# Evaluation of Chum and Fall Chinook Salmon Spawning Below Bonneville Dam

Annual Report

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## ABSTRACT

Pacific salmon *Oncorhynchus* spp. populations have declined over the last century due to a variety of human impacts. Chum salmon (*O. keta*) populations in the Columbia River have remained severely depressed for the past several decades, while upriver bright (URB) fall Chinook salmon (*O. tshawytscha*) populations have remained relatively healthy. For the past eight years we have collected data on adult spawning and juvenile emergence and outmigration for chum and URB fall Chinook salmon populations in the Ives and Pierce islands complex below Bonneville Dam. In 2005, we estimated 229 chum salmon and 1,275 fall Chinook salmon spawned in this area. Chum salmon spawning peaked 6 December with 101 redds observed and fall Chinook salmon spawning peaked 15 November with 319 redds. Biological metrics were similar to previous observations, suggesting chum salmon in our study area are similar to nearby stocks in Hardy and Hamilton creeks, and Chinook salmon are similar to other URB stocks. Temperature data indicated that 2005 brood chum salmon emergence began 13 February and continued through 27 April 2006, with peak emergence occurring on 5 April. Fall Chinook salmon emergence began on 24 December 2005 and ended 28 May 2006, with peak emergence occurring 10 May. Between 31 January and 30 June, we sampled 302 juvenile chum salmon and 3,116 juvenile Chinook salmon. The peak catch of juvenile chum salmon occurred 3 April. Juvenile chum salmon outmigrated at 40-55 mm fork length, primarily in April. The peak catch of juvenile fall Chinook salmon occurred on 30 May. The majority of fall Chinook salmon appeared to outmigrate in May and early June, at 70-80 mm fork length. We also released 3,905 coded-wire tagged juvenile fall Chinook salmon to assess survival. Nine fish tagged in 2001 (2000 brood year) were recovered in 2005, demonstrating fall Chinook salmon spawning below Bonneville Dam contribute progeny to commercial and recreational fisheries.

## INTRODUCTION

Columbia River chum salmon (*Oncorhynchus keta*) were prolific in the late 1800s and early 1900s, with populations estimated to be greater than one million fish. The development of the federal Columbia River hydropower system, overexploitation, habitat degradation, and loss of key spawning locations contributed to dramatic declines in chum salmon populations during the last century (Nehlsen et al. 1991; Johnson et al. 1997; Hillson 2003). Historically, chum salmon had the widest distribution of all Pacific salmonids and composed up to 50% of the annual salmonid biomass (Salo 1991). Returning adult chum salmon in the Columbia River were in decline by the late 1930s and had been extirpated from most tributaries by the 1950s (Johnson et al. 1997). Presently the Lower Columbia River evolutionarily significant unit (ESU) contains three small but stable groups of chum salmon: the Grays River, Hardy Creek and Hamilton Creek populations (Johnson et al. 1997). Persistently low numbers of chum salmon in the Lower Columbia River ESU prompted the National Oceanic and Atmospheric Administration (NOAA) to list them as threatened under the Endangered Species Act (ESA) in May 1999 (NOAA 1999).

Although populations of chum salmon have remained depressed in the lower Columbia River; some upriver bright (URB) fall Chinook salmon *O. tshawytscha* stocks have been relatively healthy. There have been three near-record returns of adult fall Chinook salmon since 2001 to the Columbia River (ODFW 2005). Historically, URB fall Chinook salmon composed the largest segment of the fall run (ODFW 2002). Chinook salmon spawning in the Hanford Reach of the Columbia River represent one of the largest and healthiest wild populations of the URB stock (Nelson et al. 1991). Genetically similar groups have established viable populations outside of previously documented geographic ranges. The fall Chinook salmon population that is currently spawning around the Ives/Pierce Island complex (Figure 1) is one example (van der Naald et al. 2005), and is the only known wild URB fall Chinook salmon population in the lower Columbia River. Genetic analyses by the Washington Department of Fish and Wildlife (WDFW) have indicated that these lower river spawners are similar to upriver populations (WDFW, unpublished data).

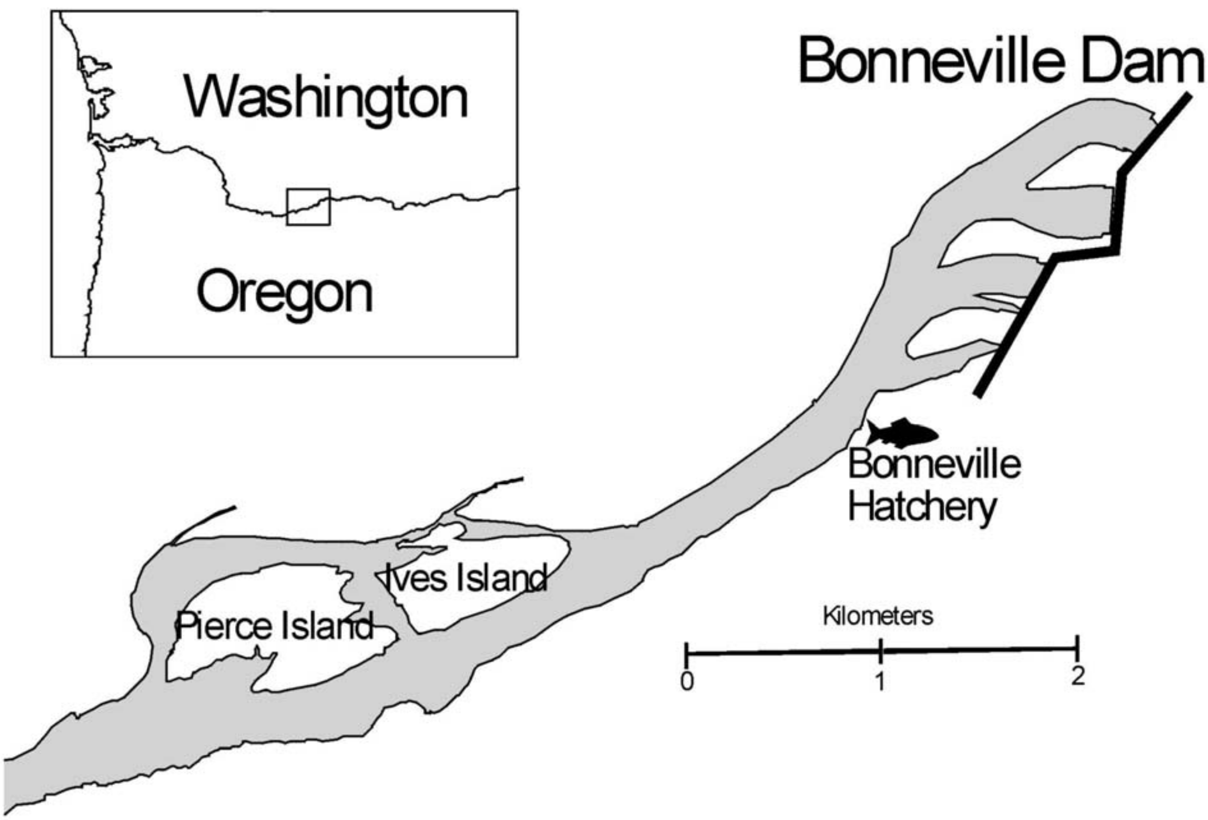


FIGURE 1. The Columbia River below Bonneville Dam.

The Ives/Pierce Island complex includes both side channel and main channel spawning habitat between river kilometer (rkm) 228 and 229 and is described further by Hoffman (2001) and Tiffan et al. (2005). This area is host to a significant amount of spawning activity in the fall and winter for both chum and fall Chinook salmon (van der Naald et al. 2005). In the past decade, the U. S. Geological Survey (USGS), U. S. Fish and Wildlife Service (USFWS), Oregon Department of Fish and Wildlife (ODFW), Pacific States Marine Fisheries Commission (PSMFC), Battelle Pacific Northwest Natural Laboratories (PNNL), and WDFW have conducted research in and around this location, with much of the work focusing on the monitoring and recovery of chum salmon populations.

In this report, we describe work conducted by ODFW and PSMFC from 1 October 2005 to 30 September 2006, and how this work relates to two of the four primary objectives identified in the collaborative statement of work. The first objective is to document and describe fall Chinook and chum salmon spawning in the mainstem Columbia River below Bonneville Dam. On-the-ground surveys are conducted and biological data is collected from adult spawners to describe the populations and determine stock origins. The second objective is to sample naturally-produced juvenile fall Chinook and chum salmon to determine emergence timing, size and time of emigration from local rearing areas, spatial rearing distribution. Naturally-produced fall Chinook salmon from the Ives/Pierce island area are also marked with coded-wire tags (CWTs) to determine juvenile to adult survival rates and contributions to area fisheries. Available habitat and spawning success for chum salmon (Tiffan et al. 2005), egg-to-fry survival, and fry emergence (presumably) are dependent on water availability and fluctuations below Bonneville Dam; in-season data from this study are provided regularly to hydrosystem managers to help provide adequate flows.

## METHODS

### Adult Salmon Surveys

We began spawning ground surveys for chum and fall Chinook salmon below Bonneville Dam on 4 October 2005 and surveyed twice weekly through 29 December 2005. The survey area included the shoreline areas of Pierce and Ives islands and both Oregon and Washington shorelines of the Columbia River that are adjacent to the island complex (Figure 2). We divided the study area into 13 sections, and surveyed each section by boat, or by foot in areas not accessible by boat. All viable redds, live fish and carcasses were identified and counted from the bow of the boat; most carcasses were recovered and processed on shore. The locations of newly formed chum and fall Chinook salmon redds were fixed with a differentially corrected Trimble® GPS receiver (Trimble Navigation Limited, Sunnyvale, California).

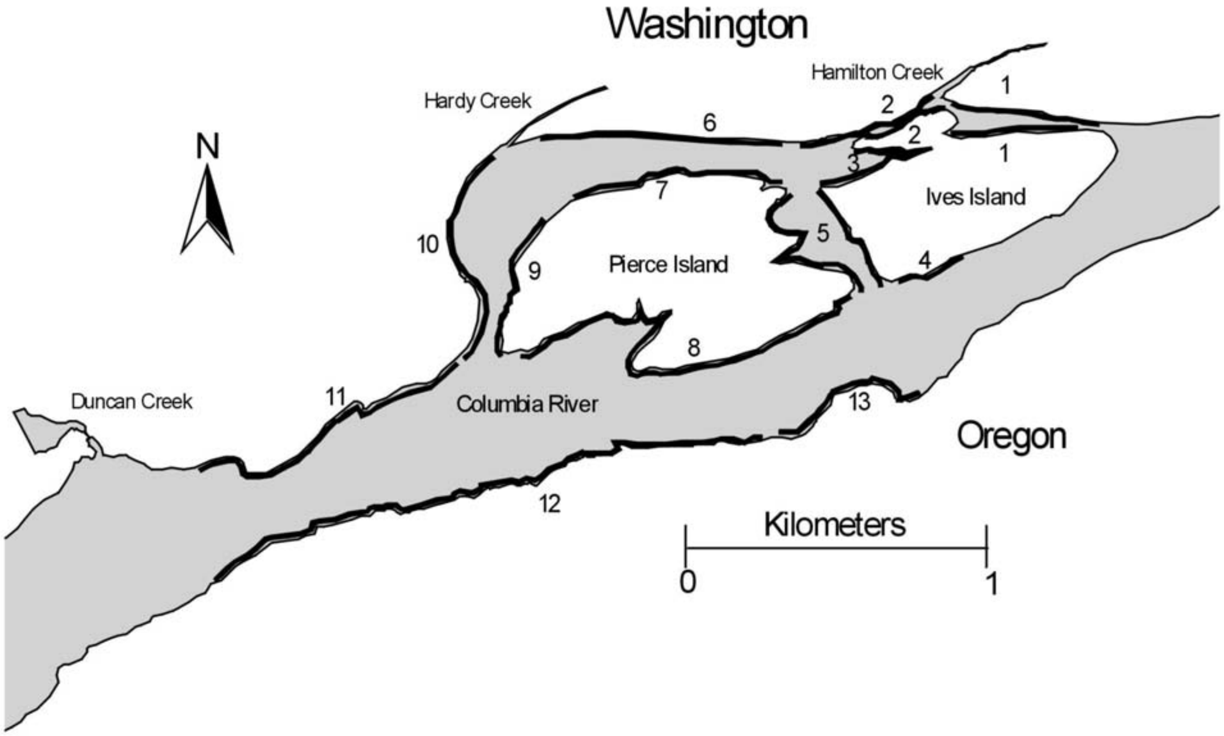


FIGURE 2. Survey areas for adult fall Chinook and chum salmon below Bonneville Dam, 2005.

