Evaluate Factors Limiting Columbia River Gorge Chum Salmon Populations

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FY2000 Annual Report

Prepared by:

Thomas A. Hoffman
Ann E. Gray
Scott A. Barndt
Travis C. Coley

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
Habitat and Natural Production Team
9317 N.E. Highway 99, Suite I
Vancouver, Washington 98665 USA

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Abstract

Juvenile and adult chum salmon were monitored in fiscal year 2000 to continue evaluating factors limiting production. Total adult salmon caught (in weirs or by carcass surveys) in Hardy Creek and Hamilton Springs in 1999 was 92 and 204 fish, respectively. However, only 19 fish were radio-tagged and monitored. One of six fish radio tagged in Hardy Creek was tracked in both Hardy Creek and Hamilton Springs and one fish radio tagged in Hamilton Springs was later tracked in Hardy Creek. Fish were regularly monitored moving between the lower Hamilton Creek and Columbia River sites. These sites were close enough together that the aerials' reception ranges overlapped.

The outmigration pattern was similar for both Hamilton Springs and Hardy Creek with peak migration delayed a couple of days in Hardy Creek. Peak migrations were from late March until early April. Total smolts captured in Hardy Creek and Hamilton Springs was 43,787 and 23,803, respectively. Bootstrap population interval estimates for smolts are 127,416±14,995 in Hardy Creek and 118,016±28,763 in Hamilton Springs.

Introduction

Historically, chum salmon (*Oncorhynchus keta*) had the widest distribution of all Pacific salmon species, comprising up to 50% of annual biomass of the seven species and may have spawned as far up the Columbia River drainage as the Walla Walla River (Nehlsen et al. 1991). Though there is no historic run size data for the Columbia River chum, the maximum historical commercial fishery landings were approximately 700,000 fish in 1928 (Columbia Basin Fish and Wildlife Authority (CBFWA) 1991). By the 1950s, landings declined dramatically to 10,000 fish (CBFWA 1991). On May 24, 1999 the National Marine Fisheries Service (NMFS) listed Columbia River chum populations as threatened under the Endangered Species Act (NMFS 1998).

Chum salmon are primarily limited to the tributaries downstream of Bonneville Dam and the majority of the fish spawn in Washington tributaries of the Columbia River. The only known stable, natural chum salmon production occurs in the Grays River (Gorley Creek), Hamilton Creek, and Hardy Creek (CBFWA 1990, Washington Department of Fisheries (WDF) et al. 1993). Hardy and Hamilton Creeks are the farthest upstream populations at river kilometer (rkm) 227 (Bonneville Dam is rkm 232), separated by over 160 rkm from the Grays River. Irregularly, chum salmon have spawned in a side channel of the Columbia River located between Hardy and Hamilton Creeks, near Ives Island ("Pierce/Ives Island Complex").

The United States Fish and Wildlife Service (USFWS) Columbia River Fisheries Program Office (CRFPO) has monitored adult and juvenile chum populations on Hardy Creek since 1997. In 1999, Bonneville Power Administration (BPA) funded CRFPO to monitor the chum salmon runs in Hardy and Hamilton Creeks as well as the Pierce/Ives Island Complex. Continued monitoring will provide a better understanding of the life history requirements for Columbia River chum salmon.

