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

Annual Technical Report

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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 hatchery stray fraction of 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 20 August through 26 September 2012. We observed 1,770 spring Chinook redds while surveying 309.4 km of potential spawning habitat (194.7 km of census, 78.3 km of index, and 36.3 km of random reaches). We estimated a total of 17 redds in the 14.1 km of stream where we were denied access (14 redds in the Mainstem John Day River and 3 redds in Clear Creek of the Granite Creek System). We estimated 1,787 spring Chinook redds were constructed in the John Day River basin at an overall density of 6.5 redds/km for the survey area. Redd abundance decreased from 2011 both basinwide and within the Mainstem and Middle Fork subbasins. Redds in the Mainstem population declined 42% from the 2011 estimate of 638 redds, which was the highest estimate observed since implementing census surveys in 2000. Our spring Chinook escapement estimate for 2012 is 5,391 fish using a ratio of 3.02 adults and jacks per redd (estimated at the Catherine Creek weir in the Grande Ronde River basin). We recovered 1,557 Chinook carcasses, 1,432 (92%) of which had an adipose fin and were assumed to be of wild origin, 14 (1%) had a clipped adipose fin and were assumed to be of hatchery origin, and the remaining 111 could not be identified. Stock-recruit analyses for the Mainstem and Middle Fork John Day populations indicate that smolts produced per redd decreased as the number of redds increased, indicating that rearing habitat may be limiting freshwater production. The Mainstem stock-recruit curve shows the strongest density-dependence, production decreases when escapement exceeds 400 redds. Conversely, the curve for the North Fork suggests no decrease in production at higher escapements. Average sustainable yield in the Middle Fork is 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 Jeff Neal and Brent Smith for providing guidance and advice. We also thank the countless volunteers for helping conduct field surveys. Ben Clemens and Kanani Bowden provided assistance and advice on scale analysis. This project was funded by Pacific Coastal Salmon Recovery Funds distributed through the Oregon Watershed Enhancement Board, Contract Number 212-909. We thank Tom Stahl and Greg Sieglitz 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 3) 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 3). Spawning has also occurred in the South Fork

John Day River (hereafter called South Fork; Figure 4), the North Fork tributaries Camas and Trail creeks, and the Mainstem tributaries Deardorff, Reynolds, and Bridge creeks.

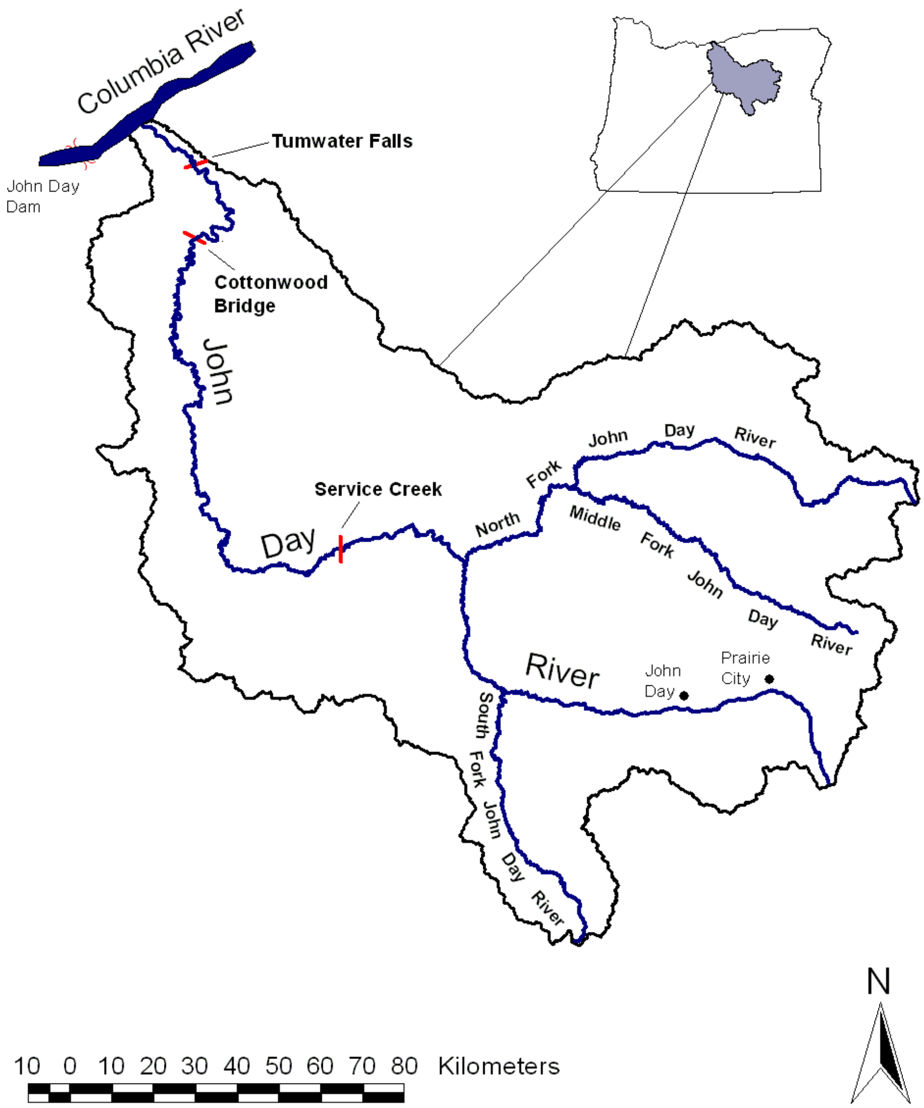

Figure 1. Map of the John Day River basin.

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 2012, 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 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 accuracy when distinguishing redds. In each section, surveyors recorded the number of new redds, live fish (on- or off-redd), and carcasses. On index and census reaches, the first team of surveyors marked redds with numbered colored flagging placed near each redd or group of redds. During subsequent surveys, surveyors re-identified flagged redds and recorded any new redds. During the last survey of each reach, surveyors georeferenced redds with a global positioning system receiver and previous flags were removed.

Every carcass we observed was examined unless decomposition or scavenging damage disallowed accurate measures. Fork length (FL, mm) and medial eye to posterior scale length (MEPS, mm) were measured and some carcasses were dissected to verify sex. Amount of eggs retained was noted for every female and was estimated to the nearest ¼ cup. Every carcass was scanned for the presence of a passive integrated transponder (PIT tag) unless there were not enough PIT readers for every crew. 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. Trained surveyors selected carcasses with intact organs and membranes and non-glazed eyes, indicative of recent mortality. Clean disposable plastic knives and spoons were used to collect a 1–2 g sample of kidney tissue from each carcass. Samples were placed in sterile 1-ounce Whirl-pack™ bags and stored in a cooler with ice until transported 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. Samples were still being processed in the laboratory at the time of this report. Results will be reported in the 2013 annual report.

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 thirty 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 located using a magnetic detector. Once excised, CWTs were visually decoded under magnification. Tag codes were entered into the Oregon Department of Fish and Wildlife (ODFW) database and hatchery of origin was queried using the Pacific States Marine Fisheries Commission (PSMFC) database.

We marked carcasses that were in good condition (i.e., intact and their body cavity was not breached) with an operculum punch and returned 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 operculum punches were recorded by surveyors. We used these mark-recovery data to estimate carcass detection probability 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 areas in the Mainstem and Clear Creek (Granite Creek System, GCS) where landowners denied access. A Geographic Information System (GIS) incorporating a 1:100,000 digital stream network was used to estimate stream reach and total reach lengths. We expanded our redd density estimate to non-surveyed reaches by multiplying adjacent-reach mean density by the length of the reach where we were denied access.

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 2012 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 2011 index:total data and used this equation to predict the 2012 total count based on the 2012 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.

$$N_p = r_p \cdot f$$

where:
N_p = Estimated number of spawners in the population
r_p = Number of redds observed in the population

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 in the John Day River basin. Several thousand Chinook smolts are 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, 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 the 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 escapement of spring Chinook to the spawning grounds of the three John Day populations with the Petersen estimator (White et al. 1982):

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

where:

N = Escapement to the John Day River basin

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)

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

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 mean) 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. A 1.52 m RST was 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 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. 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:

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

The Upper Mainstem and Middle Fork populations have a low proportion of age-5 females. For these two populations we analyzed the 2000 to 2008 brood years. Although the age-5 females from the 2008 brood are yet to spawn, past data suggest very few will return, making only minor changes to the stock-recruitment relationship. Conversely, the North Fork population has a higher percentage of age-5 females, thus we only analyzed the completed 2000 to 2007 brood years.

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 323.4 km of potential Chinook spawning habitat within the John Day River basin in 2012 (Table 2). A total of 84.5 km of spawning habitat was within the index area, which was surveyed with the exception of 6.3 km to which we were denied access (Table 2; Figures 2 and 3). The census area included 202.6 km of spawning habitat, 7.9 km of which we were denied access (Table 2; Figures 2, 3, and 4). We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork for a total length of 36.3 km of stream (Table 2; Figures 2, 3, and 4).

Table 2. Access status (Y = Yes, N = No), survey type, and reach length (km) for 2012 spawning survey reaches in the John Day River basin.

		Survey Type		
Stream Name	**Access Status**	**Census**	**Index**	**Random**
Mainstem				
Bridge Creek	Y	5.9		5.8
Canyon Creek	Y			2.0
Deardorff Creek	Y	2.0		
John Day River	*N*	*6.7*	*6.3*	
John Day River	Y	9.1	11.4	8.8
Reynolds Creek	Y	4.1		
South Fork				
S.F. John Day River	Y	17.3		3.2
Middle Fork				
Bridge Creek	Y	2.9		
Clear Creek	Y	4.1		2.0
Granite Boulder Creek	Y	2.3		
M.F. John Day River	Y	27.7	19.8	6.4
Vinegar Creek	Y	0.6		
North Fork				
Baldy Creek	Y			1.6
Big Creek	Y	0.1		
Camas Creek	Y	0.8		
Crawfish Creek	Y	0.2		
N.F. John Day River	Y	63.2	28.5	6.4
Trail Creek	Y	3.0		
W.F. Meadowbrook	Y			0.2
Granite Creek System				
Bull Run Creek	Y	2.3	4.9	
Clear Creek	*N*	*1.2*		
Clear Creek	Y	4.3	4.7	
Granite Creek	Y	7.5	9.0	
Desolation Creek				
Desolation Creek	Y	35.3		
S.F. Desolation Creek	Y	1.8		
Total		**202.6**	**84.5**	**36.3**

