Identification and Assessment of Fall Chinook Salmon(*Oncorhynchus tshawytscha*) Spawning below The Dalles, John Day and McNary Dams

Final Report for Redd Surveys 2001 – 2006

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Summary

This report describes research conducted from 2001 to 2006 to investigate use of the mainstem Columbia River below The Dalles, John Day and McNary dams by spawning fall Chinook salmon through deep water redd surveys. Initial reconnaissance level surveys conducted in 2001 documented salmon redds below John Day Dam. No redds were observed below The Dalles or McNary dams and researchers concluded that spawning habitat conditions below The Dalles were not conducive to spawning, however, conditions appeared to be well suited below McNary Dam. Comprehensive redd surveys were subsequently conducted below John Day Dam from 2002 to 2006. However, 2006 surveys were incomplete because of high turbidities. No surveys were conducted below the other dams in any other years, but researchers recommended additional surveys below McNary Dam. Redd surveys documented a low of 96 redds in 2002 and a high of 183 in 2004. Expanded estimates for a total redd population below John Day Dam ranged from 880 to 1,597 redds for the same years. A run reconstruction exercise was conducted for the John Day Dam tailrace, to determine what the adult escapement may have been with index escapement estimates ranging from 20,362 (2005) to 57,823 (2003) adult fall Chinook salmon for the comprehensively sampled period (2002 – 2005).

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Table of Contents

List of Figures

List of Tables

List of Appendices

Introduction

This report describes studies conducted by the U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office from 2001 – 2006 to identify and assess mainstem spawning fall Chinook salmon (*Oncorhynchus tshawytscha*) below The Dalles, John Day and McNary dams in the Columbia River through deep water redd surveys. We present the results of six years of surveys in a single report for reader continuity. These studies also support concurrent and subsequent research goals to quantify suitable spawning habitat for these populations over a range of hydrosystem operations. Spawning habitat studies are discussed in a complimentary companion report. The work is funded by the Bonneville Power Administration (BPA) under the Northwest Power and Conservation Council's Fish and Wildlife Program. The Program is an attempt to mitigate, protect and enhance fish and wildlife losses from the construction and operation of the Columbia River hydrosystem.

This specific project, BPA project No. 1999003 "Evaluation of Fall Chinook and Chum Salmon Spawning below Bonneville, The Dalles, John Day and McNary Dams", was initially funded in 1998 under the program after fall Chinook and chum salmon were both discovered spawning in the Columbia River below Bonneville Dam in the Ives/Pierce Island Complex. Various studies related to the research below Bonneville Dam can be reviewed in: Hymer (1997), Garland et al. (2003), Tiffan et al. (2004), Tiffan et al. (2005), van der Naald (1999 – 2005), Geist et al. (2002) and Mueller (2000 – 2004). In addition, a wide array of data and maps can be viewed and downloaded from the Fish Passage Center's web page at www.fpc.org. Past studies conducted below Bonneville Dam, which are part of the same project (BPA Project 1999003), are not discussed in this report. When funding was initially approved for the research below Bonneville Dam in 1998, we hypothesized that fall Chinook could also be spawning in the tailraces below The Dalles, John Day and McNary dams if habitat conditions were suitable or fall Chinook potentially could spawn in these areas with favorable or alternate configurations of the hydrosystem. This report details efforts to explore the question: Are fall Chinook spawning below The Dalles, John Day and McNary Dams?

The studies below each of the mainstem dams are composed of two separate and complementary tasks. The first task is simply identifying and enumerating fall Chinook redds that are present below each of the dams and the second task is quantifying how much habitat is available. Hydrodynamic and the resulting habitat modeling would be within normal operating limits for the fall time period (November and December) and would not include excessive pool draw-downs or run of the river modeling scenarios. If Chinook are not observed (via redd surveys) or the habitat is determined predominantly unsuitable, (i.e. bedrock or the habitat is prohibitively deep), no quantitative habitat assessment would be conducted. This report specifically describes efforts related to identifying spawning populations through redd surveys, numerically and spatially quantifying the redds, measuring the relevant habitat metrics and describing the methodologies used in the assessments. Field studies conducted below The Dalles and McNary dams represents work related to the identification of spawning fall Chinook only, while the studies conducted below John Dam represented a quantitative effort to estimate the total number and spatial distribution of redds excavated each year.

Historically, the mainstem Columbia River supported at least eight major fall Chinook spawning areas, extending from river kilometers 235 – 1124 (Dauble et al. 2003). At the turn of the 20th century, mainstem fall Chinook populations were a major contributor to the 10 to 16 million salmon returning annually to the Columbia River (ISAB 2000). The present annual return of salmon to the river is approximately 1-2 million fish, of which the majority (>80%) are produced artificially in hatcheries (ISAB 2000). It is estimated that the construction and operation of the hydrosystem has decreased the historical abundance by 5 to 11 million fish annually (ISAB 2000). Today, the Hanford Reach is the only significant vestige of what once was a highly-productive natural system for fall Chinook, and the Hanford Reach may be functioning as a meta-population, potentially seeding other suitable mainstem Columbia River habitats, including those in this study. In addition to the Hanford Reach, recent research has documented natural spawning of fall Chinook below many of the Columbia and Snake River dams including Bonneville, Priest Rapids, Wanapum, Rock Island and Wells dams in the Columbia River and Little Goose, Lower Granite and Hells Canyon dams in the Snake River (Figure 1) (Rogers et al. 1989; Hymer 1997; Horner and Bjornn 1979; Giorgi 1992; Dauble et al. 1999).

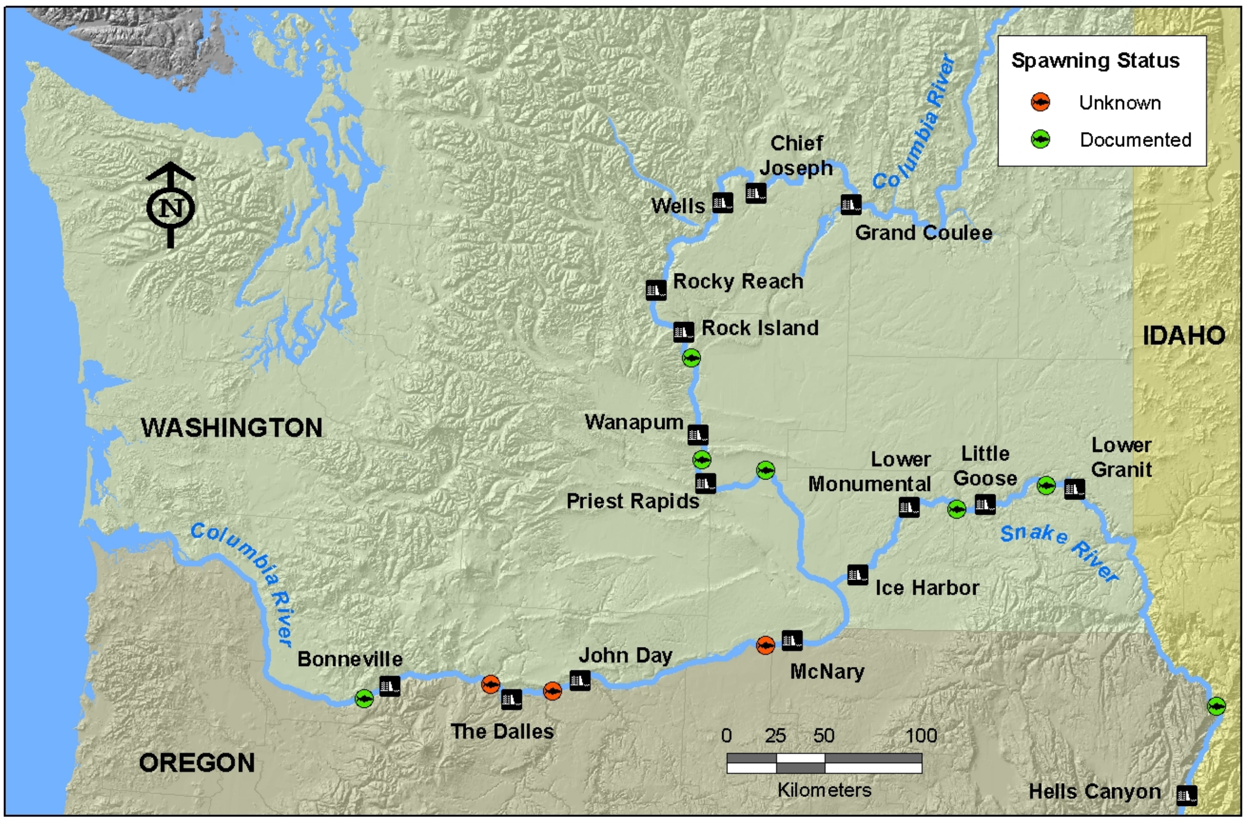

Figure 1. Status of mainstem Columbia and Snake River spawning locations for fall Chinook. With the exceptions of the Hanford Reach and Hells Canyon, all known spawning is located in tailrace areas. A single redd in the 1990's was observed below Ice Harbor dam, but is not included in this figure.

