number of sockeye consumed by sculpin captured in the USACE Groundwater Side Channel and the lower Cedar River, Washington, February-June, 2000 and 1995.

				Sockeye Consumed			
		No. Sculpin	**Mean Length (mm)**	**No.**	**Rate**	**Max.**	**Frequency of Occurrence**
USACE Groundwater Side Channel	March	2	72	0	0.00	0	0.0
	April	15	80	65	4.33	13	93.0
	May	30	78	68	2.27	13	56.7
	June	4	88	1	0.25	1	25.0
	Total	***51***	***79***	***134***	***2.63***	***13***	***43.7***
Tabor & Chan (1996)	March	6	107	42	7.00	11	100.0
	April	9	107	19	2.11	4	100.0
	May	12	109	3	0.25	1	25.0
	June	12	133	1	0.08	1	8.0
	Total	***39***	***114***	***65***	***1.67***	***11***	***49.0***

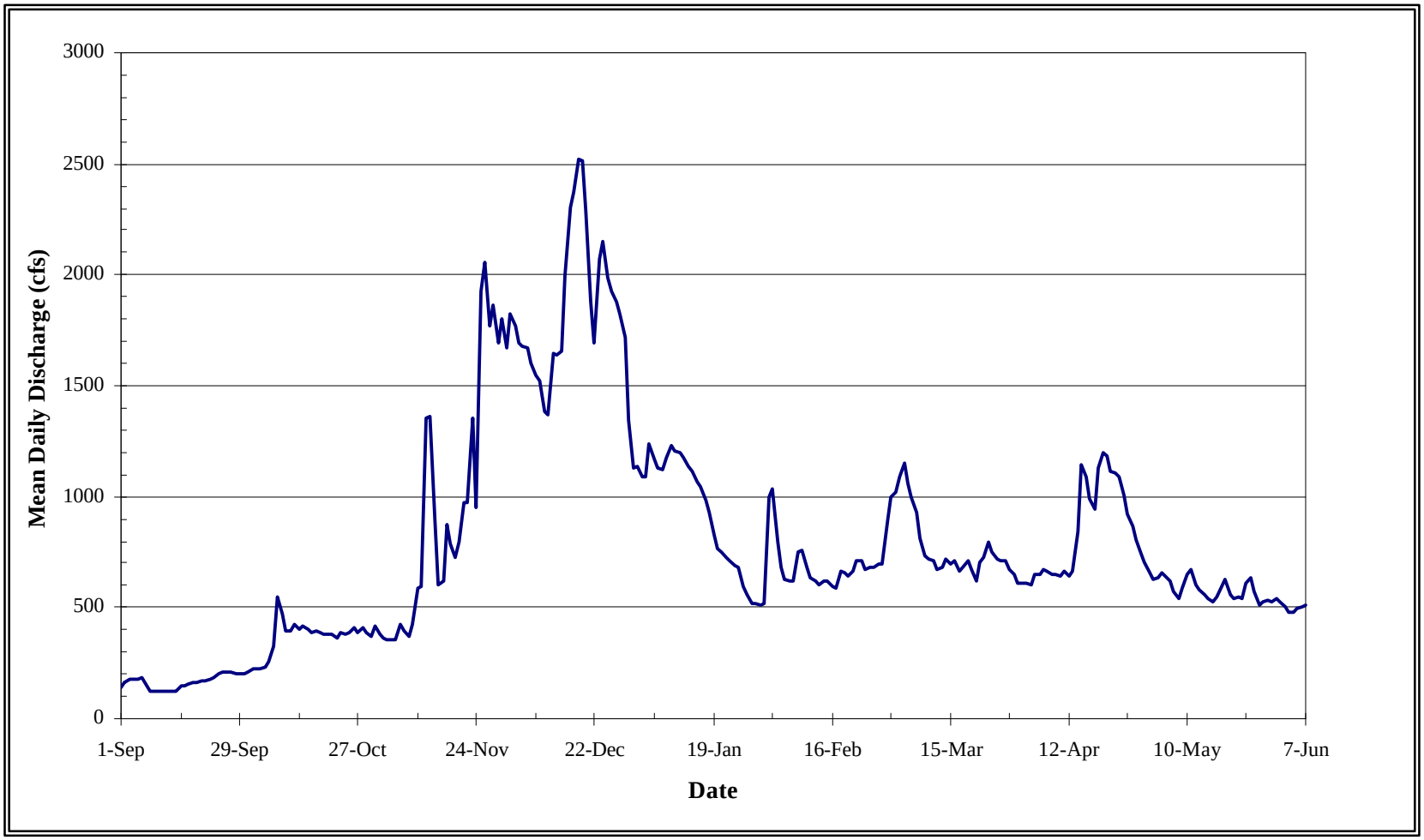

Figure 13. Mean daily discharge in the lower Cedar River at Renton, Washington, 1999-2000 (USGS Gage No. 12119000).

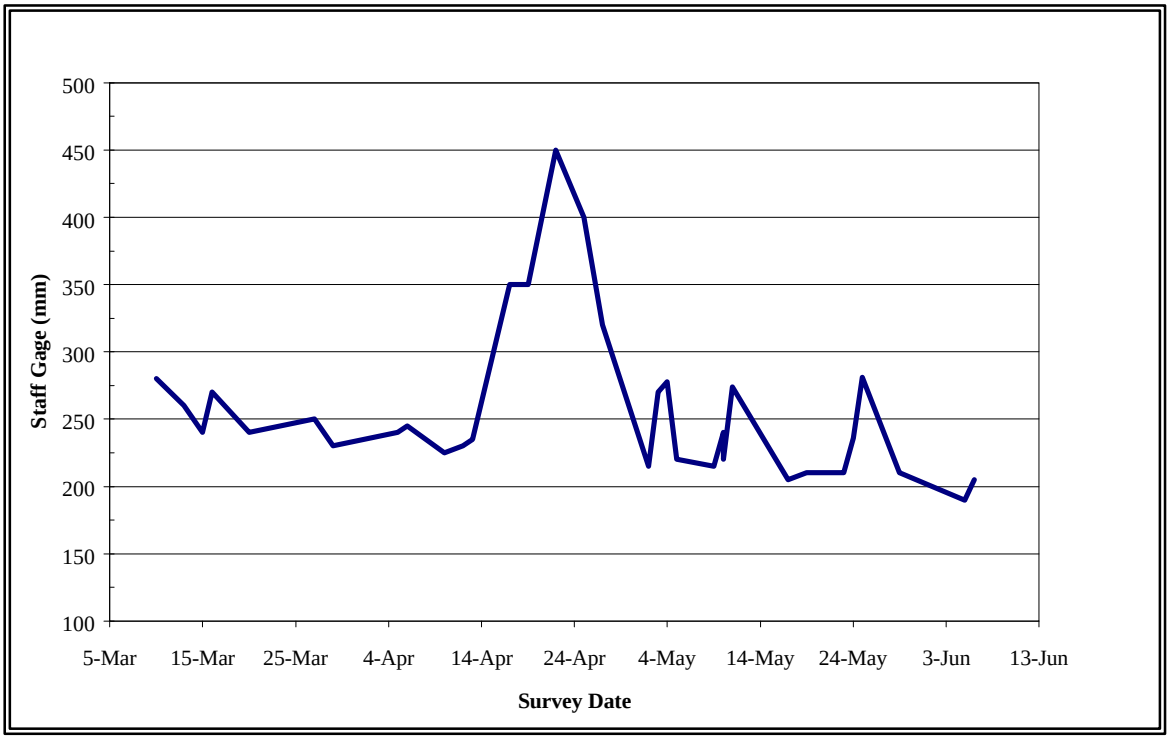

Figure 14. Stage (staff gage mm) recorded in the USACE Groundwater Side Channel, lower Cedar River, Washington, 1999-2000.

