Chinook Salmon *(Oncorhynchus tshawytscha)* Adult Abundance Monitoring in Lake Creek and Secesh River, Idaho in 2005

Annual Report

January 2005 – December 2005

Prepared by:

Paul A. Kucera and Rick W. Orme

Nez Perce Tribe
Department of Fisheries Resources Management
Lapwai, ID 83540

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 199703000
Contract Number 00020615

June 2006

TABLE OF CONTENTS

CHAPTER 1

Chinook Salmon *(Oncorhynchus tshawytscha)* Adult Abundance Monitoring in Lake Creek

Annual Report

January 2005 – December 2005

Prepared by:

Paul A. Kucera and Rick W. Orme

Nez Perce Tribe
Department of Fisheries Resources Management
Lapwai, ID 83540

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 199703000
Contract Number 00020615

June 2006

ABSTRACT

Underwater time lapse video technology was used to determine tributary specific adult spring and summer chinook salmon abundance in Lake Creek in 2005. In 2005, the first upstream salmon passage occurred on June 25, 14 days after installation of the fish counting station. Total wild and hatchery salmon abundance in Lake Creek was 140 fish, with 95% confidence intervals of ± 2 fish. Wild salmon abundance was estimated to be 138 adults. Estimated hatchery fish composition represented 1.5% of the spawning population. Chinook salmon jacks comprised an estimated 5.3% of the run. There was an estimated 1.77 fish per redd in Lake Creek in 2005.

The salmon spawning migration in Lake Creek occurred from June 25 to September 4 with a total of 576 fish passages observed at the fish counting station. Median net upstream salmon passage was observed on July 13, and the maximum number of net upstream migrating salmon were in the Lake Creek system by August 23. Adult salmon moved freely upstream and downstream through the fish counting station. The downstream movement of salmon afforded by the fish count station design may be an important factor in the reproductive success of listed chinook salmon as compared to other more traditional weir designs.

Lake Creek adult salmon abundance information, from 1998 through 2005, provided in this report have been standardized and refined. Salmon abundance data from this annual report supercedes that presented in previous years' reports.

Substantial between observer variation existed in salmon redd counts. The average difference in index area redd counts between two experienced observers ranged from 28.7% to 39.9% in two streams. Variation in fish per redd relationships was described, and was significantly different ($p < 0.05$) between several streams. Accounting for between observer redd count variation, and variation in fish per redd values is an important consideration when performing redd count expansions to estimate salmon abundance. We recommend incorporating uncertainty around these two variables when redd count expansion abundance estimates are used to compare to listed species population viability thresholds (ICTRT 2005) and rolled up to the ESU level for larger scale recovery metrics monitoring.

Video determined adult salmon abundance was compared to redd count expansion abundance point estimates in Lake Creek. Index and extensive area redd count expansion point estimates varied from 12.2% to 61.7% higher than underwater video determined salmon abundance. For all years of study, redd count expansion methods estimated from 61% fewer salmon to 172% more salmon than were actually present in the Lake Creek system. Unlike the video determined abundance, redd count expansion abundance estimates have an unknown amount of variation associated with the point estimates.

This project has successfully demonstrated the application of underwater video monitoring as a non-invasive method to accurately quantify wild chinook salmon abundance in an unsupplemented stream. Time lapse videography provided more accurate adult salmon abundance information than either peak index area, multiple pass index area, or multiple pass extensive area redd count expansion abundance estimates. Accurate adult abundance

information will allow managers to assess the effectiveness of conservation actions for listed chinook salmon in Snake River basin streams.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The Bonneville Power Administration provided funding for this research project. We thank the Nez Perce Tribe for providing the administrative framework necessary for this project to be successful. We also would like to acknowledge Nez Perce Tribe Department of Fisheries Resources Management personnel Mike Busby, Dan Felt, Mitch Daniel, Doug Nelson, Wes Keller, and John Gebhards for project operations and structure placement. We especially thank Tribal Idaho Salmon Supplementation (ISS) study personnel Jerry Lockhart, Ryan Kinzer, Travis Covel, and Neal Meshell for sharing of salmon redd count and carcass recovery data and for assistance in the field. Rishi Sharma and Chris Beasley provided statistical consulting to standardize salmon abundance estimation methods and variance estimators. We thank Jay Hesse for review and comments on an earlier version of this report. Jeff Cronce of the Nez Perce Tribe Land Services Department provided GIS maps of the Secesh River drainage.

INTRODUCTION

Salmon recovery within the Columbia River basin has become a focal point in the Pacific Northwest. In 1992 spring and summer chinook salmon (*Oncorhynchus tshawytscha*) in the Snake River basin were listed as threatened under the Endangered Species Act (NMFS 1992). Large amounts of time, effort and funding have been spent to improve fish passage conditions, augment flows, enhance and restore habitat, constrain harvest and use hatchery supplementation to increase salmon populations. Despite these efforts, salmon populations continued to decline through 2000 with recent increases in adult returns since 2001. The National Marine Fisheries Service issued a Biological Opinion for the operation of the federal Columbia River power system (NMFS 2000) that attempted to define reasonable and prudent actions and criteria/population levels that would ensure continued existence of critical fish stocks. NMFS (2002) further defined interim abundance targets in terms of numbers of naturally spawning adult salmon returning to streams or watersheds. Recomended guidelines have been proposed by the Interior Columbia River Technical Recovery Team (ICTRT 2005) to identify population size categories for basic, intermediate, and large size salmon spawning aggregates. Accurate determination of adult salmon spawner abundance is of utmost importance to fisheries managers.

NMFS (2000) recommended that accurate assessment of spawner escapement of listed Evolutionary Significant Units (ESU) were required for determining the characteristics, viability, recovery status, and delisting of ESU's under the Endangered Species Act (ESA). NMFS (2000) further defined the degree to which species-level biological requirements must be met: "At the species level, NMFS considers that the biological requirements for survival, with an adequate potential for recovery, are met when there is a high likelihood that the species population will remain above critical escapement thresholds over a sufficiently long period of time. The particular thresholds, recovery levels, and time periods were to be selected depending upon the characteristics and circumstances of each salmon species under consultation" (NMFS 2000). NMFS interim abundance and productivity targets for South Fork Salmon River chinook salmon are 9,200 adults and a geometric mean cohort replacement rate that exceeds one, during the eight years immediately prior to delisting (NMFS 2000). The ICTRT (2005) has recomended abundance threshold, productivity, and spatial distribution criteria to maintain viable salmon populations. The NMFS recommended characterizing populations by abundance/productivity, diversity (viability), spatial structure, and habitat capacity (NMFS 2000), most of which rely on some quantitative measure of adult abundance. Adult abundance determination is also a necessary component of proposed population level stock status monitoring (McElhany et al. 2000). The Validation Monitoring Panel (Botkin et al. 2000) provided a science-based analysis for monitoring of salmon for conservation plans. The panel identified the need for accurate adult salmon abundance information in relation to conservation and restoration plans.

Determination of adult spawner abundance information was identified as a critical aspect of a viable population management strategy (Foose et al. 1995, Botkin et al. 2000), and was recognized within the scientific community and in recovery planning efforts (NMFS 2000). Currently, there is limited quantitative information available to determine the abundance of adult spring and summer chinook salmon in tributary streams of the Snake River basin. Therefore, we cannot measure the effectiveness of conservation actions for a threatened species (Botkin et al. 2000). Quantifying adult salmon spawner abundance will provide a direct measurement of benefits of the Northwest Power and Conservation Council's Fish and Wildlife Program projects (funded by BPA) and efforts of recovery alternatives.

Chinook salmon index area redd counts were initiated in Idaho in the mid 1950's to provide an index of relative abundance and population trend information over time. Chinook redd counts relied upon one-time counts at the peak of spawning (Elms-Cockrum 1999). More recent studies have used multiple ground counts of spawning activities for more accurate assessment of salmon redds (Kucera 1987, Cowley and Kucera 1989, Kucera and Banach 1991, Kucera and Blenden 1994, Kucera and Blenden 1999). While neither of these redd count survey techniques were intended to provide accurate spawner abundance information, redd counts have been expanded by some researchers by an estimated fish per redd value to provide some approximation of spawner abundance.

However, expansion of redd counts to spawner numbers are influenced by measurement error and uncertainty of assumptions regarding estimates of fish per redd, relative numbers in surveyed and unsurveyed areas, prespawning mortality rates, age composition, and hatchery fish composition (Beamesderfer et al. 1998). These uncertainties result in unknown and unquantified error in the resulting redd count expansion abundance point estimate.

The unknown error incorporated within redd counts and assumed fish per redd values will likely produce bias and unceratiny when used in redd count expansion abundance estimates. Adult salmon abundance is a primary performance measure used to assess listed species viability thresholds, population growth rates, between population comparisons (between basins or years), and calculating derived performance measures such as adult-to-adult ratios, smolt-to-adult return rates, number of smolts per female, etc. .

Alternate and more accurate methods are needed to determine adult salmon abundance. Time-lapse video has been used to enumerate adult salmon at fish counting/viewing windows at hydroelectric projects (Hatch et al. 1994a, 1994b). In some cases, cameras have been submerged in fish ladders to evaluate fish passage (USFWS -unpublished data). Limited studies have used cameras underwater in a natural setting. Holubetz and Leth (1996) experimentally operated a remote video recording system on Running Creek, in the headwaters of the Selway River, Idaho. Studies in Alaska have used time-lapse video cameras from above the stream (T. Otis -Alaska Department of Fish and Game, personal communication), in conjunction with a fish wheel (D. Daum - U. S. Fish and Wildlife Service, personal communication) and underwater in a stream (N. Hetrick - U. S. Fish and Wildlife Service, personal communication). This project has used underwater time-lapse video to enumerate adult chinook salmon abundance since 1998.

Information collected from this project is expected to determine chinook salmon population status in Lake Creek, including assessment of performance measures (primary and derived) and standards. Fisheries managers will use the data for population management and for assessment of listed species status monitoring.

The goal of this project is to accurately assess the adult spring and summer chinook salmon spawning migration in the Secesh River and Lake Creek drainages by emphasizing collection of tributary specific adult salmon abundance information. Project objectives are to annually collect accurate adult chinook salmon abundance and migration timing in Lake Creek, and to determine the accuracy of redd count expansion abundance estimates with actual abundance derived from underwater video.

DESCRIPTION OF PROJECT AREA

The Lake Creek drainage is approximately 90 square km with the headwaters above Burgdorf Hot Springs at an elevation of 2,417 m. Elevation drops overs its 25 km length to 1,838 m where Lake Creek joins Summit Creek to form the Secesh River (Figure 1). Elevation of the Secesh River then drops to 1,110 m where it flows into the South Fork Salmon River. Channel gradients range from less than one percent along Lake Creek and the upper Secesh Meadows to over 10 percent in the lower canyon section.

The Lake Creek fish counting station was located 45 km upstream from the South Fork Salmon River and 100 m upstream from the mouth of Lake Creek. Average gradient in the vicinity of the fish counting station is 0.5 percent. The major chinook salmon spawning habitat is located upstream of the fish counting station from Burgdorf Meadows upstream to Willow Creek (Figure 1). Additional spawning habitat exists upstream of Willow Creek. In addition to chinook salmon, the Secesh River drainage contains resident rainbow trout and anadromous steelhead (*O. mykiss*), westslope cutthroat (*O.* c*larki lewisi*), bull trout (S*alvelinus confluentus*), brook trout (*S. fontinalis)*, mountain whitefish (*Prosopium williamsoni*), longnose dace (*Rhinichthys cataractae*) and sculpin (*Cottus sp.*).

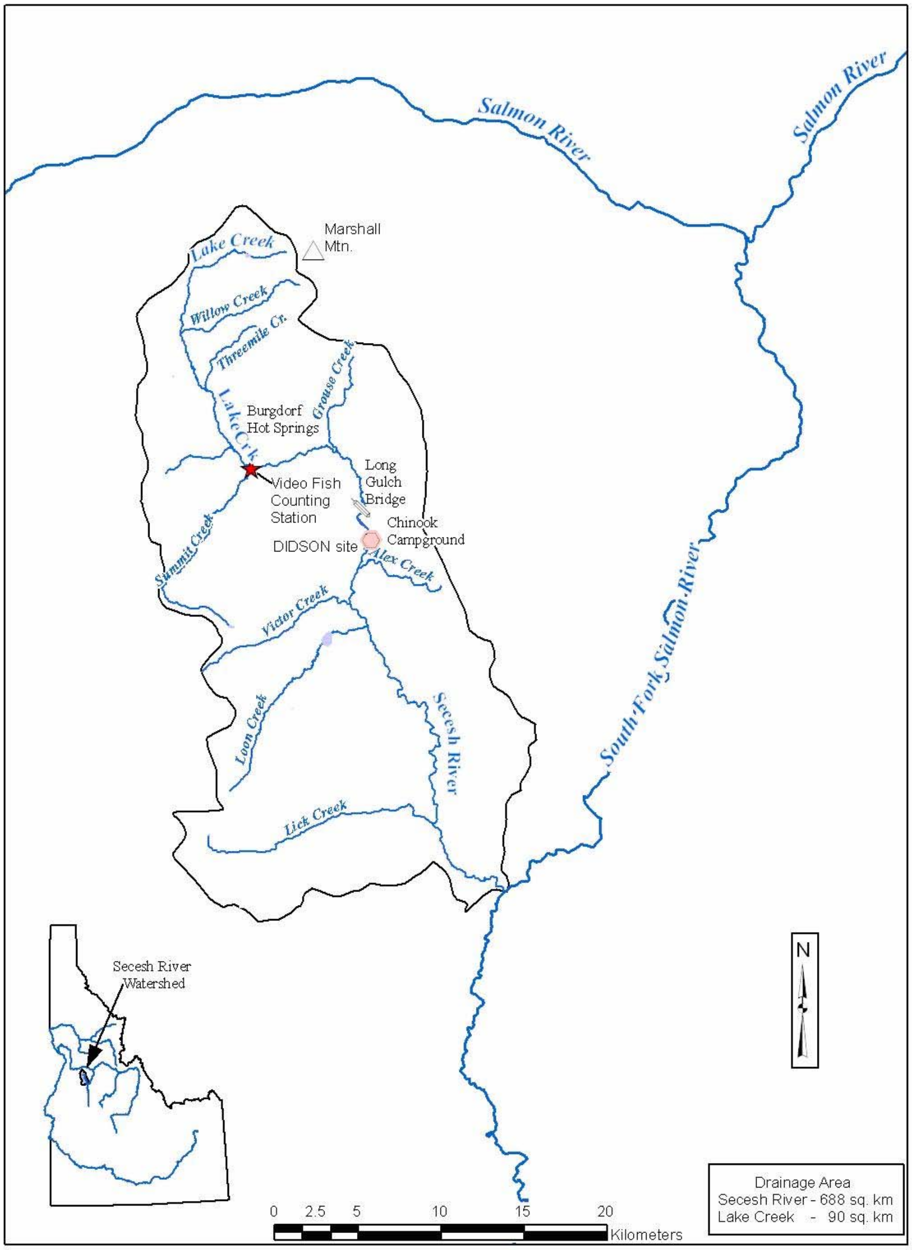

Figure 1. Map of the Lake Creek and Secesh River drainage indicating the location of the underwater video fish counting station.

METHODS

TIMING AND ABUNDANCE

Equipment

Since this project involved an ESA listed species, it was important to minimize any potential negative impacts to the fish. The underwater video system is passive, non-invasive, and allowed unobstructed upstream and downstream movements of fish. Fish were never trapped or handled which eliminated potential incidental mortality. Primary video system components were a tripod supported temporary picket guide fence, fish counting chamber, and the underwater video equipment (Figure 2).

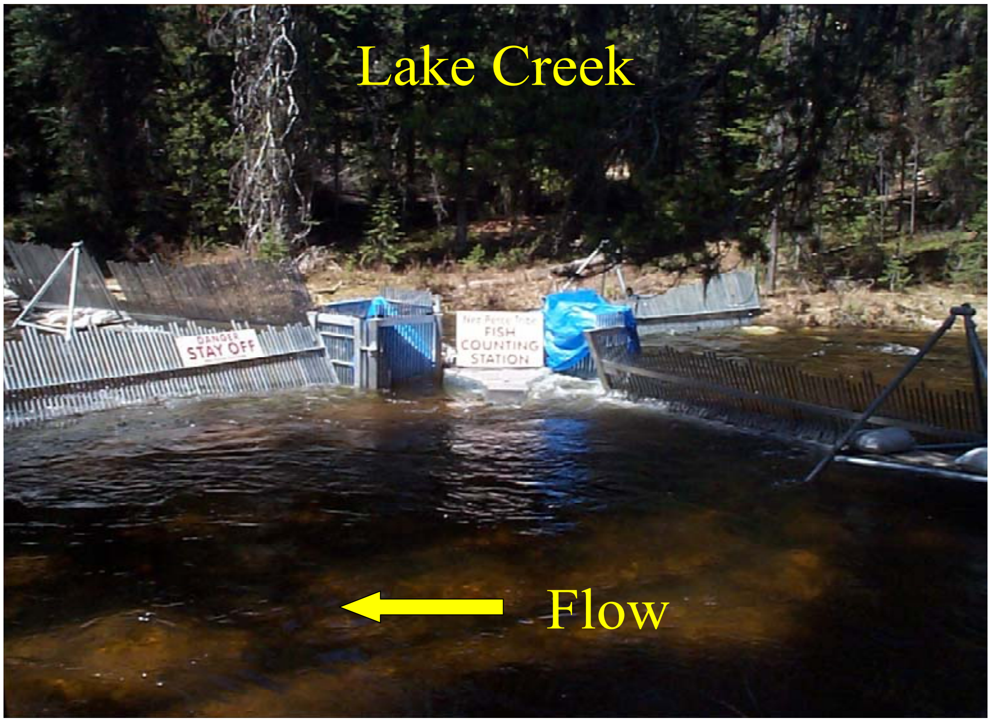

Figure 2. Lake Creek underwater video fish counting station.

The structure was shaped like two "V"s connected at their apexes by the counting chamber. The two downstream wings were angled at 30 to 45 degrees to orient and direct upstream migrating fish through the counting chamber. The two upstream wings functioned in a similar fashion for downstream moving fish. The counting chamber was located in the thalweg, which was believed to be the preferred migration route. The entrance to the counting chamber was 0.9 m wide by 0.76 m high. One interior wall of the fish counting chamber was fitted with Plexiglas, allowing for fish passages to be recorded by the underwater video camera. The entire fish counting station is described in detail by Faurot and Kucera (2003). The temporary structure was installed (usually within a day) as soon as possible after the peak of spring runoff to document the entire chinook salmon migration.

Because this project dealt with a threatened species, special efforts were made to reduce impacts to the resources and the landscape. Sandbags filled with spawning size gravel were used to add weight to tripods, seal open areas between the substrate and pickets, fill the space between end of the pickets and the undercut banks, and reinforce banks to prevent sloughing. Bags that deteriorated contributed spawning gravel to the stream instead of sand or sediment. Impacts to the riparian area were minimized by utilizing distinct pathways covered with bark chips.

Red LED lights were chosen to provide nighttime lighting in the fish counting chamber. Infrared lighting has been advocated, but dissipates rapidly in water and it has not been tested a the Lake Creek counting station. White light was not used because of the amperage draw of 5 amperes per hour compared to ½ amperes per hour for the red LEDs, and to eliminate possible fish avoidance of white light. In 1997 and 1998, two LED light arrays were mounted beside the camera approximately four to five feet from the fish passage zone. Since 1999, LED arrays have been attached on the inside of the Plexiglas viewing window, facing the back plate, for better illumination of the counting chamber. Lights can be positioned on the bottom, middle and top of the counting chamber at the entrance and exit. However, four light arrays two each at the top and bottom positions are now used at high water levels. The top two lights are removed when the water level recedes below them.

Power for equipment operation was obtained from four six-volt deep cycle batteries (Trojan, T-105) connected to produce 12 volts. Batteries were recharged on-site using two sets of three 75 watt solar panels. No power failures occurred during 2005. Initially several 12 volt batteries in parallel were used to power the system but required daily transport for recharging, or onsite charging with a generator. Numerous power outages were experienced with this method. A hydro generator (basically a propeller) was used in 1998 and worked early in the spring during high flows, but was not sufficient as the water level and velocity dropped.

Initially, 8 mm time-lapse recorders and T-120 8mm videotapes were used. The 8mm T-120 tapes could record roughly 30 hours at 2 frames per second. In 2002 the 8 mm recorders were replaced with VHS recorders. VHS T-160 videotapes are now used and they are capable of recording for 32 hours in extended play mode at 4.5 frames per second. Both systems were reliable, although VHS videotapes were less expensive and provided more frames of fish passage.

Procedure

The fish counting station was installed on June 11, approximately 100 m above the mouth of Lake Creek and operated continuously through September 11, 2005. Considerable effort was invested into making the fish counting station structure fish tight. No fish were observed jumping at the picket weir, and no fish were ever seen between the upstream and downstream wings on either side. We were confident that the weir structure was fish tight and assumed that no fish passed the fish counting station without passing through the counting chamber.

Project personnel exchanged videotapes and maintained the fish counting station structure daily. Videotapes were briefly reviewed after the tape exchange to ensure that both lights and recorders were operating properly. This brief review allowed for the quick correction of any equipment malfunction. The collected videotapes were reviewed in the office at approximately 40 frames per second. Fish passage date, time of day, direction of passage (up or down), estimated length, and fin clips of chinook salmon and bull trout (> 40 cm) were recorded (Figures 3, 4 and 5). Adipose fin clips were recorded to determine the number and percentage of hatchery chinook salmon in the run. Ventral fin clips were difficult to detect, especially on the side away from the camera. Salmon carcass recovery data on Lake Creek was examined annually to confirm the presence or absence of ventral fin clipped adult salmon on the spawning grounds. If ventral fin clipped salmon were confirmed during carcass recoveries, the data was used to adjust the estimated hatchery composition at the fish counting station. The proportion of hatchery fish in the run was caluclated from video observation. During the intial review, each observed chinook passage was recorded to a master tape for data backup and future review. Species identification was simple and non-ambiguous. Visual keys and fish size was used to identify chinook. All adult chinook salmon were 50 cm or larger. Other fish species to reach this size were whitefish, bull trout, and steelhead all of which were easily differentiated visually. Bull trout and jack chinook salmon of similar size were differentiated by the longer anal fin and flattened body form of bull trout.

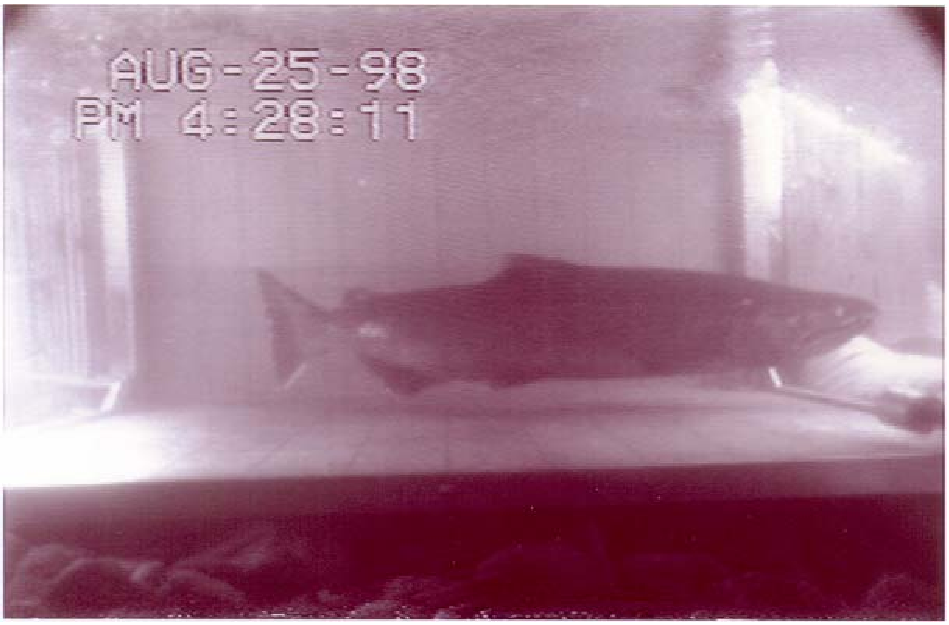

Figure 3. Underwater video photograph of a male chinook salmon migrating through the fish counting chamber.

Figure 4. Underwater video photograph of chinook salmon migrating through the fish counting chamber at night.

Figure 5. Underwater video photograph of multiple (4) chinook salmon migrating through the fish counting chamber.

Secondary identification characteristics were the squarer tail and erect dorsal fin of bull trout. Identification of fish smaller than 40 cm was difficult and not recorded.

Redd counts within the Secesh River and Lake Creek were conducted independently by the Nez Perce Tribe Department of Fisheries Resources Management (NPT) and Idaho Department of Fish and Game (IDFG) personnel. The NPT conducts multiple pass surveys of index areas and larger extensive area surveys. The IDFG conducts single pass surveys of index areas near the peak of spawning activity. Multiple pass surveys usually entail three to five surveys, one at the beginning of the spawning period, and the last after spawning has been completed.

Adult salmon abundance in Lake Creek was calculated as the maximum net upstream number of salmon that had migrated through the fish counting station once spawning had commenced. The calculation of net upstream movement was simply the cumulative addition when a salmon moved upstream, or subtraction when a salmon moved downstream. In 2005, videotapes of passages were reviewed by two different observers.

Two potential sources of error existed that were addressed to adjust the observed adult abundance. Error may be introduced into the abundance estimate from passages that occurred during periods of turbidiy, equipment failure, or passages that were missed by tape reviewers. To estimate reader specific error, one day's video recordings from each week of the season was randomly selected and independently reviewed by the other observer covering approximately 14% of the season. Observations were pooled for all dates reviewed to calculate each reviewers' reader specific error both in the upstream and downstream direction. Reader specific error was calculated as the total number of passages (upstream or downstream) recorded by an individual observer divided by the actual number of passages. The actual number of passages was determined as the maximum number of passages observed after comparing the passage times of both reviewers. Each observers' error was applied as a correction factor to the specific dates reviewed by each observer.