Study Area

The Columbia River and its basin are the second largest drainage in the United States and supports a large range of natural and human interests including hydroelectric power production, flood control, irrigation, navigation, native and non-native fish stocks, and sport, commercial and tribal fisheries on those stocks. The former free-flowing Columbia River is now a sequence of slack-water reservoirs with the exception of the Hanford Reach and a tidally influenced section which extends from Bonneville Dam to the Pacific Ocean. The lower Columbia River, defined here as the section of the river from McNary Dam downstream to the Pacific Ocean is impounded by Bonneville, The Dalles, John Day and McNary dams. Moreover, the hydrodynamic conditions of the river are largely influenced by their respective reservoirs, rather than functioning as a free flowing river. The geographic extent of the work conducted for this report extends from the tailrace of The Dalles Dam, upstream to the tailrace of McNary Dam (Figure 2) but the actual field work takes place over a few kilometers below each dam in its respective tailrace.

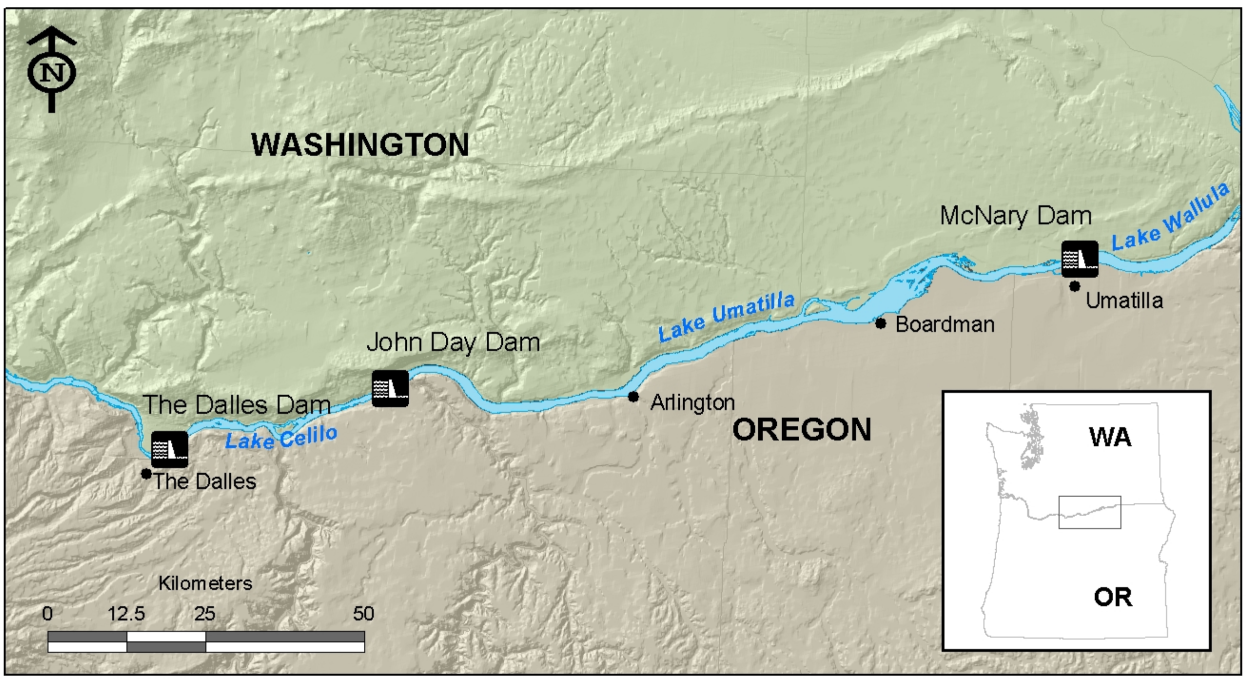

Figure 2. Overview and locations of The Dalles, John Day and McNary Dams and their respective impoundments. The states of Washington and Oregon lie to the north and south respectively, while the Columbia River flows from east to west.

The tailrace is defined here as the portion of the river immediately below the dam, extending downstream and terminating at the interface with the downstream reservoir where water velocity slows significantly and depths increase along with channel area. Tailrace habitats are unique in that they can resemble normal riverine habitats, but they are also affected by the seasonal, daily, and hourly operation of the hydrosystem. The actual length of the tailrace varies at each dam and with river and reservoir operations. A lower downstream pool elevation results in an extended tailrace, while a full pool results in a shortened tailrace. As such, it is possible to observe the same stage for a range of discharges or the same discharge for a range of stages. This condition is evidenced by a "backwater effect" and is defined by an increase in water surface elevation and cross sectional area, and reduced water velocities. Tailrace lengths in the lower Columbia can vary from virtually nonexistent to a few kilometers in length based on the elevation of the downstream pool and river flow.

The Dalles Dam Study Area

The study site below The Dalles Dam is located in the tailrace and extends from the dam, downstream approximately 2 km to the US197 Bridge spanning the Columbia River. This section of the river is immediately north of the city of The Dalles, Oregon (Figure 3). As with all the study sites, the states of Washington and Oregon define the northern and southern shorelines, respectively. The shoreline and much of the riverbed below The Dalles Dam is largely composed of bedrock, which is somewhat evident in the aerial photograph (Figure 3). This study site is the deepest of the three study sites with depths often in excess of 30 m. Fish ladders are located along both shorelines at either end of the dam.

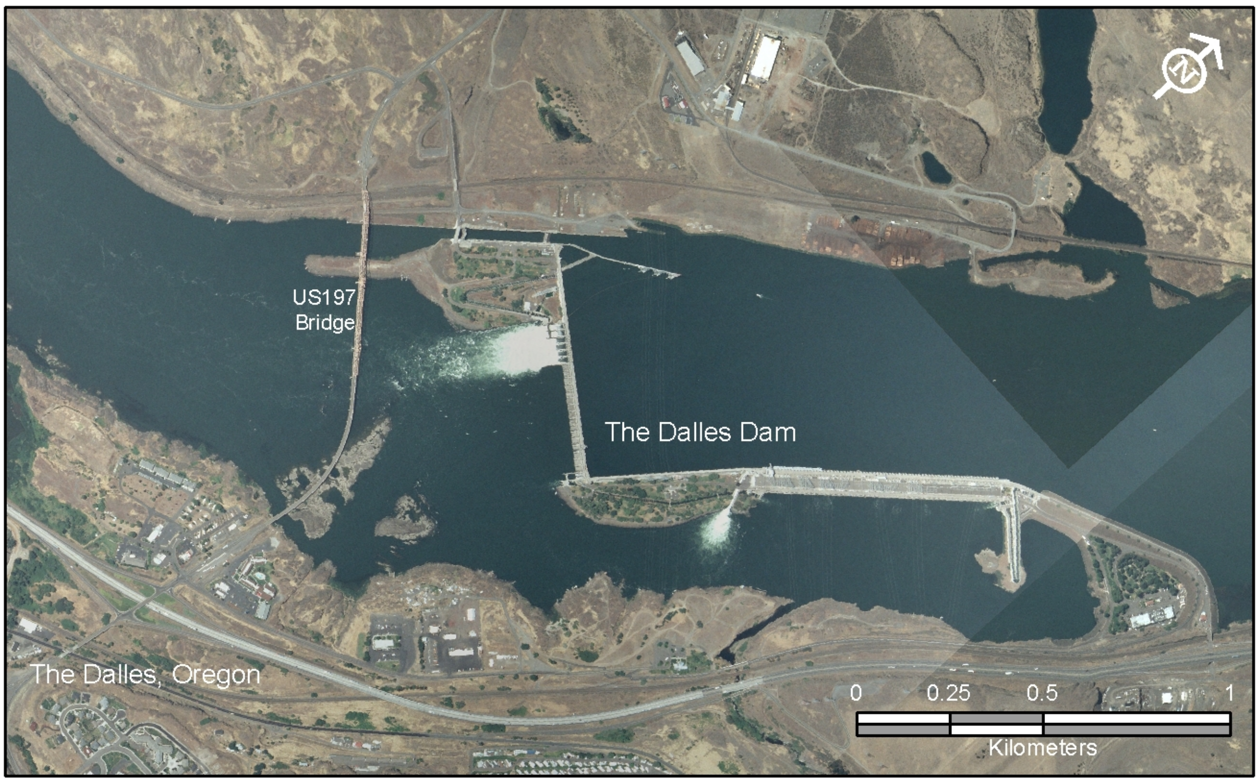

Figure 3. Aerial photograph of The Dalles Dam study site with portions of The Dalles, Oregon visible just to the south. Irregular bedrock formations are also evident along most of the Oregon shoreline. In this photo, the spillway is actively spilling water for ESA listed salmon stocks.

