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

Annual Technical Report

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EXECUTIVE SUMMARY

Objectives

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

2. Estimate age composition and hatchery stray fraction of the John Day River subbasin spring Chinook salmon populations.

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

Accomplishments and Findings

Spawning ground surveys for spring Chinook salmon *Oncorhynchus tshawytscha* were conducted in the John Day River basin from 8 August through 6 October 2011. We observed 1,787 spring Chinook redds while surveying 332.5 km of potential spawning habitat (203.2 km of census, 84.5 km of index, and 44.8 km of random reaches). We estimated a total of 59 redds in the 14.5 km of census area where we were denied access (54 redds in the Mainstem John Day River and 5 redds in Clear Creek of the Granite Creek System). We estimated 1,846 spring Chinook redds were constructed in the John Day River basin at an overall density of 6.42 redds/km for the survey area. We were able to determine the origin of 1,799 Chinook carcasses, 1,788 (99.4%) were of wild origin and 11 (0.6%) were of hatchery origin. Redd numbers increased from 2010 both basinwide and within the Mainstem, Middle Fork, and North Fork subbasins. Middle Fork redd counts more than doubled. The 2011 estimate of 638 redds in the Mainstem is the highest we have observed since implementing census surveys in 2000. Our spring Chinook escapement estimate for 2011 is 7,227 fish using a 3.9 fish/redd ratio observed at the Catherine Creek weir in the Grande Ronde River basin.

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. This project was funded by Pacific Coastal Salmon Recovery Funds distributed through the Oregon Watershed Enhancement Board, Contract Number 212-909.

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 will 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 Planning Council (NWPPC) 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) above the mouth of Indian Creek, in the Middle Fork John Day River (hereafter called Middle Fork; Figure 3) above Armstrong Creek, and the North Fork John Day River (hereafter called North Fork; Figure 3) above the mouth 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.

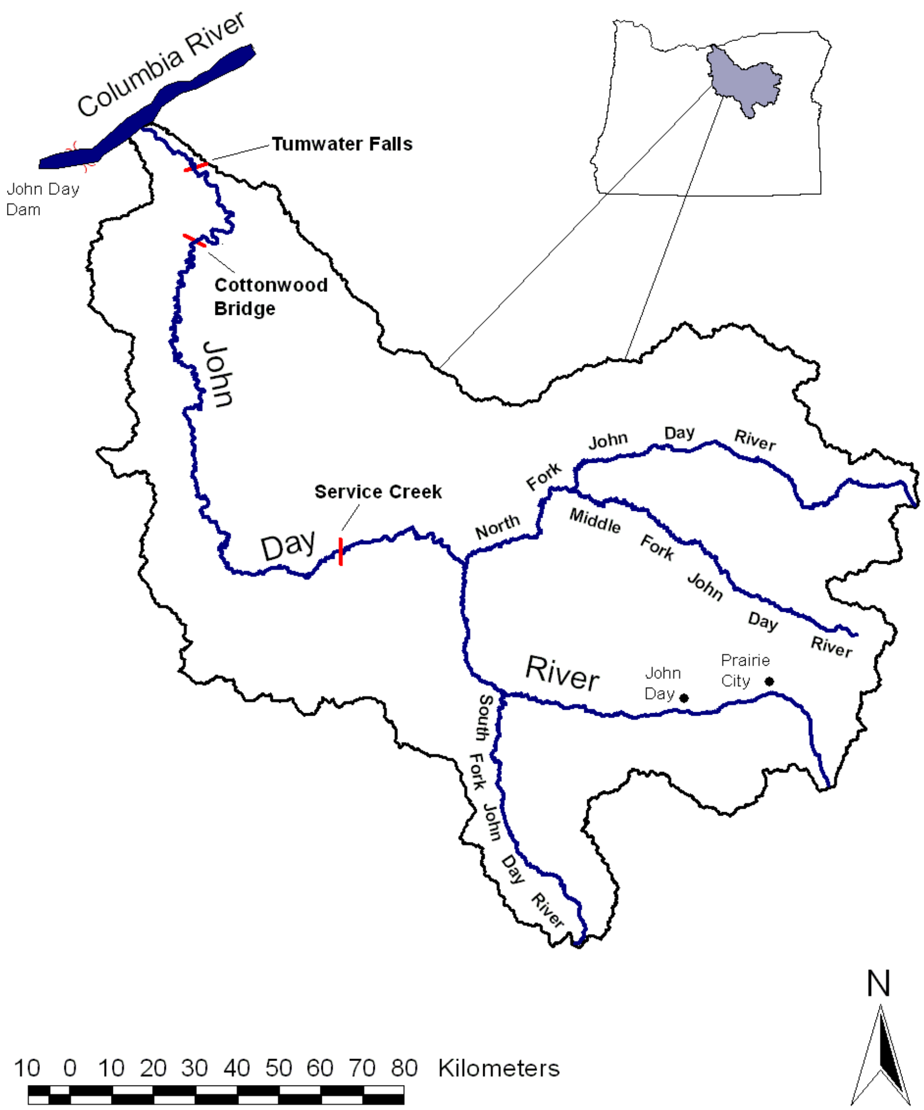

Figure 1. Map of the John Day River basin.

METHODS

Sampling Design

Spring Chinook salmon spawning surveys were conducted during the months of August and September to encompass the spatial and temporal distribution of Chinook spawning in the John Day River basin. These surveys included historic index, census, and random surveys. Index sections were surveyed to provide relative abundance comparisons with historic redd count data collected since 1964. Census surveys were conducted in areas where redds have been previously documented. Random surveys were conducted outside of the known spawning area to account for range expansion. Collectively, these surveys are assumed to provide an annual census of spawning spring Chinook salmon and their redds. Random survey sections, approximately 2 km in length, were drawn from a non-random sampling universe. The sampling universe extends from the downstream border of current census survey sections to 20 km downstream or extends from the most downstream redd observed in each Hydrologic Unit Code (HUC) to 20km downstream (4th level HUC; Mainstem, Middle Fork, and North Fork). A second sampling universe extends from the upstream border of our current census reaches to 4 km upstream or from the most upstream redd observed since 1959 to 4 km upstream. Survey sections were selected with a random number generator based on river kilometer. For every one site selected above the census section, two sites were selected below if stream length allowed. If redds were observed in a random site, that survey section was added to the census survey for all following years.

Index surveys were scheduled to take place near 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. Post-index surveys were not conducted in the Middle Fork or Granite Creek System because few live fish were observed during the index survey. Post-index counts were not included in the overall index count. Census and index surveys were conducted the same day in all spawning areas as well as in the South Fork and various tributaries of the North Fork to ensure that all spawning habitat was observed. If many live fish were observed during the initial surveys, we would return one week later to re-survey and make certain that all spawning was complete. We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork on the same day of the index for their respective streams.

Spawning Surveys

Spawning surveys were conducted by walking in an upstream direction on the Mainstem, Middle Fork, South Fork, Trail Creek, and Clear Creek, and in a downstream direction on the North Fork, Camas Creek, Desolation Creek, Granite Creek, and Bull Run Creek. Where we were denied access to one side of the river on the Mainstem, we surveyed on the permissible side only. Survey sections ranged in length from 0.01 to 13.3 km depending on accessibility and difficulty. Typically, teams of two surveyors walked the stream for safety reasons and to ensure accuracy when distinguishing redds. In each section, surveyors recorded the number of new redds, live adult fish (on- or near-and off-redd), and carcasses. On reaches surveyed more than once, 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 recorded locations of redds with a GPS 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 the carcasses were dissected to verify sex. Percent egg retention was noted for every female and was estimated to the nearest 25%. 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.

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 wild and hatchery carcasses with a MEPS length of < 550 mm and > 650 mm. 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 readers to determine saltwater age. We examined age structure separately for the Mainstem, Middle Fork, and North Fork populations. We assumed all fish were age-2 smolts. Carcasses from 550 to 650 mm were assumed to be age-4 fish (2 years in freshwater and 2 years in saltwater), based on the size-at-age distribution of carcasses examined during previous years. Carcasses with a MEPS length of < 550 mm were either age-3 or age-4 fish, depending on the saltwater age read from the scale. Carcasses with a MEPS length of > 650 mm were either age 4, 5, or 6; depending on the saltwater age read from the 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. Tails were removed from all carcasses to prevent repeat sampling and carcasses were then returned near their original position in the stream. 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.

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 (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. Prior to 2009, redd density estimates in sampled reaches were expanded to areas where surveyors were denied access. However, after reviewing historic data, it is apparent that spawning habitat in areas we are denied access is not representative of the entire spawning reach, primarily in the section from Indian Creek to Prairie Wood Products on the Mainstem. Issak and Thurow (2006) suggest that Chinook redds are not spatially distributed in a random fashion, but are clustered, and these clusters are driven by habitat and run size.

In order to better estimate the number of redds constructed in the Mainstem and account for this non-random distribution, we used a spatially-stratified reach rank approach. Using the 1:100,000 digital stream network layer, we divided the Mainstem spawning grounds into 500-m reaches. We then used redd locations from 2002-2011 to determine the number of redds in each reach for every year, with the 2002 spawning year providing the only complete dataset. Each reach was ranked based on the number of redds observed within individual years. From 2003 to 2011, we appended the rank from the 2002 rank order to the current year dataset and each subsequent reach rank was ordered one rank higher. We then used liner regression of reach rank versus $\log_e$ (redds [n]) to fit a model predicting redds in sections where we were denied access. In certain individual years, the GPS data did not account for all redds observed in the areas we surveyed. When this was the case, we used the proportion of redds observed to redds georeferenced in order to estimate the total number of redds based on the regression model. Because we were denied access to a relatively short stream reach in Clear Creek, we expanded our redd density estimate from the Clear Creek census count to the reach where we were denied access.

We evaluated the relationship between index and census redd counts at the population level. We used linear regression to determine if the census redd counts for 2000 to 2011 were significantly related to index redd counts. Next, we plotted the residuals from each of these three regressions against streamflow (Service Creek gauging station) to evaluate whether deviations in the index:census regression were related to streamflow. Finally, we developed a linear regression for the 2000 to 2010 index:census data and used this equation to predict the 2011 census count based on the 2011 index count. The predicted census count was then compared with the observed census count to evaluate the necessity of census surveys.

A lack of weir counts in the basin prevents basin-specific fish/redd estimates. Therefore, we estimated spawner escapement by multiplying the number of redds by the fish/redd ratio estimated from the Catherine Creek weir located in the adjacent Grande Ronde River basin (ODFW unpublished data).

PIT Tag Detection-Recapture Escapement Estimation

During 2011 we developed an alternate method for estimating the abundance of adult Chinook in the John Day River basin. Several thousand Chinook smolts were tagged annually with PIT tags when emigrating from the John Day River basin (DeHart et al. 2012). These Chinook were 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 seen 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):

$$N = \frac{M \cdot C}{R}$$

Escapement to the John Day River basin (*N*) was estimated where *M* is the number of returning adult Chinook that were originally PIT tagged when emigrating from the John Day River and subsequently detected crossing Bonneville Dam, *C* is the total number of intact carcasses scanned for a PIT tag on spawning ground surveys (inclusive of both males and females), and *R* is the 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 census redd counts among the 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 relationship among redd counts for John Day populations and indicators of ocean productivity. Specifically, we used Pacific Decadal Oscillation (PDO; data available online at: http://jisao.washington.edu/pdo/PDO.latest) values for the summer (May to September mean) of the year that age-4 Chinook (the dominant age class for females in all three populations) entered the ocean. The PDO index is an indicator of ocean productivity, as measured by upwelling and temperature. 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. We used Pearson correlation to evaluate whether redd counts were correlated with these PDO indicators.