The second source of error, salmon that may have passed the fish counting station during periods of turbidity or equipment downtime, was also corrected. Salmon passages (corrected for reader specific error) during days that experienced equipment downtime were adjusted by dividing that days net upstream passage rate by the proportion of time sampled during that day. Daily net upstream salmon passages, adjusted for both observer error and equipment downtime was then summed over all days. Actual abundance was calculated as the maximum number of net upstream fish at the fish counting station.

The daily net upstream migration ($E_{i,r}$) was the sumation of observed passages ($E_{i,s,r}$) and passages that occured during periods of downtime ($E_{i,US,r}$) as

$$E_{i,r} = E_{i,s,r} + E_{i,US,r}$$

where i is a given day, s is the proportion of sampled observations, and US is the unsampled estimate (estimated number of fish missed in a given day as a result of downtime). This was stratified by reader specific error (r), which is assumed to be known with zero error. The sampled observations ($E_{i,s,r}$) was calculated as

$$E_{i,s,r} = A_r \times \left[U_{i,s,r} - D_{i,s,r}\right]$$

where A is the reader error adjustment factor, U is the upstream count and D is the downstream count for each strata i. The unsampled passages that occured during downtime ($E_{i,US,r}$) was estimated as

$$E_{i,us,r} = \frac{A_r \times \left[U_{i,s,r} - D_{i,sr}\right]}{sf} - E_{i,S,r}$$

Where sf is the proportion of time sampled for strata i calculated as $sf = \frac{n}{N}$ where n is the time the camera was operational over the entire time in a given day (e.g., if the camera worked for 12 hrs in a given day, sf = 0.5).

The variance for the sampled ($\mathrm{var}(E_{i,us,r})$) proportion is given by

$$\mathrm{var}(E_{i,us,r}) = \left[\frac{A_r}{sf}\right]^2 \times \mathrm{var}\left[U_{i,s,r} - D_{i,sr}\right].$$

Since the sampled observations are based on a correction with zero variance, they are considered a census and they too have zero variance. For the unsampled component (number of fish estimated to have passed during the down time on a given day) variance ($\mathrm{var}(E_{i,us,r})$) is given by

$$\mathrm{var}(E_{i,us,r}) = \left[\frac{A_r}{sf}\right]^2 \times \mathrm{var}\left[U_{i,s,r} - D_{i,sr}\right]$$

and

$$\mathrm{var}\left[U_{i,s,r} - D_{i,s,r}\right] = \frac{\sum_{i=1}^{n}\left[U_{i,s,r} - D_{i,s,r}\right] - \left[\overline{X}\right]}{n-1}$$

where $\overline{X}$ is the mean count on any given day in the season (note that these counts are adjusted for reader error).

Overall variance is only a component of the unsampled proportion as the sampled proportion is essentially a census (as described above) and is given by

$$\mathrm{var}(E_i) = \sum_{r=1}^{n} \mathrm{var}(E_{i,us,r}).$$

Optic StowAway thermographs recorded hourly water temperature data in Lake Creek in 2005. Stream discharge was calculated from a stream discharge and staff gauge regression. Staff gauge measurements were recorded daily. Stream discharge was measured following U. S. Geological Survey standardized procedures using a Marsh McBirney model 2000 flow meter, with accuracy ± 0.01 m/s.

RESULTS AND DISCUSSION

ABUNDANCE

The Lake Creek fish counting station was installed on June 11, 2005. The first upstream salmon passage occurred on June 25, 14 days after installation of the fish counting station. Total adult salmon abundance, wild and hatchery, in Lake Creek was 140 fish ± 2 (95% confidence interval) (Tables 1 and 2, Figure 6). Wild chinook salmon abundance was estimated to be 138 adults, after adjustment for the proportion of hatchery adults on the spawning grounds. The fish counting station was operational for 97.9% of the season in 2005, while the videotape reviewers' reader error was zero. Abundance adjustment (expansion) for periods of equipment downtime equaled four salmon (Table 3).

A maximum number of 140 net upstream migrating natural and hatchery salmon was observed in Lake Creek on August 23. This number is important methodology-wise, because it was the largest number of adults that was available to contribute to potential salmon reproductive success in the system. After August 23, there were 16 additional total salmon passages (12 downstream and 4 upstream) through the fish counting station. Given the methodology employed, if the four upstream salmon passages were all unspawned late arriving fish (3 males and 1 female) they would not have been accounted for in the season-wide abundance estimate. After the August 23 date there was one net downstream moving female salmon, and seven male salmon that were either in the process of seeking other females to spawn with or dying and drifting out of the system. When operations ceased on September 11, a total of 132 salmon remained upstream of the fish counting station.

Adult salmon abundance has varied dramatically from 1998 to 2005, ranging from 45 to 697 salmon (Figure 6); a fifteen fold range in abundance. Ninety five percent confidence intervals bracketing the abundance estimates have been very precise ranging from 0 to 3.1% (Table 1). Lake Creek adult salmon abundance information, from 1998 through 2005, provided in this report have been standardized and refined. Salmon abundance data from this annual report supercedes that presented in previous years' reports.

Table 1. Adult salmon abundance estimate, 95% confidence intervals, standard error, percent jacks, adult hatchery composition, and fish per redd numbers in Lake Creek from 1998 to 2005.

Year	Adult Abundance Estimate	95% Confidence Interval Range (± as %)	Standard Error (s.e.)	Percentage of Jacks (%)	Hatchery Composition (%)	Fish Per Redd
1998	45	45-46 (2.2)	0.26	1.9[1]	4.3[2]	0.90
1999	65	63-66 (3.1)	0.86	26.9	6.2[2]	2.71
2000	299	295-304 (1.3)	2.26	9.2	1.1[2]	1.67
2001	697	680-714 (2.4)	8.77	10.0	7.8	2.07
2002	409	404-414 (1.2)	2.45	6.9	6.7	2.05
2003	481	- (0)	0	16.1	1.4	1.97
2004	408	396-420 (2.9)	6.19	4.7	3.0	2.15
2005	140	138-142 (1.4)	0.95	5.3	1.5	1.77

---

[1] One jack salmon sampled during carcass recoveries.
[2] Hatchery compositions from carcass recoveries.

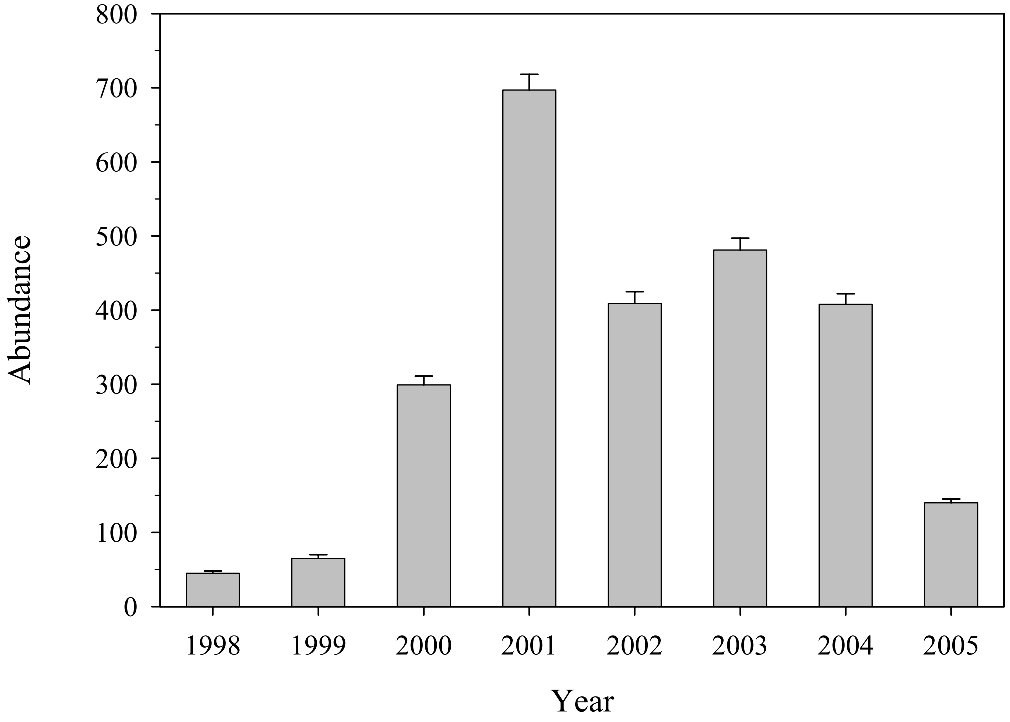

Figure 6. Adult chinook salmon abundance in Lake Creek from 1998 to 2005. Vertical bars represent 95% confidence intervals.

Table 2. Potential sources of error in video abundance estimation methodology in Lake Creek in 2005.

Source of Potential Error	Potential Effect on Abundance Estimate
Fish passages before installation	None
Undetected fish that escaped under counting station pickets	None
Undected fish that escaped around counting station fence ends	None
Fish passages during turbidity and equipment downtime	Corrected
Videotape reader specific error	None

Table 3. Adult chinook salmon abundance estimate, 95% confidence intervals, and corrections for equipment down time and tape reader error in Lake Creek from 1998 to 2005.

Year	Adult Abundance Estimate	95% C. I.	Equipment Downtime %	Equipment Downtime (Correction)	Tape Reader Error (Correction)
1998	45	45-46	7.1	-1	-3
1999	65	63-66	6.7	-3	-6
2000	299	295-304	5.7	36	-16
2001	697	680-714	2.6	50	4
2002	409	404-414	2.0	-1	1
2003	481	--	0.0	0	-9
2004	408	395-420	1.0	18	6
2005	140	138-142	2.2	4	0

Hatchery fish comprised 1.5% of the salmon spawning run in 2005 (2 adipose fin clipped fish, Table 1). The estimated hatchery fraction during the study period has ranged from 1.1 to 7.8%. In 2001 and 2002 hatchery adults comprised the largest observed percentage of 7.8% (51 fish) and 6.7% (30 fish), respectively. Hatchery composition was estimated from carcass recoveries from 1998 to 2000 due to poor or partial adipose fish clips which were not clearly discernible on videotapes. Due to the proximity of the hatchery smolt release site in the South Fork Salmon River, these fish were assumed to be of McCall Hatchery origin. There have been several McCall Hatchery, and Rapid River Hatchery, coded-wire-tag carcass recoveries in Lake Creek in past years (Jerry Lockhart – personal communication).

The McCall Fish Hatchery releases adipose-clipped yearling chinook salmon smolts into the upper South Fork Salmon River annually for fisheries mitigation and to enhance natural production. Non-adipose fin clipped/VIE marked smolts are also released into Johnson Creek for the purpose of augmenting the natural population. Non-adipose fin clipped fish from Johnson Creek releases would not be identifiable as hatchery fish at the Lake Creek fish counting station. Carcass recoveries in Lake Creek in 2005 have not identified any ventral fin clipped adults or VIE marked Johnson Creek hatchery adults straying into the system. Therefore, the estimated adult hatchery composition in Lake Creek (Table 1) is considered an accurate estimate.

The estimated fish per redd value in Lake Creek in 2005 was 1.77 fish/redd (Table 1). Fish per redd numbers during the study period have varied over three fold, from 0.90 to 2.71. Unbalanced age structure at low population sizes in 1998 and 1999 contributed to the low and high ranges in fish per redd values observed. Fish per redd estimates at population sizes of approximately 400 adults or more, were less variable ranging from 1.97 to 2.15 fish per redd. Calculation of fish per redd values in this report have not been adjusted for prespawning mortality estimates.

In 2005, jack salmon comprised 5.3% (7 fish) of the salmon spawning run into Lake Creek (Table 1). The proportion of jack salmon has ranged from 1.9% to 26.9% during the study period. The proportion of jacks in the spawning run has been most variable during years of low population size. At an adult escapement of 45 adults in 1998, one jack was observed in the run. When an estimated 65 salmon returned to spawn in 1999, jacks comprised 26.9% of the spawning escapement. During years when population abundance ranged from roughly 400 fish or greater, the proportion of jacks in the spawning run varied from 4.7 to 16.1% (Table 1). The proportion of jack salmon in any given years spawning escapement appears to affect the number of fish per redd on the spawning grounds (Figure 7) as the two variables were significantly correlated (Pearson Product Moment Correlation r = 0.737, p = 0.037)**.** The larger the percentage of jack salmon in the run, the larger the estimated fish per redd value. We acknowledge here that correlation does not necessarily connotate causation, and added years' information may help shed light on this relationship.

Observations from this project have documented that, in every year, male salmon migrate downstream out of Lake Creek and have the potential to spawn with Secesh River fish. This was clearly noted in 1999 when the Lake Creek run contained a relatively high percentage of jack salmon (26.9%) in the spawning run.

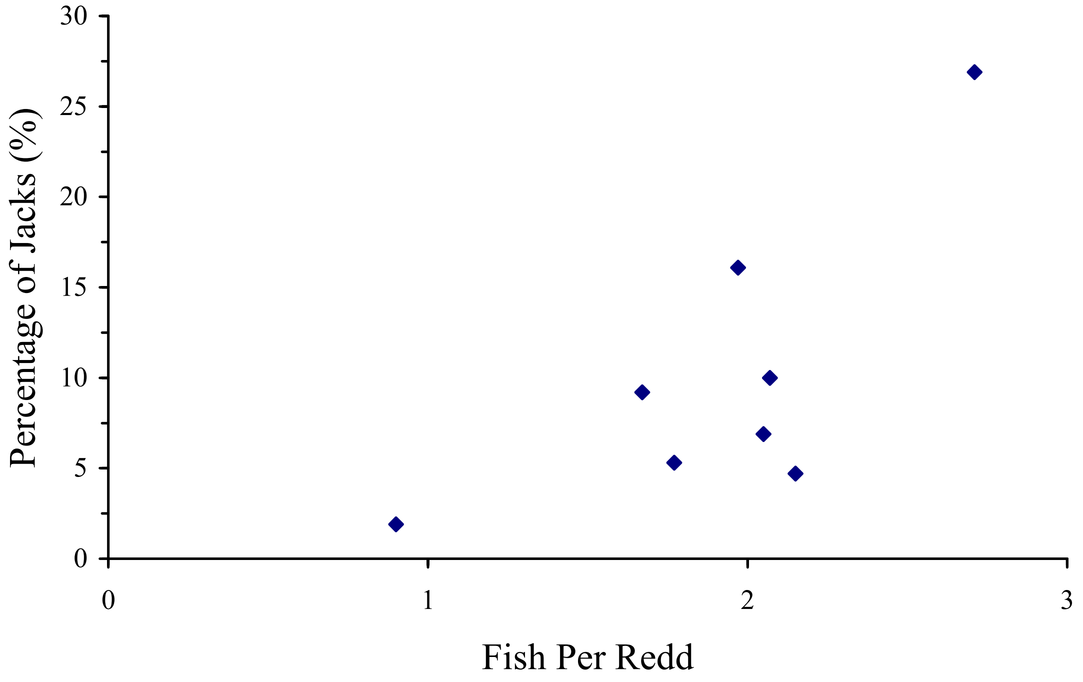

Figure 7. Relationship between the proportion of jack salmon and fish per redd values in Lake Creek from 1998 to 2005.

POTENTIAL SOURCE OF ERRORS IN UNDERWATER VIDEO MONITORING

All known sources of error were defined and corrected for in 2005. Potential sources of error in determination of adult salmon abundance by the underwater video methodology (Table 2) are described in Faurot et al. (2000). The first source is potential upstream migration of adult salmon before installation of the fish counting station. In 2005 it was highly unlikely that adult chinook salmon passed before fish count station installation. The first upstream passage occurred on June 25, 14 days after installation of the counting station. The second and third source of potential error is fish going around or under the structure. We believe that adult salmon did not get around the ends or under the fish guiding fences, as fish would have been trapped between the up and down stream guide fences (see Methods for structure description). The fourth potential source of error is passages occurring during periods of high turbidity or equipment malfuctions. In 2005, equipment down time was limited to less than 48 hours and net escapement was adjusted to account for the down time (Table 3). The last source of error is videotape reader specific error, obersevers missing or mis-identifiying fish. In 2005, observer error was estimated to be zero. There were no discrepancies between observers.

MIGRATION TIMING

Chinook Salmon

Adult chinook salmon migration timing in Lake Creek was observed from June 25 to September 4 in 2005. A total of 576 salmon passages, both upstream and downstream, were observed at the fish counting station. No adults were observed from September 5 to September 11, when fish counting station operations ceased. The salmon spawning population in Lake Creek had a median net upstream passage date of July 13**,** and the largest single day of net upstream movement occurred on July 15, when 11 fish were observed at the fish counting station (Figures 8, 9, and 10, Appendix Table A4). The maximum number of net upstream migrating salmon was in Lake Creek on August 23, when 140 fish had migrated into the stream system. Within the salmon migration period, net upstream escapement increased rapidly during the end of June and the majority of adults observed through July 4 moved upstream (Figures 8 and 9). Escapement then increased slowly until August 24, when seven fish moved downstream out of the system. The peak of the salmon spawning period in Lake Creek in 2005 occurred by August 22, and spawning was completed by September 7 (Jerry Lockhart, personal communication).

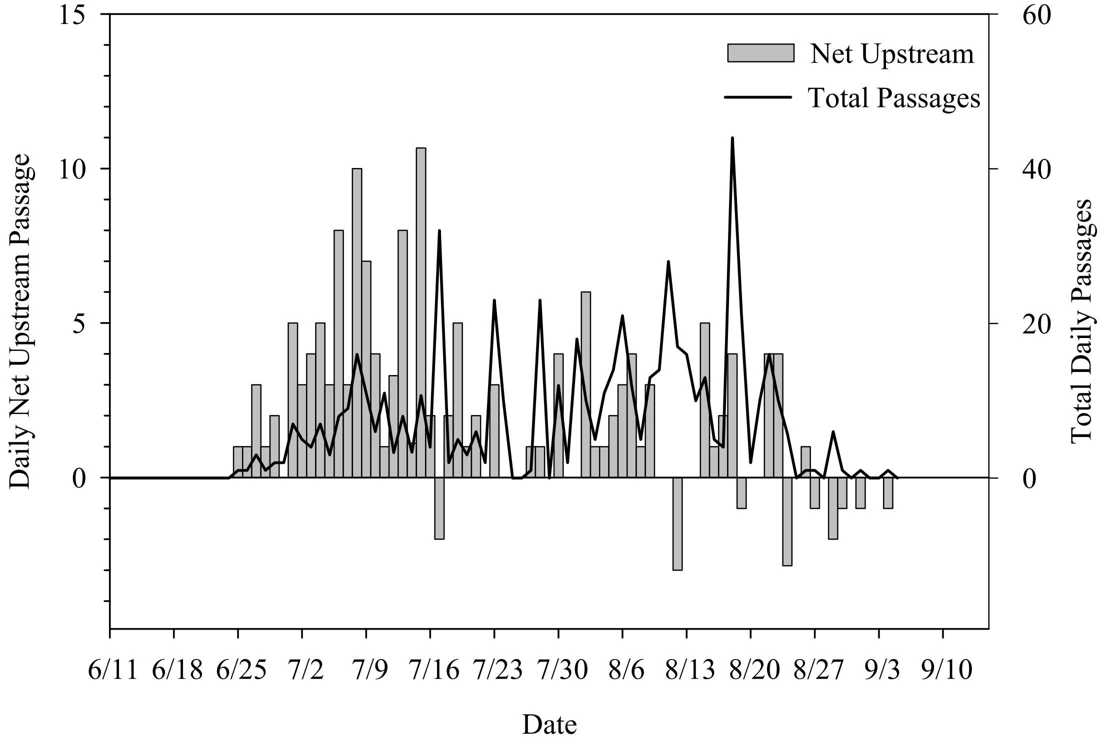

Figure 8. Daily net upstream and total movements of adult spring and summer chinook salmon through the Lake Creek fish counting station in 2005.

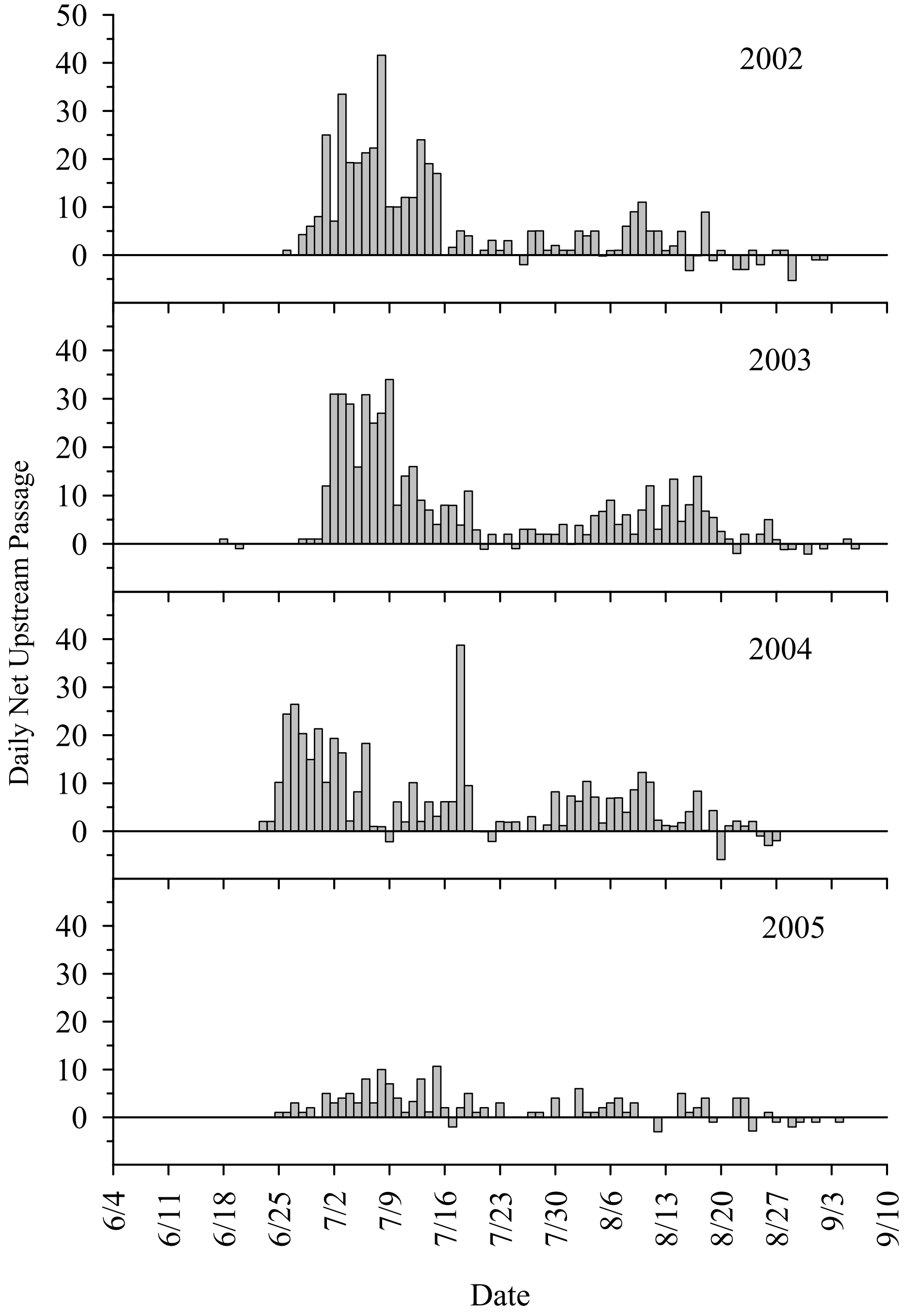

Figure 9. Net upstream spawning migration of adult spring and summer chinook salmon through the Lake Creek fish counting station from 2002 to 2005.

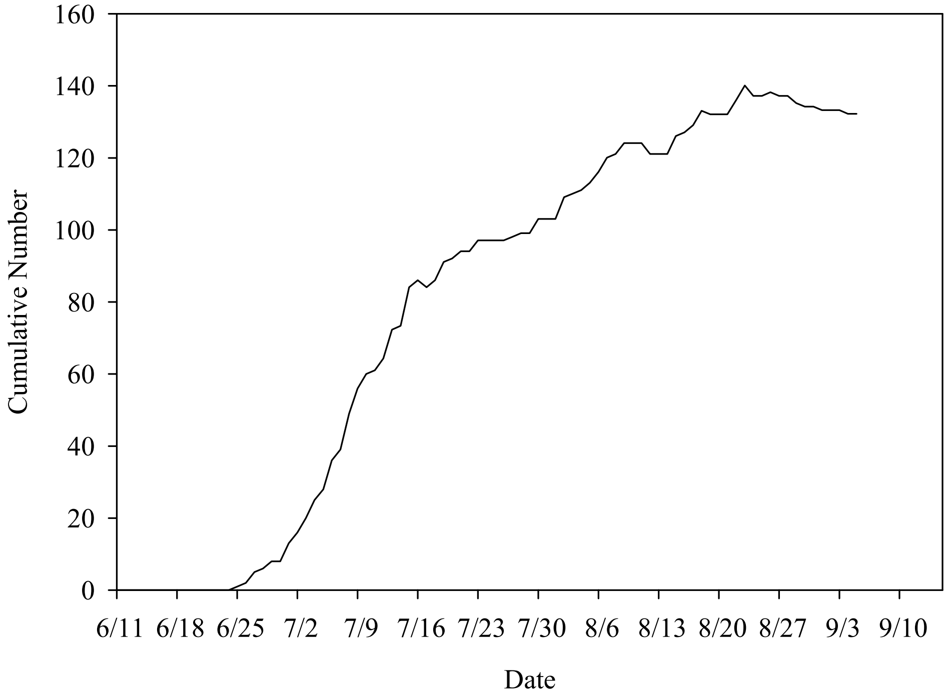

Figure 10. Cumulative observed adult spring and summer chinook salmon escapement at the Lake Creek fish counting station in 2005.