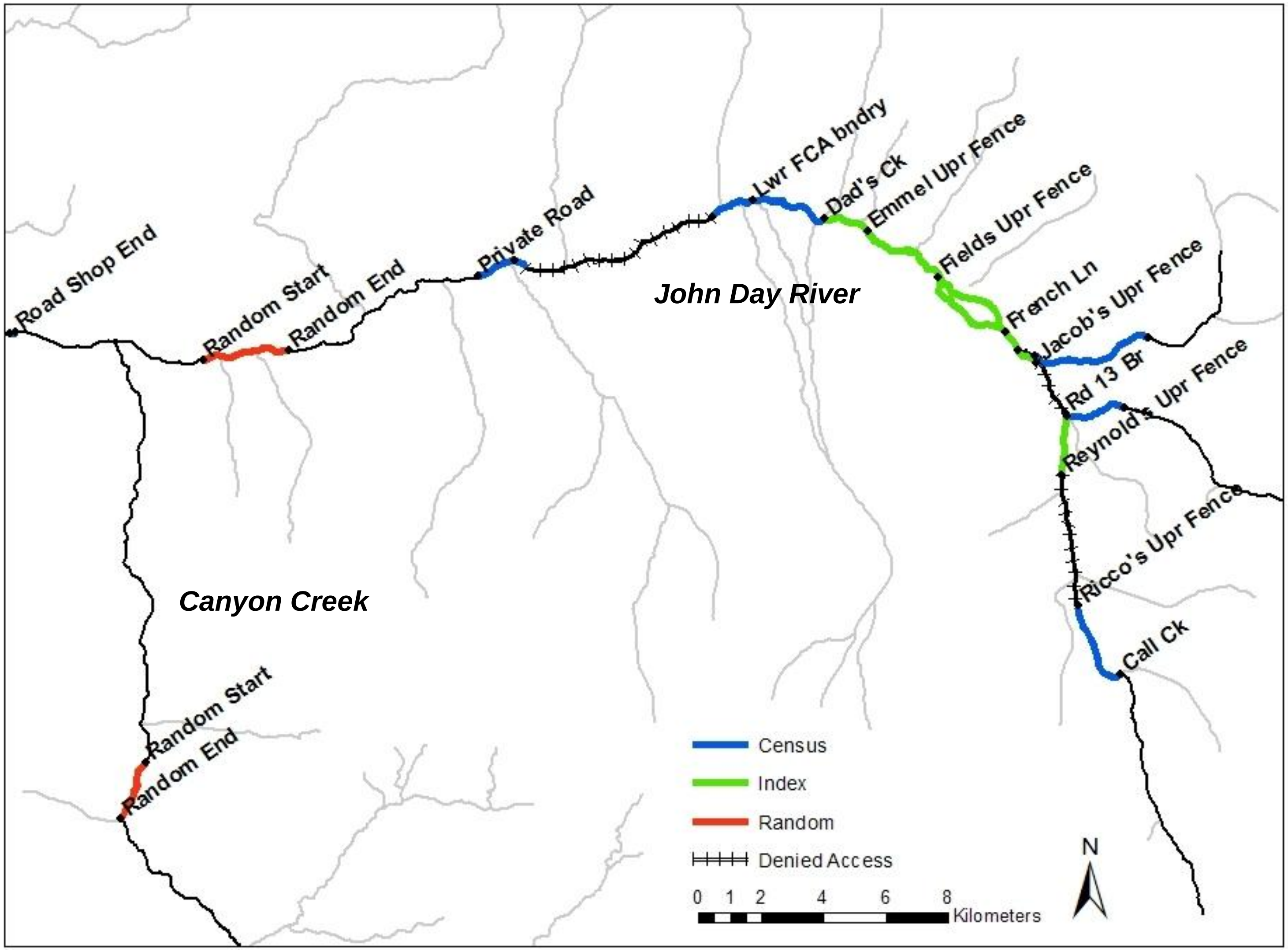

Figure 2. Map of the Mainstem spring Chinook spawning ground survey sections.

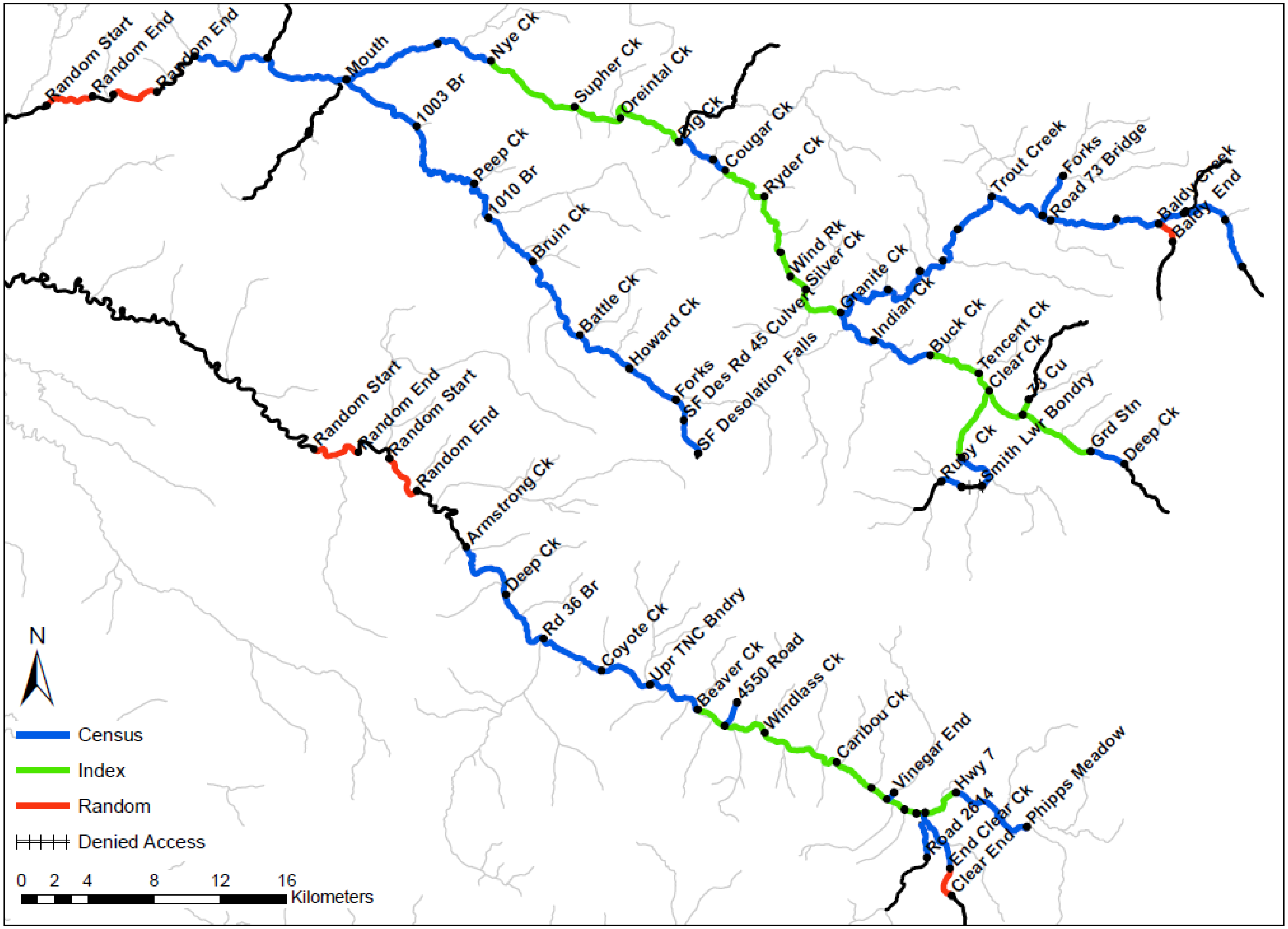

Figure 3. Map of the Middle Fork and North Fork spring Chinook spawning ground survey sections.

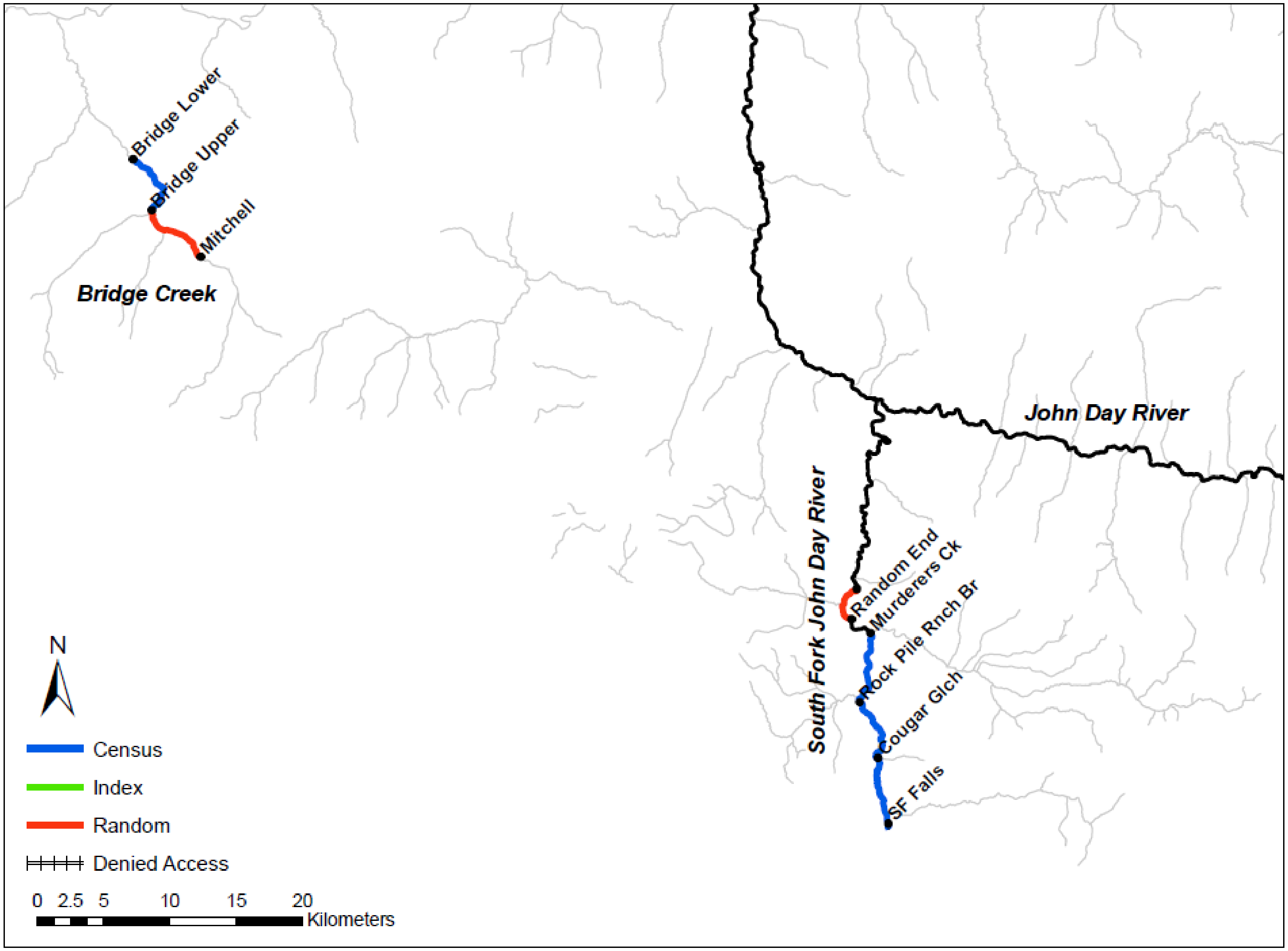

Figure 4. Map of the South Fork and Bridge Creek spring Chinook spawning ground survey sections.