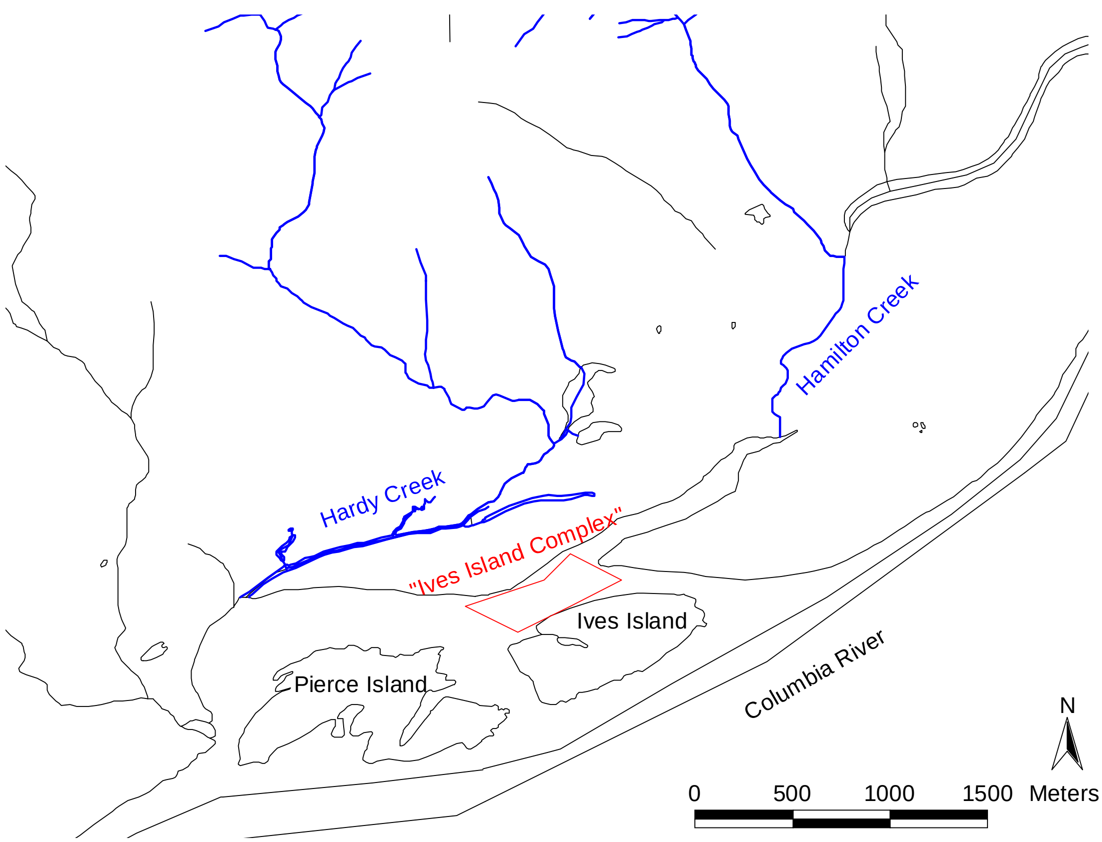
The objectives of this ongoing project are to: 1) Examine factors limiting chum salmon production in Hamilton and Hardy Creeks, 2) Enhance and restore chum salmon production in Hamilton and Hardy Creeks, and 3) Evaluate the relationship between mainstem Columbia River and tributary chum salmon populations.

Study Area

Hardy Creek

Chum salmon migrations in Hardy Creek are restricted to the lower portion of the stream (Figure 1). A culvert, which was installed during the construction of the railroad, is an impassable barrier to chum. No suitable spawning habitat exists above this culvert as the stream transitions to a higher gradient (2-10%) with a cobble substrate (USFWS unpubl. data). The lower section was re-routed and dredged in the early 1900s, creating a relatively straight, entrenched channel. Only the lower section of Hardy Creek was monitored during this project.

Figure 1. Area map of upper chum salmon spawning grounds, 2000.



During high runoff events and backwater effects from the Columbia River, fine sediments deposit on available spawning habitat. Hardy Creek experiences these detrimental backwater effects every 2-5 years (USFWS unpubl. data).

Most of the Hardy Creek watershed is in public land (primarily Washington State Park) with a small private holding bordering State Route 14. The lower portion of the stream is on Pierce National Wildlife Refuge. The entire watershed has been logged at least once. However, existing forests are considered second growth (approximately 35 years old) and will not be subject to future logging.

In 1996, USFWS undertook emergency habitat restoration actions to mitigate for catastrophic flooding that destroyed essentially all of the spawning habitat available to chum salmon in Hardy Creek. This flood scoured redds and caused egg suffocation through increased sedimentation. The USFWS stabilized eroding banks, restored riparian vegetation, and exposed previously buried spawning areas. These actions allowed subsequent runs of chum salmon to successfully spawn in much of the lower section of Hardy Creek. However, habitat restoration only uncovered 0.64 linear km of spawning habitat (USFWS, unpubl. data).

In August and September 2000, an artificial spawning channel was constructed off of Hardy Creek. This spawning channel incorporates successful designs from Canada, Alaska, and Washington (Bonnell 1991, Cowan 1991). As designed, the spawning channel will not be influenced by hydropower operations, nor will it be susceptible to catastrophic flooding events that might adversely impact spawning habitat. The spawning channel doubles the spawning habitat available for chum in Hardy Creek. Unfortunately, it can only be operated during normal or high water years because it relies on surface water sources.