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 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 stock-recruitment curves. We fit these recruitment curves for each of the populations.

To estimate smolts per redd, juvenile 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 fish upstream of the trap and then counting the number of recaptured fish (Thedinga et al. 1994). 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 census redd abundance dataset from 2000 to present. Total annual 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:

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

The Upper Mainstem and Middle Fork populations have a low proportion of age-5 females. For these two populations we analyzed the 2000 to 2007 brood years. Although the age-5 females from the 2007 brood are yet to return, 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 2006 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 indicated higher than expected productivity, whereas a negative residual indicated 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 brood year redd abundance (e.g., Peterman et al. 1998, Mueter et al. 2007).

RESULTS

Redd Counts

We surveyed 332.5 km of potential Chinook spawning habitat within the John Day River basin in 2011 (Table 2). A total of 78.3 km of spawning habitat was surveyed within the historic index areas of which we were denied access to 6.3 km (Table 2; Figures 2 and 3). The census area included 203.2 km of spawning habitat, 8.1 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 on the same day of the index surveys for their respective streams for a total length of 44.8 km of stream (Table 2; Figures 2, 3, and 4).

Table 2. Access status, survey type, and reach length (km) for 2011 spawning survey reaches in the John Day River basin.

		Survey Type		
Stream Name	**Access Allowed**	**Census**	**Index**	**Random**
Mainstem				
Bridge Creek	Y	5.8		7.5
Canyon Creek	Y			2.4
Deardorff Creek	Y	2.0		
John Day River	**N**	**6.9**	**6.3**	
John Day River	Y	7.6	11.4	13.9
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		
Granite Boulder Creek	Y	2.3		
M.F. John Day River	Y	27.7	19.8	6.4
Vinegar Creek	Y	2.8		
North Fork				
Big Creek	Y	0.1		
Camas Creek	Y	0.8		
Crawfish Creek	Y	0.2		1.4
N.F. John Day River	Y	63.2	28.5	6.4
Trail Creek	Y	3.0		
W.F. Meadowbrook	Y			3.5
Granite Creek System				
Granite Creek	Y	7.5	9.0	
Clear Creek	**N**	**1.2**		
Clear Creek	Y	4.3	4.7	
Bull Run Creek	Y	2.3	4.9	
Desolation Creek				
Desolation Creek	Y	35.3		
S.F. Desolation Creek	Y	1.8		
Total		**203.2**	**84.5**	**44.8**

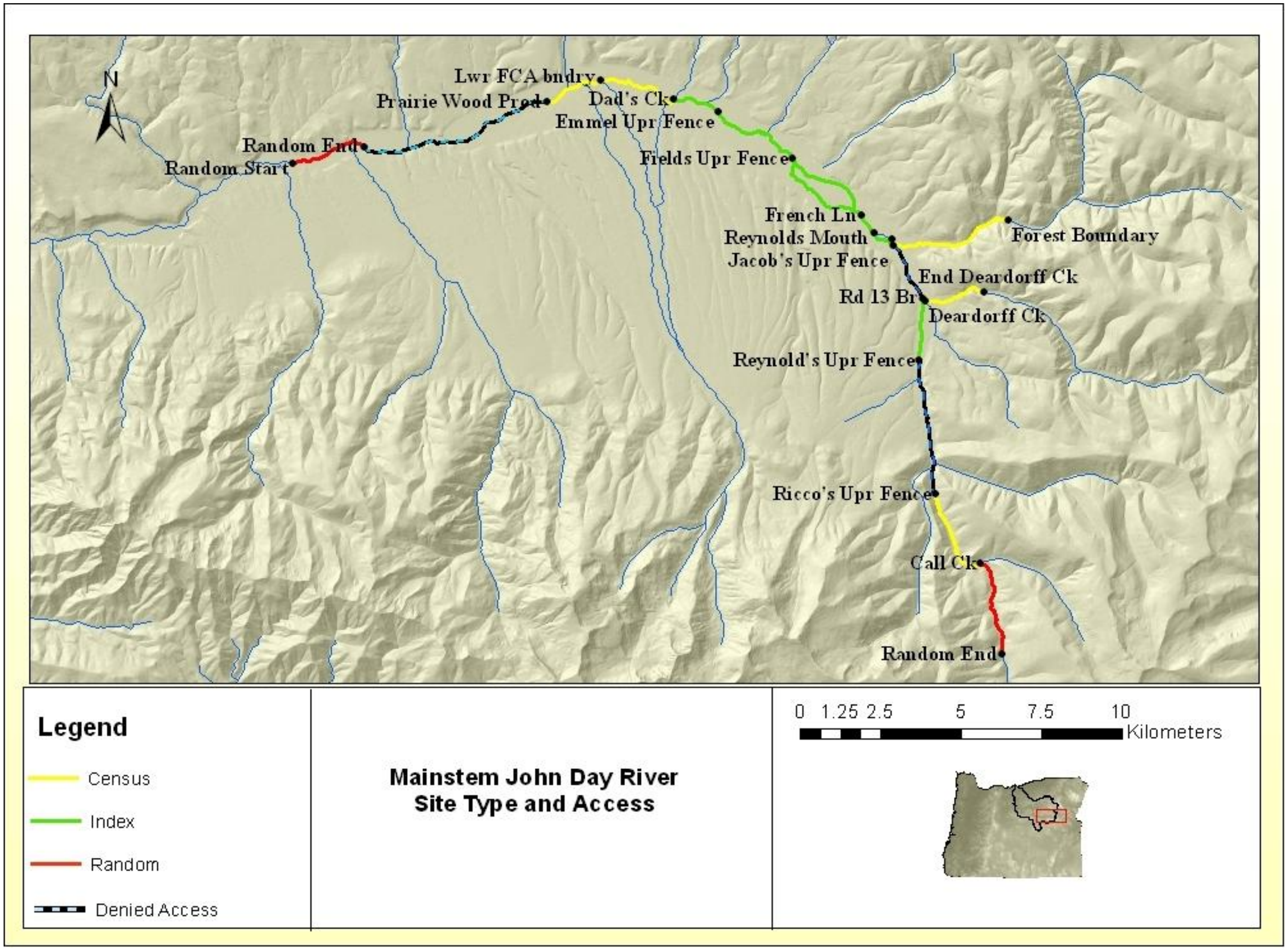

Figure 2. Map of the Mainstem spring Chinook spawning ground survey sections.

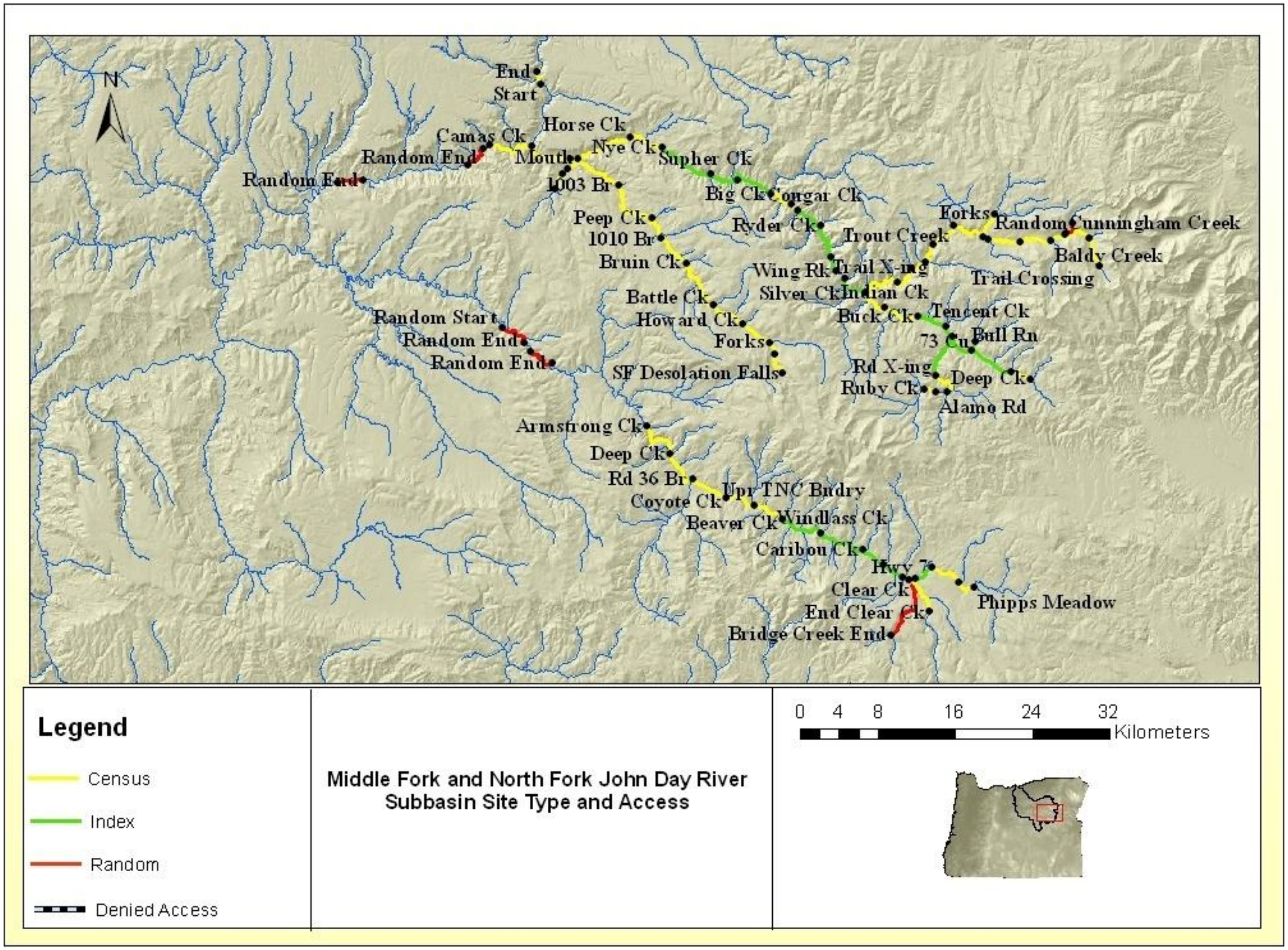

Figure 3. Map of the Middle Fork and North Fork spring Chinook spawning ground survey sections.

