Feasibility and Risks of Coho Reintroduction in Mid-Columbia Monitoring and Evaluation

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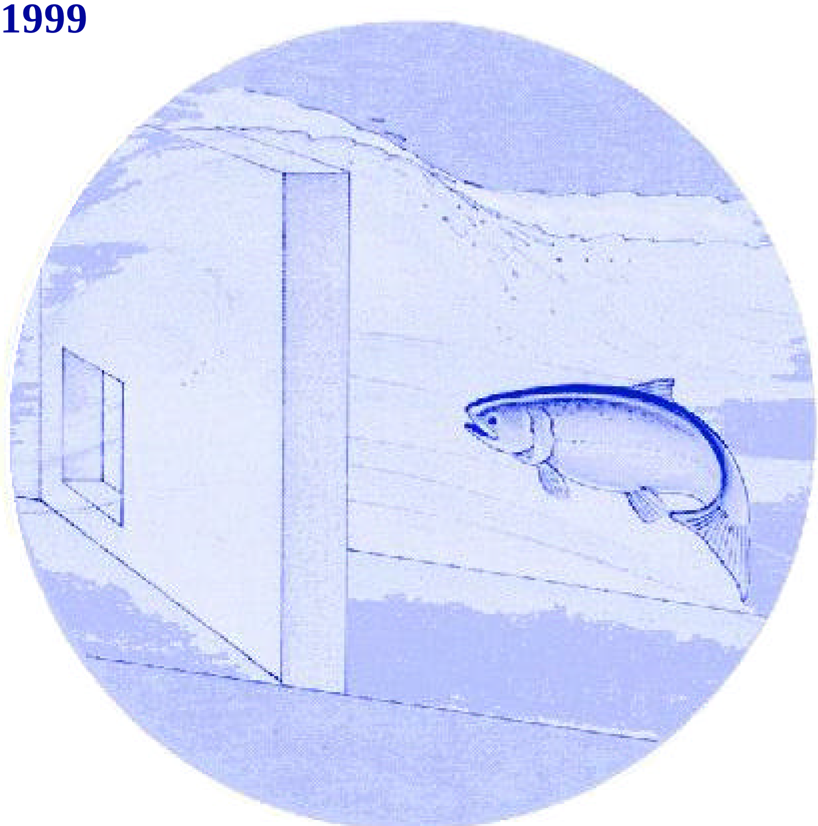

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FEASIBILITY AND RISKS OF COHO REINTRODUCTION IN MID-COLUMBIA MONITORING AND EVALUATION

1999 ANNUAL REPORT

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EXECUTIVE SUMMARY

The long-term vision for this coho re-introduction project is to reestablish naturally reproducing coho salmon populations in mid-Columbia river basins, with numbers at or near carrying capacity that provide opportunities for significant harvest for Tribal and non-Tribal fishers. The feasibility of re-establishing coho in the tributaries of the mid Columbia Basin may initially rely upon the resolution of two central issues: the adaptability of a domesticated lower river coho stock used in the re-introduction efforts and associated survival rates, and the ecological risk to other species associated with coho re-introduction efforts. Research in 1998 and 1999 focused on addressing these two central issues. The goals and objectives for this project are closely tied to ongoing reintroduction efforts in the Yakima basin. Since efforts in the Yakima basin have been ongoing for a longer period of time, opportunities to investigate basin *nonspecific* issues surrounding these two central issues in the Yakima basin occur much sooner than they may in either the Wenatchee or Methow basins. Therefore information presented in this report was is a summary of work performed in the Methow, Wenatchee and Yakima basins.

- Hatchery coho smolt predation on recently emerged wild spring chinook fry was low in 1998 and 1999. We compared two models of coho gastric evacuation, concluding that results from the two models likely bracket two predation rates for both years.

- We found no evidence of negative impacts of coho competition on steelhead (rainbow) or cutthroat trout as indicated by fish displacement, fish density or condition factor compared to groups in allopatry or sympatry with age 0 hatchery coho.

- We observed low numbers of residual hatchery coho during snorkel surveys in the Methow in 1998 or the Wenatchee or Yakima sub-basins in 1999. We present total relative abundance of hatchery coho present by assuming 100, 75, 50, 25 and 10% snorkel efficiency values.

- We transported and released a total of 43 adult hatchery coho (19 female and 24 male) collected at Prosser Dam, Yakima River to a weired off section of Wenas Creek, a tributary of the Yakima River. Females constructed a total of 14 redds in the study section. Egg retention of 11 female carcasses recovered averaged 680 eggs/female. However, after excluding 2 females that died shortly after transport, mean egg retention averaged 209 eggs/female. Descriptive data which characterized each redd was collected and summarized.

- The minimum smolt-to-adult survival rate for hatchery coho smolts released in the Methow basin in 1998 was nearly at replacement for the hatchery environment at 0.072%.

- Approximately 54% of the PIT tagged juvenile coho released in the Wenatchee basin in the spring of 1999 survived to McNary Dam.

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General Introduction

Wild stocks of coho salmon *Oncorhynchus kisutch* were once widely distributed within the Columbia River Basin (Fulton 1970; Chapman 1986). Since the early 1900s, the native stock of coho has been decimated in the tributaries of the middle reach of the Columbia River (the Wenatchee and Methow rivers; Mullan 1983). Efforts to restore coho within the mid/upper Columbia Basin rely largely upon large releases of hatchery coho. The feasibility of re-establishing coho in the tributaries of the mid Columbia Basin may initially rely upon the resolution of two central issues: the adaptability of a domesticated lower river coho stock used in the re-introduction efforts and associated survival rates, and the ecological risk to other species associated with coho re-introduction efforts.

Continued downward trends in the abundance of wild spring chinook and steelhead above Priest Rapids Dam resulted in the listing of these species as endangered by National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). The ecological risk associated with coho re-introduction efforts may be greatest for endangered species or those of critically low abundance. Many types of ecological interactions are theoretically possible between coho and other native fish species. For example, potential interactions could include predation, competition, behavioral anomalies, or disease transmission. Priorities can be assigned to different ecological interactions based on their effect on the productivity and viability of impacted populations. Although the impact of predation on an individual prey animal is unambiguous, the impact on a population of prey is not. Depending on the abundance and productivity of the prey population, the impact of predation on the persistence and productivity of the prey population may range from negligible to serious. Indeed, those ecological interactions that influence the survival, growth, or broad scale distribution of the impacted population would potentially be most serious in nature.

Yearly hatchery coho salmon that do not migrate to the ocean after release are termed residuals. Residual hatchery fish that precocially mature are termed precocials. This phenomenon is not common solely to hatchery fish. Pacific salmonids often times exhibit a variety of life history types (Groot and Margolis 1991). Precocity is one such life history strategy which wild salmonid populations exhibit (Gross 1987; Mullan et al. 1992). It is important to assess the abundance of hatchery coho residuals for 2 reasons. A high degree of residualism has the potential to negatively impact the program strictly from the aspect of anadromous production.

It is also important to quantify the abundance of residual coho from the aspect of ecological interactions between hatchery coho and other species. As the total number of coho residuals increases so may the potential for ecological interactions such as competition with and predation on other species.

The mid-Columbia coho re-introduction efforts will use early returning hatchery coho smolts from several state and/or federal facilities. Most of these facilities have a lengthy history of culture activities, which may have the potential to subject these stocks to genetic changes due to selective effects. This term is called domestication selection (Busack et al. 1997). Additionally, allozyme variation is low between hatchery populations of coho salmon in the lower Columbia River, and therefore provides little evidence of spatial population structuring (Allendorf and Utter 1979; Utter et al. 1980). However, mitrochondrial DNA variation between populations of Oregon coho salmon indicate some degree of spatial structuring of lower Columbia River hatchery coho populations (ODFW 1990; Currens and Farnsworth 1993). The genetic composition of the endemic and now extinct coho of the mid Columbia tributaries is unknown, however it is likely that genotypic differences existed between the lower Columbia River hatchery coho and the original endemic stocks. It is possible that phenotypic differences between endemic mid Columbia coho populations and lower Columbia coho populations may have included maturation timing, run timing, stamina, or size of returning adults. Thus the reproductive capability of returning hatchery coho is a critical uncertainty which may ultimately determine if this project successfully re-establishes self sustaining populations of coho.

If coho re-introduction efforts in the mid Columbia tributaries are to succeed, parent stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and middle Columbia River tributaries. The mid Columbia Coho Hatchery and Genetic Management Plan (HGMP; Draft) will outline the monitoring plan to track the local adaptation process.

We are optimistic that the project will observe positive trends in hatchery coho survival as the program transitions from the exclusive use of lower Columbia River hatchery coho to ultimately the exclusive utilization of in-basin returning broodstock during the development of a locally adapted broodstock. Therefore it is important to measure hatchery fish performance to not only use as an indicator of project performance but to track potential short and long term program benefits from the outlined project strategies. Additionally, if any re-introduction effort is to be successful, adult returns must be sufficient to meet stock replacement levels.

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Chapter 1

Predation and Competition of Hatchery Coho and Other Species

Introduction

Coho salmon have been shown to prey on several species of salmonids including sockeye salmon *O. nerka* fry (Ricker 1941; Foerster and Ricker 1953; Ruggerone and Rogers 1992), pink *O. gorbuscha* and chum *O. keta* salmon fry (Hunter 1959), and fall chinook salmon (Thompson 1966). In order to resolve the scientific uncertainty associated with the impact of coho salmon predation on spring populations within the mid-Columbia basin, the Yakama Nation conducted experiments during 1998 and 1999 to address this issue. Coho salmon predation and competition studies have not been conducted in either the Methow or Wenatchee sub-basins due partially because of the low critical abundance of spring chinook and steelhead. Studies were first conducted in the Yakima sub-basin. However, the applicability of results from ecological interaction studies in the Yakima to either the Methow or Wenatchee sub-basins warrants further discussion.

The biological significance of non-predatory types of interactions are less straightforward, even at the level of individual animals. In particular, competition for space and food may clearly alter patterns of microhabitat utilization, while having no effect on productivity or viability (Spaulding et. al 1989). Indeed, the small-scale shifts in niche partitioning that may result from “interactive segregation” may represent a significant benefit at the community level because they result in more efficient utilization of environmental resources (Nilsson 1966). We were unable to find any published studies that demonstrated complete competitive exclusion (species extirpation) by coho for any species.

Coho salmon have been shown to displace cutthroat trout *O. clarkii* from pool habitat into riffle habitat (Glova 1984;1986; 1987; Bisson et al. 1988), even though both species preferred pool habitat in allopatry. Tripp and McCart (1983) observed increasing negative impacts on cutthroat trout growth and survival as coho stocking densities increased up to 2.5 g of coho fry/m^2. Sabo and Pauley (1997) found that relative size and population origin (allopatric vs. sympatric populations) of coho and cutthroat trout were important factors that determined competitive dominance between the two species.

Coho salmon and rainbow/steelhead trout *O. mykiss* are reported to be sympatric along the western coast of North America from California to British Columbia (Frasier 1969; Hartman 1965; Johnston 1967; Burns 1971), with both species residing in freshwater for extended periods (Groot and Margolis 1991). However, the reported impacts of the presence of coho salmon on rainbow/steelhead trout are conflicting. Coho were shown not to affect steelhead habitat utilization or growth in the Wenatchee River (Spaulding et al. 1989), and only affected steelhead habitat utilization to a small extent in another Washington stream (Allee 1974; 1981). However, Hartman (1965) concluded that strong habitat selection occurred in the spring and summer as a result of agnostic behaviors which were differentially directed by coho against steelhead in pools and by steelhead against coho in riffle habitats. We conducted field experiments in the Yakima sub-basin to address the impacts which coho had on the growth, abundance, and broad scale geographical displacement of cutthroat and rainbow/steelhead trout in 1998.

Behavioral interactions may alter the dynamics of the community but have no effect on its stability or productivity. Behavioral anomalies such as the "pied piper" effect are largely theoretical for coho (Chapman et al. 1991; Spaulding et al. 1989) as are disease-related interactions (Miller 1990). These types of interactions were not investigated.

Methods

Coho Salmon Predation on Spring Chinook

We released 26,809 non-acclimated coho smolts in the upper Yakima River near Easton, Washington (RM 203) on May 26th through 27th, 1998. We released approximately 49,000 acclimated coho smolts for the season in 1999, of which 24,850 were released on May 17th and May 27th. Each year we operated two five-foot diameter rotary traps continuously over a period of ten days from the release date approximately six miles downstream of the release point. The trap was generally checked continuously, but time between fish removal from the trap never exceeded 60 minutes, in order to minimize coho predation on chinook fry within the trap. We measured fork length (mm) of all spring chinook captured in the trap. Mean daily temperature was estimated from temperature data collected using an Onset Hobo Temp that recorded river temperature every 80 minutes during the coho outmigration.