Hamilton Creek/Springs

The lower section of Hamilton Creek passes through the town of North Bonneville (Figure 1). This creek historically entered a side channel of the Columbia River between the mainland and Hamilton Island. During construction of the second power house at Bonneville Dam, the upstream portion of the side channel was filled to join Hamilton Island to the mainland and the downstream portion became an extension of Hamilton Creek. Hamilton Creek now flows directly into the Columbia River.

In the early 1960s, an artificial spawning channel was constructed in the lower section of Hamilton Creek and is referred to as "Hamilton Springs" (Figure 1). Hamilton Springs provides the majority of spawning habitat in this drainage. Water flow is largely controlled by groundwater springs, which provide a very stable environment for chum reproduction. Only Hamilton Spring and the portion of Hamilton Creek below its confluence were monitored during this project.

Pierce/Ives Island Complex

Historically, chum salmon have spawned around the Ives and Pierce Island complex. The islands are near Beacon Rock and parallel Pierce National Wildlife Refuge (Figure 1). It is not known exactly how much spawning activity occurs in the Hamilton side-channel of the Columbia River. Radio-tagged chum salmon movements were evaluated on the spawning areas by fixed receiver antennas.

Life History

Adult chum salmon return to the Columbia River at ages III to VI, although the majority typically return at age IV (WDF et al. 1993). Adult chum salmon return to Hardy Creek, Hamilton Creek/Spring, and the Ives Island Complex in late October and early November, sometimes staging in the Columbia River near the two creeks (USFWS, unpubl. data).

Spawning begins when flows are suitable, allowing fish access into the creeks. Spawning peaks in late November and continues through December (USFWS, unpubl. data). Female chum salmon enter a potential spawning area and swim slowly upstream with her nose down and fins extended, looking for areas immediately above turbulence or areas of upwelling. They attempt to find unoccupied areas without fighting. To dig nests (redds) females turn on their sides and perform a series of four to six flexures, slapping their tails on the gravel substrate. They will typically build four to six nests in succession in one place. Nests are typically 20 to 50 cm deep and lined with substrate that allows intergravel flow. Nests are covered within seconds of egg deposition (Groot and Margolis 1991). Spawning occurs in water velocities ranging from 0.0 to 167.6 cm/s. However, it was found that the developmental rate was increased and larger fry were produced at higher rather than lower flows (Groot and Margolis 1991).

Incubation and emergence are affected by stream flow, water temperature, dissolved oxygen, gravel composition, spawning time, spawner density, and genetic characteristics (Groot and Margolis 1991). Eggs develop into sac fry, which remain in the gravel until the yolk sac is completely absorbed. Temperature units (TU) are defined as the number of degrees above 0° C during a 24-hour period. Chum salmon require approximately 400 to 600 TUs to hatch and approximately 700 to 1000 for yolk absorption (Groot and Margolis 1991). Fry begin emerging from the gravel in early and mid-February, smoltify, and outmigrate immediately (USFWS unpubl. data). The smolts migrate to their ocean feeding grounds where they remain until returning to the Columbia River to spawn. The precision of homing and the degree of straying are not well documented in chum, but indications are that homing tendencies are strong (Groot and Margolis 1991).

Methods

ADULTS

Adult Weir

Adult chum salmon were captured in November and December in Hardy Creek by a resistance-board weir (Tobin 1994, Schroeder 1996) and in Hamilton Springs by a picket weir (Schroeder 1996). Since the weirs only trapped upstream fish, the weirs were only fished three days a week to allow for volitional fish movement.

Captured fish were anaesthetized in a water bath containing a solution of MS-222 (tricaine methanesulfonate). Fish were bio-sampled, marked with a jaw tag, and secondarily marked with a hole-punch in either operculum. Hole-punches were rotated on a weekly basis to determine time of marking if other marks were lost or not detectable. A scale sample was taken for age analysis. Select adults (i. e. good condition and not "spent" or "spawned out") were fitted with a LOTEK radio transmitter (gastric implant, 7 volt, 30 g, 148-152 Mhz) and were released immediately upstream of their capture site.