Migrating salmon in Lake Creek appeared to exhibit two behaviorally distinct segments of fish movement (Figure 8). Rapid upstream-only passages characterized the first segment of the run. The second segment of the run consisted of a larger total number of both upstream and downstream fish passages, usually by males, with less net upstream movement. In spite of the increased downstream movement, net escapement continued to increase slightly during the second segment (Figure 8).

Variation in arrival timing of the first adult salmon in Lake Creek between years has varied by more than one month, from June 9 in 2001 to July 11 in 1999 (Appendix Table A2). The earliest arriving salmon that occurred on June 9 in 2001, was observed during a drought year (38% of normal snowpack). The latest arrival of the first salmon passage occurred in 1999, when the highest observed snowpack occurred; 148% of normal. The amount of winter snowpack/water content, along with local climatic conditions, affects the magnitude and duration of spring stream flow and water temperature conditions. Changes in these physical habitat conditions along with photoperiod and fish maturation are believed to affect adult salmon migration timing.

Bull Trout

Relative numbers of bull trout, greater than 35-40 cm, were recorded as a secondary objective during the study. The fish counting station was installed on June 11 and removed on September 11, in 2005. Bull trout were observed the next day after count station installation, and fish actively moved into and out of Lake Creek from June 12 through September 11 (Figure 11). The entire bull trout movement, into and out of Lake Creek, was probably not captured in 2005. A total of 437 bull trout passages were observed. It is believed that bull trout movements observed at the fish counting station represent a mixture of both Lake Creek fish, and adfluvial bull trout that migrated into the Lake Creek system to spawn in tributary streams (Watry and Scarnecchia 2005). The largest number of total net upstream moving bull trout (112) was observed by August 12. Beginning on August 13 there was a pronounced downstream movement of bull trout out of the Lake Creek system. Fifty three bull trout remained upstream of the fish counting station after the counting station was removed for the season. Watry and Scarnecchia (2005) reported that all migratory radio tagged bull trout had entered Lake Creek by July 16, and left the stream by September 3 in 2004. The authors also noted that rapid post-spawning downstream movement of bull trout has been observed elsewhere in the Salmon River basin. That is consistent with bull trout movement patterns observed at the fish counting station in 2004 (Kucera and Faurot 2005), and the results from 2005.

The vast majority of bull trout observed at the Lake Creek fish counting station in 2005 were estimated to be less than 45 cm in total length. Length measurements of videotaped bull trout were estimated from a grid system on the back panel of the fish counting chamber, and were considered accurate to ± 5 cm. Three bull trout, or 2.9% of 103 net upstream moving fish, were 55 to 60 cm in total length. These were the largest bull trout observed at the fish counting station in 2005. Watry and Scarnecchia (2005) also reported radio tagging very few large fish (≥ 55 cm) in their migratory study of bull trout in the Secesh River in 2003 and 2004. Although the authors reported bull trout fork length data, we estimate that approximately four of 45 radio tagged fish in 2003, and three of 26 tagged bull trout in 2004 were ≥ 55 cm in length.

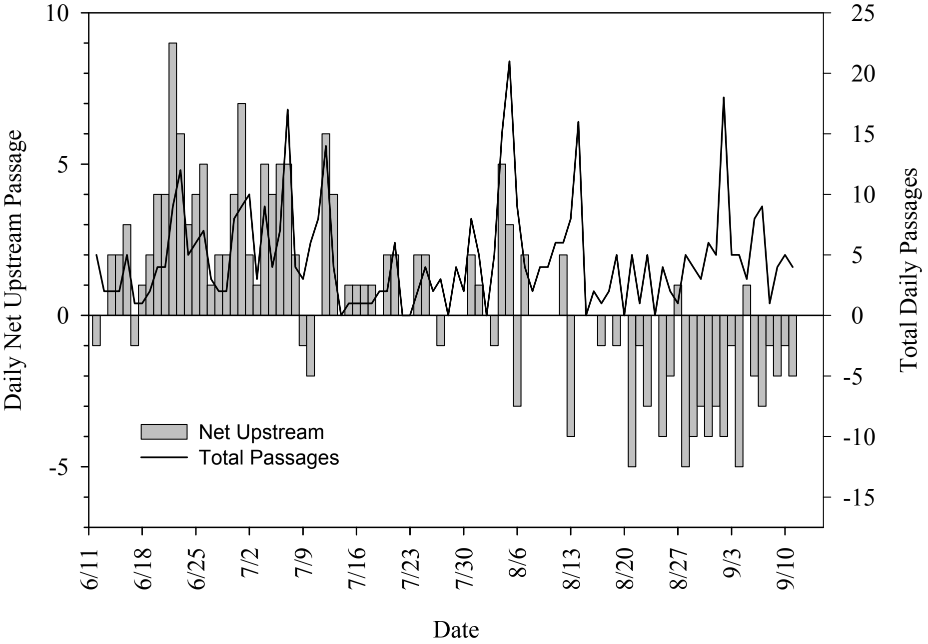

Figure 11. Net upstream movement of bull trout greater than 40 cm in Lake Creek in 2005.

REDD COUNTS

There was a total of 68 chinook salmon redds in the index area and 79 redds in extensive area redd count surveys in Lake Creek in 2005 (Jerry Lockhart - personal communication). No redds were observed downstream of the fish counting station to the mouth of Lake Creek. Index area redd counts have ranged from 1 to 296 from 1957 to 2005 (Elms-Cockrum 1999, IDFG unpublished data). Lake Creek index area and extensive area redd counts, conducted by the NPT, from 1998 to 2005 are presented in Appendix Table A3.

Redd counts provide an index of relative abundance, trend information and spawner distribution information. Redd counts are less time consuming and less expensive than alternate methods. The most commonly used measure is the index area redd count where redds are counted in the same fixed (index) area each year. IDFG conducts a single pass redd count, at the peak of spawning, for this trend information. Typically, managers expanded single pass index area chinook salmon redd counts to provide an estimate of relative abundance. Ortmann (1966) reported that "Redd counts…. while providing our best yearly trend information, introduce considerable positive bias when used to estimate the number of fish in an escapement, and should be recognized as trend indicators only". Similarly, Keifer et al. (1996) reported that index redd counts conducted by the IDFG were used for trend information, not escapement estimates. Using a power analysis, Maxwell (1999) found the power of detecting changes in bull trout population size remained low throughout the first 15 years of monitoring unless the decline or increase was as high as 50% per generation. If declines were small and steady, populations could decline by more than 47% before the decline was detected. In general, chinok salmon redd counts have provided a valuable index of relative abundance and biologically meaningful long-term population trend information.

Salmon redd count information is subject to a variety of unquantified sources of error. The most common source of redd count measurement error is observer error. Variation in redd size, age of redd, density, superimposition, water depth, turbidity, angle of the sun, stream hydraulics, substrate composition and many other factors may affect the identification of a chinook salmon redd. Redd counts are affected by the experience, or lack of experience of the observer. Counts conducted from the ground are usually more accurate than aerial counts or those conducted from a boat. The IDFG peak index area count is conducted on the predicted peak date of spawning activity. Spawning activity varies annually depending on environmental conditions. Schwartzberg and Roger (1986) found on the Yakima River, in two of the four years studied, the predicted peak date of spawning did not coincide with or even closely follow the true peak of spawning activity and redd deposition. The timing of redd counts may lead to errors if redds are formed after counting or, if redds constructed before counts are conducted become obscured before counting is initiated (Dunham et al. 2001). Both of these errors will underestimate the number of redds.

The number of redds counted in a stream depends on the area surveyed. Index areas are fixed in size while extensive area surveys cover all available salmon spawning habitats. Dunham et al. (2001) found observer redd counts within a fixed area ranged between 28 and 254% of the best estimates of bull trout redd numbers. Chinook salmon index area redd counts, which are part of the larger extensive survey area, are generally less than the extensive survey area count. However, there are exceptions as index area and extensive area survey counts are sometimes conducted by different observers, at different times and by varying methods (aerial versus ground, and single pass versus multiple pass counts). Beamesderfer et al. (1998), Faurot et al. (2000), Roger and Schwartzberg (1986) and Schwartzberg and Roger (1986) all discussed sources of error and variation in spawning ground survey redd counts.

In Idaho, different observers count chinook salmon redds in multiple streams every year. Different redd count observers do not count salmon redds identically (no variation). Rather, there is some quantifiable source of between observer redd count error. Ideally, the interobserver redd count error would be quantified annually by a number of observers on one stream or several streams. In this manner the variation could be calculated and determinations made if stream specific differences exist. This variation should be incorporated as one component of the error in redd count expansion abundance estimates.

Comparison of chinook salmon redd counts between peak index area (IDFG) and multiple pass index area (NPT) counts are presented below. The comparison was conducted to describe the difference between two different redd count methods from multiple observers in Lake Creek, and to compare the difference between two experienced redd counters in Big Creek and Johnson Creek. This difference was termed between observer/between method redd count error because it compared both different observers and different redd count enumeration techniques. Annual redd counts from the two methods did not occur on the same date.

First, chinook salmon redd counts from multiple observers was compared between peak index and multiple pass index area counts in Lake Creek from 1987 to 2005 (Appendix Table A5). The number of redds ranged from 12 to 296 during these years. It was assumed that multiple pass index area redd counts provided more accurate redd count enumeration, and the calculated percent differences were relative to those counts. In Lake Creek, the range in between observer/between method redd count error varied from -50% to + 48.9% over the 19 year period. The average percent difference between the two redd counting methods was 11.5%. The peak index area redd count method (IDFG) was positively biased in 14 out of the 19 years that were compared.

Next, between observer/between method redd count error was described for two experienced redd counters. Peak index area (IDFG) and multiple pass index area (NPT) counts are presented from upper Big Creek (1986-1999) and Johnson Creek (1987-1997). Chinook salmon redd counts in Big Creek ranged from 1 to 93 redds over the 14 year period (Appendix Table A6). Annual variation in redd counts between experienced observers in upper Big Creek ranged from -4.3% to 150%, and averaged 39.9%. The highest percent differences in redd counting between methods occurred at low redd abundances. When years of low redd abundance (< 10 redds) are excluded from the analysis, the average difference between experienced redd counters was 25.9%. Peak index area redd counts (IDFG) in Big Creek were positively biased compared to the multiple pass index area redd counts (NPT) in 13 out of the 14 years.

In Johnson Creek, redd counts ranged from 5 to 135 from 1987 to 1997 (Appendix Table A7). The range in between observer redd count error varied from -19.2% to 143.4%, with an annual average difference of 28.7%. Peak index area redd counts (IDFG) were higher than multiple pass index area counts (NPT) in Johnson Creek in nine out of the 11 years of data comparison.

Peak index area (IDFG) and multiple pass index area (NPT) redd counts were examined through regression analysis (Table 4, Appendix Figures A1-A3). Although the variation between years was high, the multiple pass and peak index redd count relationship was highly significant ($p < 0.0001$). Multiple pass index area redd counts were consistently 85 to 92% of the peak index area redd counts across streams. The consistently lower counts suggest a fundamental difference in redd identification and counting methodology between the respective agencies. Despite these fundamental differences, it appears that one agencies counts are a good predictor of the other within the three index areas assessed.

Table 4. Results of regressing multiple pass index area redd counts (NPT) against peak index area redd counts in Big Creek, Johnson Creek and Lake Creek.

Stream	Years	Slope	SE	N	R Square	P-value
Big Creek	1986-1999	0.84	0.054	14	0.95	< 0.001
Johnson Creek	1987-1997	0.92	0.091	11	0.92	< 0.001
Lake Creek	1987-2005	0.92	0.051	19	0.95	< 0.001

Accounting for between observer redd count variation is an important consideration given the annual and average percent differences in salmon redd counts described above. Salmon redd count expansion abundance estimates are currently calculated with no estimated variation, due to between observer redd count error, around the point estimates. These abundance estimates are then compared to population level viability thresholds (ICTRT 2005) and rolled up to the ESU level for larger scale recovery metrics monitoring. We recommend caution be excercised when applying redd count expansion abundance estimates to population level viability thresholds.

FISH PER REDD

Fish per redd values determined annually on Lake Creek used video determined salmon abundance and extensive area multiple pass redd counts. The fish per redd value for Lake Creek in 2005 was 1.77. Fish per redd values in Lake Creek, from 1998 to 2005, have ranged from 0.90 to 2.71 (Table 5), with a regression slope of 2.12 (Table 6). The arithmatic mean fish per redd value averaged 1.91 over the eight years of study. The average fish per redd value used each year by the PATH process (Beamesderfer et al. 1998) for the South Fork Salmon River is 2.31 fish per redd. The average fish per redd value for the South Fork Salmon River used by the Idaho Salmon Supplementation Studies is 3.2. Typically, average fish per redd numbers are used in redd count expansion abundance estimation techniques. Substantial inter-annual variation in fish per redd numbers can exist and this variation should be incorporated as a second component of error in redd count expansion abundance estimates.

Fish per redd information from five streams was examined to assess variation in the data (Figure 12). Regression analysis was employed to estimate the mean fish per redd value (slope) and standard error (SE of slope) to assess the variability between streams. All five streams were located within the Snake River basin. Fish per redd data on Johnson Creek, a South Fork Salmon River tributary, has ranged from 1.34 to 3.67 ($n = 7$) from 1998 and 2000-2005 (Craig Rabe – personal communication) (Table 5). The slope of the fish per redd regression on Johnson Creek was 3.23 (Table 6). The salmon population in Johnson Creek has been influenced by adult hatchery returns from 2001 to 2005. Fish per redd values on the Imnaha River, a hatchery influenced system, ranged from 1.6 to 8.24 fish per redd over 21 years (Fred Muncyk – personal communication), with a regression slope of 4.95. Lostine River fish per redd information has varied from 1.8 to 5.9 from 1997 to 2005 (Peter Cleary – personal communication). Slope of the fish per redd regression on the Lostine River was 4.69 (Table 6). The Lostine River is another hatchery influenced system with both conventional and captive brood returns. Fish per redd data from Lookingglass Creek (ODFW unpublished data) from 1967 to 1971 and 1992 to 1994 varied from 2.0 to 2.9 ($n = 8$), with a regression slope of 2.55. Both the Lostine River and Lookingglass Creek are located in the Grande Ronde River subbasin. Regression analysis of salmon abundance versus number of redds in these streams (Figure 12, Table 6) described the slope and 95% confidence intervals around the slope. All of the abundance versus redd regressions were highly significant ($p < 0.001$). Comparison of the slopes via a two-tailed t-test demonstrated that significant differences existed between streams (Table 7). Lake Creek was significantly different than Johnson Creek, Imnaha River and the Lostine River (Table 7); all hatchery influenced streams. It was interesting to note that Lake Creek was significantly different than another stream in the same drainage (Johnson Creek). Lake Creek represents the only wild salmon population in this comparison. Lookingglass Creek was significantly different than both the Imnaha River and the Lostine River. The Lookingglass Creek data from 1967 to 1971 is believed to represent a wild salmon population prior to supplementation efforts that were initiated in 1980 in the Grande Ronde River (Carmichael et al. 1998). The Lookingglass Creek data from 1992 to 1994 would represent a hatchery influenced system.

Significant differences in fish per redd relationships exist between chinook salmon producing streams. Caution should be excercised when applying average fish per redd values to wild and hatchery influenced salmon populations. Variation in fish per redd data should be incorporated in subsequent redd count expansion abundance estimates that utilize average fish per redd assumptions.

Table 5. Fish per redd values in Lake Creek compared to data from Johnson Creek, Imnaha River, Lookingglass Creek, and the Lostine River.

Year	Lake Creek	Johnson Creek	Lostine River[1]	Imnaha River[1]	Lookingglass Creek
1967					2.10
1968					3.01
1969					2.94
1970					2.56
1971					2.09
1985				3.71	
1986				2.92	
1987				2.94	
1988				3.04	
1989				3.50	
1990				3.37	
1991				3.61	
1992				4.04	4.49[1]
1993				2.71	2.25[1]
1994				1.67	3.02[1]
1995				6.04	
1996				2.94	
1997				2.50	
1998	0.90	1.34	5.10	3.16	
1999	2.71	NA	1.80	6.83	
2000	1.67	3.70	5.90	6.51	
2001	2.07	3.63[1]	4.70	8.24	
2002	2.05	3.31[1]	4.20	4.00	
2003	1.97	2.14[1]	5.20	6.42	
2004	2.15	2.55[1]	5.30	2.87	
2005	1.77	2.64[1]	4.20	2.19	

[1] Hatchery influenced system.

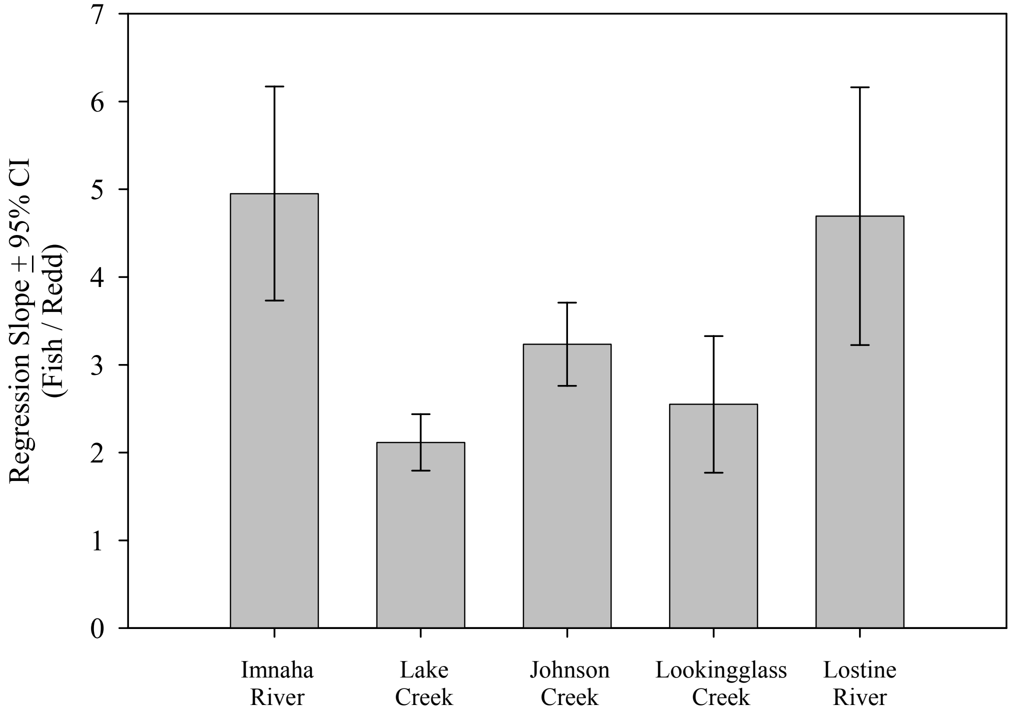

Figure 12. Mean fish per redd estimates based on regression analysis.

Table 6. Results of regressing estimated abundance against the number of redds in the Imnaha River, Lake Creek, Johnson Creek, Lookingglass Creek, and the Lostine River.

Stream	Years	Slope	SE	N	R Square	P-value
Imnaha River	1985-2005	4.95	0.58	21	0.79	< 0.001
Lake Creek	1998-2005	2.12	0.13	8	0.98	< 0.001
Johnson Creek	1998, 2000-05	3.23	0.47	7	0.90	< 0.001
Lookingglass Creek	1967-71, 1992-94	2.55	0.32	8	0.91	< 0.001
Lostine River	1997-2005	4.69	0.60	8	0.91	< 0.001

Table 7. P-values resulting from two-tailed t-test between estimates of fish per redd slopes between streams in Table 6. Significant difference at $p < 0.05$ level highlighted in bold.

Stream	Imnaha River	Lake Creek	Johnson Creek	Lookingglass Creek
Lake Creek	**0.0063***			
Johnson Creek	0.1161	**0.0314***		
Lookingglass Creek	**0.0203***	0.2287	0.2418	
Lostine River	0.8028	**0.0009***	0.0845	**0.0075***

ACCURACY OF REDD COUNT EXPANSIONS

The third objective of this study was to determine the accuracy of redd count expansion methodology compared to the underwater video determined adult abundance. Accurate and precise wild stock adult salmon abundance estimates are necessary to guide fisheries management actions for ESA listing decisions and recovery monitoring, conservation program priorities, harvest levels, and hatchery supplementation implementation and evaluation. Adult salmon abundance is determined either through a direct measurement of fish numbers (adult traps, video, resistivity, etc.) or expanding redd counts by a predetermined average fish per redd value. Expansion of redd counts to estimate abundance is influenced by redd count measurement error and uncertainty of assumptions regarding estimates of fish per redd, relative numbers in surveyed and unsurveyed areas, prespawning mortality rates, age composition, and hatchery fish composition (Beamesderfer et al. 1998). Actual abundance is used with other information to calculate derived fish performance measures, such as fish per redd numbers, spawner to spawner ratios, recruits per spawner and population growth rates. There has been a heavy reliance on the historic index area redd count database in Idaho because of its relatively long time series (1957-2005). It is important to remember the purpose of these surveys. Redd count surveys were intended to count salmon redds (not fish) and provide an index of relative abundance. The underwater video method specifically measures the adult abundance performance measure. The methods should be scrutinized based on their intended purpose and strengths and weaknesses.

Redd count expansion abundance estimates are calculated by expanding the number of redds by an average fish per redd estimate to determine a point estimate of abundance. Fish per redd numbers have been developed at several instream fish weirs throughout the Columbia River basin using various fish population estimation methods and redd counts from the same area over a period of years. Average fish per redd numbers are used to expand salmon redd counts each year. Fish per redd values vary by year, by stream, by survey area (index versus extensive area), and method used in the calculation.

Adult salmon abundance data in Lake Creek from 1998 to 2005 was compared to expanded redd count abundance point estimates (index area and extensive area surveys) to examine the difference from the actual Lake Creek video obtained abundance (Figure 13, Table 8). Three different redd count approaches were assessed and they were: 1) IDFG peak index area redd counts, 2) NPT multiple pass index area redd counts, and 3) NPT multiple pass extensive area redd counts. All three methods used ground redd counting techniques. The average fish per redd value (2.31) used by PATH (Beamesderfer et al. 1998) was used for redd count expansion abundance estimates because it represented one of the most accurate values that could be applied in the calculations. The values were then applied to Lake Creek redd counts and the point estimates compared to video determined abundance to assess the accuracy of redd count expansion techniques. Variation was expressed as the percent difference of redd count expansion point estimates from the actual abundance estimate.

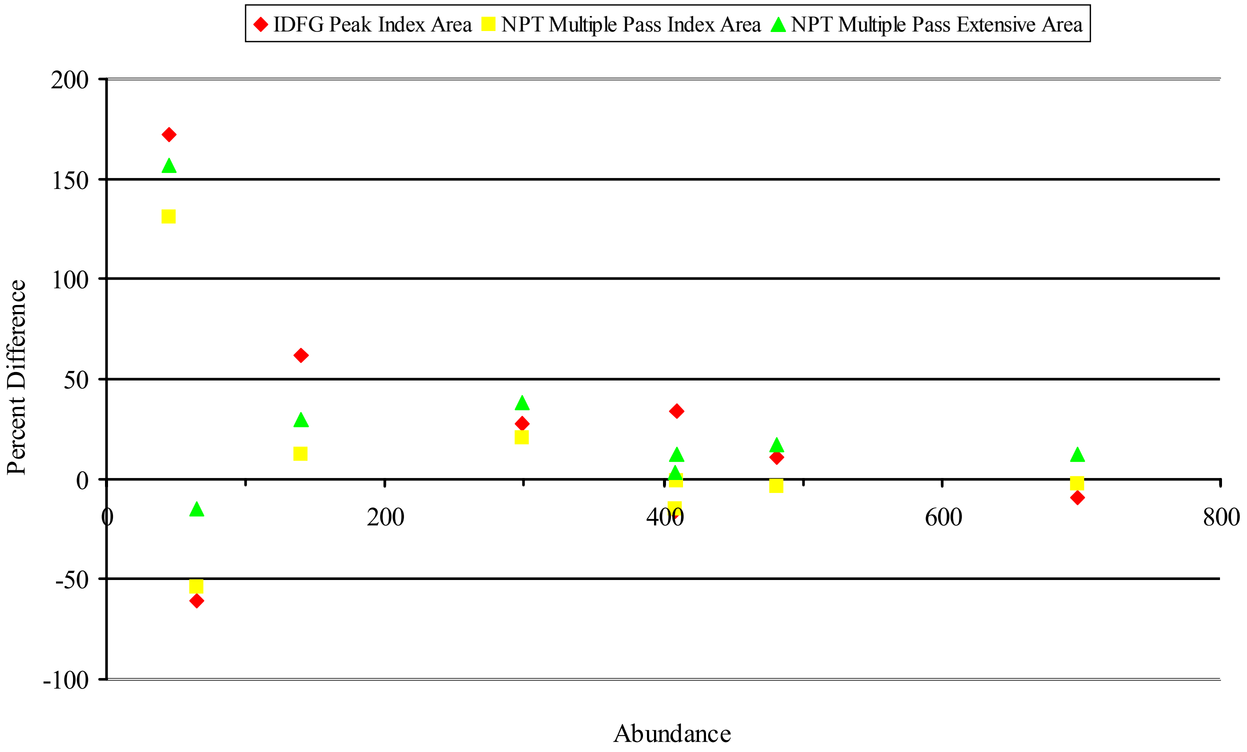

Figure 13. Estimated percent difference between chinook salmon redd count expansion abundance estimate techniques compared to underwater video determined adult salmon abundance in Lake Creek from 1998 to 2005.