John Day Dam Study Area

The study site below John Day Dam is located in the tailrace between river kilometers 346.0 to 349.2 (Figure 4). The John Day Dam tailrace is bisected by a small gravel island 1.8 kilometers below the dam (Figure 4) and by the island's large eddy (Preachers Eddy) located immediately downstream. The north half of the tailrace lies along the Washington State shoreline, contains the navigation locks and shipping channel and is immediately downstream of the spill gates. The southern half of the tailrace is bounded by the Oregon shoreline and is immediately downstream of the powerhouse (Figure 4). Fish ladders are located along both shorelines at either end of the dam.

Figure 4. Aerial view of John Day Dam and the downstream study site.

McNary Dam Study Area

Of the three study sites, the tailrace below McNary Dam is the largest and was a previously documented spawning site for fall Chinook salmon (Fulton 1968). Our study site extended from the dam, downstream 5 km to the mouth of the Umatilla River (Figure 5). The Umatilla River enters the Columbia River from the south near the south end of the study site and is adjacent to the city of Umatilla, Oregon. Plymouth Island, just south of Plymouth, Washington, lies opposite the Umatilla River.

Figure 5. Aerial view of McNary Dam and the downstream tailrace with spill occurring at the dam.

Methods

In an initial effort to document spawning below The Dalles, John Day and McNary Dams, project cooperators from a joint ODFW and WDFW field crew, conducted spawning ground surveys in each of the three tailrace areas from 1998 though 2001. Prior to these surveys and after the completion of the Columbia River hydrosystem there was no knowledge of fall Chinook spawning in any of these locations with the exception of the historical note from Fulton (1968) who mentions spawning was occurring in the 160 km section of the Columbia River below the confluence with the Snake River. Visual surveys by ODFW and WDFW were conducted weekly from the bow of a 6 m jet boat along each shoreline from October 26 through December 15 when water visibilities were approximately 1.5 m. Carcasses, redds and any live fish were documented for each survey (Table 1) and mapped with a GPS. This technique documented some potential use by fall Chinook (Table 1), however, the redd counts were likely low due to deep water spawning (>3 m) which requires other techniques such as underwater videography to adequately observe and count redds.

Table 1. **Summary of tailrace spawning ground surveys conducted jointly by WDFW and ODFW over a four year period from 1998 – 2001. Surveys were discontinued after 2001. Table adopted from van der Naald (1999 – 2002).**

The Dalles Dam Tailrace

Year	Redds	Live	Dead
1998	0	1	4
1999	0	0	0
2000	0	0	1
2001	0	0	3
Total (All Years)	0	1	8

John Day Dam Tailrace

Year	Redds	Live	Dead
1998	0	2	54
1999	0	1	7
2000	2	4	19
2001	0	2	12
Total (All Years)	2	9	92

McNary Dam Tailrace

Year	Redds	Live	Dead
1998	0	1	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
Total (All Years)	0	1	0

Reconnaissance Redd Surveys

To expand and further investigate the redd observations made by the ODFW and WDFW field crew, we conducted exploratory deep water reconnaissance surveys in 2001 in each of the three tailrace areas using underwater videography (Groves 1998). Underwater videography is the acquisition of live video with underwater video cameras to observe the river bottom. The results of each reconnaissance survey are presented here to provide context in regard to the overall goals and ensuing methods of the project. The objective of these surveys was to determine if any redds were present as well as make qualitative habitat suitability assessments about the river in terms of substrate, depth and velocity. Positive identification of redds would support a subsequent and more rigorous effort to quantify redds with a systematic methodology utilizing underwater videography.

To increase the probability of finding fall Chinook redds, we focused the reconnaissance surveys on geographic locations where fall Chinook could potentially spawn based on published spawning habitat suitability criteria. The criteria selected for the surveys were generous and included depths less than 10 m, slopes less than about 10%, substrates composed of any size gravel or cobble and velocities generally ranging from 0.3 – 2.0 m/s. Again, we included the extreme ends of potential spawning habitat criteria so that even marginally suitable habitat would be searched in the event that it was suitable under flow regimes that may have been different in the days or weeks prior to the survey. The data we queried for spawning site suitability included: NOAA - Navigation Charts for the Columbia River, USACE - Reach Inventory Reports - Columbia River to McNary Dam, USGS topographic maps, and aerial photography. By querying those data, the survey crew avoided sampling in some areas where depths exceeded 10 m, over large flats of documented bedrock, or over any known hazards. No substrate data existed prior to the surveys but we did make some bedrock inferences from the NOAA Charts and aerial photography. Additionally, for each survey we acquired access into the boat restricted zone (BRZ) from the USACE to assess spawning adjacent to each of the dams and locks.

As previously mentioned, the reconnaissance survey methods were bounded by spawning habitat suitability criteria but were also flexible to account for potential unknowns. Underwater video surveys were performed along transects perpendicular to river flow from one shoreline to the other. Transect spacing for these surveys was somewhat variable to account for unknowns and the exploratory nature of the surveys. The primary goal was to determine if any spawning was occurring in each of the three tailrace areas through redd observations. Positive identification of redds would lead to a more intensive and rigorous assessment in subsequent years with more advanced methods. Again, the results of our reconnaissance surveys are presented here since they are the determinate factor in how the ensuing field methods were developed, and for which tailraces subsequent surveys were warranted.

2001 - The Dalles Dam Tailrace Reconnaissance Survey.

On November 5, 2001, we conducted redd surveys in The Dalles Dam tailrace using underwater videography. The survey was conducted early in the spawning season as referenced to index redd counts for fall Chinook redd counts in the Hanford Reach. Based on the available data layers reviewed and the reconnaissance surveys, the majority of the study site was in excess of our 10 m depth criteria and was not surveyed. Where depths were less than 10 m, observed substrates were predominantly composed of bedrock. Only a few small patches of cobble were mapped and no redds were observed. All videography surveys were conducted upstream of the US197 Bridge (Figure 6).

