Chinook Salmon Productivity and Escapement Monitoring in the John Day River Basin

Annual Technical Report

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Prepared by:

Chris M. Bare
Jennifer J. Rogers

Oregon Department of Fish and Wildlife
John Day, Oregon

Ian A. Tattam
James R. Ruzycki

Oregon Department of Fish and Wildlife
La Grande, Oregon

Funded by:

Oregon Department of Fish and Wildlife

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EXECUTIVE SUMMARY

Objectives

1. Estimate number and distribution of spring Chinook salmon *Oncorhynchus tshawytscha* redds and spawners for three John Day River populations.

2. Estimate age composition and proportion of hatchery-origin spawners for three John Day River spring Chinook salmon populations.

3. Estimate productivity metrics including smolts per redd for three John Day River spring Chinook populations.

Accomplishments and Findings

Spawning ground surveys for spring Chinook salmon were conducted in the John Day River basin from 13 August through 15 October 2015. We observed 1,628 spring Chinook redds while surveying 313.3 km of potential spawning habitat (206.2 km of census, 83.6 km of index, and 13.1 km of random reaches). The number of spring Chinook redds constructed in 2015 in the John Day River basin dropped 26% from the previous year and the overall density decreased from 7.5 to 5.6 redds/km for the survey area. Redd abundance decreased from 2014 in all three populations. The redd count in the Mainstem decreased 7%, the Middle Fork redd count dropped 15%, and North Fork redd total was down 51% from 2014. The 2015 Mainstem redd total of 771 was the second highest observed since census monitoring began in 2000 (829 redds were observed in 2014). The Middle Fork redd total of 442 is greater than the 16-year average, despite a mid-summer fish kill. However, the North Fork produced one of the lowest redd totals observed since 2000 with only 415 redds.

Estimated spring Chinook escapement for 2015 is 3,826 fish (using a ratio of 2.35 adults and jacks per redd estimated at the Catherine Creek weir in the Grande Ronde River basin). We recovered 681 Chinook carcasses (18% of the estimated total spawners). The presence or absence of an adipose fin was determined on 669 carcasses. We observed that 668 (99.8%) had an adipose fin and were assumed to be of wild origin, and 1 (0.2%) had a clipped adipose fin and was assumed to be of hatchery origin. The origin of the remaining 12 carcasses was not determined.

Stock-recruit analyses for the Mainstem and Middle Fork John Day populations indicate that smolts produced per redd decreases as the number of redds increases, indicating that rearing habitat may be limiting freshwater production. The Middle Fork stock-recruit curve shows the strongest density-dependence, with production decreasing when escapement exceeds 200 redds. Conversely, an adult-to-adult recruitment curve for the North Fork suggests very little decrease in production at higher escapements. Average sustainable yield in the Middle Fork appears to be lower than the Mainstem.

ACKNOWLEDGEMENTS

We acknowledge the assistance and cooperation of private landowners throughout the John Day River basin that allowed us to survey on their property. We thank Brent Smith for providing assistance and advice. We also thank the countless volunteers for helping conduct field surveys. Michael Scheu provided assistance with scale aging. Sally Gee and Tony Capps analyzed kidney samples. This project was funded by the Oregon Department of Fish and Wildlife. We thank Tom Stahl for assistance with contract administration.

INTRODUCTION

The John Day River basin supports three wild populations of spring Chinook salmon. Distinct populations are present in the upper Mainstem, Middle Fork, and North Fork of the John Day River (Narum et al. 2008). These populations remain depressed relative to historic levels. Numerous habitat protection and rehabilitation projects have been implemented in the basin to improve salmonid freshwater production and survival. Often, these projects lack effectiveness monitoring (Bayley and Li 2008). While our monitoring efforts outlined here do not specifically measure the effectiveness of any individual project, they will provide much needed programmatic or watershed-scale (status and trend) information to help evaluate project-specific effectiveness monitoring efforts as well as meet the data needs as index stocks. Our continued monitoring efforts to estimate salmonid abundance, age structure, smolts per redd, freshwater habitat use, and distribution of critical life stages will allow managers to assess the long-term effectiveness of habitat projects.

Because Columbia River basin managers have identified the John Day River basin spring Chinook population aggregate as an index population for assessing the effects of alternative future management actions on salmon stocks in the Columbia River basin (Schaller et al. 1999), we continue our ongoing studies. This project is high priority based on the level of emphasis by the Northwest Power and Conservation Council (NWPCC) Fish and Wildlife Program, Independent Scientific Advisory Board (ISAB), Independent Scientific Review Panel (ISRP), National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), and the Oregon Watershed Enhancement Board (OWEB). Each of these groups has placed priority on monitoring and evaluation to provide the real-time data to guide restoration and adaptive management in the region.

STUDY AREA

The John Day River drains 20,300 km^2 of east central Oregon, the third largest drainage area in the state (Figure 1). From its source in the Strawberry Mountains at an elevation near 1,800 m, the John Day River flows 457 km to the Columbia River at an elevation near 90 m. It enters the Columbia River at river kilometer (rkm) 351. The basin is bounded by the Columbia River to the north, the Blue Mountains to the east, and the Ochoco Mountains to the west.

Spring Chinook salmon primarily spawn in the upper Mainstem John Day River (hereafter called Mainstem; Figure 2) upstream from Indian Creek, in the Middle Fork John Day River (hereafter called Middle Fork; Figure 3) upstream of Armstrong Creek, and the North Fork John Day River (hereafter called North Fork; Figure 4) upstream of Camas Creek. Important spawning tributaries of the North Fork include Granite Creek and its tributaries (Clear Creek and Bull Run Creek; hereafter called Granite Creek System) and Desolation Creek (Figure 4). Spawning has also occurred in the South Fork

John Day River (hereafter called South Fork; Figure 5), the North Fork tributaries Camas and Trail creeks, and the Mainstem tributaries Deardorff, Reynolds, and Bridge creeks.

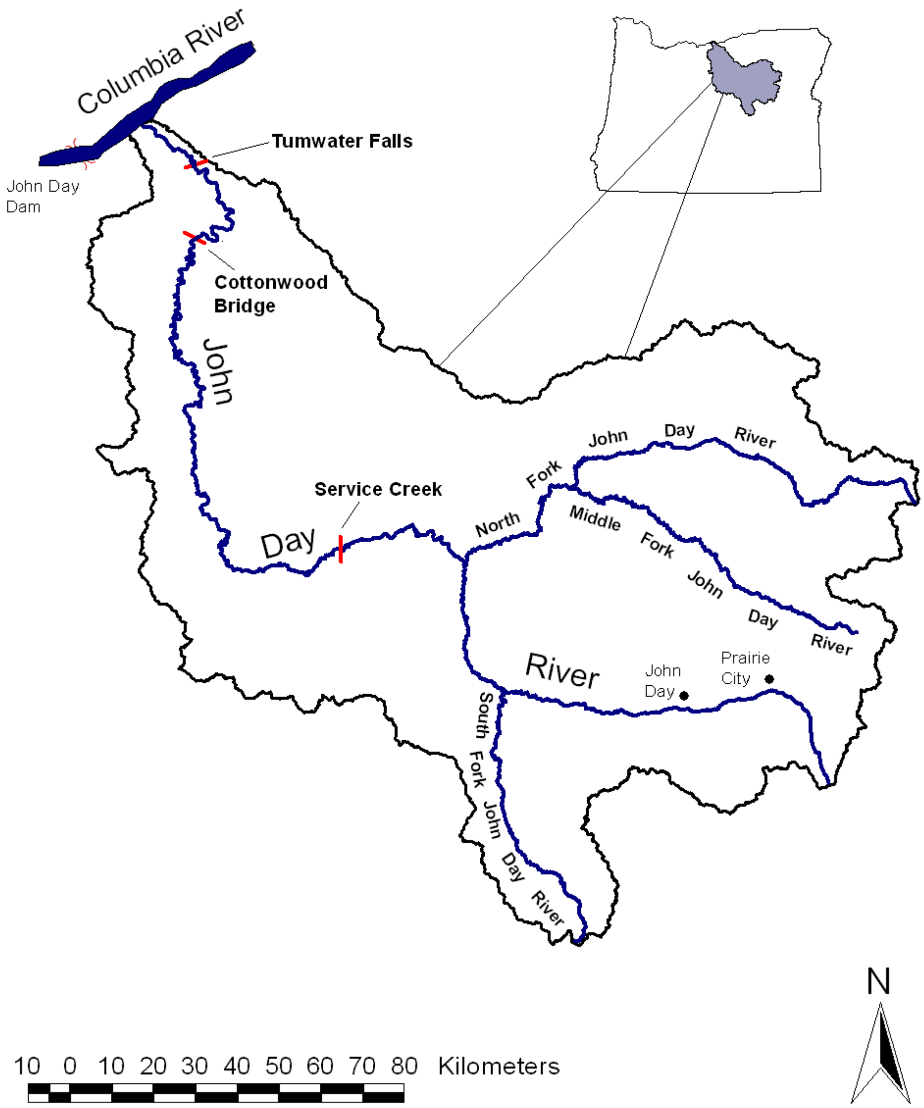


Figure 1. Map of the John Day River basin.

METHODS

Sampling Design

Spring Chinook salmon spawning surveys were conducted during August and September to encompass the temporal distribution of Chinook spawning in the John Day River basin. These surveys included index, census, and random sections. Index sections were defined as locations where redd counts have occurred annually since 1964. Census sections were defined as any location where spring Chinook redds have been previously documented. Random surveys (2 km in length) were defined as surveys located outside of the known spawning universe. The intent of random surveys was to check for range expansion. Our random sampling universe extended 20 km downstream from the most downstream redd observed in each Hydrologic Unit Code (4th level HUC; Mainstem, Middle Fork, and North Fork). A second sampling universe extended 4 km upstream from the most upstream redd observed. Survey sections were selected with a random number generator based on river kilometer. For every one site selected upstream from the census section, two sites were selected downstream from the census section. If redds were observed in a random site, that survey section was added to the census universe for all following years. The index, census, and random sections were collectively assumed to provide a census count of spring Chinook salmon redds (hereafter referred to as "total").

Index surveys were scheduled to occur at the peak of spawning in each of the three populations (Mainstem, Middle Fork, and North Fork). Pre-index surveys were conducted one week prior to the index surveys and post-index surveys were conducted one week after the index surveys to account for temporal variation in spawning. However, post-index counts were treated as census counts and not included in the overall index count. During 2015, with the exception of wilderness areas, we surveyed census sections three times on the same dates as the pre-index, index, and post-index surveys. We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork on the day of the index or post-index surveys, or soon thereafter, for their respective streams.

Spawning Surveys

Spawning surveys were conducted on foot, and ranged in length from 0.01 to 13.3 km depending on accessibility and difficulty. Typically, teams of two surveyors walked the stream, with one surveyor on each bank to ensure detection and accuracy when distinguishing redds. In each section, surveyors recorded the number of new redds, live fish (on- or off-redd), and carcasses. During index and census surveys, the first team marked redds with numbered flagging placed near each redd or group of redds. During subsequent surveys, teams re-identified flagged redds and recorded any new redds. During the last survey in each reach, surveyors geo-referenced redds with a global positioning system receiver and removed all flags.

Every carcass we observed was examined unless decomposition or scavenging damage disallowed accurate measures. Medial eye to posterior scale length (MEPS) was measured to the nearest millimeter and carcasses were dissected to verify sex. Volume (in milliliters) of eggs retained was noted for every intact female. Every carcass was scanned for the presence of a passive integrated transponder (PIT tag) unless there were fewer PIT scanners than survey crews. Tag codes from recaptured PIT tags were queried for their tagging and observation history using PTAGIS (data available online at: www.ptoccentral.org). Kidney samples were collected from recently deceased spring Chinook in each of the main spawning areas to determine concentration and prevalence of *Renibacterium salmoninarum* (Rs) antigen, the causative agent of bacterial kidney disease (BKD), in the spawning population. Surveyors selected carcasses with intact organs and membranes and non-glazed eyes, indicative of recent mortality, as donors for kidney tissue analyses. Clean disposable plastic knives and spoons were used to collect 1–2 g samples of kidney tissue from each carcass. Samples were placed in sterile 1-ounce Whirl-pack™ bags and stored in a cooler until they could be transferred to a freezer. The enzyme-linked immunosorbent assay (ELISA) was used to obtain optical density (OD) values according to methodology adapted from Pascho and Mulcahy (1987). The Rs antigen level is an indication of bacterial infection load of *R. salmoninarum*. Table 1 summarizes the optical density value ranges and standard infection level categories used for BKD.

Table 1. Summary of ELISA optical density value ranges, designated Rs antigen category, and significance of result with respect to adult Chinook salmon.

Optical Density value (OD_{405})	**Rs antigen category**	**Significance to adult Chinook**
≤ 0.100	Negative or Very Low	Infection not detected by ELISA
0.100–0.299	Low Positive	Not a factor in death, did not have BKD
0.300–0.699	Moderate Positive	Beginning of significant infection, signs of disease absent, rarely a factor in death
0.700–0.999	High Positive	Gross signs rare, could be a factor in death
≥ 1.000	Clinical	Signs of disease usually present, death probable, fish had BKD

Surveyors collected scale samples from the first fifteen carcasses encountered on each survey section as well as all adipose-clipped fish. Scales were cleaned and mounted on gummed cards, imprinted on acetate using a hydraulic press fitted with hot plates, and subsequently viewed through a microfiche reader by two different people to determine age. We visually determined both freshwater and saltwater age for all scales without regeneration in either region. Fish with a freshwater annulus were classified as yearling smolts (approximately 18 month freshwater residence period post egg deposition, “stream-type” life history, Lichatowich and Mobrand 1995) and fish without a freshwater annulus were classified as sub-yearling smolts (less than 12 month freshwater residence period post egg deposition, “ocean-type” life history, Lichatowich and Mobrand 1995). We summarized age structure at the population scale.

Carcasses of hatchery fish were identified by an adipose fin clip and subsequently had their snout removed to determine the presence of a coded wire tag (CWT). Snouts were bagged with a numbered identification card and frozen. In the laboratory, snouts were dissected and CWTs were recovered using a magnetic detector. If a tag is detected, it is excised and visually decoded under magnification. The tag code is then entered into the Oregon Department of Fish and Wildlife (ODFW) database and hatchery of origin is queried using the Pacific States Marine Fisheries Commission (PSMFC) database. We applied a chi-square test of frequencies to detect differences in the presence of hatchery fish among populations.

We marked carcasses that were in good condition (i.e., intact and body cavity not breached) with a uniquely numbered black cable tie passing through the mouth and under the operculum and returned the marked carcasses to their original position in the stream. Tails were removed from carcasses with breached body cavities to prevent repeat sampling. During subsequent surveys, carcasses with cable tie marks were recorded by surveyors. We used these mark-recovery data to estimate carcass detection probability for three size classes ($\leq$ 499 mm, 500–599 mm, and $\geq$ 600 mm) and at the population scale. We used binomial logistic regression to model the influence of potential explanatory variables such as carcass size and population on carcass detection probability. After constructing candidate regression models, we used Akaike's information criterion, corrected for small sample size (AIC_c), to rank each candidate model.

Redd Count Escapement Estimation

All spring Chinook redds in the basin were visually counted with the exception of a few isolated reaches in the Mainstem and Clear Creek (Granite Creek System, GCS) where landowners denied access. Theses reaches were short enough that we did not attempt to estimate redds therein.

We evaluated the relationship between index and total (total = index + census + random) redd counts at the population level. We used linear regression to determine if the census redd counts for 2000 to 2015 were significantly related to total redd counts. Next, we plotted the residuals from each of these three regressions against streamflow (Service Creek gauging station) to evaluate whether deviations were related to streamflow. Finally, we developed a linear regression for the 2000 to 2014 index:total data and used this equation to predict the 2015 total count based on the 2015 index count. The predicted total count was then compared with the observed total count to evaluate the necessity of census surveys.

Absence of weirs in the John Day River basin prevents basin-specific fish/redd estimates. Therefore, we estimated spawner escapement by using the following equation.

$$\widehat{N}_p = r_p \cdot \hat{f}$$

where:

$\widehat{N}_p$ = Estimated number of spawners in the population
r_p = Number of redds observed in the population
$\hat{f}$ = Estimated fish per redd above Catherine Creek weir located in the adjacent Grande Ronde River basin (ODFW unpublished data)

PIT Tag Detection-Recapture Escapement Estimation

Mark-recapture analysis using PIT-tagged fish provides an alternate method for estimating the abundance of adult Chinook returning to the John Day River basin. Several thousand Chinook smolts are intra-peritoneally PIT tagged annually when emigrating from the John Day River basin (DeHart et al. 2012). Tagged Chinook are subsequently detected at Bonneville Dam when returning as adults. Chinook salmon have a homing fidelity rate that typically exceeds 95% (Quinn 2005). Empirical evidence from the John Day River basin corroborates this. Lindsay et al. (1986) tagged juvenile Chinook in the three John Day populations and observed homing to natal spawning areas. Similarly, Narum et al. (2008) analyzed genetic evidence from the three populations and also concluded that homing dominated among these populations. Thus, we assumed a 100% homing rate between Bonneville Dam and spawning grounds for Chinook originally PIT tagged in the John Day River.

Following this assumption, John Day spring Chinook detection-recapture data were deemed applicable to a mark-recapture analysis (J. Peterson, Oregon State University, personal communication). When John Day Chinook crossed Bonneville Dam (rkm 232), some of these adults were "marked" at Bonneville Dam via passive detection of the PIT tags they carried. The detections we acquired each spring at Bonneville Dam (data available online at: www.ptoccentral.org) were analogous to operating a trap in the Lower John Day River that captured, PIT tagged, and released upstream migrating adults. Tagging a small portion (2–5%) of the population migrating upstream is sufficient, provided that a larger portion (> 15%) of the population is recovered as carcasses and examined for marks. This methodology is commonly used in the Pacific Northwest for estimating adult salmon escapement (e.g., Parsons and Skalski 2010).