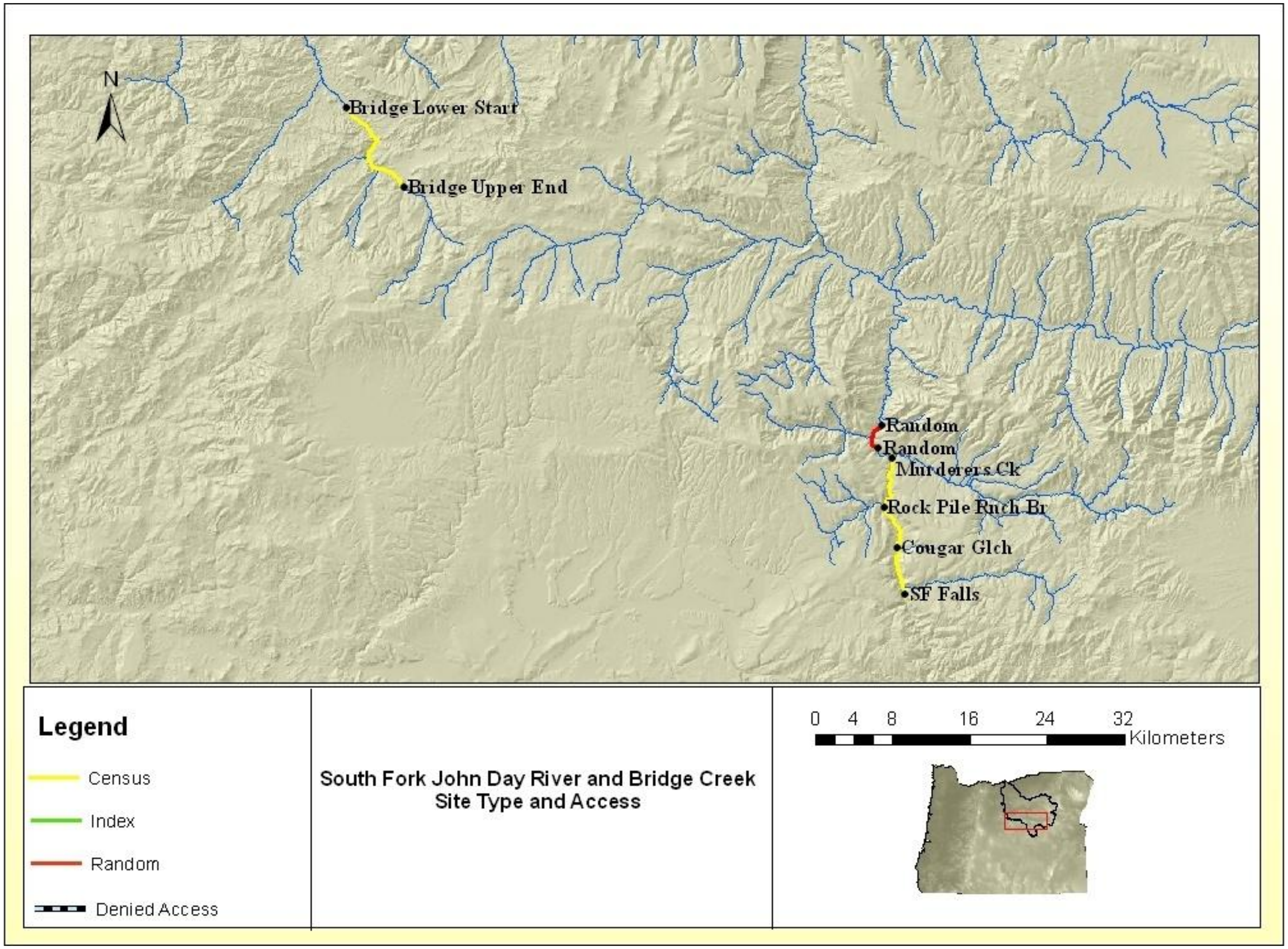

Figure 4. Map of the South Fork and Bridge Creek spring Chinook spawning ground survey sections.

We observed 1,787 spring Chinook redds within the John Day River basin in 2011 (Table 3). In the 14.5 km of combined census and index reaches where we were denied access, we estimated a total of 59 redds (54 redds in the Mainstem and 5 redds in Clear Creek, GCS). There was a statistically significant relationship ($r^2 = 0.91$, p-value <0.001; Figure 5) between reach rank and $\log_e$ (redds [n]) to estimate redds in the Mainstem reaches where access was denied. This resulted in a total estimated 1,846 spring Chinook redds in the John Day River basin in 2011. The estimated redds composed 3.2% of the total redd abundance. We estimated an overall density of 6.4 redds/km for the entire survey area, excluding random reaches where spawning was not present (Table 4). Of the 1,846 estimated redds in the basin, 1,134 were in the historic index reaches at a density of 13.4 redds/km. Six redds were observed in random reaches of the Mainstem near Indian Creek. The Mainstem accounted for 37.5% of the total redds observed in 2011, the Middle Fork had 27.4%, and the North Fork had 35.2%. We did not observe any redds in the South Fork. The Mainstem had the highest density of redds with 15.8 redds/km, followed by the Middle Fork with 8.5 redds/km, and the North Fork with 3.9 redds/km (Figures 6, 7, and 8).

Table 3. Total number of redds and carcasses observed during spring Chinook salmon spawning surveys in the John Day River basin, 2011.

	Redds (n)			**Carcasses[a] (n)**	
Stream Name	**Census**	**Index**	**Random**	**Wild**	**Hatchery**
Big Creek (NFJD)	0			0	0
Bridge Creek (LMJD)	1			0	0
Bridge Creek (MFJD)	1			0	0
Bull Run Creek (GCS)	0	14		10	0
Camas Creek (NFJD)	0			0	0
Canyon Creek (UMJD)	0			0	0
Clear Creek (GCS)	20	24		65	1
Clear Creek (MFJD)	33			36	1
Crawfish Creek (NFJD)	0			0	0
Deardorff Creek (UMJD)	27			19	0
Desolation Creek (NFJD)	49			37	1
Granite Boulder Creek (MFJD)	4			1	0
Granite Creek (GCS)	21	46		118	2
Mainstem John Day River	145	468	6	353	2
Middle Fork John Day River	97	368	0	811	4
North Fork John Day River	253	214	0	334	0
Reynolds Creek (UMJD)	45			0	0
South Fork John Day River	0		0	0	0
Trail Creek (NFJD)	8			3	0
Vinegar Creek (MFJD)	2			1	0
W.F. Meadowbrook Creek (NFJD)	0			0	0
Total	**706**	**1,134**	**6**	**1,788**	**11**

[a]*origin was unknown for 135 carcassses*

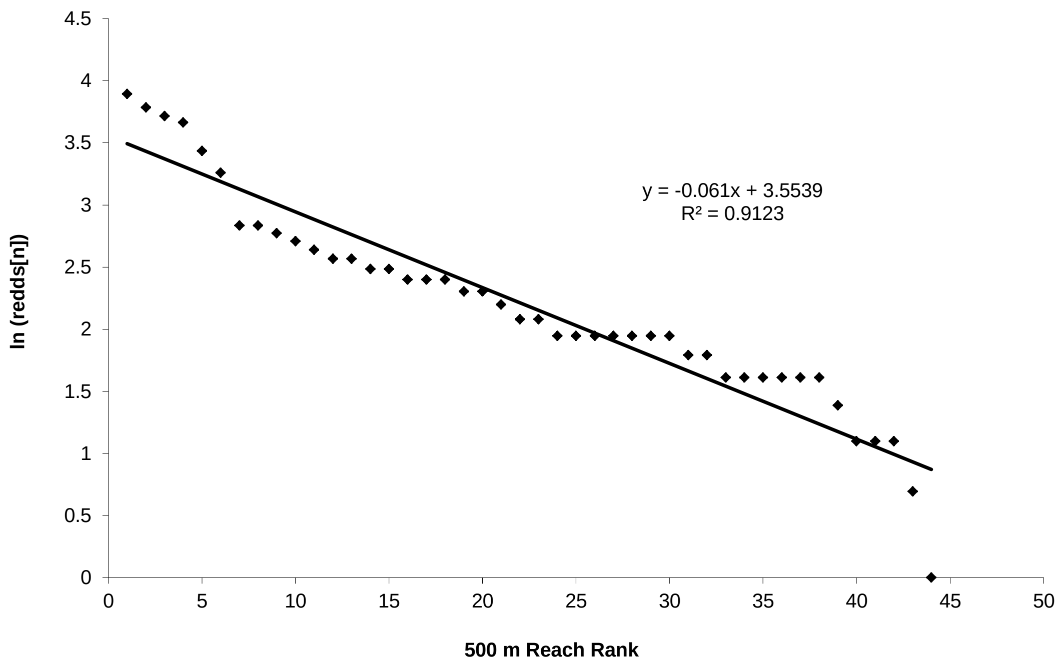

Figure 5. Mainstem ranked reaches versus $\log_e$ redd counts.

Table 4. Distance surveyed, number of unique redds observed, redd density, fish per redd estimate, and spring Chinook spawner escapement for the John Day River basin from 2000 to 2011.

Year	Distance (km)	Redds	Redds/km	Fish/Redd	Escapement
2000	236.1	1,869	7.9	1.69	3,163
2001	243.2	1,863	7.7	4.20	7,822
2002	255.9	1,959	7.7	2.90	5,676
2003	243.0	1,354	5.6	2.94	3,980
2004	260.0	1,531	5.9	2.27	3,469
2005	267.5	878	3.3	2.14	1,878
2006	264.6	909	3.4	2.42	2,197
2007	267.5	746	2.8	2.96	2,212
2008	264.6	963	3.6	2.15	2,072
2009	265.9	1,221	4.6	3.24	3,958
2010	268.2	1,440	5.4	2.60	3,744
2011	287.7[a]	1,846	6.4	3.93	7,247

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

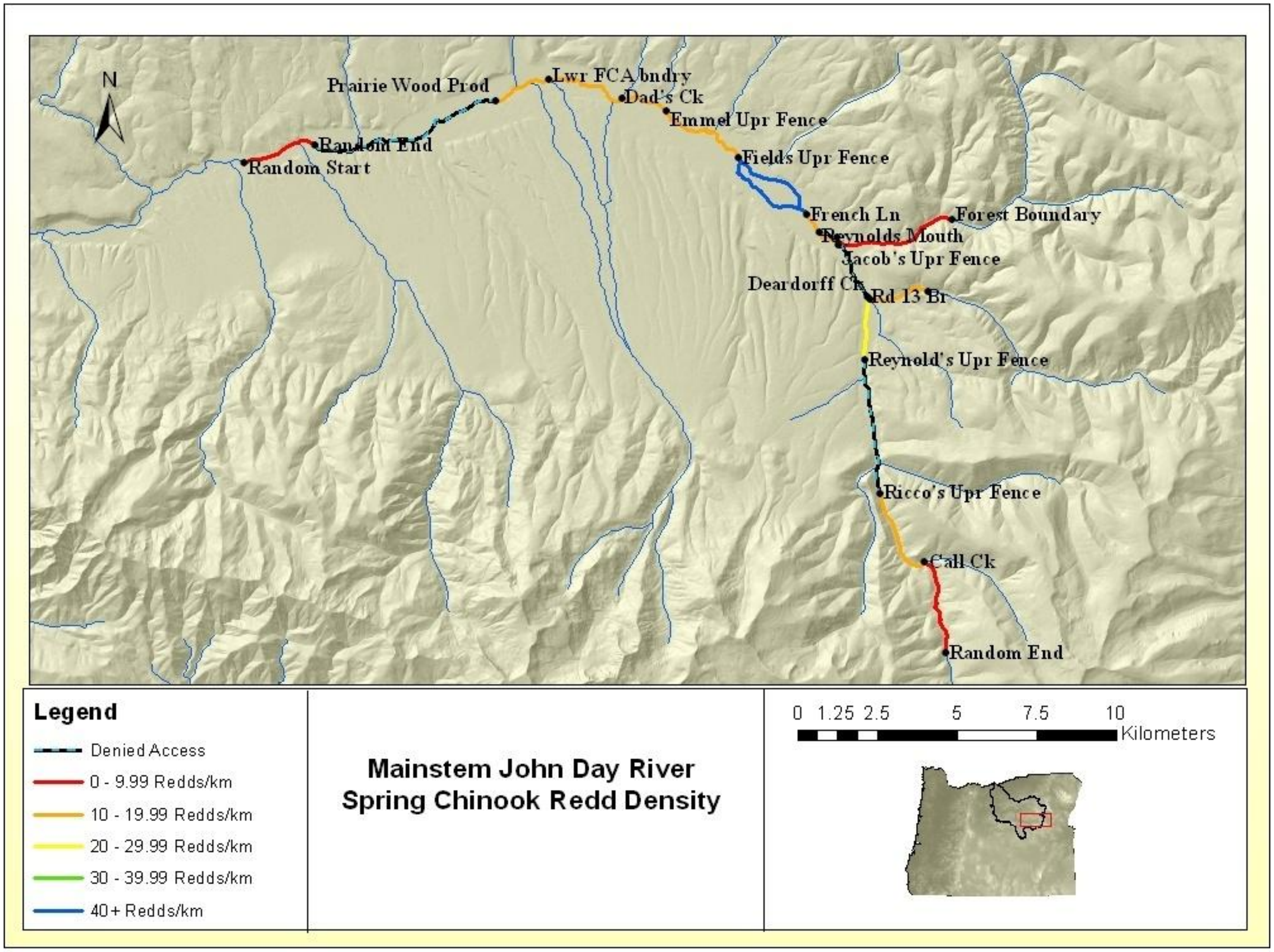

Figure 6. Map of site locations and density of redds observed in the upper Mainstem John Day River subbasin during 2011 spring Chinook spawning surveys.