We estimated the Ives/Pierce Island chum salmon spawning population using mark-and-recover techniques. Each week we marked newly found carcasses by attaching a colored vinyl tag to the underside of the left operculum and returned the carcasses to their original location. Tags varied by color and shape depending on capture week. When we recovered a tagged carcass we removed the tag from the operculum and severed the tail at the caudal peduncle so it was not double-counted. We removed each carcass from the population upon recapture because the tags were not individually identifiable. Each week we recorded the number of newly assigned tags and the number of tags recovered from each of the previous tagging weeks.

We calculated the population estimate with a modified parameterization of the Jolly-Seber model (Schwarz and Arnason 1996, Rawding and Hillson 2003), which is based on individual life histories. We began by transforming the summary of carcasses tagged and recovered to individual tag and recovery histories for each fish. We had a maximum of two encounters with each carcass because carcasses were removed from the population upon recapture. We then ran the series of individual life histories through a recovery-only program in MARK (White and Burnham 1999) and then analyzed the resulting summary statistics with an online version of POPAN 6 – a population analysis program (Schwarz 1996). POPAN 6 calculates standard parameter estimates with standard error (SE) and derived estimates with SE, including salmon escapement (Rawding and Hillson 2003).

To estimate the adult fall Chinook salmon population, we counted live and dead Chinook salmon twice a week, marked carcasses by removing the caudal fin, and kept an ongoing count of the previously sampled fish. This data was provided to PSMFC, who calculated the population estimates using an area under the curve (AUC) analysis (Ames 1984).

We collected biological data from Chinook and chum salmon carcasses to profile stocks for age composition, average size at return, and sex ratios. Scales from the carcasses were removed and analyzed to determine age. To help determine stock origin of salmon found in the study area, we inspected fall Chinook salmon carcasses for fin clips. The snouts of fish with adipose fin clips were removed and kept for CWT recovery and analysis at the ODFW laboratory in Clackamas. We referenced the Regional Mark Processing Center (RMPC) for tag recovery information from our samples. The RMPC incorporated the total number of tags recovered and the sampling methods used to recover each tag into an estimate of smolt to adult survival for the tag group.

### Juvenile Salmon Surveys

We began the 2006 juvenile sampling season on 31 January and completed sampling on 30 June. We surveyed for juvenile fish near Ives and Pierce islands in and around areas where adult spawning occurred (Figure 3). We utilized two types of beach seines to capture juvenile fish.

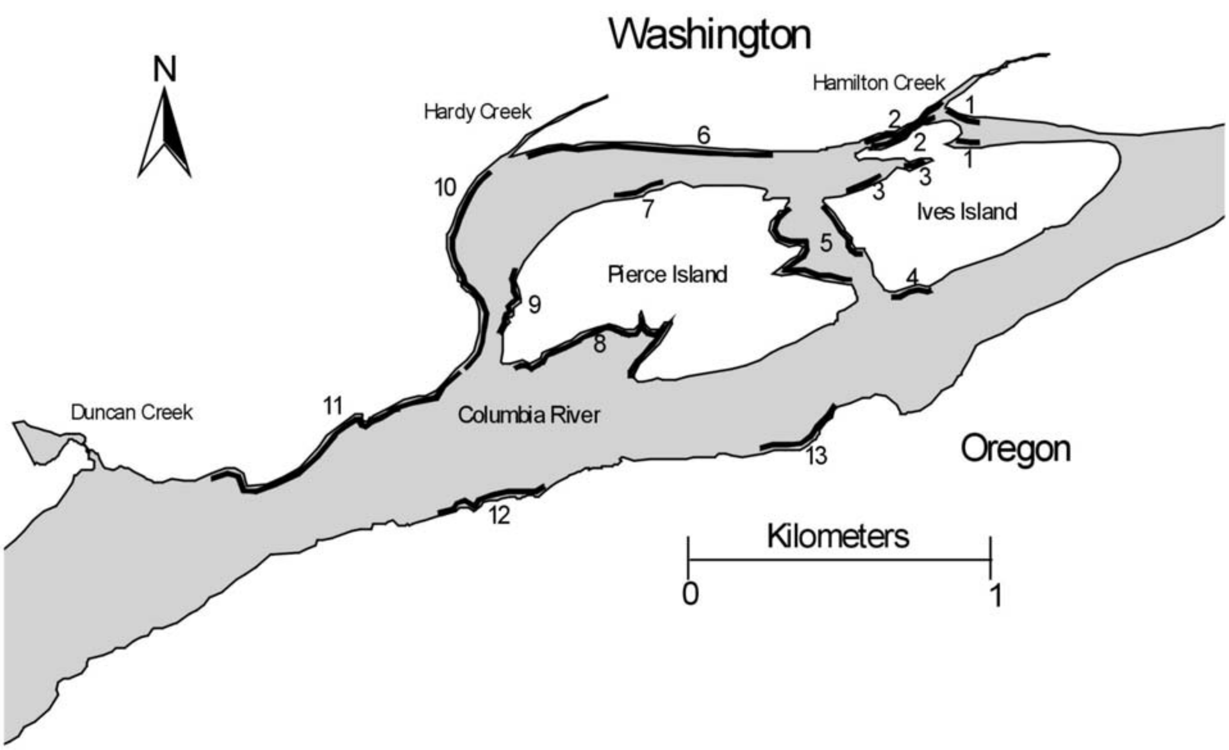


FIGURE 3. Survey sites for juvenile fall Chinook and chum salmon below Bonneville Dam, 2006.

We fished shoreline areas with either 1.2-m deep stick seines (3.2 mm mesh) in lengths of 5.5 and 8.5 m, or a 30.5 m beach seine (1.6 mm mesh). In-water fishing time was approximately five minutes. We used the 30.5 m beach seine in sections of the river that were free of snags and large obstructions, and had moderate flow velocities; stick seines were an effective alternative in areas where it was difficult to deploy the beach seine. We calculated the catch per unit effort (CPUE) for each net type, using one net set as the unit of effort. We also calculated a relative density index (DI) using the formula $1/z^{0.5}$, where z is the proportion of zero-catch sets (Bannerot and Austin 1983; Zimmerman and Parker 1995).

We placed all salmonids collected into 5-gallon buckets containing the anesthetic MS-222. Once anesthetized, they were identified to species, measured (fork length; mm) and examined for fin clips. We also recorded start and end times for each sampling day, the number of sets fished, water temperature (°C), and Bonneville Dam discharge (kcfs; Fish Passage Center 2005). Processing time was 5-10 minutes per set. After the data was collected, we released the fish at the site of capture, unless they were Chinook salmon retained for CWT marking. Two days per week we seined only to collect fall Chinook salmon to tag; these fish were sorted by size but not measured.

We compared juvenile chum and Chinook salmon fork lengths among years (2003 – 2006) using a Kruskal-Wallis analysis of variance (ANOVA) on ranks test. We also compared beach and stick seine CPUE for chum and fall Chinook salmon (2004 – 2006) using the Kruskal-Wallis ANOVA. All subsequent pairwise comparisons were analyzed using Dunn's test.

Salmon eggs and fry require a specific cumulative temperature for hatching and emergence. To help determine when to begin sampling for juvenile salmon we used temperature units (TU) calculated as Celsius degree-days to estimate hatching and emergence dates. The dates were calculated in TU by summing the daily average temperature in °C from the initiation of spawning to hatching of eggs and the beginning and ending of emergence. Chum salmon are known to hatch between 400 and 600 °C TU and complete yolk absorption between 700 and 1000 °C TU (Salo 1991). For the Ives/Pierce population we estimate chum salmon hatching to occur at 600 °C TU (Hillson 2004) and emergence to occur at 825 °C TU (Hillson 2003). Chinook salmon hatch between 500 and 540 °C TU and emerge between 880 and 955 °C TU when raised at constant temperatures (Murray and McPhail 1988). We used 500 °C TU to estimate Chinook salmon hatching and 1,000 °C TU to estimate their emergence (Becker et al. 1982).

To obtain the most accurate estimate for both species, we used readings from four temperature gauges, one above Hamilton Channel and three within the channel area (Figure 4). Gauge 1 (G1) is located at the head of the Hamilton Channel area, near the east end of Ives Island. This gauge records temperatures within the water column and is representative of the mainstem Columbia River. For an accurate record of temperatures within the Hamilton Channel, we used three additional gauges. Two of the three (T1LB and T2LB) are located on the south bank of the channel. The third Hamilton Channel gauge (T2MC) is located mid-channel near the upper south bank gauge. These three Hamilton Channel gauges are maintained by Pacific Northwest National Laboratories (PNNL), and G1 is maintained by the USFWS. The three Hamilton Channel gauge sites each have two temperature sensors; a bed sensor located about 50

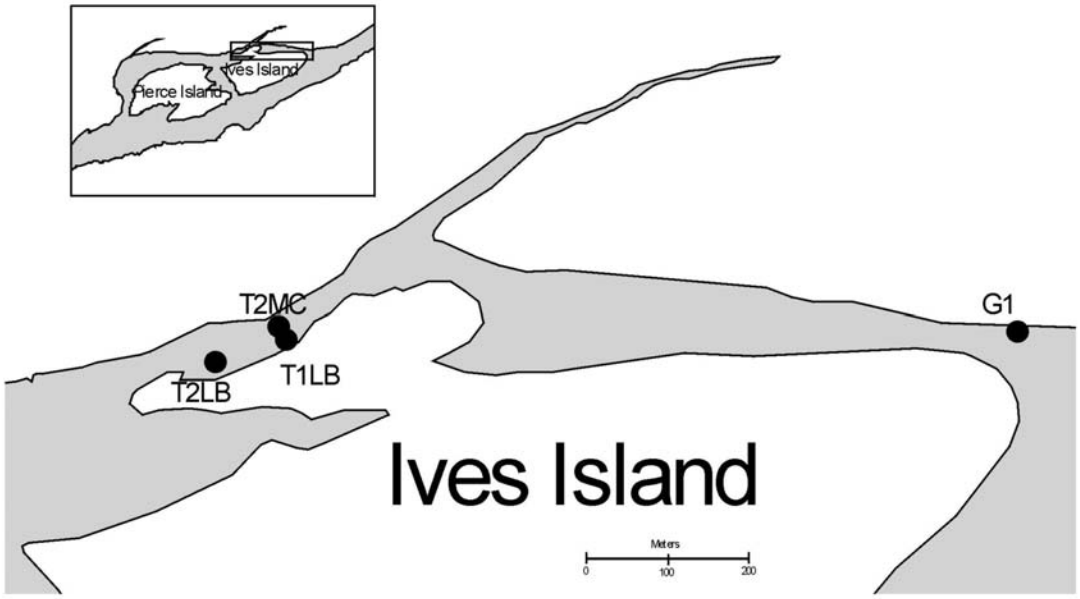


FIGURE 4. Location of temperature gauges (G1, T1LB, T2LB, and T2MC) at Ives Island.

cm below the river bed to measure subsurface temperatures, and a river water sensor to record temperatures from the water column. We combined the temperatures from the bed and river water sensors in formulas created by PNNL (unpublished data) to calculate a redd pocket temperature for each location. We used these temperatures and those from Gauge 1 as the basis for our emergence estimates.

To ensure that we began sampling as close as possible to the beginning of juvenile emergence, we estimated fry development and emergence timing using temperature unit data from the gauges described above. We chose estimates to represent emergence dates based on how closely they matched our juvenile catch data from the current year.

We collected some non-target juvenile fall Chinook salmon that migrated into our survey areas from other upriver locations. Our criteria for differentiating unmarked, local, native Chinook salmon from unmarked hatchery releases and upriver natural production was based on fork length (FL). Through March, we assumed unmarked Chinook salmon < 60 mm FL were naturally produced fall stock from localized areas around Ives and Pierce islands. Until the end of March, larger fish were assumed to be spring-stock fish from upriver. In the Columbia River system, hatcheries release Chinook salmon at sizes > 60 mm FL, and wild Chinook salmon do not begin migrating until they are larger than 60 mm FL (L. Basham, Fish Passage Center, personal communication).