Mortality may occur en route between Bonneville Dam and the spawning grounds, but we assumed the mortality to be equal between tagged and untagged Chinook, hence there was no change to the tagged:untagged ratio. PIT tags have been inside the body cavity of the fish since smoltification, so we assumed no tag loss during the upstream migration. On spawning ground surveys, the tags cannot be observed externally by the surveyor, thus eliminating the possibility of bias toward detection of a marked carcass. All carcasses that were physically intact (scavenged carcasses were excluded) were used for this estimate. There is evidence that female Chinook frequently expel an intra-peritoneally implanted PIT tag during spawning. For example, Prentice et al. (1986) observed 100% retention of PIT tags when hand spawning male Atlantic salmon (*Salmo salar*), but only 83% retention of PIT tags during hand spawning of female Atlantic salmon. We corrected for this tag loss by summing the spawning ground recaptures of males only, and then dividing by the fraction of males observed in our carcass recoveries to estimate the number of females that had PIT tags prior to expulsion.

We estimated the number of John Day origin spring Chinook to Bonneville Dam with Chapman's modification of the Petersen estimate (White et al. 1982):

$$\hat{N} = \frac{(M+1)(C+1)}{(\hat{R}+1)} - 1$$

where:

$\hat{N}$ = Number of returning adult Chinook crossing Bonneville Dam that originated from the John Day River

M = Number of returning adult Chinook that were originally PIT tagged when emigrating from the John Day River and subsequently detected crossing Bonneville Dam

C = Number of intact carcasses scanned for a PIT tag on spawning ground surveys (inclusive of both males and females)

$\hat{R}$ = Number of fish in group M that were recovered on spawning ground surveys, after correcting for female tag shed by assuming an equal rate of tag presence between males and females

We estimated the number of Chinook salmon migrating past the Middle Fork PIT tag array using methods similar to those described above where:

$\hat{N}$ = Number of adult Chinook salmon passing the Middle Fork PIT array (rkm 69)

M = Number of PIT tagged adults detected migrating upstream past the Middle Fork PIT array

C = Number of intact carcasses scanned for a PIT tag on Middle Fork spawning ground surveys (inclusive of both males and females)

$\hat{R}$ = Number of fish in group M that were recovered on carcass surveys, including pre-spawn mortality surveys

Population Productivity Analyses

We assessed covariation of total redd count among three John Day populations and other streams studied by ODFW's Northeast-Central Oregon research and monitoring program (NECORM) using Pearson correlation. Additionally, we evaluated the correlation between total redd count for each John Day population and an indicator of ocean productivity. The ocean indicator we selected was Pacific Decadal Oscillation (PDO; data available online at: http://jisao.washington.edu/pdo/PDO.latest) for the summer (May to September) that age-4 Chinook (the dominant age class in all three populations) entered the ocean. Negative values of the PDO indicate cooler sea surface temperatures and more productive ocean conditions for juvenile salmonids entering the ocean from the Columbia River.

Productivity of the three populations was assessed at two life history stages: smolt recruitment and adult recruitment. The smolt recruitment metric was an estimate of the number of out-migrant yearling smolts produced per redd. This metric was only available for the Mainstem and Middle Fork populations. The second metric was adult female to adult female (redd to redd) stock-recruitment curves. We fit these recruitment curves for each of the populations.

To estimate smolts per redd, yearling spring Chinook migrants were captured at two rotary screw trap (RST) sites. The RST sites are located downstream of all known spring Chinook spawning habitat within their respective subbasin, with the exception of Bridge Creek that is included in the Mainstem population. A 1.52 m or 2.44 m diameter RST was fished at the Mainstem (rkm 352) trap site depending on water conditions to optimize capture efficiency. Two 1.52 m RSTs were fished at the Middle Fork (rkm 24) trap site. Trapping efficiency was estimated separately at each RST site by releasing marked yearling chinook upstream of the trap(s) at civil twilight to mimic natural migration patterns (Tattam et al. 2013). A complete description of smolt collection methods is described by DeHart et al. (2012). Data collected from each of the RSTs were then used to estimate smolt abundance for the Mainstem and Middle Fork populations.

Adult to adult recruitment rates for each population were modeled with Ricker stock-recruitment curves fit to the total redd abundance dataset from 2000 to present. We analyzed the 2000 to 2010 brood years separately for each population. Total redd counts were partitioned based on the age structure of female Chinook recovered on spawning ground surveys in each population. This allowed us to determine the number of redds produced by each brood year. For instance, the "redd to redd" productivity of the Middle Fork population during brood year 2000 was estimated as:

$$\frac{(\text{2004 redds} \cdot (\text{proportion Age 4 females})) + (\text{2005 redds} \cdot (\text{proportion Age 5 females}))}{\text{Total Year 2000 redds}}$$

The natural log of recruit redds per brood year redds was regressed against brood year redds to parameterize a Ricker stock-recruitment curve for each population. Salmonid populations frequently exhibit density-dependence during freshwater rearing (Achord et al. 2003; Milner et al. 2003). That is, the rate of per-capita production (which we measure as recruit redds per brood year redd) decreases with increasing brood year redd abundance. Thus, we expect lower productivity values at higher levels of brood year redd abundance and vice versa. This regression models density dependence by predicting lower recruitment rates at higher brood year redd abundances. The residuals from this regression measure the deviation between observed recruitment and the recruitment rates predicted after adjusting for density-dependence. A positive residual indicates higher than expected productivity, whereas a negative residual indicates lower than anticipated productivity. We plotted the residuals against brood year to evaluate temporal trends in productivity. Residuals from a stock-recruitment relationship can thus be used to investigate changes in productivity over time without the confounding effects of parental stock abundance (e.g., Peterman et al. 1998, Mueter et al. 2007).

RESULTS

Redd Counts

We surveyed 302.9 km of potential Chinook spawning habitat within the John Day River basin in 2015 (Table 2; Figures 2, 3, 4, and 5). A total of 83.6 km of spawning habitat was surveyed within the index area, excluding 2.1 km where we were denied access, and 206.2 km of spawning habitat was surveyed within the census area. We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork for a total length of 13.1 km of stream.

Table 2. Survey location, access status, survey type, and reach length (km) for 2015 spawning survey reaches in the John Day River basin.

		Survey Type		
Stream Name	**Access Status**	**Census**	**Index**	**Random**
Mainstem				
Bridge Creek (LMJD)	Yes	11.7		
Canyon Creek	Yes			1.4
Deardorff Creek	Yes	2.0		
Mainstem John Day River	*No*		*0.9*	
Mainstem John Day River	Yes	14.1	16.7	1.5
Reynolds Creek	Yes	4.1		
South Fork				
South Fork John Day River	Yes	17.3		2.0
Middle Fork				
Bridge Creek (Middle Fork)	Yes	2.9		
Clear Creek (MFJD)	Yes	4.1		
Granite Boulder Creek - MFJDR	Yes	2.3		
Middle Fork John Day River	Yes	27.7	19.8	4.0
Vinegar Creek	Yes	0.6		
North Fork				
Baldy Creek	Yes	1.1		
Big Creek	Yes	0.1		
Camas Creek	Yes	0.8		2.0
Crawfish Creek	Yes			0.2
North Fork John Day River	Yes	63.2	28.5	2.0
Trail Creek	Yes	3.0		
Granite Creek System				
Bull Run Creek	Yes	2.3	4.9	
Clear Creek (Granite tributary)	*No*		*1.2*	
Clear Creek (Granite tributary)	Yes	4.3	4.7	
Granite Creek	Yes	7.5	9.0	
Desolation Creek				
Desolation Creek	Yes	35.3		
Desolation Creek (South Fork)	Yes	1.8		
Total		**206.2**	**83.6**	**13.1**

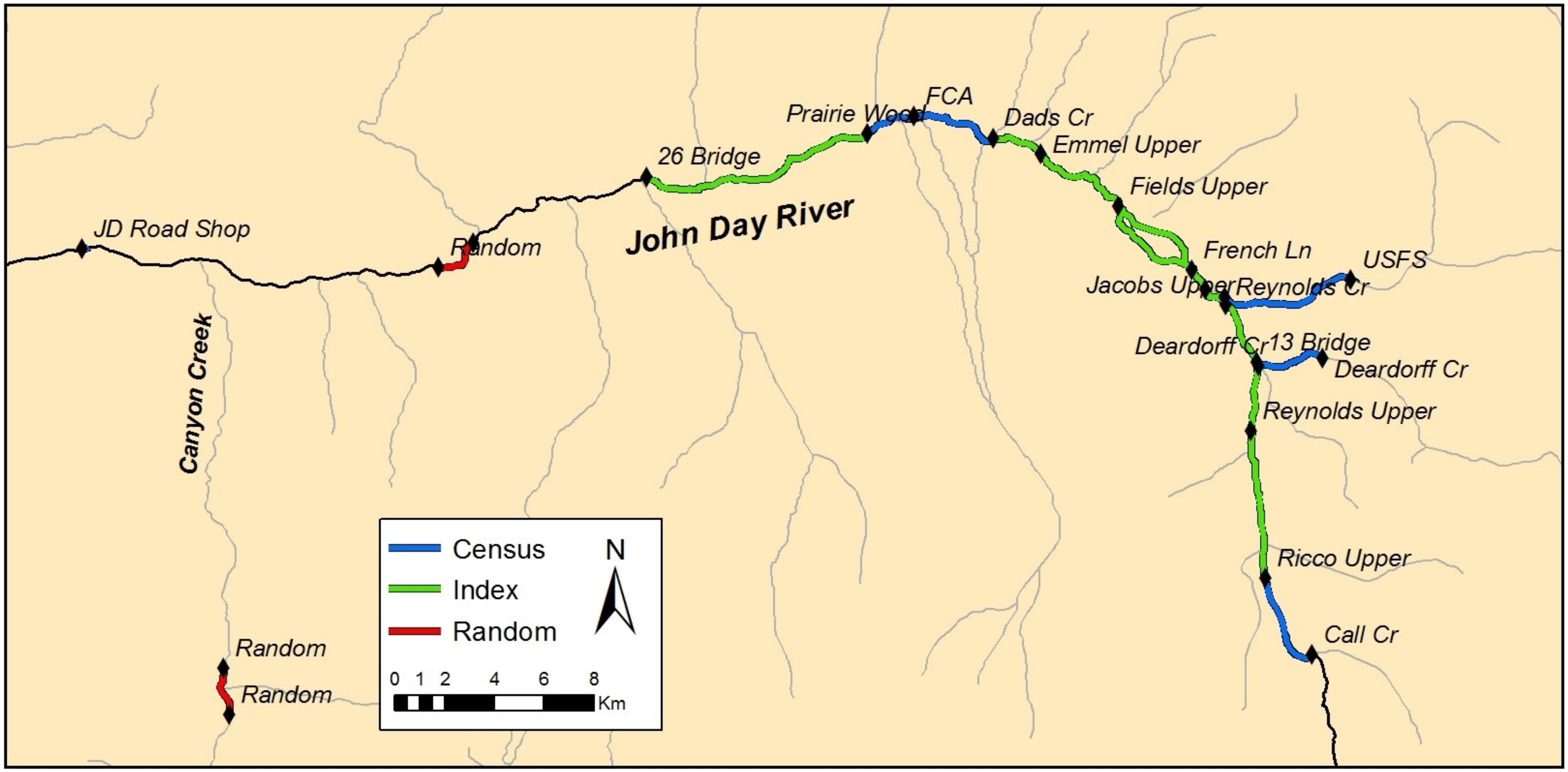


Figure 2. Map of the 2015 Mainstem spring Chinook spawning ground survey sections.

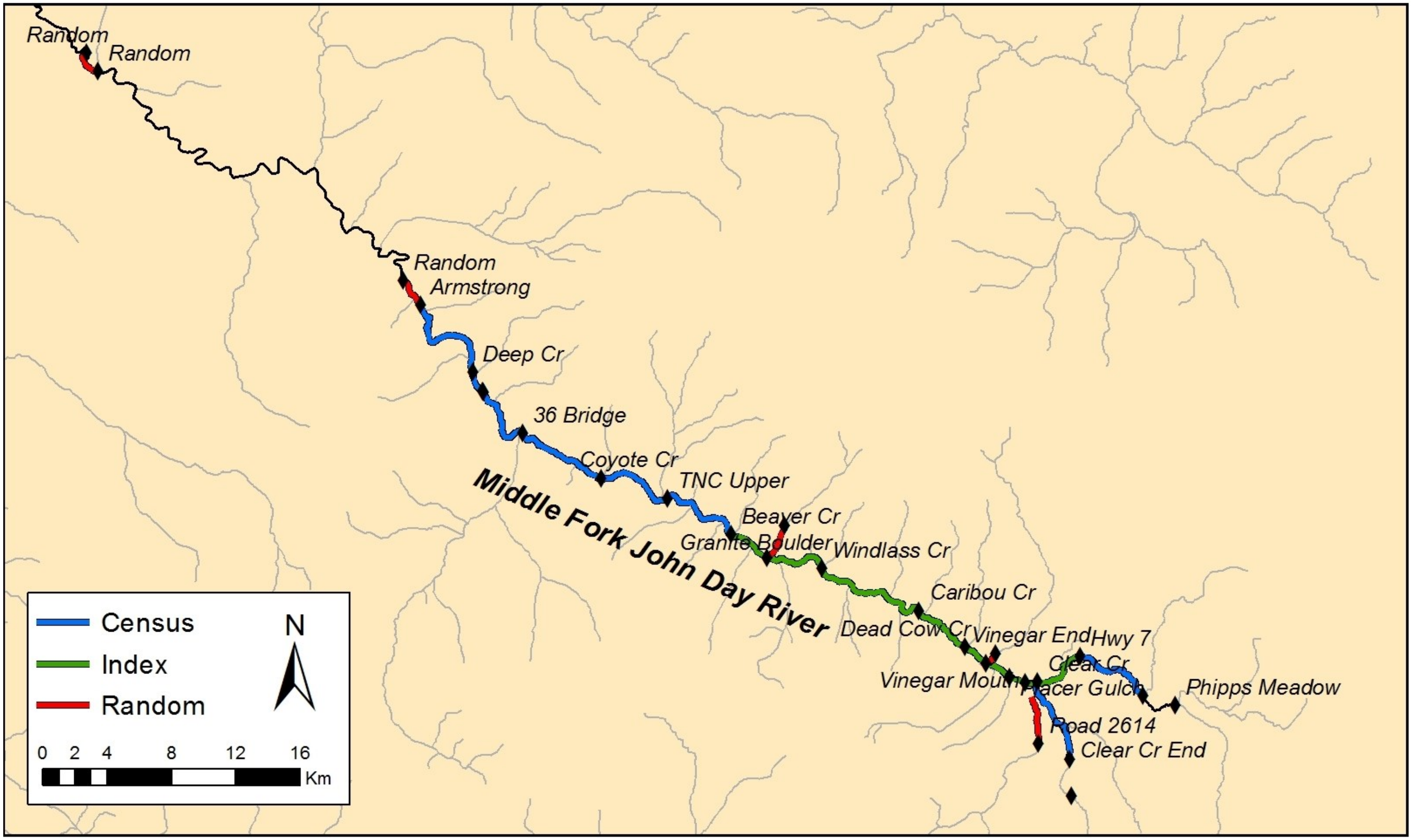


Figure 3. Map of the 2015 Middle Fork spring Chinook spawning ground survey sections.

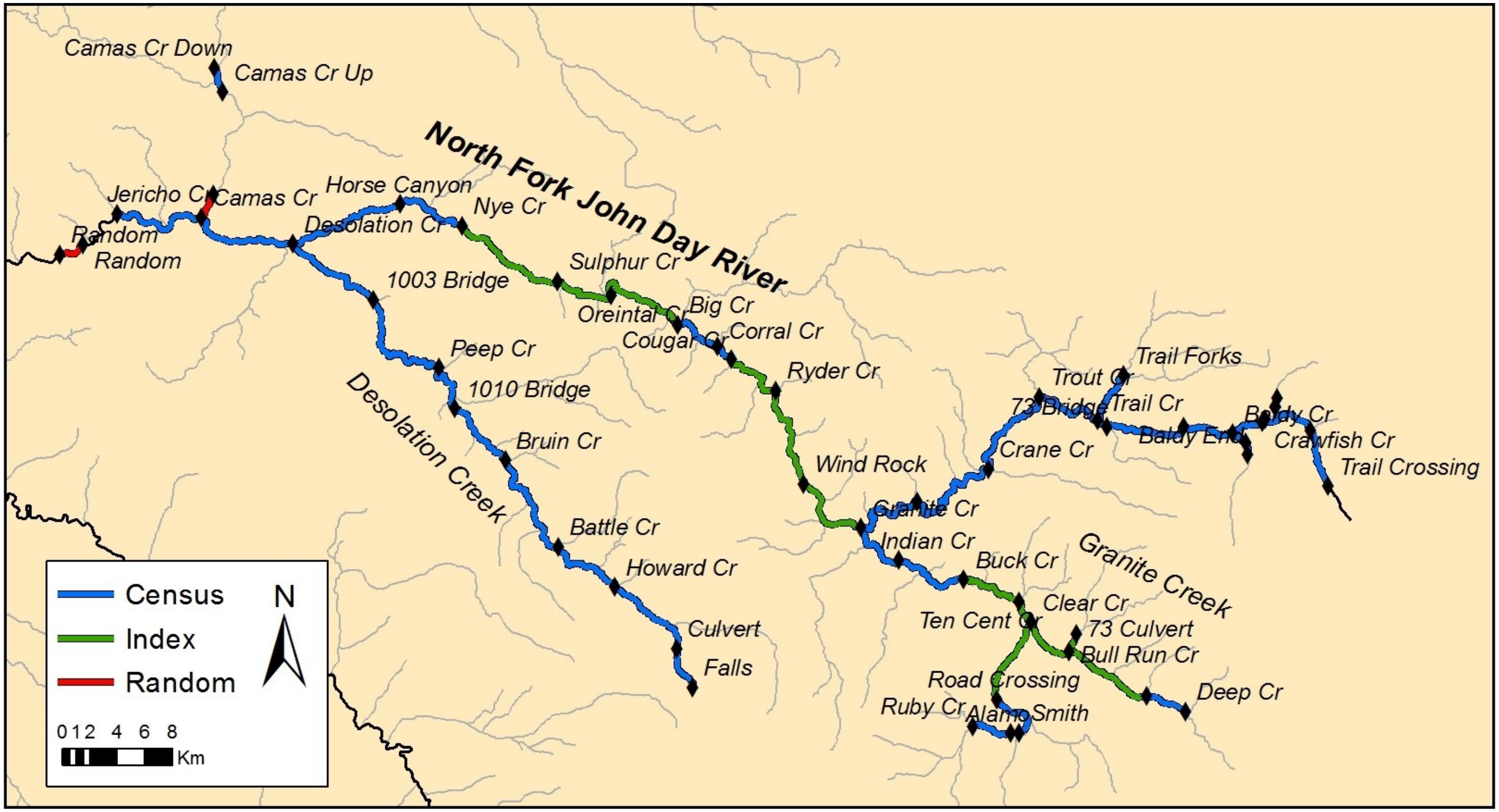


Figure 4. Map of the 2015 North Fork spring Chinook spawning ground survey sections.