All coho captured were given a lethal dose of MS 222, and a small amount of 10% formalin solution was injected into the stomach of each fish. Fish were preserved in individual whirl pack bags with a liberal amount of 10% formalin solution, and later dissected in the laboratory. Any fish remains that were found in the coho were digested using a digestive enzyme (Taylor and Van Dyke 1985), stained (Cailliet et al. 1986), and identified with the use of diagnostic bones (Hansel et al. 1988).

We calculated the mean weight of spring chinook fry from all fry sampled at the trap using an existing spring chinook weight-length relationship (Yakama Nation, unpublished data). Coho residence time was estimated from the catch at the trap. We estimated the potential total number of spring chinook fry available for coho predation by expanding 1997 and 1998 brood year redd counts (respectively) for redds deposited from the Cle Elum River confluence upstream to Easton Dam. This procedure assumes 60% egg-fry survival (Fast et al. 1986) and used the 1997 mean upper Yakima spring chinook mean fecundity estimate of 4,200 eggs per female (Yakama Nation, unpublished data).

Statistical Analyses

We estimated the incidence of spring chinook predation for the 1998 and 1999 data using the following formula:

$$I = \frac{n}{N}$$

where I = the incidence of predation, n = the number of coho samples containing chinook remains, and N = the total number of coho samples collected. We calculated 95% confidence intervals for the incidence of predation (Zar 1999). Gastric evacuation rates were estimated using a linear model for juvenile coho consumption of sockeye fry (Ruggerone 1989) and exponential model (He and Wurtsbaugh 1993) developed for brown trout preying upon small juvenile rainbow trout (He and Wurtsbaugh 1993). Mean daily temperature was estimated from temperature data collected using an Onset Hobo Temp that recorded river temperature every 80 minutes during the period of coho residence. For both evacuation models, we estimated the total number of chinook consumed using the following formula:

$$NP = \frac{I * COHO * R}{E}$$

where NP = the total number of prey (chinook) consumed by coho, I = the incidence of predation, COHO = the number of coho present in the river during that time period, R = the coho weighted mean residence time within that reach of the river, and E = the mean gastric evacuation rate. In a similar fashion, we used the upper and lower bounds of the 95% confidence interval for the incidence of predation to calculate the upper and lower bounds of the total number of chinook consumed for each gastric evacuation model.

To assess the relative impact the coho predation had on the chinook population, we expressed the total number of chinook consumed by coho as a proportion of the entire chinook population produced each year.

Coho Competition with Rainbow/Steelhead and Cutthroat Trout

We scatter-planted a total of 404,340 non-acclimated coho fry (mean fork length = 75 mm; mean weight = 4.2 g) into the Naches River Basin between June 17th – June 24th, 1998. We estimated stocking densities by estimating available habitat within each stream/reach by querying existing habitat information (U.S. Forest Service, unpublished data; Yakama Nation, unpublished data), and then estimated coho carrying capacity for the amount of each habitat type (i.e. riffle, pool, glide, side channel, etc.) (Reeves et al. 1989). Releases occurred in four broad geographical areas within the basin: lower mainstem Naches River (RM 2 – 16; 121,600 fish), mainstem Bumping River (RM 0 – 17; 132,000 fish), upper Naches tributaries (RM 28 – 42; 67,400 fish), and the Little Naches River mainstem and tributaries (RM 45; 83,431 fish), each group was marked with a florescent pigment to estimate survival of each group to the Chandler Juvenile Monitoring Facility. This overall experimental design presented additional monitoring opportunities. We chose the Little Naches River Basin due its relatively small size, accessibility, and its relatively well suited monitoring locations for a rotary and weir traps. Releases within the Little Naches River basin occurred at several locations, including tributaries and mainstem locations (Table 1). The primary focus of our field activities described below was to estimate post release survival of hatchery coho fry within the Little Naches River basin during the mid-summer and again during the spring smolt migration period. Thus the competition data collected and reported within this report was ancillary to our efforts.

We installed a rotary trap near the confluence of the Little Naches River (RM 0.25) to monitor downstream fish movement. We installed panel weir traps in Quartz and Pileup creeks to monitor upstream and downstream fish movement. Traps were installed prior to release of fish and were checked approximately every 1 – 2 days.

We conducted electrofishing surveys in Quartz and Pileup creeks between July 1st and July 15th to assess the distribution and abundance of hatchery coho and resident fish. The length of each stream was measured on a 7.5-minute U.S. Geological Survey topographic map. Pileup Creek and the South Fork of Quartz Creek each were divided into two equal length reaches; Quartz Creek was divided into three equal length reaches. Three 30-meter sites from each reach were randomly selected for multiple-pass electrofishing. The total distance (m) from the confluence to each sampling site was measured with a hipchain device. We determined mean elevation above sea level for each sampling location by determining location on a topographic map.

We measured fork length (1 mm) and weighed (0.01 g) each salmonid captured, and we enumerated all other species. Wetted stream width and bank-full width (to 0.1 m) were measured at a minimum of five locations at each sampling site. Estimates of population abundance and capture efficiency were calculated for each species captured at each site using the maximum likelihood estimator (Van Deventer and Platts 1983). Mean densities for each reach and stream were calculated for cutthroat and rainbow trout and coho salmon, based on wetted stream width.

We used a student's t-test to test for differences (< 0.05) in cutthroat and rainbow trout densities and condition factor for each species that occurred in allopatry and sympatry with coho salmon. We investigated the effects of site elevation on resident fish density using simple linear regression. We used a student's t-test to examine the residuals from the regression analysis to test for differences ($p < 0.05$) between cutthroat and rainbow trout density for each species that occurred in allopatry and sympatry with coho salmon.

Results

Coho Salmon Predation on Spring Chinook

We collected 1,097 coho salmon smolts (mean FL = 150.6 mm; standard deviation = 7.0) at the rotary trap (RM 203) in 1998. Most coho were captured during the night. Coho predation on fish was generally uncommon. Five coho within our sample (0.45%) had consumed fish. We identified two coho prey items as *Oncorhynchus* spp., both of which were consumed by a single coho. The mean fork length of all chinook juveniles during trap operation was 51.6 mm (standard deviation = 7.2 mm). Mean daily water temperature during the period of trap operation was 9.6 C. The fish weighted mean residence time within the study reach (release point to rotary trap) was approximately 4 days (Figure 1).

During the 1999 field season, we collected 993 coho during the early release (May 17 – 22), and 764 coho during the late release (May 27- June 9; Figure 1). Mean coho and spring chinook fry fork lengths were lower in 1999 (Mean FL = 132 and 37.2 mm; standard deviation = 8.3 and 7.4 respectively) than in 1998. However, coho movement was generally similar between years, with most coho moved during the night and passing the trap within a few days after release. The fish weighted mean residence time within the Easton study reach was 2.5 and 3.2 days respectively for the early and late releases in 1999. Coho predation on juvenile fish was less common in the 1999 samples than the 1998 samples. Two coho in our sample had consumed fish (0.11%). A single fish from both the early and late sample periods in 1999 consumed fish. Neither of these prey items was identified as *Oncorhynchus* spp.

The exponential model (He and Wurtsbaugh 1993) provided the lowest estimates of coho gastric evacuation, and the linear model (Ruggerone 1989) provided the most rapid estimates of gastric evacuation rates for both years (Tables 2 and 3). We attempted to apply an exponential model that Ruggerone (1989) provided. However this model produced absurd results (i.e. evacuation rates in excess of 3,000 hours for a single spring chinook consumed). We believe these absurd results were due largely to the fact that the gastric evacuation rate Ruggerone (1989) used to calculate the exponential model for coho relied on smaller (mean weight = 0.163 g) sockeye fry, and that we extrapolated beyond the range of his data set when we applied our spring chinook fry to the model (mean weight = 1.78 and 0.88 g in 1998 and 1999 respectively). Ruggerone (1989) suggests that the linear model probably under estimates evacuation rates. The gastric evacuation model developed for brown trout (He and Wurtsbaugh 1993) predicted evacuation rates that were approximately 2.5X longer than the linear coho model (Tables 2 and 3; Ruggerone 1989).

The estimates of the number of fry consumed provided by the linear and exponential models (Tables 2 and 3) probably brackets the true number of spring chinook consumed in the Easton Reach. Based on the upper bound for the total number of fry consumed (linear model--1,800 fry), the highest level of impact that the 1998 Easton coho release may have had was no higher than 0.57% of the total number of spring chinook fry produced within that reach for 1998 or 1999 (Tables 2 and 3).

Table 1. Hatchery coho fry planting summary for the Little Naches basin, 1998.			
Release site	**River Mile**	**Release Date**	**Number of fish**
North Fork mainstem	13.2	June 24	4,388
Pyramid Cr. (North Fk)	7.9	June 24	1,097
Blowout Cr. (North Fk)	0.6	June 24	1,097
Middle Fork mainstem	13.2	June 24	3,291
Mainstem at 1913 bridge	13.2	June 24	45,036
Bear Cr.	10.9	June 24	439
W. Fk. Bear Cr.	1.0	June 24	6,033
South Fork mainstem	9.9	June 24	6,582
Mathew Cr.	9.5	June 24	1,207
Pileup Cr.	6.6	June 24	4,388
Quartz Cr.	3.4	June 24	9,873

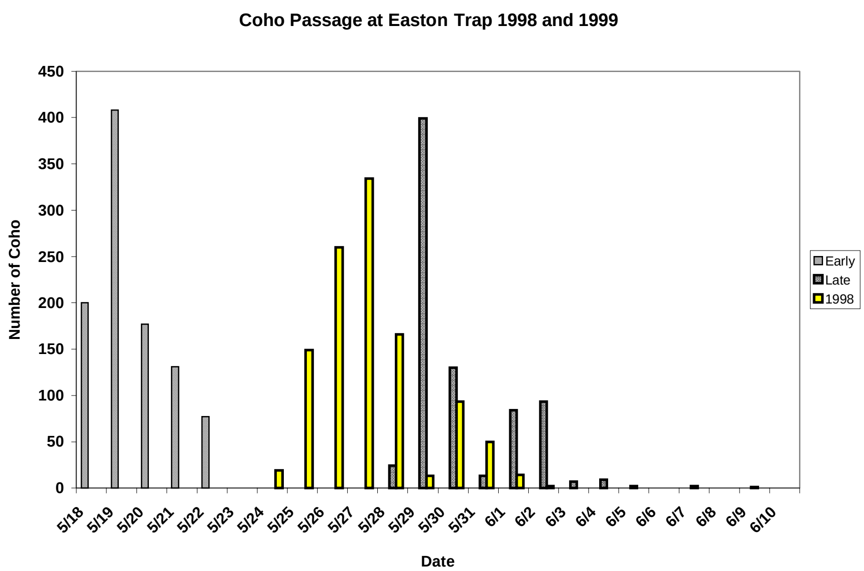

Figure 1. Coho catch at the Elk Meadows rotary trap during the 1998 (May 27-June 5) and 1999 (May 17-22 and May 27-June 9). Based on the raw catch, coho smolt-weighted residence time with this reach was approximately 4, 2.5, and 3.2 days for the May 27, 1998, May 17, and May 27, 1999 releases respective.

Table 2. Upper Yakima River 1998 coho predation results yielded.									
Location	Sample Size	Model Used	Observed Incidence of Predation	95% CI Incidence of Predation	Total Estimated Number of Prey Consumed	95% CI for Number of Prey Consumed	Percent of Estimated Spring Chinook Population Consumed 95% CI	Residence Time (days)	Evacuation Time (hours)
Easton 1998	981	Linear	0.00102	0.00002-0.0057	324	8-1800	0.002 - 0.498%	4	8.1
Easton 1998	981	Exponential	0.00102	0.00002-0.0057	93	2-517	0.0005 - 0.141%	4	28.20

Estimated numbers of spring chinook fry consumed were calculated by the linear evacuation model presented by Ruggerone (1989) for coho salmon preying upon sockeye salmon fry (first row) and estimated numbers by the exponential evacuation model presented by He and Wurtsbaugh (1993) for brown trout preying upon juvenile rainbow trout (second row). We estimated the total number of spring chinook fry produced within this reach from 1997 redd counts (146) to be 367,920 fry. We assumed a mean egg-fry survival rate of 60% (Fast et. al 1986), and a mean fecundity of 4200 eggs (Yakama Nation, unpublished data).

Table 3. Upper Yakima River 1999 coho predation results.									
Location and Time	Sample Size	Model Used	Observed Incidence of Predation	95% CI Incidence of Predation	Total Estimated Number of Prey Consumed	95% CI for Number of Prey Consumed	Percent of Estimated Spring Chinook Population Consumed 95% CI	Residence Time (days)	Evacuation Time (hours)
Easton Early	993	Linear	0	0 – 0.0030	0	0 – 349	0 – 0.35%	2.5	12.9
Easton Early	993	Exponential	0	0 – 0.0030	0	0 – 149	0 – 0.15%	2.5	30.3
Easton Late	764	Linear	0	0 – 0.0039	0	0 – 579	0 – 0.57%	3.2	12.9
Easton Late	764	Exponential	0	0 – 0.0039	0	0 – 247	0 – 0.25%	3.2	30.3
Easton All	1757	Linear	0	0 – 0.0017	0	0 – 441	0 – 0.44%	2.8	12.9
Easton All	1757	Exponential	0	0 – 0.0017	0	0 - 188	0 – 0.19%	2.8	30.3

Estimated numbers of spring chinook fry consumed were calculated by the linear evacuation model presented by Ruggerone (1989) for coho salmon preying upon sockeye salmon fry and estimated numbers by the exponential evacuation model presented by He and Wurtsbaugh (1993) for brown trout preying upon juvenile rainbow trout. We estimated the total number of spring chinook fry produced within this reach from 1998 redd counts (40) to be 100,800 fry. We assumed a mean egg-fry survival rate of 60% (Fast et. al 1986), and a mean fecundity of 4200 eggs (Yakama Nation, unpublished data).