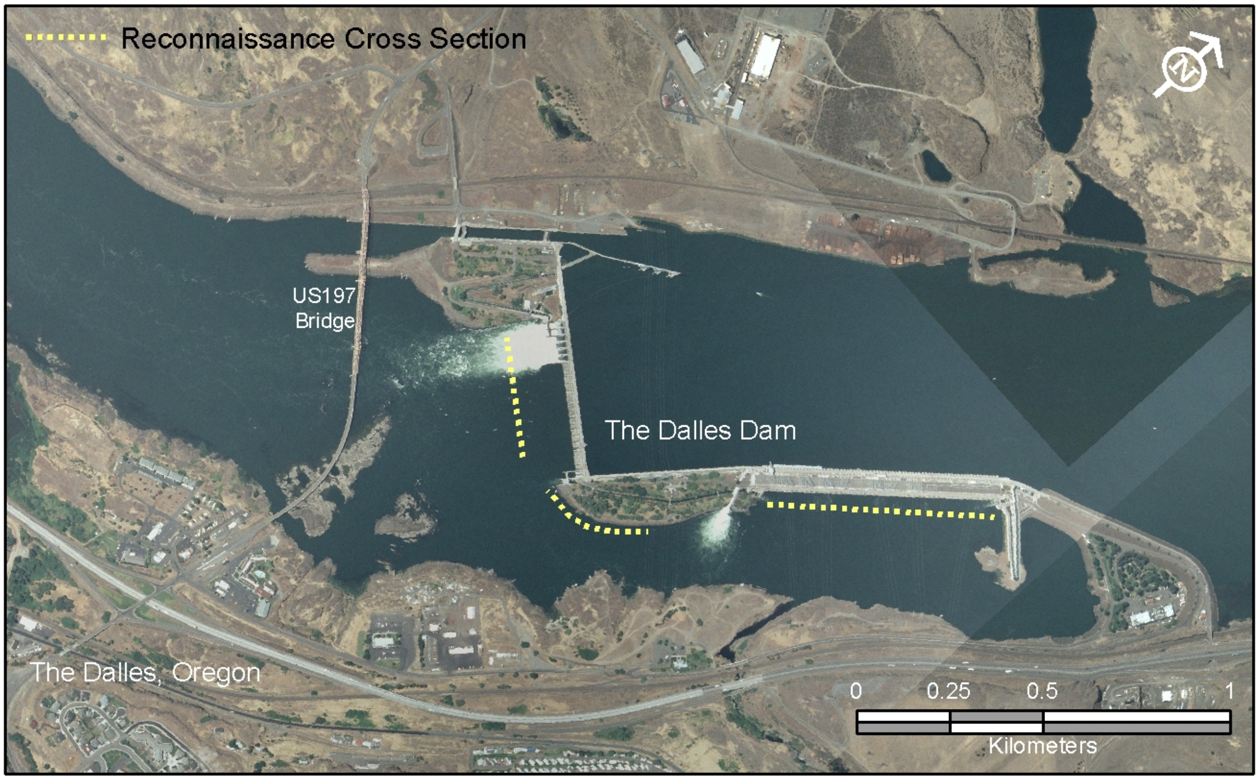

Figure 6. 2001 – The Dalles Dam reconnaissance survey area.

2001 - McNary Dam Tailrace Reconnaissance Survey.

On November 6 and 7, 2001, we conducted redd surveys in the McNary Dam tailrace. Again, using videography, we surveyed a 5 km section of the tailrace starting at the dam and extending downstream to the mouth of the Umatilla River (Figure 7). We surveyed a total of 10 cross sections perpendicular to the river flow from riverbank to riverbank. Cross section length varied from 350 to 900 m and was spaced at 500 m intervals (Figure 7). Substrates were variable ranging from bedrock to gravel. No fall Chinook redds were observed but based on observations of suitable depth and substrates, there was definite potential for spawning to occur in the McNary tailrace. Again, this survey was early in the spawning season and redds may have been observed at a later survey date or they may have been simply missed with the coarse cross sectional spacing in relation to the large area of river.

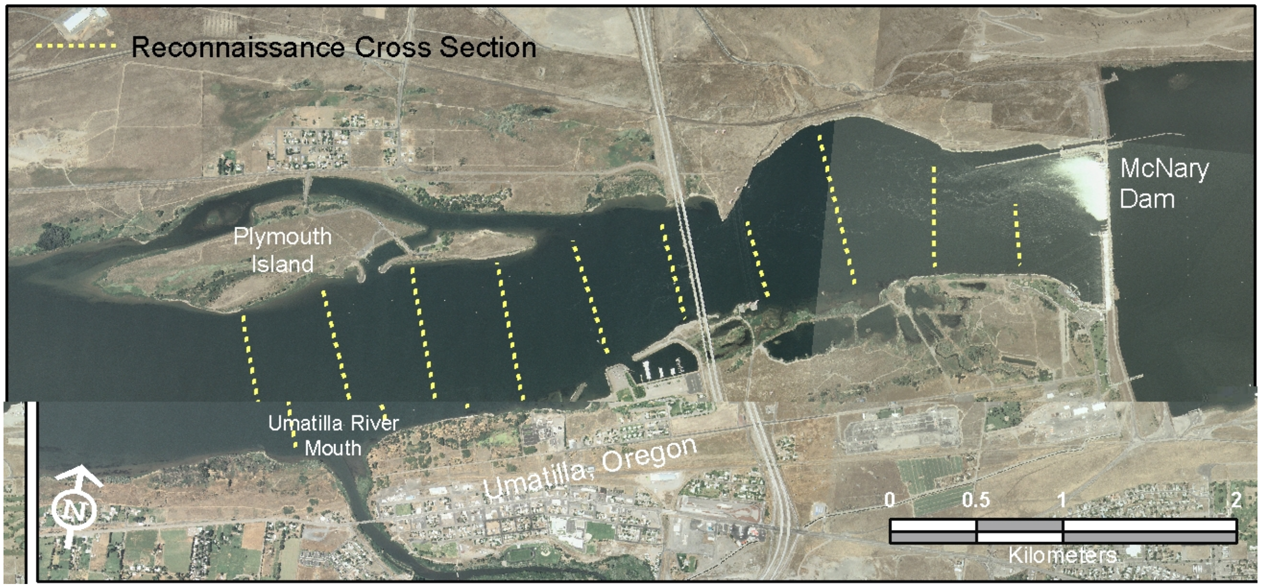

Figure 7. **2001 - McNary Dam reconnaissance survey area.**

2001 - John Day Dam Reconnaissance Survey.

On November 8 and 9, 2001, we conducted redd surveys in the John Day Dam tailrace (Figure 8). The segment of the Columbia River surveyed was approximately 2.2 km in length below John Day Dam and included the BRZ. From the previous visual surveys (Table 1) we knew that some spawning was likely occurring in the tailrace so we intensified our exploratory transects to 275 m intervals and we surveyed a total of 8 cross sections perpendicular to the flow. Cross sectional lengths varied from 200 to 700 m depending on whether or not the island was present in the transect site. A total of 14 deepwater redds were observed. Depths over the redds ranged from 3.1 to 5.8 m and they could not have been observed from above the water surface given the depths and turbidities. Again, this survey was early in the spawning season and additional redds may have been observed at a later survey date and with a finer cross section spacing. Some bedrock was observed but the majority of the tailrace appears to be at least moderately suitable for fall Chinook spawning.

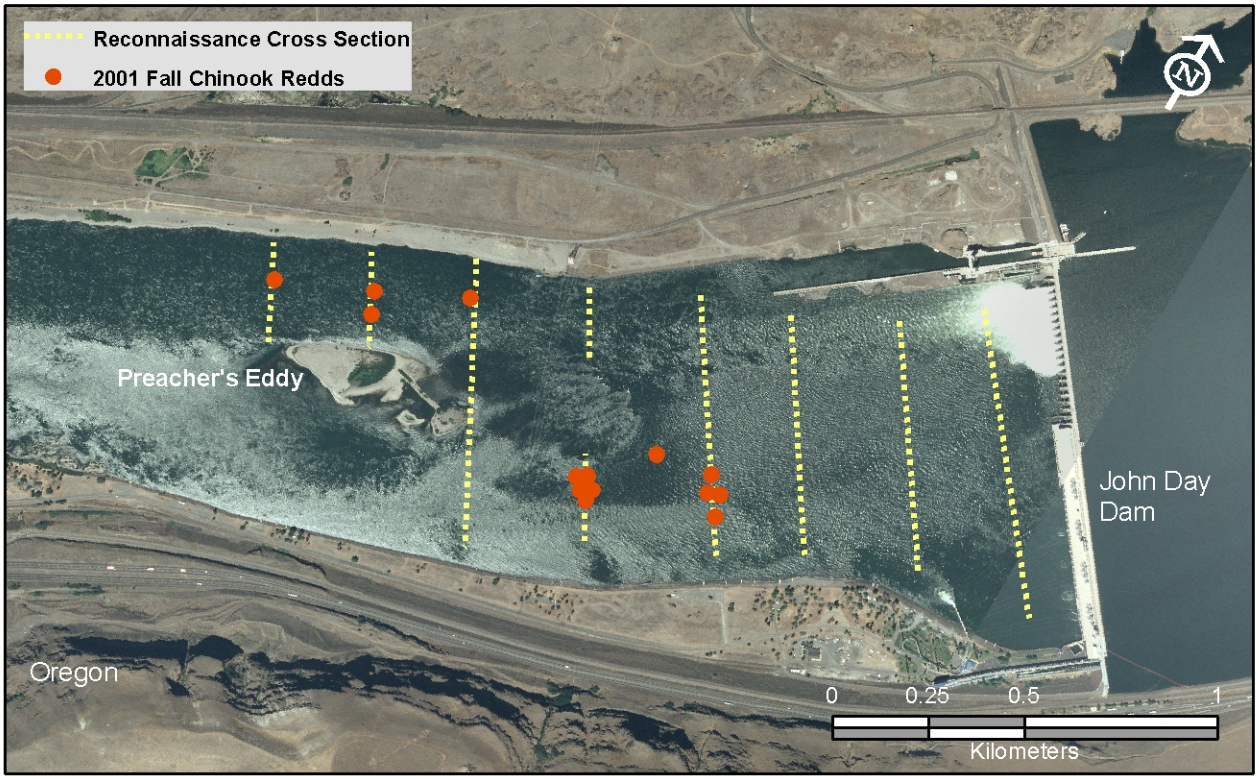

Figure 8. Area of John Day Dam tailrace searched and resulting redds identified.