We observed 1,770 spring Chinook redds within the John Day River basin in 2012 (Tables 3 and 4). In the 14.5 km of combined census and index reaches where we were denied access, we estimated a total of 17 redds (14 redds in the Mainstem and 3 redds in Clear Creek, GCS). This resulted in a total estimated 1,787 spring Chinook redds in the John Day River basin in 2012. We estimated an overall density of 6.5 redds/km for the entire survey area, excluding random reaches where spawning was not present (Table 3). Of the 1,787 total redds, 1,151 were in index reaches at a density of 14.7 redds/km. The ratio of index to census redd counts in 2012 was 1.8, greater than the ratio observed in the last five years of surveying. Since 2000, the contribution of index counts to the total count has declined (Figure 5). Two redds were observed in random reaches of Clear Creek in the Middle Fork and one redd was observed in a random reach of Baldy Creek, a tributary to the upper North Fork John Day River. The Mainstem accounted for 22.6% of the total redds observed in 2012, the Middle Fork had 27.6%, and the North Fork had 49.9%. We did not observe any redds in the South Fork. The Mainstem had the highest density of redds with 12.4 redds/km, followed by the Middle Fork with 8.3 redds/km, and the North Fork with 5.3 redds/km (Figures 6, 7, and 8).

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 2000–2012.

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	2.63	3.93	4,852	7,247
2012	276.7[a]	1,787	6.5	2.90	3.02	5,187	5,391

[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, 2012.

Stream Name	Redds (n)			Carcasses (n)		
	Census	Index	Random	Wild	Hatchery	Unknown
Mainstem John Day						26
Deardorff Creek	2					
Mainstem John Day River	61	322		150	2	
Reynolds Creek	4					
Middle Fork John Day						
Bridge Creek				1		
Clear Creek	37		2	25		10
Middle Fork John Day River	154	300		659	3	29
North Fork John Day						35
Baldy Creek			1			
Bull Run Creek	2	35		40		
Clear Creek	6	60		30		1
Desolation Creek	51			43	1	1
Granite Creek	19	120		123	1	9
North Fork John Day River	205	389		361	7	
Total	**541**	**1226**	**3**	**1432**	**14**	**111**

Figure 5. Ratio of index to census redd count totals from 2000–2012 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.

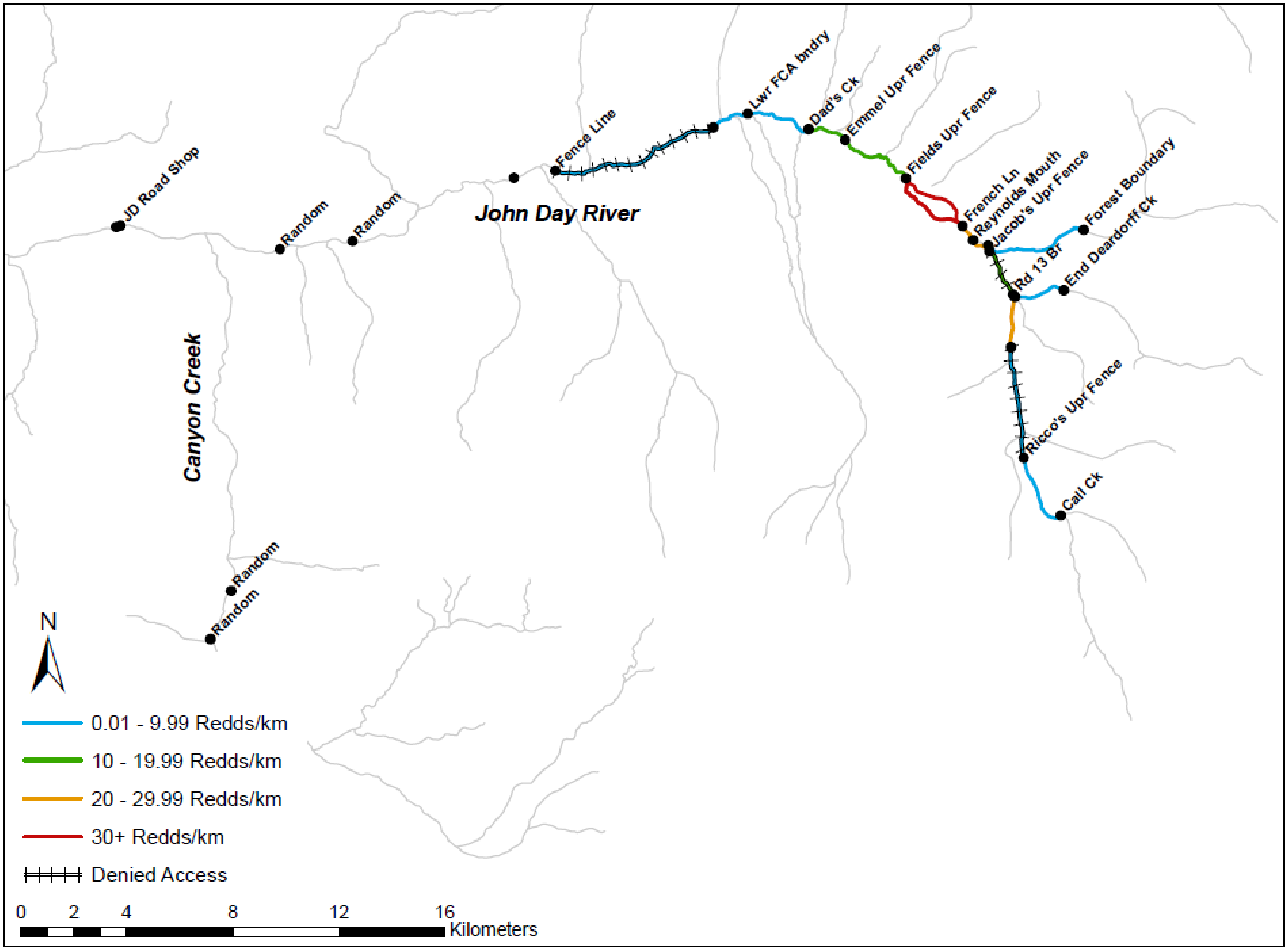

Figure 6. 2012 spring Chinook spawning survey sites and redd densities in the Mainstem John Day River.

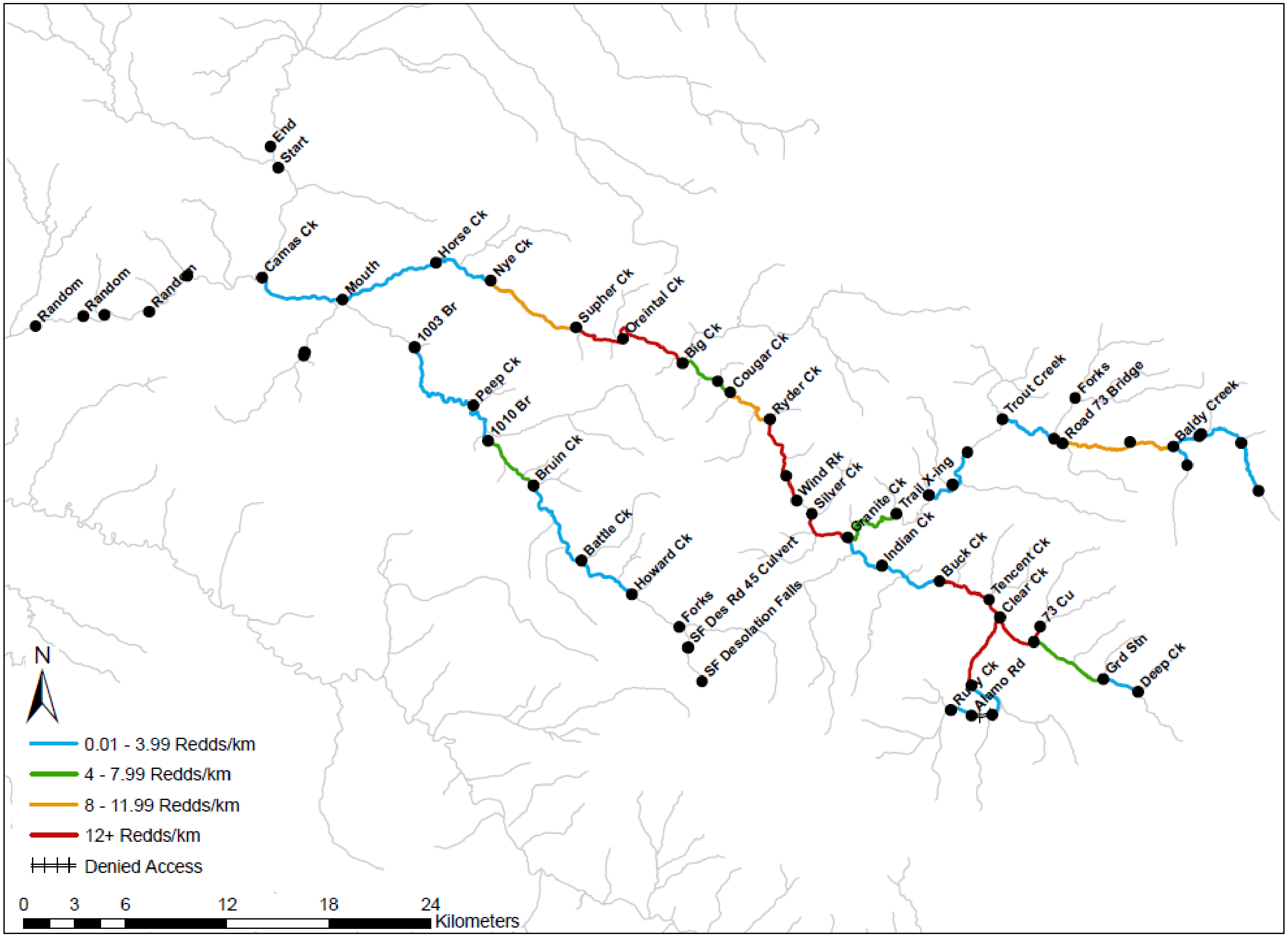

Figure 7. 2012 spring Chinook spawning survey sites and redd densities in the North Fork John Day River.