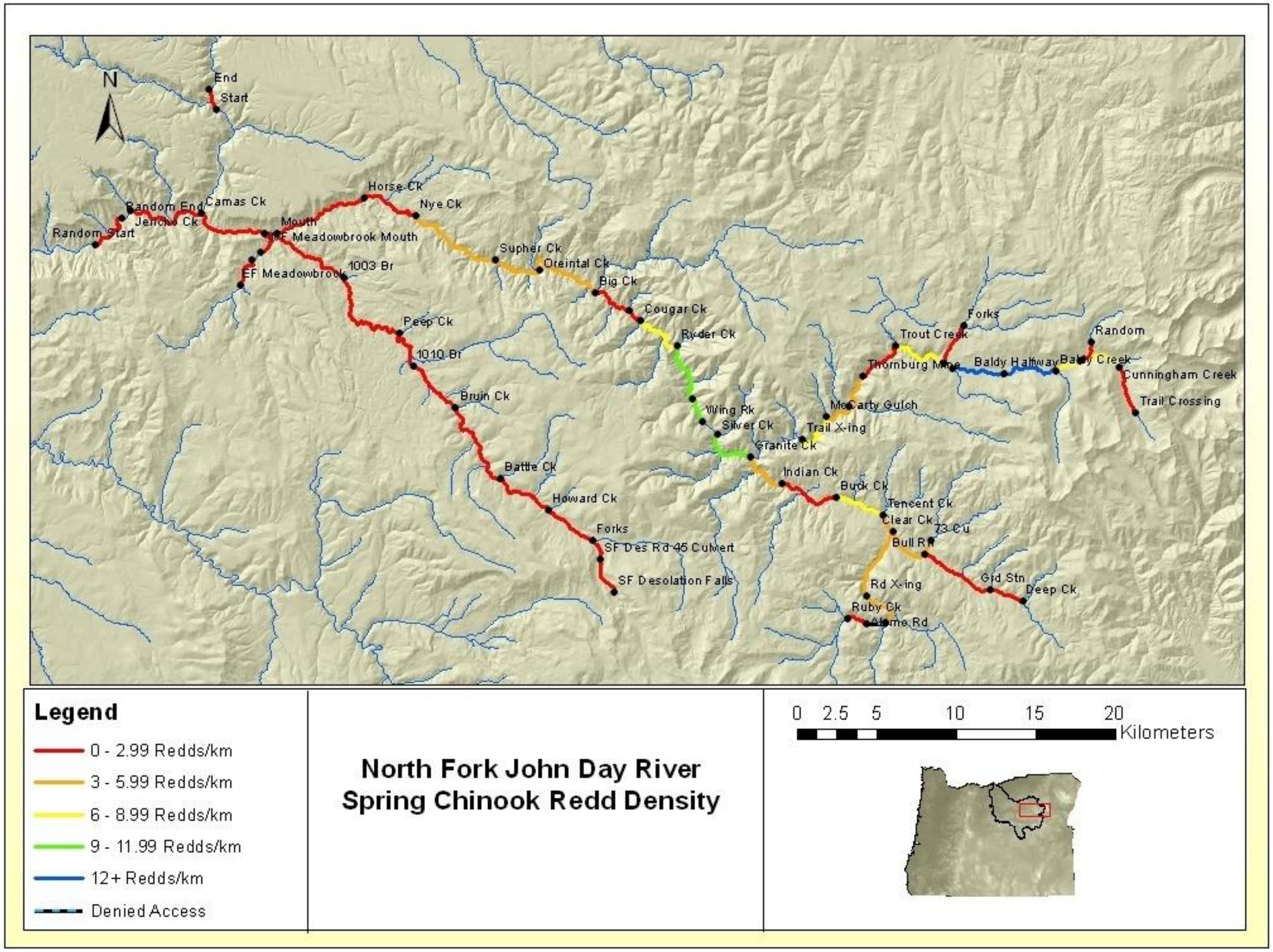

Figure 7. Map of site locations and density of redds observed in the North Fork John Day River subbasin during 2011 spring Chinook spawning surveys.

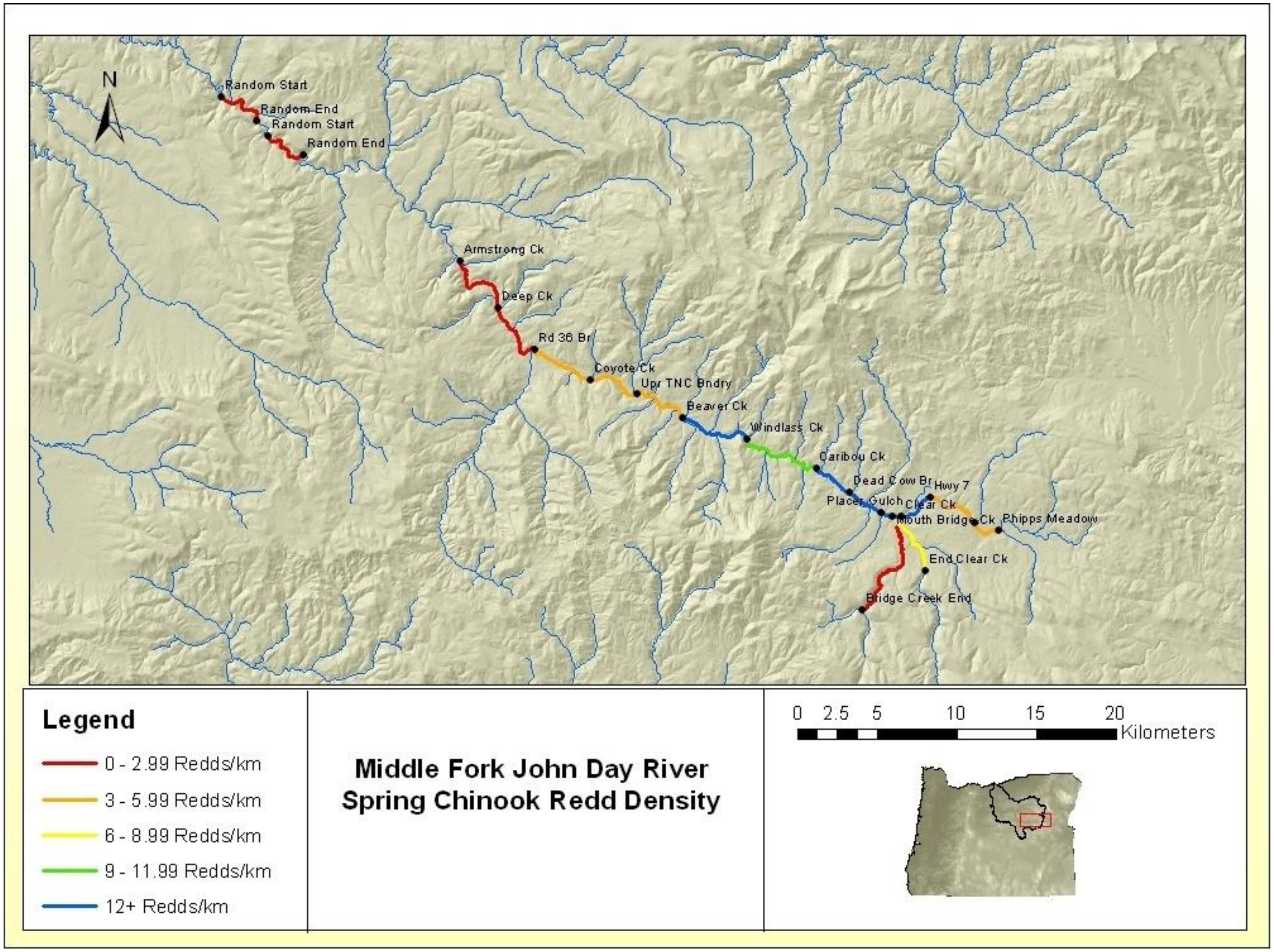

Figure 8. Map of site locations and density of redds observed in the Middle Fork John Day River subbasin during 2011 spring Chinook spawning surveys.

Linear regression analysis of index and total redd counts from 2000 to 2011 revealed significant relationships for all three John Day populations (Mainstem R = 0.93, P < 0.01, Middle Fork R = 0.97, P < 0.01, and North Fork R = 0.95, P < 0.01) (Figure 9). Plotting the residuals from the regression analysis against mean daily discharge in August for the John Day River at Service Creek (rkm 252) suggests discharge has an effect on redd distribution, particularly in the Mainstem and North Fork populations (Figure 9).We also found a significant linear relationship between basinwide census and index counts for 2000 to 2010 (R = 0.95, P = <0.001). Applying the observed 2011 index count of 1,134 redds to this equation predicted a total redd count of 1,573 for 2011. This prediction underestimated the observed total redd count of 1,846 by 15%.