Reconnaissance Survey Conclusions

Based on the results of the 2001 reconnaissance surveys, a decision was made with project cooperators to move forward with a quantitative approach to enumerate redds below John Day Dam and forego surveys below The Dalles and McNary dams. While the McNary Dam tailrace surveys in 2001 suggested spawning could be occurring there, the site was relatively large and would require a survey effort greater than our available resources and budget. The extent of bedrock formations observed below The Dalles Dam indicated spawning habitat was extremely limited there and no redds were mapped in the small number of sites that were marginally suitability.

John Day Tailrace Field Methods

Cross Section Sampling Design

To develop an efficient and systematic methodology for enumerating fall Chinook redds below John Day Dam for survey years 2002 - 2006, we incorporated the geographic field data collected in the tailrace in 2001 as well as other ancillary data including orthophotos, NOAA Charts and bathymetric data acquired from the USACE into our GIS. To guide the underwater videography surveys, a series of transects were plotted parallel to the river flow using our GIS (Figure 9). The extent of each transect was determined by: the presence/absence of redds from the 2001 surveys, suitable substrates, and suitable depths. The cross sections were limited by the presence of the boat restricted zone (BRZ), depths in excess of 12 m, observed bedrock, and the presence of a large eddy just below the island (Figure 9). A transect spacing of 15 m was selected to preclude surveying a single redd more than once. The 15 m spacing also accounts for the accuracy of our GPS equipment and the ability of our survey boat to maintain an accurate position over each transect to within +/- 3 m. Prior to the 2003 survey, we clipped the cross sections along the Oregon shore to account for additional bedrock formations encountered near the center of the survey area during the 2002 survey. In 2004, the survey lines on the Washington shore were extended 600 m downstream and 50 m upstream to account for the density of redds observed at the ends of the survey transects (Figure 9). Due to the presence of redds at the upstream end of transects near the Oregon shore which terminated at the BRZ, transects should have been extended further upstream to search for additional redds, but safety protocols, man power and logistics required for access into the BRZ precluded surveys within this area (Figure 9).

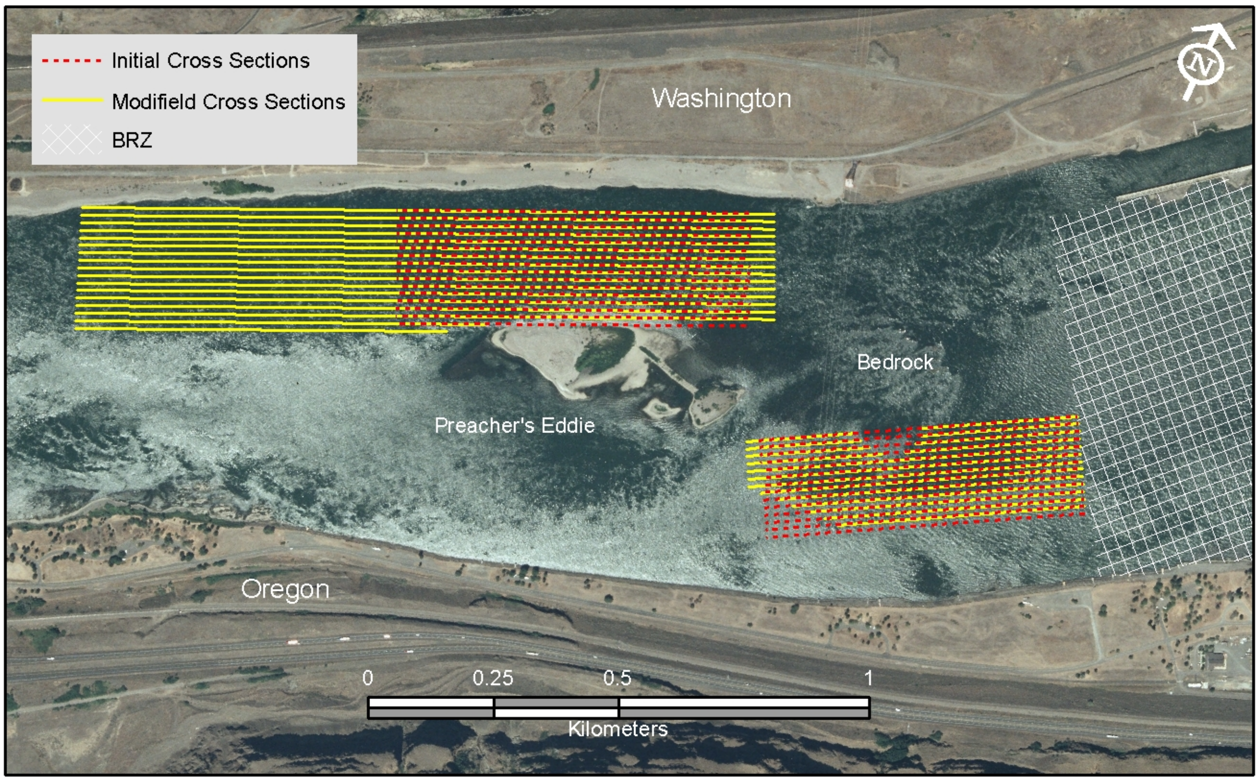

Figure 9. Initial cross section placement and subsequent modified cross sections in the John Day tailrace and location of the BRZ.

Survey Gear

For all of the redd surveys, a 6.5 m survey boat with a bow-mounted davit and 24-volt electric hoist for deploying the mobile underwater video gear was used. The system consists of an underwater sled adopted from Groves (1998) and weighted with two 22.7 kg lead fish (Figure 10-A). A high-sensitivity, low light remote camera and two lasers for scale reference were mounted in parallel to a forward-looking adjustable cone (Figure 10-A). The angle of the cone is adjustable to accommodate variable environmental conditions or protocols but is generally mounted looking down and slightly forward into the current. In the boat cabin, two monitors, one for each of the two survey members, were used to identify redds and assess substrates. Video images were recorded with a standard video cassette recorder and video locations were stamped with locational (Northing, Easting) and date/time data strings for subsequent review if required. We used a real-time Differential Global Positioning System (DGPS) receiver (Trimble Pathfinder™ Pro XR) for recording redd locations and their observed habitat metrics using a pre-written data dictionary. This DGPS was also used to send date/time and locational data strings for digital stamping on the video images (Figure 10-B). The DGPS unit has an integrated beacon which receives GPS position corrections in real time to achieve sub-meter accuracies. A second GPS (Trimble Geo XT) enabled with the Wide Area Augmentation System (WAAS) facilitated increased accuracies for real-time navigation, was used to both plot the survey transects and to record the actual track of the boat for later analysis in our GIS.


A)

B)

Figure 10. (A) Underwater sled and video camera used to observe fall Chinook redds, and (B) a screenshot representing a typical view of the Columbia River bottom while surveying for fall Chinook redds.

Survey Methods

From 2002 to 2006, we conducted underwater video surveys for fall Chinook redds in the John Day Dam tailrace. Redd surveys below John Day Dam were conducted immediately after the end rather than the peak of fall Chinook spawning season. A peak season survey would result in an underestimate. The end of spawning was determined based on the cessation of new redds at surveys downstream near Ives and Pierce islands just below Bonneville Dam and upstream in the Hanford Reach. With a single post-season survey, we could potentially enumerate the entire redd population in an economical manner with a two man crew since all of the fish would have spawned. However, if too much time passed between the end of spawning and our surveys, redds would become difficult to identify. Each single season survey in the John Day tailrace takes three to four days to complete depending on redd density and environmental conditions that could slow the pace of the survey, including high water velocities, wind chop, or turbid water. Generally, conditions below John Day Dam in later November and early December are favorable for conducting deep water redd surveys. After each of the transects were surveyed, the field crew randomly selected a number of locations outside the survey area to search for redds and map substrates throughout the study site. This was done for all survey years except in 2006.