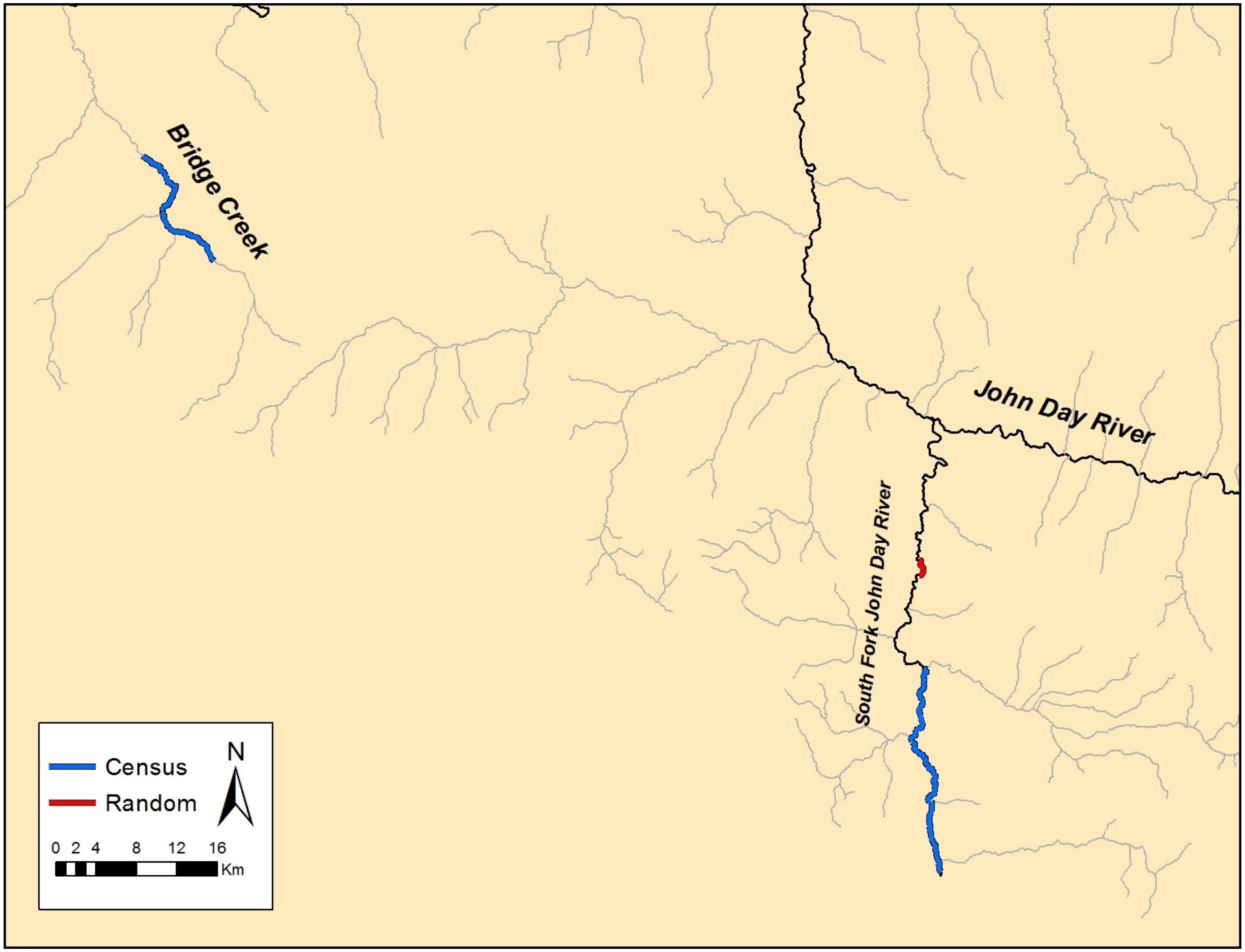


Figure 5. Map of the 2015 South Fork and Bridge Creek spring Chinook spawning ground survey sections.

We observed 1,628 spring Chinook redds within the John Day River basin in 2015 (Tables 3 and 4). We estimated an overall density of 5.6 redds/km for the entire survey area, excluding random reaches where spawning was not present (Table 3). Of the 1,628 total redds, 832 were observed during index surveys at a density of 10.0 redds/km. The ratio of index to census redds, with post-index redds treated as census redds, was slightly greater than 1 (Figure 6). No redds were observed in any of the random reaches for 2015. The Mainstem accounted for 47.4% of the total redds observed in 2015, the Middle Fork had 27.1%, and the North Fork had 25.5%. We did not observe any redds in the South Fork. The Mainstem had the highest density of redds with 15.9 redds/km, followed by the Middle Fork with 7.7 redds/km, and the North Fork with 2.5 redds/km (Figures 7, 8, and 9).

Table 3. Distance surveyed, total unique redds observed, redd density, fish per redd estimates generated at the Catherine Creek weir, adult escapement, and total escapement for spring Chinook spawners in the John Day River basin from 2000–2015.

Year	Distance (km)	Redds	Redds/km	Adults/Redd	Jacks and Adults/Redd	Adult Escapement	Total Escapement
2000	236.1	1,869	7.9	1.54	1.69	2,875	3,163
2001	243.2	1,863	7.7	2.92	4.19	5,447	7,808
2002	255.9	1,959	7.7	2.71	2.90	5,299	5,689
2003	243.0	1,354	5.6	2.76	2.92	3,742	3,955
2004	260.0	1,531	5.9	2.13	2.24	3,257	3,437
2005	267.5	878	3.3	1.92	2.07	1,683	1,817
2006	264.6	909	3.4	2.29	2.41	2,079	2,190
2007	267.5	746	2.8	2.77	2.93	2,068	2,186
2008	264.6	963	3.6	1.99	2.15	1,916	2,072
2009	265.9	1,221	4.6	2.24	3.23	2,737	3,944
2010	268.2	1,440	5.4	2.55	2.71	3,671	3,905
2011	287.7[a]	1,846	6.4	2.62	3.90	4,844	7,205
2012	276.7[a]	1,787	6.5	2.91	3.01	5,202	5,384
2013	267.9[a]	995	3.7	3.81	4.68	3,795	4,663
2014	267.9[a]	2,195	7.6	2.70	2.89	5,920	6,349
2015	289.8[a]	1,628	5.6	2.19	2.35	3,565	3,826

[a] *excludes random sites where redds were not observed*

Table 4. Total number of redds and carcasses observed during spring Chinook salmon spawning surveys in the John Day River basin, 2015.

	Redds (n)			Carcasses (n)		
Stream Name	**Census**	**Index**	**Random**	**Wild**	**Hatchery**	**Unknown**
Mainstem Population						
Deardorff Creek						
Mainstem John Day River	397	374		205		3
Reynolds Creek						
Middle Fork Population						
Bridge Creek				1		
Clear Creek	19			4		2
Middle Fork John Day River	157	266		353		6
North Fork Population						
Baldy Creek						
Bull Run Creek	6	5		6		
Clear Creek	9	7		10		
Desolation Creek	33			8		
Granite Creek	22	10		12	1	
North Fork John Day River	153	170		69		1
Total	**796**	**832**	**0**	**668**	**1**	**12**

Figure 6. Ratio of index to census redd count totals from 2000–2015 for the John Day River basin. The dotted line indicates a ratio of 1:1 between the number of index redds and the number of census redds.

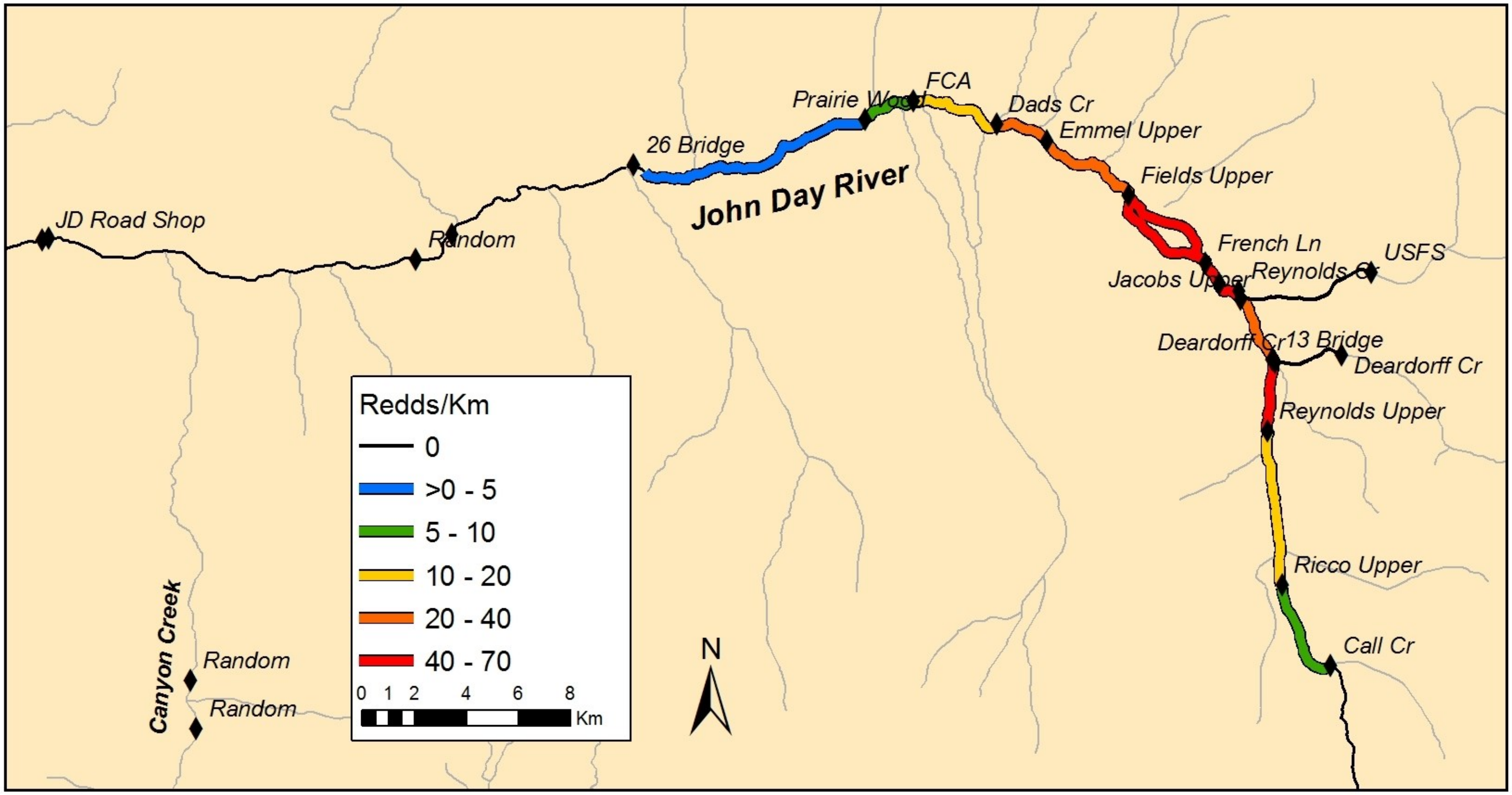


Figure 7. 2015 spring Chinook spawning survey sites and redd densities in the Mainstem John Day River.

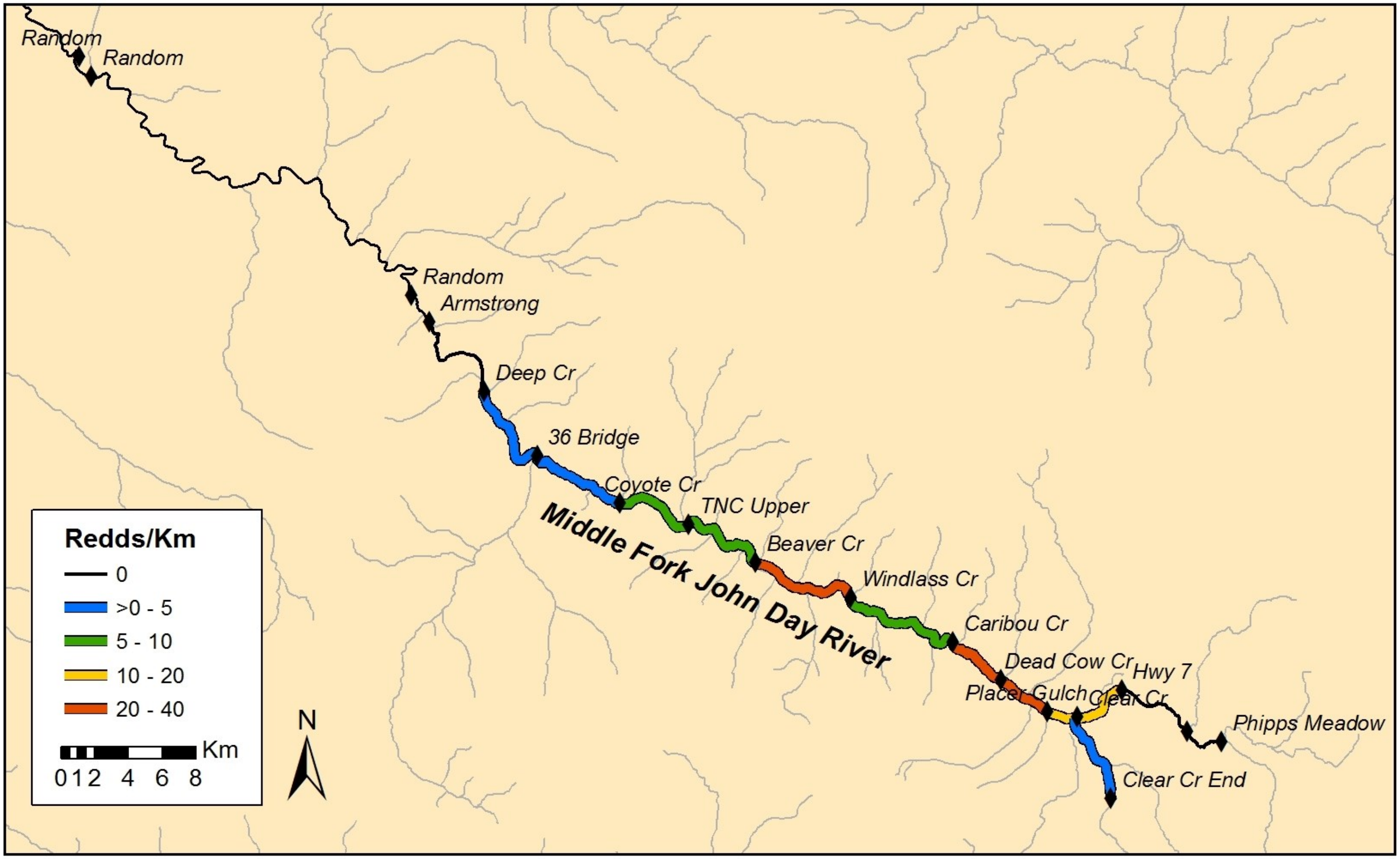


Figure 8. 2015 spring Chinook spawning survey sites and redd densities in the Middle Fork John Day River.