Several points are apparent from this information even though it represents a limited time series of data (n = 8). First, overall, the redd count expansion techniques estimated from 60.9% fewer salmon to 172% more salmon compared to video determined salmon abundance from 1998 to 2005 (Figure 13). In general, the NPT multiple pass index area count provided the most accurate redd count expansion abundance estimate. This method estimated from 53.8% fewer to 131% more adult salmon than were actually in the stream. This result was not expected, as the extensive area redd count survey should have provided the most complete total enumeration of redds in the system to expand to an abundance estimate. The IDFG peak index area count expansion provided the most variable abundance estimates in six out of eight years of data comparison (Table 8). The IDFG peak index redd count expansion method estimated from 60.9% fewer to 172% more salmon than underwater video determined abundance (Table 8).

Table 8. Comparison of video determined adult salmon abundance with multiple pass index area redd count (NPT), multiple pass extensive area redd count (NPT), and peak index area redd count (IDFG) expansion abundance estimates in Lake Creek from 1998 to 2005.

Method	Year	Redds Counted	Video Abundance	Average Fish/Redd Expansion Value	Redd Count Expansion Fish Estimate	Numerical Difference From Video Determined Abundance	Percent Difference From Video Determined Abundance
NPT Extensive	1998	50	45	2.31	115.5	70.5	157.0
IDFG Index	1998	53	45	2.31	122.4	77.4	172.0
NPT Index	1998	45	45	2.31	103.9	58.9	131.0
NPT Extensive	1999	24	65	2.31	55.4	-9.6	-14.7
IDFG Index	1999	11	65	2.31	25.4	-39.6	-60.9
NPT Index	1999	13	65	2.31	30.0	-35.0	-53.8
NPT Extensive	2000	179	299[1]	2.31	413.5	114.5	38.3
IDFG Index	2000	165	299[1]	2.31	381.1	82.1	27.5
NPT Index	2000	157	299[1]	2.31	362.7	63.7	21.3
NPT Extensive	2001	337	697	2.31	778.5	81.5	11.7
IDFG Index	2001	276	697	2.31	637.6	-59.4	-8.5
NPT Index	2001	296	697	2.31	683.8	-13.2	-1.9
NPT Extensive	2002	200	409	2.31	462.0	53.0	12.9
IDFG Index	2002	237	409	2.31	547.5	138.5	33.8
NPT Index	2002	176	409	2.31	406.6	-2.44	-0.6
NPT Extensive	2003	244	481	2.31	563.6	82.6	17.2
IDFG Index	2003	231	481	2.31	533.6	52.6	10.9
NPT Index	2003	200	481	2.31	462.0	-19.0	-3.9
NPT Extensive	2004	183	408	2.31	422.7	14.7	3.6
IDFG Index	2004	149	408	2.31	344.2	-63.8	-15.6
NPT Index	2004	151	408	2.31	348.8	-59.2	-14.5
NPT Extensive	2005	79	140	2.31	182.5	42.5	30.3
IDFG Index	2005	98	140	2.31	226.4	86.4	61.7
NPT Index	2005	68	140	2.31	157.1	17.1	12.2

---

[1] Estimated abundance believed to represent greater than 95% of adult escapement in 2000.

Second, at low population size redd count expansion methods appear highly variable and not consistently biased. In 1998 when 45 salmon were estimated in Lake Creek (Table 1) redd count expansions were strongly positively biased (Figure 13). Redd count expansions would have estimated from 131% to 172% more chinook salmon to have been present, than were actually in the stream system.

In 1998, there was an unbalanced age structure with a low proportion of jack salmon estimated to be in the spawning run. Subsequently, the observed fish per redd value in Lake Creek in 1998 (0.90) was much lower than the PATH average fish per redd value (2.31) that was applied. In 1999, with an estimated abundance of 65 salmon in the Lake Creek system (Table 1) redd count expansions were moderately negatively biased (Figure 13). Unbalanced population age structure in 1999 was affected by jack salmon comprising an estimated 27% of the spawning run, causing a much higher fish per redd value of 2.71 fish/redd. Inconsistent bias and potential high variability in either redd count or fish per redd data make redd count expansion techniques highly inaccurate at low population size.

Finally, at larger population sizes redd count expansion techniques appear to be generally positively biased (Figure 13). Redd count expansions, at larger population size, estimated from 15.6% fewer to 33.8% greater number of chinook salmon present when compared to video determined abundance. The percent jack composition in the spawning run was comparatively less variable (range – 4.7-16%) at population sizes greater than 400 fish.

It should be noted that underwater video salmon abundance monitoring occurs at the mouth of Lake Creek as the adult spawner migration ensues. It does not take into account prespawning mortality that salmon experience upstream prior to completion of spawning activity; which the redd count data accounts for.

Inherent variation in chinook salmon redd count data and annual variation in fish per redd numbers makes it difficult to utilize redd count expansion methods to accurately estimate salmon abundance at the population level. Application of the PATH fish per redd number to the multiple pass index area redd count has produced the most accurate escapement estimate in Lake Creek. This was not intuitively obvious since the PATH average fish per redd expansion value was applied to the smallest redd count survey area (the index area), not the extensive area redd count total.

Regressions were also performed to describe the relationships between video determined salmon abundance and peak index area, multiple pass index area, and extensive area chinook salmon redd counts. (Appendix Figures A4-A6) All of the regressions were significant at the $p < 0.001$ level. Regression equations, R^2 values, and standard error of the slope information are provided.

Accurate adult abundance estimates from unsupplemented salmon spawning aggregates are a necessary tool to monitor listed species recovery metrics. Spawning ground survey redd count trend information is subject to a variety of potential sources of error. Expansion of redd count data into salmon spawner abundance estimates serves to magnify this error. The underwater video technology provided an accurate assessment of adult salmon abundance and a benchmark to compare the redd count expansion methods. We believe underwater video methodology provided an accurate abundance estimate for Lake Creek from 1998 to 2005. Redd count expansion methods provided highly variable estimates of salmon abundance, especially at low population sizes, with an unquantified error. We recommend multiple pass index area redd counts continue to be used on the majority of streams in Idaho to provide an index of relative abundance, trend information and spawner distribution. However, for streams that will be used to provide population status, population growth rate and recovery metric information to satisfy requirements of the NMFS Biological Opinion (NMFS 2000, NMFS 2004), or the ICTRT (2005) we recommend actual adult salmon abundance information to be collected to measure the effectiveness of conservation actions for threatened salmon.

STREAM TEMPERATURE AND DISCHARGE

Stream temperature and discharge were collected and compared with net upstream salmon passage (Figure 14). The fish counting station was installed on June 11 when the estimated discharge was 180 cfs. The first adult salmon passage occurred on June 25 at a stream discharge of 130 cfs, and an average daily water temperature of 11.5°C. During the salmon migration period, discharge increased to 242 cfs on June 28 and then decreased steadily throughout the summer period to a low of 25 cfs on September 4. Average daily stream temperatures increased to a high of 15.2°C on August 9, with the highest hourly water temperature reaching 18.6°C on August 8. Water temperatures declined to 9.2°C by August 31.

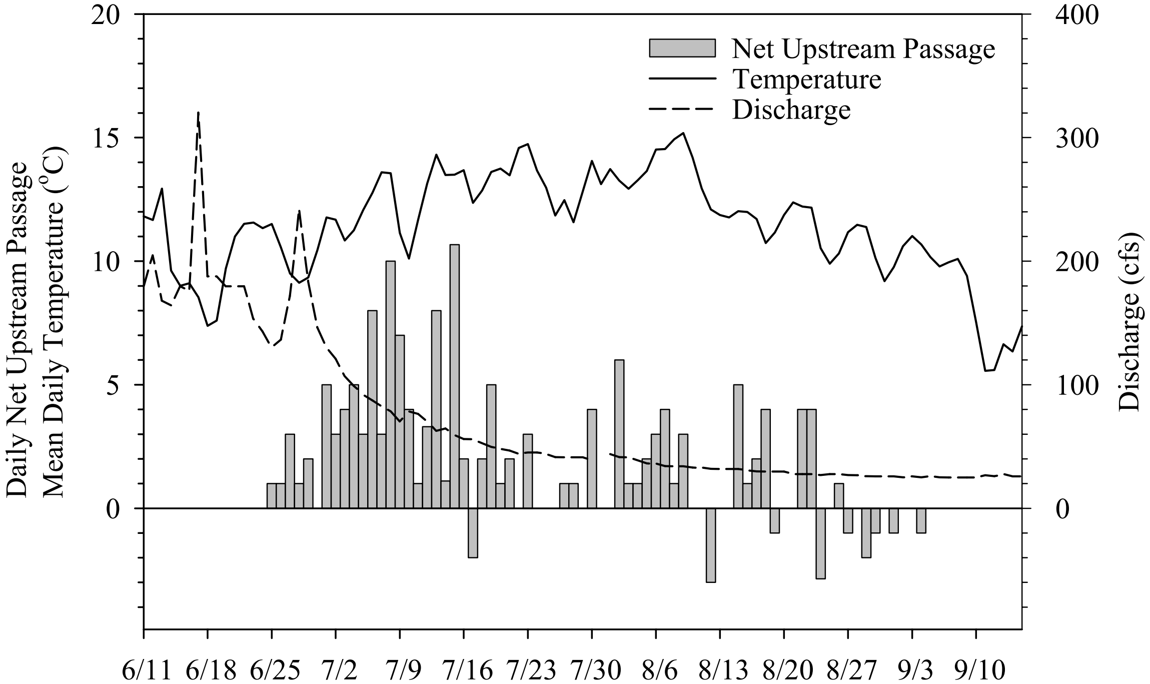

Figure 14. Stream temperature and stream discharge in relation to net upstream adult chinook salmon migration at the Lake Creek fish counting station in 2005.

RECOMMENDATIONS

- Provide extensive training to personnel. This should reduce down time due to operator error and, with the additional experience, operators would be able to quickly identify and correct for equipment malfunctions.

- Operate the Lake Creek underwater video fish counting station in 2006 to determine adult salmon abundance. Experimentally test the automated computer fish counting software to enumerate adult salmon passages. Manually count fish on a randomly selected portion of the videotapes to statistically compare the results between the two methods. Transition to automated counting of salmon as soon as it is feasible.

- The fish counting station design, which allows unimpeded downstream movement of adults, may be an important factor in the reproductive success of listed chinook salmon compared to more traditional weir designs.

- Accounting for between observer redd count variation, and variation in fish per redd values is an important consideration when performing redd count expansions to estimate salmon abundance. We recommend incorporating uncertainty around these two variables when redd count expansion abundance estimates are used to compare to listed species population viability thresholds (ICTRT 2005) and rolled up to the ESU level for larger scale recovery metrics monitoring.

- We recommend multiple pass index area redd counts continue to be used on the majority of streams in Idaho to provide an index of relative abundance, trend information and spawner distribution.

- We recommend actual adult salmon abundance information to be collected to measure the effectiveness of conservation actions for threatened salmon.

LITERATURE CITED

Beamesderfer, R. C. P., H. A. Schaller, M. P. Zimmerman, C. E. Petrosky, O. P. Langness, and L. LaVoy. 1998. Spawner-recruit data for spring and summer chinook salmon populations in Idaho, Oregon and Washington. Draft report to Marmorek, D. R., and C. N. Peters (eds.). J. Anderson, R. Beamesderfer, L. Botsford, J. Collie, B. Dennis, R. Deriso, C. Ebbesmeyer, T. Fisher, R. Hinrichsen, M. Jones, O. Langness, L. LaVoy, G. Matthews, C. Paulsen, C. Petrosky, S. Saila, H. Schaller, C. Toole, C. Walters, E. Weber, P. Wilson, M. P. Zimmerman. 1998. Plan for Analyzing and Testing Hypotheses (PATH): Retrospective and Prospective Analysis of Spring/Summer Chinook Reviewed in FY 1997. Compiled and edited by ESSA Technologies Ltd. Vancouver, B. C.

Botkin, D. B., D. L. Peterson, and J. M. Calhoun (technical editors). 2000. The scientific basis for validation monitoring of salmon conservation and restoration plans. Olympic Natural Resources Technical Report. University of Washington, Olympic Natural Resources Center. Forks, Washington, USA

Bowles, E. and E. Leitzinger. 1991. Salmon supplementation studies in Idaho rivers (ISS). Experimental design. Idaho Department of Fish and Game. Prepared for Bonneville Power Administration. Portland, OR.

Calvin, L.D. 1975. Estimating Night Fish Passage over Bonneville, The Dalles and John Day Dams. U.S. Corps of Engineers Report, Portland District, OR.

Carmichael, R.W., S.J. Parker, and T.A. Whitesel. 1998. Status review of the spring chinook salmon hatchery program in the Grande Ronde River basin, Oregon. In Proceedings of the Lower Snake River Compensation Plan Status Review Symposium. U.S. Fish and Wildlife Service. Boise, ID.

Cowley, K. and P. Kucera. 1989. Chinook salmon spawning ground survey in Big Creek, Johnson Creek, Secesh River and Lake Creek, Salmon River subbasin, Idaho 1989. Nez Perce Tribe Department of Fisheries Management. Lapwai, Idaho.

Dunham, J. B., B. E. Rieman, and K. Davis. 2001. Sources and magnitude of sampling error in redd counts for bull trout *Salvelinus confluentus.* North American Journal of Fisheries Management 21:343-352.

Elms-Cockrum, T. E. 1999. Salmon spawning ground surveys, 1998. Idaho Department of Fish and Game. Pacific Salmon Treaty Program: Award No. NA67FP0325 IDFG 99-32, November 1999. 26 p. plus appendices.

Faurot, D. and P. A. Kucera. 1999. Escapement monitoring of adult chinook salmon in the Secesh River and Lake Creek, Idaho, 1997. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Faurot, D., P. A. Kucera and J. Hesse. 2000. Escapement monitoring of adult chinook salmon in the Secesh River and Lake Creek, Idaho, 1998. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Faurot, D. and P. A. Kucera. 2001a. Adult chinook salmon abundance monitoring in the Secesh River and Lake Creek, Idaho, 1999. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Faurot, D. and P. A. Kucera. 2001b. Adult chinook salmon abundance monitoring in the Secesh River and Lake Creek, Idaho, 2000. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Faurot, D. and P. A. Kucera. 2002. Adult chinook salmon abundance monitoring in Lake Creek, Idaho, 2001. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Faurot, D. and P. A. Kucera. 2003. Chinook salmon adult abundance monitoring in Lake Creek, Idaho, 2002. Annual Report to the U. S. Department of Energy, Bonneville Power Administration by the Nez Perce Tribe Department of Fisheries Resources Management. Contract No. 97AM30423, Project No. 97-030.

Fish Management Consultants. 1991. Feasibility, design and location of a weir for escapement estimation of summer chinook salmon in the Secesh River, Idaho. Report prepared for the Nez Perce Tribe. Fish Management Consultants, Olympia, WA.

Foose, T. J. ,L. deBour, U. S. Seal and R. Lande. 1995. Conservation Management Strategies based on viable populations. Pages 273-294 *in* J. D. Ballou, M. Gilpin and T. J. Foose eds. Population Management for Survival and Recovery. Columbia University Press. New York, Chichester, West Sussex.

Hatch, D.R., M. Schwartzberg, and P.R. Mundy. 1994a. Estimation of Pacific Salmon Escapement with a Time-Lapse Video Recording Technique. North American Journal of Fisheries Management 14:626-635.

Hatch, D.R., D.R. Pederson, J.K. Fryer, M. Schwartzberg, and A. Wand. 1994b. The Feasibility of Documenting and Estimating Adult Fish Passage at Large Hydroelectric Facilities in the Snake River Using Video Technology. Columbia River Inter-Tribal Fish Commission, Annual Report to Bonneville Power Administration, Contract DE-BI79-92BP61404.

Hatch, D. R., J.K. Fryer, M. Schwartzberg, D.R. Pederson, and A. Wand. 1998. A Computerized Editing System for Video Monitoring of Fish Passage. North American Journal of Fisheries Management 18(3) 694-699.

Hevlin, W. and S. Rainey. 1993. Considerations in the Use of Adult Fish Barriers and Traps in Tributaries to Achieve Management Objectives. Paper presented at the National American Fisheries Society Annual Meeting, 1993, Portland, OR.

Holubetz, T. B., and B.D. Leth. 1996. Evaluation and Monitoring of Wild/Natural Steelhead Trout Production. Annual Progress Report to BPA, 1995. Idaho Department of Fish and Game. Boise, ID.

Interior Columbia River Technical Recovery Team (ICTRT). 2004. Preliminary guidelines for population-level abundance, productivity, spatial structure, and diversity supporting viable salmonid populations: An update. Interior Columbia River Technical Recovery Team. December 13, 2004.

Interior Columbia River Basin Technical Recovery Team (ICTRT). 2005. Interior Columbia Basin TRT: Viability criteria for application to interior Columbia basin salmonid ESUs. Interior Columbia River Basin Technical Recovery Team. July, 2005.

Johnson, R. L., C. A. McKinstry and R. P. Mueller. 2004. Chinook salmon adult abundance monitoring – Hydroacoustic assessment of chinook salmon escapement to the Secesh River, Idaho. Prepared for Bonneville Power Adminstration, Contract DE-AC06-76RL01830. Pacific Northwest National Laboratory, Richland, WA.

Keifer, S., M. Rowe and K. Hatch. 1996. Stock summary reports for Columbia River anadromous salmonids, Volume V: Idaho subbasins. Prepared for BPA project Number 88-108. Idaho Department of Fish and Game. Boise, ID.

Kucera, P.A. 1987. Chinook salmon spawning ground survey in Big Creek, Johnson Creek, Secesh River and Lake Creek, Salmon River subbasin, Idaho 1987. Nez Perce Tribe Department of Fisheries Management. Lapwai, Idaho.

Kucera P. A. and M. J. Banach. 1991. Chinook salmon spawning ground survey in Big Creek, Johnson Creek, Secesh River and Lake Creek, Salmon River subbasin, Idaho - 1990. Nez Perce Tribe Department of Fisheries Management. Lapwai, Idaho.

Kucera P. A. and M.L. Blenden. 1994. Chinook salmon spawning ground survey in Big Creek, and tributary streams of the South Fork Salmon River, Idaho - 1991. In LSRCP Evaluation Studies Annual Report – 1991. AFF1/LSR-94-12. Nez Perce Tribe Department of Fisheries Resources Management. Lapwai, Idaho.

Kucera P. A. and M.L. Blenden. 1999. Chinook salmon spawning ground survey in Big Creek, and tributary streams of the South Fork Salmon River, Idaho – 1992 - 1995. Assessment of the status of salmon spawning aggregates in the Middle Fork Salmon River and South Fork Salmon River. Nez Perce Tribe Department of Fisheries Resources Management. Technical Report 99-7. Lapwai, Idaho.

Maxwell, B. A. 1999. A power analysis on the monitoring of bull trout stocks using redd counts. North American Journal of Fisheries Management 19:860-866.

McCart, P. 1969. Digging behavior of *Onchorhynchus nerka* spawning in streams at Babine Lake, British Columbia. *In:* Symposium on salmon and trout in streams, T. G. Northcote, (ed). H. R. McMillan Lectures in Fisheries. University of British Columbia: 39-51.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. U. S. Department of Commerce. NOAA Technical Memorandum. NMFS-NWFSC-42,156 p.

Nelson, R. L., D. C. Burns, K. L. Ketchu and D. D. Newbery. 2002. Deposition of fine in the South Fork Salmon River and Chamberlain Creek watersheds Payette and Boise National Forests, Idaho. 78 pages. Unpublished report, McCall, ID. U. S. Department of Agriculture, Payette National Forest.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon, final rule. Federal Register 57:78 (22 April 1992) 7:14, 653,663.

NMFS (National Marine Fisheries Service). 2000. Final Biological Opinion: Operation of the federal Columbia River power system including the juvenile fish transportation program and the Bureau of Reclamation's 31 projects, including the entire Columbia Basin Project. December 21, 2000

NMFS (NOAA Fisheries). 2002. Interim abundance and productivity targets for interior Columbia basin salmon and steelhead listed under the Endangered Species Act (ESA). Letter to Northwest Power Planning Council. April 4, 2002. National Oceanic and Atmospheric Administration. National Marine Fisheries Service. Seattle, WA.

NOAA Fisheries. 2004. Endangered Species Act – Section 7 consultation biological opinion. Concultation on remand for operation of the Columbia River power system and 19 Bureau of Reclamation projects in the Columbia basin (revised and reissued pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)). F/NWR/2004/00727. NOAA Fisheries, Northwest Region. Seattle, WA

Ortmann, D. 1966. Salmon and steelhead investigations. Investigations Project F49-R-3 (1964), Job 1: salmon and steelhead harvest and escapement studies, South Fork of Salmon River. Idaho Department of Fish and Game, Boise, ID.

River Masters Engineering. 1994. Preliminary design of a non-impeding fish counting facility in the Secesh River for adult summer chinook. Prepared for Nez Perce Tribe Fisheries Resources Management. Pullman, WA.

Roger, P. B. and M. Schwartzberg. 1986. An annotated compendium of spawning ground surveys in the Columbia River Basin above Bonneville Dam, 1960-1984. Columbia River Inter-Tribal Fish Commission Technical Report 86-1. Portland, OR.

Schwartzberg, M. and P. B. Roger. 1986. Observations on the accuracy of redd counting techniques used in the Columbia basin. Columbia River Inter-Tribal Fish Commission Technical Report 86-2.

U.S. Army Corps of Engineers. 2004. web site Fish Passage Report 2004.

Walters J., J. Hansen, J. Lockhart, C. Reighn, R. Keith, and Jill Olson. 2000. Idaho supplementation studies, five year report 1992 – 1996. Prepared for Bonneville Power Administration. IDFG Report Number 99-14. Idaho Department of Fish and Game, Boise, Idaho.

Watry, C.B. and D.L. Scarnecchia. 2005. Migratory patterns of bull trout in the Secesh River watershed, Idaho. Final completion report to Payette National Forest. University of Idaho. Moscow, ID.

APPENDIX A

Table A1. Dates and hours of equipment downtime at the Lake Creek fish counting station in 2005.

Date	Equipment Stopped	Equipment Re-Started	Hours of Outage
06/17/05	4:52:00	7:30:00	2:38:00
06/17/05	21:30:00	0:00:00	2:30:00
06/18/05	0:00:00	6:15:00	6:15:00
07/12/05	21:45:00	0:00:00	2:15:00
07/13/05	0:00:00	6:00:00	6:00:00
07/14/05	21:40:00	0:00:00	2:20:00
07/15/05	0:00:00	6:00:00	6:00:00
08/24/05	16:47:00	0:00:00	7:13:00
08/25/05	0:00:00	11:22:00	11:22:00

Table A2. Summary of major chinook salmon escapement dates in Lake Creek from 1998 to 2005.

	Year							
	1998	1999	2000	2001	2002	2003	2004	2005
Installation	22 June	9 July	22 June	21 May	11 June	16 June	11 June	11 June
First fish	8 July	11 July	Prior to 22 June	9 June	26 June	28 June	23 June	25 June
Peak net upstream movement	18 July (6)	20 July (14)	27 June (27)	22 June (54)	8 July (41)	9 July (34)	18 July (27)	8 July (10)
Median net upstream passage	18 July	21 July	Undeter-mined	29 June	8 July	10 July	11 July	13 July
Peak of activity	6 August (29)	19 August (34)	7 August (113)	22 June (54)	18 August (57)	19 August (97)	9 August (89)	18 August (44)
Last fish	26 August	3 September	31 August	6 September	2 September	6 September	27 August	4 September
Operation ceased	15 September	13 September	12 September	14 September	11 September	12 September	5 September	11 September
Total fish passages	222	418	1,265	1,793	1,337	1,456	1,375	576
Escapement	45	65	299	697	409	481	408	140

Table A3. Chinook salmon redd count data from the Secesh River and tributaries from 1998 to 2005.

	Lake Creek						
Year	Index Area	Non-index Area	Secesh River main-stem[2]	Summit Creek	Grouse Creek	Lick Creek	Total Secesh Drainage Redds
1998	45	5	54	8	5	0	117
1999	13	11	34	8	0	0	66
2000	157[1]	22	118	7	23	0	327
2001	296[1]	41	276	36	66	3	718
2002	176[1]	24	244	55	29	0	528
2003	200[1]	44	257	61	31	2	595
2004	151	32	146	53	13	0	395
2005	68	11	102	6	18	0	205

[1] Redds observed between video count station and the mouth of Lake Creek: 2000-1 redd; 2001-1 redds; 2002-2 redds; and 2003-2 redds.

[2] Six redds and five redds were counted below the DIDSON monitoring site in the Secesh River in 2004 and 2005, respectively.

Table A4. Dates of net upstream migration and total movements of adult spring and summer chinook salmon through the Lake Creek fish counting station in 2005.

Date	Net Up	Total Movements	Cumulative Net Upstream
25-Jun	1	1	1
26-Jun	1	1	2
27-Jun	3	3	5
28-Jun	1	1	6
29-Jun	2	2	8
30-Jun	0	2	8
1-Jul	5	7	13
2-Jul	3	5	16
3-Jul	4	4	20
4-Jul	5	7	25
5-Jul	3	3	28
6-Jul	8	8	36
7-Jul	3	9	39
8-Jul	10	16	49
9-Jul	7	11	56
10-Jul	4	6	60
11-Jul	1	11	61
12-Jul	3	3	64
13-Jul	8	8	72
14-Jul	1	3	73
15-Jul	11	11	84
16-Jul	2	4	86
17-Jul	-2	32	84
18-Jul	2	2	86
19-Jul	5	5	91
20-Jul	1	3	92
21-Jul	2	6	94
22-Jul	0	2	94
23-Jul	3	23	97
24-Jul	0	10	97
25-Jul	0	0	97
26-Jul	0	0	97
27-Jul	1	1	98
28-Jul	1	23	99
29-Jul	0	0	99

Table A4. continued

Date	Net Up	Total Movements	Cumulative Net Upstream
30-Jul	4	12	103
31-Jul	0	2	103
1-Aug	0	18	103
2-Aug	6	10	109
3-Aug	1	5	110
4-Aug	1	11	111
5-Aug	2	14	113
6-Aug	3	21	116
7-Aug	4	12	120
8-Aug	1	5	121
9-Aug	3	13	124
10-Aug	0	14	124
11-Aug	0	28	124
12-Aug	-3	17	121
13-Aug	0	16	121
14-Aug	0	10	121
15-Aug	5	13	126
16-Aug	1	5	127
17-Aug	2	4	129
18-Aug	4	44	133
19-Aug	-1	21	132
20-Aug	0	2	132
21-Aug	0	10	132
22-Aug	4	16	136
23-Aug	4	10	140
24-Aug	-3	5	137
25-Aug	0	0	137
26-Aug	1	1	138
27-Aug	-1	1	137
28-Aug	0	0	137
29-Aug	-2	6	135
30-Aug	-1	1	134
31-Aug	0	0	134
1-Sep	-1	1	133
2-Sep	0	0	133
3-Sep	0	0	133
4-Sep	-1	1	132
5-Sep	0	0	132

Table A5. Multiple observer chinook salmon index area redd counts from peak index surveys (IDFG) and multiple pass index surveys (NPT), and annual percent difference of redd counts from multiple pass index counts in Lake Creek from 1987 to 2005.