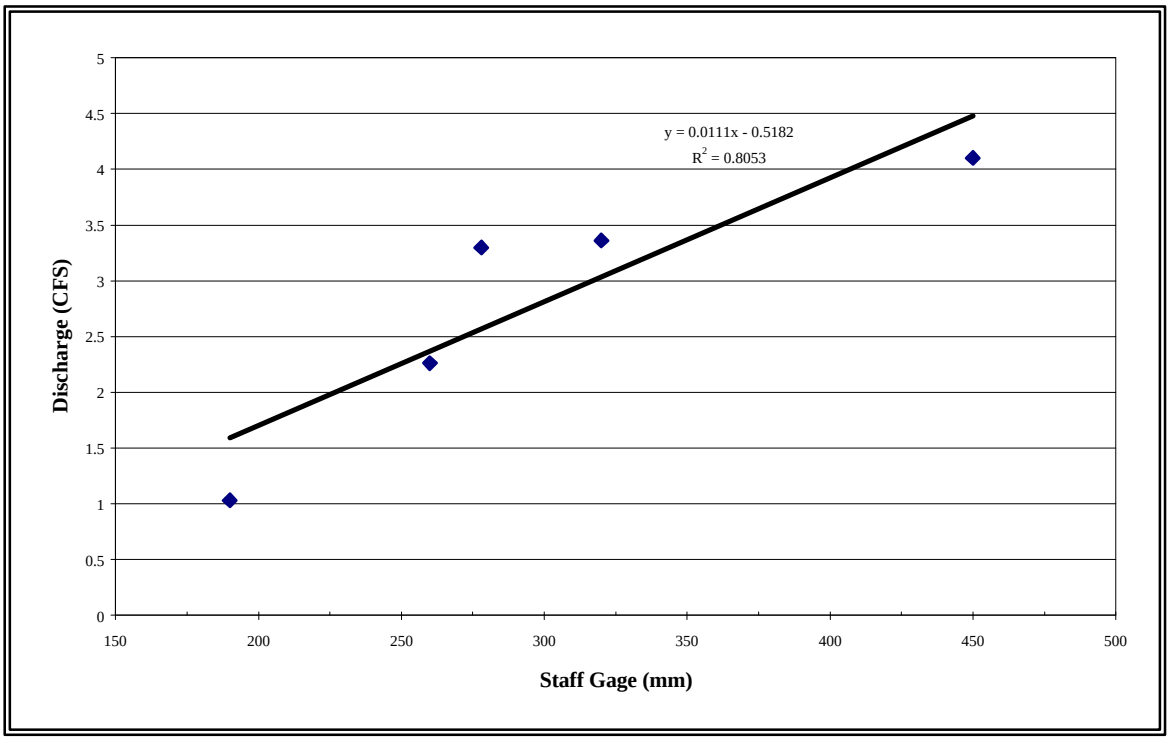

Figure 15. Stage-discharge relationship recorded in the USACE Groundwater Side Channel, lower Cedar River, Washington, 1999-2000.