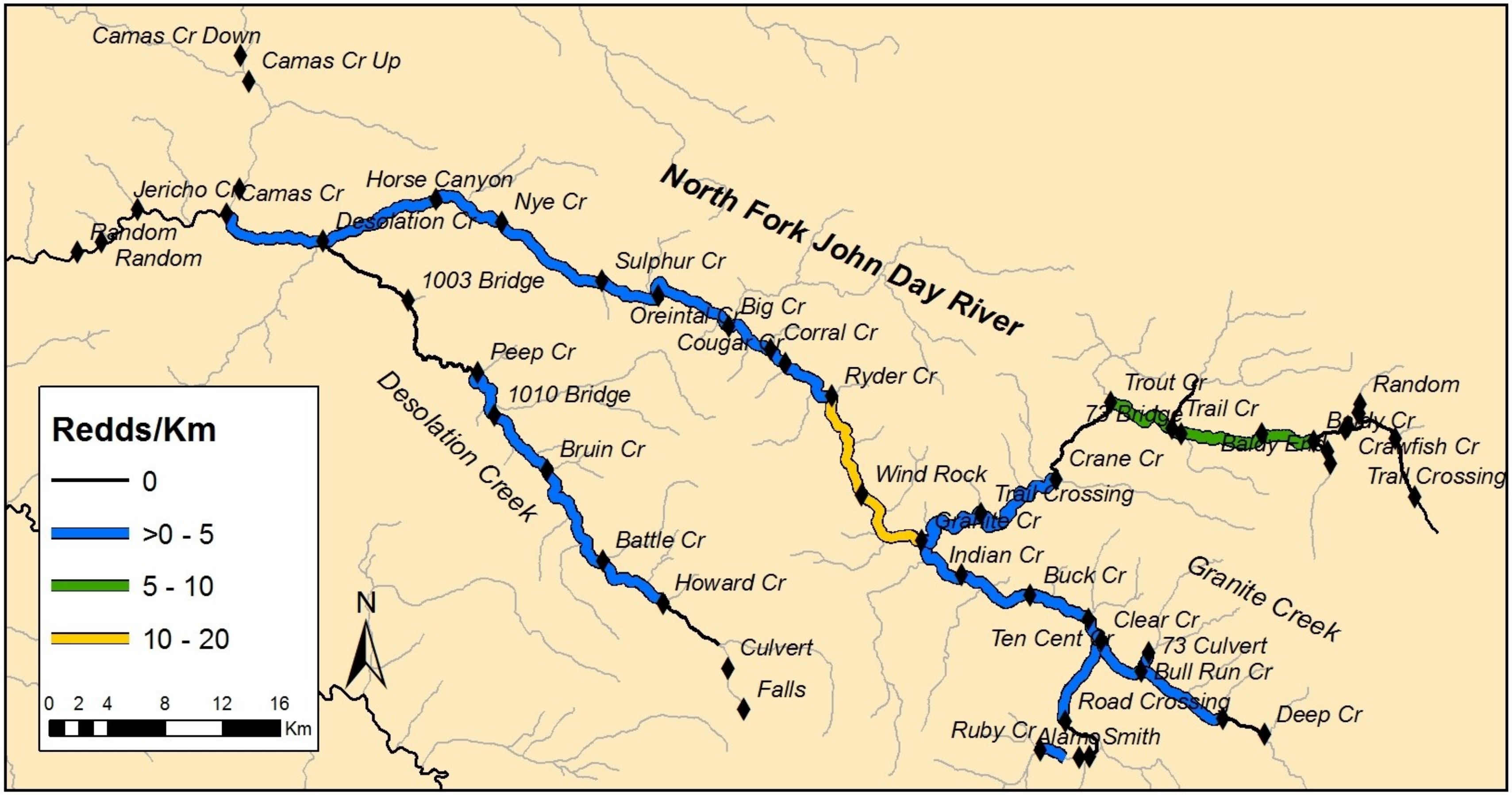


Figure 9. 2015 spring Chinook spawning survey sites and redd densities in the North Fork John Day River.

Significant correlations exist between index and total redds (total = index + census + random) for all three John Day populations (Mainstem $r = 0.86$, $P < 0.01$, Middle Fork $r = 0.90$, $P < 0.01$, and North Fork $r = 0.93$, $P < 0.01$; Figure 10). Plotting the residuals against mean daily discharge in August for the John Day River at Service Creek (rkm 252) suggests summer flow does not influence redd distribution (Figure 10). We also found a significant correlation between basinwide total and index counts for 2000 to 2015 ($r = 0.90$, $P < 0.01$). Applying the regression equation between index and total redd counts for survey years 2000–2014 to the 2015 index count predicted a total redd count of 1,326. This prediction would have underestimated the actual total redd count by 23%.

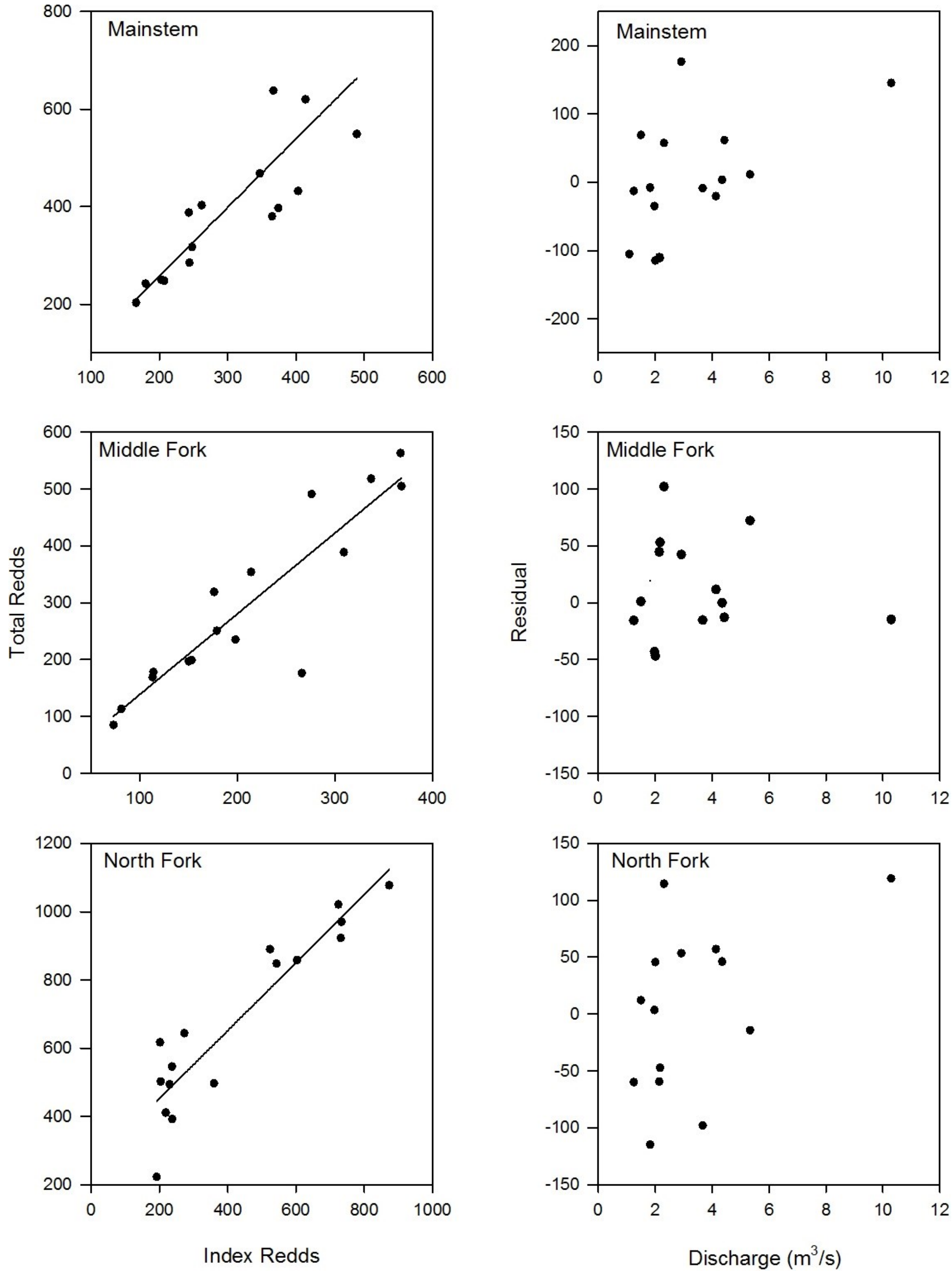


Figure 10. Regression between index and total redd counts from 2000–2015 spawning ground surveys and the residuals from these regressions plotted against mean August discharge of the John Day River for spawning populations in the Mainstem, Middle Fork, and North Fork of the John Day River.

Redd Count Expansion Escapement Estimation

The 2.35 fish per redd ratio generated from Catherine Creek spawning surveys in 2015 is lower than the past fifteen year average (2.93). Applying the ratio to the John Day River basin, we estimated an escapement of 3,826 spring Chinook spawners in the John Day River basin for 2015 (Table 3). We estimate that 1,812 fish spawned in the Mainstem, 1,039 spawned in the Middle Fork, and 975 spawned in the North Fork.

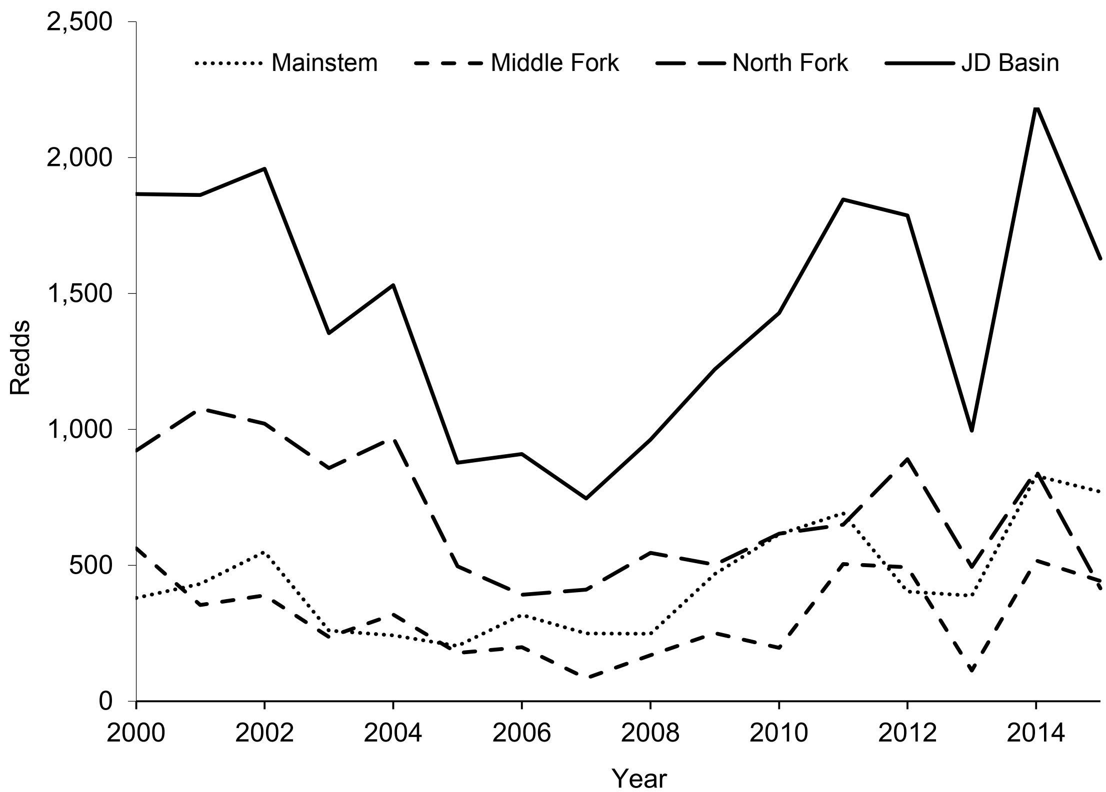


Figure 11. Redd totals from 2000–2015 for three John Day River basin spring Chinook salmon populations and the basinwide total.

Redd abundance at the John Day River basin scale during 2015 was down 26% from 2014 (Figure 11), however, it is above the average redd count of 1,436. At the population scale, the Mainstem showed a 7% decrease, the Middle Fork declined 15%, and the North Fork dropped the most with 51% fewer redds in 2015 than we observed in 2014. The Middle Fork population did experience another pre-spawn mortality in 2015 as a result of elevated water temperatures similar to those observed in 2007 and 2013. Redd counts in other northeast Oregon river basins (e.g., Grande Ronde and Imnaha) also decreased in 2015 (Figure 12); Grande Ronde River basin redd counts decreased 45% and Imnaha River basin redds went down 18% from 2014 to 2015. Annual Middle Fork redd counts are significantly correlated with counts in both Mainstem and North Fork populations (Table 5), however, the Mainstem is not significantly correlated with the North Fork. Redd counts for the Mainstem were significantly correlated to both Grande Ronde and Imnaha river populations. The Middle Fork showed a nearly significant correlation with the Grande Ronde (p-value = 0.10) and the North Fork was nearly significantly correlated with Imnaha counts (Table 5, Appendix Table VIII). The similar trends in redd totals observed across northeast Oregon populations appear to be inversely related to PDO values for the summer those spawners entered the ocean (Figure 12). Redd counts for every population except the Middle Fork and North were either significantly or suggestively correlated with PDO values during the summer two years prior to the redd count (Table 5, Figure 13).

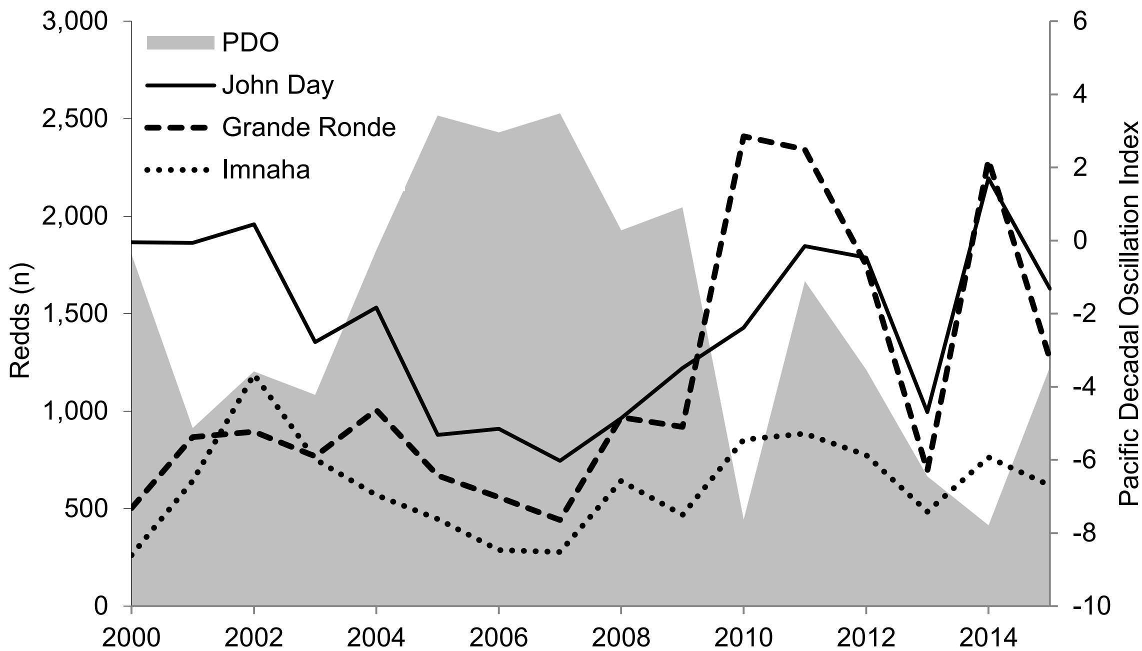


Figure 12. Redd totals from 2000–2015 for the John Day, Grande Ronde, and Imnaha river basins plotted with summer values of the Pacific decadal oscillation index. Pacific decadal oscillation index values are for the summer of entry for age-4 Chinook.

Table 5. Matrix of correlation coefficients (Pearson's r) between Mainstem, Middle Fork, North Fork, Grande Ronde, and Imnaha rivers Chinook redd counts from 2000–2015 and Pacific Decadal Oscillation (PDO) values observed during the summer two years prior to the redd count year (Imnaha and Grande Ronde data provided by J. Feldhaus, ODFW). Significant correlations ($P < 0.05$) are indicated in bold, nearly significant ($P < 0.10$) are indicated by italics.

	Middle Fork Redd Count	North Fork Redd Count	Grande Ronde Redd Count	Imnaha Redd Count	Summer Entry PDO
Mainstem Redd Count	**0.55**	0.23	**0.78**	**0.58**	**-0.65**
Middle Fork Redd Count	-	**0.68**	*0.43*	0.38	-0.26
North Fork Redd Count	-	-	0.10	*0.48*	-0.38
Grande Ronde Redd Count	-	-	-	**0.58**	**-0.57**
Imnaha Redd Count	-	-	-	-	**-0.65**

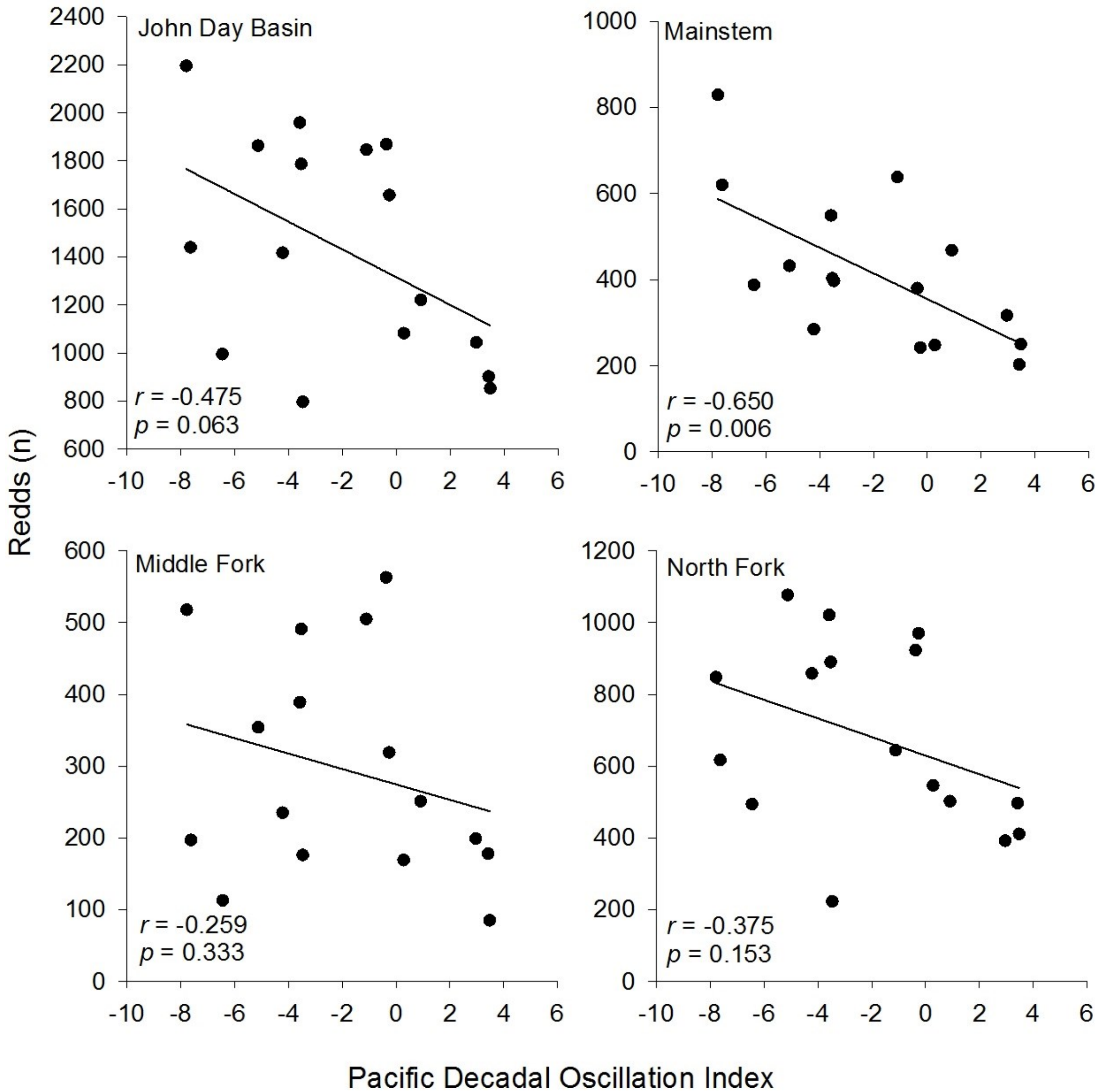


Figure 13. Correlation between Pacific Decadal Oscillation values and total redd counts from 2000–2015 spawning ground surveys in the John Day basin, Mainstem, Middle Fork, and North Fork.