To estimate the juvenile to adult survival rate for wild fall Chinook salmon we adipose fin-marked and applied a CWT to a portion of the catch. We tagged fish during April, May and June when local, native Chinook salmon began reaching an acceptable minimum tagging size of 47 mm FL (Norman 1987). To avoid tagging fish that may have migrated in from outside our study area, we terminated our tagging operation when fin-marked fish of comparable size to the local population (>75 mm FL) began to appear in the catch.

We held fish to be tagged in a net pen after each seining day (Monday – Thursday). On Friday of each week we tagged all fish collected during that week. Fish were transported to the tagging site, anesthetized with MS-222, measured to the nearest mm, sorted by fork length, fin clipped (adipose fin) and tagged with a standard-length CWT. After tagging, we checked each fish with a metal detector to confirm tag presence, and at the beginning of each tagging day, we sacrificed one fish to ensure proper CWT placement. Fish were then placed into a recovery tank for approximately 30 minutes prior to their transfer to a liberation point downstream of the study area, where they were released at the end of each tagging day. We held approximately 5% of all tagged fish over the weekend (minimum time 69 hours) to check short-term tag retention and estimate short-term mortality.

# RESULTS

## Adult Chum Salmon

The first returning chum salmon was observed 28 October 2005. The majority of chum salmon redds we observed were below the mouth of Hamilton Creek (Figure 5). We also observed spawning chum salmon in the channel between Ives and Pierce islands (section 5), below Woodward Creek (section 10), and on the Oregon side of the Columbia River below McCord Creek (section 13). Based on spawning ground surveys, initiation of spawning below Bonneville Dam for chum salmon was 15 November (Figure 6). Peak spawning for chum salmon was 2 December. We observed 75 redds, 122 live adults and 62 dead adults at peak spawning. Our peak redd count, 101 redds, occurred on 6 December. Spawning ended on approximately 22 December 2005. One chum salmon carcass was observed during our last spawning ground survey.

In 2005, we estimated that 229 ± 48 chum salmon returned to the spawning areas in the Ives and Pierce Island complex (Figure 7). The population was not significantly smaller than our estimated spawning population in 2004; however, both 2004 and 2005 spawning populations were significantly smaller than the estimated 2003 population (Figure 6).

We analyzed biological information collected from 129 chum salmon carcasses recovered in our surveys. The majority of the fish were female (63.6%), and age 4 fish were the dominant age class for both males and females (74.5% combined) (Table 1). Male chum salmon tended to be larger, but females exhibited a greater range of sizes.

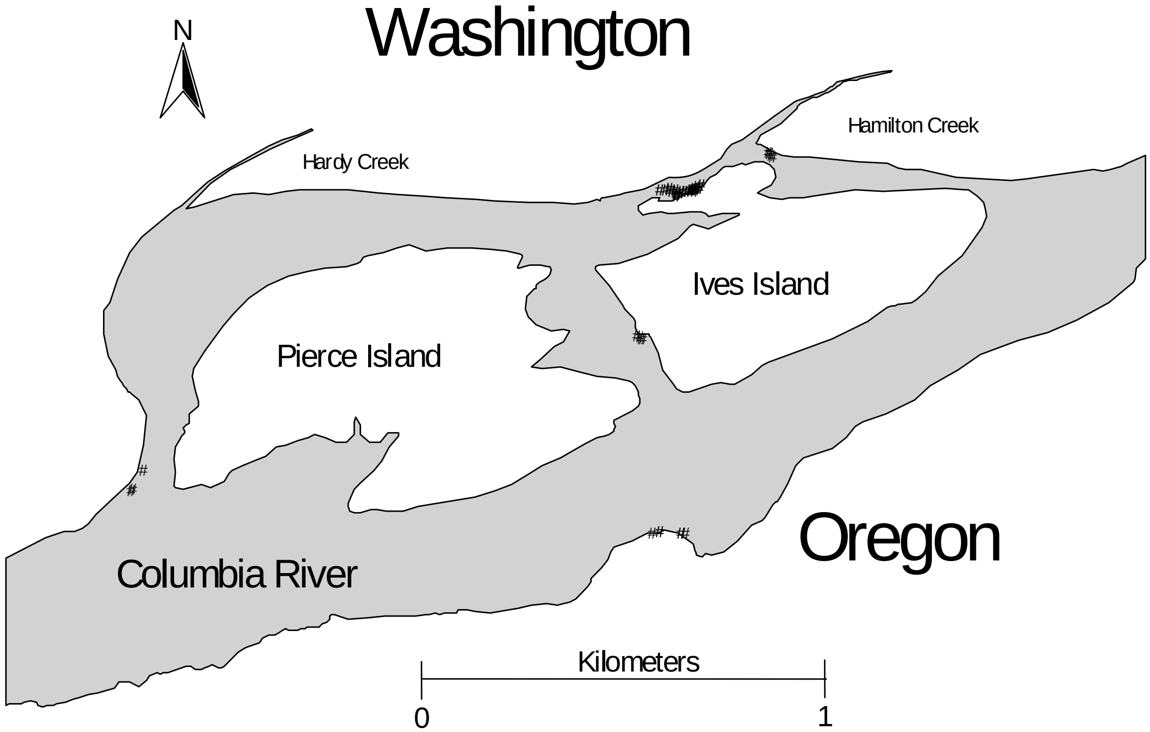


FIGURE 5. Locations of chum salmon redds below Bonneville Dam, 2005.

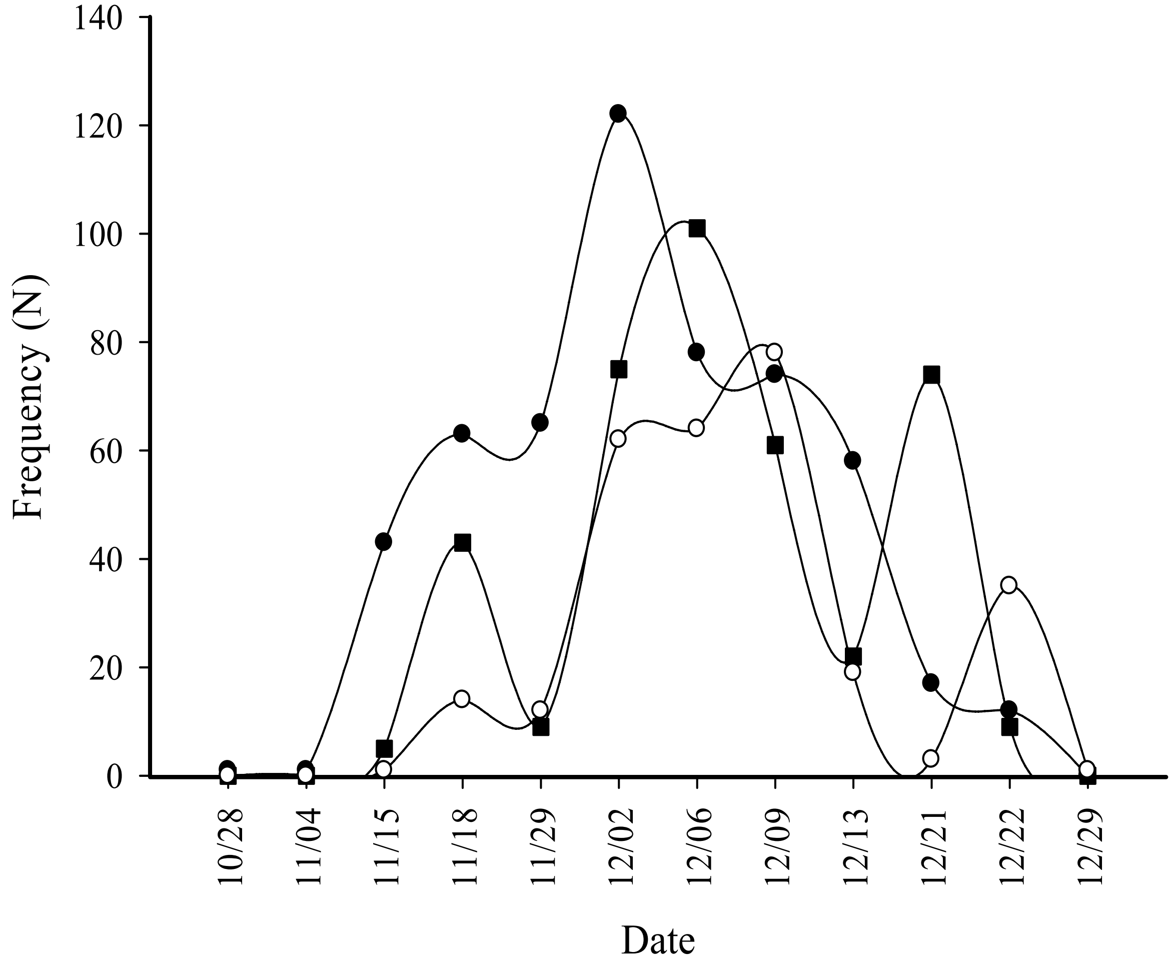


FIGURE 6. Number of chum salmon redds (shaded squares), and live (shaded circles), and dead (open circles) chum salmon observed below Bonneville Dam, 2005.

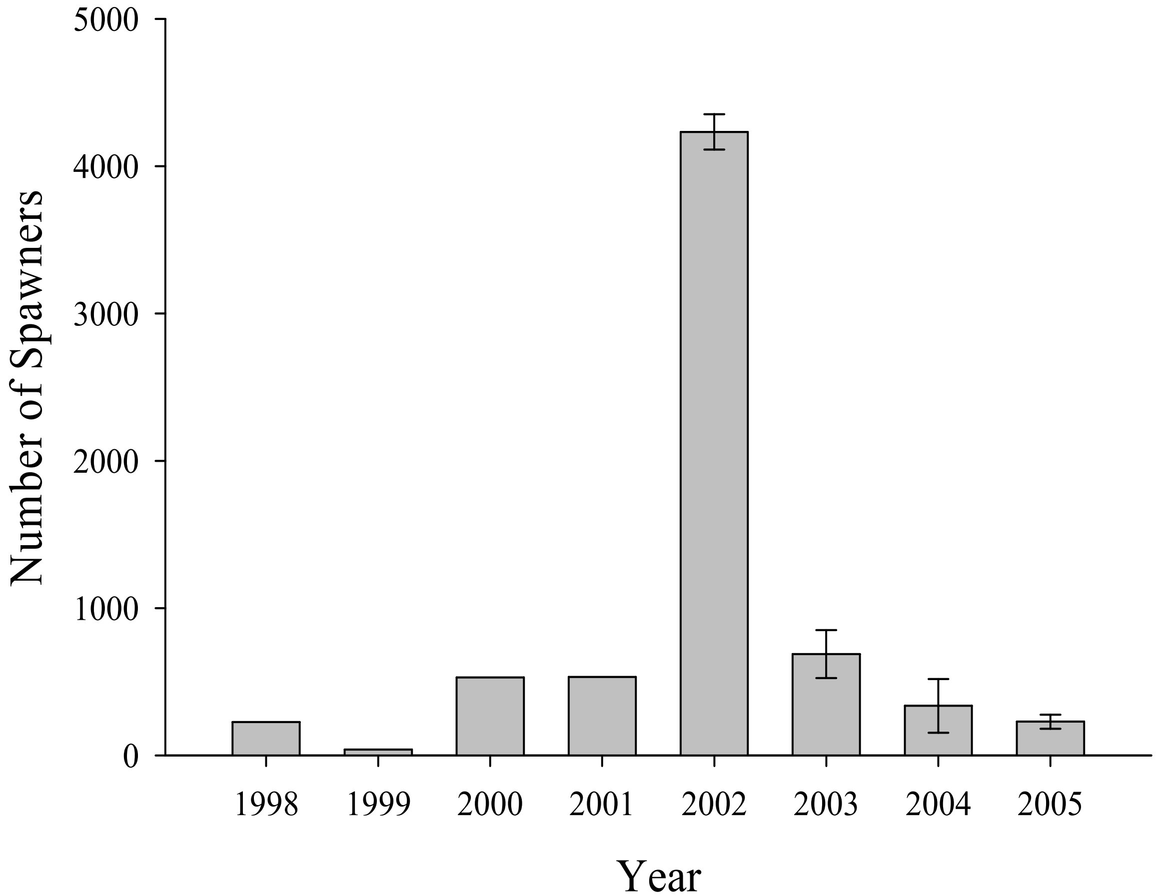


FIGURE 7. Population estimates for chum salmon in the Ives/Pierce island area below Bonneville Dam, 1998 to 2005. Estimates are shown with 95% confidence limits where available.