Coho Competition with Rainbow/Steelhead and Cutthroat Trout

We observed minimal coho and resident fish movement downstream after the coho were stocked within the Little Naches based on catch estimates from the rotary and weir traps (Figures 2-4). These results suggest that minimal displacement of resident fish occurred as a result of stocking coho within the Little Naches basin.

Electrofishing and snorkel surveys conducted approximately one month after initial coho stocking suggest that the coho remained relatively close to the release locations. Coho were present at 38% of all electrofishing sites sampled in Quartz and Pileup creeks. The highest coho densities were observed in upper Quartz Creek (0.422 fish/m^2), and the lowest coho densities were observed in the middle reach of Quartz Creek and the lowest reach of the South Fork Quartz Creek (Table 4). Both of the latter two reaches lacked road access and were not stocked with coho.

Cutthroat trout abundance increased with elevation (Figure 5; $r^2 = 0.40$; $p = 0.002$), and rainbow trout density decreased with elevation (Figure 6, $r^2 = 0.39$; $p = 0.002$). Although rainbow trout were more abundant than cutthroat trout in the lower sections of Pileup and Quartz creeks, cutthroat trout were overall more abundant in the each stream (Tables 5 and 6). Coho salmon abundance was largely an artifact of stocking location, and was not correlated with elevation (Figure 7). We found no evidence that coho salmon influenced the abundance of cutthroat or rainbow trout ($p > 0.05$) when we compared the abundance of each species in allopatry and sympatry with coho salmon. We repeated each test after removing the effects of elevation on cutthroat and rainbow trout abundance, and found no difference ($p > 0.05$) between allopatric and sympatric mean densities of resident trout. Similarly we found no evidence that coho salmon affected the growth of cutthroat or rainbow trout ($p > 0.05$) when we compared the condition factor of each species in allopatry and sympatry with coho salmon.

Discussion

We believe that the predation experiments conducted in the Easton Reach represented the worst case scenario to test for coho predation on spring chinook fry for the given time of release within the Yakima sub-basin. We based this conclusion on the fact that this study reach has the highest density of spring chinook redds in the upper Yakima basin, and that during the period of the experiment, spring chinook fry were abundant and potentially vulnerable to coho smolt predation. Spring chinook fry were relatively less abundant during the 1999 sampling period than the 1998 period. Based on spring chinook redd counts, the relative abundance of fry in the study reach in 1998 was approximately 3.7 times higher than in 1999. It is possible that the decrease in spring chinook fry in 1999 was responsible for the decrease in observed predation rate between years, suggesting a density dependant relationship between the predator/prey relationship. However, significant differences in the low observed predation rates between years would be difficult to detect with the given sample sizes. Although there were fewer spring chinook fry present in the Easton reach in 1999 compared to 1998, the spring chinook fry were

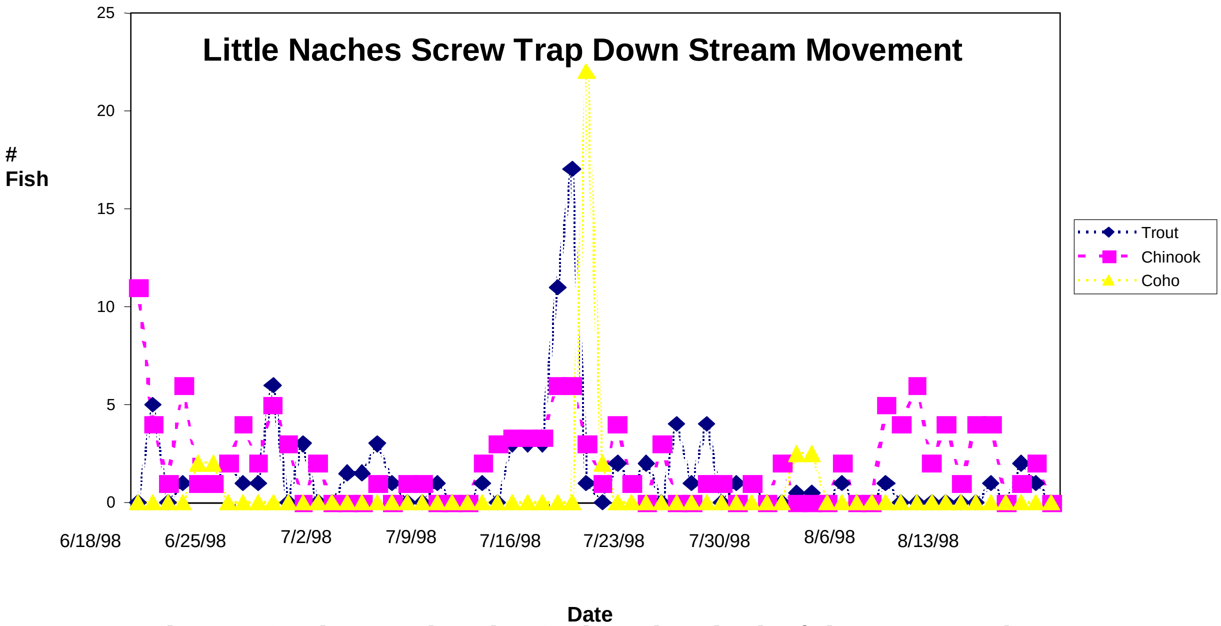

Figure 2. Daily trout (cutthroat and rainbow), chinook and coho fish counts past the rotary trap, Little Naches River, 1998. The highest peak coho outmigration on July 22nd is the result of marked calibration fish released the previous day.

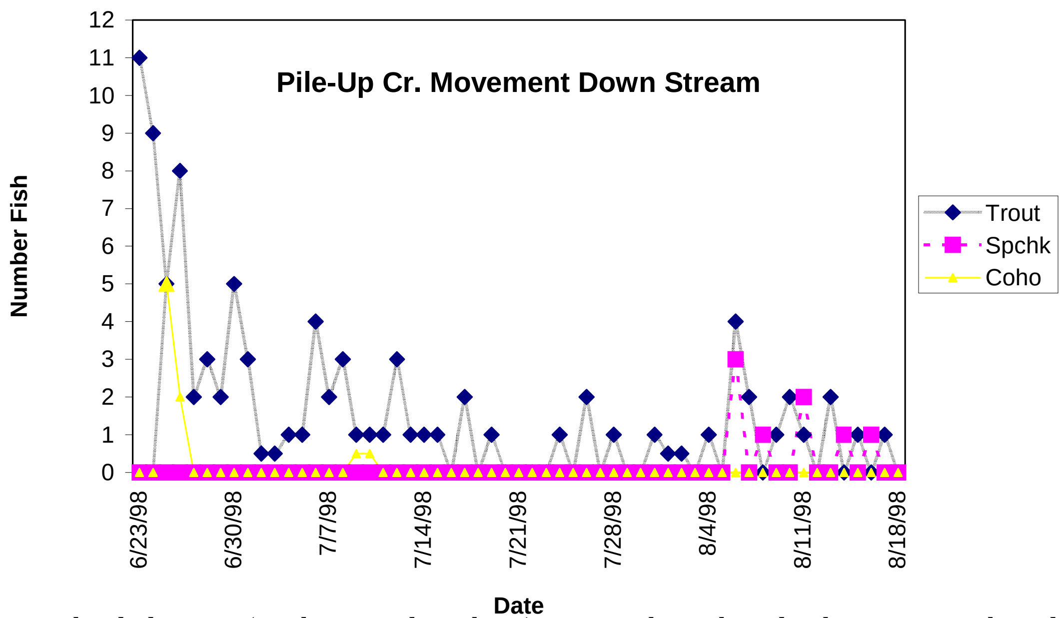

Figure 3. The daily trout (cutthroat and rainbow), spring chinook and coho counts at the Pile-Up Creek box trap, 1998.

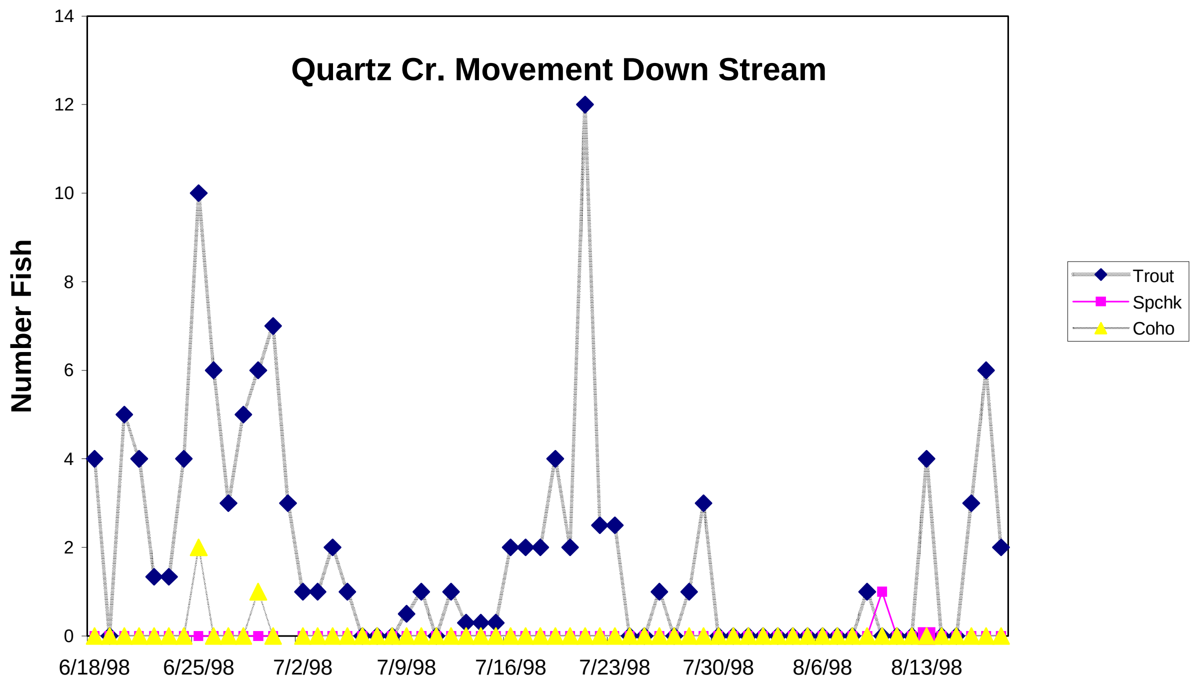

Figure 4. The daily trout (cutthroat and rainbow), spring chinook and coho counts at the Quartz Creek box trap, 1998.

Table 4. The estimated total, mean density, and 95 % confidence intervals (CI) of coho summarized for each stream and reach sampled by electrofishing.

Stream	Reach	Total Coho	95% CI Total Coho	Coho Density (Fish/m^2)	95% CI Coho Density
Pileup	All	4,341	132 – 11,032	0.225	0.001 – 11.622
Pileup	1	3,227	95 – 9,551	0.351	0.010 – 1.061
Pileup	2	1,115	37 – 3,300	0.110	0.004 – 0.344
Quartz	All	4,355	1,374 – 7,336	0.160	0.008 – 0.514
Quartz	1	2,292	120 – 4,562	0.333	0.017 – 0.740
Quartz	2	0	N/A	0.000	N/A
Quartz	3	2,020	93 – 3,950	0.422	0.019 – 0.967
S.F. Quartz	1	0	N/A	0.000	N/A
S.F. Quartz	2	43	2 – 126	0.010	0.001 – 0.028

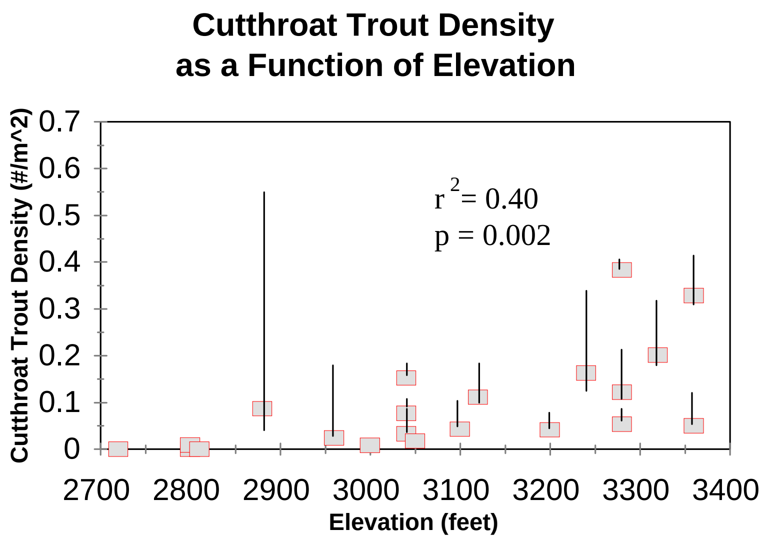

Figure 5. Cutthroat trout abundance as a function of elevation in Quartz and Pileup creeks. The whisker bars signify the 95% confidence intervals.