Carcass Recovery

In 2015, we recovered 681 carcasses throughout the John Day River basin. We were able to determine origin of 669 carcasses. The only fish that had a clipped adipose fin was recovered in Granite Creek of the North Fork population. The 2015 proportion of hatchery origin Chinook was the lowest observed since 1998 (Figure 14). We did not detect a significant difference in the frequency of hatchery fish among populations (P = 0.07). The snout recovered from the one hatchery fish found in 2015 was not found to have a coded wire tag. We determined the sex of 633 carcasses, 299 (47.2%) were male and 334 (52.8%) were female. We determined age for 481 carcasses using scale pattern analysis. There was a total of 9 age-3 (1.9%), 375 age-4 (78.0%), and 97 age-5 (20.2%) fish (Figure 15; Tables 6 and 7). Four of the scales were found to have sub-yearling smolt growth patterns (i.e., age-1 freshwater); two of the fish were in the Middle Fork and the other two were found in the Mainstem and North Fork.

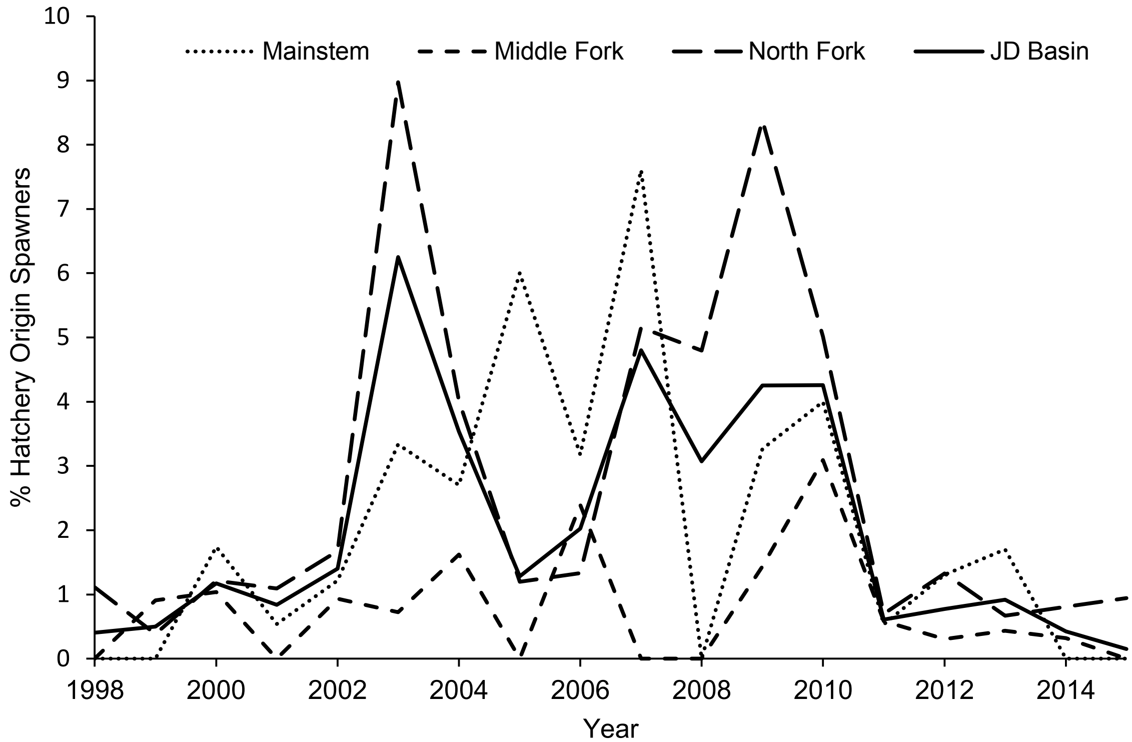


Figure 14. Percent hatchery origin spawners from 1998–2015 for three John Day River basin spring Chinook salmon populations and the entire basin.

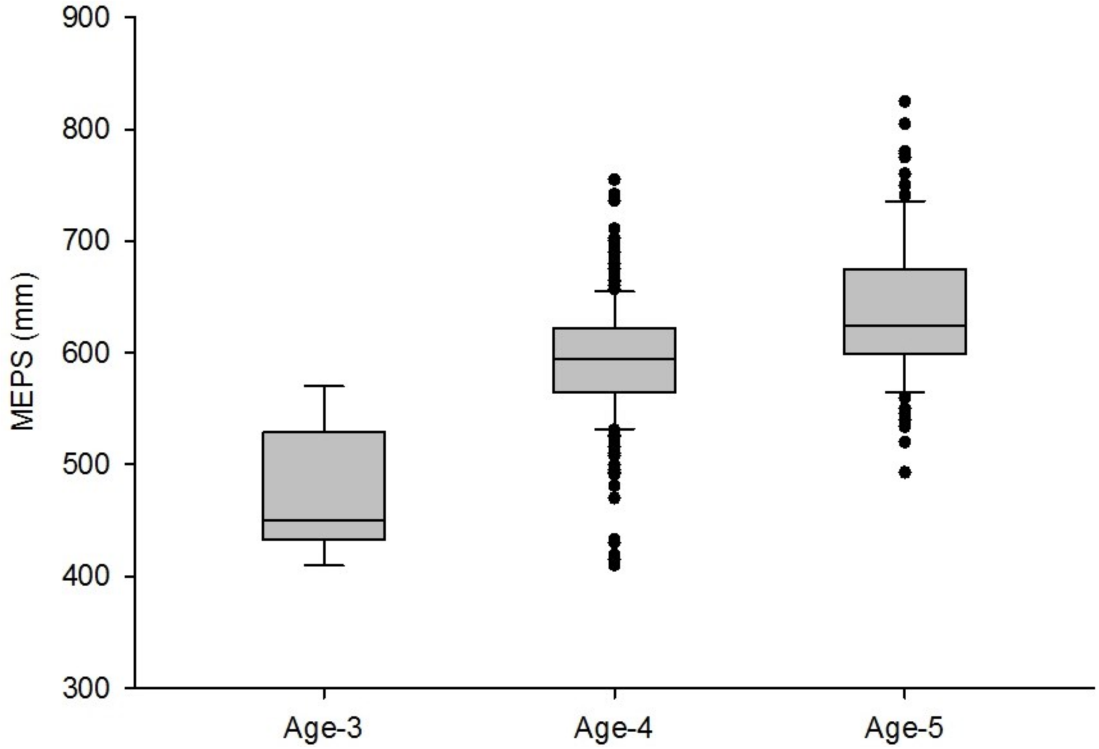


Figure 15. Age versus MEPS length for Chinook carcasses recovered in 2015. Boxes indicate 25th percentile, median, and 75th percentile. Error bars indicate 10th and 90th percentiles.

Laboratory analysis produced optical density values for kidney samples taken from 67 carcasses and Rs antigen levels revealed 19 samples were negative or very low, 45 samples were low positive, and three samples were moderate positive (Appendix Table V). Of the 230 female carcasses for which we estimated egg retention, 199 (87%) were completely spawned. The 31 females that were partially spawned contained an average of 400 ml (SD = 291) of eggs. Additional samples of partially spawned females will allow us to develop a linear regression between egg volume and egg number.

Table 6. Age, mean MEPS length (mm), standard error (SE), sample size (n), range (mm), and percentage of total known-sex aged Chinook from 2015 carcass recovery. Twenty-seven fish of unknown sex were also aged.

	Male					**Female**				
Age	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**
3	458.5	23.1	7	410 - 570	1.5%	512.5	32.5	2	480 - 545	0.4%
4	589.4	4.4	181	410 - 755	37.6%	598.6	3.2	171	430 - 711	35.6%
5	645.2	17.8	20	520 - 780	4.2%	641.9	7.6	73	493 - 825	15.2%

Table 7. Percentage of known-sex aged Chinook carcasses by population for 2015.

		% Males by Age				**% Females by Age**		
	n	**3**	**4**	**5**	**n**	**3**	**4**	**5**
Mainstem	77	9.1	89.6	1.3	92	0.0	81.5	18.5
Middle Fork	98	0.0	87.8	12.2	101	2.0	68.3	29.7
North Fork	33	0.0	78.8	21.2	53	0.0	50.9	49.1
Basin Total	**208**	**3.4**	**87.0**	**9.6**	**246**	**0.8**	**69.5**	**29.7**

PIT Tag Detection-Recapture Escapement Estimation

A total of 644 carcasses, including those that had been scavenged, were scanned for PIT tags during the spawning ground surveys and 6 tags were recovered (Table 8). All of the recaptured fish were of wild origin. Three of the PIT-tagged carcasses were male and three were female. One carcass, originally tagged as a juvenile in the Middle Fork, was recovered in that subbasin, one carcass was tagged as a juvenile and later recovered in the Upper Mainstem, and the other fish was tagged as a juvenile in the lower Mainstem John Day River (below the confluence with the North Fork) and recovered in the Middle Fork. Three of the recaptured fish were tagged as adults during April of 2015 in the Columbia River; one at a trawling site between the Columbia River mouth and Three Tree Point, Washington (rkm 0-49) and two at the adult fish facility of Bonneville Dam (rkm 234). Two of the carcasses in the Middle Fork were recovered during pre-spawn mortality surveys conducted on July 9 and 15.

Table 8. Spring Chinook passive integrated transponder (PIT) tags recovered on John Day River spawning ground surveys during 2009–2015. U = unknown sex.

	Intact Wild Carcasses Scanned			**Carcasses with John Day Origin PIT Tags[b]**			**Carcasses with Out of Basin Origin PIT Tags**		
Year	**Male**	**Female**	**U**	**Male**	**Female**	**U**	**Male**	**Female**	**U**
2009	114	137	2	3	1	0	1	0	0
2010	259	233	24	7	0	1	3	1	0
2011	746	759	42	31	4	0	6	5	0
2012	228	318	619	8	1	5	3	6	5
2013	319	245	4	6	0	0	6	3	0
2014	549	685	38	7	1	0	6	7	0
2015	238	263	22	2	1	0	1	2	0

[b] *Only includes PIT-tagged individuals that were detected at Bonneville Dam*

Detections at Bonneville Dam indicated that 139 John Day origin PIT-tagged Chinook passed the dam in 2015. Spawning surveys scanned a total of 523 intact wild origin carcasses (Table 8). We recaptured two John Day basin origin males and one female. We estimated the number of recaptured John Day origin PIT-tagged females to be 3, producing a total of 5 recaptured adults. Estimated wild escapement at Bonneville Dam was 12,272 (95% CI: 3,428−21,116) (Figure 16).

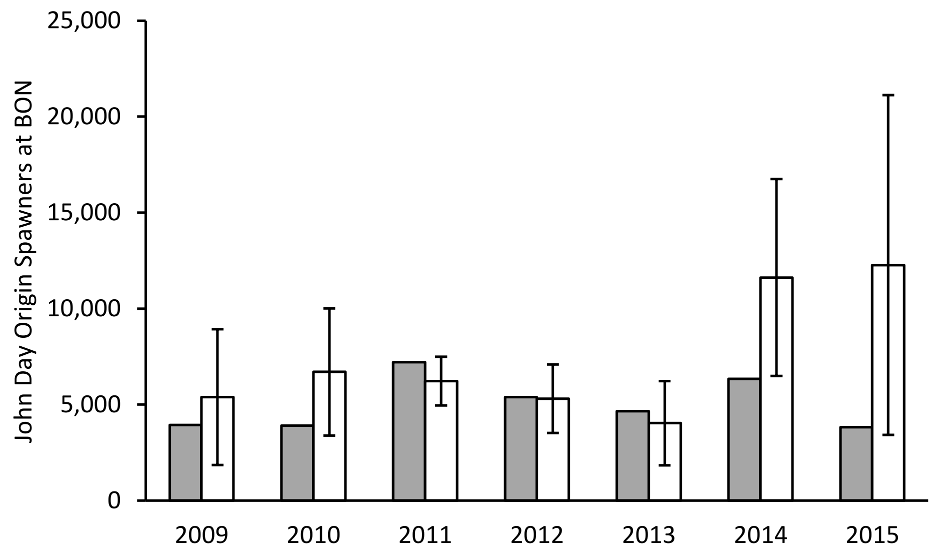


Figure 16. John Day River basin mark-recapture abundance estimates (white) with 95% confidence intervals and redd count escapement estimates (gray) for spawning years 2009–2015.

Detections at Middle Fork Array indicated that 39 PIT-tagged Chinook entered the river in 2015. Spawning surveys scanned a total of 283 intact wild origin carcasses. We recaptured two males and estimated the number of recaptured PIT-tagged females to be 3, producing a total of 5 recaptured adults. Estimated escapement in the Middle Fork was 1,892 (95% CI: 613−3,171) (Figure 17).

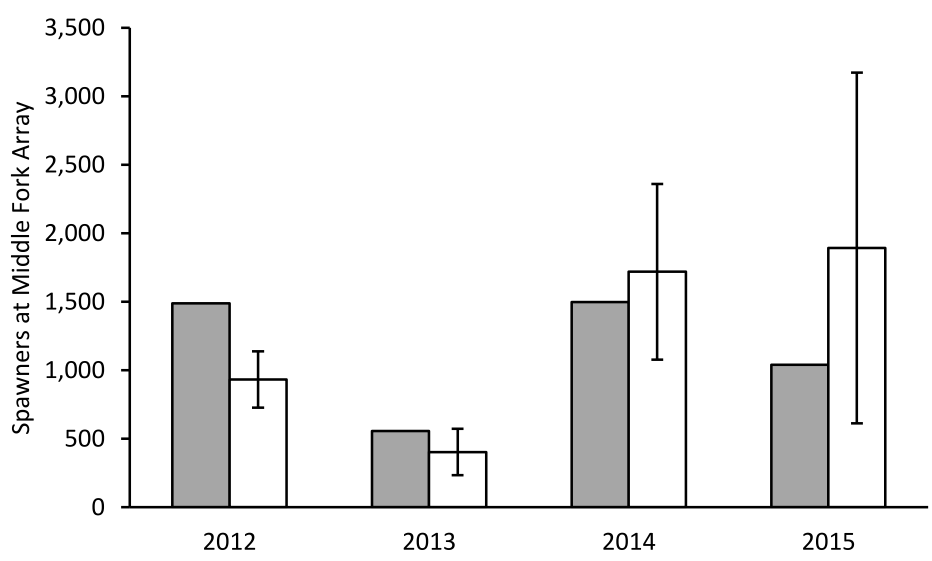


Figure 17. Middle Fork John Day River mark-recapture abundance estimates (white) with 95% confidence intervals and redd count escapement estimates (gray) for spawning years 2012–2015.

Carcass Detection Probabilities

We marked 113 carcasses with uniquely numbered cable-ties, 112 of which had their MEPS length recorded. We recovered 42 of these marked carcasses on subsequent surveys. The probability of a marked carcass being recovered was highest in the Middle Fork (0.49; n = 63), intermediate in the North Fork (0.36; n = 22), and lowest in the Mainstem (0.11; n = 27). Information theoretic selection of four candidate logistic regression models (Table 9) indicated that the "population" and "size + population" were competing models (Delta AICc < 2). Logistic regression models which incorporated size alone, or no explanatory variables (i.e., intercept), did not fit the data as well.

Table 9. Akaike's information criterion (AICc) model selection results for binomial logistic regressions of marked carcass recoveries in 2015 versus different explanatory variables. Explanatory variables included: population and size. The intercept model is a null model with no explanatory variables.

Model	K	AIC_c	ΔAIC_c	w_i
Population	3	27.93	0.00	0.59
Size + Population	5	28.71	0.78	0.40
Intercept	1	36.73	8.01	0.01
Size	3	37.26	9.33	0.01

Population Productivity Analyses

We estimated that freshwater productivity for the 2013 brood year was 108 smolts per redd (95% CI: 92–129) in the Mainstem and 55 smolts per redd (95% CI: 49−63) in the Middle Fork. The estimated number of smolts produced per redd declined with increasing redd abundance for both the Mainstem and Middle Fork populations (Figures 18 and 19).