Adult Movement

All fish tagged in Hardy Creek were captured using a seine, while the fish tagged in Hamilton Springs were captured with the picket weir. Chum salmon movements were tracked between the three primary spawning grounds using LOTEK telemetry receivers placed at five sites: near the mouths of Hardy and Hamilton Creeks, near the spawning area of Hardy Creek and Hamilton Springs, and at the Pierce/Ives Island Complex.

Spawning Ground Survey

Spawning ground surveys were performed from November through mid-January 2000 and were conducted as often as every 2 days during peak spawning activity. One to three surveyors walked the stream and visually enumerated the number of live fish, redds, and carcasses. Surveyors avoided walking through redds to minimize disturbance to spawning and/or staging chum. Carcasses were bio-sampled and scales were taken for aging. Peak counts were determined by summing the number of live chum and carcasses present in the stream during the spawning ground survey.

Recovered radio and jaw tags from carcasses were used to estimate the stream-life of individual fish. Stream-life is defined as the time spent in the stream from tagging until carcass recovery and is used along with peak counts in the Area-Under-the-Curve program to produce population estimates (Ames 1982). Peak counts are plotted to produce a curve. The program calculates area underneath the curve. Divide this area by the residence time to produce a population estimate. So, the shorter the residence time, the larger the population estimate, and the longer the residence time, the lower the population estimate.

JUVENILES

Juvenile salmon were trapped from late February until June. In Hardy Creek, a floating fyke net modified from Davis et al. (1980) was used to capture smolts, while a traditional fyke net was used in Hamilton Springs. Outmigrant traps were checked daily, where all captured fish were identified to species, checked for marks, and enumerated. A small group of chum salmon smolts were marked with a solution of strontium chloride ($SrCl_2$) to determine future adult return rates. The strontium solution produces a visible mark on fish otiliths, which can be extracted in the future from returned adults. Hobo Tidbit temperature loggers recorded water temperature every 4 hours. Daily averages were calculated from these readings.

Once per week, fish were anaesthetized, measured for fork length, and individually marked on the caudal fin with a florescent dye using a Microject tag injector. A different color dye was used each week and for each trap. A maximum of 200 chum salmon were marked and released upstream at dusk to reduce predation risk (Murphy et al. 1996). A subsample of marked fish (20 or 10% of the total number marked if less than 200 fish) was held overnight in a live box to evaluate short-term mark retention and survival (Murphy et al. 1996). Weekly trap efficiencies were determined for each trap by the percentage of marked fish recaptured within a weekly marking period. If there was not a significant difference in trap efficiencies between marking periods (Chi-Square, $p<0.05$), they were grouped and mean trap efficiency was used to calculated daily abundance. There were nine marking periods for Hamilton Springs and Hardy Creek. Trap efficiencies and daily catches were used to estimate population abundance and bootstrap intervals were calculated to determine the variance associated with the population estimate (Murphy et al. 1996).

Results

ADULTS

Adult Weir

The Hardy Creek weir operated from November 11 until November 25, when it was breached by high flows associated with a rain-on-snow event. Only one male chum was captured to this point. Continued high flows prevented the re-installation of the weir. A total of 92 fish were bio-sampled, including carcass surveys (Table 1). Numbers and mean lengths at specific ages are illustrated in Table 1. Sex ratios are approximately 1:1 in Hardy Creek. Population estimates for adult chum salmon were 418 in Hardy Creek.

The Hamilton Spring weir was operated between November 17 and December 22. This weir was not breached because water flow is closely controlled. Thirty-six males and two females were captured. Thirteen fish were radio tagged and released upstream of the weir. A total of 204 fish were bio-sampled, including carcass surveys (Table 1). Sex ratios are 3:1 in favor of males in Hamilton Springs (Table 1). Population estimates for adults were 318 individuals.

Table 1. Age structures and mean lengths for Hardy Creek and Hamilton Springs, 2000.