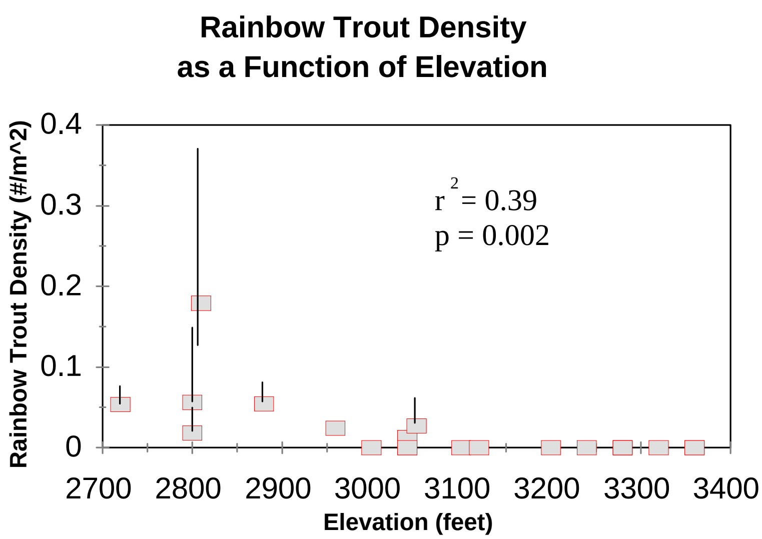

Figure 6. Rainbow trout abundance as a function of elevation in Quartz and Pileup creeks, 1998. The Whisker bars signify 95% confidence intervals.

Table 5. The estimated total, mean density, and 95 % confidence intervals (CI) of cutthroat trout summarized for each stream and reach sampled by electrofishing.

Stream	Reach	Total Cutthroat	95% CI Total Cutthroat	Cutthroat Density (Fish/m^2)	95% CI Cutthroat Density
Pileup	All	645	493 – 797	0.033	0.014 – 0.053
Pileup	1	176	76 – 276	0.019	0.001 – 0.040
Pileup	2	469	354 – 584	0.046	0.002 – 0.125
Quartz	All	2725	2,125- 3,326	0.100	0.061 – 0.139
Quartz	1	0	N/A	0.000	N/A
Quartz	2	200	35 – 418	0.036	0.006 – 0.087
Quartz	3	520	237 – 803	0.109	0.005 – 0.280
S.F. Quartz	1	640	495 – 785	0.115	0.048 – 0.183
S.F. Quartz	2	1365	905 - 1,826	0.304	0.130 – 0.478

Table 6. The estimated total, mean density, and 95 % confidence intervals (CI) of rainbow trout summarized for each stream and reach sampled by electrofishing.

Stream	Reach	Total Rainbow	95% CI Total Rainbow	Rainbow Density (Fish/m^2)	95% CI Rainbow Density
Pileup	All	88	3 - 260	0.004	0.0001 – 0.267
Pileup	1	88	3 – 260	0.010	0.0003 - 0.029
Pileup	2	0	N/A	0	N/A
Quartz	All	797	213–1381	0.029	0.001 – 0.111
Quartz	1	509	24 – 1021	0.074	0.004 – 0.165
Quartz	2	160	7 – 367	0.029	0.001 – 0.069
Quartz	3	0	N/A	0	N/A
S.F. Quartz	1	128	6 – 320	0.023	0.001 – 0.058
S.F. Quartz	2	0	N/A	0	N/A

Coho Salmon Density as a Function of Elevation

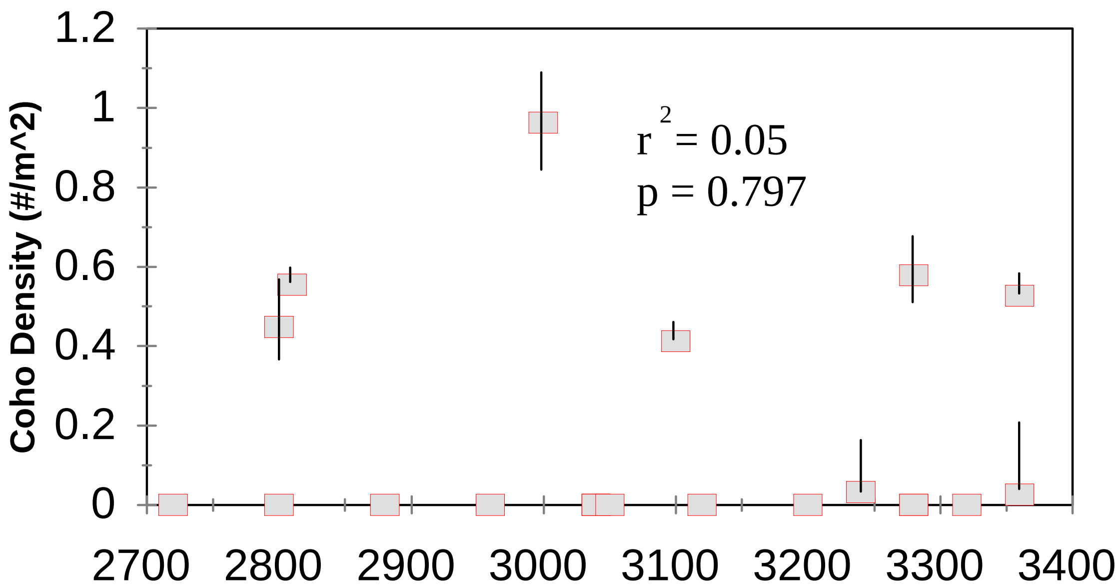

Figure 7. Coho abundance as a function of elevation in Quartz and Pileup creeks, 1998. The whisker bars signify 95% confidence intervals.

significantly ($P < 0.00001$) smaller in 1999 than in 1998 (mean FL = 37 and 51 mm, respectively). We believe that it is likely that the smaller fry in 1999 were potentially more vulnerable to predation than the larger fry in 1998, however several factors offset the higher prey vulnerability in 1999 and resulted in a lower overall predation rate. These factors included: lower abundance of fry in 1999, lower water temperatures which resulted in lower coho metabolic rate, and an extended acclimation period which resulted in reduced coho residence time within the study area. The relatively low density of spring chinook fry in the upper Yakima in 1999 compared to 1998 would be more closely comparable to spring chinook fry densities in the mid-Columbia tributaries due to the depressed nature of stocks of spring chinook in these areas. However the relative availability of other potential prey items between the upper Yakima and tributaries in the mid-Columbia region make further comparisons and data transfer between basins ambiguous. Similarly, diet, and behavior differences between migrating hatchery and rearing or migrating naturalized coho make interpretations between hatchery and naturalized coho difficult.

We feel that the exponential model presented by He and Wurtsbaugh (1993) provided a better estimate of coho gut evacuation rates than did the linear model (Ruggerone 1989). Therefore, the exponential model probably more closely represents the actual losses of spring chinook to coho salmon predation. The total number of adult spring chinook equivalents consumed was no higher than approximately 7 (or 0.38% of the potential number of returning adults to the study reach) adults assuming 0.14% egg-to-adult survival rate (Fast et al. 1991). We believe this estimate of consumption is a worst case scenario, because it is based on the upper 95% bound for the consumption exponential model. We concluded that the actual impact of coho predation on spring chinook fry within the study reach was probably even lower, and represented a negligible proportion of the spring chinook produced in this study reach in 1998 and 1999.

We further believe that the potential for competition and predation between coho and other species was minimized due to habitat segregation and resource partitioning (Ross 1986). Age 0 salmonids have been shown to typically utilize shallower and lower velocity microhabitats than do yearling salmonids (James et al. 1999; Hillman et al. 1989). Our observations were consistent with these findings, and further lead us to believe that minimal spatial overlap between hatchery coho residuals and age 0 salmonids limits the opportunity for predation and competition.

We found no evidence in the field studies we conducted to suggest coho were having a negative impact on these native fish species in the two streams we examined. We attribute these low levels of impacts that we observed in part to low stocking densities of coho fry. We believe that spatial segregation (Hartman 1965; Allee 1974) and resource partitioning (Ross 1986) reduced the potential for competition between coho and steelhead. Johnson and Ringler (1980) found that diet overlap of sympatric steelhead and coho was low, with the diet of coho similar in composition to the drift and the diet of steelhead most similar to the benthic fauna. Differences in diet were attributed to innate differences in habitat segregation and feeding behavior potentially minimized competition between the two species (Johnson and Ringler 1980).

Our ability (statistical power) to detect small differences in either abundance or condition factor was likely limited by relatively small sample sizes. We acknowledge this limitation, bearing in mind that competitive interactions were not the primary focus of these field activities. Competitive interactions between coho and other species are often investigated using 2 general techniques, controlled field studies and laboratory investigations. Each general approach has potential strengths and weaknesses. Field studies have the potential to lack power, but are seldom criticized for lacking tangibility to actual conditions. Laboratory conditions on the other hand, statistical power is easily achievable through controlled replication, but natural conditions which closely parallel the stream ecosystem are difficult to replicate. We believe that future investigation into competitive interactions between coho and other species should be conducted in replicated and controlled stream sections that are designed to investigate these topics will be the primary focus of the study and will be designed to achieve adequate statistical rigor. Additional efforts will likely be expanded to include spring chinook salmon in the investigations if logistically possible.

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Chapter 2

Relative Abundance of Residual Hatchery Coho in the Methow, Wenatchee and Yakima Rivers

Introduction

Minimizing the levels of adverse ecological interactions of hatchery fish is one of the fundamental cornerstones of supplementation and the Yakima Klickitat Fisheries Project (YKFP; Busack et al. 1997). Fish that do not migrate after release are termed residuals, and fish that do not migrate and participate in spawning are termed precocials. Gross (1987) suggests that precocity may have evolved as an alternative life history pattern for Pacific salmon. However Mullan et al. (1992) indicated that often hatcheries release larger fish when compared to naturally produced fish, in order to increase survival, and that this practice may result in a higher numbers of precocial fish which are mostly males. The frequency of precocialism may range from 0-29% for anadromous salmonids (Mullan et al. 1992).

The abundance of residual coho in the Yakima sub-basin is important for two reasons. Residual hatchery coho do not contribute to anadromous adult production, and precocial fish may have the potential to significantly alter sex and anadromous versus precocial ratios on the spawning grounds (Mullan et al. 1992; Busack et al. 1997). Residual hatchery fish may also have the potential to either compete with or prey upon other species. Precocial salmonids are virtually all males (Mullan et al. 1992), and are typically larger than yearling parr. Larger fish have been shown to generally dominate smaller fish in studies which examined both inter- and intraspecific competition (Griffith 1972; Abbott et al. 1985; Hearn 1987; Chandler and Bjornn 1988; Hughes 1992).

This investigation was initiated to determine baseline levels of hatchery coho residuals in the upper Yakima sub-basin, Methow River, and Nason Creek a tributary of the Wenatchee River. Prior to this investigation no estimates of relative abundance of residual fish existed. After several years of gathering baseline hatchery coho residual data, YKFP managers will determine if densities of residual coho are high enough to warrant investigation of either residual hatchery coho ecological interactions with other species or abundance of precocials on the spawning grounds.

Methods

Methow River

A single snorkel survey to assess hatchery coho residualism near the Winthrop NFH (Methow) and the Eight-Mile Creek (Chewuch) confluence (Figure 1) was conducted June 30, 1998. The Methow River was surveyed from river mile (RM) 51.5 (Foghorn Dam; 0.9 miles upstream of Winthrop NFH) downstream to RM 47.5. The Methow survey was conducted between 10:30 – 13:30, the discharge was 1,880 cfs, and the water temperature was 52^{o} F. Water visibility was excellent. Snorkel surveys techniques employed in the Methow in 1998 included the non-random selection of sample sites and low proportion of the total habitat sampled, therefore we did not attempt to expand our sample results to sections of this area that were not sampled.

Chewuch River

The Chewuch River was surveyed from RM 11.25 (Eight-Mile Cr. confluence) downstream to RM 9.5 (Figure 1). The survey occurred between 14:15 and 16:00 and the water temperature was 15.5^{o} C. The discharge was 838 cfs, and water visibility was good.

A single snorkeler surveyed in a downstream direction along each bank. The approximate number of salmonids by species was recorded for each survey.