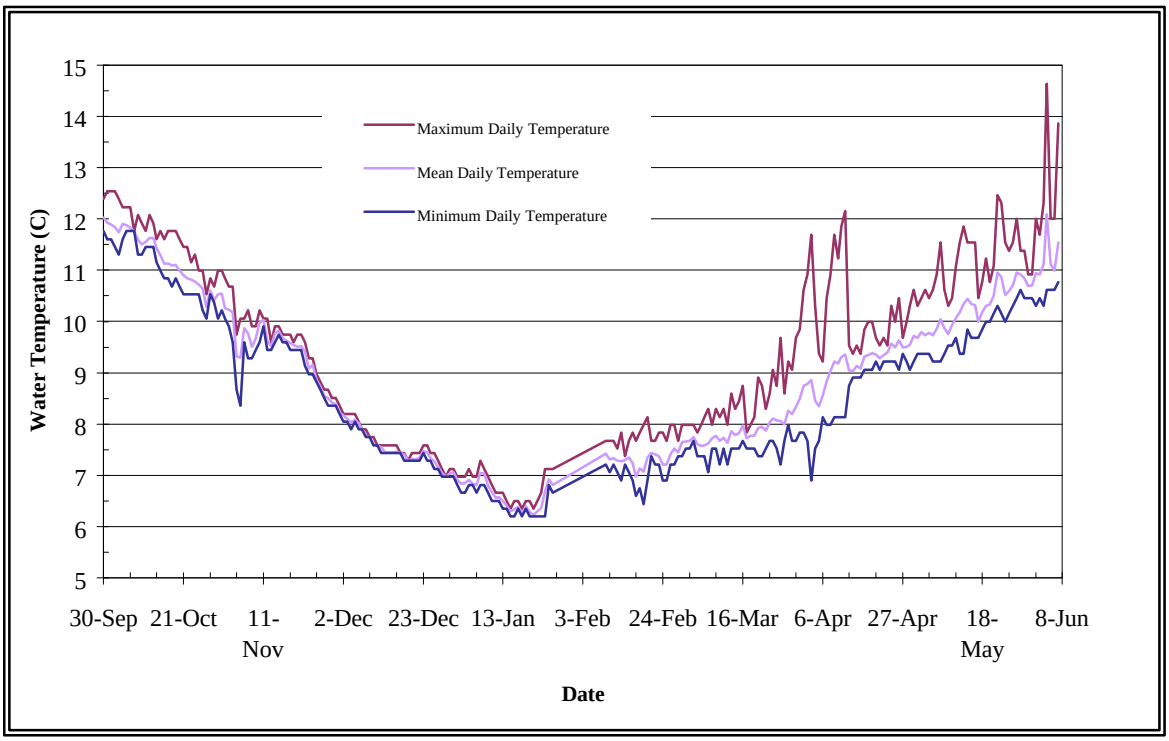

Figure 16. Daily maximum, mean, and minimum water temperatures (°C) recorded in the USACE Groundwater Side Channel, lower Cedar River, Washington, 1999-2000.