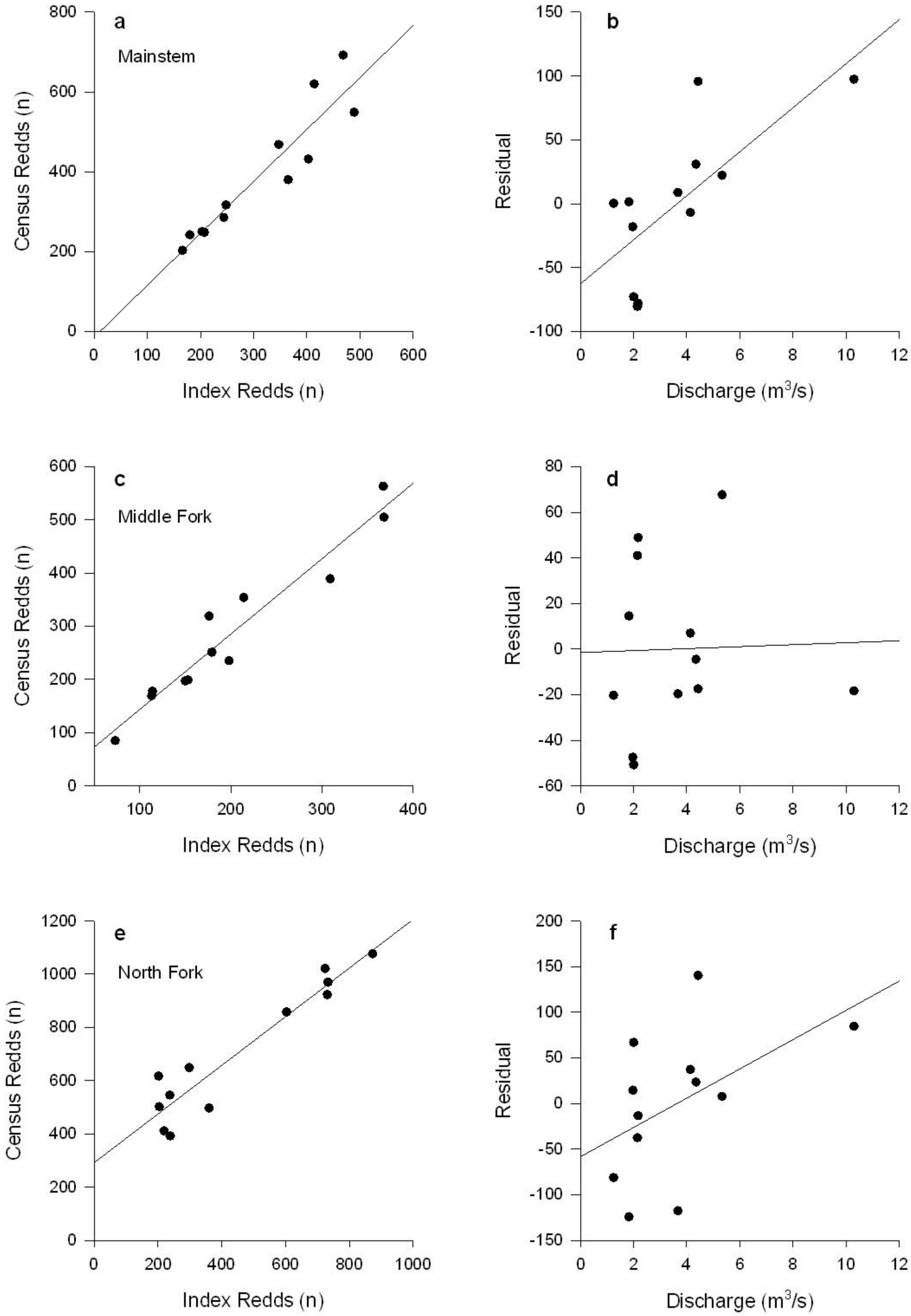

Figure 9. Regressions between census and index redd counts from 2000 to 2011 spawning ground surveys and the residuals from these regressions plotted against August discharge of the John Day River for spawning populations in the Mainstem (a and b), Middle Fork (c and d), and North Fork (e and f) of the John Day River.

Redd abundance in the John Day River basin has varied over the past decade, however, total redd counts appear to have steadily increased in the last four years (Figure 10). Annual Middle Fork and North Fork population census redd counts were significantly correlated with each other (Table 5), however, the Mainstem was not significantly correlated with either the Middle Fork or North Fork. Redd counts in other northeast Oregon rivers have also increased over the last four years (Figure 11). Redd counts for the Mainstem were significantly correlated to both Grande Ronde and Imnaha river basins, however, the Middle Fork and North Fork were not correlated with either the Grande Ronde or Imnaha basins (Table 5, Appendix Table VII). Redd counts for every basin 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 census Mainstem, Middle Fork and North Fork John Day River basin Chinook redd counts from 2000 to 2011, Imnaha River census redd counts from 2000 to 2011, Grande Ronde River census redd counts from 2000 to 2011, and Pacific Decadal Oscillation (PDO) values observed in the Pacific Ocean during the summer two years prior to the redd count year (Imnaha and Grande Ronde data provided by Joseph Feldhaus, ODFW). Significant correlations ($\alpha = 0.05$) are indicated in bold, nearly significant ($P = 0.06$) 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	0.52	0.17	**0.77**	**0.60**	*-0.56*
Middle Fork Redd Count	-	**0.63**	0.21	0.25	-0.28
North Fork Redd Count	-	-	-0.02	0.45	**-0.61**
Grande Ronde Redd Count	-	-	-	**0.58**	*-0.55*
Imnaha Redd Count	-	-	-	-	**-0.70**

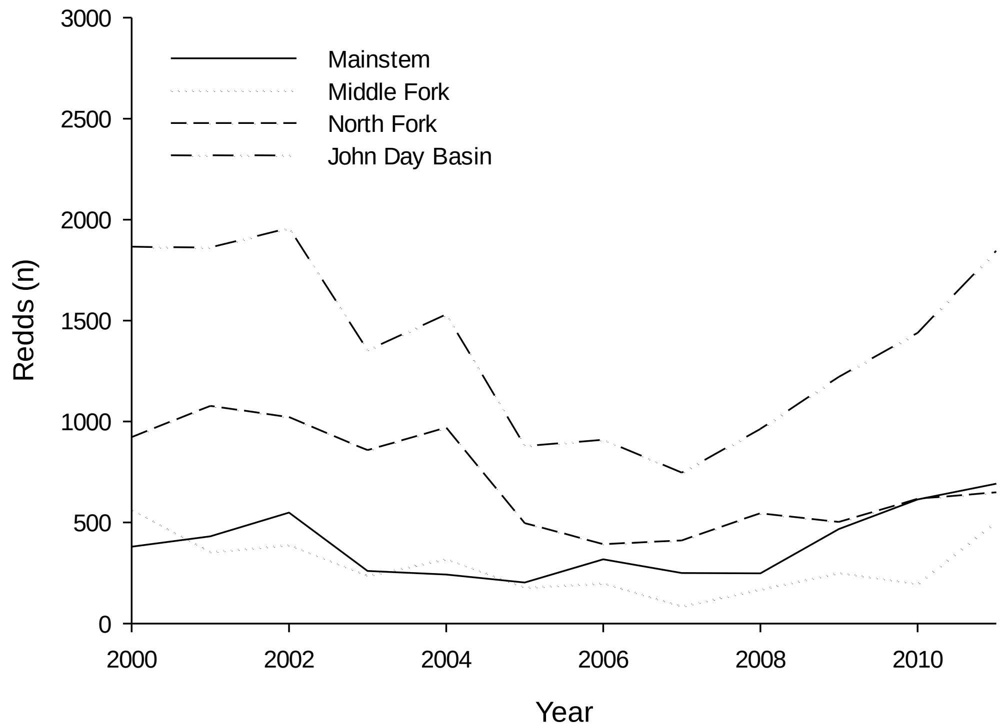

Figure 10. Redd totals from 2000 to 2011 for three John Day River basin populations, and the basinwide total.

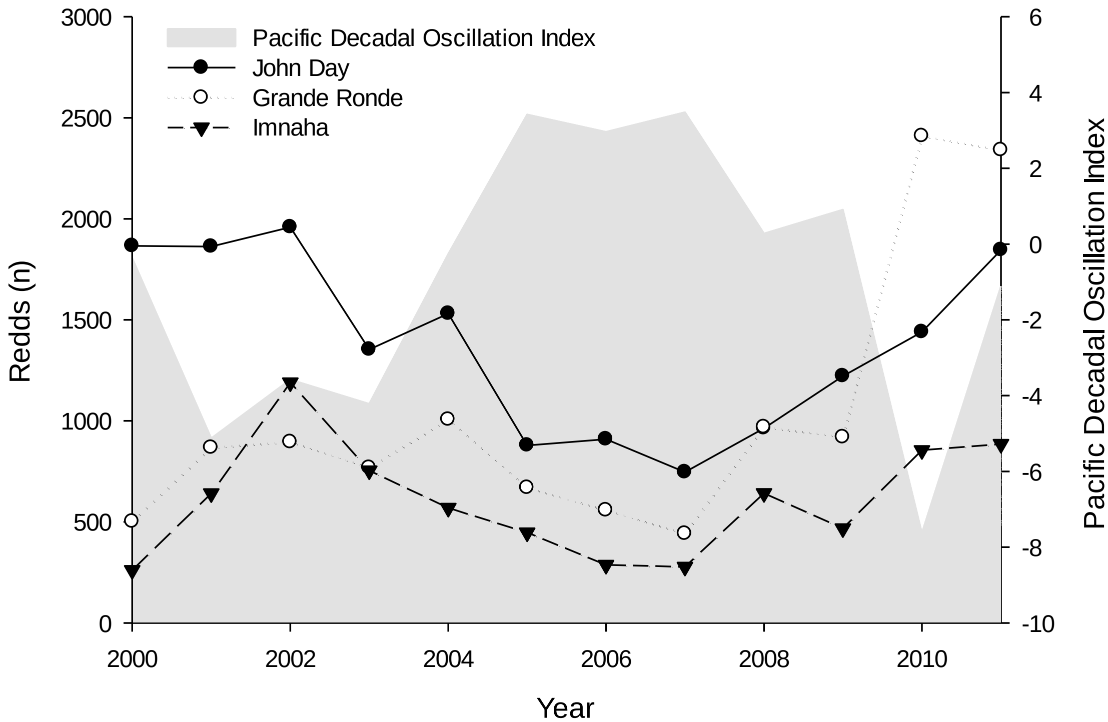

Figure 11. Redd totals from 2000 to 2011 for John Day, Grande Ronde, and Imnaha river basins plotted with summer values of the Pacific Decadal Oscillation index. Pacific Decadal oscillation index values are for the summer of entry for age-4 Chinook.

Carcass Recovery

In 2011, we recovered 1,945 carcasses representing 27% of the estimated spring Chinook spawner escapement (Table 6). We sampled approximately 15% of the estimated carcasses in the Mainstem, 45% in the Middle Fork, and 25% in the North Fork. We were able to determine origin of 1,799 carcasses, 11 fish had clipped adipose fins, two were in the Mainstem, five were in the Middle Fork, and four were in the North Fork population. The proportion of hatchery carcasses observed in 2011 (0.6%) 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 did not recover any Lookingglass Hatchery CWTs this year, a trend that we have seen in surveys from previous years (Schultz et al. 2006, Schultz et al. 2007, Wilson et al. 2007, Wilson et al. 2008, McCormick et al. 2009). Two of the ten snouts we collected from adipose-clipped fish contained coded wire tags. One fish was a jack that was released in the Grande Ronde River and we recovered in Granite Creek of the North Fork basin. The other was an age-4 female released in the Lostine River, which we recovered in Clear Creek of the Middle Fork basin. Scales were taken from the jack (age 3) and it was aged correctly by scale readers.

We determined the sex of 1,746 carcasses, 883 (50.6%) females and 863 (49.4%) males. We estimated the age of 1,632 carcasses, 576 from scale pattern analysis and

1,038 were within the 550–650 mm MEPS length range that we assumed to be age-4 fish. There was a total of 108 age-3 (7 %), 1,327 age-4 (81 %), and 197 age-5 (12 %) fish (Figure 12; Table 6). All age-3 Chinook carcasses recovered were males. The North Fork had the highest proportion of recovered age-5 fish with 24% (Table 7).

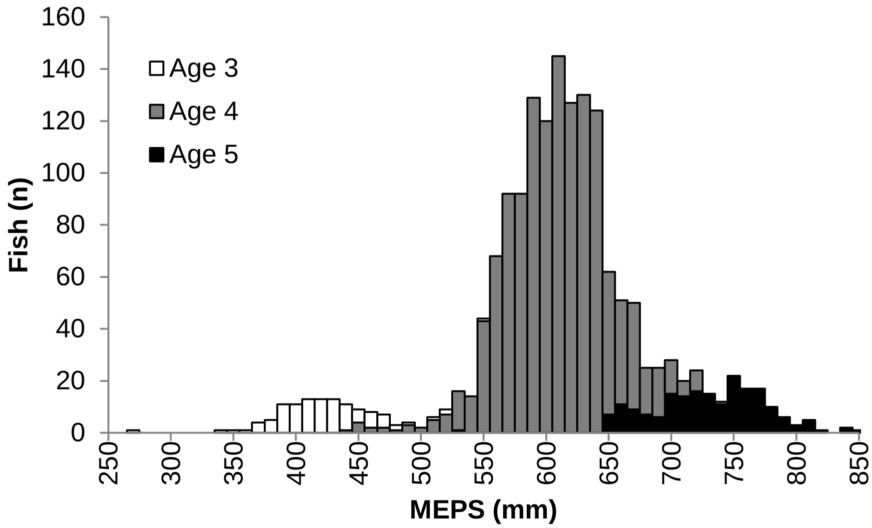

Figure 12. Length frequency and age distribution of Chinook carcasses (n = 1,632).