Wenatchee River (Nason Creek)

On April 25, 1999 approximately 75,000 yearling coho smolts were released after a period of approximately 5 weeks of acclimation in back water slough of Nason Creek at RM 4.5 (Swamp Crk. acclimation site; Figure 2). Snorkel surveys were conducted in Nason Creek June 11, 29 and July 27, 1999 to detect the presence of hatchery coho smolts that did not migrate during the April 25 smolt release. June surveys were limited to 2 sections of stream. These sections began at RM 4.25 (Swamp Creek acclimation site) and RM 0.4 (Lake Wenatchee State Park). The upriver site began at the downstream end of the highway culvert downstream approximately 0.5 miles to a right bank log jam. The lower site began about 0.1 rm upstream to the state park boundary, downstream to the bridge located in the park. On June 29, snorkel surveys included a 0.3 mile transect upstream of the acclimation site in addition to the sections downstream of the acclimation site described above. The July 27, 1999 survey included 100% of Nason Creek from the acclimation site to the confluence with the Wenatchee River. Areas that were perceived as the highest quality coho rearing habitat (including pools, back water eddies, areas with large woody debris, and undercut bank areas) were intensively scrutinized for the presence of coho. On each sampling period, observers snorkeled in a downstream direction between 10:00 and 16:00. The approximate number of salmonids by species was recorded for each survey.

Snorkel counts were expanded by 100, 75, 50, 25, and 10% to reflect a range of potential snorkel efficiencies. The total number of residual hatchery coho smolts within the survey section was estimated for each sampling period, by assuming a 100, 75, 50, 25, and 10% sampling efficiency. For each estimate of relative abundance of hatchery coho we calculated the estimated number per mile within the sampled section. Estimates of the number of hatchery coho in Nason Creek are represented as numbers per 75,000 coho released. The number of residual hatchery coho smolts from the Nason Creek acclimation site to Icicle Creek confluence was estimated by multiplying the estimated number of

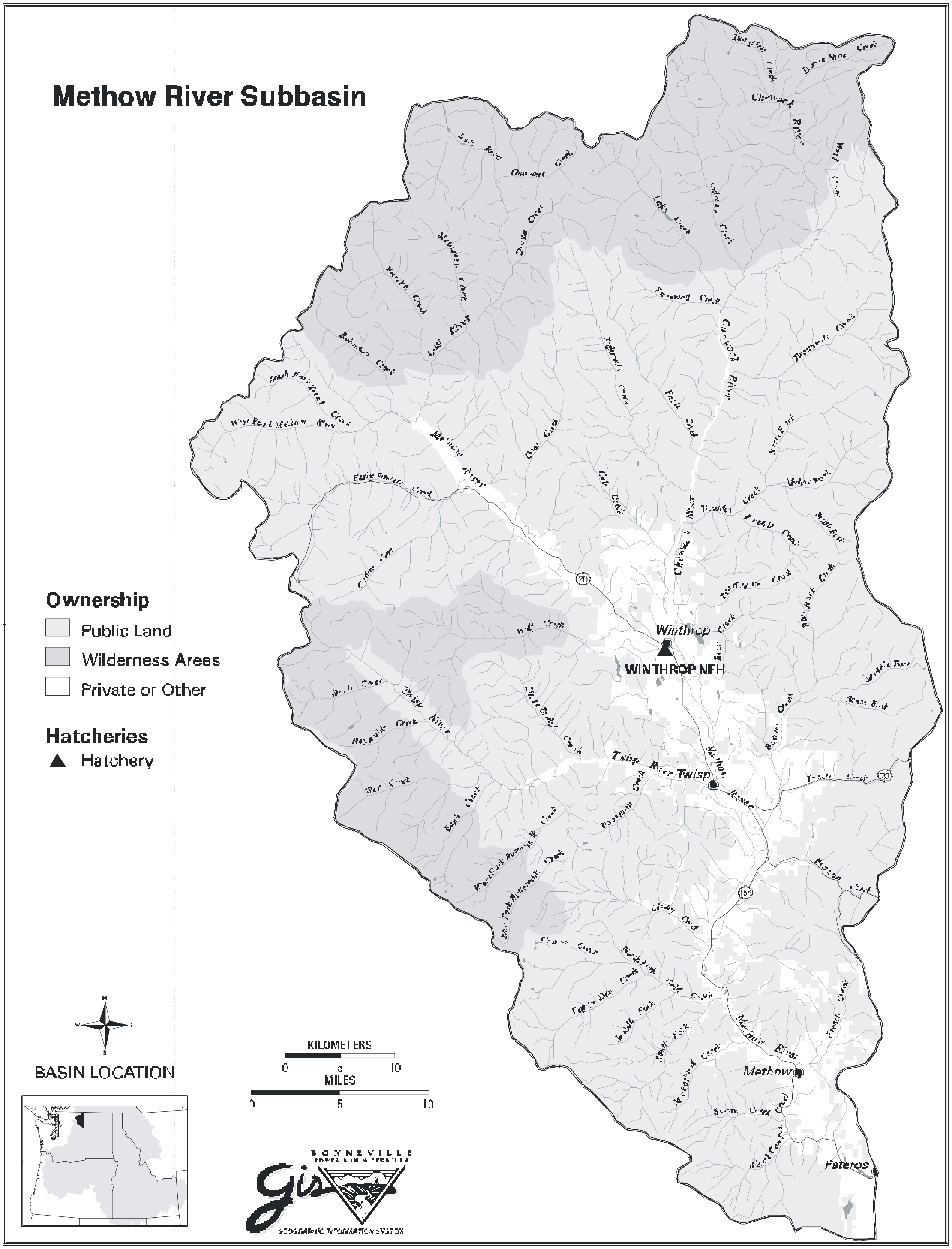

Figure 1. Map of the Methow Subbasin, including the location of Winthrop National Fish Hatchery, and snorkel survey locations.

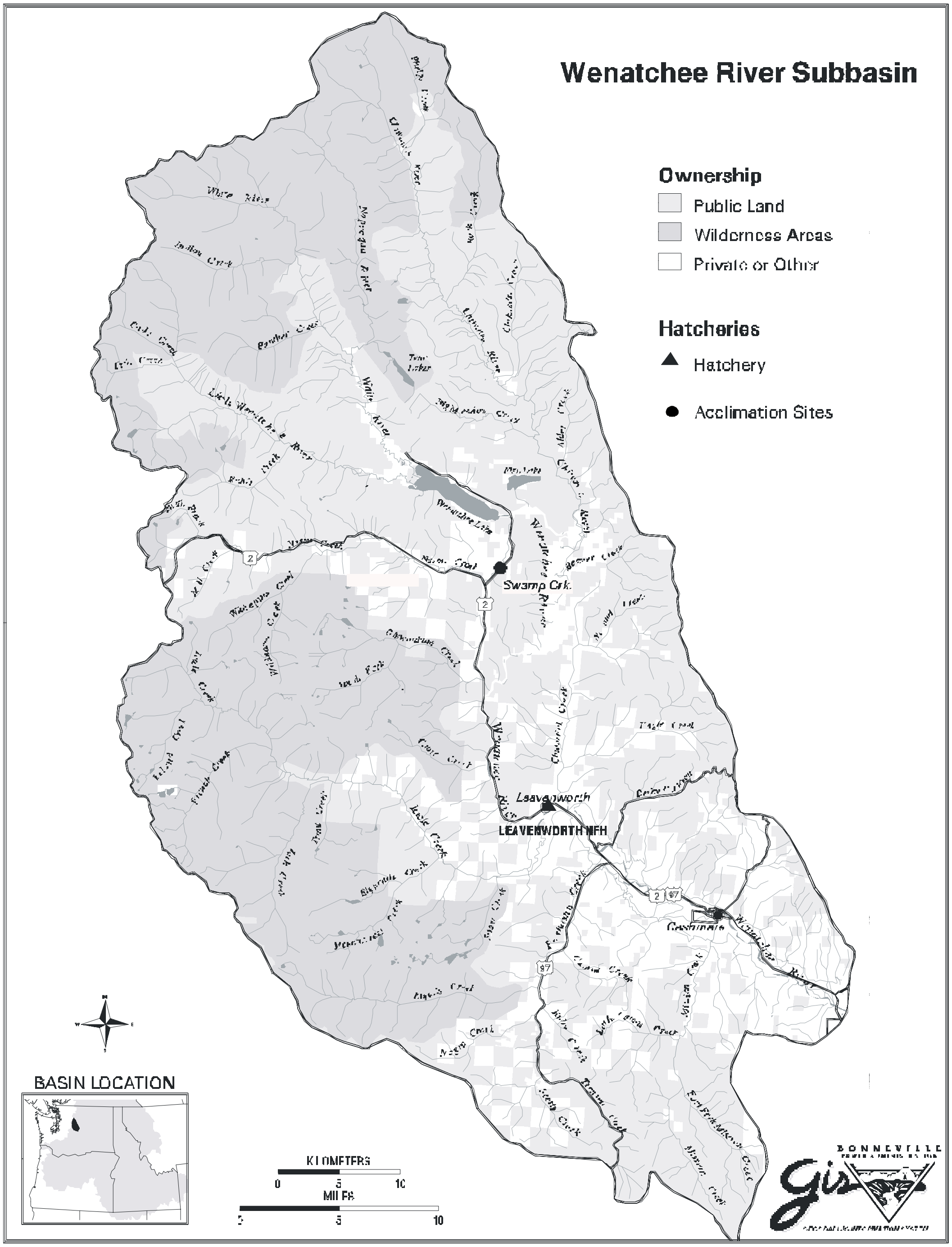

Figure 2. Map of the Wenatchee Subbasin, including the location of Leavenworth National Fish Hatchery, the Swamp Creek coho acclimation site and 1999 snorkel survey locations.

hatchery coho per mile (for each sampling period) by the total distance from the Nason Creek acclimation site to the Icicle Creek confluence with the Wenatchee River (28 miles).

Yakima River

On May 17, approximately 24,850 and 125,000 yearling coho smolts were volitionally released after a period of approximately 5 weeks of acclimation at the Easton and Jack Creek spring chinook acclimation facilities respectively (Figure 3). Identical volitional releases were made from each location on May 27, for a season total release of 49,700 and 250,000 smolts from each facility. Snorkel surveys were conducted in the Yakima and Teanaway rivers downstream of the acclimation sites from July 8-20, 1999 to detect the presence of hatchery coho smolts that did not migrate during the May smolt releases. During the period July 8-10 we snorkeled the entire main river channel from the Easton acclimation to the confluence of the Cle Elum River. During the period from July 16-20, we focused our efforts in areas that were perceived as the highest quality coho rearing habitat, in an effort to maximize the potential to encounter juvenile coho. These areas included pools, back water eddies, and undercut bank areas. On each occasion, observers snorkeled in a downstream direction between the hours of 10:00 and 16:00. The number of salmonids by species was recorded for each survey.

Snorkel counts were expanded by 100, 75, 50, 25, and 10% to reflect a range of snorkel efficiencies. The total number of residual hatchery coho smolts within the survey sections was estimated for each sampling period, by assuming a 100, 75, 50, 25, and 10% sampling efficiency. For each estimate of relative abundance of hatchery coho we calculated the estimated number per mile within the sampled section. Estimates of the number of hatchery coho for the Easton Section are represented as numbers per 49,700 coho released, and the Teanaway estimates are represented as numbers per 250,000 coho released. The number of residual hatchery coho smolts from the Cle Elum Slough to Roza Dam was estimated by multiplying the estimated number of hatchery coho per mile per fish released (for each sampling period and section) by the total distance from the Cle Elum Slough to Roza Dam (55 miles).

Results

Methow River

No hatchery coho were observed in the Methow survey reach. The following salmonids were recorded: wild rainbow/steelhead trout fry (~40-45 mm in length), wild rainbow/steelhead trout parr, hatchery steelhead smolts, wild spring chinook parr (~50-80 mm in length), whitefish *Prosopium williamsoni* , bull trout *Salvelinus confluentus* (1), brook trout *Salvelinus fontinalis* (1), and brown trout *Salmo trutta* (1).