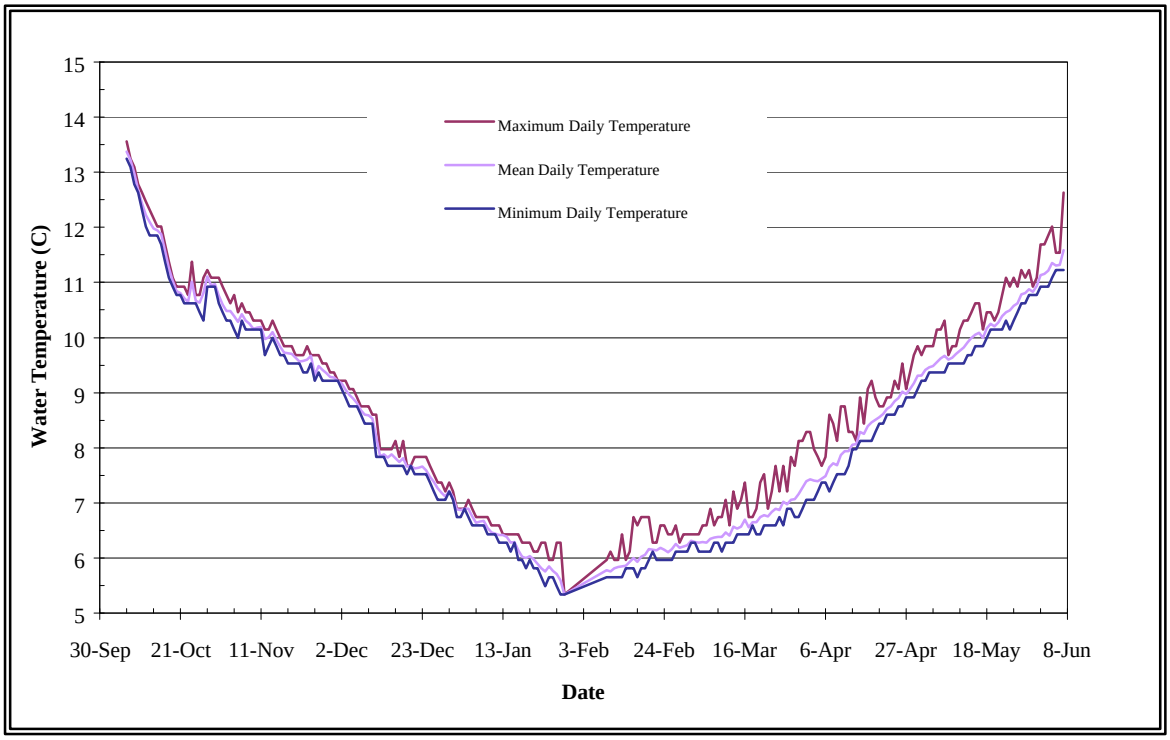

Figure 17. Daily maximum, mean, and minimum water temperatures (°C) recorded in the Elliot Levee Groundwater Channel, lower Cedar River, Washington, 1999-2000.