Year	Peak Index Area Redd Count	Multiple Pass Index Area Redd Count	Percent Difference Compared to Multiple Pass Index Redd Count
1987	43	39	10.2
1988	68	48	41.7
1989	39	36	8.3
1990	20	40	- 50
1991	47	34	38.2
1992	55	43	27.9
1993	44	44	0
1994	8	12	- 33.3
1995	14	12	16.7
1996	37	32	15.6
1997	67	45	48.9
1998	53	45	17.8
1999	11	13	- 15.3
2000	165	157	5.1
2001	276	296	- 6.7
2002	237	176	34.6
2003	231	200	15.5
2004	149	151	- 1.3
2005	98	68	44.1

Table A6. Experienced observer chinook salmon index area redd counts from peak index surveys (IDFG) and multiple pass index surveys (NPT), and annual percent difference of redd counts from multiple pass index counts in Big Creek from 1986 to 1999. Experienced observer comparison included Don Andersen (IDFG) and Paul Kucera (NPT).

Year	Peak Index Area Redd Count	Multiple Pass Index Area Redd Count	Percent Difference Compared to Multiple Pass Index Redd Count
1986	67	41	63.4
1987	36	24	50
1988	101	93	8.6
1989	30	26	15.4
1990	20	13	53.8
1991	13	12	8.3
1992	22	23	- 4.3
1993	56	46	21.7
1994	3	2	50
1995	2	1	100
1996	1	1	0
1997	33	26	26.9
1998	15	13	15.4
1999	10	4	150

Table A7. Experienced observer chinook salmon index area redd counts from peak index surveys (IDFG) and multiple pass index surveys (NPT), and annual percent difference of redd counts from multiple pass index counts in Johnson Creek from 1987 to 1997. Experienced observer comparison included Don Andersen (IDFG) and Paul Kucera (NPT).

Year	Peak Index Area Redd Count	Multiple Pass Index Area Redd Count	Percent Difference Compared to Multiple Pass Index Redd Count
1987	72	59	22
1988	137	135	1.5
1989	42	52	- 19.2
1990	56	23	143.5
1991	64	57	12.3
1992	76	49	55.1
1993	142	126	12.7
1994	20	23	- 13
1995	9	5	80
1996	23	21	9.5
1997	94	84	11.9

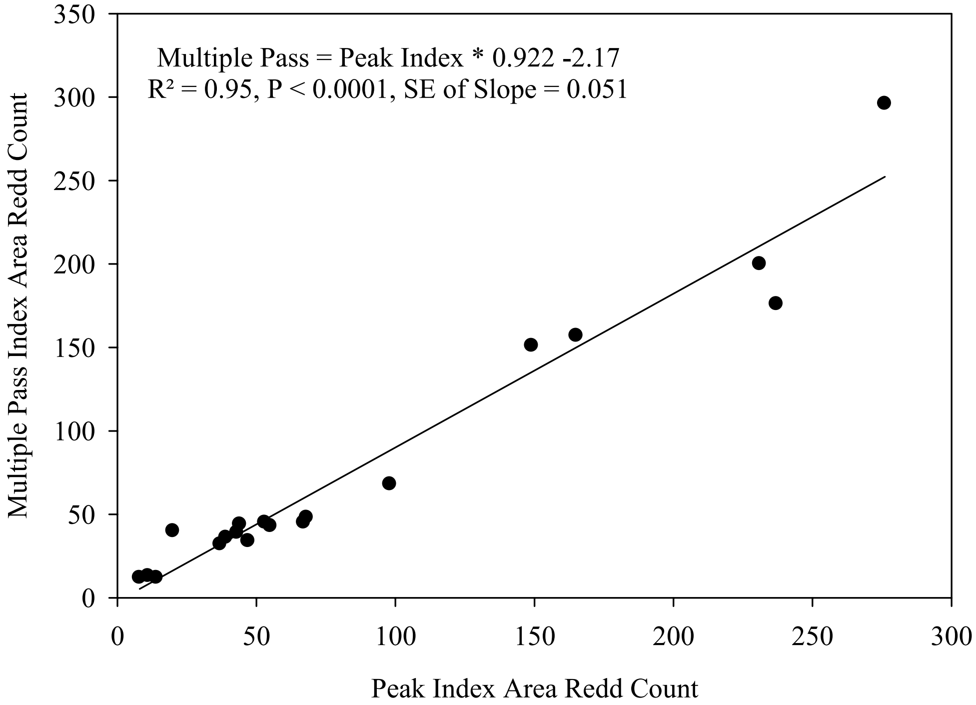

Figure A1. Linear regression between multiple observer peak index area salmon redd counts (IDFG) and multiple pass index area redd counts (NPT) in Lake Creek from 1987 to 2005.

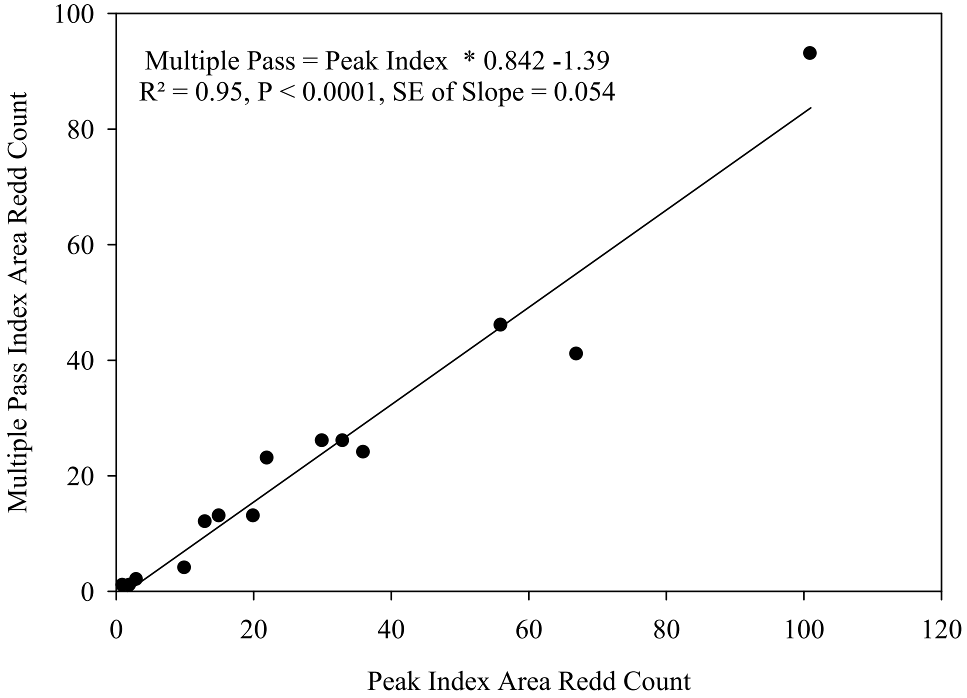

Figure A2. Linear regression between experienced observer peak index area salmon redd counts (IDFG) and multiple pass index area redd counts (NPT) in Big Creek from 1986 to 1999.

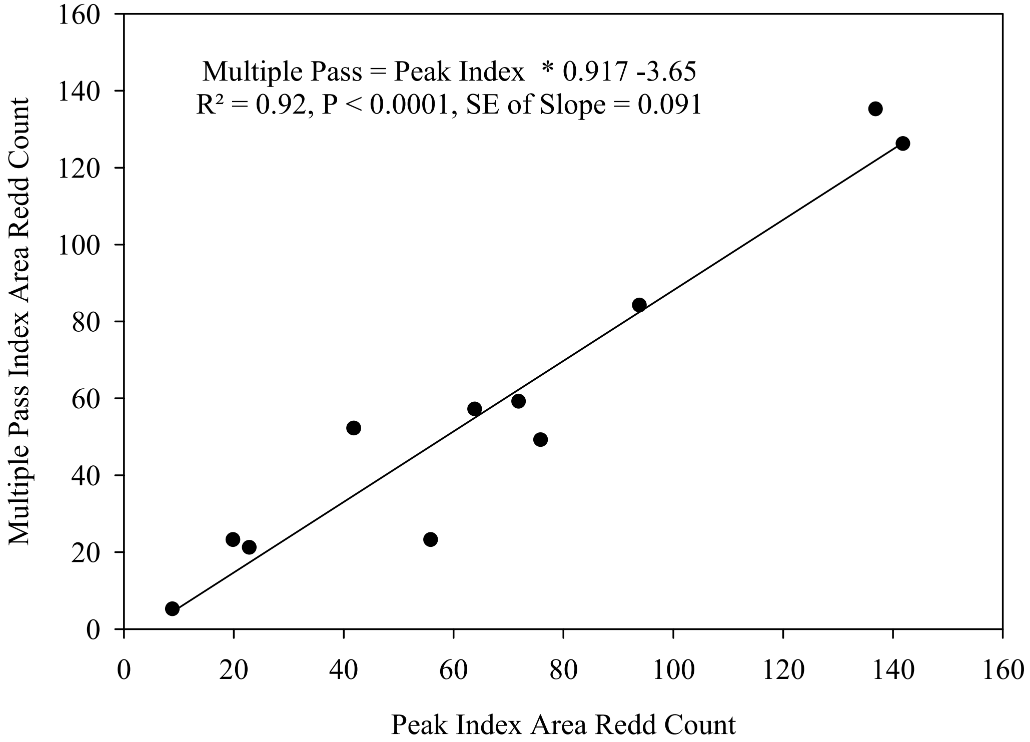

Figure A3. Linear regression between experienced observer peak index area salmon redd counts (IDFG) and multiple pass index area redd counts (NPT) in Johnson Creek from 1987 to 1997.

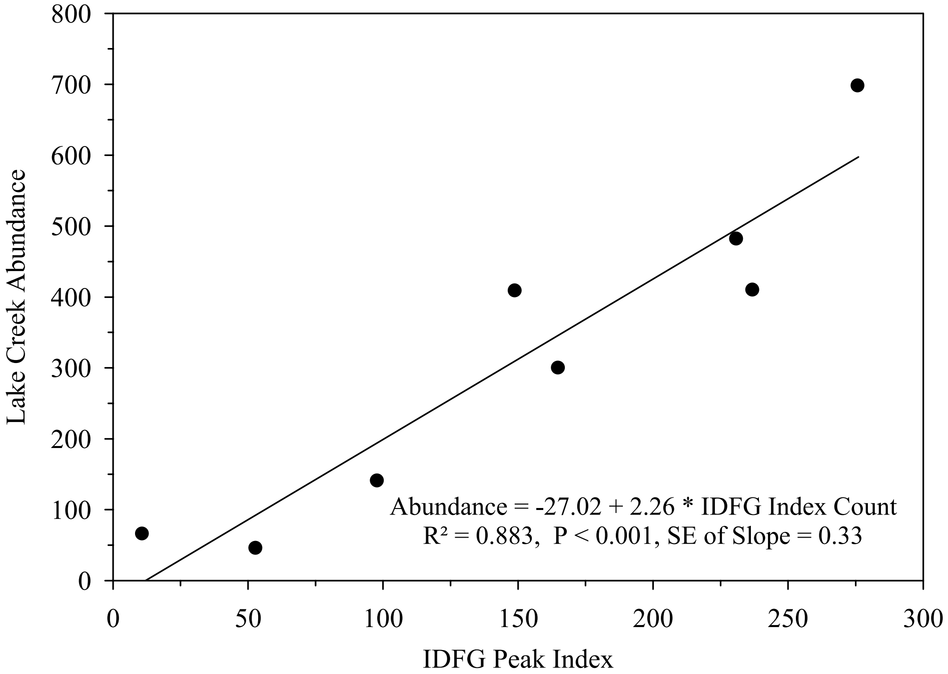

Figure A4. Linear regression between underwater video determined abundance and peak index area salmon redd counts (IDFG) in Lake Creek from 1998 to 2005.

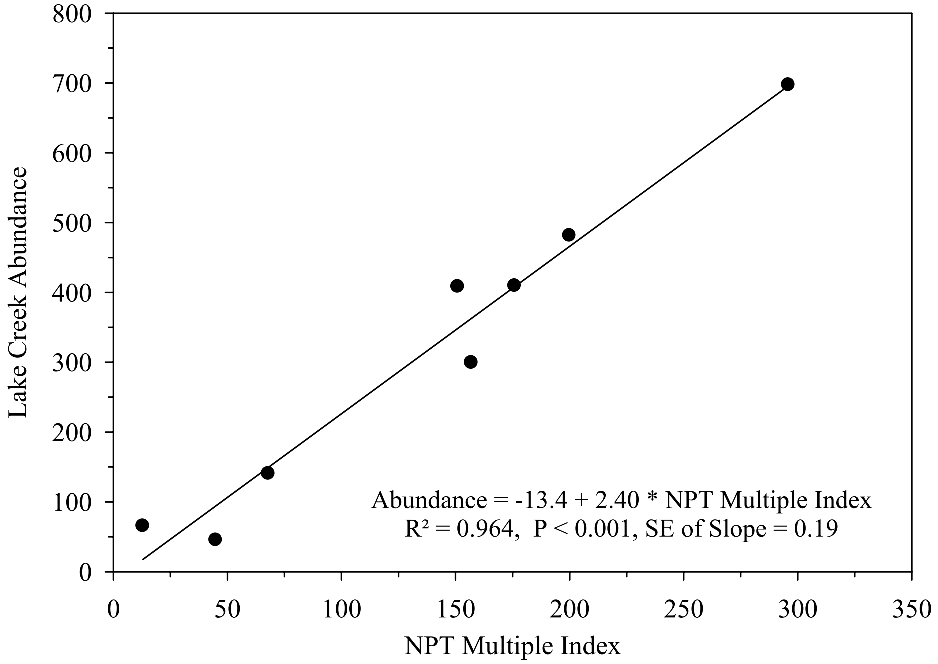

Figure A5. Linear regression between underwater video determined abundance and multiple pass index area salmon redd counts (NPT) in Lake Creek from 1998 to 2005.

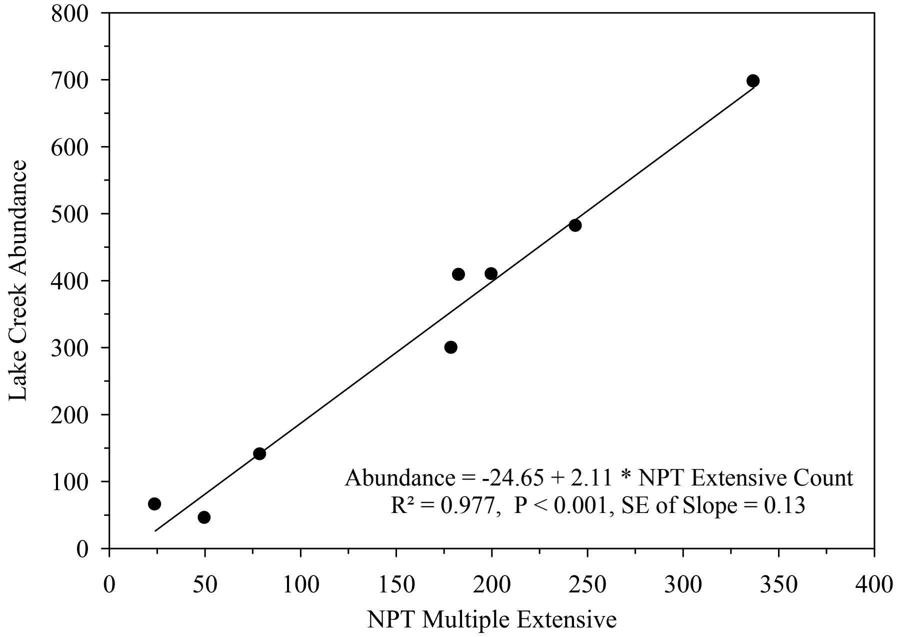

Figure A6. Linear regression between underwater video determined abundance and multiple pass extensive area salmon redd counts (NPT) in Lake Creek from 1998 to 2005.

CHAPTER 2

Use of Dual Frequency Identification Sonar to Determine Adult Chinook Salmon *(Oncorhynchus tshawytscha)* Abundance in the Secesh River

Annual Report

January 2005 – December 2005

Prepared by:

Paul A. Kucera and Rick W. Orme

Nez Perce Tribe
Department of Fisheries Resources Management
Lapwai, ID 83540

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 199703000
Contract Number 00020615

June 2006

ABSTRACT

Dual frequency identification sonar (DIDSON) was used for adult spring and summer chinook salmon population status monitoring in the Secesh River in 2005. Secesh River chinook represent a wild salmon population within the South Fork Salmon River system. DIDSON provided a non-invasive method for salmon escapement monitoring that avoided trapping and handling incidental mortality, and fish impedance related concerns. This was an important consideration when dealing with an Endangered Species Act listed species.

The DIDSON monitoring site was operated continuously from June 8 to September 19. The first salmon passage was observed on June 11, three days after installation of the DIDSON unit. Total estimated salmon abundance, natural and hatchery, was 339 fish ±3 fish (95% confidence interval). The DIDSON unit was operational 96.5% of the salmon migration period.

The salmon spawning migration in the Secesh River occurred from June 11 to September 11, with 4,682 fish passages observed at the DIDSON monitoring site. Median net upstream salmon passage was observed on July 14, and the maximum number of net upstream migrating salmon was above the DIDSON monitoring site on August 27.

Fish targets that were identified as chinook salmon via the DIDSON technology were validated by an independent technique, underwater optical cameras. Validation monitoring in 2005 occurred during daytime and nighttime periods, within the validation zone. Validation information from 14 randomly selected days indicated the DIDSON technology successfully acquired 100% of 435 total salmon passages observed on optical cameras during validation monitoring in the Secesh River.

Adult spring and summer chinook salmon escapement was estimated for the entire Secesh River drainage for effective population management and for use in listed species recovery monitoring. Wild stock salmon abundance in the Secesh River in 2005 was 344 fish. Wild salmon abundance levels in the Secesh River in 2005 have declined by 63% from population levels observed in 2004.

Secesh River wild stock adult abundance information, from 1998 to 2005, provided in this report has been standardized and refined. Salmon abundance data from this annual report supercedes that presented in previous years' reports.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The Nez Perce Tribe provided the administrative framework for successful operation of this project. We acknowledge the Bonneville Power Administration for providing funding for this research project. The authors greatfully acknowledge the contribution of Bob Johnson of the Pacific Northwest National Laboratory (PNNL), whose idea it was to utilize DIDSON technology as an adult salmon abundance monitoring technique and for technical assistance in sonar operations. We would like to thank Nez Perce Tribe Department of Fisheries Resources Management personnel Mike Busby and Dan Felt for project operations and structure placement. We especially thank the Tribal Idaho Salmon Supplementation (ISS) study personnel Jerry Lockhart, Ryan Kinzer, Travis Covel, and Neal Meshell for sharing of salmon redd count and carcass recovery data and for assistance in the field. Rishi Sharma and Chris Beasley provided statistical consulting to standardize salmon abundance estimation methods and variance estimators. Jay Hesse provided review and comments on an earlier version of this report. We also thank Ed Belcher and Bill Hanot of Sound Metrics for assistance with DIDSON operations and computer software.

INTRODUCTION

Determination of adult spawner abundance is a critical aspect of a viable population management strategy (Foose et al. 1995, Botkin et al. 2000) which is recognized within the scientific community, in listed species recovery planning (NMFS 2000, NMFS 2002, McElhaney et al. 2000), and for effective resource management. Spring and summer chinook salmon (*Oncorhynchus tshawytscha*) in the Snake River basin were listed as threatened under the Endangered Species Act in 1992 (NMFS 1992). Currently, there is limited quantitative information available to determine chinook salmon abundance in Snake River basin streams.

The research division of the Nez Perce Tribe Department of Fisheries Resources Management has been investigating new and innovative methods to determine adult salmon abundance in Snake River basin streams. Underwater video has proven to be an effective method for quantifying adult salmon abundance in smaller headwater stream environments. However, underwater video and temporary weir structures have not proven effective in larger chinook salmon producing streams (Faurot et al. 2000, Faurot and Kucera 2001a, and Faurot and Kucera 2001b). Dual frequency identification sonar (DIDSON) was identified as a potential technology for salmon escapement monitoring that does not require permanent structures and can operate during high spring flows and turbid stream conditions. In 2003, we collaborated with the Pacific Northwest National Laboratory (Johnson et al. 2004) and the Applied Physics Laboratory from the University of Washington for initial testing of DIDSON technology to determine adult chinook salmon abundance in the Secesh River. The encouraging initial test results led to full scale experimental testing of the DIDSON technology in 2004 and 2005 to attempt to determine adult salmon abundance in the Secesh River. This is the first project in the Snake River basin that has attempted to use DIDSON technology to enumerate adult salmon escapement in a stream.

This project emphasizes collection of wild stock adult salmon abundance information in the only remaining unsupplemented stream in the South Fork Salmon River system, the Secesh River. The Secesh River chinook salmon population is recognized by the Nez Perce Tribe and ICTRT (2005) for recovery planning purposes. The Secesh River also represents a control stream under the Idaho Salmon Supplementation studies (Bowles and Leitzinger 1991), and a reference stream for the Johnson Creek and northeast Oregon hatchery supplementation programs (Vogel et al. 2005, Hesse et al. 2006).

This project is expected to determine chinook salmon population staus and provide information for the assessment of performance measures (primary and derived) and standards. Fisheries managers will use the information from this project for population management and in recovery metric status monitoring. Information from this project, and other projects that collect actual escapement data, will provide the abundance data sets necessary to provide a scientifically sound basis for salmon conservation and allow evaluation of viability thresholds (NMFS 2000, NMFS 2002, ICTRT 2005).

DESCRIPTION OF STUDY AREA

The Secesh River is located in west central Idaho (Figure 1) and has a watershed that encompasses 688 square kilometers. The DIDSON monitoring site was located 30 km upstream from the South Fork Salmon River at the U.S. Forest Service Chinook Campground. Salmon abundance monitoring occurred at this site because it is located downstream of the vast majority of chinook salmon spawning habitat in the Secesh River, and in upstream headwater tributaries of Lake Creek and Summit Creek. Some chinook salmon spawning does occur downstream of this site in marginal habitat in the mainstem Secesh River, and in Lick Creek.

METHODS

Dual frequency identification sonar technology (DIDSON) is a new method in fisheries science that has been used to document fish passage at hydroelectric projects (Moursund et al. 2002, Mueller et al. 2003), to determine adult salmon passage rates and abundance in remote stream environments (Maxwell and Gove 2004, Kucera and Faurot 2005), and to document deep water fall chinook redds (Tiffan et al. 2004). However, DIDSON has not been thoroughly tested and validated in streams to estimate adult salmon abundance.