TABLE 1. Estimated age composition, sex composition, and fork length of chum salmon that spawned below Bonneville Dam, 2005.

| Age | Number in Sample | | Percent in Sample (%) | | Mean Fork Length (cm) | | Fork Length Range (cm) | |
|---|---|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females | Males | Females |
| 3 | 8 | 12 | 6.2 | 9.3 | 74 | 66 | 69-84 | 60-74 |
| 4 | 34 | 62 | 26.4 | 48.1 | 83 | 74 | 73-89 | 67-90 |
| 5 | 5 | 8 | 3.9 | 6.2 | 81 | 76 | 78-85 | 63-80 |
| Total | 47 | 82 | 36.4 | 63.6 | 81 | 73 | 69-89 | 60-90 |

## Adult Fall Chinook Salmon

We conducted our first fall Chinook salmon spawning ground surveys on 4 October 2005 and our last on 29 December; completing 21 surveys in the Ives/Pierce Island area. Surveys were cancelled twice due to unsafe weather conditions. Initiation of spawning below Bonneville Dam for bright stock fall Chinook salmon was 7 October, and peak spawning was 15 November. We observed 319 redds and 505 live adults during fall Chinook salmon peak spawning. Spawning ended by 22 December (Figure 8).

In 2005, 1,275 fall Chinook salmon were estimated to have returned to the spawning areas around Ives and Pierce islands (Figure 9). We observed fall Chinook salmon spawning in deeper main channels where carcasses could not be recovered, suggesting that the actual number of spawners may have been higher. Relative to the first four years of the study, population estimates were considerably higher during 2002-2005.

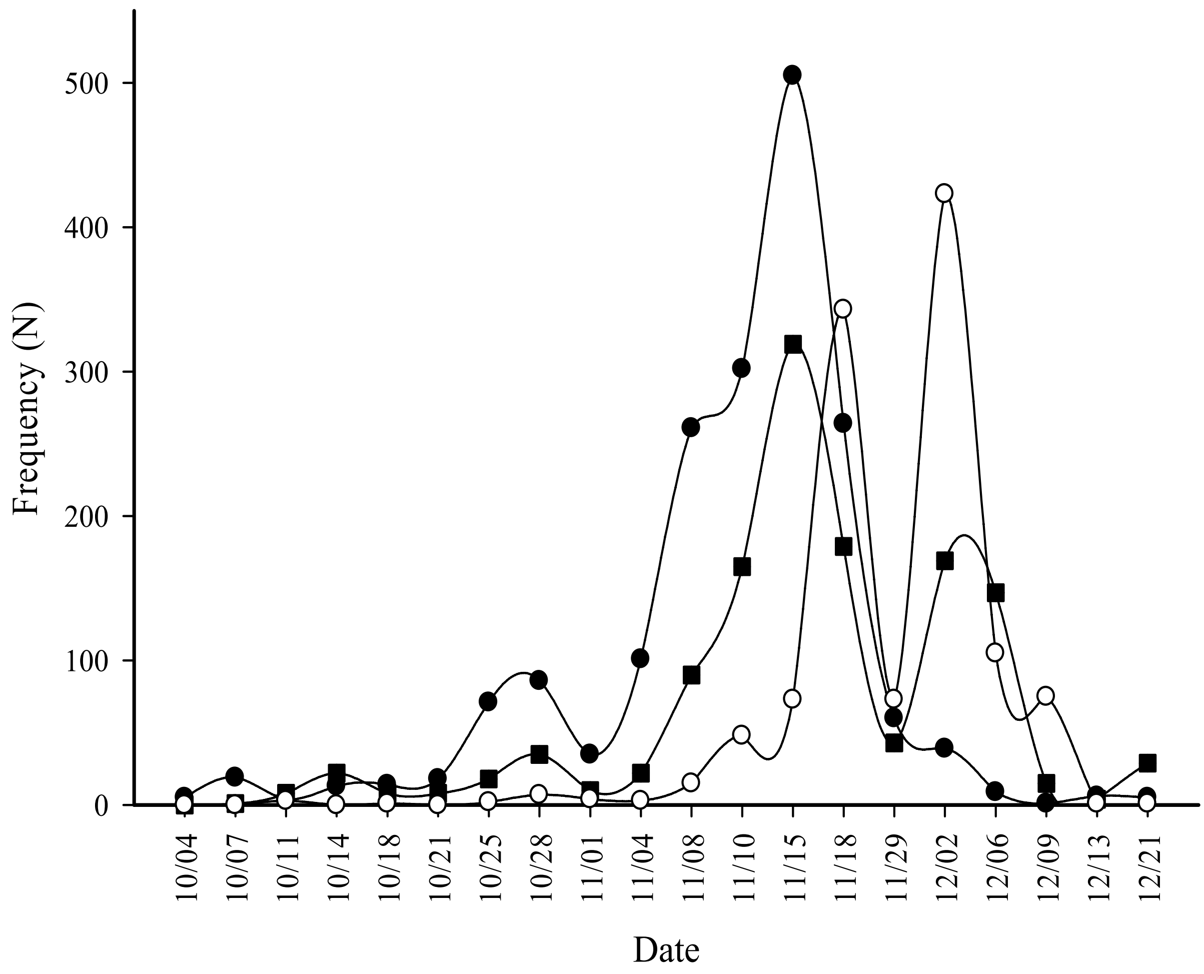


FIGURE 8. Number of redds (shaded squares), live (shaded circles) and dead (open circles) fall Chinook salmon observed below Bonneville Dam, 2005.

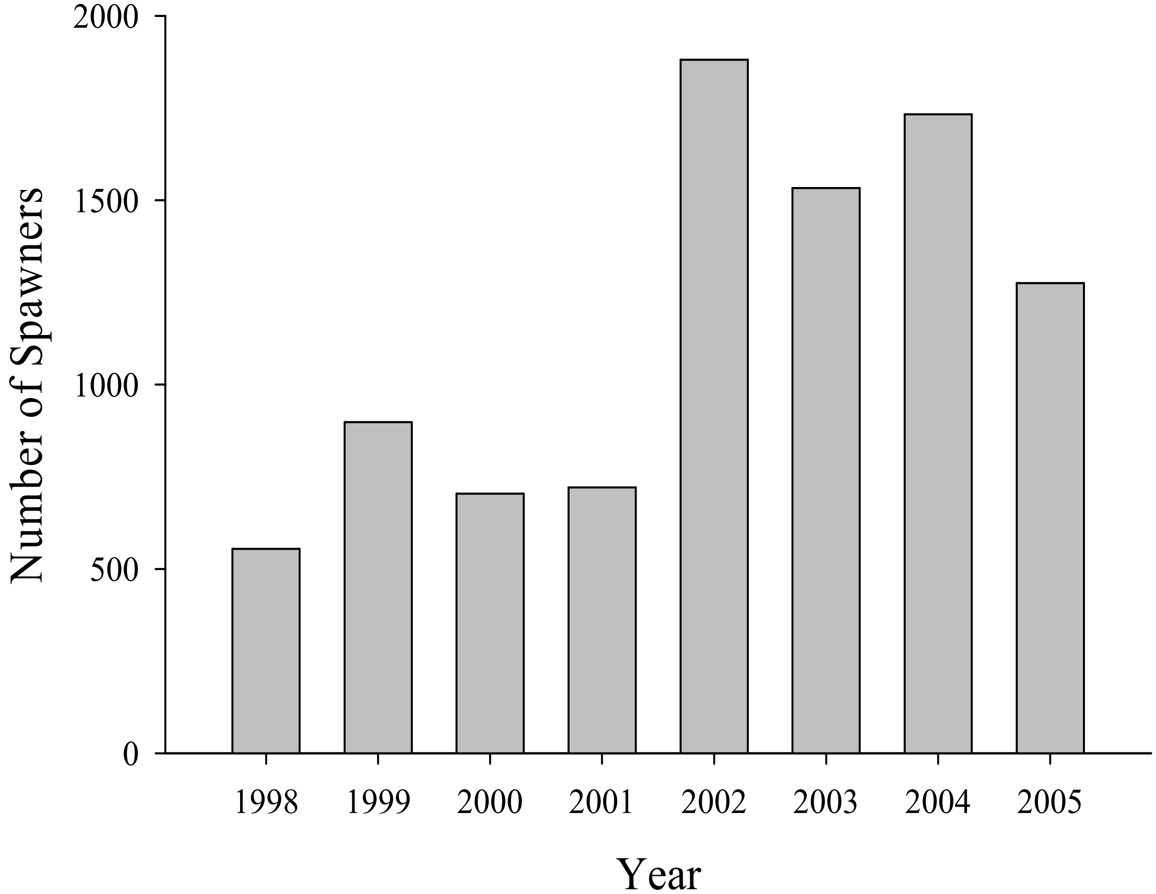


FIGURE 9. Population estimates for fall Chinook salmon in the Ives/Pierce island area below Bonneville Dam, 1998 - 2005.

Chinook salmon redds were more evenly distributed than chum salmon redds (Figure 10). We found the majority of fall Chinook salmon redds above and below the mouth of Hamilton Creek (Section 2), between Ives and Pierce islands (Section 5), and in the main channel along the south side of Pierce Island (Section 8). A few Chinook salmon also spawned at the upriver tip of Ives Island (Section 1).

We analyzed biological information from 295 Chinook salmon carcasses recovered in our surveys. Females slightly outnumbered males, and most fish were either age 3 (28.8%) or age 4 (57.3%) (Table 2). Male and female fish were of similar size, but fork length varied considerably more among males (range 67 mm) among than females (range 37 mm).

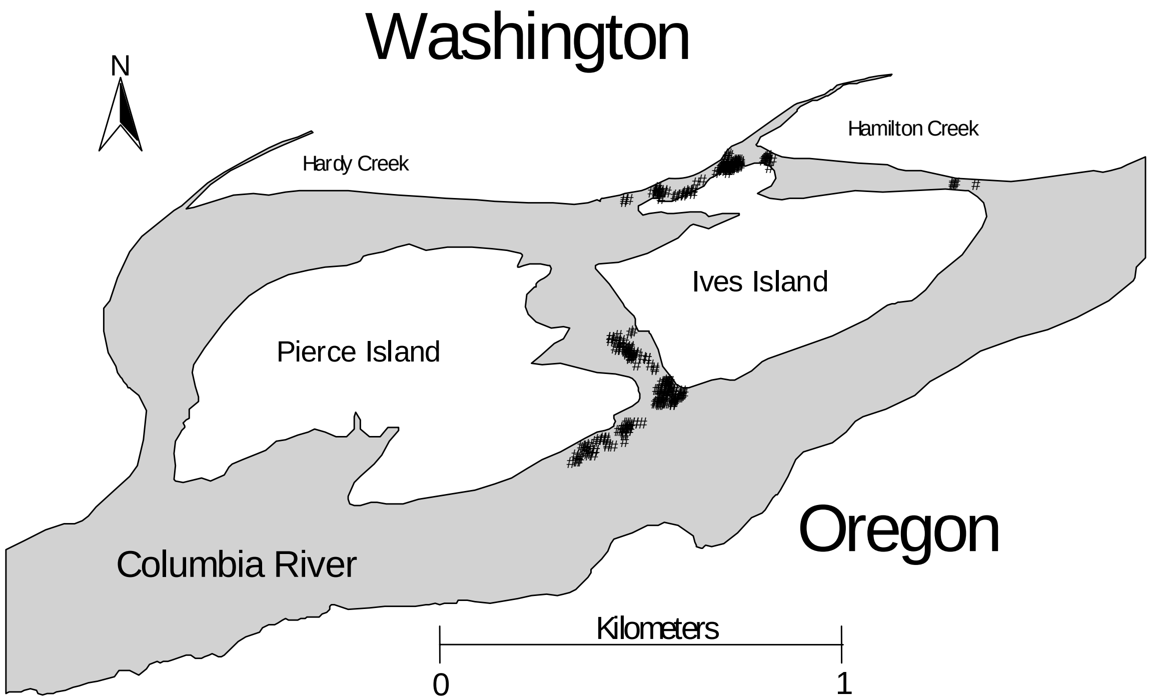


FIGURE 10. Locations of fall Chinook salmon redds below Bonneville Dam, 2005.