		Males				Females				
		III	IV	V	Subtotal	III	IV	V	Subtotal	Grand Total
Hardy Creek	Number	28	5	11	44	32	11	5	48	92
	Mean Length	765	820	824		687	723	732		
Hamilton Springs	Number	110	24	20	154	36	10	4	50	204
	Mean Length	756	804	822		694	711	720		

Adult Movement

A total of 19 fish were radio tagged in Hardy Creek (6) and Hamilton Springs (13). Six chum salmon (all male) were radio-tagged at Hardy Creek and thirteen chum salmon (12 male and 1 female) were radio-tagged at Hamilton Springs. Twelve of the 13 chum tagged in Hamilton Springs were subsequently recorded by the stationary unit at the Columbia River site. One of these males was tracked into Hardy Creek, returned to the Columbia River site for three days, re-entered Hardy Creek for four days, and finally returned to the Columbia River site. One male, originally tagged at Hardy Creek remained there for two days, moved to upper Hamilton Creek for a few hours, then moved to the Columbia River site for 10 days. The other five chum tagged in Hardy Creek remained in the creek.

Spawning Ground Survey

A total of 48 redds were counted in Hardy Creek and 43 redds were counted in Hamilton Springs. The number in Hamilton Springs is a conservative estimate due to superimposition of redds. Live chum were observed in both creeks for approximately seven weeks. Residence time, calculated from 23 recovered jaw tags (3 in Hardy Creek and 20 in Hamilton Springs), was six days.

The first fish were observed in Hardy Creek on 14 November 1999 and the last fish were observed on 7 January 2000. The peak count in Hardy Creek was 168 fish on 8 December 1999. The first fish were observed in Hamilton springs on 16 November 1999 and the last fish were observed on 7 January 2000. Peak count in Hamilton Springs was 188 observed on 8 December 1999.

JUVENILES

A total of 43,787 smolts were captured in Hardy Creek and 23,803 smolts were captured in Hamilton Springs (Table 2). Mean trap efficiencies were 0.252 in Hardy Creek and 0.309 in Hamilton Springs. Population estimates for Hardy Creek and Hamilton Springs were 127,416±14,995 and 118,016±28,769, respectively. A small group (n=123) of smolts was tagged with a solution of $SrCl_2$ to determine future adult return rates.

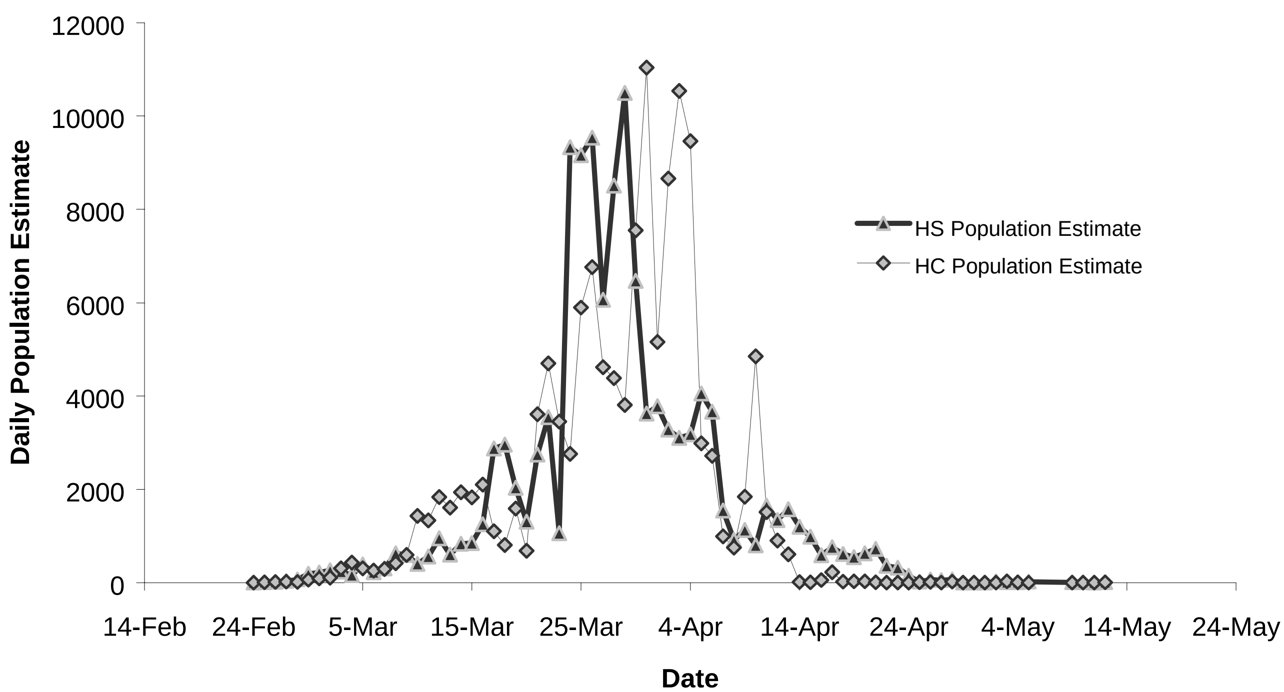
Table 2. Summary table for smolt trapping in Hardy Creek and Hamilton Springs, 2000.