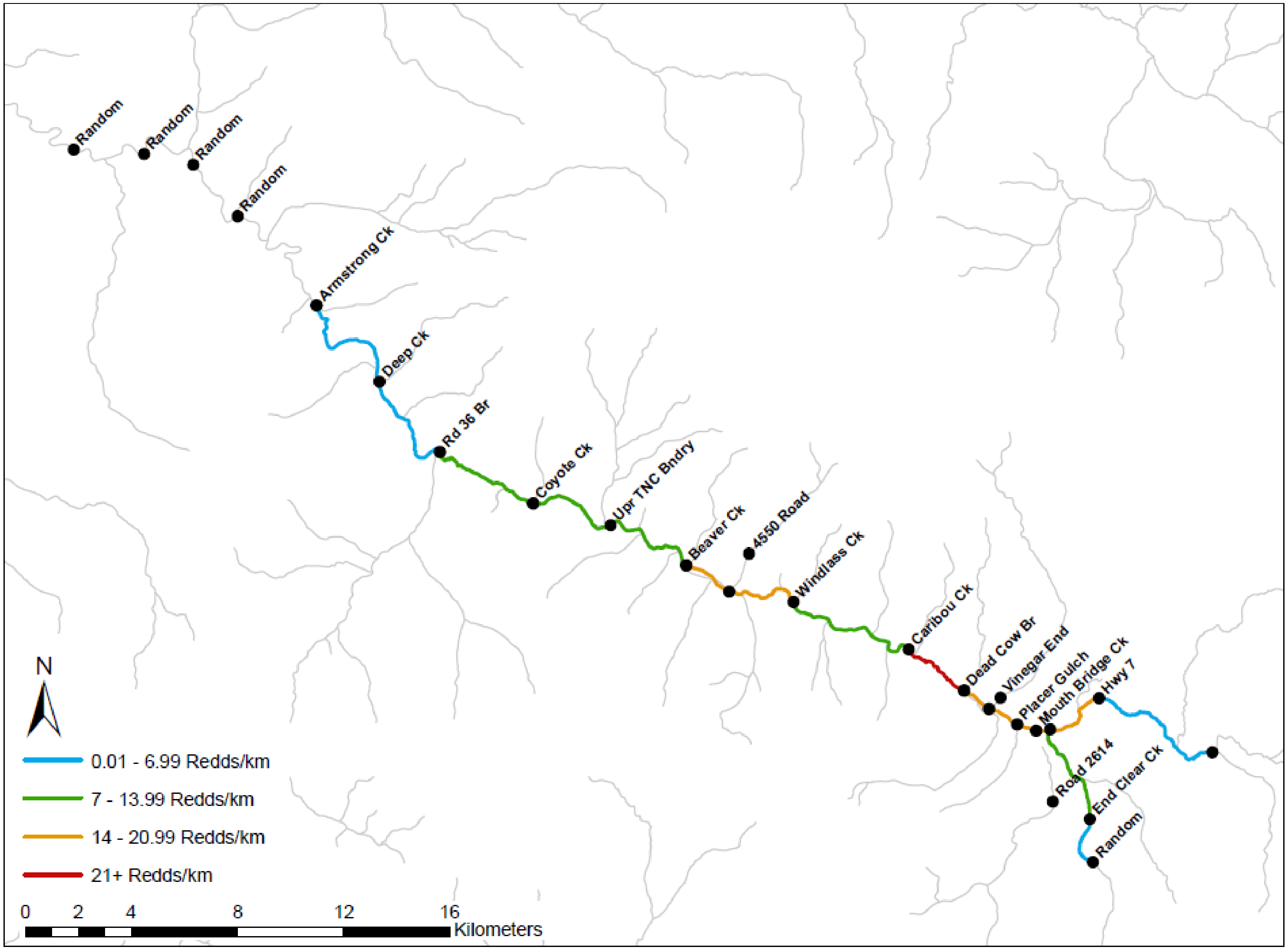

Figure 8. 2012 spring Chinook spawning survey sites and redd densities in the Middle Fork John Day River.

We found significant correlations between index and total (total = index + census + random) for all three John Day populations (Mainstem $r = 0.93$, $P < 0.01$, Middle Fork $r = 0.96$, $P < 0.01$, and North Fork $r = 0.95$, $P < 0.01$; Figure 9). Plotting the residuals against mean daily discharge in August for the John Day River at Service Creek (rkm 252) suggests discharge may influence redd distribution, particularly in the Mainstem and North Fork populations (Figure 9). We also found a significant correlation between basinwide total and index counts for 2000 to 2012 ($r = 0.95$, $P < 0.01$). Applying the regression equation between index and total redd counts for survey years 2000–2011 to the 2012 index count predicted a total redd count of 1,746. This prediction underestimated the actual total redd count by 2%.

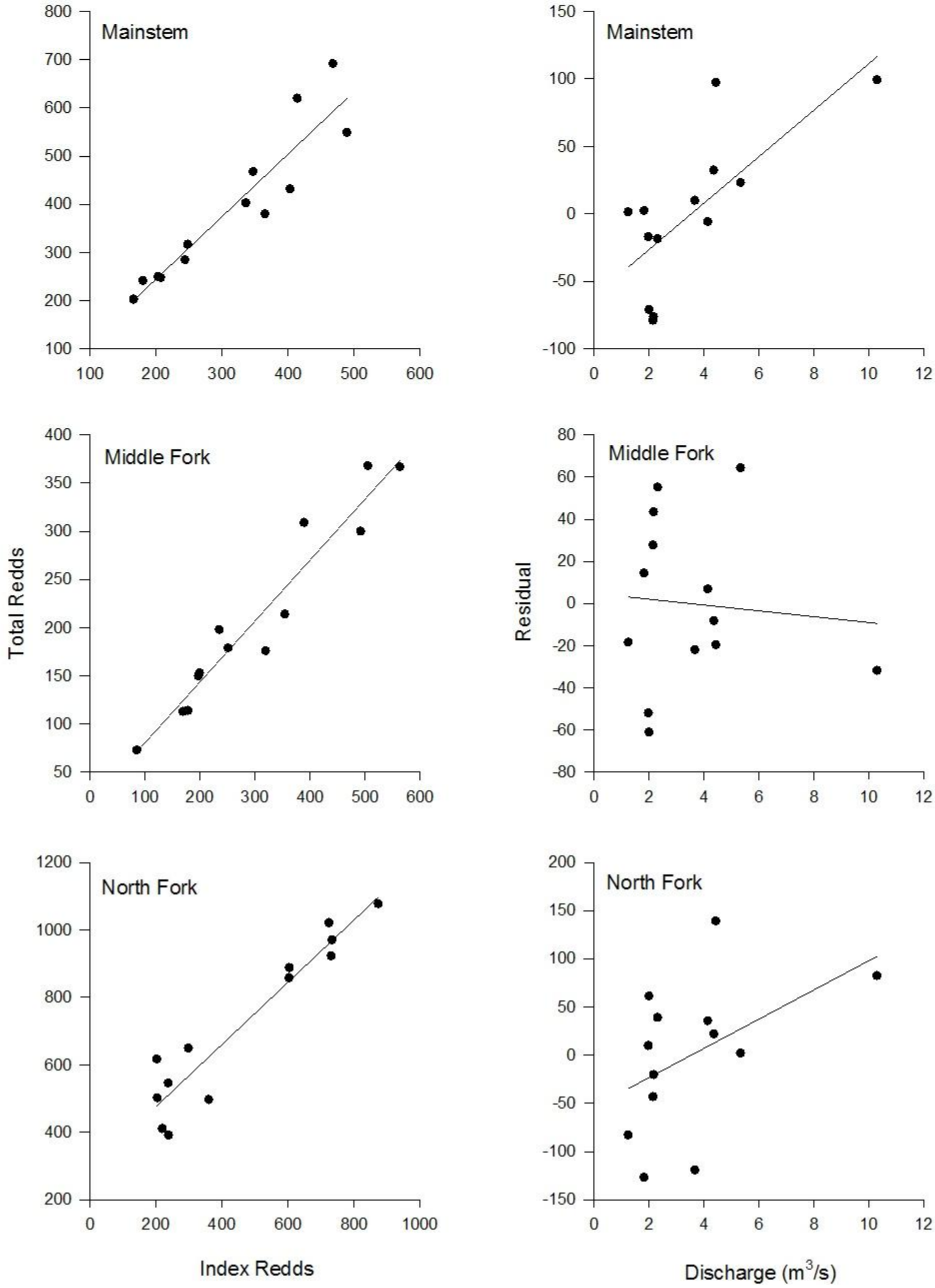

Figure 9. Regressions between index and total redd counts from 2000–2012 spawning ground surveys and the residuals from these regressions plotted against August discharge of the John Day River for spawning populations in the Mainstem, Middle Fork, and North Fork of the John Day River.

Redd abundance at the John Day River basin scale during 2012 was comparable with 2011 (Figure 10). At the population scale, the Mainstem population showed a 42% decline, while the North Fork had 27% more redds in 2012 than 2011. Middle Fork redd counts during 2012 were comparable with counts observed in 2011. Redd counts in other northeast Oregon river basins (e.g., Grande Ronde and Imnaha) also decreased in 2012 following an increasing trend from 2007 to 2011 (Figure 11). Annual Middle Fork and North Fork redd counts are significantly correlated with each other (Table 5), however, the Mainstem is not significantly correlated with either the Middle Fork or North Fork. Redd counts for the Mainstem were significantly correlated to both Grande Ronde and Imnaha river populations, however, the Middle Fork and North Fork were not correlated with either the Grande Ronde or Imnaha basins (Table 5, Appendix Table VIII). Redd counts for every population except the Middle Fork were either significantly or suggestively correlated with PDO values during the summer two years prior to the redd count (Table 5).

Table 5. Matrix of correlation coefficients (Pearson's r) between Mainstem John Day, Middle Fork John Day, North Fork John Day, Imnaha, and Grande Ronde rivers Chinook redd counts from 2000–2012 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	0.49	0.17	**0.74**	**0.60**	*-0.55*
Middle Fork Redd Count	-	**0.65**	0.30	0.29	-0.33
North Fork Redd Count	-	-	0.05	0.47	**-0.63**
Grande Ronde Redd Count	-	-	-	**0.60**	**-0.58**
Imnaha Redd Count	-	-	-	-	**-0.71**

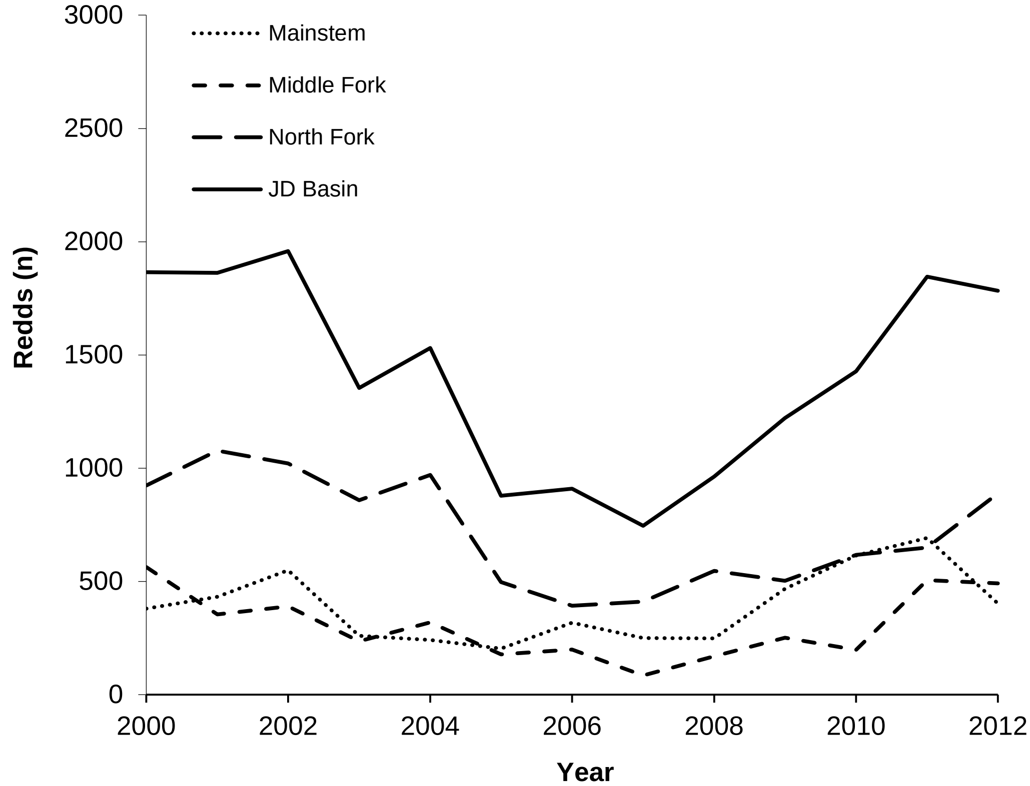

Figure 10. Redd totals from 2000–2012 for three John Day River basin spring Chinook salmon populations and the basinwide total.