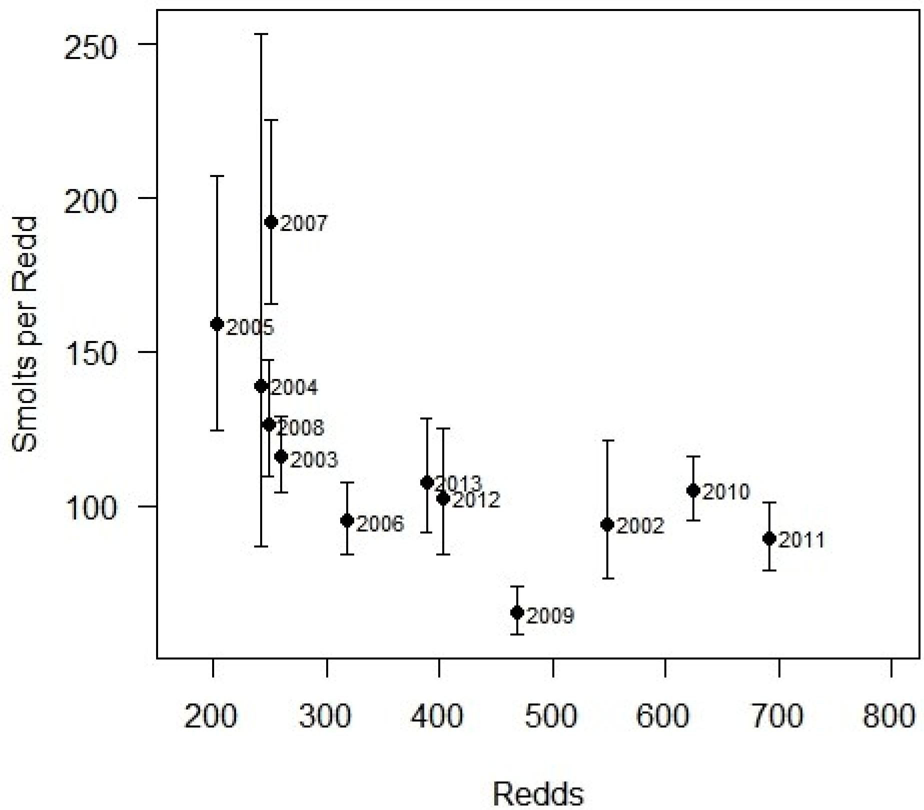


Figure 18. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2013 for the Mainstem population. Error bars are 95% Confidence Intervals.

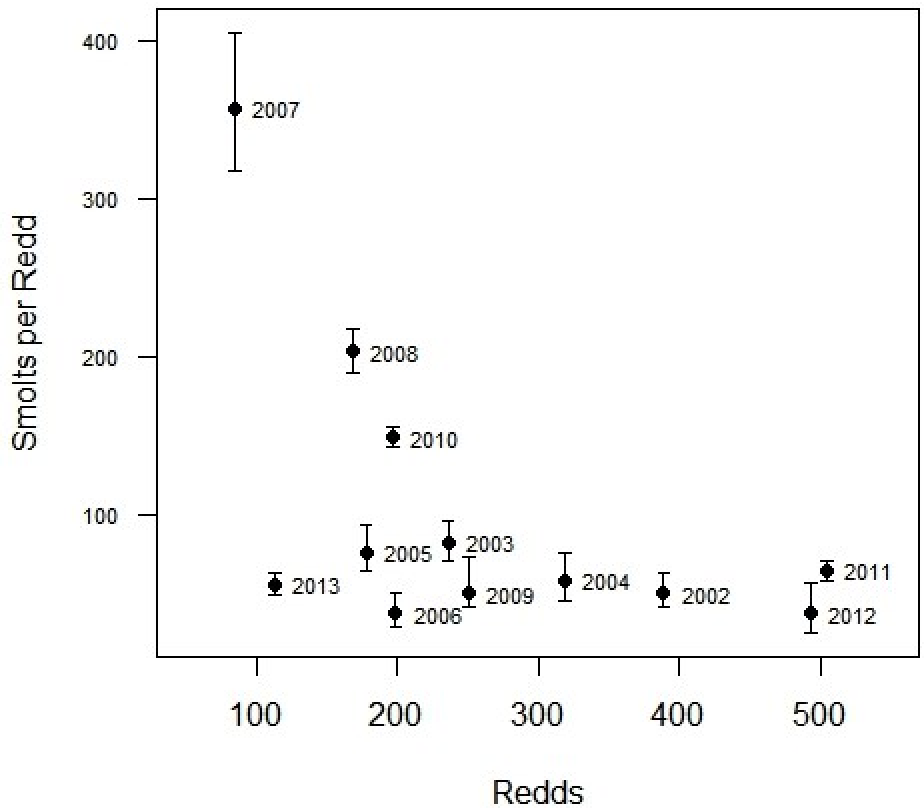


Figure 19. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2013 for the Middle Fork population. Error bars are 95% Confidence Intervals.

Stock-recruitment analysis for the Mainstem population suggests a replacement level (unexploited equilibrium) of 430 redds (Figure 20a). The Middle Fork population appears to have a replacement level of 250 redds (Figure 20c). Replacement level for the North Fork population is 626 redds (Figure 20e).

Plots of residuals from the stock-recruitment regressions suggest an upward trend for the Mainstem population. The first five brood years for the Mainstem had negative residuals. Conversely, four of the most recent six brood years had positive residuals (Figure 20b). Residuals for the Middle Fork (Figure 20d) and North Fork (Figure 20f) do not appear to share this pattern; residuals for both of these populations appear symmetrically distributed about zero, with no discernible trend through the available monitoring period.

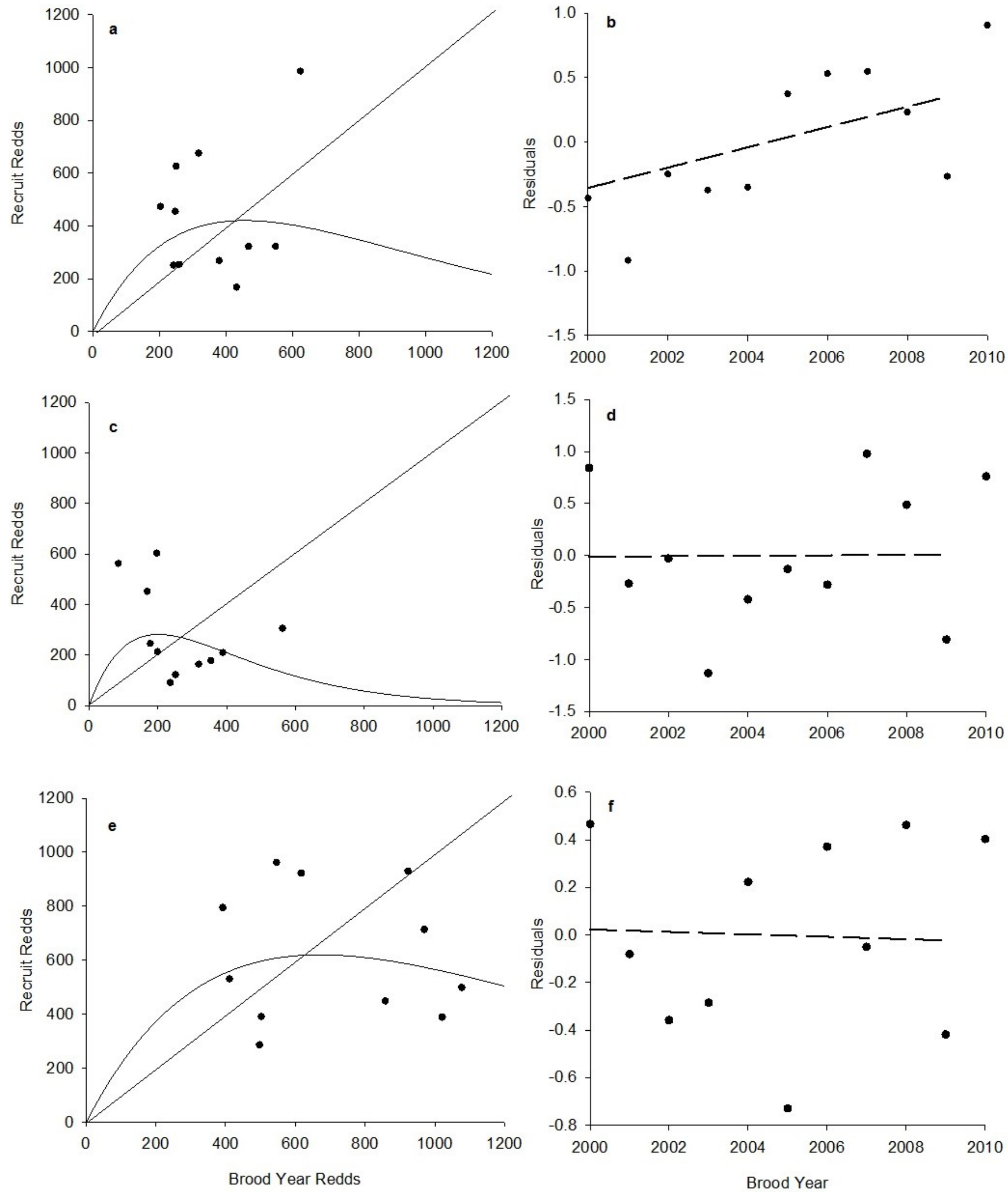


Figure 20. Comparison of Ricker stock-recruitment curves for 2000 through 2010 brood years and associated residual versus brood year plots for Chinook spawning populations in the Mainstem (a and b), Middle Fork (c and d), and North Fork (e and f) of the John Day River. Diagonal lines in panels a, c, and e are 1:1 replacement lines. Dashed lines in panels b, d, and f are linear regression lines fit to the residuals to illustrate trends over time.

DISCUSSION

Status of John Day River Spring Chinook Salmon

Chinook redd counts for 2015 decreased from the monitoring period high observed in 2014, however, the basinwide redd total was higher than the monitoring period mean. Decreases in John Day redd counts were mirrored by 53% and 18% drops in Grande Ronde and Imnaha basin redd counts, respectively. Covariation among redd counts in northeast Oregon populations continues to suggest a large-scale environmental effect is occurring across these populations. Such ecological responses to large-scale changes in the physical environment are known to occur with Pacific salmon (Hare et al. 1999). Once again, low ocean-entry PDO values appear to correspond with higher than average escapement in 2015. Significant inverse relationships between PDO values during the summer of smolt ocean-entry and adult returns to most of the northeast Oregon populations suggest that ocean conditions were a driving factor. An exception to this trend exists in the Middle Fork. High summer temperatures here may create higher pre-spawn mortality rates in this population, and hence obscure the influence of ocean conditions on adult abundance. Similar lethal conditions may also occur in the North Fork, however, monitoring pre-spawn mortality in this geographically remote population is more difficult and detecting mortality events is hence less likely.

Given the effect of ocean conditions on adult abundance, trends in freshwater productivity provide a more appropriate measure of population status than simple adult abundance (e.g., Lawson 1993). Mainstem and Middle Fork smolts produced per redd decrease as the number of redds increase, indicating that juvenile rearing areas are fully seeded at recent escapement levels and rearing habitat may be limiting freshwater production. Stock-recruit analyses for the John Day populations illustrate the effect of density-dependence. The Mainstem stock-recruit curve shows a strong density-dependent effect, production decreases rapidly once escapement exceeds 400 redds. Conversely, the curve for the North Fork indicates no immediate concern about decreased production at higher escapements. In the Mainstem population, there is also a broad range of escapement that produced a positive sustainable yield and a large yield when brood redds approach 200. Average sustainable yield in the Middle Fork, however, is low and extends over a shorter range of brood year redds. In the North Fork, sustainable yield is roughly constant for a comparatively broader range of brood year redds.

The Mainstem now comprises more of the basinwide adult escapement than the North Fork. For the first eleven years of census counts, the North Fork contributed 41–63% of the basinwide totals. During 2015, however, the North Fork counts were just 25% of the total redd count. Residuals from the Mainstem stock-recruitment curve suggest non-stationarity because a positive slope is apparent through the years (Figure 20). Since this pattern is not reflected in the Middle and North Fork populations (Figure 20), it appears to be specific to the Mainstem environment. Spatial connectivity may explain the trends we see in productivity; many habitat improvement projects have been completed in the upper Mainstem in recent years, which have presumably increased fish passage and juvenile rearing habitat. Removing barriers and allowing juvenile and adult

Chinook access to additional spawning and rearing habitat may be increasing population productivity (Sharma and Hilborn 2001). Conversely, the transition from the North Fork being the most abundant population to the Mainstem being the most abundant population may also be natural population asynchrony (i.e., "portfolio-effect"). Productivity of neighboring populations can oscillate on decadal scales, even in the absence of habitat changes (Hilborn et al. 2003). Continued monitoring will allow us to discern whether this abundance and productivity shift from the North Fork to the Mainstem is a natural "portfolio-effect" oscillation, or a response to habitat changes in the Mainstem.

Straying of adipose-clipped hatchery Chinook into the John Day River basin decreased to a monitoring period low in 2015; less than one percent of our recovered carcasses were adipose-clipped hatchery fish. Additionally, we did not detect any wild strays during 2015. Numerous wild Chinook juveniles in Snake and Upper Columbia River populations are marked with PIT tags, creating the possibility of re-detection in the John Day River. Although Narum et al. (2008) suggested that wild strays may be more prevalent than hatchery strays in the John Day River basin, we did not recover or passively detect any wild strays. Reduced barging of smolts collected at Lower Granite Dam in the Snake River basin, which impairs homing ability (Keefer et al. 2008), may be contributing to the reduced level of hatchery straying and lack of wild straying we have observed in the past four years. Continued emphasis on scanning carcasses for PIT tags will improve our understanding of straying by wild and hatchery Chinook. Installation of PIT detection arrays on the North Fork John Day would also improve our ability to detect stray wild adults.

Survey Methodology

Continuing to monitor index reaches allows us to see trends in redd density from 1964 to present, yet these reaches only comprise a portion of the spawning range in the basin. Index reaches were not chosen using a non-biased random process. Furthermore, index sites are based on redd distributions that were established five decades ago in reaches that may no longer provide the most suitable spawning habitat nor the highest redd densities. Although index counts constituted 51% of redds observed in 2015, our more extensive census efforts reveal an overall downward trend in index representation since 2000 (Figure 6). For example, the 2011 index:census redd count ratio equaled 0.5 (index representation of 33%). Although our census area has expanded over time, our analyses suggest spawner distribution shifts toward census reaches as run size increases, possibly resulting from competition for spawning gravel among adult females. Our data also suggest a greater percentage of fish utilize census areas during higher flow conditions. This may be the result of managers in the 1950s selecting index sites based on redd distribution during normal flow conditions, thereby excluding spawning reaches made available by above average discharge. Hence, our data indicate that index counts alone are not an accurate method for estimating escapement. Although it is necessary to continue monitoring index reaches to maintain long-term trend data, it is also necessary to monitor census sites to account for inter-annual variation in spawning distribution.

The 2015 spawning season was the fourth consecutive year that we conducted a carcass detection study. Similar to results from the past three years, our 2015 carcass detection probability data indicate that carcasses were more readily recovered in the Middle Fork, where nearly half of marked carcasses were subsequently detected. Factors contributing to higher recovery probability in the Middle Fork may include: stream banks with sparse brush and shading, low stream flow, narrow stream width, limited undercut banks and large woody debris jams, and less evidence of scavenging. The 2015 detection probability in the Mainstem decreased from the previous year, and remains lower than the rates observed in the Middle and North forks. Lower carcass detection probability in the Mainstem is likely the result of the dense riparian cover, higher turbidity, more frequent log jams, undercut banks, and moderate amounts of scavenging. In the North Fork population, scavenging appears to be a major limitation to carcass recovery; evidence of black bears feeding upon salmon carcasses is abundant on streambanks within roadless reaches. Compared to previous years, we were able to mark very few carcasses in the North Fork in 2015. Despite the limitations, marking and resighting carcasses throughout the spawning grounds improved our understanding of factors influencing carcass recovery probability and the data derived from carcasses we do recover.

Mark-recovery data from PIT tags implanted into John Day River Chinook provided an independent alternative to estimating John Day River spawner abundance as the product of redd count and the out-of-basin fish per redd estimate. Catherine Creek (Grande Ronde River basin) fish-per-redd estimates are used for John Day escapement estimation because a similar weir-based fish count station does not exist in the John Day basin. Despite John Day basin redd counts correlating with those of Catherine Creek, we currently have no way of measuring the correlation of fish-per-redd values between the two basins. As demonstrated during the 2013 spawning season, when rain events resulted in turbidity affecting the final redd count, survey conditions in Catherine Creek may not reflect those encountered in the John Day basin and can result in fish per redd estimates that are not representative. Such occasions demonstrate the need for additional means of estimating escapement.

Unlike the redd expansion estimate that uses out-of-basin fish per redd estimates, the PIT tag mark-recovery escapement estimation relies solely on John Day spring Chinook data. Although results from the first five years of mark-recovery data (2009-2013) suggest that this approach is feasible, the 2014 and 2015 escapement estimates demonstrate that the estimate is sensitive to even slight differences in the number of marked and recovered fish. Therefore, a minimum number of returning marked fish is necessary to generate an estimate with acceptable confidence and greater effort must be made to scan and detect as many PIT tagged carcasses as possible. Overall, the concordance of escapement estimates generated by these discrete methodologies increases our confidence in the suitability of both methods for estimating John Day spring Chinook salmon escapement and we intend to continue both estimations for immediate future years.

Management Implications

As observed in 2012 and 2013, scale-aging techniques identified a small portion of spawning adult Chinook salmon that exhibited a sub-yearling smolt life history pattern. While it is uncertain whether these fish originated from the John Day River, out-migrant monitoring has identified sub-yearling smolts migrating past our Mainstem and Middle Fork RSTs and into the Columbia River. Abundance and survival of sub-yearling spring Chinook salmon smolts will be an important component of future research, as production potential of sub-yearling smolts may be less limited by spatial rearing habitat constraints. We intend to continue monitoring the occurrence of a sub-yearling life history pattern via scales recovered from adult Chinook carcasses.