TABLE 2. Estimated age composition, sex composition, and fork length of bright fall Chinook salmon that spawned Below Bonneville Dam, 2005.

| Age | Number in Sample | | Percent in Sample (%) | | Mean Fork Length (cm) | | Fork Length Range (cm) | |
|---|---|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females | Males | Females |
| 2 | 6 | 0 | 2.0 | 0.0 | 52 | -- | 46-61 | -- |
| 3 | 53 | 32 | 18.0 | 10.9 | 73 | 73 | 60-86 | 61-80 |
| 4 | 66 | 103 | 22.4 | 34.9 | 88 | 83 | 79-107 | 67-95 |
| 5 | 14 | 21 | 4.7 | 7.1 | 101 | 91 | 89-113 | 81-98 |
| 6 | -- | -- | -- | -- | -- | -- | -- | -- |
| Total | 139 | 156 | 47.1 | 52.9 | 82 | 82 | 46-113 | 61-98 |

Seven fall Chinook salmon carcasses we recovered on the spawning grounds had adipose fin clips, three of which contained coded-wire tags. One was an age 4 female fall Chinook salmon tagged and released from Bonneville Hatchery as a subyearling. The other two fish were age 5 female Ives Island fall Chinook salmon that we tagged in 2001 (2000 brood year). These were the first fish marked by our project to be recovered during the mainstem spawning ground surveys. Seven other tagged fish from the same brood year were recovered in commercial and sport fisheries in 2005. Three of these were harvested by commercial ocean fisheries, one in Alaska and two in Canada. Two others were caught in the Columbia River commercial gillnet fishery and the remaining two were harvested in the Columbia River sport fishery. All nine fish were reported in the RMPC database. The RMPC estimated that brood year 2000 had a survival rate of 0.23%.

### Juvenile Chum Salmon

We estimated that juvenile chum salmon emergence began on 13 February, using the T2LB gauge. We estimated that the peak and end of emergence occurred on 5 April and 27 April, using the T2MC gauge.

In 2006 we caught the first chum salmon fry on 14 February and the last one on 11 May; however, the majority of the chum salmon were caught by the end of April. Both CPUE and DIs indicated that we captured far fewer juvenile chum salmon than in most other years. In 2006 we collected 302 juvenile chum salmon, the third lowest catch in eight years of sampling. The average annual catch over the eight years of the study was 1,692 ± 648. While we can compare total catch numbers from all years, CPUE and DI calculations are only available from 2004 to the present. The mean CPUE for beach and stick seines during the 2006 field season was 0.9 ± 0.3 and 1.5 ± 0.7. The CPUE for the beach seine peaked at 11.0 in 2006, while the CPUE for stick seine peaked at 20.3 (Figure 11). The beach seine CPUE in 2006 was significantly different than 2004 and 2005 ($P < 0.05$). However, the 2004 and 2005 beach seine CPUEs were not significantly different. Stick seine CPUE was not significantly different among years.

We collected chum salmon in 10 of 13 (77%) sampling areas in 2006 (all sections except 4, 7, and 12). Section 1 had the highest beach seine CPUE (Table 3) and produced the most beach seine caught juvenile chum salmon (61). Section 3 had the highest stick seine CPUE but produced the fourth highest stick seine catch of juvenile chum salmon (16), while section 6 had the second highest stick seine CPUE and produced the highest total catch (91) (Table 3). Density indices were highest in section 3 (2.2) and section 5 (no zero catches).

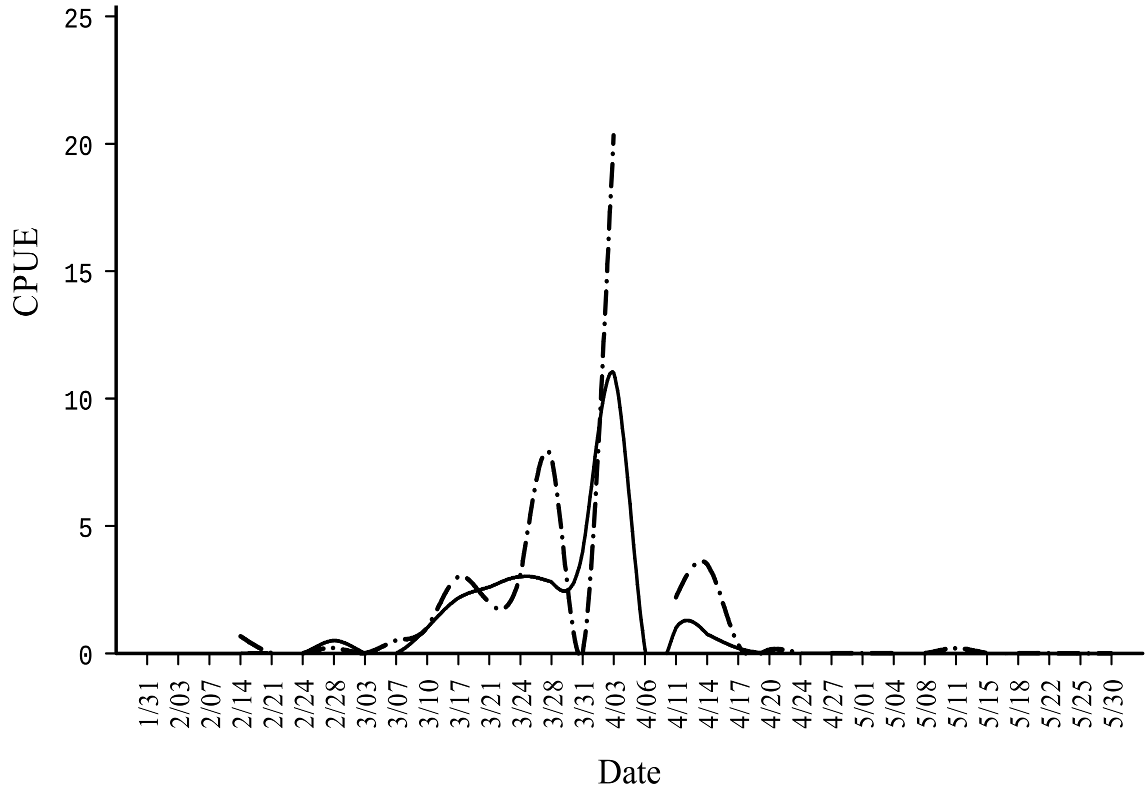


FIGURE 11. Catch per unit effort of juvenile chum salmon caught with beach (solid line) and stick (dashed line) seines below Bonneville Dam, January - May 2006.

TABLE 3. Beach and stick seine CPUE and density indices of chum salmon by sampling area, 2006. ∞ = no zero-catch sets.

| Area | CPUE | | Density Index | |
|---|---|---|---|---|
| | Beach | Stick | Beach | Stick |
| 1 | 8.7 | 0.0 | 1.3 | 1.0 |
| 2 | 1.8 | 1.6 | 1.4 | 1.2 |
| 3 | 0.2 | 3.2 | 1.1 | 2.2 |
| 4 | -- | 0.0 | -- | 1.0 |
| 5 | 0.3 | 1.0 | 1.1 | ∞ |
| 6 | 1.1 | 2.5 | 1.3 | 1.2 |
| 7 | 0.0 | -- | 1.0 | -- |
| 8 | 1.5 | 0.8 | 1.2 | 1.4 |
| 9 | 0.5 | 0.0 | 1.4 | 1.0 |
| 10 | 0.2 | -- | 1.1 | -- |
| 11 | 0.3 | 0.0 | 1.1 | 1.0 |
| 12 | 0.0 | -- | 1.0 | -- |
| 13 | -- | 1.3 | -- | 1.5 |
| Total | 1.1 | 1.6 | 1.1 | 1.2 |

Newly emerged fish (< 40 mm) were present in the catch February through April; however, by March fish > 40 mm FL comprised the majority of the catch (Figure 12). Most of the juvenile chum salmon were 40-49 mm FL but we did collect a few larger fish in the 50-70 mm FL range. The juvenile chum salmon catch peaked on 3 April (Appendix Table 1).

The average FL for juvenile chum salmon in 2006 was 42 ± 0 mm. Median fork lengths were significantly different among years (2003-2006) (H = 477.832, df = 3, $P < 0.001$). All pairwise comparisons were significantly different ($P < 0.05$) with the exception of 2005 vs. 2006.

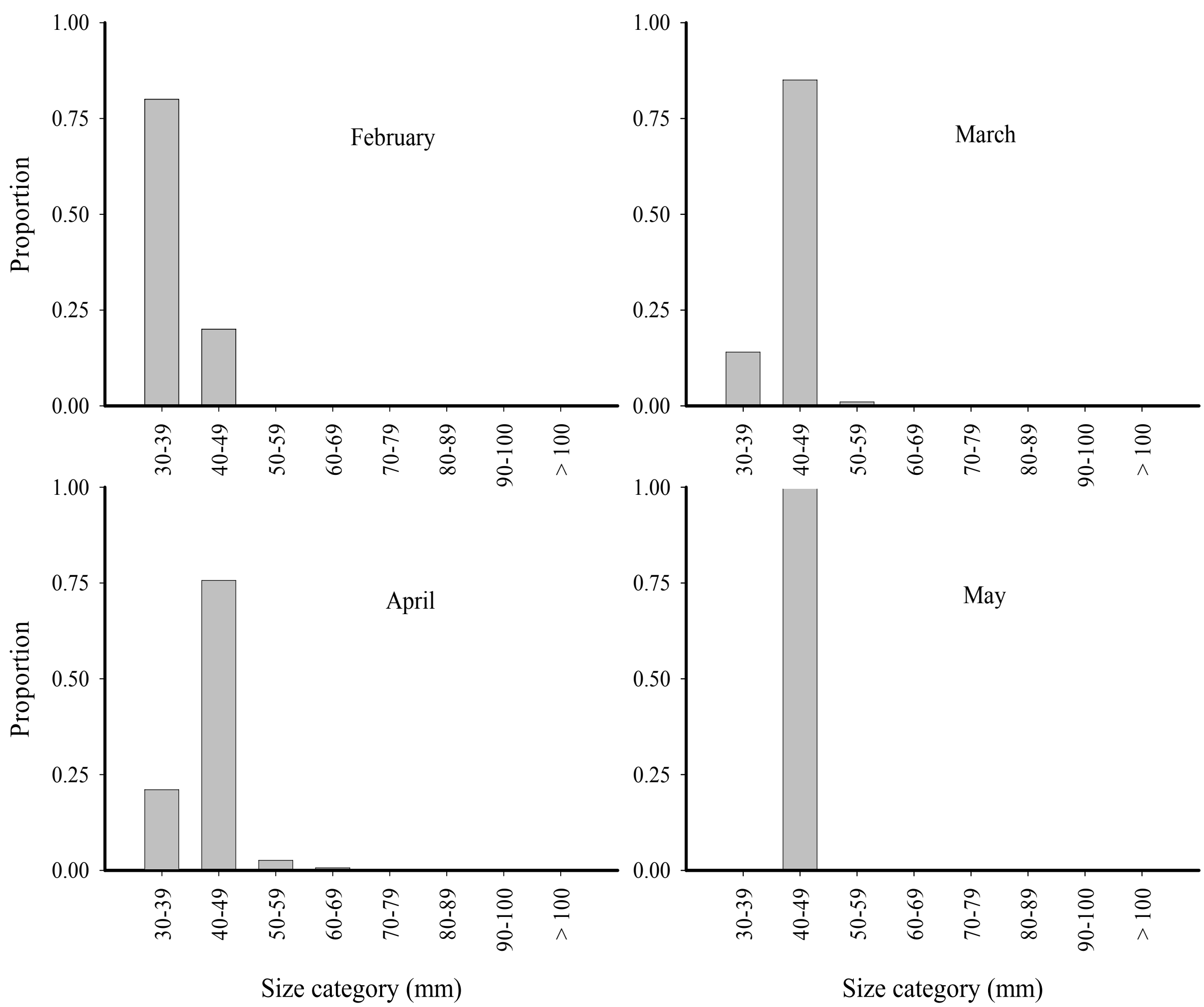


FIGURE 12. Monthly juvenile chum salmon catch by size category (fork length) below Bonneville Dam, 2006 (n=2, 144, 152, and 1 for February, March, April, and May, respectively).

## Juvenile Fall Chinook Salmon

We estimated that juvenile fall Chinook salmon first emerged on 24 December 2005 using the T1LB gauge. We estimated that peak emergence occurred 10 May and end of emergence occurred 28 May, both estimated using gaugeG1.

We handled 1,040 hatchery and 7,463 wild juvenile fall Chinook salmon. Of the 8,503 wild and hatchery fish collected, 37% (n = 3,116) were from our index sets; and all further descriptions of catch are based on these fish. The 1,040 hatchery fish we caught included 628 that were adipose clipped and 36 that were coded-wire tagged. We did not sacrifice any of the hatchery tagged fish to read their tags.