The rainbow/steelhead trout fry were located immediately below Foghorn Dam in less than 12 inches of water, of near zero velocity. Steelhead/rainbow trout parr were located throughout the reach. They preferred large cobble substrate or deep pools with large

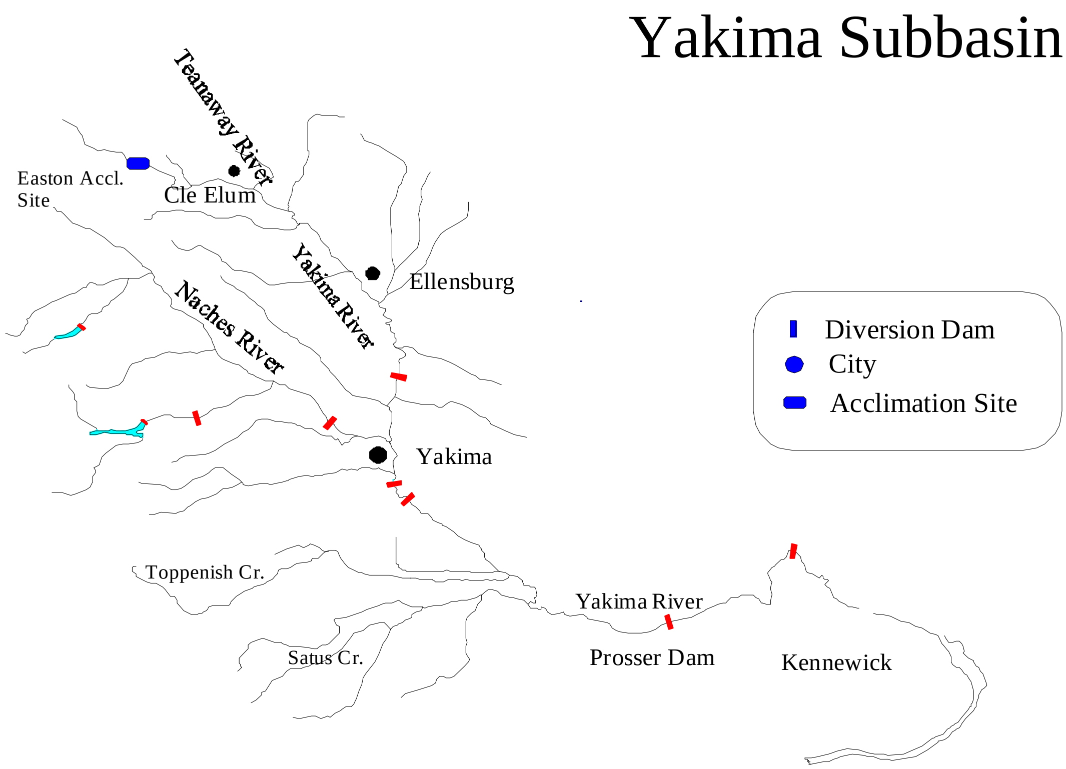

Figure 3. Map of the Yakima Subbasin and 1999 snorkel survey locations.

boulders, along with fast velocity conditions. Hatchery steelhead smolts were most abundant immediately upstream of the Chewuch confluence to approximately one-half mile below the Winthrop Bridge, but were located in lesser abundance throughout the remainder of the survey reach. Spring chinook juveniles were located throughout the reach. They occurred most frequently in association with woody instream structures or medium size cobble substrate in less than 24 inches of water depth, or large back-eddy pools in less than 24 inches of water depth. Whitefish were located in low numbers throughout the reach in association with deep pools and/or fast-deep runs.

Chewuch River

Thirteen hatchery coho were observed throughout the survey reach. Most occurred in the middle portion of the reach. With one exception, coho were observed in the vicinity of other species of salmonids. One hatchery coho was observed in association with a pod of five spring chinook parr in a small lateral pool along the bank margin. The remaining coho were observed further offshore in less than 24 inches of water. There were about 20 hatchery coho remaining in the lower Eight-Mile acclimation pond. These fish all appeared to be much smaller than the mean release size of 15 fish per pound, as did the 13 fish observed in the river.

Other salmonids observed included wild steelhead/rainbow trout parr, wild spring chinook parr, whitefish and bull trout.

Wenatchee River (Nason Creek)

We observed the highest numbers of hatchery coho during the July snorkel surveys in Nason Creek. We observed a total of 7 hatchery coho during this period, which included a total survey downstream of the acclimation site. No coho were observed in either of the June snorkel surveys. Mean number of hatchery coho smolts per mile and total number for snorkel efficiency estimates ranging from 10-100% are presented in Table 1. Estimates of the total number of hatchery coho residuals in Nason Creek and the Wenatchee River upstream of the Icicle River resulting from the 1999 Nason Creek release of 75,000 hatchery fish ranges from 15 – 462 coho (Table 2).

Yakima River

We observed higher numbers of coho during the early July snorkel surveys in the upper Yakima from Easton to the Cle Elum River confluence than compared to the late July snorkel surveys. We observed a total of 75 and 11 hatchery coho during the periods July 8-10 and July 16-20, 1999 from Easton to the Cle Elum River confluence. Mean number of hatchery coho smolts per mile and total number within the Easton reach for snorkel efficiencies ranging from 10-100% are presented in Table 3. Numbers of coho per mile for the Easton surveys are expressed as the number of residual smolts per 50,000 released. A single coho hatchery smolt was observed in Teanaway River below the Jack Creek acclimation facility. The total number of hatchery coho smolts in the Teanaway River for snorkel efficiencies ranging from 10-100% are also presented in Table 3. Numbers of coho per mile for the Teanaway survey are expressed as the number of residual smolts per 250,000 smolts released.

Estimates of the total number of hatchery coho residuals for the 1999 upper Yakima coho release of 500,000 hatchery fish ranges from 75 to 21,505 fish (Table 4). The Teanaway River coho residual rate produced the lowest estimate of the total number of coho residuals from Cle Elum to Roza Dam. The highest estimates of the total number of coho residuals from Cle Elum to Roza dam were calculated using the early July coho residual rates (Table 4).

Table 1. Nason Creek June-July, 1999 coho residual snorkel survey results. Total number and mean number of coho per mile for each given snorkel efficiency. Total coho smolt released was 75,000.

River Location and Time Period	**Snorkel Efficiency Rates**				
	100%	**75%**	**50%**	**25%**	**10%**
June 11, 1999	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
June 29, 1999	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
July 27, 1999	7 (1.6)	9 (2.1)	14 (3.3)	28 (6.6)	70 (16.5)

Table 2. Nason Creek June-July, 1999 expanded coho residual estimates from acclimation site (Nason Creek RM 4.2) to Icicle River confluence with Wenatchee River using June 11, 29, July 27 and mean expansion rates of all sampling periods for each given snorkel efficiency.

	Snorkel Efficiency Rates				
	100%	**75%**	**50%**	**25%**	**10%**
June 11 Expansion	0	0	0	0	0
June 29 Expansion	0	0	0	0	0
July 27 Expansion	45	59	92	185	462
Mean of all Surveys Expansion	15	20	31	62	154

Table 3. July, 1999 coho residual snorkel survey results. Total number and mean number of coho per mile for each given snorkel efficiency. Total coho smolt release numbers were 50,000 and 250,000 for Easton and Jack Creek acclimation facilities respectively.					
River Location and Time Period	**Snorkel Efficiency Rates**				
	100%	**75%**	**50%**	**25%**	**10%**
Easton to Cle Elum River Early	75 (3.9)	100 (5.2)	150 (7.8)	300 (15.6)	750 (39.1)
Easton to Cle Elum River late	11 (0.6)	15 (0.8)	22 (1.1)	44 (2.3)	110 (5.7)
Easton to Cle Elum average	43 (2.2)	57 (3.0)	86 (4.5)	172 (9.0)	430 (22.4)
Jack Cr. to Yakima River	1 (0.06)	1 (0.06)	2 (0.12)	4 (0.24)	10 (0.6)

Table 4. July, 1999 upper Yakima expanded coho residual estimates from Cle Elum Hatchery Slough to Roza Dam using Easton (Early, Late and Mean), Teanaway, and Mean of Teanaway, and Easton Mean hatchery coho residual rates.					
River Location and Time Period	**Snorkel Efficiency Rates**				
	100%	**75%**	**50%**	**25%**	**10%**
Easton Early Expansion	2,145	2,860	4,290	8,580	21,505
Easton Late Expansion	330	440	605	1,265	3,135
Easton Mean Expansion	1,238	1,650	2,448	4,923	12,320
Teanaway Expansion	8	10	18	36	88
Mean of Teanaway and Easton Mean Expansion	623	830	1,233	2,480	6,204

Discussion

We observed no fish in the immediate release area in the Methow and few fish were observed in the Chewuch (near Eight-Mile Creek), in 1998. Therefore we believe that the relative proportion of hatchery coho residuals in the Methow sub-basin was low 1998. However additional surveys in 1999 were performed to encompass greater geographic area, within and across sub-basins, and within the season.

Based on observations in the Methow in 1998 and Nason Creek and the upper Yakima River in 1999, we believe that the overall proportion of hatchery coho that did not migrate during the spring was low. Although some coho were observed in the Nason Creek acclimation pond several weeks after release (J. Foster, personal communication), we found no coho in the pond during our July surveys. Snorkel results were consistently low across basins in 1999. Based on what we believe to be reasonable snorkel efficiency expansion rates (50-25% efficiency) there may have been up to 8,580 (1.7%) hatchery coho residuals from the Cle Elum River confluence to Roza Dam for all (500,000) coho released in the upper Yakima sub-basin in 1999 (Table 4). We believe these estimates likely represent the worst case scenario. We base this assumption on 2 factors. These estimates were calculated using early July snorkel observations, which were higher than late July estimates. We believe that many of the coho present in the early July sample may have migrated downstream and therefore were not detected during the late July surveys. Secondly, the Easton reach contains probably the highest quality rearing habitat within the entire Yakima basin which likely maximized the potential for coho to inhabit this area and therefore our potential to observe these fish in our surveys. Furthermore, hatchery coho residual rates observed in the Teanaway River were much lower than the Easton reach, even though it is likely that Teanaway surveys had higher snorkel efficiency due the narrower stream width. Therefore expansions based on observations within the Easton reach are likely over-estimates of hatchery coho residual rates for areas of lower quality rearing habitat located downstream. Washington Department of Fish and Wildlife snorkel and electrofishing surveys in the upper Yakima sub-basin in the summer and fall of 1999 collaborate our findings that hatchery coho smolt residual rates were low (T. Pearsons, personal communication). We attribute the observed low levels of hatchery coho residuals to sound fish cultural practices including good fish health prior to release, and an adequate acclimation period of 5-6 weeks prior to release. An acclimation period of 5-6 weeks for fish transported has been shown to increase post-release survival rates (Johnson, et al. 1990).

It is important to quantify the total number of hatchery coho residuals for 2 reasons. A high degree of residualism has the potential to negatively impact the program strictly from the aspect of production. Based on the low estimated number of residual hatchery coho observed in the Yakima and Wenatchee sub-basins, it is unlikely that residualism significantly impacted smolt survival estimates or future smolt-to-adult survival estimates.

It is also important to quantify the abundance of residual coho from the aspect of ecological interactions between hatchery coho and other species. As the total number of coho residuals increases so may the potential for ecological interactions such as competition and predation with other species. Although we did not directly investigate competition or predation between hatchery coho and other species, based on the low number of estimated residual coho in 1999, we believe that the potential for negative ecological interactions between coho and other species was minimal. In order for competition to occur, the common resource (space or food) must be in limited supply and important to the well being of each species. We believe that it is unlikely that the low estimates of hatchery coho residuals were ecologically capable of negatively impacting any species present unless the environment was at or exceeded the natural carrying capacity. This situation seems unlikely given the recent levels of adult anadromous salmon returns in the Yakima, Wenatchee and Methow sub-basins. Similarly, we believe that the potential for hatchery coho residual predation on other species was negligible due primarily to the low numbers of coho present after the spring migration.

We further believe that the potential for competition and predation between coho and other species was minimized due to habitat segregation and resource partitioning (Ross 1986). Age 0 salmonids have been shown to typically utilize shallower and lower velocity microhabitats than do yearling salmonids (James et al. 1999; Hillman et al. 1989). Our observations were consistent with these findings, and further lead us to believe that minimal spatial overlap between hatchery coho residuals and age 0 salmonids limits the opportunity for predation and competition between coho residuals and other species.

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Chapter 3

Reproductive Ecology of Returning Hatchery Coho Adults

Introduction

Success of the coho re-introduction program is reliant upon the use of hatchery fish to develop naturalized spawning populations. Hatchery coho will be transferred from lower Columbia River hatcheries. Inter-basin coho salmon transfers throughout this century were common for most hatcheries in the lower Columbia River, with the exception of the Sandy River Hatchery (Currens and Farnsworth 1993). Additionally, many of the lower Columbia River coho hatcheries have been in operation since the early 1900s. Given the lengthy culture history of these stocks it is likely that many have been subjected to intensive domestication selection for many generations. Domestication is usually attributed to the effects of genetic drift which may result from low founding broodstock numbers or selections pressures from rearing fish in the hatchery environment (Calaprice 1969; Cross and King 1983; Allendorf and Phelps 1980). Fish populations which have been subjected to artificial selection may perform well in the hatchery, but poorly in the wild (Busack et al. 1997). Fish hatchery environments shift mortality to later stages of life, and therefore produce the opportunity for genetic change within the population (Waples 1991). Many studies have indicated that the reproductive success of hatchery fish is significantly lower than their wild counterparts (Fleming and Gross 1993; Chilcote et al. 1986; Berejikian et al. 1997). Chilcote et al. (1986) estimated that egg for egg, the reproductive success of hatchery steelhead was 28% of that for wild fish. Fleming and Gross (1993) found that male hatchery coho adults were competitively inferior to wild males, and as a consequence were restricted access to spawning females. Female hatchery coho were at less of a disadvantage, having similar levels of aggressive behavior. However, hatchery female coho retained a higher proportion of their eggs, suffered greater delays in the onset of mating, and lost a higher proportion of their eggs due to superimposition of redds by other female when compared to wild females. Berejikian et al. (1997) found similar results with captively reared coho. Our efforts described below are the fundamental beginning to address or quantify the reproductive success of lower Columbia River hatchery coho that return to the mid-Columbia tributaries. The mid Columbia Coho Hatchery and Genetic Management Plan (HGMP; Draft) outlines the future monitoring plan to assess the reproductive success of returning coho.