Surveys were initiated by navigating to the downstream end of the first transect using GPS receivers with chart (transect) plotting abilities. As the boat operator held position on the end transect to within +/- 3 m, the hoist operator lowered the sled to a location just above the substrate with the lasers and river bottom in view. The boat was then powered forward along the transect at an approximate rate of 0.7 m/s. As the boat was powered forward along the transect into the current, the hoist operator adjusted the sled height over the bottom maintaining a relatively constant distance of about a meter over the substrate. When a redd was encountered, the boat operator held a fixed position over the redd while it was assessed in real-time and its geographic position and habitat attributes were recorded on a GPS. We collected depth, dominant substrate, subdominant substrate, and percentage fines for all data points. Dominant and subdominant substrates were classified using a modified Brusven Index coding system (Delong and Brusven 1991). Substrate descriptions and class values are documented in Table 2 and percent fines in Table 3. Each transect was surveyed a single time for each season.

Sharp changes in bed topography, substrate sorting, changes in background contrast and relative abundance of periphyton and invertebrates were used in descending order of significance as the criteria to identify Chinook redds. Substrate sorting occurs as similar sized substrate particles settle out of temporary suspension just downstream of salmon redds in distinct clusters or patches. The largest of these patches is known as the tailspill and can be very pronounced. However, the identification of tailspills or even entire redds can become difficult as the amount of time passes between the completion of a redd and the actual survey date. Additionally, if salmon redds are excavated in very close proximity to one another or actually overlap, redd superimposition can occur and mapping individual redds can become very difficult. Substrates and depths are assumed to remain relatively constant throughout the spawning season and are relatively easy to assess. Velocities, however, can change widely from day to day based on total discharge and load following patterns. For this reason we did not record velocities over redds. The habitat report describes how velocities were assessed.

Table 2. **Substrate classes and values used for classification during spawning surveys.**

Code	Particle size (mm)	Particle size (inch)	Description
1	<6.3	<.25	Fines
2	6.30 - 25.4	0.25 - 1.0	Pebble
3	25.4 - 50.8	1.0 - 2.0	Gravel
4	50.9 - 76.2	2.0 - 3.0	Large Gravel
5	76.3 - 152.0	3.0 - 6.0	Cobble
6	150 - 300	6.0-12.0	Large Cobble
7	>300	>12.0	Boulder
8	NA	NA	Bedrock

Table 3. **Percent fine codes and values**

Code	Description
1	0 and 25 percent of substrate belongs to Substrate code 1
2	25 and 50 percent of substrate belongs to Substrate code 1
3	50 and 75 percent of substrate belongs to Substrate code 1
4	75 and 100 percent of substrate belongs to Substrate code 1

Analytical Methods – Estimating a Total Redd Population

The analytical methodology conducted in our GIS consists of tasks related to enumeration of redds surveyed in each cluster, delineating the spatial extent and total area of each redd cluster and determining the actual proportion and percent of the whole cluster surveyed with transects. Once the ratio of redds to surveyed area is calculated, that ratio is applied to the entire cluster to estimate the total number redds the cluster contains.

Data collected in the field consisting of point locations were first differentially corrected to an accuracy approaching +/- 1.0 m and then imported into our GIS. In the GIS, we plotted the locations of all observed redds for each year along with the locations of the survey transects and the actual path surveyed. These positions vary slightly (Figure 11) and as such it is possible to drift laterally from one transect to an adjacent transect. This can potentially result in mapping a single redd twice. Within the GIS, we reviewed these data and redds that were recorded twice were corrected to a single observation.

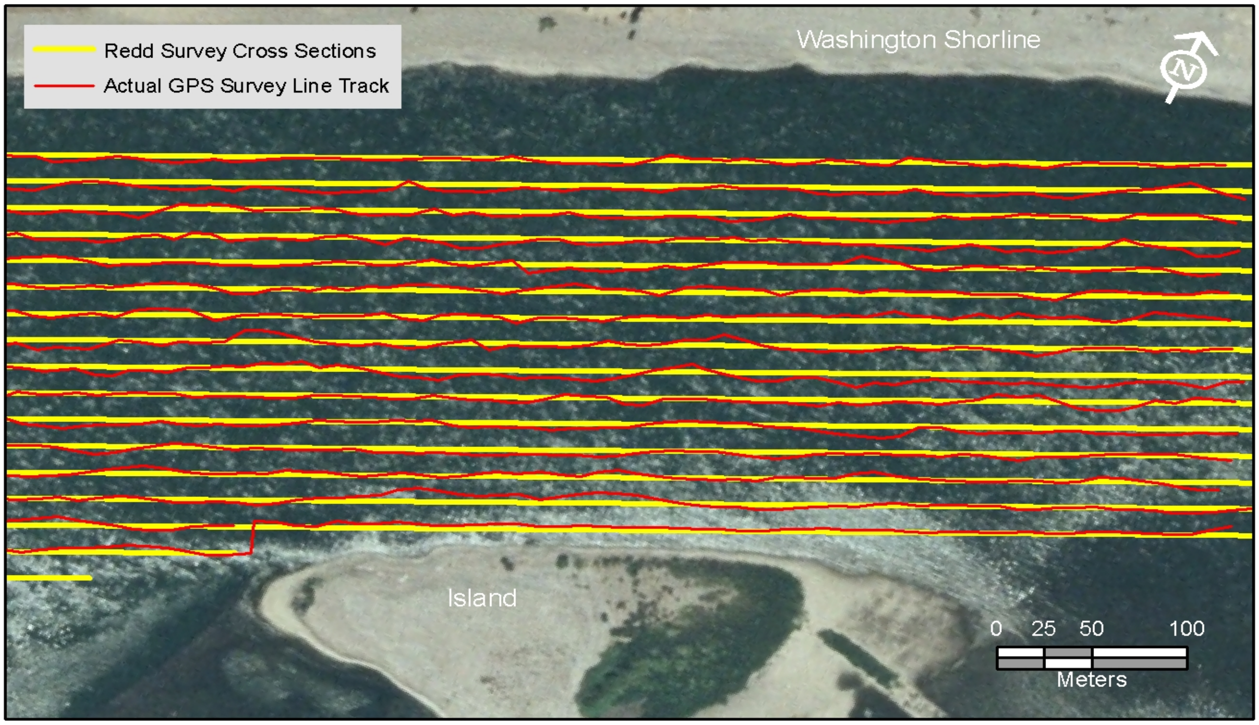

Figure 11. Comparison of the actual survey path traversed in the field compared to the GIS transect path.

Mainstem Columbia River spawning fall Chinook, spawn in aggregations or clusters known as redd clusters. Redds within 15 m of one another and numbering more than 10 are usually considered a "cluster" (Anglin et al. 2006; Geist et al. 2000; Visser et al. 2002). We used these criteria to identify clusters and calculate a maximum convex polygon around the perimeter of each cluster using a GIS algorithm (Figure 12). With this information, the GIS was then used to determine the total area of the redd cluster which we defined as the total area used. A 3 m buffer was added to this polygon since the center of each redd was mapped, rather than the distal edge.

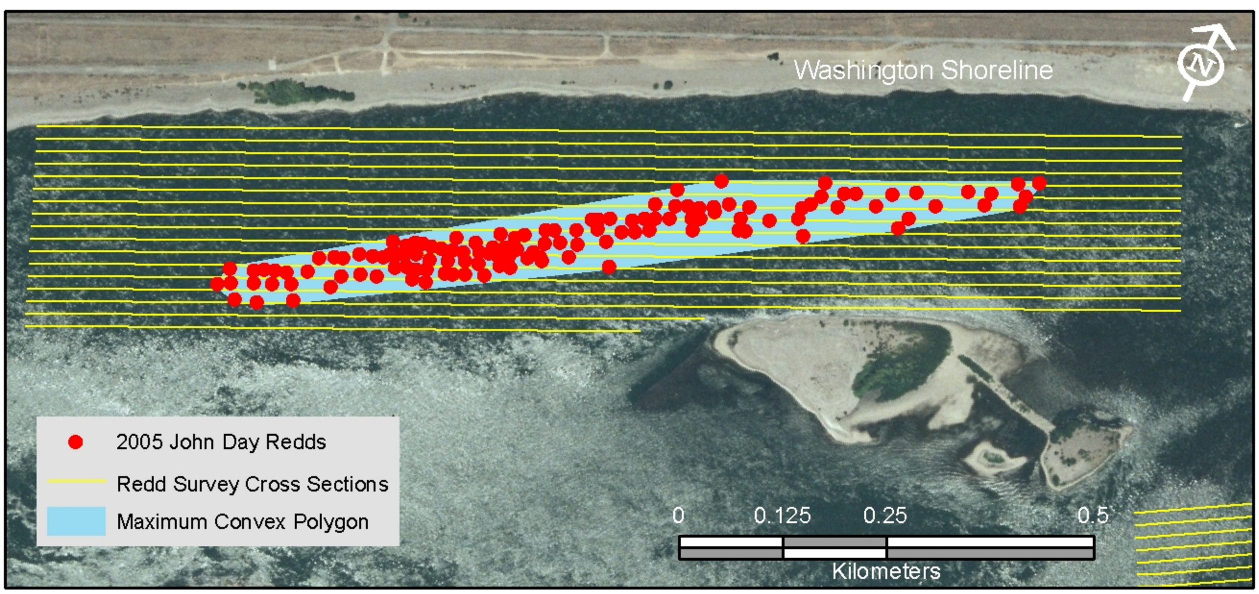

Figure 12. Depiction of fall Chinook redds, survey transects and the delineation of a maximum convex polygon.