Adult escapements in recent years are at or above the current capacity of freshwater habitat to produce yearling smolts. Increases in escapement above the levels observed in 2011–2012 may not result in increases of yearling smolts unless significant restoration actions improve freshwater rearing survival. Setting escapement goals equal to the replacement level (Figure 20) is a cautious approach that should allow for sufficient production of all juvenile life-history types. Managing for replacement levels of escapement will provide "cushion" in the event of unanticipated ocean or freshwater environmental changes. With opportunities for recreational fisheries targeting wild populations being scarce for Columbia River Chinook populations, improvements to rearing habitat in the John Day River basin would increase the potential of future fisheries for these wild populations.

REFERENCES

Achord, S., P. S. Levin, and R. W. Zabel. 2003. Density-dependent mortality in Pacific salmon: the ghost of impacts past? Ecology Letters 6:335–342.

Banks, S. K., C. M. Bare, K. B. DeHart, J. L. Latshaw, C. A. James, I. A. Tattam, J. R. Ruzycki, and R. W. Carmichael. 2014. Escapement and Productivity of Steelhead and Spring Chinook Salmon in the John Day River, 2013 Annual Report, Bonneville Power Administration Project 1998-016-00, {92 Electronic Pages}

Bare, C. M., A. M. Bult, and I. A. Tattam. 2013. Chinook Salmon Productivity and Escapement Monitoring in the John Day River Basin, 2013 Annual Report, Oregon Watershed Enhancement Board, project no. 212-909.

Bayley, P. B. and H. W. Li. 2008. Stream fish responses to grazing exclosures. North American Journal of Fisheries Management 28:135–147.

DeHart, K. B., I. A. Tattam, J. R. Ruzycki, and R. W. Carmichael. 2012. Productivity of spring Chinook salmon and summer steelhead in the John Day River basin, 2011–2012 annual report, project no. 199801600, Bonneville Power Administration. Available at: https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P126255

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaska and west coast Pacific salmon. Fisheries 24(1):6–14.

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Science 100:6564-6568.

Keefer, M. L., C. C. Caudill, C. A. Peery, and S. R. Lee. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications 1888–1900.

Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6–10.

Lichatowich, J. A. and L. E. Mobrand. 1995. Analysis of Chinook salmon in the Columbia River from an ecosystem perspective. Bonneville Power Administration Project Number 92-1 8.

Lindsay, R. B., W. J. Knox, M. W. Flesher, B. J. Smith, E. A. Olsen, and L. S. Lutz. 1986. Study of wild spring Chinook salmon in the John Day River system. Bonneville Power Administration Project Number 79-4, Final Report.

McCormick, J. L., J. R. Ruzycki, W. H. Wilson, J. Schricker, A. Bult, and R. W. Carmichael. 2009. Chinook salmon productivity and escapement monitoring in the John Day River basin 2008–2009 annual report. Oregon Watershed Enhancement Board (OWEB) project no. 207-906.

Milner, N. J., J. M. Elliott, J. D. Armstrong, R. Gardiner, J. S. Welton, and M. Ladle. 2003. The natural control of salmon and trout populations in streams. Fisheries Research 62:111–125.

Mueter, F. J., J. Boldt, B. A. Megrey, and R. M. Peterman. 2007. Recruitment and survival of Northeast Pacific Ocean fish stocks: temporal trends, covariation, and

regime shifts. Canadian Journal of Fisheries and Aquatic Sciences 64(6): 911–927.
Narum, S. R., T. L. Schultz, D. M. Van Doornik, and D. Teel. 2008. Localized genetic structure persists in wild populations of Chinook salmon in the John Day River despite gene flow from outside sources. Transactions of the American Fisheries Society 137:1650–1656.
Parsons, A. L. and J. R. Skalski. 2010. Quantitative Assessment of salmonid escapement techniques. Reviews in Fisheries Science 18(4):301–314.
Pascho, R. J. and D. Mulcahy. 1987. Enzyme-linked immunosorbant assay for a soluble antigen of *Renibacterium salmoninarum*, the causative agent of salmonid bacterial kidney disease. Canadian Journal of Fisheries and Aquatic Sciences 44:183–191.
Peterman, R. M., B. J. Pyper, M. F. Lapointe, M. D. Adkison, and C. J. Walters. 1998. Patterns of covariation in survival rates of British Columbian and Alaskan sockeye salmon stocks. Canadian Journal of Fisheries and Aquatic Sciences 55:2503–2517.
Prentice, E. F., D. L. Park, T. A. Flagg, and S. McCutcheon. 1986. A study to determine the biological feasibility of a new fish tagging system, 1985-1986. Bonneville Power Administration Project No. 1983-31900, 97 electronic pages, (BPA Report DOE/BP-11982-2).
Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle.
Ruzycki, J. R., T. L. Schultz, W. H. Wilson, J. Schricker, and R. W. Carmichael. 2008. Chinook salmon productivity and escapement monitoring in the John Day River basin 2007–2008 annual report. Oregon Watershed Enhancement Board (OWEB) project no. 207-906.
Schaller, H. A., C. E. Petrosky, and O. P. Langess. 1999. Contrasting patterns of productivity and survival rates for stream-type Chinook salmon (*Oncorhynchus tshawytscha*) populations of the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 56:1031–1045.
Schultz, T. L., W. H. Wilson, J. R. Ruzycki, R. W. Carmichael, J. Schricker, D. Bondurant. 2006. John Day basin Chinook salmon escapement and productivity monitoring 2003–2004 annual report, project no. 199801600, 101 electronic pages, (BPA Report DOE/BP-00005840–4).
Schultz, T. L., W. H. Wilson, J.R. Ruzycki, R. W. Carmichael, and J. Schricker. 2007. Escapement and productivity of spring Chinook and summer steelhead in the John Day River basin 2005–2006 annual report. Project No. 199801600 (BPA Contract 25467).
Sharma, R. and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (*Oncorhynchus kisutch*) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1453–1463.
Tattam, I. A., J. R. Ruzycki, P. B. Bayley, H. W. Li, and G. R. Giannico. 2013. The Influence of Release Strategy and Migration History on Capture Rate of *Oncorhynchus mykiss* in a Rotary Screw Trap. North American Journal of Fisheries Management 33:237–244.
White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture

and removal methods for sampling closed populations. Los Alamos National Laboratory, New Mexico.

Wilson, W. H., J. Schricker, J. R. Ruzycki, and R. W. Carmichael. 2008. Productivity of spring Chinook salmon and summer steelhead in the John Day River basin 2006–2007 annual report, project no. 199801600, 29 electronic pages, (BPA Report P105270).

Wilson, W. H., T. L. Schultz, J. R. Ruzycki, R. W. Carmichael, J. Haire, and J. Schricker. 2007. Escapement and productivity of spring Chinook and summer steelhead in the John Day River basin 2004–2005 technical report, project no. 199801600, 98 electronic pages (BPA Report DOE/BP -00020364-1). http://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=00020364-1

APPENDIX

Appendix Table I. Spring Chinook total redd counts in the John Day River basin, 2000–2015. Includes redds observed in index, census, and random sections.

				North Fork Subbasin					
					Granite Creek System				
Year	Mainstem	South Fork	Middle Fork	North Fork	Granite Creek	Clear Creek	Bull Run Creek	Desolation Creek	Basin Total
2000	380	3	563	612	198	96	12	5	1,869
2001	432	0	354	803	126	80	45	23	1,863
2002	549	0	389	707	163	64	31	56	1,959
2003	260	0	236	668	118	32	1	39	1,354
2004	242	0	319	806	72	38	8	46	1,531
2005	203	0	178	420	43	15	4	15	878
2006	318	0	199	262	55	28	14	33	909
2007	250	0	85	358	19	9	2	23	746
2008	248	0	169	432	57	16	10	31	963
2009	468	0	251	360	47	53	4	38	1,221
2010	624	2	197	386	93	50	18	70	1,440
2011	692	0	505	475	67	44	14	49	1,846
2012	403	0	493	595	139	69	37	51	1,787
2013	388	0	113	494	53	37	7	44	995
2014	829	0	518	848	124	103	33	77	2,195
2015	771	0	442	415	32	16	11	33	1,628

Appendix Table II. Census and index survey lengths (km) for spring Chinook salmon spawning surveys in the John Day River basin, 2000–2015. Includes stream lengths in areas where we were denied access.

				North Fork Subbasin					
					Granite Creek System				
Year	Mainstem	South Fork	Middle Fork	North Fork	Granite Creek	Clear Creek	Bull Run Creek	Desolation Creek	Basin Total
2000	32.2	17.3	51.5	83.9	16.5	7.6	5.7	21.4	236.1
2001	32.2	17.3	51.5	83.9	16.5	7.6	5.7	28.5	243.2
2002	32.2	17.3	51.5	86.9	16.5	10.3	7.2	34.0	255.9
2003	32.2	0.2	51.5	86.9	16.5	10.3	7.2	38.2	243.0
2004	34.3	17.3	51.5	88.3	16.5	10.3	7.2	34.6	260.0
2005	34.3	17.3	51.5	92.2	16.5	10.3	7.2	38.2	267.5
2006	34.3	17.3	51.5	92.2	16.5	10.3	7.2	35.3	264.6
2007	34.3	17.3	51.5	92.2	16.5	10.3	7.2	38.2	267.5
2008	34.3	17.3	51.5	92.2	16.5	10.3	7.2	35.3	264.6
2009	34.3	17.3	51.5	94.8	16.5	10.2	7.2	34.0	265.9
2010	34.3	17.3	51.5	97.5	16.5	10.2	7.2	34.0	268.6
2011	43.9	17.3	57.4	95.8	16.5	10.3	7.2	37.1	285.6
2012	45.3	17.3	59.4	96.0	16.5	10.3	7.2	37.1	290.8
2013	43.6	17.3	59.4	96.7	16.5	10.3	7.2	37.1	287.2
2014	43.6	17.3	59.4	96.7	16.5	10.3	7.2	37.1	287.2
2015	48.5	17.3	57.4	96.7	16.5	9.0	7.2	37.1	289.8

Appendix Table III. Spawning density (redds/km) in the John Day River basin, 2000–2015. Includes density estimates for areas where we were denied access.

				North Fork Subbasin					
					Granite Creek System				
Year	Mainstem	South Fork	Middle Fork	North Fork	Granite Creek	Clear Creek	Bull Run Creek	Desolation Creek	Basin Total
2000	11.8	0.2	10.9	7.3	12.0	12.6	2.1	0.2	7.9
2001	13.4	0.0	6.9	9.6	7.6	10.5	7.9	0.8	7.7
2002	17.0	0.0	7.6	8.1	9.9	6.2	4.3	1.6	7.7
2003	8.1	0.0	4.6	7.7	7.2	3.1	0.1	1.0	5.6
2004	7.1	0.0	6.2	9.1	4.4	3.7	1.1	1.3	5.9
2005	5.9	0.0	3.5	4.6	2.6	1.5	0.6	0.4	3.3
2006	9.3	0.0	3.9	2.8	3.3	2.7	1.9	0.9	3.4
2007	7.3	0.0	1.7	3.9	1.2	0.9	0.3	0.6	2.8
2008	7.2	0.0	3.3	4.7	3.5	1.6	1.4	0.9	3.6
2009	13.6	0.0	4.9	3.8	2.8	5.2	0.6	1.1	4.6
2010	18.2	0.1	3.8	4.0	5.6	4.9	2.5	2.1	5.4
2011	15.8	0.0	7.8	5.0	4.1	4.3	1.9	1.3	6.3
2012	12.4	0.0	8.3	6.2	8.4	6.7	5.1	1.4	6.1
2013	8.9	0.0	1.9	3.6	3.2	3.6	1.0	1.2	3.9
2014	19.0	0.0	8.7	5.1	7.5	10.0	4.6	2.1	7.6
2015	15.9	0.0	7.7	3.3	1.9	1.8	1.5	0.9	5.6

Appendix Table IV. Mainstem and Middle Fork John Day River smolt/redd ratios based on estimates of smolt abundance and redd counts for spring Chinook salmon, 2002–2013 brood years.

		Mainstem				Middle Fork			
				95% CI				95% CI	
Brood Year	Smolt Year	Redds (n)	Smolts/ redd	Lower	Upper	Redds (n)	Smolts/ redd	Lower	Upper
2002	2004	549	94	76	121	389	50	41	63
2003	2005	260	116	105	129	236	82	70	95
2004	2006	242	139	87	253	319	58	45	76
2005	2007	203	159	124	207	178	76	64	93
2006	2008	318	95	84	107	199	37	28	50
2007	2009	250	192	166	225	85	357	317	404
2008	2010	248	126	109	147	169	203	190	218
2009	2011	468	65	59	74	251	50	42	73
2010	2012	624	105	96	116	197	148	142	155
2011	2013	692	90	79	101	505	64	58	71
2012	2014	403	103	85	125	493	37	25	56
2013	2015	388	108	91	129	113	55	49	63

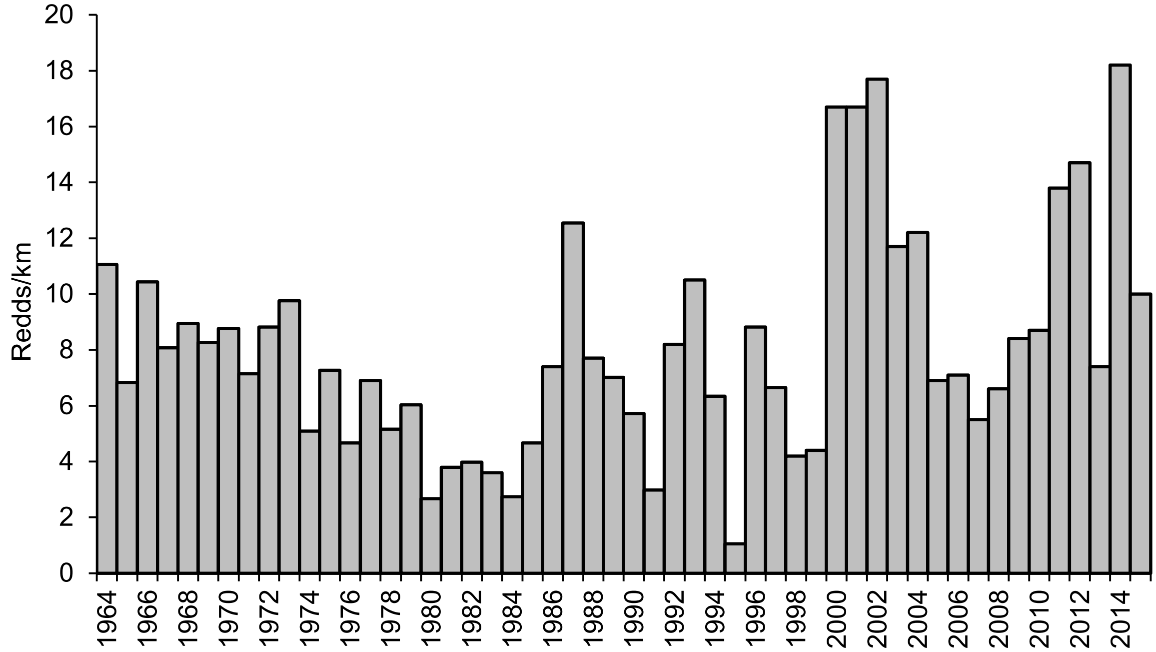
[a] Mainstem trap was moved upstream of the confluence with the South Fork. Estimated abundance from Mainstem and South Fork traps were henceforth combined.

Appendix Table V. Egg retention and ELISA optical density values for adult spring Chinook kidneys sampled from carcasses in the John Day River basin, 2015.

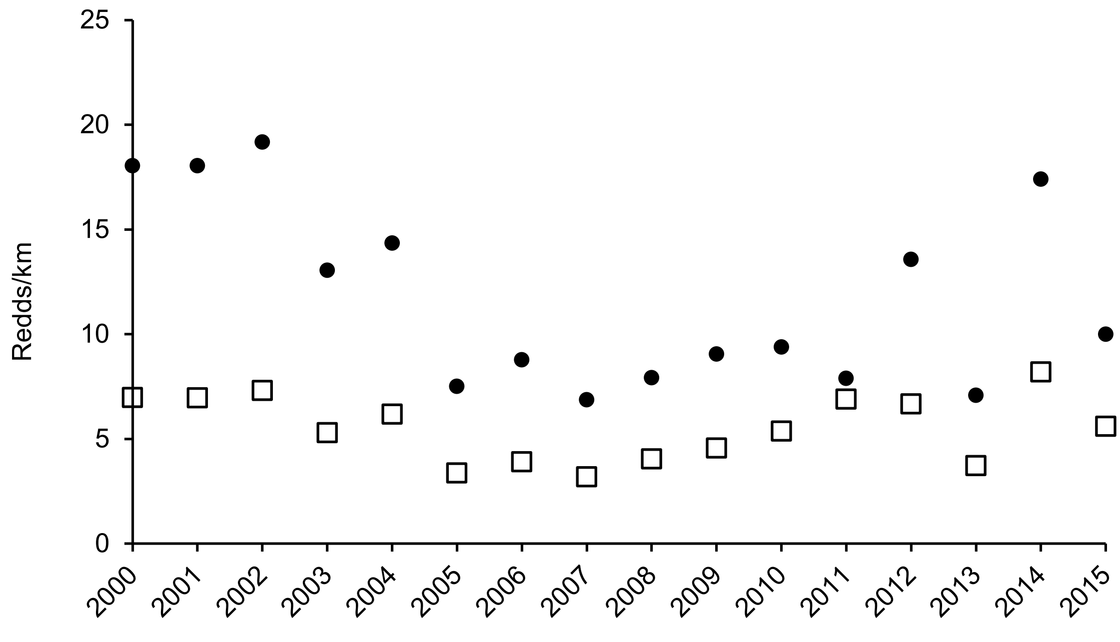
Population	Egg Retention (ml)	Optical Density (OD_{405})
Mainstem John Day River		0.175
Mainstem John Day River		0.148
Mainstem John Day River	100	0.148
Mainstem John Day River		0.145
Mainstem John Day River		0.144
Mainstem John Day River		0.134
Mainstem John Day River		0.127
Mainstem John Day River		0.123
Mainstem John Day River		0.117
Mainstem John Day River	600	0.115
Mainstem John Day River		0.113
Mainstem John Day River		0.112
Mainstem John Day River	0	0.111
Mainstem John Day River	0	0.11
Mainstem John Day River		0.105
Mainstem John Day River	0	0.104
Mainstem John Day River		0.101
Mainstem John Day River		0.101
Mainstem John Day River		0.100
Mainstem John Day River		0.096
Mainstem John Day River	100	0.095
Mainstem John Day River		0.092
Mainstem John Day River	100	0.092
Mainstem John Day River		0.091
Mainstem John Day River	0	0.084
Mainstem John Day River	0	0.084
Mainstem John Day River		0.082
Mainstem John Day River		0.081
Mainstem John Day River		0.079
Mainstem John Day River	450	0.077
Mainstem John Day River		0.073
Mainstem John Day River		0.070
Mainstem John Day River		0.068
Middle Fork John Day River	0	0.397
Middle Fork John Day River		0.292
Middle Fork John Day River	0	0.292
Middle Fork John Day River		0.229
Middle Fork John Day River		0.228
Middle Fork John Day River		0.219
Middle Fork John Day River	0	0.213
Middle Fork John Day River		0.206

Appendix Table V. Continued.