The 2006 average CPUE for beach and stick seines were 8.7 ± 1.6 and 8.7 ± 1.7. Beach seine CPUE peaked at 52.0 and stick seine CPUE peaked at 50.5 (Figure 13). The CPUE varied among years for beach ($H = 21.229$, $df = 2$, $P < 0.001$) and stick seines ($H = 27.616$, $df = 2$, $P < 0.001$). The 2006 beach seine CPUE differed significantly from both 2004 CPUE and 2005 CPUE ($P < 0.05$). However, 2004 and 2005 beach seine CPUEs did not differ significantly. The 2006 stick seine CPUE also was significantly different than 2004 CPUE and 2005 stick seine CPUE ($P < 0.05$). As with beach seine CPUE, the 2004 and 2005 CPUEs for fall Chinook salmon were not significantly different.

We caught juvenile fall Chinook salmon in all of the sampling areas around Ives and Pierce Islands. Section 3 produced the highest beach seine catch of juvenile fall Chinook salmon (553) and had the highest beach seine CPUE (Table 4). Section 1 had the highest stick seine CPUE; section 6 had the second highest stick seine CPUE and produced the highest total catch of juvenile fall Chinook salmon (740) (Table 4). Density indices were highest in sections 2 and 12 (beach seine) and sections 1 and 5 (stick seine) (Table 4).

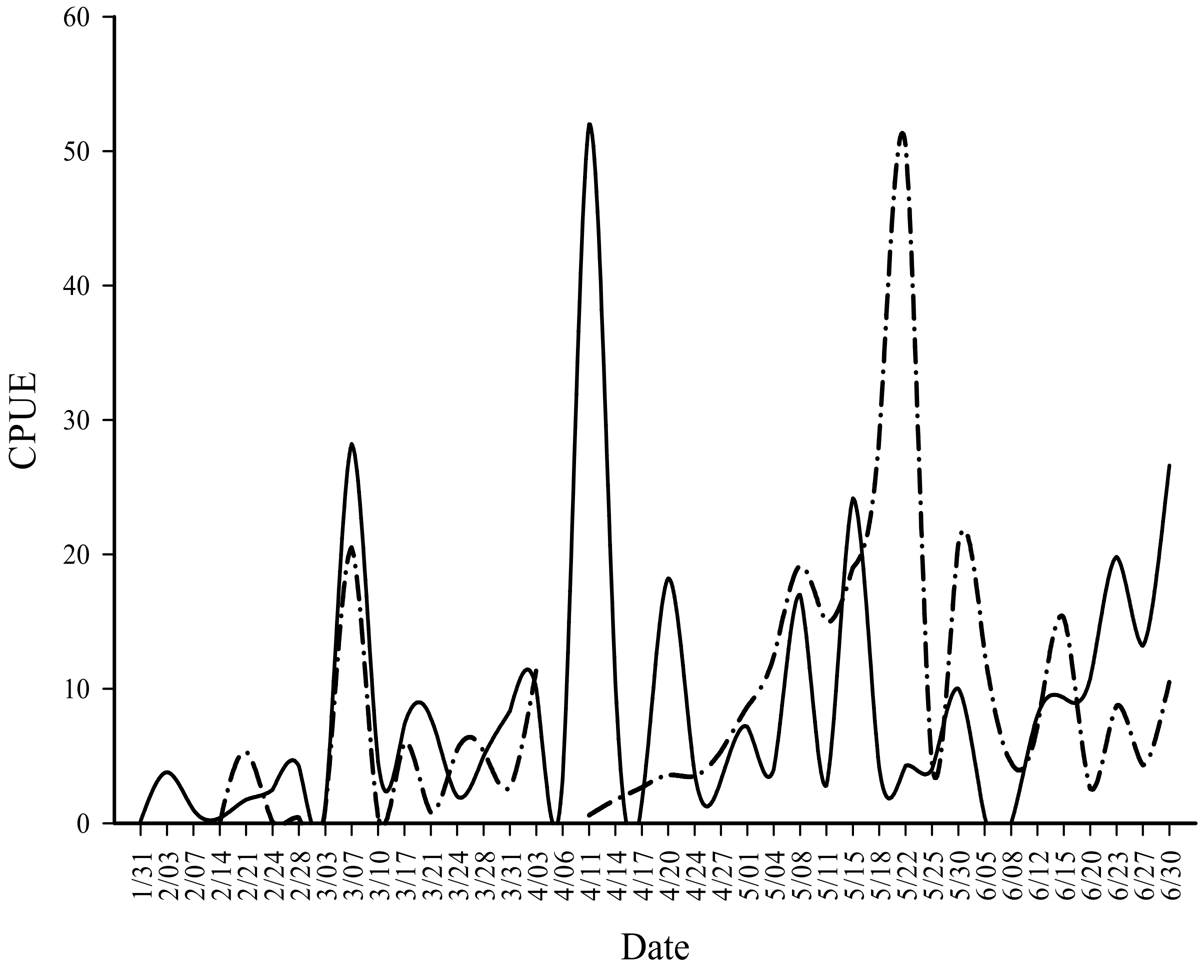


FIGURE 13. Catch per unit effort of juvenile fall Chinook salmon with beach (solid lines) and stick (dashed line) seines below Bonneville Dam, January - June 2006.

TABLE 4. Beach and stick seine CPUE and density indices for juvenile fall Chinook salmon by sampling area, 2006.

| Area | CPUE | | Density Index | |
|---|---|---|---|---|
| | Beach | Stick | Beach | Stick |
| 1 | 8.1 | 16.3 | 2.8 | 5.0 |
| 2 | 5.8 | 8.5 | 5.0 | 1.7 |
| 3 | 14.9 | 3.3 | 2.5 | 2.6 |
| 4 | -- | 3.1 | -- | 2.4 |
| 5 | 6.5 | 1.3 | 2.2 | 5.0 |
| 6 | 2.4 | 12.3 | 2.1 | 2.7 |
| 7 | 6.9 | -- | 1.7 | -- |
| 8 | 9.8 | 2.7 | 2.4 | 1.4 |
| 9 | 14.7 | 0.0 | 2.4 | 1.0 |
| 10 | 0.5 | -- | 1.2 | -- |
| 11 | 5.6 | 5.2 | 3.5 | 3.2 |
| 12 | 3.0 | -- | 5.0 | -- |
| 13 | -- | 4.1 | -- | 1.8 |
| Total | 8.8 | 8.3 | 2.2 | 2.2 |

Newly-emerged fish were present in the catch from the onset of sampling, 31 January, through 30 May. Fall Chinook salmon 40-49 mm dominated the catch during February, April, and May. In March 46% (n = 221) of the catch was composed of larger hatchery fish. By June the catch was more evenly distributed; none of the size categories comprised more than a third of the catch, which ranged from 40 mm to over 100-mm FL (Figure 14). The peak catches of wild juvenile fall Chinook salmon (< 60 mm) and of juvenile wild and hatchery fall Chinook salmon in all size categories (< 150 mm) both occurred on 30 May (Appendix Table 2). In June we collected approximately two-thirds of the total taggable-sized fish for the season.

The average FL of juvenile fall Chinook salmon was 57 ± 0 mm. There were significant between-year differences in the median fork length of fall Chinook salmon caught during 2003 – 2006 ($H = 1489.668$, $df = 3$, $P < 0.001$). All pairwise comparisons were significant ($P < 0.05$).

We adipose fin-marked and coded-wire tagged 3,923 juvenile fall Chinook salmon between April and June 2006 (Appendix Table 3). We released 3,905 live tagged fish; this was the second lowest total since 2002 (Figure 15). In all other years at least 10,000 smolts were tagged and released and in two years the number of smolts tagged exceeded 24,000. The holding times for tag retention and mortality samples ranged from 69 to 95 hours. Our tag retention rate was 99.4% and the mortality rate was 0.5% (Appendix Table 3).

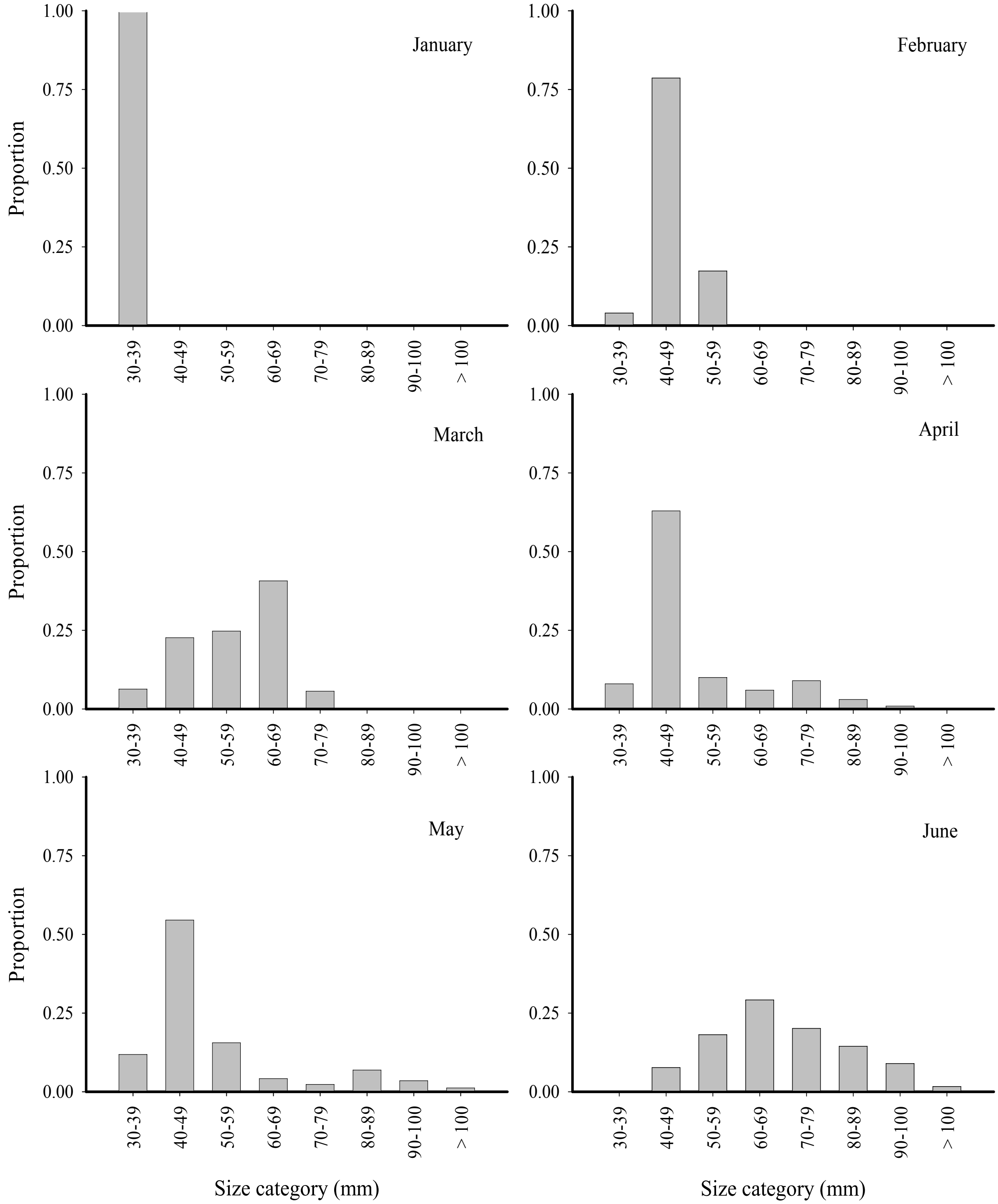


FIGURE 14. Monthly juvenile fall Chinook salmon catch by size category (fork length) below Bonneville Dam, 2006 (n=1, 75, 477, 577, 1201, 785 for January, February, March, April, May, June, respectively).