DIDSON is a new class of identification sonar that allows near video quality images for identification of objects under water (Figure 2). The acoustic imaging camera operates at ultra high frequencies, at 1.8 MHz and 1.1 MHz, and uses acoustic lens' which allow high quality images up to 60 m. It was developed by the Applied Physics Laboratory at the University of Washington for the Space and Naval Warfare Systems Center harbor surveillance program (Belcher et al.2001). The literature was examined to determine the potential for salmon and steelhead avoidance to these frequencies. Gregory et al. (2001) summarized the relevant published literature on fish sensitivity to sound (Table 1.) Chinook salmon, rainbow trout (*O. mykiss*), and atlantic salmon (*Salmon salar*) have demonstrated avoidance behavior at 10 Hertz (Hz) (Knudsen et al. 1997, Knudsen et al. 1994, Enger et al. 1992, Knudsen et al. 1992) which is at a very low frequency. Atlantic salmon have detected sound frequencies below 380 Hz (Hawkins and Johnstone 1978). Some of the Alosidae family, alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), blueback herring (*A. aestivalis*), and twaite shad (*A. fallax fallax*), demonstrate avoidance responses up to 162,000 Hz. The frequencies the DIDSON unit operates at (1.8 MHz) is ultra high frequency sound and appears to be well above the audible range of chinook salmon. By using up to 96 different sonar beams high frequency sound waves are sent through water to register vibrations reflected from an object. DIDSON collects sufficient information to show the size, shape, and direction of movement (upstream or downstream) of an object. The observer views a two dimensional silhouette of a fish swimming (Figure 2), not a sonar blip that requires positive identification in the laboratory. The advantages of the acoustic imaging camera are: 1) it uses a higher frequency resulting in better target resolution, 2) provides a more understandable target image, 3) it has a larger signal beam of 12°x29°, instead of 6°x 6°, that allows the target to be tracked over a greater distance, 4) it does not require extensive

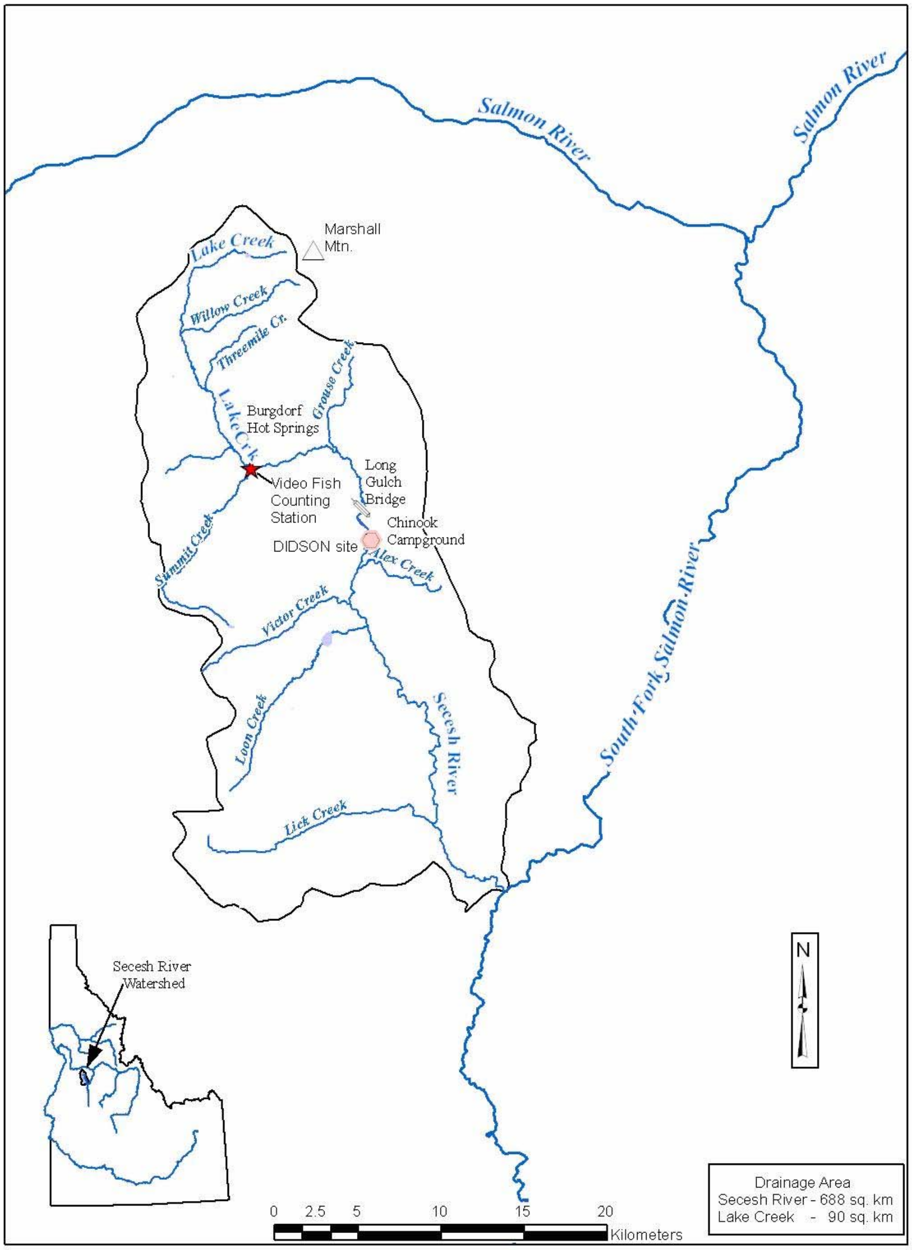

Figure 1. Location of the DIDSON monitoring site in the Secesh River.

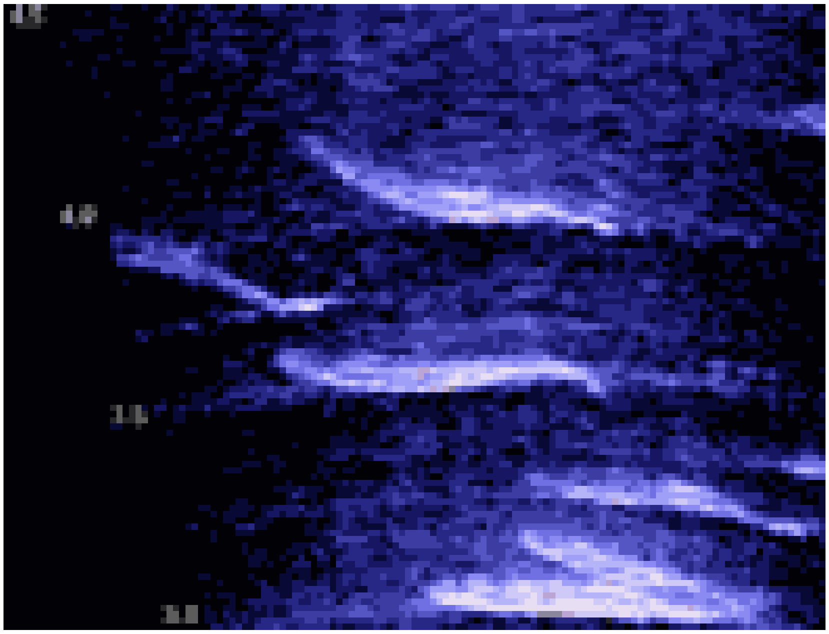

Figure 2. High frequency acoustic camera image showing six adult salmon passing through the ensonified zone of the device.

Table 1. Chinook salmon, rainbow trout, and other fish species sensitivity to sound (after Gregory et al. (2001).

Species	Frequency (Hz)	Citation
Chinook Salmon	10	Knudsen et al. (1997)
Rainbow Trout	10	Knudsen et al. (1997)
Atlantic Salmon	10	Knudsen et al. (1994) Enger et al. (1992)
Alewife	122,000-128,000 @ 190 dB	Ross et al. (1993)
	110,000 and 125,000 @ 175 dB or above	Dunning et al. (1992)
	125,000 @ 172 dB or above (continuous)	Dunning et al. (1992)
	117,000-133,000 @ 157 dB or above	Dunning et al. (1992)
	180,000 Hz @ 172 dB	Popper et al. (1998)
American Shad	161,900 Hz	Kynard and O'Leary (1990)
Blueback Herring	110,000-140,000 Hz @ 180 dB	Nestler et al. (1992)
Twaite Shad	200,000 Hz	Gregory et al. (1992)

aiming and testing, 5) records at frame rates of 4 to 21 frames per second, 6) the ease of operation, 7) does not require permanent structures, 8) does not require NEPA and an EIS, 9) can be relocated easily, and 10) operates equally well in high turbid water conditions, low stream flow conditions, and at night. Cost of each acoustic camera

($75,000) appears relatively high, but when compared to other alternatives (Johnson et al. 2004) is not that expensive.

Dual Frequency Identification Sonar (DIDSON) Operation

Two DIDSON units were installed and operated in the Secesh River in 2005. The purpose of the upstream most DIDSON unit was to estimate adult chinook salmon abundance similar to 2004 operations. The second DIDSON unit was installed approximately 12 m downstream of the first DIDSON site (Figure 3). The purpose of the second DIDSON unit was to provide a measure of the precision of DIDSON technology in counting adult salmon. This information will be presented in future years' reports. The upstream most DIDSON unit was installed on June 8 and was operated continuously through September 19, except for periods of downtime. The downstream DIDSON unit was installed on June 25 and operated continuously through September 19. High frequency DIDSON files at the upstream DIDSON site were recorded at seven frames per second, 24 hours per day, and seven days per week. The downstream DIDSON unit was operated similarly, except that high frequency files were recorded at nine frames per second. Operationally, stream width at the DIDSON site was approximately 26 m and maximum stream depth was 2.1 m. Through consultation with the Pacific Northwest National Laboratory, who have extensive sonar expertise, it was decided to install a crump style artificial substrate on the stream bottom and a bank standoff structure on the far bank (Figure 3). This was implemented to force adult salmon off of the stream bottom and away from undercut banks to ensure that clear sonar recordings of migrating adult salmon would be collected. Standoff structures were also installed to keep salmon from getting too close to the DIDSON unit. Anytime the DIDSON unit was deployed or moved, a calibration target was placed instream from the DIDSON unit surface to the bottom and from the far shore surface to bottom to ensure that the entire water column was ensonified. If the calibration target was not successfully acquired the DIDSON unit was re-aimed until it was. The DIDSON unit and optical cameras were connected into a topside box where DIDSON files were collected and recorded through use of a laptop computer and an external hard drive (Figure 4). DIDSON file size was 29 gigabytes of data per day. The topside box, DIDSON unit, and optical cameras were powered by four sets of 6 volt batteries, connected in series, which were charged daily by a generator.

Figure 3. DIDSON monitoring site in the Secesh River depicting location of both DIDSON monitoring transects (top) and low summer stream flow conditions (bottom) in 2005.

Figure 4. Topside box with laptop computer that collects DIDSON files on an external hard drive, and quadplexes optical camera data with the DIDSON signal on a VHS tape for validation studies.

DIDSON Motion Detection

In 2005, original high frequency DIDSON files were compressed to fish motion-only using newly developed computer software. The Convoluted Samples Over Threshold (CSOT) is a motion detection algorithm of the DIDSON software that allows for the capture and recording of DIDSON frames that contain movement of sonar targets. The CSOT feature presents a methodology allowing for saving both in terms of disk space and in terms of observation time. The algorithm is based on three user specified parameters, a background subtraction parameter "A", the number of samples, and a threshold value (dB). The viewable DIDSON image consists of 49,152 individual pixels (512 x 96 beams), also called samples, with each sample having a target strength value measured in dB. The user specifies the number of samples (non-contiguous) above a threshold value that is of interest, and only frames that contain a greater number of samples with targets strengths above the specified threshold are recorded. The back ground subtraction value "A" (range >0<1) sets the rate at which stationary objects are removed from the image. At low values of "A", objects (such as bottom features) are removed more quickly (within 10s of frames) than at high values (100s of frames).

For our application, the recording of frames with fish passages, the proper parameter settings were unknown. The number of samples an object occupies in the DIDSON image depends upon the length and width of the object, as well as the distance from the sonar unit. Because of the spread of the sonar beams, objects farther away from the sonar occupy less samples (pixels) than object close to the sonar. In addition, the target strength of an object varies with its aspect to the sonar unit. Therefore, there is no specific set of parameters that ensures the capture of all fish passages.

The CSOT parameters for the DIDSON files collected on the Secesh River were selected on a trial and error basis. Eight days throughout the season were viewed and all salmon passages recorded. The files were then processed with the CSOT feature using a range of values for the parameters of "A", number of samples, and threshold values. Background subtraction values ranged from 0.95 to 0.985. The number of samples parameter varied from 25 to 225. Threshold parameter values of 5 and 6 dB were used. Processed files were then viewed and salmon passages compared to salmon observed during the viewing of original DIDSON files. Parameter selection was conservative, accepting larger file sizes (more frames) to ensure the capture of all salmon passages.

To verify that all salmon passages were captured with the CSOT process, original files from 21 days throughout the season were viewed and all salmon passages recorded and compared to salmon passages observed in CSOT files from those dates. Motion detection efficiency was calculated as the number of passages present on CSOT files divided by the number of passages present on original files.

Abundance Estimation

Adult chinook salmon abundance in the Secesh River was determined by viewing DIDSON files that were processed to fish motion-only periods, and manually counting fish silhouettes (Figure 2) that were ≥ 55 cm in length. The DIDSON software maintains a feature that allows total length measurement of individual fish images. This size-based approach allowed identification and enumeration of adult chinook salmon separate from other fish species moving through the DIDSON monitoring site. Adult steelhead overlap in size with and could potentially be counted as adult chinook salmon. However, the steelhead spawning migration timing was temporally discrete from the salmon migration timing in 2005. Adult steelhead had completed spawning and had migrated downstream prior to adult chinook salmon upstream movement. Bull trout was the only other fish species large enough to overlap in size with jack salmon (55 cm or greater). The proportion of bull trout in the Lake Creek spawning migration in 2005 that were greater than 55 cm in length was low (2.9%, n = 3 fish) (see Chapter 1). Subsequently, the potential for biasing the DIDSON salmon counts by incorrectly counting larger bull trout as a salmon was considered negligible. A representative high frequency DIDSON file of adult salmon (Figure 5) and mountain whitefish (*Prosopium williamsoni*) (Figure 6) was selected to demonstrate the relative difference in fish size between species. Confidence in fish species identification was gained when viewing and comparing the relative size of hundreds of salmon with non-salmon species and comparing it with optical camera validation information (Figures 7 and 8).

Adult salmon abundance in the Secesh River is determined by first calculating the maximum net upstream number of fish that migrates past the DIDSON monitoring site once spawning had commenced. Determination of net upstream movement is simply a matter of cumulative addition for upstream movement, or subtraction when a salmon moved downstream. Three known sources of error exist that are addressed to adjust adult salmon abundance. First, original DIDSON files were compared to fish motion-only file compressions to ensure that fish motion-only files accurately captured all chinook salmon passages. Salmon passages were compared between original DIDSON file and fish motion-only file over a stratified random sample of 21 days, and motion detection error was determined for upstream and downstream moving fish. Motion detection error was applied daily, for upstream and downstream salmon passages, during two periods in the salmon migration. The two periods in salmon migration were defined as June 8 through July 26, and July 27 through September 15.

Secondly, since fish motion-only DIDSON files are read manually, the observed abundance is adjusted up or down by what is termed reader specific error (viewer efficiency). Reader specific error may be variable between individual viewers and between up and down stream passages. Using a single fish passage as the sampling unit, viewer efficiency is determined by a stratified random sample. Weekly, one day's DIDSON files are randomly selected and that day's files are viewed independently by two additional readers besides the original reader. This amounts to approximately 14% of all DIDSON files. An individuals reader specific error is determined as the total number of fish passages recorded by the individual observer divided by the maximum number of salmon passages compiled from comparisons of the fish passages observed by the three independent readers. The reader specific error is calculated separately for upstream passages and downstream passages for each viewer. This assumes that three independent viewers will observe all fish passages. The viewer specific efficiencies calculated for each individual viewer for upstream and downstream passages are used to correct each individuals daily observed passages for the entire season to estimate the corrected passage.

The third source of error is salmon that could potentially migrate past the DIDSON monitoring site during periods of equipment down time. Adjustments for equipment down time are made by applying that days average salmon passage rate to the proportion of downtime experienced for that day. Once these downtime adjustments are made, the daily net upstream number of salmon is determined. The 95% confidence interval is calculated by summing the downtime variance and applied to the season wide population estimate.

Overall, the formulas for salmon abundance adjustments and variance component calculations follow below. The daily net upstream migration ($E_{i,r}$) was the sumation of observed passages ($E_{i,s,r}$) and passages that occured during periods of downtime ($E_{i,US,r}$) as

$$E_{i,r} = E_{i,s,r} + E_{i,US,r}$$

where i is a given day, s is the proportion of sampled observations, and US is the unsampled estimate (estimated number of fish missed in a given day as a result of downtime). This was stratified by reader specific error (r), which is assumed to be known with zero error. The sampled observations ($E_{i,s,r}$) was calculated as

$$E_{i,s,r} = A_r \times \left[U_{i,s,r} - D_{i,s,r} \right]$$

where A is the reader error times the motion detection error adjustment factor, U is the upstream count and D is the downstream count for each strata i. The unsampled passages that occured during downtime ($E_{i,US,r}$) was estimated as

$$E_{i,us,r} = \frac{A_r \times \left[U_{i,s,r} - D_{i,sr} \right]}{sf} - E_{i,S,r}$$

Where sf is the proportion of time sampled for strata i calculated as $sf = \frac{n}{N}$ where n is the time the camera was operational over the entire time in a given day (e.g., if the camera worked for 12 hrs in a given day, sf = 0.5).

The variance for the sampled ($\text{var}\left(E_{i,us,r}\right)$) proportion is given by

$$\text{var}\left(E_{i,us,r}\right) = \left[\frac{A_r}{sf} \right]^2 \times \text{var}\left[U_{i,s,r} - D_{i,sr} \right].$$

Since the sampled observations are based on a correction with zero variance, they are considered a census and they too have zero variance. For the unsampled component (number of fish estimated to have passed during the down time on a given day) variance ($\text{var}\left(E_{i,us,r}\right)$) is given by

$$\text{var}\left(E_{i,us,r}\right) = \left[\frac{A_r}{sf} \right]^2 \times \text{var}\left[U_{i,s,r} - D_{i,sr} \right]$$

and

$$\text{var}\left[U_{i,s,r} - D_{i,s,r} \right] = \frac{\sum_{i=1}^{n} \left[U_{i,s,r} - D_{i,s,r} \right] - \left[\overline{X} \right]}{n-1}$$

where $\overline{X}$ is the mean count on any given day in the season (note that these counts are adjusted for reader error).

Overall variance is only a component of the unsampled proportion as the sampled proportion is essentially a census (as described above) and is given by

$$\text{var}\left(E_i\right) = \sum_{r=1}^{n} \text{var}\left(E_{i,us,r}\right).$$

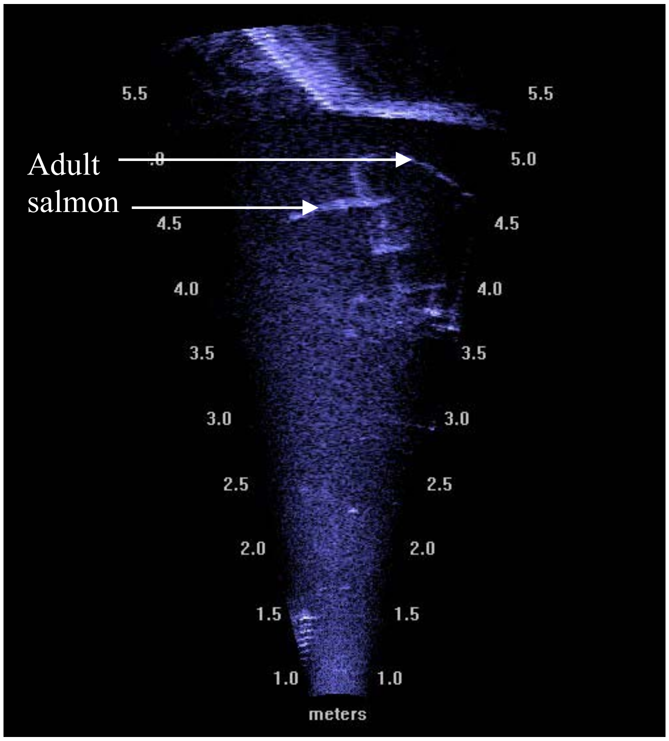

Figure 5. High frequency DIDSON recording of two adult chinook salmon in the Secesh River.

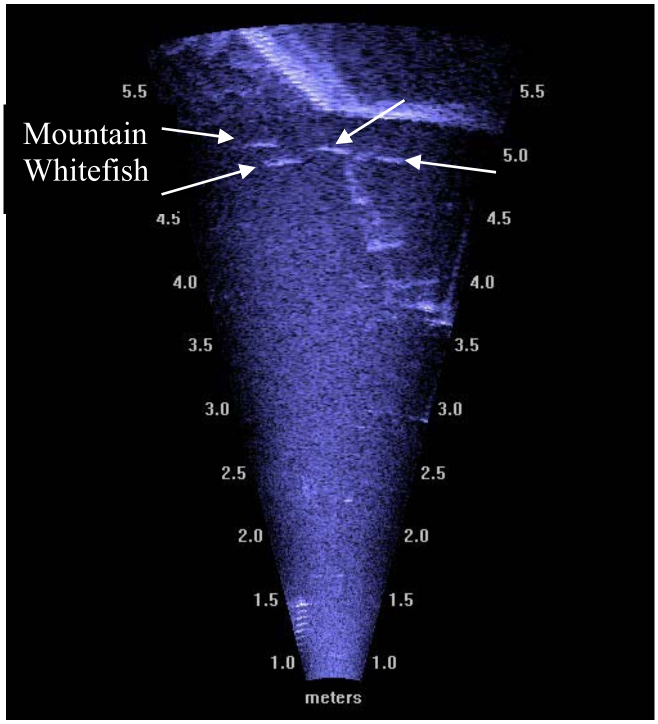

Figure 6. High frequency DIDSON recording of four mountain whitefish in the Secesh River.

Figure 7. Optical camera photograph of the same two adult chinook salmon displayed in Figure 5.

Figure 8. Optical camera photograph of the same four mountain whitefish displayed in Figure 6.

Validation

Validation followed the validation plan approach outlined in Johnson et al. (2004). The validation approach used three underwater optical cameras to provide the independent methodology to validate DIDSON salmon observations at the monitoring site. Three optical cameras were located near the far standoff structure in a five foot validation zone (Figure 9 and Figure 3). Three optical cameras were mounted on a well point and aimed toward the vertical white background located next to the bank standoff structure (Figure 3). The camera coverage overlapped each other to ensure complete coverage of the water column within the five foot validation zone so that no salmon passages went undetected. Validation optical cameras and the DIDSON signal were multiplexed and recorded on a videotape to ensure synchronization in time of both sources. Near simultaneous viewing of DIDSON and the three optical cameras was then possible. Optical camera data was stored along with the DIDSON data on a VHS T-160 tape on extended play at 8.0 frames per second to ensure that no salmon passages were missed. Data collected included number of adult salmon, date, time, and direction of movement. Validation used three optical cameras during daytime and nighttime periods from approximately 3:00 p.m to 9:00 a.m. the following morning. Optical cameras validated the DIDSON size-based salmon enumeration, counting silhouettes ≥ 55 cm, with date and time stamped optical camera counts.

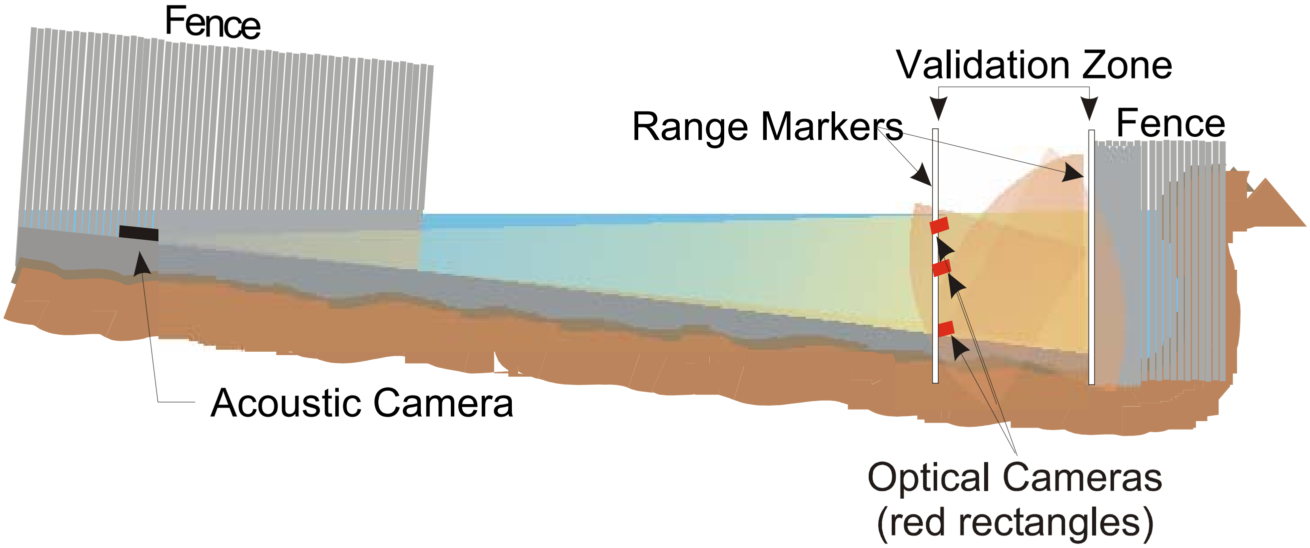

Figure 9. Cross-section view of the validation zone indicating where optical cameras were used as the independent method to validate DIDSON salmon counts in the Secesh River in 2005.

A stratified random sample of videotapes (n = 14 days) was viewed by two independent observers to determine upstream and downstream salmon passages within the validation zone. This was used to compare with the original DIDSON file salmon counts within the validation zone. A single fish was defined as the sampling unit with the total number of passages defined as the number of unique fish observed by both observers.

Listed Chinook Salmon Population Assessment

Adult chinook salmon abundance in the entire Secesh River drainage was estimated for application to listed species recovery metrics monitoring. The acoustic imaging camera (DIDSON) was used to estimate adult salmon abundance in 2004 and 2005. Adult abundance estimation methods for 1998 to 2003 are described in Faurot and Kucera (2004). The DIDSON adult salmon abundance estimate was used to represent natural and hatchery salmon escapement upstream of the Chinook Campground site. The number of redds located below the DIDSON monitoring site in 2005 (5 redds) was identified from extensive area redd count surveys (Appendix Table B4). The number of redds located downstream of the DIDSON site was expanded by a DIDSON generated fish per redd number. This number was determined by dividing the DIDSON abundance estimate by extensive area redd counts upstream of the DIDSON site. The DIDSON salmon abundance estimate was summed with the redd count expansion abundance estimate to estimate total adult salmon abundance in the Secesh River system (natural and hatchery fish combined). An average hatchery fraction was calculated using values calculated from the Lake Creek underwater video fish counting station and from carcass recoveries on the Secesh River. It was believed these provided the most accurate estimate of hatchery composition for the entire Secesh River. The hatchery fraction observed at the video count station was utilized as no pelvic fin clipped carcass recoveries were obtained on Lake Creek in 2005; which the video may have missed. The estimated number of wild chinook salmon for the entire Secesh River was derived as follows. The DIDSON abundance estimate was added to, the number of chinook redds located below the DIDSON site multiplied by the DIDSON fish per redd number, and then multiplied by one minus the average hatchery fraction.

RESULTS AND DISCUSSION

Abundance Estimation

The DIDSON monitoring site was installed and fully operational on June 8, 2005. The first upstream salmon passage was observed on June 11, three days after installation of the DIDSON unit. The estimated salmon abundance at the DIDSON monitoring site was 339 ± 3 fish (95% confidence interval) (Figure 10). This estimated salmon abundance represents both wild and hatchery chinook salmon escapement in the Secesh River at the monitoring site. The DIDSON monitoring site was operational for 96.5% of the adult salmon migration in 2005. Expansions for equipment downtime equalled a positive three salmon (Appendix Table B6).