	Hardy Creek	Hamilton Springs
Total Captured	43,787	23,803
Total Mortality	342	222
Percent Mortality	0.78%	0.93%
Mean Trap Efficiency	0.252	0.309
Population Estimate*	127,416+/-14,995	118,016+/-28,769

* Includes 95% confidence interval.

Daily population peaked at 11,033 smolts on 31 March 2000 in Hardy Creek and 10,493 smolts on 29 March 2000 in Hamilton Springs (Figure 2). Migrations followed the same pattern for both spawning areas, but were slightly later by a couple of days in Hardy Creek (Figure 2).

Figure 2. Daily population estimates for Hamilton Springs and Hardy Creek, 2000.



No fish were marked in periods two and seven in Hardy Creek. Smolts were significantly larger in marking period nine for both Hardy Creek and Hamilton Springs, but otherwise showed similar patterns (Figure 3). In Hardy Creek, lengths during marking period five were significantly different from all other marking periods (Table 3). Lengths of smolts were significantly different for almost all marking periods in Hamilton Springs (Table 4). Finally, when comparing lengths of smolts between Hardy Creek and Hamilton Springs, lengths in Hardy Creek were larger in marking periods one, five and six (Table 5). Smolts were significantly larger in Hamilton Springs in marking periods three and four (Table 5). In marking periods eight and nine, lengths were NOT significantly different (Table 5).

Figure 3. Mean lengths per marking period in Hamilton Springs and Hardy Creek, 2000.

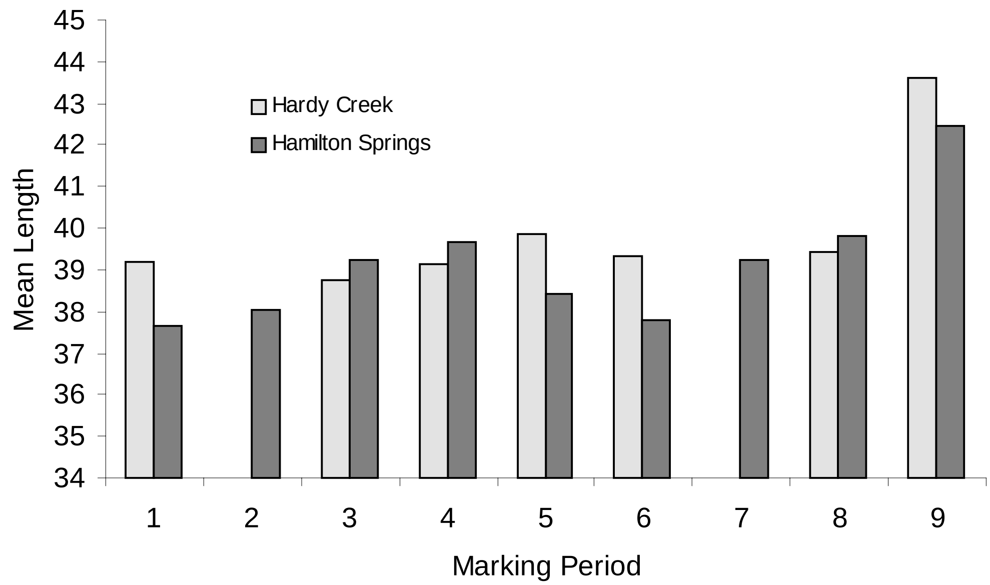


Table 3. P-values for within marking period analysis of Hardy Creek smolts, 2000.

Marking period	1	2	3	4	5	6	7	8	9
1	-----								
2	NFM	----							
3	0.173	NFM	----						
4	1.000	NFM	0.438	----					
5	**0.004**	NFM	**0.000**	**0.003**	----				
6	0.995	NFM	0.123	0.973	0.185	----			
7	NFM	NFM	NFM	NFM	NFM	NFM	----		
8	0.964	NFM	0.164	0.913	0.757	1.000	NFM	----	
9	**0.000**	NFM	**0.000**	**0.000**	**0.000**	**0.000**	NFM	**0.000**	----

NFM: No fish marked in marking period.