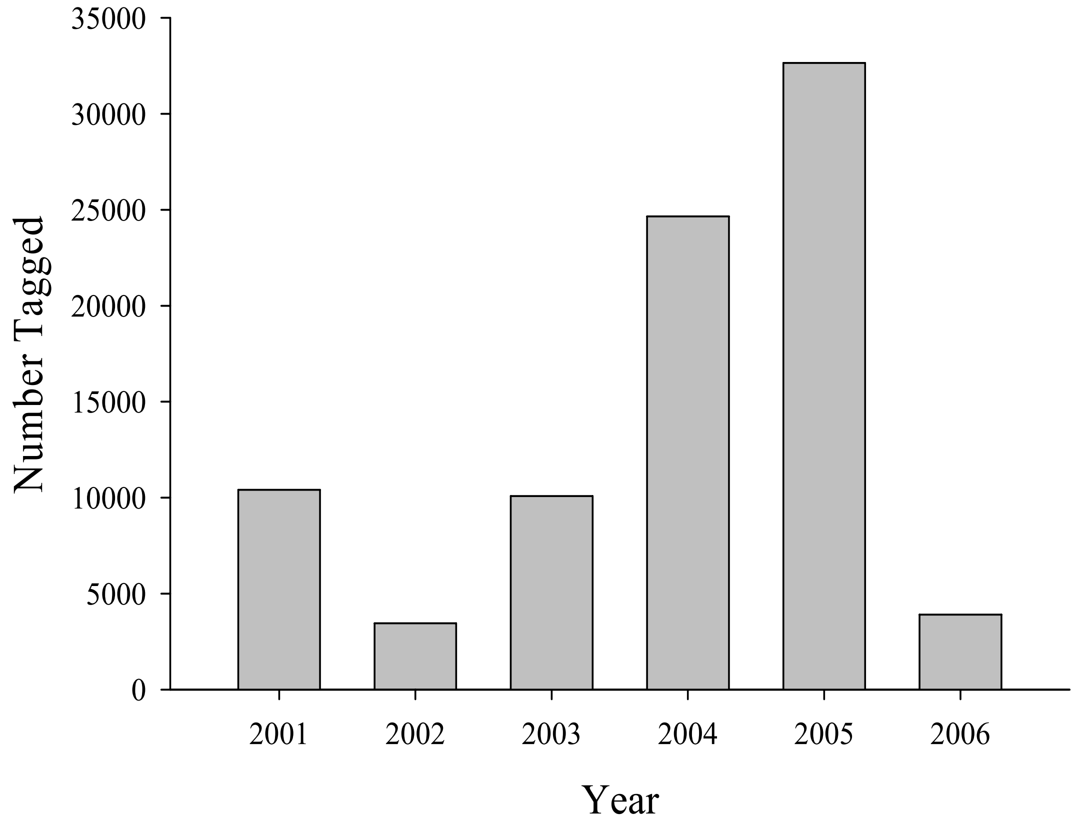


FIGURE 15. Number of juvenile fall Chinook salmon coded-wire tagged and fin marked in the Ives/Pierce island area, 2001-2006.

## DISCUSSION

### Adult Chum Salmon

Since the 1998, the onset of chum salmon spawning has been between 4 and 12 November. In 2005 chum salmon began spawning somewhat later, on 15 November. Peak spawning and end of spawning in 2005 were both within the historical ranges, 16 November to 3 December and 14 December to 3 January. The peak number of redds and live fish observed were similar to counts made in past years.

Chum salmon migration is related to water temperature; peak migration generally occurs between 7 and 11°C (Salo 1991). Chum salmon spawning around Ives and Pierce islands seem to follow this pattern of temperature-dependent migration and spawning. We have observed the first chum salmon between 28 October and 9 November each year, corresponding to mean daily river temperatures of about 11 - 15°C. The Ives/Pierce islands chum salmon population begin spawning when river temperatures are between 10° and 13°C, and spawning peaks at river temperatures between 7 and 12°C.

Our estimate of 229 spawning chum salmon in 2005 was slightly lower, but not significantly different from, the 2004 estimate of 336. However, both were significantly lower than 2003 and are the lowest estimates since 2000. This trend suggests these fish continue to be vulnerable to poor spawning, rearing and ocean conditions, and not much progress has been made towards recovery of the population.

When dealing with small and vulnerable populations, precisely estimating population size is important. Increasing the number of encounters in the recapture history would allow us to calculate a more precise population estimate because with enough second recaptures, we could run goodness-of-fit tests on the estimates (Rawding and Hillson 2003). In addition, we would know which specific fish had been recaptured and would not need to remove the fish from the population on the second encounter. Therefore, in 2006 we propose using individually numbered (or otherwise identifiable) carcass tags.

Additionally, releasing tagged carcasses above their original collection point would allow us to ensure complete mixing of tagged and non-tagged fish (Rawding and Hillson 2003). This would allow tagged carcasses to migrate into deep-water areas where fish cannot be retrieved; this should help provide a better estimate of the whole population. We intend to implement this methodology in 2006.

Relatively small numbers of chum salmon returned to spawn and most spawned in the side channel below the mouth of Hamilton Creek. This side channel is known to have areas of upwelling, which chum salmon prefer (Geist et al. 2002). Chum salmon did spawn in several other locations around the islands, however; it is not likely that the entire brood year could be destroyed by a single event.

Biological metrics of chum salmon that spawned in 2005 were generally similar to those from previous years. Age 4 fish comprised a large majority of the population in 2005. The Ives/Pierce islands population generally contains a high percentage of age 4 fish; however, the proportion in 2005 was higher than most other years. These fish were from the 2001 brood year, when an estimated 532 adults returned to spawn.

## Adult Fall Chinook Salmon

Fall Chinook salmon spawning has begun between 7 October and 29 October, peaked between 9 November and 24 November and ended between 23 November and early January. We did not sample in January 2006 and therefore could not determine the exact end date of the 2005 run. The onset, peak, and end spawn dates were all within ranges previously observed. The peak number of redds was the highest in the history of the project, and the peak live fish count was the second highest.

The 2005 population estimate was the fourth highest since the project's inception. Before 2002 the fall Chinook salmon spawning population was estimated to be fewer than 900 individuals each year. Since 2002 the estimates have all been greater than 1,200 spawners. The sudden and sustained increase in population sizes may be due to increased sampling pressure.

Fall 2002 was the first sampling season that focused entirely on the area below Bonneville Dam. In previous years, sampling effort was divided among areas below The Dalles, John Day and McNary Dams as well as the area below Bonneville Dam. WDFW and PSMFC have used the AUC method to estimate fall Chinook salmon spawner abundance size since the inception of the project. Unfortunately, the AUC program outputs a point estimate with no measure of variance. It is difficult to compare values among years without a measure of precision.

Fall Chinook salmon utilized three main areas to spawn in 2005, two of which are not used heavily by chum salmon. The third area, the channel near the mouth of Hamilton Creek, is used frequently by chum salmon. Chum salmon spawn preferentially in upwelling areas in Hamilton Channel while Chinook salmon preferentially spawn in downwelling areas, which have higher dissolved oxygen content than other spawning areas in Hamilton Channel (Geist et al. 2002). Chinook salmon are known to spawn in areas of upwelling at other spawning locations (Healey 1991; Geist 2000). In Hamilton Channel fall Chinook salmon may spawn in non-upwelling areas to avoid disturbance of their redds by later-spawning chum salmon (Geist et al 2002). We have documented overlapping spawning areas where Chinook salmon redds are often disturbed by chum salmon digging redds on top of them.

Biological characteristics describing the 2005 spawning population of fall Chinook salmon were similar to those we observed in previous years. As in all other years, age 4 fish composed the majority of the fish we sampled. Female fish were more numerous than males, as in six of the previous eight years.

Coded-wire tags recovered in 2005 indicated that fall Chinook salmon spawning in the mainstem Columbia River below Bonneville Dam in 2000 contributed to several fisheries, including commercial and recreational fisheries in Alaska, British Columbia, Oregon, and Washington. Two individuals survived to spawn again in their natal area. Because adults returning to the Ives/Pierce island area tend to be dominated by age 4 fish, it is odd that the only adults recovered to date from the 2000 brood year were age 5 fish. This was a relatively large CWT release group (10,402), and we recovered no age 4 fish in 2004.

## Juvenile Chum Salmon

Emergence estimates have ranged from 27 January to 29 March, from 25 February to 4 April, and from 31 March to 4 May (beginning, peak and end, respectively). This year's estimates for beginning and end of emergence, 13 February and 27 April, fall within these ranges. However, the 2005 peak emergence estimate, 5 April, lies slightly outside the historic range. Different gauges best predicted chum salmon emergence this year than in the past. The formulas that we calculate redd pocket temperatures with have only been in use for two years so we cannot yet determine whether one gauge is a better predictor of emergence than the others. In the future we plan to determine which gauge or gauges best estimate emergence for chum salmon by comparing our emergence estimates to actual catch data over several years.

Differences we observed in chum salmon catch rates among years were likely related to sampling efficiency. Low water years coincided with high catch rates, and high water years coincided with low catch rates. Our ability to sample in high water with seines was greatly hampered by shoreline vegetation. The significance of water fluctuations to juvenile chum salmon in the lower Columbia River is largely unknown. The additional complex habitat provided may increase survival by providing refuge and foraging benefits, or decrease survival through stranding or delayed migration.

Chum salmon catch rates and density indices varied among sampling sites. These areas may have had differing habitat (e.g., complexity, shade, cover) or water velocities that contributed to the variation we observed. Chum salmon respond to changes in current velocity by heading into the current until they cannot maintain their position, and during migration they are attracted to shaded areas (Salo 1991). Beach seine catch rates were highest in section 1; stick seine catch rates were highest in sections 3 and 6. All three of these sections are located in the side channel between Ives and Pierce Islands and the Washington shore, and appeared to be more protected than other sections in the main channel. During 2006 these areas had vegetation large enough to provide shelter but small enough that sampling was not impaired. We acknowledge our observations are limited and somewhat outside of our scope of work (and likely biased by our sampling methods). However, assessments of juvenile chum salmon habitat preferences may be useful in recovery efforts.

Our chum salmon catch was comprised mostly of fish less than 50-mm FL. Chum salmon fry begin their migration very soon after emerging; they spend very little time in fresh water. However, the median size of chum salmon fry varied significantly among years in our study area. Since fish from low water years have been found to be in better condition (Salo 1991), chum salmon fry might have larger median sizes during low water years. We plan to further investigate the potential relationship between flow levels and juvenile chum salmon size.

The juvenile chum salmon rearing around Ives and Pierce Islands are likely a mixture of natural production from Hamilton and Hardy Creeks and the mainstem Columbia. Chum salmon spawn in both tributaries as well as portions of the mainstem near tributary mouths. Some dye-marking is done in Columbia River tributaries but the fry are not 100% marked. We caught only one dye-marked juvenile chum salmon in 2006. There is some interest in quantifying the production of the mainstem spawners. We cannot determine the proportion of chum salmon juveniles we collected that were spawned in the mainstem because there is no estimate of the number of fry emigrating from Hardy and Hamilton creeks, and only a small proportion of these are marked. Some juveniles are marked by USFWS in Hamilton Springs and are used to generate a population estimate. However, there is no population estimate for Hamilton Creek. The cooperators hope to better quantify the chum salmon production in the tributaries and the mainstem Columbia River in the future.

### Juvenile Fall Chinook Salmon

Emergence timing estimates for 2006 were all outside the range of other years of this study. Fall Chinook salmon emergence has begun as early as 6 January and as late as 5 April; peak emergence has varied from 12 March to 6 May and emergence has ended anywhere from 28 April to 27 May. This year emergence began 24 December 2005. Peak and end emergence, estimated as 10 May and 28 May, were both later than previous years. There was a colder than normal period during the winter that may have caused the delayed emergence of progeny from fish that spawned late in the season.

The gauges that best predicted the onset and end of emergence were the same this year as last (van der Naald et al. 2005). However, this gauge system has only been in use for those two years. It is too early to determine if a specific gauge outperforms the others in predicting begin, peak or end emergence. Alternatively, different gauges may best predict emergence in different years because the fish spawn in different areas. In 2005 peak emergence was best described by a gauge in Hamilton Channel but in 2006 by a gauge in the main river flow. This difference may be because the peak of the run spawned in different locations and the embryos were exposed to different temperature regimes.

Though we did not address habitat use in detail, we observed that unmarked and hatchery juvenile Chinook salmon were both present at nearshore habitats in our study area. Fish spawned around Ives and Pierce Islands appeared to use the habitat for rearing before beginning their downstream migration. However, this area was also used by fish originating upriver, both hatchery and wild, as they moved downstream. The juvenile spring Chinook salmon that migrate through the study area are much larger than the locally-produced fall Chinook salmon fry and it is possible that they dominated the best habitats. Although we did not sacrifice any of the tagged hatchery fish to determine their origin, they generally arrived a few days after an upstream hatchery release.