The next component required for the redd assessment is determining the actual area surveyed within each redd cluster. In the GIS, we determined the length of each transect within each redd cluster and multiplied it by the cameras' field of view or width. To determine the field of view width we randomly assessed images to determine the average field of field (width). The lengths of survey lines falling within each cluster along with the widths are multiplied, then summed to determine the amount of riverbed surveyed.

To complete the exercise, we calculated a ratio of area searched to redds observed. This ratio was then extrapolated to the entire area represented by the convex polygon as the redd cluster. This exercise was conducted individually for each of the two redd clusters and for all the years we collected data except for 2006. With this technique, we could quantify the total area of each redd cluster, the amount or percent of each that we surveyed with video, the proportion of redds to area searched, and then estimate how many redds were in the entire redd cluster if every m^2 would have actually been surveyed.

Run Reconstruction

To provide context and support for our redd estimates, we reconstructed runs of adult fall Chinook to develop an index of the number of fish that may have been available to spawn in the John Day tailrace. Dam passage data were collected from the Fish Passage Center's website and assembled in a spreadsheet. Tribal and sport catch data for the Columbia and Deschutes rivers were acquired from the tribes, ODFW and WDFW. In addition, estimates for naturally spawned Chinook in the Deschutes River were acquired to complete the data sets required for the reconstruction. We tabulated the differences by subtracting each of the data elements from the difference between The Dalles and John Day Dam counts. We did not attempt to account for fall-back, which can occur when a fish ascends the dam and then falls back over or the dam. This can result in some small error for each dam count.

Results

Redd Surveys

Fall Chinook redds were successfully identified and mapped in the tailrace of John Day Dam from 2001 to 2006. All surveys were conducted after the peak and near the end of the spawning season. On our initial reconnaissance surveys in 2001, we mapped 14 redds for the portion of the John Day study site surveyed. This was a qualitative effort with the goal of determining if spawning was, or was not occurring and generally where it was occurring. The highest redd count was in 2004 with 183 redds observed (Table 4). In 2006, high turbidities precluded a complete and accurate survey but we did observe 36 redds. The incomplete survey did not allow for a redd expansion into a total estimate. Redd depths for 386 measurements (2003 – 2005) ranged from 1.8 to 8.2 m with an average of 5.8 m (Figure 13). No redds were observed in a subset of observations conducted each year outside the survey areas. Dominant substrates obtained from the same redds were comprised almost exclusively of large gravel and cobble (Figure 14). Fines were absent in all redds observed. In Appendix A, we present the results of each year's survey separately.

Table 4. Number of fall Chinook redds mapped below John Day Dam 2002 – 2006. *Surveys in 2006 were incomplete due to high turbidities.

	Redd Mapped by Year				
Site	2002	2003	2004	2005	2006*
WA - Shore	52	55	140	127	13
OR - Shore	44	41	43	18	23
Total	96	96	183	145	36

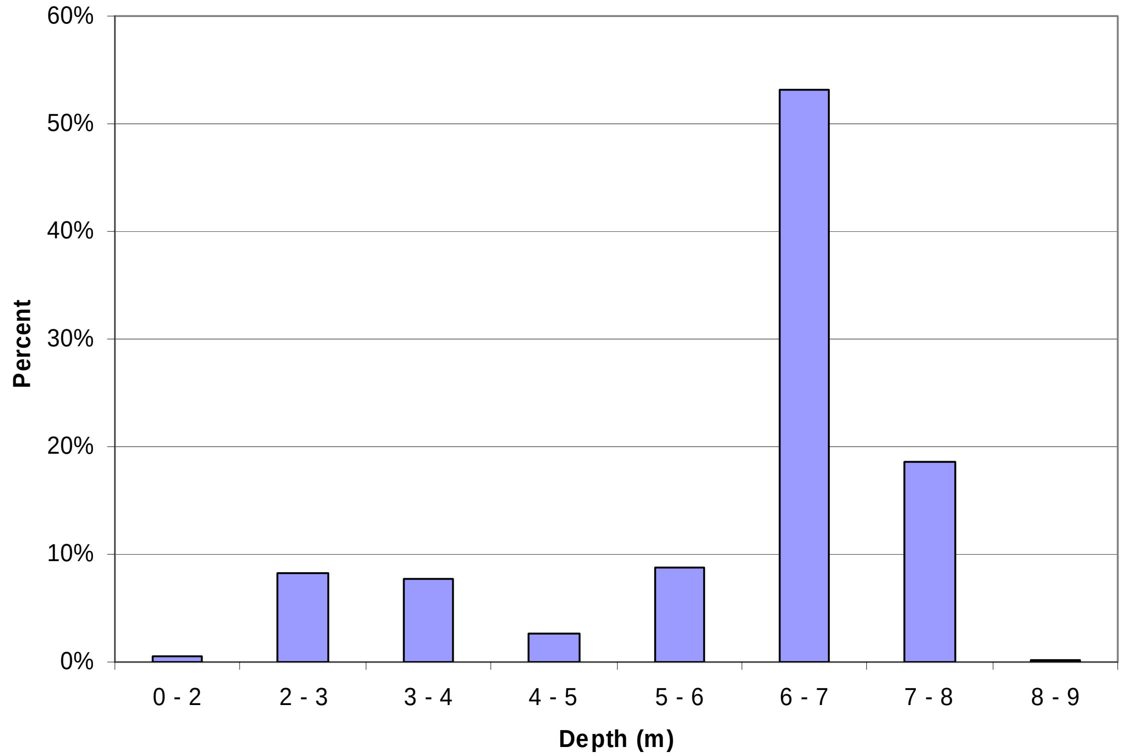

Figure 13. Distribution of fall Chinook salmon redds (n=386) relative to water depth for survey years 2003, 2004 and 2005.

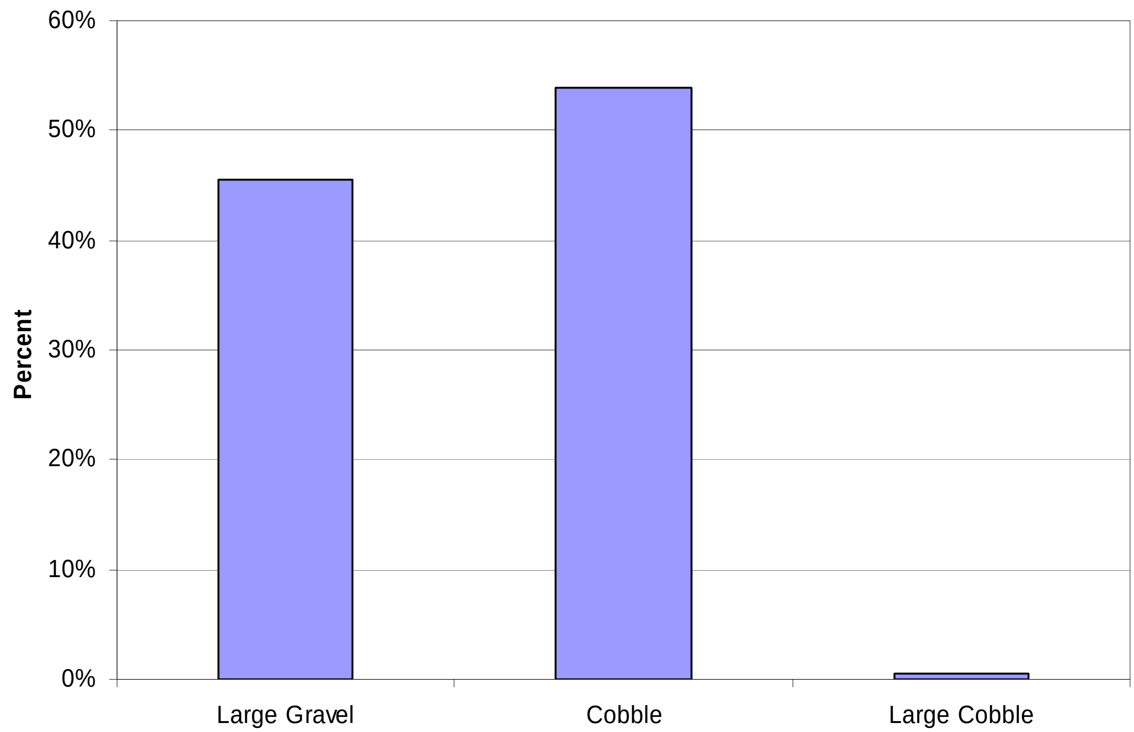

Figure 14. Dominant substrate classification of fall Chinook redds (n=386) mapped in 2003, 2004 and 2005. Substrate sizes (mm) Large Gravel (50.9 – 76.2) Cobble (76.3 – 152.0) and Large Cobble (150.0 – 300.0)