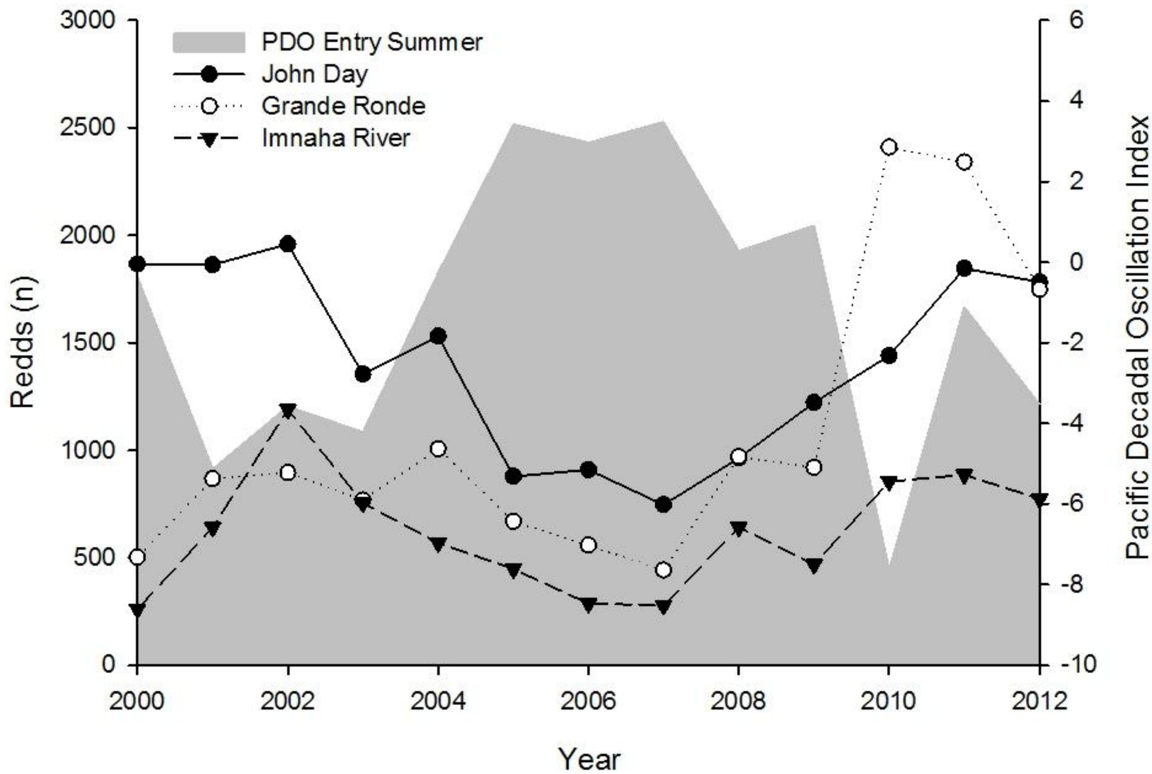

Figure 11. Redd totals from 2000–2012 for the John Day, Grande Ronde, and Imnaha river basins plotted with summer values of the Pacific decadal oscillation index. Pacific decadal oscillation index values are for the summer of entry for age-4 Chinook.

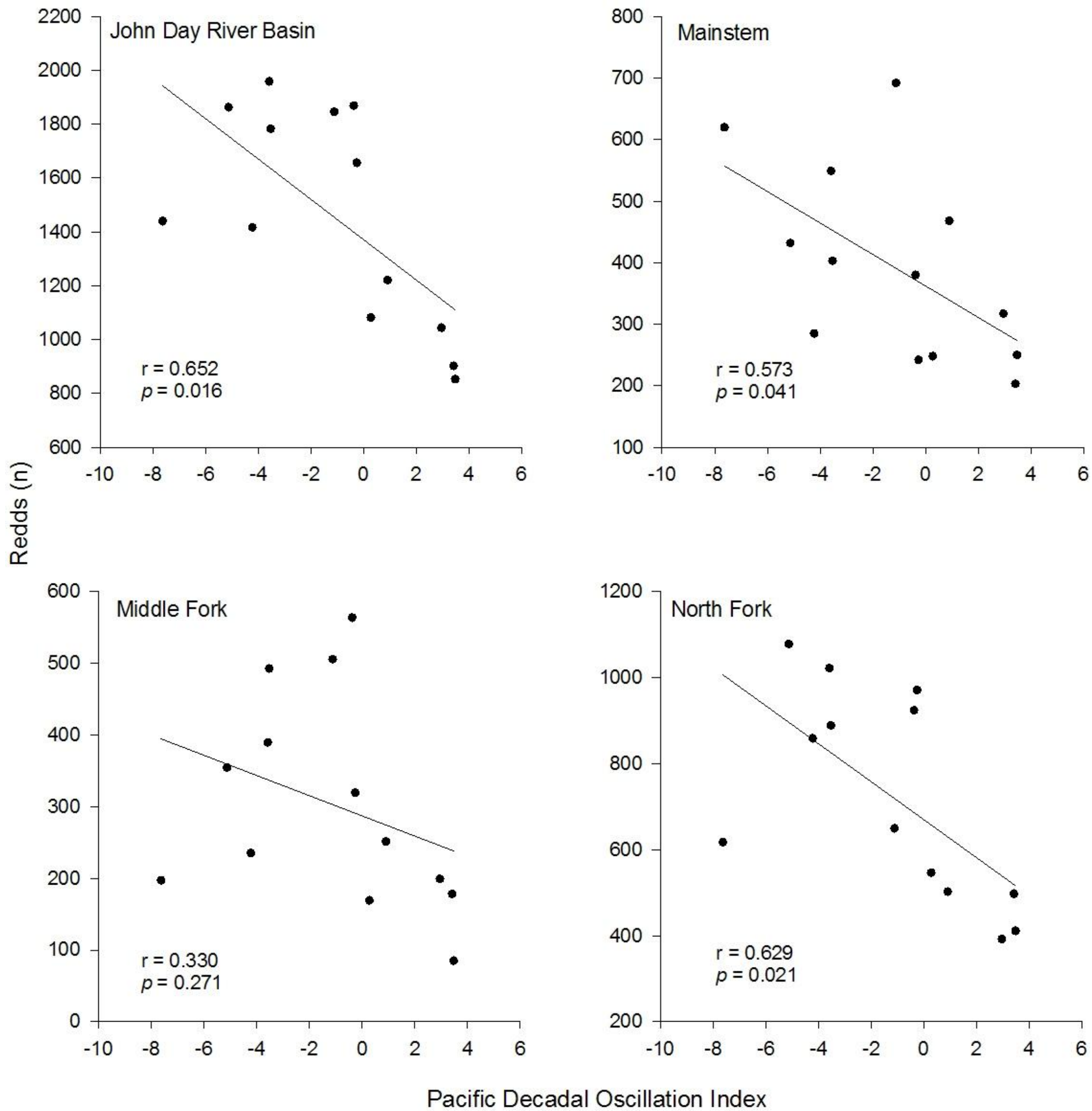

Figure 12. Correlation between Pacific Decadal Oscillation values and total redd counts from 2000 to 2012 spawning ground surveys in the Mainstem, Middle Fork, and North Fork of the John Day River.

Carcass Recovery

In 2012, we recovered 1,557 carcasses representing 30% of the estimated spring Chinook spawner escapement (Table 6). We sampled approximately 15% of the estimated carcasses in the Mainstem, 51% in the Middle Fork, and 25% in the North Fork. We were able to determine origin of 1,446 carcasses. Of the 14 fish which had clipped adipose fins, two were recovered in the Mainstem, three in the Middle Fork, and nine in the North Fork population. The proportion of adipose-clipped carcasses observed in 2012 (1.0%) was within the range reported since 1998, which has ranged from a low of <1% in 1998 to a high of 5% in 2007. We recovered five CWTs from 14 hatchery carcass snouts. Three of the tags were from the Grande Ronde River captive broodstock and two originated in the Lookingglass Creek Hatchery conventional broodstock. All five CWTs were recovered in the North Fork basin.

We determined the sex of 738 carcasses, 424 (57.5%) were females and 314 (42.5%) were males. We estimated the ages of 600 carcasses using scale pattern analysis. There was a total of 10 age-3 (2%), 528 age-4 (88%), and 62 age-5 (10%) fish (Figure 13; Table 7). None of the age-3 Chinook carcasses recovered were female. Two adult Chinook were identified as sub-yearling smolts during their freshwater rearing phase. The remainder of the non-regenerated scales indicated a yearling smolt life history pattern.