Of the 817 female carcasses for which we estimated egg retention, 722 (88%) were completely spawned, 52 (6%) were partially spawned, and 43 (5%) were pre-spawn mortalities (≥ 75% egg retention). Twenty-two (51%) of pre-spawn mortality fish were recovered in the North Fork.

A total of 141 kidney samples were collected from salmon carcasses and analyzed for the Rs antigen using the ELISA method. Six of the 141 samples (4%) had a clinical ELISA OD value above 1.0 (ranging from 1.206 to 2.449 OD units) indicating the presence of BKD. Four of the infected fish were sampled in the Mainstem and two were from the North Fork. All six were females of wild origin. One of the Mainstem females had 100% egg retention and one of the North Fork females had 50% egg retention, the other four fish had 0% egg retention. One other wild female in the North Fork exhibited a moderate positive OD value (0.604) and all other samples had negative or low positive OD values of ≤ 0.240 (Appendix C). Results from 300 kidney samples collected in the Grande Ronde River basin determined 1.7% of fish had clinical ELISA OD values (Julie Keniry, ODFW Microbiology Technician, personal communication).

Table 6. Age, mean MEPS length (mm), standard error (SE), sample size (n), range (mm), and percentage of total known-sex aged Chinook from 2011 carcass recovery.

	Male					Female				
Age	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**
3	425.9	3.9	101	273–555	6	-	-	0	-	0
4	612.5	1.9	604	445–727	38	611.2	1.3	698	460–742	44
5	741.2	6.6	62	535–844	4	731.0	3.8	128	652–850	8

Table 7. Percentage of known-sex aged Chinook carcasses by population for 2011.

		% Males by Age			% Females by Age		
	n	**3**	**4**	**5**	**3**	**4**	**5**
Mainstem	332	9.0	28.6	4.2	0.0	51.2	6.9
Middle Fork	746	3.6	45.8	2.0	0.0	46.5	2.0
North Fork	515	8.5	32.4	6.4	0.0	35.1	17.5
Basin Total	**1593**	**6.3**	**37.9**	**3.9**	**0.0**	**43.8**	**8.0**

Redd Count Expansion Escapement Estimation

Applying the 2011 fish per redd ratio of 3.9 observed above the Catherine Creek weir (Grande Ronde River basin) to the John Day River basin, we estimate an escapement of 7,247 spring Chinook spawners in the John Day River basin for 2011 (Table 4). We estimate that 2,716 fish spawned in the Mainstem, 1,983 spawned in the Middle Fork, and 2,548 spawned in the North Fork. The 2011 fish per redd and related escapement estimate are the second highest recorded since 2000.

PIT Tag Detection-Recapture Escapement Estimation

A total of 1,591 carcasses (some of which had been scavenged) were scanned for PIT tags during the spawning ground surveys and 47 tags were recovered (Table 8). One PIT tag code was omitted from this summary due to transcription error. Nine PIT-tagged carcasses were female and 38 were male, all of them were wild origin. Twenty-one carcasses had been tagged as juveniles in the Middle Fork and were all recovered in that subbasin. One fish was tagged as a juvenile in the upper Mainstem and later recovered there. Eleven fish were tagged as adults between April and July of 2011; two were tagged in the Columbia River (rkm 0–49), eight were tagged in the adult fish facility at Bonneville Dam (rkm 234), and one was tagged at Lower Granite Dam in the Snake River (rkm 522.173). This fish, possibly a jack (MEPS = 454), traveled approximately 792 km after being tagged at Lower Granite Dam on 8 July and was recovered in Granite Creek near the mouth of Clear Creek (rkm 351.298.142.8). A similar wandering event was observed for a male that was tagged in the John Day River as a smolt in March 2009 and was detected moving through the Columbia and Snake rivers to Lower Granite Dam in May 2011 before homing to the Middle Fork to spawn.

Table 8. Spring Chinook PIT recoveries from spawning ground surveys 2009–2011.

	Intact Wild Carcasses Scanned		Carcasses with John Day Origin PIT Tags[b]		Carcasses with Out of Basin Origin PIT Tags	
Year	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
2009	124	138	3	1	1	0
2010	268	249	6	0	3	1
2011[a]	747	759	31	4	6	5

[a] *Does not include 42 carcasses of unknown sex*

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

Detections at Bonneville Dam indicated that 266 John Day origin PIT-tagged Chinook passed the dam in 2011. Spawning surveys scanned a total of 1,548 intact wild origin carcasses. 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. This resulted in a total of 63 estimated recaptured adults. Estimated wild spawner abundance was 6,520 (95% CI: 5,333 to 8,101)

Population Productivity Analyses

We estimate that freshwater productivity in the Mainstem was 176 smolts per redd (95% CI: 158–198) and 85 smolts per redd (95% CI: 71-104) in the Middle Fork for the 2009 brood year. These values are 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 13 and 14).

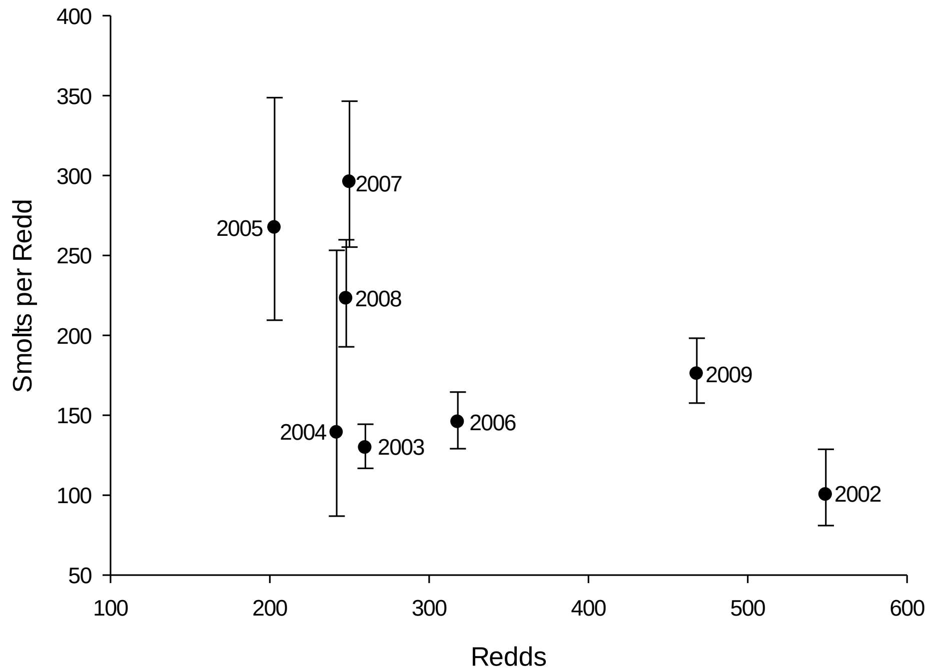

Figure 13. Estimated smolts produced per redd for brood years 2002 through 2009 for the Mainstem John Day Chinook population. Error bars are 95% Confidence Intervals.

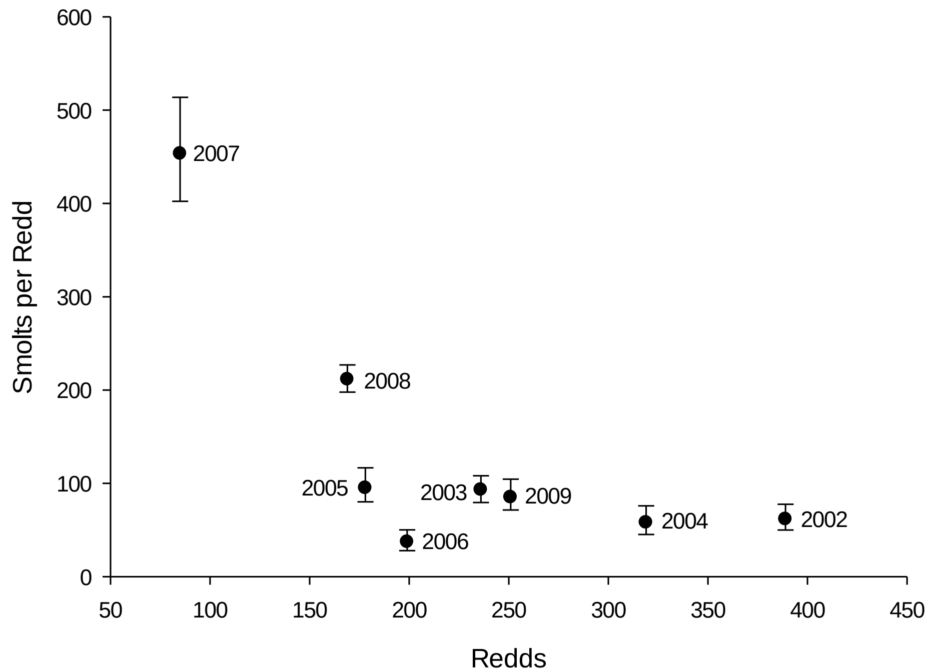

Figure 14. Estimated smolts produced per redd for brood years 2002 through 2009 for the Middle Fork John Day Chinook population. Error bars are 95% Confidence Intervals.

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 15a). 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 15c). 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 15e).

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 15b). Residuals for the Middle Fork (Figure 15d) and North Fork (Figure 15f) do not appear to share this pattern. Residuals for both of these populations appear symmetrically distributed about zero, with only slight trends over time.