Bold indicates significance.

Table 4. P-values for within marking period analysis of Hamilton Springs smolts, 2000.

Marking period	1	2	3	4	5	6	7	8	9
1	-----								
2	**0.000**	----							
3	**0.000**	**0.000**	----						
4	**0.000**	**0.000**	0.172	----					
5	**0.000**	0.999	**0.000**	**0.000**	----				
6	**0.008**	**0.031**	**0.000**	**0.000**	**0.008**	----			
7	**0.000**	**0.002**	**0.003**	**0.000**	**0.048**	**0.000**	----		
8	**0.000**	**0.004**	1.000	0.932	**0.017**	**0.000**	0.662	----	
9	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	----

Bold indicates significance.

Table 5. Marking period analysis between Hamilton Springs and Hardy Creek smolts, 2000.

	Marking Period								
	1	2	3	4	5	6	7	8	9
p-value	**0.000**	NA	**0.000**	**0.000**	**0.000**	**0.000**	NA	0.248	0.371

Bold indicates significance.

Conclusions

ADULTS

Adult Weir

The adult weir in Hamilton Springs was more successful in capturing fish than the weir in Hardy Creek. High flows and the flashy nature of Hardy Creek make weir fishing difficult to sustain. When fishing under normal conditions the resistance board weir in Hardy Creek is very efficient in capturing adult chum salmon.

Hamilton Springs shows more consistent flows over time and is more conducive to a temporary weir structure. A traditional picket weir in Hamilton Springs is sufficient in capturing the majority of adult fish entering the system to spawn. Overall, the weirs were a very effective way to capture adults in order to collect biological data. Methods of fish handling at the weirs were conducive to tagging and recording data and, more importantly, reducing stress on the fish that can be incurred through other capture methods.

Adult Movement

The majority of fish radio tagged have been captured either at one of the weirs or seined near the spawning grounds. Even though most of the fish that were tagged were already in either system, radio telemetry showed movement between Hamilton Springs, Hardy Creek, and the mainstem Columbia River. The degree of movement cannot be determined yet, but may be substantial as indicated by the proportion of tagged that moved. Hopefully, when more fish are tagged in the future, it can be determined if fish are spawning in more than one area or if they are moving to find the best place to spawn and concentrate efforts.

Spawning Ground Survey

Spawning ground surveys were instrumental in deriving population abundance estimates. With the aid of the Area-Under-the-Curve program (Ames 1982), residence time and peak counts were used to estimate that 418 adults were in Hardy Creek and 318 adults were in Hamilton Springs. Residence time is a key component because it can greatly change population estimates. Longer residence times produce lower population estimates. If residence time is difficult to determine (e.g. weir difficulties), 10 days is used as a conservative rule-of-thumb. In the case of Hamilton Springs, it proved to be too conservative. The population estimate produced was lower than the number of fish sampled through carcass surveys. Re-calculation of residence time showed six days to be a better estimate. More jaw tags in the future will produce a more accurate estimate of residence time, thereby producing more accurate population estimates.

JUVENILES

Daily population estimates were produced using daily catch and mark-recapture to estimate mean trap (fyke net) efficiency. Outmigration in both Hamilton Springs and Hardy Creek showed similar patterns. Hardy Creek outmigration seemed to drop off more quickly than in Hamilton Springs. This is misleading due to the inability to calculate population estimates for the last two marking periods. Instead of calculating daily population estimates for the last two marking periods, the daily catches were simply added to the summed abundance estimates. So, the Hardy Creek smolt population estimate is conservative.

Smolts were not marked during marking periods two and seven in Hardy Creek. Large fluctuations in water level due to rainfall and backwater effects from the Columbia River caused problems with the floating fyke net. The wings of the net lifted off the bottom and allowed most of the smolts to pass the net without being collected. Smolts in marking periods five and nine were significantly larger than in other marking periods indicating residence time before outmigration.

In Hamilton Springs, most lengths were different in all marking periods. Overall, only marking periods eight and nine were not significantly different when comparing lengths per marking period between Hardy Creek and Hamilton springs. This also indicates residence time, but the degree is not yet known.

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