The largest number of net upstream migrating chinook salmon (339), observed in the Secesh River in 2005, occurred on August 27. This number is important methodology-wise because it represents the largest number of spawning adults that was available to contribute to salmon reproductive success. After August 27 there was a total net downstream salmon passage of two fish at the DIDSON monitoring site (Appendix B6). When operations ceased a total of 337 salmon remained upstream of the DIDSON site.

DIDSON technology has been used to estimate adult salmon abundance in the Secesh River in 2004 and 2005 (Figure 10). The total estimated salmon abudance at the DIDSON monitoring site in 2004, wild and hatchery, was 950 fish. Salmon abundance has declined dramatically, and has varied almost three fold, from 2004 to 2005.

An estimated fish per redd value was calculated upstream of the DIDSON site in 2005 by using the DIDSON abundance estimate divided by extensive area redd count totals located upstream of the DIDSON monitoring site (Jerry Lockhart – personal communication). Extensive area redd counts identified 200 chinook salmon redds upstream of the DIDSON monitoring site in 2005, with five redds located downstream of the site. In 2005, 2.4% of the chinook salmon redds (5 out of 205 redds) were located downstream of the DIDSON monitoring site. The estimated fish per redd value was 1.70. This was consistent with the fish per redd value (1.77) obtained for Lake Creek in 2005 (see Chapter 1 – this report).

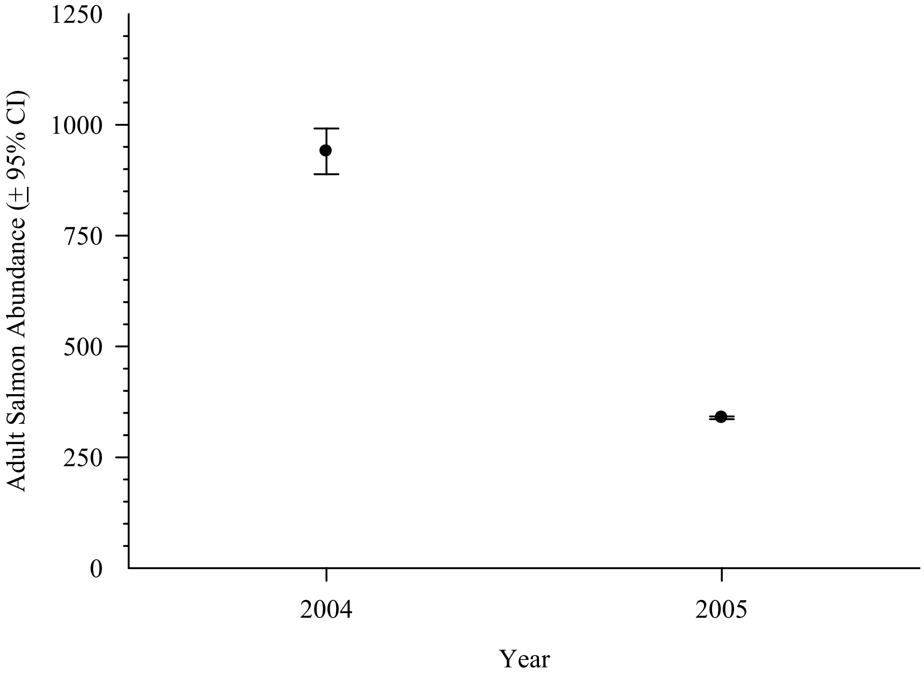

Figure 10. Estimated wild and hatchery adult chinook salmon abundance at the DIDSON monitoring site in the Secesh River in 2004 and 2005.

Potential Sources of Error in DIDSON Abundance Monitoring

All potential sources of error in DIDSON abundance monitoring were defined and corrected for in 2005 (Table 2). It was believed that no adult chinook salmon passed undetected before DIDSON site installation. The first upstream salmon passage was observed on June 11, three days after installation of the DIDSON unit. Given the general high quality salmon images provided from high frequency DIDSON files, and the validation results, we believe it unlikely that migrating salmon went undetected. This was the first year that original DIDSON files were processed to fish motion-only periods of salmon movement to reduce the size of files that had to be manually read. Since this was the first year software was available for file processing, a substantial amount of analysis was involved to ensure accurate methodology and salmon counting.

The following describes the approach used and results of fish motion detection with the CSOT motion detection algorithm. Two parameters were constant for the entire season while one varied within season. The background subtraction value "A" had a large effect on resulting file size and the number of successfully captured salmon passages. Lower values (0.95-0.97) (lower values results in faster background subtraction), were found to actually subtract some of the salmon frames both as salmon entered and exited the viewing window. High values (> 0.985), resulted in the removal of very few frames. For our application the relationship between the background subtraction value and the number of frames captured was exponential in nature. A background subtraction value of 0.98 was selected and used for all files processed. A threshold value of 6 was selected for the CSOT processing; larger values resulted in missed salmon passages.

The number of samples selected parameter varied throughout the season, with a value of 25 being using early in the season and ending with a value of 125. The number of samples varied due to changes in the window length (10 m to 5 m) and changes in the distance between the sonar unit and the far shore. During June and early July, higher flows (wider stream) required a longer window length (10 m) resulting in salmon occupying fewer samples and thus requiring a smaller number of samples. By September, low stream flows allowed for a 5 m window length to be used. In addition, salmon passages were closer to the sonar unit, allowing for a higher number of samples to be used.

The use of the CSOT feature reduced the entire season file size from 2,649 gb to 738.6 gb of motion only files, or 27.9% of the original size. The number of frames recorded varied throughout the season. Early season high flows resulted in a high amount of surface turbulence which was enhanced by the structures placed in the stream, and created a high level of background "noise". The high noise level in conjunction with a small sample size value resulted in only a small reduction in file size. The mean daily file size from June 8 through July 26 was 11.0 gb. Conversely, lower stream flows late in the season resulted in minimal background noise, coupled with the shorter window length and a large sample size value used, resulted in a large reduction in file size. The mean daily file size from July 27 through September 15 was 3.9 gb.

The number of frames captured and recorded also varied with time of day. Fewer frames were captured and recorded during afternoon hours with relatively more frames being captured at night. During the early part of the season, peaking stream flow at night is believed to have caused the larger frame count during night time periods. The day time average file size was only 85% of the night time file size from June 8 through July 26. However, later in the season, salmon and smaller fish (presumed to be bull trout) remained within the ensonified zone for much of the night time hours but were absent during daylight hours. From July 27 through September 15, average day time file size was just 30% of night time file size.

The comparison of salmon passages on original files to passages on motion detection files showed that the motion detection feature captured most but not all salmon passages (Appendix Table B1). Of the 21 stratified random sample days compared, a total of 615 upstream and 510 downstream passages were present on original files. The motion detection feature captured 97.8% to 99.7% of the upstream passages during period one and two (Appendix Table B1). The percentage of downstream moving passages detected by motion only files during period one and two ranged from 92.4% to 95.5%. More upstream passages were missed during the early part of season (June 8 through July 26) compared to later in the season (July 27 through September 15). Conversely, more downstream passages were missed later in the season relative to the early part of season. Therefore, motion detection efficecies were stratified by early and late season and for up and downstream passages, and were applied to correct the daily number of observed salmon passages.

The majority of missed salmon, in fish motion-only files, moved through the ensonified zone at a similar angle and distance from the DIDSON unit. Missed passages were generally salmon that were traveling downstream, head first, at an acute angle, with little aspect perpendicular to the sonar unit. These fish turned and faced toward the DIDSON unit while moving downstream. The failure to detect these passages was not a result of improper parameterization. Salmon moving downstream at an acute angle encompassed only a small number of samples. In addition, the acute angle also reduced the returning target strength. In order to capture these types of downstream moving salmon, the parameter would have to be set at such a low threshold (sample size of 10 and a threshold value of 4 or less) that nearly all available frames would be captured.

Fish motion-only reader specific error was determined for each observer, statistically evaluated between observers, and was applied by direction of salmon movement to adjust daily salmon counts per observer. Adult abundance was adjusted for periods of equipment downtime. The potential error from not counting jack salmon that were less than 55 cm in total length was considered negligible. Over all years, the average percentage of jack salmon in the Secesh River that are less than 55 cm averaged 1.7% (Jerry Lockhart – personal communication). This represented a negligible effect on salmon abundance estimation. The potential for counting bull trout greater than 55 cm in length as salmon was also considered a negligible effect. The few adfluvial bull trout greater than 55 cm observed in the Lake Creek fish counting station in 2005 (3 fish) is negligible and would balance out the effect of not counting small jack salmon.

Table 2. Potential sources of error in DIDSON salmon abundance estimation in the Secesh River in 2005.

Concern	Potential Effect
Fish passages before installation	None
Undetected fish	None
DIDSON original file to fish motion-only file error	Corrected
Fish motion-only reader specific error	Corrected
Fish passages during equipment downtime	Corrected
Not counting jack salmon less than 55 cm in length	Negligible
Counting bull trout greater than 55 cm in length as salmon	Negligible

Migration Timing

Adult chinook salmon migration timing in the Secesh River occurred from June 11 to September 11 in 2005 (Figure 11, Appendix Table B5). A total of 4,682 salmon passages were observed at the DIDSON monitoring site (adjusted data). No fish were observed from September 11 to September 15. The salmon spawning population in the Secesh River had a median net upstream passage date of July 14, and the largest single day of net upstream movement occurred on July 7. At the end of the spawning season only two salmon moved downstream out of natural production areas.

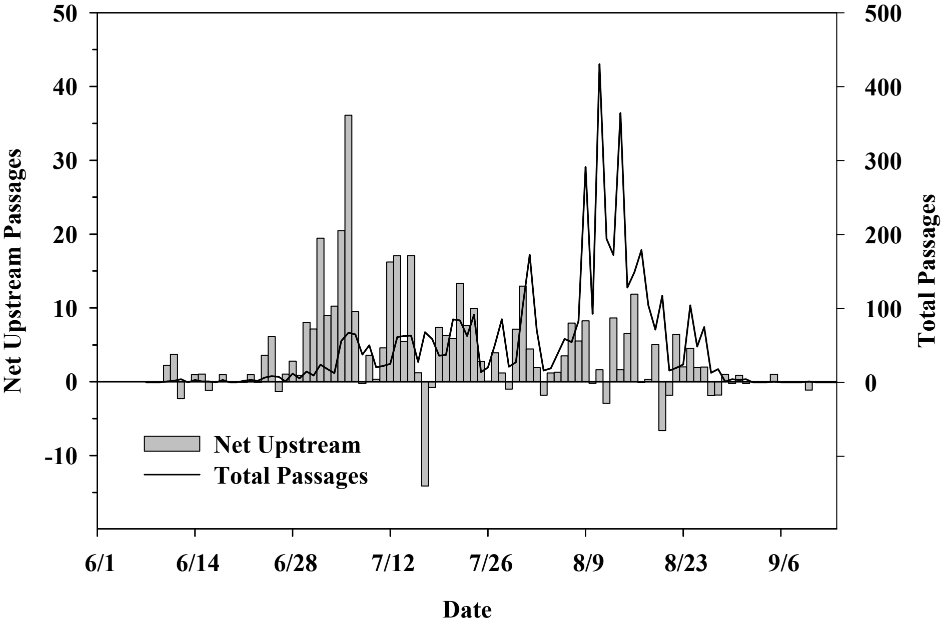

Figure 11. Net upstream and total movement (adjusted data) of adult spring and summer chinook salmon migrating past the DIDSON monitoring site in the Secesh River in 2005.

Validation Monitoring

DIDSON files allowed collection of high quality two dimensional fish images that could be measured by computer software to allow counts of fish greater than 55 cm in length as salmon. The question existed whether fish counted as salmon were indeed actually salmon. In particular, there was a concern that other fish species that overlaped in size with jack chinook salmon (namely bull trout) would be erroneously counted as salmon. To address this question, three underwater optical cameras were used as the independent method for validation of DIDSON salmon counts at the Secesh River monitoring site in 2005. Optical cameras are the standard validation approach used for hydroacoustics (Gregory et al. 2001, Gough and Gregory 1997), resistivity counters (Smith et al.1996, McCubbing et al. 2000), and electronic counters (Shardlow 1998). The three optical cameras were multiplexed with the DIDSON unit to allow synchronization in time for near simultaneous viewing of salmon passages with optical and DIDSON methods. The validation approach followed the Validation Plan for acoustic imaging camera counting of adult chinook salmon in the Secesh River (Johnson et al. 2004 *in* Faurot and Kucera 2004). In 2005, validation occurred in a five foot validation zone in the main stream channel during daytime and nightime periods. A stratified randon sample of 14 days was selected, one day per week, to compare total daily DIDSON salmon counts and optical camera counts. The DIDSON unit successfully counted 435 out of 435 adult salmon passages (100%) in the validation zone over the 14 randomly selected days (Figure 12). Since the data was identical (i.e. - no variation existed), a paired t-test was not conducted. No other fish species were enumerated as salmon in the validation comparison in 2005. Results of the validation zone comparison in 2005 were consistent with those observed in 2004. During 2004 validation zone comparisons DIDSON correctly counted 913 out of a total of 914 adult salmon passages (Kucera and Faurot 2005). A paired t-test demonstrated no significant difference between the means ($p < 0.05$). Over the two year period, DIDSON missed only one adult salmon out of 1,349 total validation zone salmon passages. No other fish species were counted as chinook salmon over the two year period. In 2004, DIDSON chinook salmon counts were also compared to underwater video fish counting station salmon counts in the Secesh River. This validation test compared total daily net upstream fish counts over a 51 day period. A linear regression indicated that the fish counting station salmon counts and adjusted DIDSON net upstream daily counts were nearly identical (slope = 1.01), and were highly correlated ($R^2 = 0.998$). The fish counting station total net upstream chinook salmon estimate was four fish higher than the DIDSON salmon count over the 51 day period, and two salmon redds were observed between the sampling sites. These data provided a compelling case that the DIDSON technology provided accurate salmon target counts at the monitoring site.

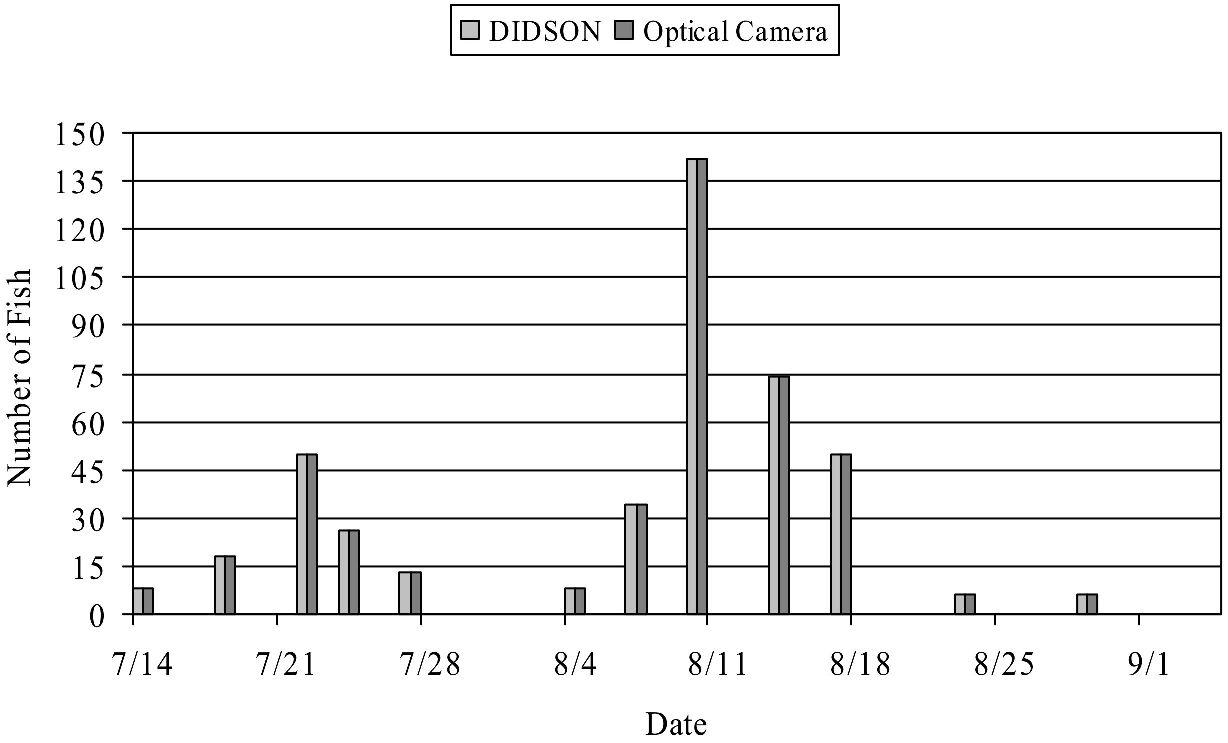

Figure 12. Validation zone comparison between DIDSON salmon counts and optical camera salmon counts from 14 randomly selected days in the Secesh River in 2005.

DIDSON Operations

This section is intended to share DIDSON operational results from 2005 to estimate adult chinook salmon abundance in the Secesh River. The following discussion presents information relative to challenges encountered with DIDSON data collection, data management, abundance estimation, and validation testing.

Instream structures within the DIDSON monitoring transect, well points used to attach optical cameras, created substantial amounts of entrained bubbles in the water column. This created problems with the computer software used to process original DIDSON files into fish motion-only files. Any entrained bubbles created a background noise signal that was of the size of a salmon that the software would record. In 2006 we plan to remove all instream objects from the DIDSON monitoring transect in an attempt to minimize entrained bubbles. Hopefully, this will allow more efficient processing of files to fish motion-only periods which then will be manually read.

Kucera and Faurot (2005) reported several challenges that created interruption in continous data collection with the DIDSON unit. In 2004, storm and turbidity events would cause Ponderosa Pine pollen and/or fine sediment to coat the acoustic lenses and automatic focusing pin on the DIDSON unit. The project lost several days worth of monitoring information due to these problems. Routine preventative maintenance of acoustic lenses and the automatic focusing pin every three to five days rectified this problem in 2005. In 2005, we continued to experience downstream moving adult salmon that would get too close to the DIDSON unit. This presented a challenge in identifying fish on fish motion-only files. We have not found a solution for placement of an acoustically permeable structure instream to prevent this occurrence. We believe that the location of the DIDSON monitoring site so close to a natural production area added to the number of downstream salmon passages. Location of the monitoring site lower in the stream system may minimize the number of downstream passages observed. We continue to highly recommend anyone envisioning using DIDSON for adult abundance monitoring to field test the unit at the selected monitoring site at least one year prior to full scale monitoring.

Data management and data processing are an important challenge for the project. High frequency DIDSON files collected 29 gb of data each day. Data were stored on external 400 gb Iomega hard drives. Electronic files were backed up in case external hard drive failure occurred. Original DIDSON files were processed into fish motion-only periods which reduced file size to 27.9% of the original size. Processing of one days original DIDSON files usually required two to three hours. However, the time savings associated with compressing files was partially negated by the fact that a random sample of original DIDSON files had to be read to compare with fish motion-only files. This was conducted to ensure that the computer software correctly identified salmon passages. A correction factor had to be applied to the fish motion-only files. Lack of automated fish counting software continued to necessitate manual reading of the fish motion-only files. It was necessary for three independent observers to read randomly selected fish motion-only files to determine reader specific error. The reader specific error was then applied to the days each individual had read. Continued improvement in automated salmon counting of DIDSON files will be a high priority, in collaboration with Sound Metrics Corporation. State of the art field laptop computers and office computers are a prerequisite to deal with the sheer volume of data and data processing requirements of DIDSON files.

Salmon abundance estimation was corrected for differences between original DIDSON files compared to fish motion-only files (Appendix Table B1), and for reader specific error when viewing fish motion-only files (Appendix Table B2). This was the first year that computer software was available to process original DIDSON files to periods of fish motion-only. It was unknown how effective the fish motion-only file processing would be in correctly capturing periods of chinook salmon movement. When the fish motion-only files were compared to the original files the proportion of correctly identified upstream moving fish was high, ranging from 0.978 to 0.997. The proportion of correctly identified downstream moving salmon was less, and varied from 0.923 to 0.955 (Appendix Table B1). These proportions were applied daily, upstream and downstream, to correct for the difference between original DIDSON files to the fish motion-only files. We view these corrections to be necessary each year until further improvements in fish motion-only file procesing, or automated counting of salmon movements from original DIDSON files are made.

Chinook salmon abundance estimation was also corrected for reader specific error in viewing fish motion-only files (Appendix Table B2). The proportion of correctly identified upstream moving fish, by observer, was relatively high ranging from 0.932 to 0.997. The proportion of correctly identified downstream moving salmon was lower (0.838 to 0.991), and varied depending on the observer. These proportions were also applied on a daily basis to correct for the fish motion-only files each individual had read. Daily corrections to adult abundance were directional in nature, resulting in both upstream and downstream adjustment. Finally, salmon abundance was adjusted for periods of equipment down time.

Underwater optical cameras were used as the independent method to validate DIDSON salmon counts. Planning and set up of optical camera arrays are challenging. In 2005, it was decided not to install optical cameras, LED arrays, and power cords until after ice-out due to the risk of losing the equipment during subsequent high stream disharge and debris loads. The cameras would also have been inaccessible and become inoperable if covered by debris. Instead, optical cameras and LED arrays were installed and operational on July 14, once stream discharge and velocity allowed access to the validation zone area. The white vertical background was necessary to backlight and identify fish passages given the dark stream environment.

LISTED CHINOOK SALMON POPULATION STATUS

The Biological Opinion for operation of the federal Columbia River power system (NMFS 2000) recommended that accurate assessment of spawner escapement of listed ESU's were required for determining the characteristics, viability, recovery status, and delisting of ESU's under the Endangered Species Act. NMFS (2002) further identified interim abundance and productivity targets necessary for delisting. The recovery metric for listed ESU's was the likelihood that the eight year geometric mean abundance of natural spawners would equal or exceed 9,200 spring and summer chinook salmon in the South Fork Salmon River. The geometric mean cohort replacement rate must also exceed one during the eight years immediately prior to delisting. The recovery standards related to ESU status were to be evaluated during the 3, 5, and 8 year reviews. Viability criteria for application to interior Columbia Basin salmonid ESU's have been updated and recommended by the Interior Columbia Basin Technical Recovery Team (ICTRT 2005). A minimum adult salmon abundance (viability) threshold of 3,250 fish was recommended by the ICTRT for the South Fork Salmon River major population group (MPG). This included designation of the Secesh River as an intermediate population size category, with a viability level of 750 fish. The ICTRT recommended MPG viability guidelines require that two of the populations in the South Fork Salmon River should exceed VSP guidelines. Specific application to ICTRT proposed criteria also involves productivity and spatial distribution criteria, and geometric mean calculations. The Secesh River is the only remaining wild salmon stock in the South Fork Salmon River, and is a logical candidate for measurement of delisting criteria under the ESA to roll up to the larger ESU level. Botkin et al. (2000) state that without abundance information, we cannot measure the effectiveness of conservation actions for a threatened species. Information from this project may be used by NOAA Fisheries to assess effectiveness of conservation actions and delisting decisions for spring and summer chinook salmon in the Snake River basin.

This section provides information on wild stock adult salmon abundance in the Secesh River from 1998 to 2005. Adult salmon abundance estimates in this report have been standardized and refined and supercede that presented in previous years' reports. Wild adult salmon abundance in the Secesh River in 2005 was estimated to be 344 fish (Table 3). This salmon abundance estimate was adjusted for five chinook salmon redds located downstream of the DIDSON monitoring site, and for the estimated adult hatchery fraction on the spawning grounds. Wild salmon abundance levels in 2005 declined by 63% compared to the observed salmon abundance in 2004. DIDSON technology was used to estimate adult salmon abundance in the Secesh River in 2004 and 2005. Adult abundance estimation methods for 1998 to 2003 are described in Faurot and Kucera (2004). Estimated wild stock salmon abundance in the Secesh River has ranged from 96 to 1,391 fish from 1998 to 2005 (Table 3). Salmon abundance increased from perilously low levels in 1998 and 1999 to over 800 adults per year from 2001 to 2004 (Figure 13). The value of the Secesh River abundance information is that it provides a direct measure of listed species quasi-extinction and viability (delisting) thresholds (Figure 13) with actual abundance data. The error that is inherent in utilizing redd count expansion abundance estimates is avoided.

Table 3. Total estimated Secesh River adult chinook salmon abundance (wild and hatchery), wild adult chinook salmon abundance, and average hatchery fraction in the Secesh River from 1998 to 2005.

Year	Average Hatchery Fraction	Secesh River Adult Salmon Abundance (Wild and Hatchery)	Secesh River Adult Salmon Abundance (Wild)
1998	*[1]	105	96
1999	*[1]	179	175
2000	*[1]	548	545
2001	*[1]	1,488	1,391
2002	*[1]	1,086	1,000
2003	*[1]	1,176	1,163
2004[2]	2.52[3]	965	937
2005[2]	0.96[3]	349	344

[1] Hatchery fraction used in abundance estimates from 1998 to 2003 are described in Faurot and Kucera (2004).
[2] DIDSON salmon abundance estimate used in 2004 and 2005.
[3] Average hatchery fraction calculated from video fish counting station and Secesh River carcass recoveries.