Population	Egg Retention (g)	Optical Density (OD_{405})
Middle Fork John Day River		0.177
Middle Fork John Day River	0	0.171
Middle Fork John Day River	0	0.169
Middle Fork John Day River		0.166
Middle Fork John Day River		0.157
Middle Fork John Day River		0.139
Middle Fork John Day River	0	0.139
Middle Fork John Day River		0.124
Middle Fork John Day River		0.094
North Fork John Day River		0.483
North Fork John Day River		0.302
North Fork John Day River		0.257
North Fork John Day River	0	0.183
North Fork John Day River		0.163
North Fork John Day River	370	0.142
North Fork John Day River		0.136
North Fork John Day River		0.131
North Fork John Day River		0.129
North Fork John Day River		0.127
North Fork John Day River		0.125
North Fork John Day River		0.123
North Fork John Day River		0.114
North Fork John Day River	0	0.098
North Fork John Day River	100	0.091
North Fork John Day River	0	0.078
North Fork John Day River		0.073



Appendix Figure I. Spring Chinook index redd densities in the John Day River basin, 1964–2015. Densities include estimated redd counts in areas where we were denied access. Data from 1959–1963 are not presented because they do not represent the same spatial extent.



Appendix Figure II. Spring Chinook index (black circles) and census (open squares) redd densities in the John Day River basin, 2000–2015. Densities include estimated redd counts in areas where we were denied access.

Appendix Table VI. Index redd density (redds/km) in the John Day River basin 1998–2015. Includes estimated redd densities in areas where we were denied access. GCS = Granite Creek system (tributary to North Fork John Day).

Year	Mainstem	Middle Fork	North Fork	GCS	Total
1998	6.1	8.2	3.8	3.1	4.2
1999	3.3	4.0	4.2	4.7	4.4
2000	19.0	5.3	16.7	13.0	16.7
2001	21.6	18.0	21.3	11.9	16.7
2002	27.1	10.1	18.0	10.6	17.7
2003	13.6	15.6	16.9	4.4	11.7
2004	9.7	9.3	21.1	4.4	12.2
2005	8.8	8.9	9.5	2.2	6.9
2006	12.5	5.8	5.6	3.4	7.1
2007	9.9	7.7	6.9	1.1	5.5
2008	11.7	3.7	6.1	3.4	6.6
2009	18.4	5.7	4.5	4.1	8.4
2010	21.9	7.6	2.8	6.3	8.7
2011	26.6	18.6	7.5	4.5	13.4
2012	29.6	15.2	12.8	6.4	15.8
2013	13.8	4.1	6.1	3.0	6.6
2014	27.3	17.0	14.5	11.0	16.1
2015	22.4	13.5	4.1	2.8	10.0

Appendix Table VII. 2015 spring Chinook spawning survey section locations and coordinates (DD.DD, NAD 1983 Oregon Lambert).

		Start		End	
System	**Description**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
Mainstem John Day River	Indian Creek to Prairie Wood Products	44.443455	-118.797648	44.454705	-118.717714
Mainstem John Day River	Prairie Wood to Forrest Conservation Area	44.453559	-118.722180	44.459277	-118.701083
Mainstem John Day River	Forrest Conservation Area to Dads Creek	44.459277	-118.701083	44.453506	-118.672481
Mainstem John Day River	Dads Creek to Emmel Upper Fence	44.453506	-118.672481	44.449536	-118.655137
Mainstem John Day River	Emmel Upper Fence to Field Upper Fence	44.449536	-118.655137	44.435896	-118.627021
Mainstem John Day River	Field Upper Fence to French Lane	44.435896	-118.627021	44.419336	-118.600508
Mainstem John Day River	French Lane to Jacobs Upper Fence	44.419336	-118.600508	44.410514	-118.588248
Mainstem John Day River	Jacobs Upper Fence to Rd 13 Bridge	44.410514	-118.588248	44.395640	-118.577286
Mainstem John Day River	Rd 13 Bridge to Reynolds Fence	44.395640	-118.577286	44.377879	-118.579106
Mainstem John Day River	Reynold's Fence to Ricco Upper Fence	44.377879	-118.579106	44.340011	-118.574012
Mainstem John Day River	Ricco Upper Fence to Call Creek	44.340011	-118.574012	44.320119	-118.55734
Mainstem John Day River	Near Grant Road Shop, City of John Day	44.425048	-119.001531	44.425384	-118.999349
Mainstem John Day River	RM 254 (Random)	44.433873	-118.847016	44.426455	-118.860298
Canyon Creek	RM 12 (Random)	44.316519	-118.950502	44.304577	-118.948424
Reynolds Creek	Mouth to U.S. Forest Boundary	44.412546	-118.588818	44.417049	-118.543229
Deardorff Creek	Mouth to 2.0 km upstream	44.394786	-118.576509	44.396724	-118.553344
Bridge Creek (LMJD)	Woodward fence to Mitchell	44.605424	-120.218222	44.573504	-120.171854
Bridge Creek (LMJD)	Fossil Beds to Woodward fence	44.640008	-120.236093	44.605424	-120.218222
Middle Fork John Day River	Armstrong Creek to Deep Creek	44.743248	-118.851359	44.716848	-118.821969
Middle Fork John Day River	Deep Creek to Rd 36 Bridge	44.716848	-118.821969	44.692588	-118.794073
Middle Fork John Day River	Rd 36 Bridge to Coyote Creek	44.692588	-118.794073	44.674525	-118.750240
Middle Fork John Day River	Coyote Creek to Upper TNC Boundary	44.674525	-118.750240	44.666466	-118.713502
Middle Fork John Day River	Upper TNC Boundary to Beaver Creek	44.666466	-118.713502	44.652418	-118.677977
Middle Fork John Day River	Beaver Creek to Windlass Creek	44.652418	-118.677977	44.638962	-118.627342
Middle Fork John Day River	Windlass Creek to Caribou Creek	44.638962	-118.627342	44.622012	-118.573089
Middle Fork John Day River	Caribou Creek to Dead Cow Bridge	44.622012	-118.627342	44.622012	-118.573089

Appendix Table VII. Continued.

System	Description	Start Latitude	Start Longitude	End Latitude	End Longitude
Middle Fork John Day River	Dead Cow Bridge to Placer Gulch	44.607644	-118.547349	44.595637	-118.522586
Middle Fork John Day River	Placer Gulch to Highway 7	44.595637	-118.522586	44.603958	-118.483250
Middle Fork John Day River	Highway 7 to Phipps Meadow	44.603958	-118.483250	44.588330	-118.448254
Middle Fork John Day River	RM 25 (Random)	44.843342	-119.037652	44.835885	-119.031335
Middle Fork John Day River	RM 42 (Random)	44.753176	-118.861107	44.743248	-118.851359
Granite Boulder Creek - MFJDR	Mouth to 4550 Road	44.647386	-118.665057	44.655800	-118.647961
Vinegar Creek	Mouth upstream 0.62km	44.601232	-118.535686	44.604931	-118.530114
Bridge Creek	Mouth to Road 2614	44.593407	-118.513618	44.569226	-118.506281
Clear Creek	Mouth to 1.6 km upstream of Hwy 26 Bridge	44.593743	-118.506834	44.562465	-118.488907
Clear Creek	Road 180 to 2.0 km upstream	44.562895	-118.489093	44.548271	-118.488078
North Fork John Day River	Trail Crossing to Cunningham Creek	44.885060	-118.254856	44.910764	-118.266677
North Fork John Day River	Cunningham Creek to Baldy Creek	44.910764	-118.266677	44.909619	-118.317805
North Fork John Day River	Baldy Creek to Road 73 Bridge	44.909619	-118.317805	44.912888	-118.400227
North Fork John Day River	Road 73 Bridge to Trout Creek	44.912888	-118.400227	44.926657	-118.444597
North Fork John Day River	Trout Creek to Crane Creek	44.926657	-118.444597	44.893568	-118.477699
North Fork John Day River	Crane Creek to Trail Crossing	44.893568	-118.477699	44.874560	-118.520736
North Fork John Day River	Trail Crossing to Granite Creek	44.874560	-118.520736	44.865611	-118.562299
North Fork John Day River	Granite Creek to Wind Rock	44.865611	-118.562299	44.885947	-118.599879
North Fork John Day River	Wind Rock to Ryder Creek	44.885947	-118.599879	44.929562	-118.618474
North Fork John Day River	Ryder Creek to Cougar Creek	44.929562	-118.618474	44.944108	-118.647593
North Fork John Day River	Cougar Creek to Big Creek	44.944108	-118.647593	44.960194	-118.682884
North Fork John Day River	Big Creek to Oriental Creek	44.960194	-118.682884	44.973791	-118.726782
North Fork John Day River	Oriental Creek to Sulphur Creek	44.973791	-118.726782	44.980441	-118.761786
North Fork John Day River	Sulphur Creek to Nye Creek	44.980441	-118.761786	45.006291	-118.824657
North Fork John Day River	Nye Creek to Horse Canyon	45.006291	-118.824657	45.016381	-118.865414
North Fork John Day River	Horse Canyon to Desolation Creek	45.016381	-118.865414	44.997921	-118.935827

Appendix Table VII. Continued.

System	Description	Start		End	
		Latitude	Longitude	Latitude	Longitude
North Fork John Day River	Desolation Creek to Camas Creek	44.997921	-118.935827	45.010210	-118.995950
North Fork John Day River	Camas Creek to Jericho Creek	45.010210	-118.995950	45.011857	-119.051625
North Fork John Day River	RM 51 (Random)	44.992927	-119.089421	44.997663	-119.074162
Camas Creek	RM 0 (Random)	45.052161	-118.971949	45.064404	-118.974060
Camas Creek	0.4 km above and below Fivemile Creek	45.010009	-118.996138	45.020743	-118.988308
Big Creek	Footbridge to mouth	44.960922	-118.682390	44.960194	-118.682884
Trail Creek	Mouth to Forks	44.915541	-118.406310	44.820401	-118.689409
Baldy Creek	Mouth to 1 mi upstream	44.909619	-118.317805	44.899615	-118.307586
Granite Creek	73 Road Culvert to Ten Cent Creek	44.816141	-118.420549	44.831070	-118.458033
Granite Creek	Ten Cent Creek to Buck Creek	44.831070	-118.458033	44.841373	-118.494582
Granite Creek	Buck Creek to Indian Creek	44.841373	-118.494582	44.850403	-118.537324
Granite Creek	Indian Creek to Mouth of Granite Creek	44.850403	-118.537324	44.865611	-118.562299
Clear Creek	Ruby Creek to Alamo Road	44.772950	-118.488480	44.769600	-118.473293
Clear Creek	Alamo Road to Smith Lower Boundary	44.769600	-118.473293	44.769969	-118.457903
Clear Creek	Smith Lower Boundary to Old Road Crossing	44.769969	-118.457903	44.785595	-118.472676
Clear Creek	Old Road Crossing to Clear Creek Mouth	44.785595	-118.472676	44.821483	-118.450278
Bull Run Creek	Deep Creek to the Guard Station	44.779916	-118.348625	44.787182	-118.374203
Bull Run Creek	Guard Station to Mouth	44.787182	-118.374203	44.807964	-118.425153
Desolation Creek	Road 45 Culvert to Falls	44.809318	-118.683428	44.791032	-118.673187
Desolation Creek	Culvert downstream to Forks	44.809318	-118.683428	44.820401	-118.689409
Desolation Creek	Forks to Howard Creek	44.820401	-118.689409	44.838014	-118.724023
Desolation Creek	Howard Creek to Battle Creek	44.838014	-118.724023	44.856763	-118.761268
Desolation Creek	Battle Creek to Bruin Creek	44.856763	-118.761268	44.896974	-118.796166
Desolation Creek	Bruin Creek to Road 1010 Bridge	44.896974	-118.796166	44.921231	-118.829258
Desolation Creek	Road 1010 Bridge to Peep Creek	44.921231	-118.829258	44.940121	-118.839682
Desolation Creek	Peep Creek to Road 1003 Bridge	44.940121	-118.839682	44.971799	-118.882862

Appendix Table VII. Continued.

System	Description	Start		End	
		Latitude	Longitude	Latitude	Longitude
Desolation Creek	Battle Creek to Bruin Creek	44.856763	-118.761268	44.896974	-118.796166
Desolation Creek	Bruin Creek to Road 1010 Bridge	44.896974	-118.796166	44.921231	-118.829258
Desolation Creek	Road 1010 Bridge to Peep Creek	44.921231	-118.829258	44.940121	-118.839682
Desolation Creek	Peep Creek to Road 1003 Bridge	44.940121	-118.839682	44.971799	-118.882862
Desolation Creek	Road 1003 Bridge to Mouth	44.971799	-118.882862	44.997921	-118.935827
South Fork John Day River	Murderers Creek To Rock Pile Ranch Bridge	44.314554	-119.539573	44.267652	-119.550757
South Fork John Day River	Rock Pile Ranch Bridge to Cougar Gulch	44.267652	-119.550757	44.229578	-119.533785
South Fork John Day River	Cougar Gulch to Izee Falls	44.229578	-119.533785	44.185104	-119.524821
South Fork John Day River	RM 10 (Random)	44.374033	-119.544030	44.383549	-119.543760

Appendix Table VIII. Correlation matrix for census John Day River population Chinook redd counts from 2000 to 2015 and Chinook redd counts observed in other northeast Oregon streams. Significant correlations ($\alpha = 0.05$) are indicated in bold.

John Day Population	Catherine Creek	Lookingglass Creek	Minam River	Wallowa-Lostine System	Wenaha* River	Imnaha River	Grande Ronde River
Mainstem	**0.778**	**0.619**	**0.856**	**0.628**	**0.714**	**0.528**	**0.731**
Middle Fork	0.435	**0.547**	0.477	0.311	**0.642**	0.389	0.445
North Fork	0.084	0.021	0.253	0.030	**0.669**	**0.522**	0.125

* Wenaha River was only partially sampled in 2015; therefore, only data from 2000 to 2014 were used

Appendix Table IX. Summary of Chinook coded wire tag recoveries by John Day River population from 2000 to 2015.

Year	Population	Tags (n)	Hatchery	Release Location
2000	Middle Fork	1	Round Butte, Oregon	West Fork Hood River
	North Fork	2	Lookingglass, Oregon	Grande Ronde River
	North Fork	2	Rapid River, Idaho	Rapid River
	North Fork	1	McCall, Idaho	South Fork Salmon River
2001	North Fork	1	Lookingglass, Oregon	Imnaha River
	North Fork	1	Rapid River, Idaho	Rapid River
2002	*No Recoveries*			
2003	North Fork	1	Lookingglass, Oregon	Catherine Creek
2004	Mainstem	1	Lookingglass, Oregon	Imnaha River
	Middle Fork	1	Lookingglass, Oregon	Grande Ronde River
	North Fork	6	Lookingglass, Oregon	Grande Ronde River
	North Fork	1	Lookingglass, Oregon	Catherine Creek
	North Fork	1	Lookingglass, Oregon	Lostine River
	North Fork	2	Rapid River, Idaho	Rapid River
2005	Mainstem	1	Lookingglass, Oregon	Grande Ronde River
	Mainstem	1	Round Butte, Oregon	Deschutes River
2006	Middle Fork	1	McCall, Idaho	South Fork Salmon River
	North Fork	1	McCall, Idaho	South Fork Salmon River
	North Fork	1	Lookingglass, Oregon	Grande Ronde River
2007	North Fork	1	Rapid River, Idaho	Rapid River
2008	North Fork	1	Lookingglass, Oregon	Lookingglass Creek
	North Fork	1	Lookingglass, Oregon	Catherine Creek
2009	North Fork	1	Lookingglass, Oregon	Catherine Creek
	North Fork	1	Wallowa, Oregon	Grande Ronde River
2010	North Fork	2	Rapid River, Idaho	Rapid River
2011	Middle Fork	1	Lostine, Oregon	Lostine River
	North Fork	1		Grande Ronde River
2012	North Fork	2	Lookingglass, Oregon	Lookingglass Creek
	North Fork	3		Grande Ronde River
2013	*No Recoveries*			
2014	North Fork	1	Lookingglass, Oregon	Grande Ronde River
2015	*No Recoveries*			

Appendix Table X. Summary of 2015 fall Chinook spawning surveys conducted in the lower John Day River.

				Fish	
Date	**Survey Reach**	**Length (km)**	**Redds**	**Live**	**Dead**
21-Nov-15	RKM 64 to RKM 35	29	1	0	0
04-Dec-15	RKM 36 to RKM 23	13	5	0	0