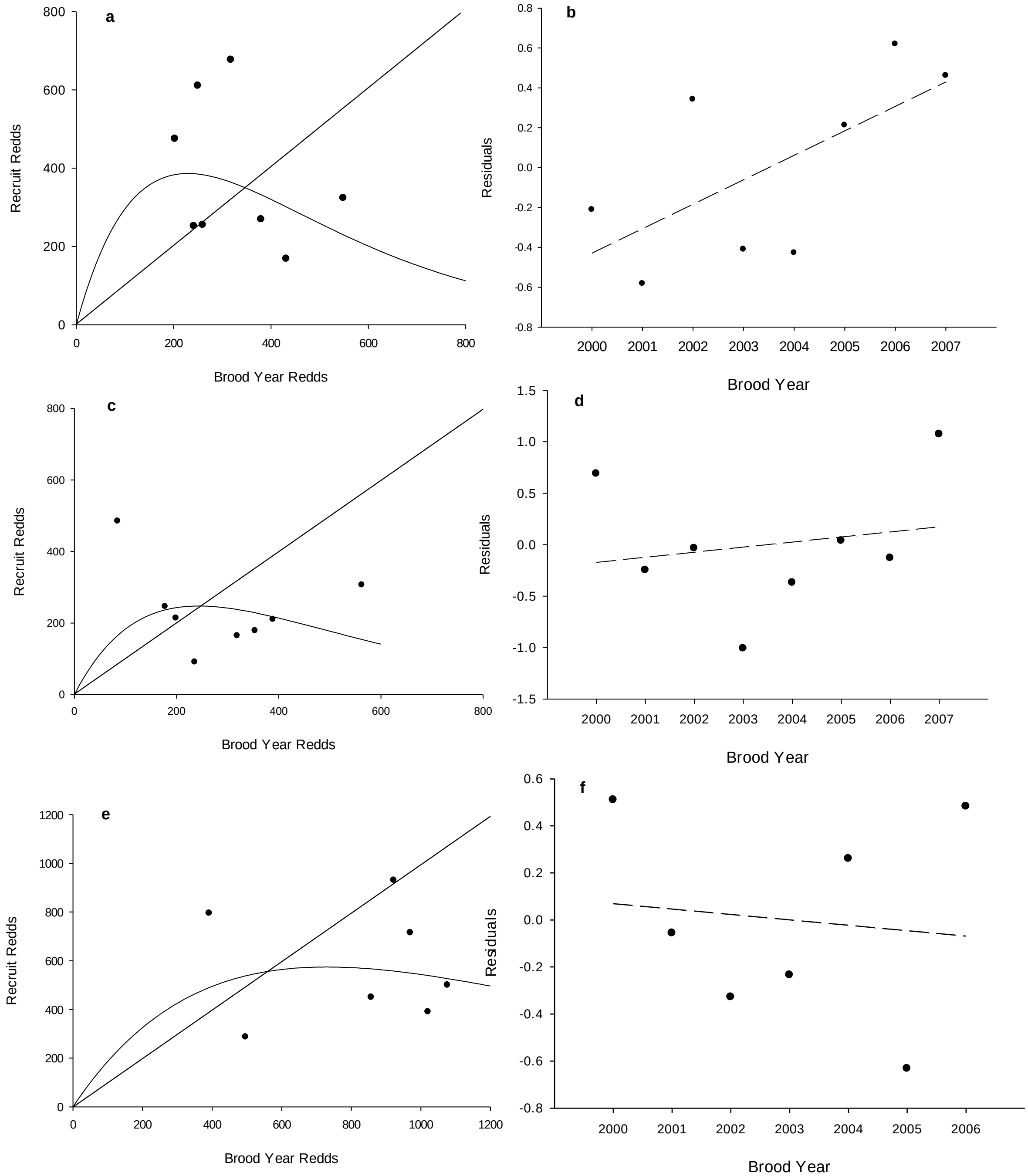

Figure 15. Comparison of Ricker stock-recruitment curves and associated residual versus brood year plots for Chinook spawning populations in the Mainstem (a and b), Middle Fork (c and d), and North Fork (e and f) of the John Day River. Diagonal lines on panels a, c, and e are 1:1 replacement lines. Dashed lines in panels b, d, and f are linear regression lines fit to the residuals to illustrate trends over time.

DISCUSSION

John Day spring Chinook populations show trends in abundance that are similar to other northeast Oregon basins and appear driven by density-independent factors such as ocean temperatures (i.e., PDO values). Recruitment trends within John Day populations, however, are likely driven by density-dependent factors. This year, 2011, marked the twelfth consecutive year of spring Chinook census monitoring in the John Day and adjacent river basins in northeast Oregon. This joint sampling effort has produced an extensive data set allowing for detailed analyses and the ability to recognize trends shared among populations.

Status of John Day River Spring Chinook Salmon

The decline in redd abundance observed across John Day populations from 2000 to 2007 followed by an increase over the following four years is a trend that is reflected in other northeast Oregon populations. Redd counts from the Mainstem population are significantly correlated with counts from the Grande Ronde and Imnaha river basins. We also found that redd counts in the North Fork population correlate with those in the Wenaha River. The covariation among basins suggests a large-scale environmental effect on eastern Oregon Chinook populations. Such ecological responses to large-scale changes in the physical environment are known to occur with Pacific salmon, beginning with estuarine and marine zooplankton production levels (Hare et al. 1999). A significant inverse correlation exists between PDO values at summer entry and the Grande Ronde, Imnaha, Mainstem, and North Fork populations. Although trends in redd abundance are similar among John Day populations, redd counts in the North Fork have not returned to levels observed during our monitoring from 2000-2004. The reasons for this decline in redd abundance in the North Fork are unclear. Concurrent with this decline, Mainstem redd counts have exceeded those in the North Fork. This rise may be the result of increased productivity benefiting from restoration efforts in the Mainstem to connect spawning and rearing habitats.

Given the apparent effect that ocean conditions have on redd abundance, trends in freshwater productivity may provide a more appropriate measure of the effects habitat alterations within the John Day River. This year, 2011, produced our highest Mainstem redd estimate, despite a 2007 brood year that experienced drought and pre-spawn mortality. Lower spawning densities can result in reduced competition among territorial juvenile salmonids, therefore, reproduction becomes more efficient and the number of juveniles produced is closely proportional to the size of the spawning stock (Milner et al. 2003). 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 further illustrate the effect density-dependence may be having on productivity. The Mainstem stock-recruit regression line shows the strongest density-dependent effect, the curve bends over steeply once brood year redds exceed 400. Conversely, the fitted curve for the North Fork indicates that there should be no immediate concern about decreased production at higher stock sizes; the curve does not bend over very steeply. In the Mainstem population there is also a broad range of brood year redds producing a positive sustainable yield and a large yield when brood redds approach 200. Average sustainable yield in the Middle Fork is relatively low and extends over a shorter range of brood year redds. In the North Fork, apparent 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). That is, the environment may be changing in the Upper Mainstem to the benefit of Chinook productivity. Since this pattern is not reflected in the Middle and North Fork populations, it appears to be specific the Upper 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 (Jeff Neal, ODFW District Fish Biologist, personal communication). While in the Middle Fork, there exist multiple tributaries that contain 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 a valuable tool to increase smolt production through freshwater habitat restoration (Sharma and Hilborn 2001). Carrying capacity varies dependent upon nature of habitat and food availability (Armstrong et al. 2003). In the two years following the removal of irrigation diversions that blocked fish passage into Reynolds Creek, a Mainstem tributary previously not known to produce redds, we have counted four and 45 redds, respectively. These habitat actions in the upper Mainstem may be contributing to apparent increases in productivity of this population.

Spring Chinook straying into the John Day River basin appears to remain low, although it may be higher than our findings suggest. Less than one percent of our recovered carcasses were adipose-clipped hatchery fish, distributed approximately evenly among the three populations. However, genetic analysis on carcasses recovered from 2004 to 2006 found the North Fork population had a higher rate of out-of-basin strays, both marked (hatchery origin) and unmarked (presumed wild origin), compared to the Mainstem or Middle Fork (Narum et al. 2008). Narum et al. also suggested that wild strays may be more prevalent than hatchery strays in the John Day River basin. Increased emphasis in future years on scanning carcasses for PIT tags will improve our understanding of straying by wild Chinook. Alternatively, the installation of PIT antenna arrays on the North Fork and Upper Mainstem John Day will greatly improve our ability to detect migrating adults. Many wild Chinook juveniles in Snake and Upper Columbia River tributaries are PIT tagged, creating the possibility of redetection should they stray into and spawn in the John Day River.

Survey Methodology

Index surveys remain a benefit because they allow us to monitor site specific redd abundance dating back to 1964, however, they are not randomly selected and represent an unknown proportion of the total population. Furthermore, index sites are based on redd distributions established five decades ago and may no longer represent areas with the most suitable spawning habitat nor greatest redd densities. While index counts still constitute a majority of redds observed in the basin (61%), there is a continuing downward trend from the index representation of 72% observed in 1998 (Ruzycki et al. 2008). For example, 2008 index redd counts in the North Fork dropped below those located in census reaches and have remained lower. Despite 2000 to 2011 index and census redd counts being correlated, using 2011 index counts to predict total redd counts would have resulted in underestimating redds by 15%. The index versus census redd count residuals suggest a spawner selection toward census reaches as run size increases, possibly resulting from competition for spawning gravel among adult females. Plotting index versus census residuals against August discharge data suggests 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 suitable spawning reaches made available by above average discharge. Conducting index counts alone is not an accurate method for counting redds and subsequently estimating escapement. It is necessary to continue monitoring census sites to assure accurate redd counts and our census reaches encompass all index reaches so we will not lose any long-term data trends initially established by index surveys.

Capture-recapture data from PIT tags implanted into John Day River Chinook provide an independent alternative to estimating John Day River spawner abundance as the product of redd count times an out-of-basin fish per redd estimate. Catherine Creek (Grande Ronde River basin) fish-per-redd ratios are used for John Day escapement estimation because a similar fish-counting 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 detection-recapture spawner abundance estimate relies solely on John Day spring Chinook data. The estimator is dependent upon a large tagging effort (mostly smolts) and a substantial carcass recovery sample during redd counts, yet results from our 2011 data suggest that it is a feasible method. The 2011 detection-recapture abundance estimate of 6,520 adults is less than the redd count expansion estimate of 7,247. However, the redd count expansion estimate is within the 95% Confidence bounds for the detection-recapture escapement estimate (5,333 to 8,101). The concordance of these discrete methodologies increases our confidence in the suitability of both methods for estimating John Day Chinook escapement.

Management Implications

The correlation of density-independent factors with John Day Chinook redd counts indicates that adult escapement estimates are not a suitable metric to assess the effectiveness of individual restoration projects (Lawson 1993). Additionally, managers may want to consider factors such as PDO values when they are predicting the size of returns. Given the inverse relationship between PDO values and redd abundance in the John Day River basin, low PDO values for the past two summer entry periods predict sustained high escapement levels.

The density-dependent relationships we are observing in John Day River populations emphasize the need for further restoration efforts targeting rearing habitat. Increased productivity in the Mainstem population is encouraging and may provide guidance for habitat management in the Middle Fork and North Fork populations. Presently, John Day populations are at or above carrying capacity and increases in brood year redds will not result in sustained increases of recruits. Therefore, higher escapement may not be the appropriate management goal. Managing for higher production across the entire Chinook life cycle may be more appropriate. Setting escapement goals equal to the replacement level (Figure 15) is a cautious approach compared to historical management of salmon populations. For instance, salmon populations were often managed at "Maximum Sustained Yield" levels of spawner abundance, which are much lower than replacement levels. Such an escapement goal would not provide "cushion" in the event of unanticipated ocean or freshwater environmental changes and should not be applied to John Day Chinook populations.

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APPENDIX

Appendix Table I. Spring Chinook census redd counts in the John Day River basin, 2000–2011. Includes redds estimated 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	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

Appendix Table II. Census and index survey lengths (km) for spring Chinook salmon spawning surveys in the John Day River basin, 2000–2011. 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	64.4	95.8	16.5	10.3	7.2	37.1	292.6

Appendix Table III. Spawning density (redds/km) in the John Day River basin, 2000–2011. Includes density estimates for areas where we were denied access.