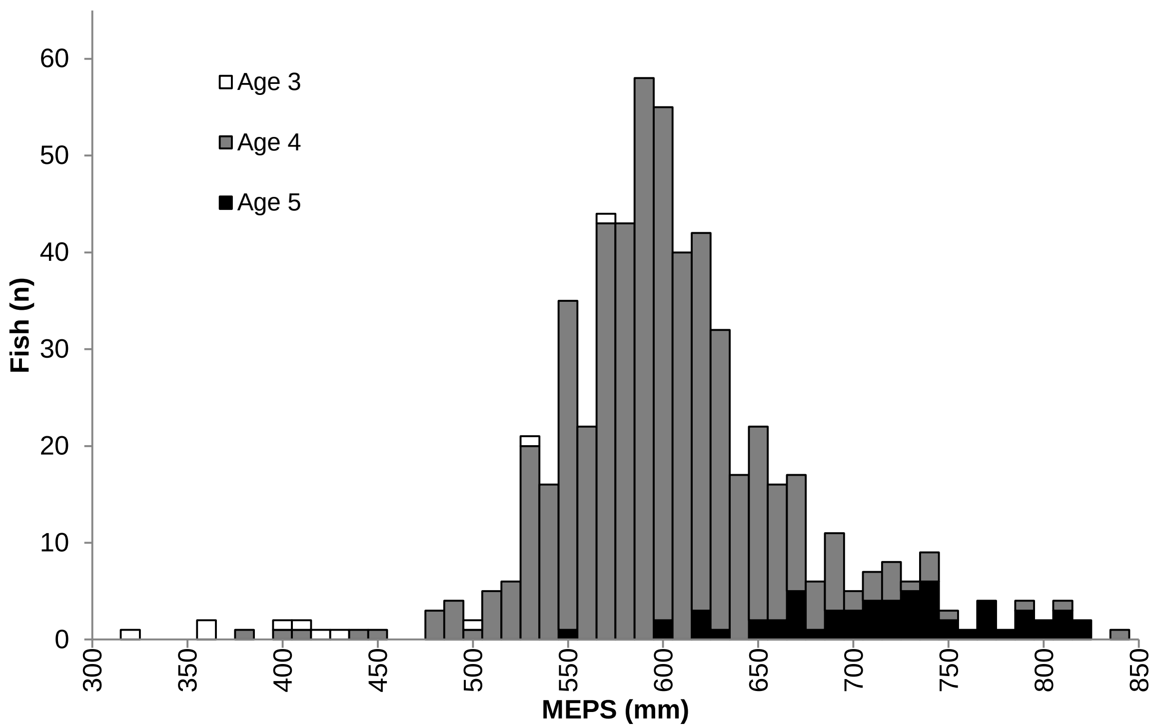

Figure 13. Length frequency and age distribution of Chinook carcasses recovered in 2012 (n = 586).

Of the 363 female carcasses for which we estimated egg retention, 328 (90%) were completely spawned. The 35 fish that were partially spawned contained an average of 0.262 L (SD = 0.274) of eggs.

Table 6. Age, mean MEPS length (mm), standard error (SE), sample size (n), range (mm), and percentage of total known-sex aged Chinook from 2012 carcass recovery.

	Male					Female				
Age	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**
3	464.3	37.2	6	325–570	1%		-	0	-	0%
4	603.1	5.3	134	400–815	22%	598.3	2.6	211	480–745	35%
5	761.6	18.1	11	672–875	2%	705.5	13.3	25	555–806	4%

Table 7. Percentage of known-sex aged Chinook carcasses by population for 2012.

		% Males by Age			% Females by Age		
	n	**3**	**4**	**5**	**3**	**4**	**5**
Mainstem	76	2.6	30.3	2.6	0.0	61.8	2.6
Middle Fork	71	0.0	42.3	4.2	0.0	45.1	8.5
North Fork	240	1.7	33.8	2.5	0.0	55.0	7.1
Basin Total	387	1.6	34.6	2.8	0.0	54.5	6.5

Redd Count Expansion Escapement Estimation

Applying the 2012 fish (jacks and adults) per redd ratio of 3.02 observed above the Catherine Creek weir (Grande Ronde River basin) to the John Day River basin, we estimated an escapement of 5,391 spring Chinook spawners in the John Day River basin for 2012 (Table 3). We estimate that 1,216 fish spawned in the Mainstem, 1,487 spawned in the Middle Fork, and 2,688 spawned in the North Fork.

PIT Tag Detection-Recapture Escapement Estimation

A total of 1,591 carcasses, including those that had been scavenged, were scanned for PIT tags during the spawning ground surveys and 28 tags were recovered (Table 8). Seven PIT-tagged carcasses were female and 11 were male, all of them were of wild origin. Seven carcasses that were tagged as juveniles in the Middle Fork were recovered in the Middle Fork. Seven other fish were tagged as juveniles in the lower Mainstem John Day River (below the confluence with the North Fork) and were recovered in all three subbasins. Fourteen fish were tagged as adults between April and June of 2012; two were tagged in the lower Columbia River (rkm 0–49), ten were tagged in the adult fish facility at Bonneville Dam (rkm 234), and two were tagged at Lower Granite Dam in the Snake River (rkm 522.173). The fish tagged at Lower Granite Dam traveled approximately 700 km (including downstream passage over at least five dams) and were recovered in the Middle Fork and Mainstem of the John Day River. Four John Day origin fish were detected at McNary Dam in the spring of 2012, two of them continued up the Snake River to Lower Granite Dam before returning to the John Day spawning grounds.

Table 8. Spring Chinook Passive Integrated Transponder (PIT) tags recovered on John Day River spawning ground surveys during 2009–2012. 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

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

Detections at Bonneville Dam indicated that 111 John Day origin PIT-tagged Chinook passed the dam in 2012, excluding "mini-jacks". Spawning surveys scanned a total of 1,175 intact wild origin carcasses. Our carcass surveys recovered eight males, 1 female, and five unknown sex John Day origin PIT-tagged fish. It is common for PIT tags to be expelled from the body cavity of females during spawning, therefore we expanded the number of recaptured John Day origin PIT-tagged females by using the male:female ratio of recovered carcasses multiplied by the number of males and adding the five fish of unknown sex. This resulted in a total of 24 estimated recaptured adults. Estimated wild spawner abundance was 5,267 (95% CI: 3,501−7,033).

Carcass Detection Probabilities

We marked 522 carcasses with operculum punches and assigned them to three size groups ($\leq$ 499 mm, 500–599 mm, and $\geq$ 600 mm). We recovered 179 of these marked carcasses on subsequent surveys. The probability of a marked carcass being recovered was highest in the Middle Fork (0.47), intermediate in the North Fork (0.21) and lowest in the Mainstem (0.02). Information theoretic selection of four candidate logistic regression models (Table 9) indicated that population was the only variable that significantly explained carcass detection probability. There were no other competing models (Delta AICc < 2). Logistic regression models which incorporated size alone, or size in combination with population, did not fit the data as well as a model with population as the only explanatory variable (Table 9).

Table 9. Akaike's information criterion (AICc) model selection results for binomial logistic regressions of marked carcass recoveries versus different explanatory variables. Explanatory variables included: population and size. The intercept model is a null model with no explanatory variables. Weight of evidence (w_i) indicates that population is the only variable that significantly explains carcass recovery probability.

Model	K	AIC_c	ΔAIC_c	w_i
Population	3	48.61	0	1
Size + Population	5	64.91	16.3	0
Intercept	1	104.54	55.93	0
Size	3	106.46	57.84	0

Population Productivity Analyses

We estimated that freshwater productivity for the 2010 brood year was 105 smolts per redd (95% CI: 96–116) in the Mainstem and 148 smolts per redd (95% CI: 142−155) in the Middle Fork. These values were comparable to our estimates from recent years. The estimated number of smolts produced per redd declined with increasing redd abundance for both the Mainstem and Middle Fork populations (Figures 14 and 15).

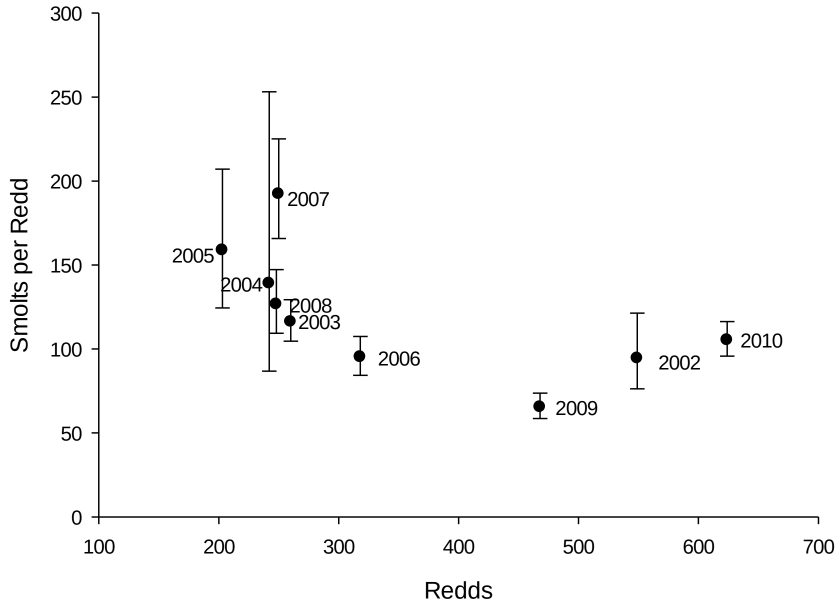

Figure 14. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2010 for the Mainstem John Day population. Error bars are 95% Confidence Intervals.

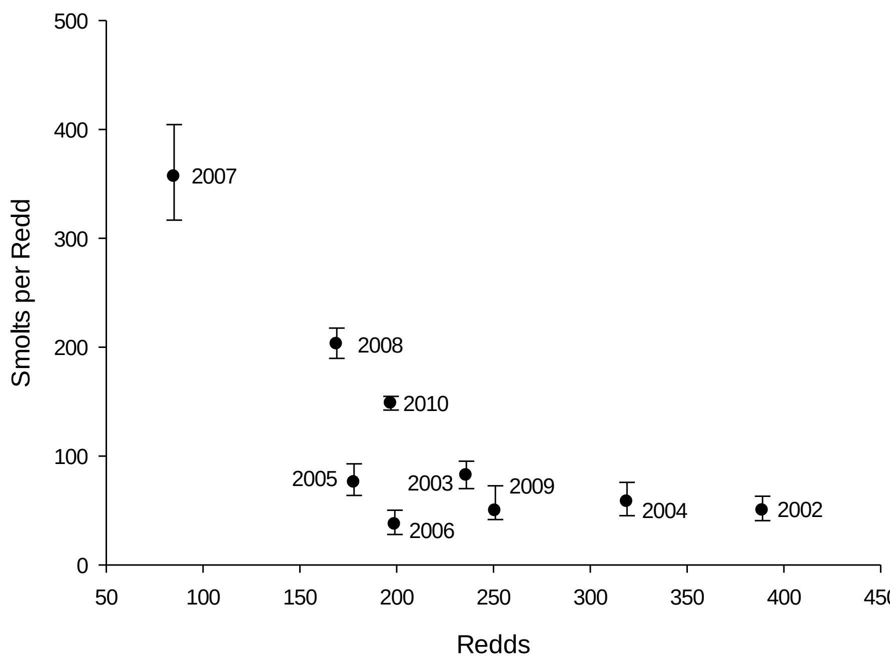

Figure 15. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2010 for the Middle Fork John Day population. Error bars are 95% Confidence Intervals.

Stock-recruitment analysis for the Mainstem population suggests a replacement level (unexploited equilibrium) of 350 redds. Maximum sustained production for the Mainstem population occurs at 230 redds (Figure 16a). The Middle Fork population appears to have a replacement level of 250 redds and maximum sustained production for the Middle Fork is achieved at 243 redds (Figure 16c). Replacement level for the North Fork population is 560 redds. Unlike the Mainstem and Middle Fork populations, maximum sustained production for the North Fork population is currently estimated to occur at an escapement of 730 redds, which is greater than the replacement level for this population (Figure 16e).

Plots of residuals from the stock-recruitment regressions suggest an upward trend for the Mainstem population. Four of the first five brood years for the Mainstem had negative residuals. Conversely, the most recent three brood years had positive residuals (Figure 16b). Residuals for the Middle Fork (Figure 16d) and North Fork (Figure 16f) do not appear to share this pattern. Residuals for both of these populations appear symmetrically distributed about zero, with no discernible trend over time.