Redd Estimates - Estimating a Total Redd Population

From 2002 to 2005 we estimated the size (m^2) for each of the two redd clusters below John Day Dam. Data collection in 2006 was incomplete due to poor water visibility and precluded an estimate. Individual redd sizes were not measured on any of the surveys. The redd clusters represent the total area used by spawning fall Chinook and serve as the basis for our spatial extrapolation and a determination for a total redd estimate. The redd cluster along the Washington shoreline was larger than the Oregon shore cluster in all years surveyed with a range from 67,165 to 150,458 m^2 (Table 5). The cluster sizes along the Oregon shore ranged from 23,380 to 73,379 m^2 (Table 5). Within each redd cluster, the actual area as a percent of the bottom imaged by our cameras ranged from 10.43 to 11.94%. These percentages, along with number of redds observed resulted in total redd population estimates ranging from 880 to 1,597 redds (Table 5).

Table 5. Data used to determine a total redd estimate for each of four years. WA and OR represent redd clusters mapped along the Washington and Oregon shorelines, respectively.

	2002		2003		2004		2005	
	WA Cluster	OR Cluster	WA Cluster	OR Cluster	WA Cluster	OR Cluster	WA Cluster	OR Cluster
Within Cluster, Area Surveyed m^2	8,422	7,654	10,463	7,786	17,474	7,260	8,020	2,788
Total Redd Cluster Area m^2	74,189	73,379	90,001	69,553	150,458	66,165	67,165	23,380
% Redd Cluster Searched	11.35%	10.43%	11.62%	11.19%	11.61%	10.97%	11.94%	11.92%
Redds Counted	52	44	55	41	140	43	127	18
Redd Density / (m^2/redd)	162.0	174.0	190.2	189.9	124.8	168.8	63.2	154.9
Redd Cluster Estimate	458	422	473	366	1,205	392	1,064	151
Total Redd Estimate	**880**		**839**		**1,597**		**1,215**	

Run Reconstruction

For the years 2001 – 2006, the adult index escapement estimate between The Dalles and John Day dams ranged from a low of 5,199 in 2006 to a high of 57,823 in 2003 (Table 6). This estimate represents an index of maximum adult spawning escapement for the John Day tailrace population of fall Chinook salmon. Regionally and historically, these fish were considered lost and simply explained away as “Passage Loss” since no other data existed.

Table 6. Run Reconstruction for adult fall Chinook that potentially spawned in the John Dam tailrace from 2001 – 2006.

	2001	2002	2003	2004	2005	2006
The Dalles Dam Count	181,316	245,928	313,697	302,032	234,255	171,104
John Day Dam Count	124,747	164,920	215,483	213,936	180,041	137,527
Passage Difference:	*56,569*	*81,008*	*98,214*	*88,096*	*54,214*	*33,577*
Dalles Pool Sport Harvest	1,420	1,350	1,397	2,364	1,499	1,095
Dalles Pool Tribal Harvest	14,634	21,596	25,326	17,383	17,968	13,124
Deschutes Harvest	334	992	1,078	1,224	835	785
Deschutes Natural Spawn	11,177	12,252	12,590	11,879	13,550	13,374
Sum of Chinook Removed:	*27,565*	*36,190*	*40,391*	*32,850*	*33,852*	*28,378*
Passage Loss or Adult Index Escapement Estimate	***29,004***	***44,818***	***57,823***	***55,246***	***20,362***	***5,199***

Discussion

Reconnaissance redd surveys conducted in 2001 were successful in identifying fall Chinook redds in the John Day Dam tailrace. While the surveys did not determine spawning was occurring below The Dalles or McNary dams, they did suggest that based on initial habitat observations, fall Chinook could be spawning in a relatively large section of river below McNary Dam. Due to the limited nature of surveys we conducted below McNary Dam and early timing of our survey, additional investigations should be conducted. We don't believe any additional surveys below The Dalles Dam are warranted at this time due to extensive depths and the presence of large amounts of bedrock.

While the use of underwater videography is useful in both identifying and quantifying salmon redds, the technique does have several limitations. The surveys are labor intensive and take a significant amount of time. Quantitative estimates for deepwater redds encompassing areas larger than the John Day study site would be difficult. Surveys conducted in 2004 and 2005 were exacerbated by redd superimposition. In many instances, it was not possible to distinguish where one redd ended and another began. This led to a lower count of redds and an underestimate of the total redds. Lastly, the technique is limited by environmental conditions and in 2006 high turbidities severely limited the survey and prevented a total redd estimate.

The number of redds observed and estimates for the total redd population in the John Day Tailrace were somewhat variable throughout the survey years. The counts in 2002 and 2003 were lower, but the surveys were conducted over less area for these years and are likely underestimates. The lowest count in 2006 is representative of the limited survey conducted due to excessively high turbidities. Only the shallowest of transects could be searched and we have reduced confidence in the redds that were observed. The potential spawning escapement estimated from the run reconstruction exercise suggests that redd estimates are minimums and that additional redds or redd clusters may exist. In addition, redd superimposition could also explain some of the differences between the escapement estimates and the redd estimates. Our survey data suggest that redds are likely present and continue into the BRZ along the Oregon shore. It is unlikely, yet possible, that undiscovered redd clusters exist further downstream into the reservoir. In addition to redds, the video observations often imaged adult salmon holding over redds. Most of these fish appeared to be spawned out females with heavily eroded white caudal fins.

The origin of fall Chinook spawning below John Day Dam is unknown but several possibilities exist. These Chinook could be stray fish originating from an upriver bright stock such as the Hanford Reach or they could actually be vestiges of the Chinook that historically spawned in the 160 km section below the Snake River confluence as cited by Fulton (1968). Fulton mentions that this stretch of river is usually more turbid than upriver sites and redd surveys are difficult. In addition, we believe that any historical estimates would have been grossly underestimated due to the amount of deepwater spawning that was likely occurring. The population of fall Chinook spawning below Bonneville Dam is thought to originate from upriver bright hatchery strays from Bonneville Hatchery (Hymer 1997) which is only 5 km upstream. A possible third option as to the origin of fall Chinook spawning below John Day could be hatchery strays, although this would appear to be the least likely. There are some hatchery releases of fall

Chinook in the Umatilla River upstream, and fall Chinook are raised at the Klickitat River and Ringold hatcheries. However, the fish released into the Umatilla River would more likely spawn in the McNary tailrace as strays, and of the two other hatchery programs, the closest in the Klickitat River is about 80 km downstream. Finally, the fall Chinook spawning in the John Day tailrace could be jointly composed of stocks from each of the above mentioned sources.

At a time when regional stocks of natural fall Chinook salmon are at historical lows, and as a sound management practice, managers should protect and enhance naturally spawning stocks of fall Chinook, wherever they exist, to the extent possible. To date, the fall Chinook spawning below John Day Dam have received no specific hydrosystem operations to enhance or provide stable spawning habitat. There may be two ways to increase the amount of habitat below John Day Dam. Restoring a portion of the river to a more normative river through a temporary (2-3 weeks) drawdown of The Dalles pool will result in a substantial increase in both the amount and quality of spawning habitat. Secondly, if the hourly flow fluctuations throughout the day and the spawning season can be minimized, a resulting stable and persistent habitat will further improve spawning conditions and increase the amount of available habitat. This could be significant, given the observations of redd superimposition.

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APPENDIX A

Appendix A. 1 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2001.

Appendix A. 2 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2002.

Appendix A. 3 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2003.

Appendix A. 4 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2004.

Appendix A. 5 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2005.

Appendix A. 6 - Fall Chinook salmon redds mapped with underwater videography below John Day Dam in 2006.