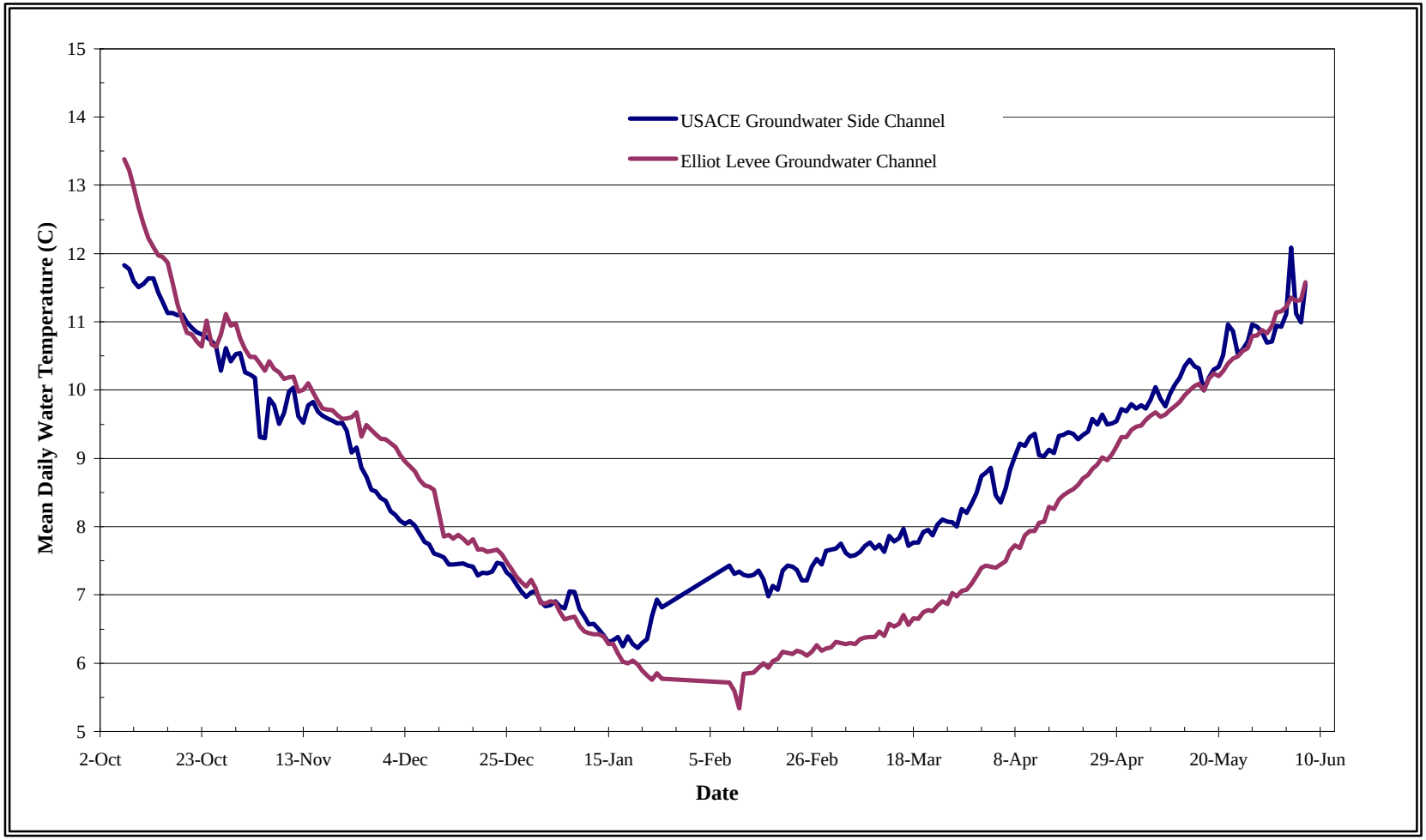

Figure 18. Mean daily water temperature recorded in the USACE Groundwater Side Channel and Elliot Levee Groundwater Channel, lower Cedar River, Washington, 1999-2000.

4. CONCLUSIONS AND RECOMMENDATIONS

- A total of 12,378 sockeye were captured at the mouth of the USACE Groundwater Side Channel from 10 March through 6 June. Total sockeye production from the 1999 brood was estimated at 44,090 for an overall density of 2.94 sockeye produced per ft^2 in the USACE Groundwater Side Channel. A single sockeye fry was captured on the initial survey date (10 March), while six sockeye were captured on the final survey (6 June).

- Sockeye outmigration peaked from 26 April through 10 May during which an estimated 1,338 sockeye moved from the USACE Groundwater Side Channel into the Cedar River, nightly. This two-week window represented approximately 50% (20,070) of the total estimated sockeye outmigration during the study period.

- Sockeye fry ranged from 20-73 mm in FL (mean = 30.7; SD = 6.1 mm) throughout the study period. Most sockeye (~80%) ranged from 26-32 mm in FL, indicating that they spent little time rearing in the USACE Groundwater Side Channel after emergence. This fact was corroborated by the large percentage (>14%) of fry that did not have their yolk-sack completely absorbed (termed button-up fry).

- Approximately 137 sockeye redds were deposited in the USACE Groundwater Side Channel upstream of the trap (144 total) during the 1999 spawning season, a year in which escapement to the Cedar River was less than 50,000 adult sockeye. Approximately 37,000 sockeye fry could be produced from the 137 redds deposited during the 1999 season. Our estimated production of 44,090 was 19% greater than the hypothetical value; however if a higher value of egg-to-fry survival were used (i.e., 10%), our estimate of production and the hypothetical production would be virtually identical.

- A total of 12,596 fish were captured, handled, and released at the USACE Groundwater Side Channel fyke net during 2000. Visible injuries occurred to 24 sockeye and resulted in 23 immediate mortalities for an overall injury rate of <0.2%. All of the observed injuries/mortalities occurred to sockeye <30 mm FL and in button-up condition, a stage at which juvenile salmonids are particularly fragile. We suggest that future fyke net surveys should be checked every hour until the catch subsides and then immediately at sunrise.

- The limited use of emergent fry traps, which was initiated as a test procedure during the 1999 field season, was marginally successful. We suggest that a more rigorous fry emergence survey be planned for future monitoring efforts, particularly in areas that may be prone to elevated fine sediment loadings. With little additional effort, 4 to 6 emergent traps could be monitored in each channel to obtain more accurate descriptions of the peak and duration of emergence timing between the two study sites.

- During this study, a total of 12,378 sockeye were captured at the mouth of the USACE Groundwater Side Channel; 19 were collected over the same period in 1999. Higher escapement within the USACE Groundwater Side Channel, frequent operation and maintenance of the trap, and fyke net position within the channel combined to yield more robust study results compared to the 1998-1999 field season.

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