				North Fork Subbasin					
					Granite Creek System				
					Granite	Clear	Bull Run	Desolation	
Year	Mainstem	South Fork	Middle Fork	North Fork	Creek	Creek	Creek	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

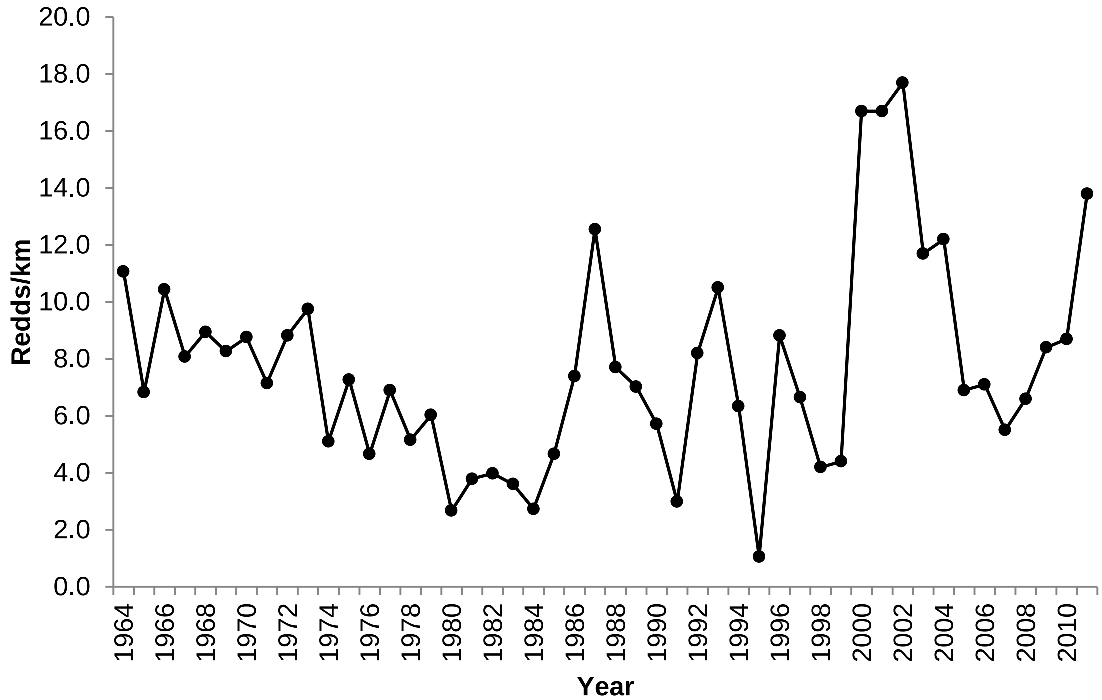
Appendix Table IV. Upper Mainstem John Day River smolt/redd ratios based on estimates of smolt abundance and redd counts for spring Chinook salmon, 2002–2009 brood years.

Brood Year	Redds (n)	Smolt Migration Year	Smolt Abundance	95% CI		Smolts/redd	95% CI	
				Lower	Upper		Lower	Upper
2002	549	2004	54,968	44,420	70,653	100	81	129
2003	260	2005	33,696	30,356	37,533	130	117	144
2004	242	2006	33,642	21,006	61,272	139	87	253
2005	203	2007	54,261	42,524	70,768	267	209	349
2006	318	2008	46,305	41,027	52,289	146	129	164
2007	250	2009	73,961	63,795	86,624	296	255	346
2008	248	2010	55,291	47,810	64,407	223	193	260
2009	468	2011	82,241	73,721	92,713	176	158	198

[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. Middle Fork John Day River smolt/redd ratios based on estimates of smolt abundance and redd counts for spring Chinook salmon, 2002–2009 brood years.

Brood Year	Redds (n)	Smolt Migration Year	Smolt Abundance	95% CI		Smolts/redd	95% CI	
				Lower	Upper		Lower	Upper
2002	389	2004	23,901	19,449	30,188	61	50	78
2003	236	2005	21,957	18,747	25,489	93	79	108
2004	319	2006	18,465	14,423	24,186	58	45	76
2005	178	2007	16,901	14,279	20,755	95	80	117
2006	199	2008	7,382	5,553	9,990	37	28	50
2007	85	2009	38,519	34,191	43,658	453	402	514
2008	169	2010	35,712	33,413	38,333	211	198	227
2009	251	2011	21,322	17,906	26,217	85	71	104



Appendix Figure I. Spring Chinook index redd density in the John Day River basin, 1964–2011. 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 VI. Index redd density (redds/km) in the John Day River basin 1998–2011. Includes estimated redd densities in areas where we were denied access.

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

Appendix Table VII. 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	2011 MS Random RM 257	44.437543	-118.821667	44.441941	-118.793809
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
Mainstem John Day River	2011 MS Random Call Ck to 2 mi upstream	44.320119	-118.557340	44.294260	-118.549608
Canyon Creek	Stimac boundary to Larson boundary	44.291196	-118.955653	44.314831	-118.950726
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	44.648576	-120.247023	44.573504	-120.171854
Middle Fork John Day River	2011 MF Random RM 26	44.83884	-119.038544	44.824943	-119.010646
Middle Fork John Day River	2011 MF Random RM 29	44.816313	-119.002461	44.805219	-118.974184
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

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	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	44.656307	-118.647587
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
North Fork John Day River	2011 NF Random RM 42	44.977992	-119.252215	44.980814	-119.216986
North Fork John Day River	2011 NF Random RM 52	44.993091	-119.080702	45.008082	-119.059332
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 VII. Continued.

System	Description	Start Latitude	Start Longitude	End Latitude	End 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
West Fork Meadowbrook	Mouth upstream to EF Meadowbrook	44.997487	-118.945483	44.968612	-118.965826
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
Crawfish Creek	Random; 200m from mouth to 1 mile upstream	44.916135	-118.296417	44.925824	-118.288678
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 VIII. Percent egg retention and ELISA optical density values for adult spring Chinook kidneys sampled from carcasses in the John Day River basin, 2011.

Stream Name	% Egg Retention	Kidney Sample #	ELISA OD Value
Mainstem John Day River	0	1	0.130
Mainstem John Day River		2	0.086
Deardorff Creek		3	0.121
Mainstem John Day River	100	4	0.077
Mainstem John Day River	0	5	0.158
Mainstem John Day River	0	6	0.101
Mainstem John Day River		8	0.096
Deardorff Creek	0	9	0.086
Deardorff Creek	0	10	0.099
Mainstem John Day River	0	11	0.116
Mainstem John Day River	0	12	0.109
Mainstem John Day River		13	0.146
Mainstem John Day River	100	14	2.189
Mainstem John Day River		15	0.090
Mainstem John Day River	0	16	0.130
Mainstem John Day River		17	0.095
Mainstem John Day River	0	18	0.075
Mainstem John Day River	50	19	0.157
Mainstem John Day River	0	20	0.087
Mainstem John Day River	0	21	0.107
Mainstem John Day River		22	0.101
Mainstem John Day River	0	23	0.163
Mainstem John Day River	0	24	0.121
Mainstem John Day River	0	25	0.166
Mainstem John Day River	0	26	0.088
Mainstem John Day River	0	27	0.133
Mainstem John Day River	0	28	0.114
Mainstem John Day River	0	29	0.089
Mainstem John Day River		30	0.073
Mainstem John Day River	0	31	2.137
Mainstem John Day River	0	32	0.117
Mainstem John Day River		33	0.096
Mainstem John Day River	0	1	0.086
Mainstem John Day River		34	0.167
Mainstem John Day River	0	35	2.039
Mainstem John Day River	0	36	0.107
Mainstem John Day River	0	37	2.449
Mainstem John Day River	0	38	0.166
Mainstem John Day River	0	39	0.175
Mainstem John Day River	0	40	0.130

Appendix Table VIII. Continued.

Stream Name	% Egg Retention	Kidney Sample #	ELISA OD Value
Middle Fork John Day River		100	0.090
Middle Fork John Day River		101	0.120
Middle Fork John Day River	0	102	0.138
Middle Fork John Day River	0	103	0.152
Middle Fork John Day River		104	0.156
Middle Fork John Day River	0	105	0.167
Clear Creek (MFJD)	0	106	0.122
Middle Fork John Day River	0	107	0.149
Clear Creek (MFJD)	0	108	0.141
Middle Fork John Day River	0	109	0.197
Middle Fork John Day River	0	110	0.138
Middle Fork John Day River		111	0.165
Middle Fork John Day River	0	112	0.117
Middle Fork John Day River		113	0.113
Middle Fork John Day River		114	0.102
Middle Fork John Day River		117	0.176
Middle Fork John Day River	0	118	0.112
Middle Fork John Day River		121	0.138
Middle Fork John Day River		123	0.123
Middle Fork John Day River		124	0.144
Middle Fork John Day River		125	0.124
Middle Fork John Day River		126	0.186
Middle Fork John Day River		127	0.142
Middle Fork John Day River		128	0.134
Middle Fork John Day River		129	0.148
Middle Fork John Day River		130	0.240
Middle Fork John Day River		131	0.224
Middle Fork John Day River		132	0.120
Middle Fork John Day River	0	133	0.095
Middle Fork John Day River		134	0.221
Middle Fork John Day River		135	0.604
Middle Fork John Day River	0	136	0.177
Middle Fork John Day River		137	0.149
Middle Fork John Day River		138	0.195
Middle Fork John Day River	0	139	0.170
Middle Fork John Day River	0	140	0.207
North Fork John Day River		200	0.113
North Fork John Day River	0	201	0.093
North Fork John Day River		204	0.119
North Fork John Day River		208	0.094
North Fork John Day River	0	209	0.113

Appendix Table VIII. Continued.

Stream Name	% Egg Retention	Kidney Sample #	ELISA OD Value
North Fork John Day River		210	0.094
North Fork John Day River		212	0.126
North Fork John Day River		215	0.065
North Fork John Day River	0	217	0.193
North Fork John Day River	0	218	0.117
North Fork John Day River	0	221	0.118
North Fork John Day River		222	0.176
North Fork John Day River	0	223	0.131
North Fork John Day River	0	228	0.094
North Fork John Day River		229	0.126
North Fork John Day River	0	230	0.207
North Fork John Day River	0	233	0.160
North Fork John Day River	0	234	0.074
North Fork John Day River		235	0.111
North Fork John Day River		236	0.100
North Fork John Day River	0	237	0.109
North Fork John Day River	0	238	0.089
North Fork John Day River		239	0.077
North Fork John Day River	0	244	0.131
North Fork John Day River	0	245	0.113
North Fork John Day River	0	246	0.110
North Fork John Day River	0	247	0.125
North Fork John Day River	0	248	0.112
North Fork John Day River	0	255	0.171
North Fork John Day River	0	258	0.070
North Fork John Day River	0	259	0.178
North Fork John Day River	0	260	0.136
North Fork John Day River	0	261	0.126
North Fork John Day River	0	262	1.847
North Fork John Day River	0	263	0.088
North Fork John Day River		264	0.151
North Fork John Day River	0	265	0.100
North Fork John Day River		266	0.143
North Fork John Day River	0	268	0.117
North Fork John Day River	0	269	0.105
North Fork John Day River	0	270	0.211
Desolation Creek	50	302	0.178
Desolation Creek	25	305	0.081
Desolation Creek		307	0.100
Desolation Creek	100	312	0.063
Desolation Creek		313	0.126
Desolation Creek	100	318	0.102
Granite Creek	0	400	0.112

Appendix Table VIII. Continued.

Stream Name	% Egg Retention	Kidney Sample #	ELISA OD Value
Granite Creek	50	401	1.206
Bull Run Creek		403	0.129
Clear Creek (GCS)	0	404	0.111
Bull Run Creek		405	0.163
Clear Creek (GCS)	0	406	0.106
Clear Creek (GCS)	0	407	0.119
Granite Creek	0	408	0.088
Granite Creek		410	0.086
Granite Creek		411	0.095
Granite Creek	0	412	0.150
Granite Creek	0	413	0.162
Granite Creek		414	0.154
Granite Creek	50	415	0.156
North Fork John Day River		416	0.099
Granite Creek		417	0.075
Granite Creek	0	420	0.099
Granite Creek		424	0.089
Granite Creek		425	0.112

Appendix Table IX. Correlation matrix for census John Day River population Chinook redd counts from 2000 to 2011 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	**0.787**	**0.682**	**0.863**	**0.727**	**0.597**	**0.611**	0.511
Middle Fork	0.239	0.285	0.306	0.081	0.543	0.302	0.082
North Fork	-0.010	-0.150	0.233	-0.158	**0.680**	0.524	-0.051