Methods

Efforts to address the reproductive success of lower Columbia River hatchery coho which return to the mid-Columbia tributaries was initially conducted in the Yakima sub-basin due primarily to the shear availability of adult returns to the Yakima. Information gathered from these investigations should be interpretable with regards to efforts to re-introduce coho in the Wenatchee and Methow sub-basins.

During the week of November 9, 1998, 19 female and 24 male adult coho were collected at the Prosser Dam right bank denil, and held at Prosser Hatchery. On November 13, we transported and released the adult coho in a 1 km section of Wenas Creek (RKM 25.8) that had been previously weired at the upper and lower boundaries of the study reach. Foot surveys were conducted approximately daily until spawning was complete. During the surveys we measured several physical attributes of each redd including the following: width, length, tailspill depth, pit velocity, tailspill velocity, and distance, direction and depth of nearest hiding cover. After a female had completed spawning and was near death, we collected several data from the carcass including: fork and post-eye to hypural plate lengths, and we enumerated the number of eggs retained. We selected 10 redds to install fry traps to estimate egg-to-fry survival during spring emergence, and collected 4 gravel samples from each of the 10 redds to characterize substrate composition. Gravel samples were collected using a McNeil core sampler from the redd margins at the 06:00, 09:00, 12:00 and 3:00 positions of each redd. Gravel samples were sieved down to 0.212 mm median particle size.

Results

Of the 19 female coho we released in Wenas Creek, we identified a total of 14 redds that were constructed between 3 and 25 days after release. We recovered a total of 12 (63.2%) female, and 9 (37.5%) male carcasses. Table 1 summarizes the mean characteristics of redds observed in Wenas Creek. The mean egg retention for 11 female coho sampled was 680 eggs (Table 1). However, 2 females died shortly after transport and although both coho constructed a redd, both retained 100% of their eggs. We believe this mortality was induced by transport. Excluding these two females, mean egg retention was 209 eggs/female or approximately 7.5% (Yakama Nation, unpublished data, Toppenish, WA). Coho typically spawned at the tail crest of pools and run-type habitats. Coho selected spawning locations where the mean dominant substrate size ranged from 26.5 – 9.5 mm median particle size (Figure 1). The mean fine (>0.425 mm) and silt (>0.212 mm) for 8 redds sampled was 16.7 and 10.2% respectively. Extraordinary snow pack and subsequent spring runoff prevented us from installing redd caps to estimate egg-to-fry survival rates.

Discussion

Coho generally spawned in locations which are considered typical spawning locations for many salmonids (at the tail of pool and run-type habitat), and they selected spawning locations in Wenas Creek where the dominant substrate size ranged from 26.5 to 9.5 mm median particle size. Tagart (1975) classified gravel which ranged between 26.9 and 3.35 mm as “good spawning gravel” for coho, and concluded that egg-to-fry survival was positively correlated to the proportion of gravel within this size class in the redd. The percent fines (>0.425 mm) was within the range reported for several streams in western Washington for wild coho populations (Tagart 1975).

Table 1. Coho Redd characteristics at time of spawning and egg retention in Wenas Creek, 1998.								
Redd #	**Width (m)**	**Length (m)**	**Tailspill Depth (m)**	**Pit Velocity (m/sec)**	**Tailspill Velocity (m/sec)**	**Distance to nearest Cover (m)**	**Depth at Cover (m)**	**Number of Eggs Retained**
9	1	2	0.05	0.29	0.59	1.5	0.2	328
1	1	3	N/A	N/A	N/A	1.5	0.3	2800
4	1	2	0.65	0.87	1.15	3	0.15	1400
5	1	2	N/A	N/A	N/A	0.3	0.2	2800
6	1.5	2.5	0.2	1.03	1.67	3.5	0.25	0
2	0.3	0.9	0.25	0.27	1.28	4	0.3	N/A
3	0.5	2	0.15	0.48	1.77	1.5	0.15	0
8	1	1.5	0.3	0.04	4.66	3	0.2	5
7	1	2.5	0.2	0.45	1.42	4	0.2	0
12	1	3.5	0.2	0.15	1.35	4	N/A	130
11	1	2	0.2	0.21	1.08	1	N/A	18
10	1	2	0.25	0.13	1.16	1	N/A	0
MEAN	**0.9**	**2.2**	**0.2**	**0.4**	**1.6**	**2.4**	**0.2**	**680.1**

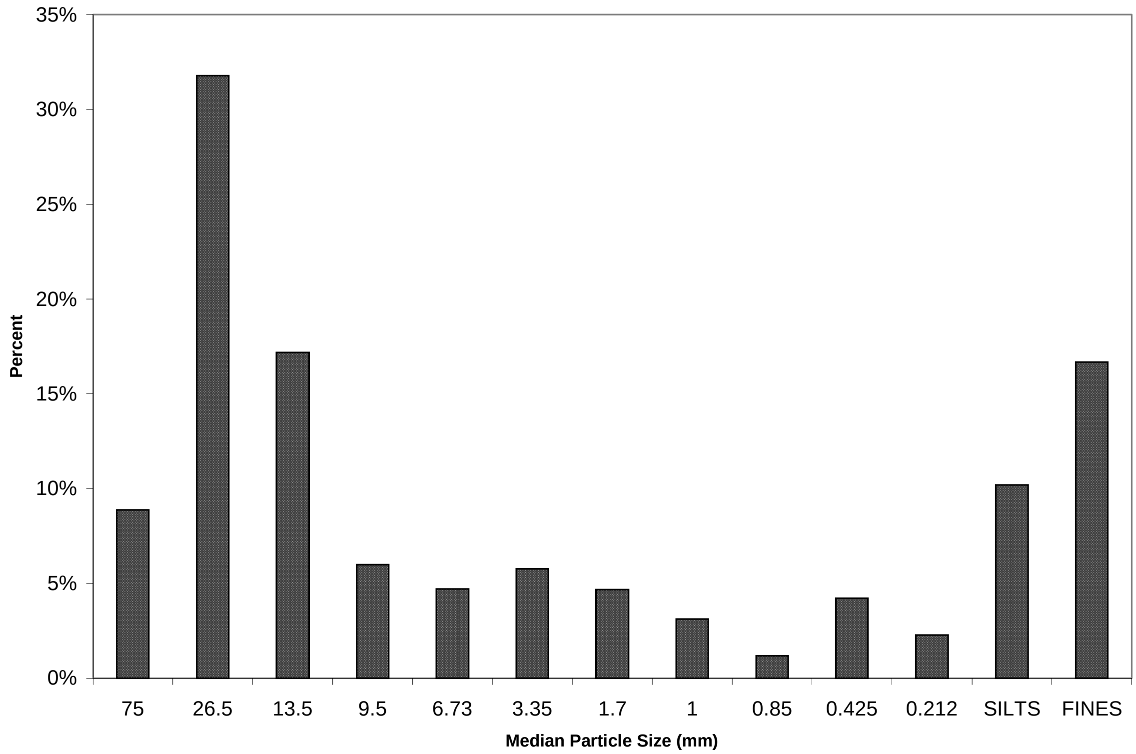

Figure 1. The particle size distribution of 8 coho redds in Wenas Creek. Substrate materials classified as fines and silts are composed of materials having a median particle size diameter of >0.425 and >0.212 mm respectively.

The mean egg retention per female we observed (680 and 209 eggs/female, see above) was higher than published values for naturally spawning populations of coho. For example, 4 eggs/female in Prairie Creek, California and Fall Creek, Oregon (Briggs 1953; Koski 1966 respectively), 7-16 eggs/female in Kamchatka (Semko 1954) and 60 eggs/female in Waddell Creek, California (Shapovalov and Taft 1954). Berejikian et al. (1997) found that the onset of spawning for captively reared coho was later than for wild coho, and suggest the delayed onset of spawning can reduce reproductive fitness by causing higher egg retention. In our study it is difficult to determine if the relatively high female egg retention was caused by transportation or the results of hatchery domestication.

Much attention has recently focused on the potential negative interactions between hatchery fish and wild fish, especially in regard to the reproductive success of hatchery fish and reproductive crosses between hatchery and wild fish (Chilcote et al. 1986; Reisenbichler and McIntyre 1977; Leider et al. 1984, 1986, 1990; Berejikian, et al. 1997). For example, Chilcote et al. (1986) found that reproductive success of hatchery steelhead was 28% of wild fish, and Fleming and Gross (1993) found that hatchery reared coho males achieved an estimated 62% spawning success of wild males, and that hatchery reared female coho achieved an estimated 82% spawning success when compared to wild female coho. Nevertheless, if coho are to be re-established in a system such as the Yakima River, acclimating and releasing hatchery smolts for the development of a locally adapted broodstock is probably the most practical method.

We were unable to determine reproductive success (egg-to-fry survival) of the adult hatchery coho in Wenas Creek due extraordinarily high runoff in the spring of 1999, which prevented us from successfully capping any redds. It is however, likely that the reproductive success of hatchery reared coho will be a critical factor which determines our ability to successfully re-introduce coho into the Yakima River system given that adult returns to the Yakima sub-basin have exceeded 1300 adults for the past 4 years. Therefore the reproductive success of returning hatchery coho remains an important critical uncertainty to be addressed by future monitoring and evaluation work. Coho for the 1998 reproductive success experiment in Wenas Creek were collected from tail portion of the run (November) and may not have been representative of entire run for maturation timing. Future efforts will be made to ensure that a representative sample of coho collected through the duration of the coho run are included in the study. Sexual maturation timing may be an important characteristic which strongly influences the reproductive success of lower Columbia River hatchery coho in the Yakima, since most acclimation sites and natural production areas are located between 201 and 312 km upstream of the Yakima River confluence.

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Chapter 4

Survival of Hatchery Coho

Introduction

Fundamental project success requires sufficient numbers of adult coho to return to the basin that they were released from in order to either spawn naturally or to be spawned in a hatchery as part of a broodstock development program. The mid-Columbia Hatchery Genetic Management Plan (HGMP; BPA 1999) identifies several project performance indicators. The performance indicator of highest interest in the short term may be smolt-to-adult survival. The HGMP speculates that development of a localized broodstock is critical to project success. However, in order to develop a localized broodstock, sufficient adults must return to the Wenatchee and Methow rivers and be collected in order to meet broodstock requirements. Thus, a monitoring program that tracks smolt-to-adult survival rates through time is essential to track the project's long term performance.

The project is also interested in juvenile survival in order to parse out that portion of the smolt-to-adult mortality that is occurring in the freshwater lifestages. Juvenile coho released in the Wenatchee and Methow rivers must migrate past 7 and 9 hydro-electric dams on the mainstem Columbia River respectively before reaching the Pacific Ocean. These dams have increased the total cross-sectional area of he Columbia River resulting in decreased water velocity and turbidity, which in turn has increased smolt travel time and generally subjected smolts to greater exposure to predators and other factors influencing survival (Raymond 1979, 1988; Williams 1989). Physical changes in the Columbia River environment attributable to hydro-projects may require salmonids to migrate under a different set of environmental conditions than they evolved under.

Juvenile and adult coho survival in the Columbia River mainstem may be further depressed by the source of broodstock. Lower Columbia River hatchery stocks of coho may not be well adapted to migrate the long distances required for them to reach the ocean and return. A baseline monitoring program that tracks both juvenile survival and smolt-to-adult survival rates will be important to determine if benefits are achieved from development of a locally adapted broodstock.

Methods

Methow Sub-basin

Yakama Nation acclimated and released between 70,000 and 350,000 yearling coho smolts in the Methow sub-basin in 1995 through 1998 at various locations (Table 1). We calculated smolt-to-adult survival by dividing the number of adults (outmigration year +1) and jacks (migration year) passing Wells Dam as enumerated via video monitoring by the total number of hatchery smolts release for returns years 1996-1997. We used two methods to estimate smolt-to-adult survival for coho returning to the Methow sub-basin in 1999. The first method we used was similar to those for previous years, except that we added the total number of coho collected for broodstock at Wells Dam to the Wells Dam passage counts. The second method estimated survival to WNFH, in which returning adults were enumerated as they volunteered into the adult holding pond at WNFH, this method allowed us to estimate smolt-to-adult survival for those fish released as smolts from the facility. Juvenile survival rates through the mainstem Columbia River are not available because coho PIT tag survival studies were not conducted.