Fall Chinook salmon catches did not follow the same pattern of lower catches during higher water years as did the catches of juvenile chum salmon. Although the three highest total catches of juvenile fall Chinook salmon were recorded in low water years, there was some overlap. Catch rates were much higher in 2004 and 2005, two low water years, than in 2006, a high water year. However, CPUE calculations cannot be performed for years prior to 2004 (zero catches were not recorded) and most of the lower catches occurred in earlier years of the study. The lack of adequate catch rate data prevents a rigorous assessment.

Juvenile fall Chinook salmon utilized habitat in all of our sampling areas; however, some areas (sections 1, 3, 6, and 9) had higher catch rates. These areas may be more productive because more food is available, or they may have better habitat either for shelter or feeding opportunities. Again, sampling efficiency (especially considering the persistent high water in 2006) is likely an important factor contributing to the variation in catches we observed.

Juvenile fall Chinook salmon emerged from late winter through mid-spring. In late spring and early summer juveniles greater than 60-mm FL represented a larger proportion of the catch. There was greater mixing of size categories for juvenile fall Chinook salmon than chum salmon because Chinook salmon spend more time rearing in fresh water while chum salmon rear in estuarine habitats. However, we found differences in median sizes among years. Median size was highest in 2006, the only high water year analyzed. Larger fish may have been more available to us because smaller fish were pushed out by high currents or because smaller fish were utilizing slower water in the vegetation where we could not sample. Because flow is positively related to migration rate for Chinook salmon (Dawley et al. 1986; Schreck et al. 1994), the high flows in 2006 may have caused larger yearling fish from upriver to move downstream sooner, increasing the observed median sizes.

## PLANS FOR FY 2007

Base activities in 2006-2007 will remain similar to 2005-2006. We will continue spawning ground surveys for adult fall Chinook and chum salmon below Bonneville Dam near Ives and Pierce islands, documenting the time and location of spawning and providing pertinent data (e.g. redd counts and locations, spawner counts) to the Fish Passage Center. By mutual agreement, WDFW will continue estimating the population sizes of spawning fall Chinook salmon, and we will continue to provide population estimates for chum salmon. As discussed, we will make some improvements to our population estimation techniques. We will continue to collect biological and CWT recovery data to describe the populations and determine stock origins for both species.

Oregon managers have expressed interest in conducting spawning surveys for chum salmon in lower Columbia River tributaries near Bonneville Dam. WDFW conducts these surveys on an annual basis on the Washington side of the Columbia River, but better information from Oregon tributaries is desirable and may identify remnant or newly colonizing populations. We intend to perform pilot surveys of some selected tributaries in 2006 during periods we are unable to complete mainstem Columbia River sampling (due to inclement weather or other logistical problems).

Surveys of juvenile Chinook and chum salmon will continue at a reduced level. Budget constraints have necessitated the elimination of the juvenile CWT component, but we expect to have fish from previous tag groups returning until 2011, allowing us to continue assessing juvenile to adult survival and contributions to fisheries. We will continue to estimate emergence timing, document outmigration, and determine size at migration for juvenile fall Chinook and chum salmon below Bonneville Dam.

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## APPENDIX:

Detailed Fork Length Distributions and Fall Chinook Salmon Tagging Data

APPENDIX TABLE 1. Fork length (FL; mm) distribution by sample date for chum salmon collected below Bonneville Dam, 2006.

| Week | Date | Total | FL Range | Number of Fish by Size Class | | | | Mean FL |
|---|---|---|---|---|---|---|---|---|
| | | | | 30-39 | 40-49 | 50-59 | 60-69 | |
| 8 | 2/14 | 2 | 38-39 | 2 | 0 | 0 | 0 | 39 |
| 9 | 2/21 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 9 | 2/24 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 10 | 2/28 | 3 | 36-41 | 2 | 1 | 0 | 0 | 39 |
| 10 | 3/3 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 11 | 3/7 | 1 | 39 | 1 | 0 | 0 | 0 | 39 |
| 11 | 3/10 | 9 | 38-44 | 3 | 6 | 0 | 0 | 41 |
| 12 | 3/17 | 16 | 39-44 | 2 | 14 | 0 | 0 | 41 |
| 13 | 3/21 | 23 | 38-47 | 4 | 19 | 0 | 0 | 41 |
| 13 | 3/24 | 46 | 39-46 | 8 | 38 | 0 | 0 | 42 |
| 14 | 3/28 | 37 | 37-46 | 3 | 34 | 0 | 0 | 42 |
| 14 | 3/31 | 12 | 42-51 | 0 | 11 | 1 | 0 | 44 |
| 15 | 4/3 | 116 | 37-58 | 23 | 90 | 3 | 0 | 42 |
| 15 | 4/6 | 1 | 44 | 0 | 1 | 0 | 0 | 44 |
| 16 | 4/11 | 15 | 39-50 | 2 | 12 | 1 | 0 | 43 |
| 16 | 4/14 | 17 | 34-64 | 6 | 10 | 0 | 1 | 42 |
| 17 | 4/17 | 2 | 47-48 | 0 | 2 | 0 | 0 | 48 |
| 17 | 4/20 | 1 | 35 | 1 | 0 | 0 | 0 | 35 |
| 18 | 4/24 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 18 | 4/27 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 19 | 5/1 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 19 | 5/4 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 20 | 5/8 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| 20 | 5/11 | 1 | 40 | 0 | 1 | 0 | 0 | 40 |
| 21 | 5/15 | 0 | -- | 0 | 0 | 0 | 0 | -- |
| Total | | 302 | | 57 | 239 | 5 | 1 | 42 |

APPENDIX TABLE 2. Fork length (FL; mm) distribution by sample date for juvenile fall Chinook salmon collected below Bonneville Dam, 2006.

| Week | Date | Total | FL Range | Number of Fish by Size Class | | | | | | | | Mean FL (<150) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 30-39 | 40-49 | 50-59 | 60-69 | 70-79 | 80-89 | 90-100 | >100 | |
| 6 | 1/31 | 1 | 39 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 |
| 7 | 2/3 | 19 | 40-48 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| 7 | 2/7 | 6 | 36-45 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 41 |
| 8 | 2/14 | 2 | 43-50 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 47 |
| 9 | 2/21 | 23 | 40-53 | 0 | 18 | 5 | 0 | 0 | 0 | 0 | 0 | 47 |
| 9 | 2/24 | 6 | 40-48 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 46 |
| 10 | 2/28 | 19 | 37-57 | 1 | 11 | 7 | 0 | 0 | 0 | 0 | 0 | 51 |
| 10 | 3/3 | 9 | 37-58 | 4 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 46 |
| 11 | 3/7 | 182 | 42-68 | 0 | 8 | 61 | 102 | 11 | 0 | 0 | 0 | 61 |
| 11 | 3/10 | 33 | 36-69 | 1 | 1 | 6 | 25 | 0 | 0 | 0 | 0 | 63 |
| 12 | 3/17 | 50 | 37-68 | 7 | 12 | 14 | 17 | 0 | 0 | 0 | 0 | 56 |
| 13 | 3/21 | 43 | 37-74 | 4 | 8 | 8 | 21 | 2 | 0 | 0 | 0 | 58 |
| 13 | 3/24 | 78 | 38-68 | 7 | 35 | 21 | 15 | 0 | 0 | 0 | 0 | 50 |
| 14 | 3/28 | 41 | 39-74 | 1 | 19 | 2 | 8 | 11 | 0 | 0 | 0 | 55 |
| 14 | 3/31 | 41 | 34-74 | 6 | 24 | 2 | 6 | 3 | 0 | 0 | 0 | 48 |
| 15 | 4/3 | 84 | 37-77 | 9 | 33 | 7 | 22 | 13 | 0 | 0 | 0 | 54 |
| 15 | 4/6 | 20 | 37-89 | 1 | 4 | 2 | 1 | 8 | 4 | 0 | 0 | 68 |
| 16 | 4/11 | 211 | 39-126 | 2 | 165 | 34 | 4 | 5 | 0 | 0 | 1 | 48 |
| 16 | 4/14 | 49 | 38-104 | 1 | 19 | 3 | 3 | 12 | 6 | 4 | 1 | 64 |
| 17 | 4/17 | 16 | 41-85 | 0 | 10 | 1 | 1 | 1 | 3 | 0 | 0 | 55 |
| 17 | 4/20 | 116 | 37-82 | 15 | 85 | 9 | 1 | 5 | 1 | 0 | 0 | 47 |
| 18 | 4/24 | 33 | 35-90 | 8 | 9 | 3 | 3 | 5 | 4 | 1 | 0 | 56 |
| 18 | 4/27 | 48 | 34-74 | 8 | 38 | 1 | 0 | 1 | 0 | 0 | 0 | 43 |
| 19 | 5/1 | 68 | 36-94 | 9 | 34 | 6 | 1 | 3 | 7 | 8 | 0 | 55 |
| 19 | 5/4 | 124 | 34-120 | 29 | 77 | 5 | 0 | 0 | 5 | 0 | 8 | 48 |
| 20 | 5/8 | 200 | 38-99 | 7 | 66 | 12 | 6 | 23 | 61 | 25 | 0 | 67 |
| 20 | 5/11 | 89 | 38-96 | 10 | 61 | 11 | 3 | 0 | 1 | 3 | 0 | 47 |
| 21 | 5/15 | 202 | 35-94 | 19 | 83 | 68 | 18 | 1 | 7 | 6 | 0 | 52 |
| 21 | 5/18 | 86 | 35-164 | 28 | 39 | 12 | 2 | 1 | 0 | 0 | 4 | 49 |
| 22 | 5/22 | 131 | 29-134 | 18 | 92 | 15 | 2 | 0 | 2 | 0 | 2 | 46 |
| 22 | 5/25 | 43 | 35-59 | 10 | 30 | 3 | 0 | 0 | 0 | 0 | 0 | 43 |
| 23 | 5/30 | 258 | 38-68 | 12 | 173 | 55 | 18 | 0 | 0 | 0 | 0 | 48 |
| 24 | 6/5 | 105 | 40-72 | 0 | 35 | 41 | 24 | 5 | 0 | 0 | 0 | 55 |
| 24 | 6/8 | 41 | 40-81 | 0 | 11 | 17 | 8 | 3 | 2 | 0 | 0 | 56 |
| 25 | 6/12 | 81 | 42-112 | 0 | 12 | 22 | 25 | 11 | 4 | 5 | 2 | 65 |
| 25 | 6/15 | 135 | 49-105 | 0 | 1 | 29 | 64 | 26 | 9 | 5 | 1 | 67 |
| 26 | 6/20 | 56 | 54-103 | 0 | 0 | 3 | 23 | 13 | 12 | 4 | 1 | 73 |
| 26 | 6/23 | 134 | 47-179 | 0 | 1 | 20 | 34 | 30 | 26 | 16 | 7 | 76 |
| 27 | 6/27 | 79 | 53-103 | 0 | 0 | 8 | 19 | 29 | 12 | 10 | 1 | 75 |
| 27 | 6/30 | 154 | 56-102 | 0 | 0 | 2 | 32 | 41 | 48 | 30 | 1 | 79 |
| Total | | 3,116 | | 220 | 1,245 | 520 | 508 | 263 | 214 | 117 | 29 | 57 |

APPENDIX TABLE 3. Juvenile fall Chinook coded-wire tagged and released below Bonneville Dam, 2006.

| Date | Number Sampled | Mean Fork Length (mm) | % Untaggable (out of size) | Number Tagged | Number Mortalities | % Mortalities | Number Released |
|---|---|---|---|---|---|---|---|
| 4/21 | 176 | 48 | 55 | 80 | 3 | 3.8 | 77 |
| 4/28 | 179 | 49 | 52 | 84 | 2 | 2.4 | 82 |
| 5/5 | 227 | 50 | 68 | 72 | 1 | 1.4 | 71 |
| 5/12 | 669 | 50 | 58 | 283 | 1 | 0.4 | 282 |
| 5/19 | 804 | 53 | 32 | 550 | 1 | 0.2 | 549 |
| 5/26 | 599 | 51 | 57 | 257 | 2 | 0.7 | 255 |
| 6/2 | 1,469 | 56 | 19 | 1,186 | 8 | 0.7 | 1,178 |
| 6/9 | 643 | 60 | 12 | 565 | 0 | 0.0 | 565 |
| 6/16 | 985 | 65 | 14 | 846 | 0 | 0.0 | 846 |
| Totals | 5,751 | 56 | 32 | 3,923 | 18 | 0.5 | 3,905 |