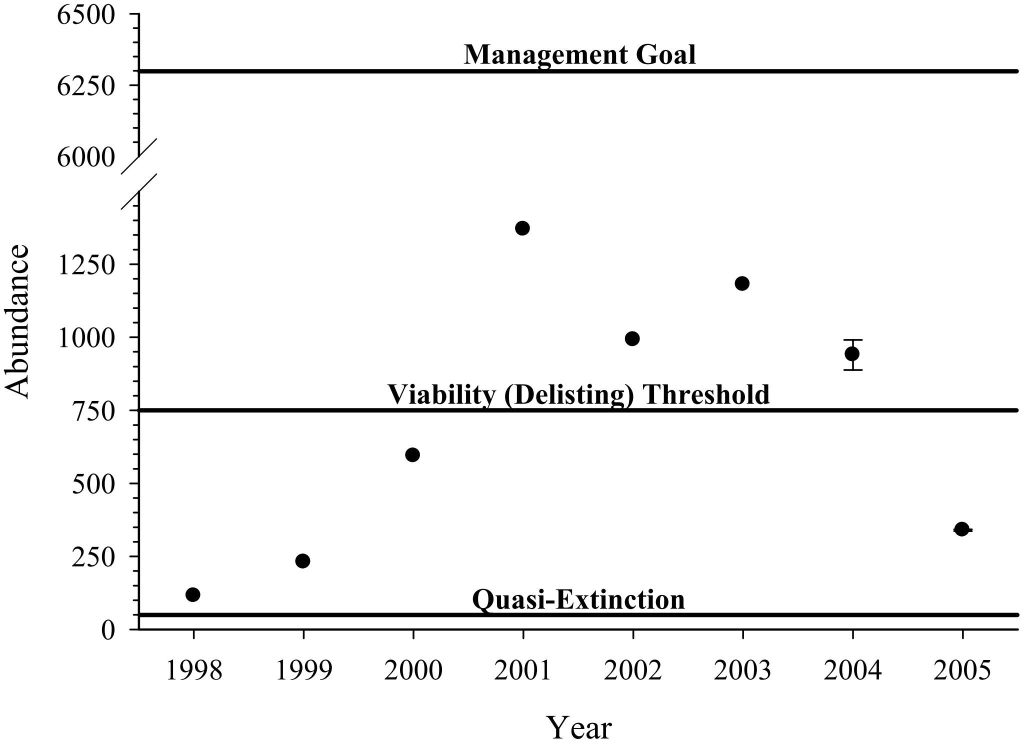

Figure 13. Estimated annual wild stock adult chinook salmon abundance in the Secesh River compared to quasi-extinction threshold, population viability (delisting) threshold (ICTRT 2005), and management goals. Vertical bars represent 95% confidence intervals around DIDSON abundance estimates.

RECOMMENDATIONS

- Install the acoustic imaging camera fish counting station in the Secesh River in 2006 to monitor the spawning migration. Follow the Validation Plan (Johnson et al. 2004 *in* Faurot and Kucera 2004) and install two DIDSON units to estimate bias.
- Install an array of optical fish cameras to validate DIDSON counts 24 hours a day at DIDSON site 1 and for randomly selected periods at DIDSON site 2.
- Provide extensive training to personnel. Early operation at the DIDSON monitoring site would allow training of personnel with the new equipment before fish start actively migrating. This should reduce down time due to operator error and, with the additional experience, operators would be able to quickly identify and correct equipment malfunctions.

- Continue to look for improvement in DIDSON file processing to fish motion-only periods of movement. Statistically compare original DIDSON files to fish motion-only files on randomly selected days to ensure accurate salmon counts.
- Provide tributary specific adult salmon abundance information on the Secesh River for use in effective management and listed species recovery metrics monitoring.
- Location of the DIDSON monitoring site lower in the stream system may minimize the number of downstream passages observed.
- It is highly recommended that anyone envisioning using DIDSON for adult abundance monitoring field test the unit at the selected site one year prior to full scale monitoring.
- Continued improvement in automated chinook salmon counting of DIDSON files is a high priority.
- The Secesh River is the only remaining wild salmon stock in the South Fork Salmon River. It is a logical candidate for measurement of delisting criteria under the ESA to roll up to the larger ESU level.
- Information from this project may be used by NOAA Fisheries to assess effectiveness of conservation actions and delisting decisions for spring and summer chinook salmon in the Snake River basin.

LITERATURE CITED

Belcher, E.OI., B. Matsuyama, and nG. Trimble. 2001. Object identification with acvoustic lenses. Available at Http://www.apl.waahington.edu/programs/DIDSON/Media/object_ident.pdf (December 10, 2003).

Botkin, D. B., D. L. Peterson, and J. M. Calhoun (technical editors). 2000. The scientific basis for validation monitoring of salmon conservation and restoration plans. Olympic Natural Resources Technical Report. University of Washington, Olympic Natural Resources Center. Forks, Washington, USA

Dunning, D.J., Q.E. Ross, P. Geoghegan, J.J. Reichle, J.K. Menezes, and J.K. Watson. 1992. Alewives avoid high-frequency sound. N. Amer. Jrnl. Fish. Manage.. Vol 12:3 - 407-416.

Enger, P.S., H.E. Karlsen, F.R. Knudsen, and O. Sand. 1992. Detection and reaction of fish to ultrasound. Fish behavior in relation to fishing operations, 1993, p. 108-112, ICES marine science symposia. Copenhagen. Vol. 196.

Faurot, D., P. A. Kucera and J. Hesse. 2000. Escapement monitoring of adult chinook salmon in the Secesh River and Lake Creek, Idaho, 1998. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Faurot, D. and P. A. Kucera. 2001a. Adult chinook salmon abundance monitoring in the Secesh River and Lake Creek, Idaho, 1999. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Faurot, D. and P. A. Kucera. 2001b. Adult chinook salmon abundance monitoring in the Secesh River and Lake Creek, Idaho, 2000. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Faurot, D. and P. A. Kucera. 2002. Adult chinook salmon abundance monitoring in Lake Creek, Idaho, 2001. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Faurot, D. and P. A. Kucera. 2003. Chinook salmon adult abundance monitoring in Lake Creek, Idaho, 2002. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Faurot, D. and P. A. Kucera. 2004. Chinook salmon adult abundance monitoring in Lake Creek, Idaho, 2003. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Foose, T. J. ,L. deBour, U. S. Seal and R. Lande. 1995. Conservation Management Strategies based on viable populations. Pages 273-294 *in* J. D. Ballou, M. Gilpin and T. J. Foose eds. Population Management for Survival and Recovery. Columbia University Press. New York, Chichester, West Sussex.

Gough, P. and J. Gregory. 1997. The development of applications and validation methods for hydroacoustic salmonid counters. A position statement on the R & D collaboration between the Environment Agency, MAFF, SOAEFD and the Spey Research Trust. Cardiff, United Kingdom.

Gregory, J., J Bray, and P. Gough. 2001. The Development of Applications and Validation Methods for Hydroacoustic Salmonid Counters. R&D Technical Report W2/037/TR/1, Environment Agency, Bristol, United Kingdom.

Hawkins, A.D. and A.D.F. Johnstone. 1978. The hearing of the Atlantic salmon, Salmon salar. J. Fish. Biol. 13:655-673.

Hesse, J.A., J.R. Harbeck, R.W. Carmichael and 17 contributors. 2006. Monitoring and evaluation plan for Northeast Oregon Hatchery Imnaha and Grande Ronde subbasin spring Chinook salmon. Report submitted to the Bonneville Power Administration. Nez Perce Tribe Department of Fisheries Resources Management. Lapwai, ID.

Interior Columbia River Technical Recovery Team (ICTRT). Draft 2003. Independent populations of chinook, steelhead and sockeye for listed Evolutionary Significant Units within the Interior Columbia River Domain. July 2003.

Interior Columbia River Technical Recovery Team (ICTRT). 2004. Preliminary guidelines for population-level abundance, productivity, spatial structure, and diversity supporting viable salmonid populations: An update. Interior Columbia River Technical Recovery Team. December 13, 2004.

Interior Columbia River Basin Technical Recovery Team (ICTRT). 2005. Interior Columbia Basin TRT: Viability criteria for application to interior Columbia basin salmonid ESUs. Interior Columbia River Basin Technical Recovery Team. July, 2005.

Johnson, R.L., C.A. McKinstry, D.A. Faurot, and P.A. Kucera. 2004. Validation plan for acoustic imaging camera counting of adult chinook salmon in the Secesh River, Idaho. *In* D. Faurot and P.A. Kucera - Chinook salmon adult abundance monitoring in Lake Creek, Idaho, 2003. Annual report submitted to the Bonneville Power Administration. Portland, Oregon.

Knudsen, F.R., P.S. Enger, and O. Sand. 1992. Awareness reactions and avoidance resoponses to sound in juvenile Atlantic Salmon, Salmon salar, L.J. Fish. Biol. 40 No. 4, 523-534.

Knudsen, F.R., P.S. Enger, and O. Sand. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic Salmon smolt. J. Fish. Biol. 45, No 2, 227-233.

Knudsen, F.R., C.B. Schreck, S. M. Knapp, P.S. Enger, and O. Sand. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. J. Fish. Biol., 51, No. 4, 824-829.

Kynard, B. and J. O'Leary. 1990. Behavioral guidance of American Shad using underwater AC electrical and acoustic fields. Proceedings of the International Symposium on Fishways '90 in Gifu, Japan, October 8-10, 1990.

Maxwell, S.L. and N.E. Gove. 2004. The feasibility of estimating migrating salmon passage rates in turbid rivers using a dual frequency identification sonar (DIDSON) -20002. Regional information report No. 2A04-05. Alaska Department of Fish and Game. Anchorage, Alaska.

McCubbingD. J., B. Ward and L. Burroughs. 2000. Salmonid escapement enumeration on the Keogh River: a demonstration of a resistivity counter in British Columbia. Province of British Columbia Fisheries Technical Circular 104. Vancouver, B. C.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. U. S. Department of Commerce. NOAA Technical Memorandum. NMFS-NWFSC-42,156 p.

Moore, D.S. and G.P. McCabe. 1993. Introduction to the Practice of Statistics. W.H. Freeman and Company. New York.

Moursund, R.A., K.D. Ham, P.S. Titzler, R.P. Mueller, G.E. Johnson, J. Hedgepeth, and J.R. Skalski. 2002. Hydroacoustic evaluations of fish passage at the Dalles dam in 2001. U.S. Army Corps of Engineers, Portland, Oregon.

Mueller, R.P., R.A. Moursund, T.M. Degerman, and G.A. McMichael. 2003. Feasability of monitoring fall chinook salmon fallback at Priest Rapids Dam using an acoustic camera – 2001. *In* Chinook salmon in the Priest Rapids project, G.A. McMichael, D.R. Geist, T.P. Hanrahan, E.V. Arntzen, R.P. Mueller, R.A. Moursund, J.A. Carter, J.M. Becker, C.A. McKinstry, W.A. Perkins, D.D. Dauble, T.M. Degerman, J.R. Skalski, R.L. Townsend, B.B. James, and D.R. Thornhill. P. 4.41-1 to 4.4-18. Technical Appendix E-4.B in Public Utility District No. 2 of Grant County, Final License Application Priest Rapids Project FERC No. 2114. Public Utility District No. 2 of Grant County, Ephrata, Washington.

Nestler, J.M. et al. 1992. Responses of blue back herring to high frequency sound and impliocations for reducing entrainment at hydropower dams. North Amer. Jrnl. Fish. Manag. 12:667-683.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon, final rule. Federal Register 57:78 (22 April 1992) 7:14, 653,663.

NMFS (National Marine Fisheries Service). 2000. Final Biological Opinion: Operation of the federal Columbia River power system including the juvenile fish transportation program and the Bureau of Reclamation's 31 projects, including the entire Columbia Basin Project. December 21, 2000

NMFS (National Marine Fisheries Service). 2002. Interim abundance and productivity targets for Interior Columbia River Basin salmon and steelhead listed under the Endangered Species Act (ESA). April 4, 2002 letter from Bob Lohn, National Marine Fisheries Service to Frank L. Cassidy, Jr. Chairman, Northwest Power Planning Council. Seattle, WA.

Ross, Q.E., D.J. Dunning, R. Thorne, J.K. Menezes, G.W. Tiller, and J.K. Watson. 1993. Response of alewives to high-frequency sound at a power plant intake on Lake Ontario. N. Amer. Jrnl. Fish. Man. 13 No. 2, 291-303.

Shardlow, T. 1998. Field assessments of the Vaki infrared counter at Cheewhat Lake and the Big Qualicum River. Report to file. Pacific Biological Station. Department of Fisheries and Oceans, Canada.

Smith I. P. , A. D. F. Johnstone and D. A. Dunkley. 1996. Evaluation of a portable electrode array for a risistivity fish counter. Fisheries management and ecology, 1996 3:129-141.

Tiffan, K.F., D.W. Rondorf, and J.J. Skalicky. 2004. Imaging fall chinook salmon redds in the Columbia River with a dual-frequency identification sonar. North American Journal of Fisheries Management 24:1421-1426.

Vogel, J.L., J.A. Hesse, J.R. Harbeck, D.D. Nelson, and C.D. Rabe. 2005. Johnson Creek summer Chinook salmon monitoring and evaluation plan. Northwest Power and Conservation Council Step 2/3 document. Prepared for BPA, DOE/BP-16450. Bonneville Power Administration, Portland, OR.

APPENDIX B

Table B1. Two sample Z test comparing the difference between randomly selected day original DIDSON 1 file salmon counts, and fish motion-only file salmon manual counts, by direction of movement, of adult salmon in the Secesh River in 2005. Ho: P1 = P2, Ha: P1≠ P2. Proportions were used to adjust daily upstream and downstream salmon counts for early season and late season. Period 1 was from June 8 to July 28, and period 2 was from July 29 to September 15.

Period	Correct	Possible	Proportion	Z Value	P value
		Up Stream Movements			
1	220	225	0.9778		
2	389	390	0.9974	2.3890	0.0084**
		Down Stream Movements			
1	148	155	0.9548		
2	328	355	0.9239	1.2865	0.0991

** - Indicates significant difference at the $p < 0.05$ level.

Table B2. Two sample Z test comparing within observer file reader error of fish motion-only DIDSON 1 file manual counts on randomly selected days, by direction of fish movement, of adult salmon in the Secesh River in 2005. Ho: P1 = P2, Ha: P1≠ P2. Proportions were used to adjust daily upstream and downstream salmon counts for individual readers. Period 1 was from June 8 to July 28, and period 2 was from July 29 to September 15.

Reader	Period	Correct	Possible	Proportion	Z Value	P value
			Up Stream Movements			
1	1	205	220	0.9318		
	2	387	389	0.9949	4.5366	0.0000**
2	1	217	220	0.9864		
	2	387	389	0.9949	1.1160	0.1322
3	1	217	220	0.9864		
	2	388	389	0.9974	1.6239	0.0522
			Down Stream Movements			
1	1	124	148	0.8378		
	2	316	328	0.9634	4.7963	0.0000**
2	1	140	148	0.9459		
	2	325	328	0.9909	3.0183	0.0013**
3	1	141	148	0.9527		
	2	322	328	0.9817	1.7971	0.0362**

** - Indicates significant difference at the $p < 0.05$ level.

Table B3. Equipment downtime at the DIDSON monitoring site in 2005.

Date	Time stopped	Time re-started	Total Outage
09-Jun-05	14:01	15:19	1:18
11-Jun-05	11:03	00:00	12:57
12-Jun-05	00:00	10:40	10:40
13-Jun-05	16:21	00:00	7:39
14-Jun-05	00:00	13:35	10:35
17-Jun-05	12:02	13:14	1:12
24-Jun-05	22:18	00:00	1:42
25-Jun-05	00:00	11:14	11:14
11-Aug-05	12:56	15:14	2:17
27-Aug-05	20:37	00:00	3:23
28-Aug-05	00:00	14:55	14:55
14-Sep-05	04:01	13:05	9:04

Table B4. Extensive area chinook salmon redd count data from the Secesh River and tributaries from 1998 to 2005.

	Lake Creek						
Year	Index Area	Non-index Area	Secesh River main-stem[2]	Summit Creek	Grouse Creek	Lick Creek	Total Secesh Drainage Redds
1998	45	5	54	8	5	0	117
1999	13	11	34	8	0	0	66
2000	157[1]	22	118	7	23	0	327
2001	296[1]	41	276	36	66	3	718
2002	176[1]	24	244	55	29	0	528
2003	200[1]	44	257	61	31	2	595
2004	151	32	146	53	13	0	395
2005	68	11	102	6	18	0	205

[1] Redds observed between video count station and the mouth of Lake Creek: 2000-1 redd; 2001-1 redds; 2002-2 redds; and 2003-2 redds.

[2] Six redds and five redds were counted below the DIDSON monitoring site in the Secesh River in 2004 and 2005, respectively.

Table B5. Dates of net upstream migration and total movements of adult spring and summer chinook salmon at the DIDSON monitoring site in the Secesh River in 2005. The data is adjusted for motion detection error, reader error and downtime.

Date	Total Movements	Net Upstream	Cumulative Net Upstream
8-Jun	0	0	0
9-Jun	0	0	0
10-Jun	0	0	0
11-Jun	1	2	2
12-Jun	2	4	6
13-Jun	4	-3	3
14-Jun	0	0	3
15-Jun	3	1	4
16-Jun	1	1	5
17-Jun	1	-1	3
18-Jun	0	0	3
19-Jun	3	1	4
20-Jun	0	0	4
21-Jun	0	0	4
22-Jun	2	0	4
23-Jun	3	1	5
24-Jun	2	0	5
25-Jun	6	4	9
26-Jun	8	6	15
27-Jun	8	-1	14
28-Jun	1	1	15
29-Jun	12	3	17
30-Jun	5	1	18
1-Jul	15	8	26
2-Jul	9	7	33
3-Jul	24	19	53
4-Jul	18	9	62
5-Jul	12	10	72
6-Jul	56	20	93
7-Jul	67	36	129
8-Jul	65	9	138
9-Jul	37	0	138
10-Jul	50	4	142

Table B5. Continued.

Date	Total Movements	Net Upstream	Cumulative Net Upstream
11-Jul	20	0	142
12-Jul	22	5	146
13-Jul	25	16	163
14-Jul	61	17	180
15-Jul	63	5	185
16-Jul	63	17	202
17-Jul	28	1	204
18-Jul	68	-14	189
19-Jul	59	-1	189
20-Jul	36	7	196
21-Jul	37	6	202
22-Jul	85	6	208
23-Jul	84	13	222
24-Jul	63	8	229
25-Jul	91	10	239
26-Jul	14	3	242
27-Jul	20	0	242
28-Jul	50	4	246
29-Jul	85	1	247
30-Jul	21	-1	246
31-Jul	27	7	253
1-Aug	104	13	266
2-Aug	172	4	271
3-Aug	70	2	272
4-Aug	16	-2	271
5-Aug	19	1	272
6-Aug	39	1	273
7-Aug	59	4	277
8-Aug	54	8	285
9-Aug	83	6	290
10-Aug	291	8	298
11-Aug	93	0	298
12-Aug	431	2	300
13-Aug	194	-3	297
14-Aug	172	9	306
15-Aug	364	2	307

Table B5. Continued.

Date	Total Movements	Net Upstream	Cumulative Net Upstream
16-Aug	128	7	314
17-Aug	149	12	326
18-Aug	179	0	326
19-Aug	104	0	326
20-Aug	71	5	331
21-Aug	117	-7	324
22-Aug	16	-2	322
23-Aug	20	6	329
24-Aug	24	2	331
25-Aug	104	5	335
26-Aug	48	2	337
27-Aug	75	2	339
28-Aug	13	-2	337
29-Aug	18	-2	336
30-Aug	1	1	337
31-Aug	4	0	336
1-Sep	3	1	337
2-Sep	4	0	337
3-Sep	0	0	337
4-Sep	0	0	337
5-Sep	0	0	337
6-Sep	1	1	338
7-Sep	0	0	338
8-Sep	0	0	338
9-Sep	0	0	338
10-Sep	0	0	338
11-Sep	1	-1	337
12-Sep	0	0	337
13-Sep	0	0	337
14-Sep	0	0	337
15-Sep	0	0	337

Table B6. Dates of observed net upstream migration, net adjustments due to reader and motion detection error, net adjustments due to downtime, adjusted daily net upstream passages, and adjusted cumulative net upstream passages of adult spring and summer Chinook salmon at the DIDSON monitoring site in the Secesh River in 2005.

Date	Observed Net Upstream	Reader-Motion Detection Adjustment	Down Time Adjustment	Adjusted Net Upstream	Cumulative Upstream
8-Jun	0	0.0	0.0	0.0	0
9-Jun	0	0.0	0.0	0.0	0
10-Jun	0	0.0	0.0	0.0	0
11-Jun	1	0.0	1.2	2.2	2
12-Jun	2	0.1	1.7	3.7	6
13-Jun	-2	-0.3	-1.1	-3.4	3
14-Jun	0	0.0	0.0	0.0	3
15-Jun	1	0.0	0.0	1.0	4
16-Jun	1	0.0	0.0	1.0	5
17-Jun	-1	-0.1	-0.1	-1.2	3
18-Jun	0	0.0	0.0	0.0	3
19-Jun	1	0.0	0.0	1.0	4
20-Jun	0	0.0	0.0	0.0	4
21-Jun	0	0.0	0.0	0.0	4
22-Jun	0	-0.1	0.0	-0.1	4
23-Jun	1	0.0	0.0	1.0	5
24-Jun	0	-0.1	0.0	-0.1	5
25-Jun	2	-0.1	1.7	3.6	9
26-Jun	6	0.1	0.0	6.1	15
27-Jun	-1	-0.3	0.0	-1.3	14
28-Jun	1	0.0	0.0	1.0	15
29-Jun	3	-0.2	0.0	2.8	17
30-Jun	1	-0.1	0.0	0.9	18
1-Jul	8	0.0	0.0	8.0	26
2-Jul	7	0.2	0.0	7.2	33
3-Jul	19	0.5	0.0	19.5	53
4-Jul	9	0.0	0.0	9.0	62
5-Jul	10	0.2	0.0	10.2	72
6-Jul	21	-0.5	0.0	20.5	93
7-Jul	36	0.1	0.0	36.1	129
8-Jul	11	-1.5	0.0	9.5	138

Table B6. Continued.

Date	Observed Net Upstream	Reader-Motion Detection Adjustment	Down Time Adjustment	Adjusted Net Upstream	Cumulative Upstream
9-Jul	1	-1.2	0.0	-0.2	138
10-Jul	5	-1.4	0.0	3.6	142
11-Jul	1	-0.6	0.0	0.4	142
12-Jul	5	-0.4	0.0	4.6	146
13-Jul	16	0.2	0.0	16.2	163
14-Jul	18	-0.9	0.0	17.1	180
15-Jul	7	-1.5	0.0	5.5	185
16-Jul	18	-0.9	0.0	17.1	202
17-Jul	2	-0.8	0.0	1.2	204
18-Jul	-11	-3.1	0.0	-14.1	189
19-Jul	1	-1.8	0.0	-0.8	189
20-Jul	8	-0.6	0.0	7.4	196
21-Jul	7	-0.7	0.0	6.3	202
22-Jul	8	-2.2	0.0	5.8	208
23-Jul	15	-1.7	0.0	13.3	222
24-Jul	9	-1.4	0.0	7.6	229
25-Jul	12	-2.1	0.0	9.9	239
26-Jul	3	-0.2	0.0	2.8	242
27-Jul	1	-0.9	0.0	0.1	242
28-Jul	6	-2.1	0.0	3.9	246
29-Jul	5	-3.8	0.0	1.2	247
30-Jul	0	-1.0	0.0	-1.0	246
31-Jul	8	-0.9	0.0	7.1	253
1-Aug	17	-4.0	0.0	13.0	266
2-Aug	12	-7.6	0.0	4.4	271
3-Aug	5	-3.1	0.0	1.9	272
4-Aug	-1	-0.8	0.0	-1.8	271
5-Aug	2	-0.8	0.0	1.2	272
6-Aug	3	-1.7	0.0	1.3	273
7-Aug	6	-2.5	0.0	3.5	277
8-Aug	10	-2.1	0.0	7.9	285
9-Aug	9	-3.5	0.0	5.5	290
10-Aug	21	-12.7	0.0	8.3	298
11-Aug	4	-4.2	0.0	-0.2	298
12-Aug	21	-19.4	0.0	1.6	300

Table B6. Continued.

Date	Observed Net Upstream	Reader-Motion Detection Adjustment	Down Time Adjustment	Adjusted Net Upstream	Cumulative Upstream
13-Aug	6	-8.9	0.0	-2.9	297
14-Aug	16	-7.3	0.0	8.7	306
15-Aug	18	-16.4	0.0	1.6	307
16-Aug	12	-5.5	0.0	6.5	314
17-Aug	18	-6.1	0.0	11.9	326
18-Aug	8	-8.1	0.0	-0.1	326
19-Aug	5	-4.7	0.0	0.3	326
20-Aug	8	-3.0	0.0	5.0	331
21-Aug	-1	-5.6	0.0	-6.6	324
22-Aug	-1	-0.8	0.0	-1.8	322
23-Aug	7	-0.6	0.0	6.4	329
24-Aug	3	-1.0	0.0	2.0	331
25-Aug	9	-4.5	0.0	4.5	335
26-Aug	4	-2.1	0.0	1.9	337
27-Aug	5	-3.3	0.3	2.0	339
28-Aug	0	-0.7	-1.2	-1.9	337
29-Aug	-1	-0.8	0.0	-1.8	336
30-Aug	1	0.0	0.0	1.0	337
31-Aug	0	-0.2	0.0	-0.2	336
1-Sep	1	-0.1	0.0	0.9	337
2-Sep	0	-0.2	0.0	-0.2	337
3-Sep	0	0.0	0.0	0.0	337
4-Sep	0	0.0	0.0	0.0	337
5-Sep	0	0.0	0.0	0.0	337
6-Sep	1	0.0	0.0	1.0	338
7-Sep	0	0.0	0.0	0.0	338
8-Sep	0	0.0	0.0	0.0	338
9-Sep	0	0.0	0.0	0.0	338
10-Sep	0	0.0	0.0	0.0	338
11-Sep	-1	-0.1	0.0	-1.1	337
12-Sep	0	0.0	0.0	0.0	337
13-Sep	0	0.0	0.0	0.0	337
14-Sep	0	0.0	0.0	0.0	337
15-Sep	0	0.0	0.0	0.0	337