Wenatchee Sub-basin

The Yakama Nation released approximately 525,000 coho smolts in the Wenatchee sub-basin in 1999 of which 75,000 (non-marked) were released at RM 2 on Nason Creek (Table 1). The remaining coho smolts, including the PIT tagged fish, were released from the pollution abatement pond at Leavenworth National Fish Hatchery. We PIT tagged 7,072 coho smolts for release in the Wenatchee River in 1999. Each group was released on April 25, 1999. PIT tagged fish were detected at McNary and John Day Dams, which allowed estimates of survival from release to be calculated (D. Neeley, personal communication).

Statistical Analyses

To obtain a McNary passage index of the PIT-tagged Wenatchee released fish, McNary Dam PIT tag detections were expanded by dividing by the McNary detection rate (efficiency). McNary's detection rate is the proportion of total PIT tagged fish passing the dam that are detected by the dam’s PIT tag detectors. An index of survival to McNary is the passage index divided by the number of PIT tagged fish released.

In this study, the estimated McNary detection rates were the proportion of John Day (JD) detections that were previously detected at McNary (McN). From studies of volitional releases of spring chinook in the upper Yakima, it was found that daily detection rates were not constant over the outmigration season, and it was necessary to stratify the passage into periods of more homogeneous daily detection rates. These same strata were used for the Wenatchee coho release because their detection rates showed the same temporal trend as the Yakima spring chinook. The estimation process is indicated in the following equations:

Equation 1. McN Detection Rate for stratum i =

[Number of coho detected at both McN and JD during stratum i]/
[Total number of coho detected at John Day Dam during stratum i]

Equation 2. McN PIT tagged Passage Index within stratum i =

[Number of coho detected at McN within stratum i]/[McN Detection Rate for stratum i]

Equation 3. Total McN PIT tagged Passage Index =

Summation over strata of McN Passage Index within strata (Equation 2)

Equation 4. Survival Index =

[Total McN PIT tagged Passage Index]/[Number of Pit tagged Fish Released]

Results

Methow Sub-basin

Coho smolt-at-release to adult-at-Wells Dam survival rates are available for smolt-release years 1995-1998 (Table 1). Estimates of hatchery coho smolt-to-adult survival in the Methow for releases made in 1995-1997 has been low, averaging 0.001%. Our estimates of smolt-to-adult rates for the 1998 release were higher by an order of magnitude compared to previous releases in the Methow. The estimates of smolt-to-adult survival for all fish released in the Methow and those released from WNFH in 1998 were 0.072 and 0.052% respectively (Table 1).

Wenatchee Sub-basin

We divided the coho outmigration period at McNary Dam (April 25 – July 31) into 7 strata based on different detection rates between strata (Table 2). The passage of hatchery PIT tagged coho released on April 25, 1999 from the Leavenworth pollution abatement pond peaked at McNary Dam between May 25 and June 7 at approximately 151 fish PIT tagged fish per day (Figure 1). We estimated that a total of 3,809 (53.9%) PIT tagged coho passed McNary Dam between April 25-July 31. Mean fish-weighted travel time from release to McNary dam was 32 days (mean fish weighted passage date 5/26/99 at McNary Dam).

Discussion

Estimates of smolt-to-adult survival for hatchery coho smolts released in the Methow sub-basin in 1998 were more than an order of magnitude higher than our smolt-to-adult estimates for previous years releases (Table 1). However, in comparison to Yakima River coho smolt-to-adult survival rates during the past 3 return years, the 1998 Methow coho return was approximately 2-4 fold lower. Our estimates of smolt-to-adult survival based on Wells Dam video and fish ladder counts for all coho released in the Methow sub-basin in 1998 and our estimate of smolt-to-adult survival of those fish released only from WNFH (based on the number of swim-ins at the adult holding pond) were similar. The similarity between methods used to estimate smolt-to-adult survival for coho released in 1998 between the two groups leads us to believe that our estimates of survival are relatively accurate.

We believe that smolt-to-adult survival rates for coho released in the Methow sub-basin during the period 1995-1997 may be higher than estimates based on dam video counts. We partially attribute these low smolt-to-adult survival rates to low counting efficiency at Priest Rapids, Rock Island, Rocky Reach and Wells Dam counting facilities. Based on our three enumeration methods in 1999 (Wells video counts and Wells trap counts) we estimate a minimum of 246 adult coho returned to the Methow sub-basin. Our minimum estimate is greatly disparate with 1999 coho video counts at Priest Rapids, Rock Island, and Rocky Reach dams (Table 3). We suspect that this disparity may have been consistent across years. Additionally, coho returning to the Methow sub-basin in 1996-1998 did not have an opportunity to enter the adult holding pond at WNFH (C. Pausley, USFWS, personal communication), and therefore we did not have the opportunity to substantiate low survival rates based on these four dam counts.

The 1999 hatchery return to the Methow River was nearly at replacement in the hatchery environment for the number of adults collected. In a typical coho hatchery environment smolt-to-adult survival would need to be approximately 0.11% to meet replacement assuming 47% female sex ratio, 3000 eggs/female fecundity, 90% pre-spawning survival (observed 1999), 85% collection efficiency and 85% egg-to-smolt survival. We did meet or expect to meet each of these assumptions except collection efficiency. Collection efficiency for coho at WNFH in 1999 was 61%. The hatchery broodstock program at WNFH would have met replacement if collection efficiency were higher. During the 1999 return, the collection trap at Wells Dam was operated only 3 days per week due to ESA restrictions. We believe if similar smolt-to-adult survival rates are achieved in future years the program will likely reach replacement in the hatchery environment. Near term releases in the Methow sub-basin will only occur from WNFH, and even if the adult trap at Wells Dam is ran only 3 days per week, recruitment into the adult holding pond will likely increase collection efficiency to at least 85%. Development of a locally adapted stock of coho is also expected to increase survival of coho released from the tributaries in the mid-Columbia region (BPA 1999).

Low smolt-to-adult survival has also plagued other anadromous salmonid stocks in the mid-Columbia region. In comparison, survival of hatchery spring chinook salmon released from WNFH for brood years 1979-1992 have averaged 0.052% smolt-to-adult survival (range 0.001 – 0.165%; Carie and Hamstreet 1999). Hatchery spring chinook salmon released from Leavenworth NFH for brood years 1979-1992 have performed better than those released from WNFH, averaging 0.257% (range 0.009 – 0.655%; Carie and Hamstreet 1999).

Table 1. Release years, numbers, locations and smolt-to-adult survival estimates for all coho smolt releases in the Methow and Wenatchee sub-basins 1995-1999.

Release Year	Sub-basin	Release Location Within Sub-basin	Smolt Release Number	Returning Adults	Smolt-to-Adult Survival Rate (%)	Adult Counting Location
1995	**Methow**	Winthrop NFH	**70,000**	**1**	**0.001%**	**Wells Dam**
1996	**Methow**		**350,000**	**3**	**0.001%**	**Wells Dam**
		Winthrop NFH	250,000			
		Chewuch River	100,000			
1997	**Methow**		**75,000 total**	**1**	**0.001%**	**Wells Dam**
		Winthrop NFH	70,000			
		Chewuch River	5,000			
1998	**Methow**		**341,000 total**	**246**	**0.072%**	**Wells Dam**
		Winthrop NFH	169,000	**88**	***0.052%**	**WNFH Adult Pond**
		Chewuch River	95,000			
		Wolf Creek	77,000			
1999	**Wenatchee**		**525,000 total**	**N/A**	**N/A**	**Leavenworth NFH & Tumwater Dam**
		Leavenworth NFH	450,000			
		Nason Creek	75,000			

*Note: The estimate of smolt-to-adult survival for fish released from WNFW is a minimum survival due to an unknown portion of returns to the adult holding pond that were collected during broodstock collection at Wells Dam.

Table 2. Strata dates, detection rates and expanded passage of PIT tagged hatchery coho at McNary Dam, released from Leavenworth Hatchery, 1999.			
Stratum	**Dates at McNary**	**McNary Dam Detection Rate**	**Expanded McNary Passage**
1	4/25-5/3	0.333	10
2	5/4-5/14	0.280	212
3	5/15-5/24	0.250	726
4	5/25-6/4	0.091	1665
5	6/5-6/7	0.124	452
6	6/8-6/14	0.104	584
7	6/15-7/31	0.079	160
Total			**3809**

Table 3. 1999 Coho counts at Columbia River Dams.			
Dam	**Adult Count**	**Jack Count**	**Total Count**
McNary Dam	4738	188	4926
Priest Rapids Dam	51	4	55
Rock Island Dam	2	0	2
Rocky Reach Dam	23	0	23
Wells Dam	184	19	203

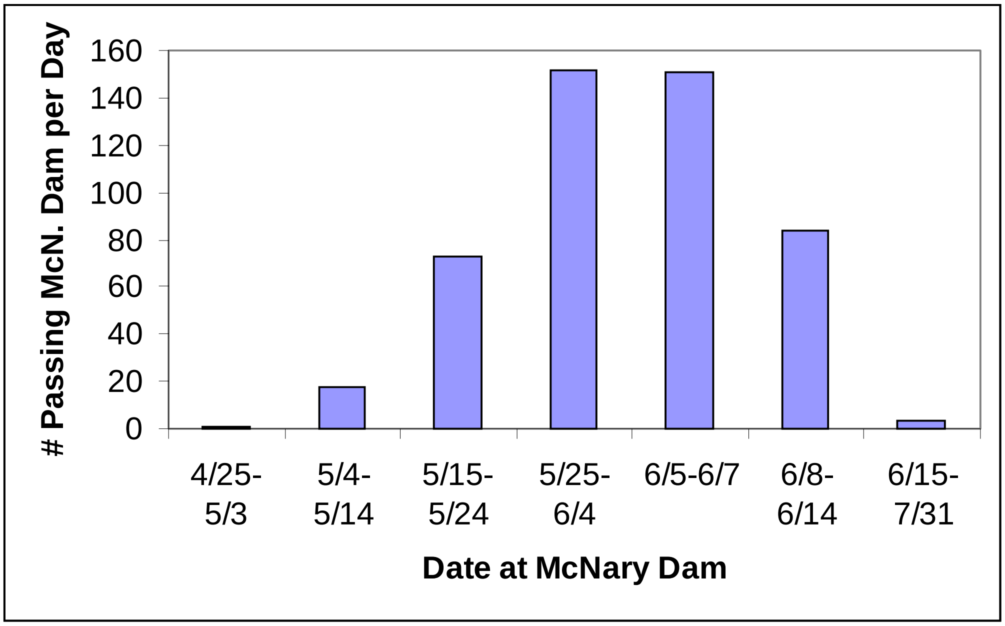

Figure 1. The expanded number of PIT tagged hatchery coho released from the Leavenworth Hatchery pollution abatement pond passing McNary Dam per day over the seven strata.

Video monitoring at Wells Dam in 1999 classified 19 coho as two year olds (jacks). If the classification was correct, these fish were either hatchery coho strays that were likely from releases made in the Wenatchee sub-basin, or naturally produced fish from previous hatchery releases made in the Methow. The proportion marked coho released from state and federal hatcheries in the lower Columbia River has increased in recent years, and ESA restrictions are likely to maintain this scenario. This project also intends to increase marking levels as the project progresses. Both situations will likely help quantify straying and natural production resulting from returning hatchery fish (BPA 1999).

We estimated that the fish-weighted mean travel time to McNary Dam was 32 days for hatchery coho released from the LNFH in 1999. This data is consistent with previous assumptions that the potential for migrating hatchery coho to negatively impact other species via ecological interactions is low, due to limited spatial and temporal overlap with other species.

We estimated approximately 54% of the juvenile coho released from the Leavenworth National Fish Hatchery pollution abatement pond survived to pass McNary Dam in 1999. We attribute the relatively high survival observed in 1999 to favorable migration conditions in the Wenatchee and Columbia rivers. Several environmental factors observed in the spring of 1999 probably contributed to the high juvenile survival to McNary Dam by reducing predation on juvenile coho. These factors included relatively high flow and turbidity conditions, and low water temperatures. In comparison, yearling summer steelhead in 1999 and yearling spring and summer chinook in 1998 released above Wells Dam survived at comparable levels. Bickford et al. (1999a) estimated that mean survival of yearling summer steelhead from release at Pateros to McNary Dam was 65%. In a similar study conducted in the spring of 1998, Bickford et al. (1999b) estimated that yearling spring chinook and yearling summer chinook survival from Pateros to McNary Dam was approximately 69 and 63% respectively. Passage timing for coho released from LNFH and steelhead near Wells Dam in 1999 were similar, as were passage timing at McNary Dam for chinook released above Wells Dam in 1998 (Bickford et al. 1999a; 1999b). In 1999, juvenile coho migration timing pattern was relatively synchronized with Methow River hatchery steelhead. Synchronous migration of hatchery coho and other ESA listed stocks ensures that coho smolt migration coincides with mainstem Columbia Hydro-project spill programs.

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