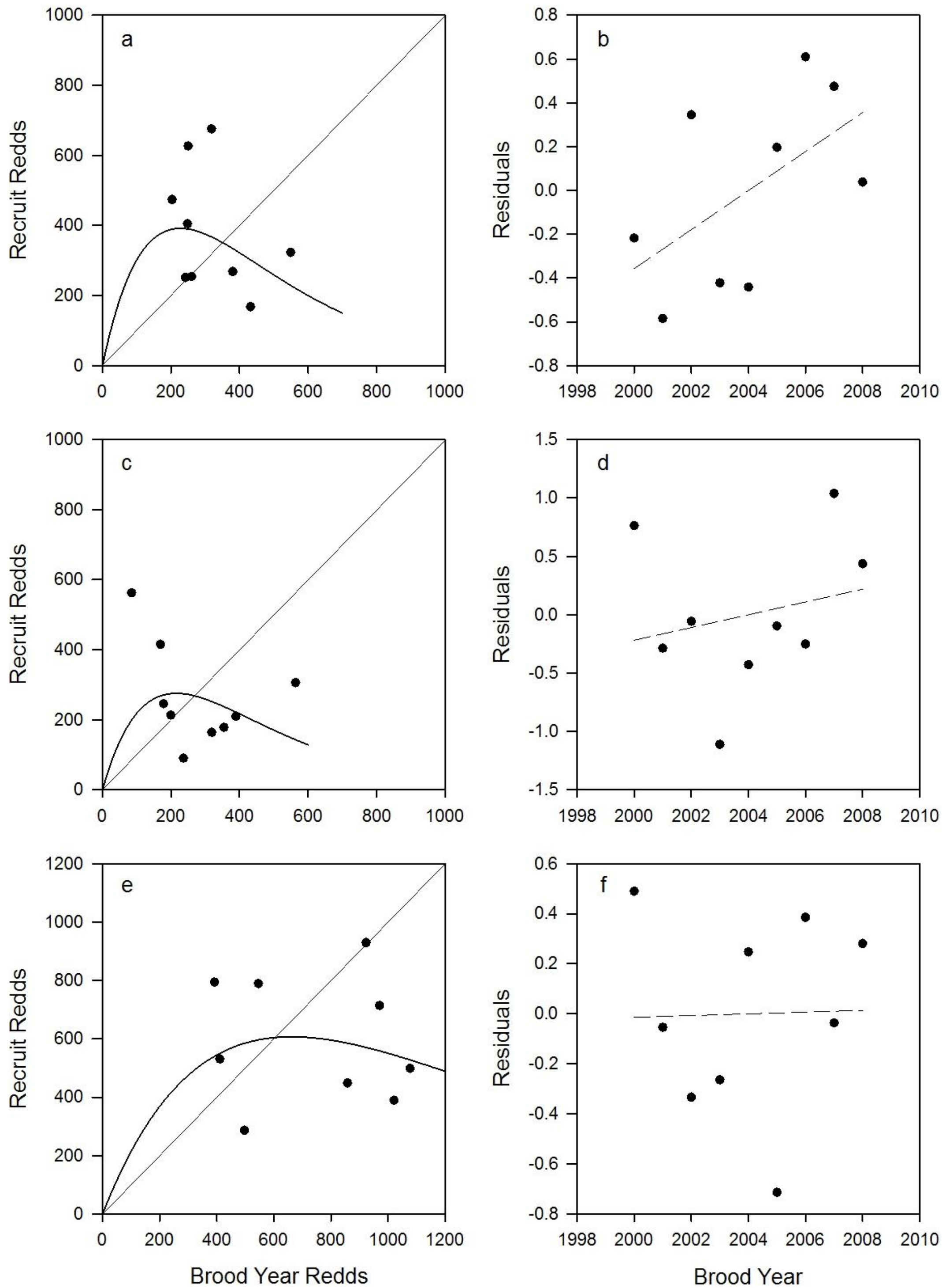

Figure 16. Comparison of Ricker stock-recruitment curves and associated residual versus brood year plots for Chinook spawning populations in the Mainstem (a and b), Middle Fork (c and d), and North Fork (e and f) of the John Day River. Diagonal lines on panels a, c, and e are 1:1 replacement lines. Dashed 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

John Day spring Chinook populations show trends in abundance similar to other northeast Oregon populations and appear to be driven by density-independent factors. The decrease in John Day redd counts in 2012 was mirrored by 25% and 13% declines in Grande Ronde and Imnaha basin redd counts, respectively. Covariation among populations suggests a large-scale environmental effect on northeast Oregon Chinook populations. Such ecological responses to large-scale changes in the physical environment are known to occur with Pacific salmon (Hare et al. 1999). A significant inverse relationship between PDO values during the summer of smolt ocean-entry and adult returns to the Grande Ronde, Imnaha, Mainstem John Day, and North Fork John Day populations suggests that ocean conditions may be a driving factor.

Redd counts in the North Fork are now approaching the high levels observed during our monitoring from 2000 through 2004. In contrast to this increase, Mainstem redd counts dropped below Middle Fork counts. This has only occurred in two other years since our monitoring began in 2000. The 2012 recreational fishery for upper Mainstem Chinook, opened for the first time since 1976, harvested an estimated total of 58 adults (95% CI: 3–113) and 21 jacks (95% CI: 1–42) (J. McCormick, ODFW personal communication). At most, this accounted for 11% of the total number of Chinook estimated to have entered the upper Mainstem and could not account for the 42% decrease compared to 2011 escapement.

Straying of adipose-clipped hatchery Chinook into the John Day River basin remains low. Less than one percent of our recovered carcasses were adipose-clipped hatchery fish. Hatchery carcass recoveries occurred at a higher proportion in the North Fork (1.5%) than either the Middle Fork (0.4%) or Mainstem (1.3%). Carcass recovery may underestimate straying if hatchery smolts are either poorly fin-clipped or not fin-clipped. Genetic analysis of carcasses recovered from 2004 to 2006 found the North Fork population had a higher rate of out-of-basin strays, both adipose-clipped and unmarked (identified as wild on spawning surveys), compared to the Mainstem or Middle Fork (Narum et al. 2008). Our recoveries of adipose-clipped carcasses, which have occurred more frequently in the North Fork population corroborate their results. Narum et al. (2008) also suggested that wild strays may be more prevalent than hatchery strays in the John Day River basin. Numerous wild Chinook juveniles in Snake and Upper Columbia River populations are PIT tagged, creating the possibility of redetection in the John Day River. Despite our recovery of 13% (14 out of 111 returning to Bonneville Dam) of the available John Day origin PIT tagged adults, we did not recover any Chinook PIT tagged as juveniles outside of the John Day River basin. Continued emphasis on scanning carcasses for PIT tags will improve our understanding of straying by wild Chinook. Installation of PIT antenna arrays on the North Fork and Upper Mainstem John Day would also improve our ability to detect stray wild adults.

Given the apparent effect that ocean conditions have on redd abundance, trends in freshwater productivity provide a more appropriate measure of population status than simply adult abundance (e.g., Lawson 1993). Mainstem and Middle Fork smolts produced per redd decreased as the number of redds increased, 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 the strongest 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 which produced a positive sustainable yield and a large yield when brood redds approach 200. Average sustainable yield in the Middle Fork is low and extends over a short range of brood year redds. In the North Fork, sustainable yield is roughly constant for a comparatively broader range of brood year redds.

A review of the residuals from the Mainstem stock recruitment curve suggests non-stationarity because a positive slope is apparent through the years (see Figure 15). The environment in the Mainstem may be changing to the benefit of Chinook productivity. Since this pattern is not reflected in the Middle and North Fork populations, 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 subbasin in recent years, which have increased fish passage and juvenile rearing habitat (J. Neal, ODFW, personal communication). Conversely, the Middle Fork has multiple tributaries with upstream migration barriers blocking access to juvenile Chinook rearing and adult Chinook spawning habitat (James et al. 2009). Removing barriers and allowing juvenile and adult Chinook access to additional spawning and rearing habitat is an approach to increasing yearling smolt production through freshwater habitat restoration (Sharma and Hilborn 2001). Our data suggest that habitat actions in the upper Mainstem may be contributing to apparent increases in productivity.

Survey Methodology

Continuing to monitor index reaches allows us to see trends in redd abundance from 1964 to present, yet these reaches only comprise a portion of the spawning range in the John Day River 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 a majority of redds observed in 2012 (69%), our more extensive census efforts reveal an overall downward trend in index representation since 2000 (Figure 5). For example, the 2010 index:census redd count ratio equaled 1.04 (index representation of 52%). 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 1950's 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.

Our carcass detection probability data indicate that carcasses were more readily recovered in the Middle Fork. 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. Carcass detection probability in the Mainstem was low, perhaps due to the dense riparian cover, dark pools, log jams, undercut banks, and moderate amounts of scavenging. Scavenging appears to be the primary limitation on carcass recovery in the North Fork population; fresh bear tracks and feces were abundant on streambanks within roadless reaches of the North Fork. As a result, we recovered very few carcasses in wilderness sections of the North Fork despite observing high redd densities. Operculum marking of carcasses improved our understanding of factors influencing carcass recovery probability. We intend to continue monitoring carcass detection probability and implement a unique marking scheme with numbered zip ties in place of operculum punches. Unique detection histories for each carcass will allow us to estimate carcass abundance.

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. The PIT tag mark-recovery escapement estimation relied solely on John Day spring Chinook data. Our 2011 and 2012 data suggest that this approach is feasible. The 2012 mark-recovery escapement estimate was very similar to the redd count expansion estimate (5,267 versus 5,391, respectively). 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. We intend to continue both estimations for immediate future years.

Management Implications

During 2012 we identified spawning adult Chinook salmon which 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 RST 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.

The density-dependent relationships we have observed indicate that 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 16) is a cautious approach which 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. Improvements to the rearing habitat would increase the potential for future fisheries for these wild populations and recreational fisheries targeting wild populations are scarce for Columbia River Chinook populations.

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APPENDIX

Appendix Table I. Spring Chinook total redd counts in the John Day River basin, 2000–2012. Includes redds observed in index, census and random sections, and redds estimated where permission to survey was denied.

				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

Appendix Table II. Census and index survey lengths (km) for spring Chinook salmon spawning surveys in the John Day River basin, 2000–2012. 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

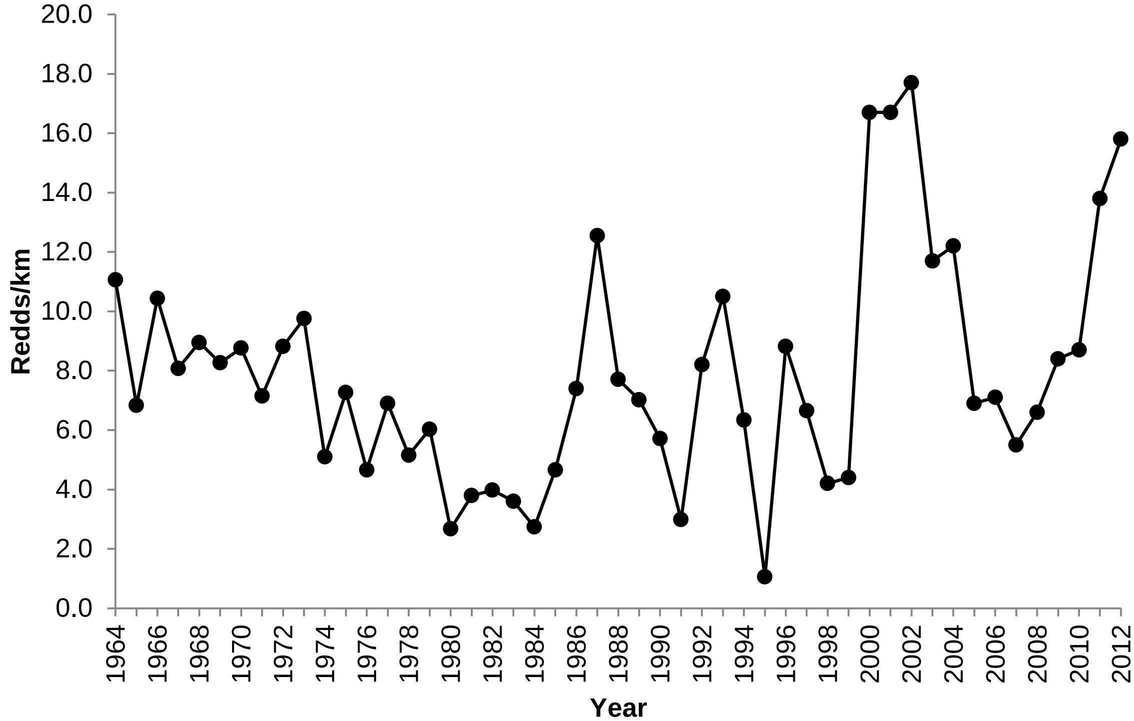
Appendix Table III. Spawning density (redds/km) in the John Day River basin, 2000–2012. Includes density estimates for areas where we were denied access.

				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	5.3	8.4	6.7	5.1	1.4	6.1

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, 2002–2010 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		100	81	129	389	61	50	78
2003	2005	549	130	117	144	236	93	79	108
2004	2006	260	139	87	253	319	58	45	76
2005	2007	242	267	209	349	178	95	80	117
2006	2008	203	146	129	164	199	37	28	50
2007	2009	318	296	255	346	85	453	402	514
2008	2010	250	223	193	260	169	211	198	227
2009	2011	248	176	158	198	251	85	71	104
2010	2012	468	105	96	116	197	148	142	155

[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 Figure I. Spring Chinook index redd density in the John Day River basin, 1964–2012. Includes estimated redd counts in areas where we were denied access. Data from 1959–1963 are not presented because they do not cover the same spatial extent.

Appendix Table V. Index redd density (redds/km) in the John Day River basin 1998–2012. 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

Appendix Table VI. 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	Near Grant Road Shop, city of John Day	44.425336	-118.999635	44.425357	-118.999509
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 Dad's Creek	44.459277	-118.701083	44.453506	-118.672481
Mainstem John Day River	Dad's 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	Rd 13 Bridge to Reynolds Upper Fence	44.395640	-118.577286	44.377879	-118.579106
Mainstem John Day River	Ricco Upper Fence to Call Creek	44.340011	-118.574012	44.320119	-118.557340
Canyon Creek	2012 MS Random, 2.0 km reach	44.300513	-118.950313	44.284264	-118.960479
Reynolds Creek	0.6 km from mouth to 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	Painted Hills N.P. to Mitchell	44.640008	-120.236093	44.605424	-120.218222
Middle Fork John Day River	2012 MF Random RM 36	44.791818	-118.908753	44.774131	-118.888068
Middle Fork John Day River	2012 MF Random RM 32	44.797744	-118.965609	44.795685	-118.932045
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 Road 36 Bridge	44.716848	-118.821969	44.692588	-118.794073
Middle Fork John Day River	Road 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	-118.573089	44.607644	-118.547349
Middle Fork John Day River	Dead Cow Bridge to Placer Gulch	44.607644	-118.547349	44.595637	-118.522586

Appendix Table VI. Continued.

System	Description	Start		End	
		Latitude	Longitude	Latitude	Longitude
Middle Fork John Day River	Placer Gulch to Highway 7	44.595637	-118.522586	44.603958	-118.483250
Middle Fork John Day River	Hwy 7 to Phipps Meadow	44.603958	-118.483250	44.584500	-118.429986
Granite Boulder Creek	Mouth upstream to 1.5 miles	44.647386	-118.665057	44.655800	-118.647961
Vinegar Creek	Mouth upstream 1.75 miles	44.601232	-118.535686	44.617141	-118.510889
Bridge Creek	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 km upstream	44.562895	-118.489093	44.548271	-118.488078
North Fork John Day River	2012 NF Random RM 47	44.986493	-119.165761	44.991268	-119.130144
North Fork John Day River	2012 NF Random RM 50	44.991841	-119.114375	44.993012	-119.080743
North Fork John Day River	Camas Creek to Jericho Creek	45.010210	-118.995950	45.011857	-119.051625
North Fork John Day River	Desolation Creek to Camas Creek	44.997921	-118.935827	45.010210	-118.995950
North Fork John Day River	Horse Canyon to Desolation Creek	45.016381	-118.865414	44.997921	-118.935827
North Fork John Day River	Nye Creek to Horse Canyon	45.006291	-118.824657	45.016381	-118.865414
North Fork John Day River	Sulphur Creek to Nye Creek	44.980441	-118.761786	45.006291	-118.824657
North Fork John Day River	Oriental Creek to Sulphur Creek	44.973791	-118.726782	44.980441	-118.761786
North Fork John Day River	Big Creek to Oriental Creek	44.960194	-118.682884	44.973791	-118.726782
North Fork John Day River	Cougar Creek to Big Creek	44.944108	-118.647593	44.960194	-118.682884
North Fork John Day River	Ryder Creek to Cougar Creek	44.929562	-118.618474	44.944108	-118.647593
North Fork John Day River	Wind Rock to Ryder Creek	44.885947	-118.599879	44.929562	-118.618474
North Fork John Day River	Granite Creek to Wind Rock	44.865611	-118.562299	44.885947	-118.599879
North Fork John Day River	Trail Crossing to Granite Creek	44.885060	-118.254856	44.865611	-118.562299
North Fork John Day River	McCarty Gulch to Trail Crossing	44.887277	-118.501108	44.885060	-118.254856
North Fork John Day River	Thornburg Placer Mine to McCarty Gulch	44.909431	-118.471271	44.887277	-118.501108
North Fork John Day River	Trout Creek to Thornburg Placer Mine	44.926657	-118.444597	44.909431	-118.471271
North Fork John Day River	Road 73 Bridge to Trout Creek	44.912888	-118.400227	44.926657	-118.444597
North Fork John Day River	Baldy Creek to Road 73 Bridge	44.909619	-118.317805	44.912888	-118.400227

Appendix Table VI. Continued.

System	Description	Start		End	
		Latitude	Longitude	Latitude	Longitude
North Fork John Day River	Cunningham Creek to Baldy Creek	44.910764	-118.266677	44.909619	-118.317805
North Fork John Day River	Trail Crossing to Cunningham Creek	44.885060	-118.254856	44.910764	-118.266677
Camas Creek	0.4 km up- and downstream of Fivemile Creek	45.079725	-118.987687	45.068389	-118.982212
Big Creek	Big Creek bridge to mouth	44.960922	-118.682390	44.960194	-118.682884
Trail Creek	Trail Creek mouth to North and South Forks	44.915541	-118.406310	44.820401	-118.689409
Crawfish Creek	Mouth upstream 200 meters	44.914948	-118.298284	44.916135	-118.296417
Baldy Creek	Baldy Creek mouth to 1 mile upstream	44.90962	-118.317806	44.899615	-118.307586
Granite Creek	Indian Creek to mouth of Granite Creek	44.850403	-118.537324	44.865611	-118.562299
Granite Creek	Buck Creek to Indian Creek	44.841373	-118.494582	44.850403	-118.537324
Granite Creek	Ten Cent Creek to Buck Creek	44.831070	-118.458033	44.841373	-118.494582
Granite Creek	73 Road Culvert to Ten Cent Creek	44.816141	-118.420549	44.831070	-118.458033
Clear Creek	Old Road Crossing to Mouth	44.785595	-118.472676	44.821483	-118.450278
Clear Creek	Smith Lower Boundary to Old Road Crossing	44.769969	-118.457903	44.785595	-118.472676
Clear Creek	Ruby Creek to Alamo Road	44.772950	-118.488480	44.769600	-118.473293
Bull Run Creek	Guard Station to Mouth	44.787182	-118.374203	44.807964	-118.425153
Bull Run Creek	Deep Creek to Guard Station	44.779916	-118.348625	44.787182	-118.374203
Desolation Creek	Road 1003 Bridge to Mouth	44.971799	-118.882862	44.997921	-118.935827
Desolation Creek	Peep Creek to Road 1003 Bridge	44.940121	-118.839682	44.971799	-118.882862
Desolation Creek	Road 1010 Bridge to Peep Creek	44.921231	-118.829258	44.940121	-118.839682
Desolation Creek	Bruin Creek to Road 1010 Bridge	44.896974	-118.796166	44.921231	-118.829258
Desolation Creek	Battle Creek to Bruin Creek	44.856763	-118.761268	44.896974	-118.796166
Desolation Creek	Howard Creek to Battle Creek	44.838014	-118.724023	44.856763	-118.761268
Desolation Creek	Forks to Howard Creek	44.820401	-118.689409	44.838014	-118.724023
S. F. Desolation Creek	Culvert downstream to Forks	44.809318	-118.683428	44.820401	-118.689409
S. F. Desolation Creek	Road 45 Culvert to Falls	44.809318	-118.683428	44.791032	-118.673187

Appendix Table VII. Correlation matrix for census John Day River population Chinook redd counts from 2000 to 2012 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	**0.777**	0.502	**0.863**	**0.709**	**0.595**	**0.604**	0.511
Middle Fork	0.289	0.457	0.300	0.172	**0.547**	0.351	0.089
North Fork	0.030	0.042	0.237	-0.095	**0.687**	**0.544**	-0.043

Appendix Table VIII. Summary of Chinook coded wire tag recoveries by John Day River population from 2000 to 2012.

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				
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

Appendix Table IX. Summary of 2012 fall Chinook spawning surveys conducted in the lower John Day River.

				Fish	
Date	**Survey Reach**	**Length (km)**	**Redds**	**Live**	**Dead**
31-Oct-12	RKM 64 to RKM 35	30.6	0	0	0
08-Nov-12	RKM 64 to RKM 35	30.6	0	0	0
14-Nov-12	RKM 64 to RKM 24	39.4	5	2	1
15-Nov-12	RKM 24 to RKM 17	8.1	0	0	0
28-Nov-12	RKM 64 to RKM 35	30.6	1	0	0