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

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 proportion of hatchery-origin spawners for three John Day River spring Chinook salmon populations.

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

Accomplishments and Findings

Spring Chinook spawning ground surveys, which have included all known reaches of spawning activity, have been conducted in the John Day River basin from 2000 through 2018. Since 2000, total redd counts have averaged 1,314 and ranged from a low of 339 redds, to a high of 2,195. In 2018, we observed 568 redds while surveying 290.8 km of potential spawning habitat (192.8 km of census, 82.4 km of index, and 15.6 km of random reaches). Redd distribution across populations has changed substantially during our monitoring; the Nork Fork accounted for 49% of the total redd count in 2000 and has declined to 27% in 2018. The fluctuation in redd counts from John Day River and other northeast Oregon systems is correlated with sea surface temperature.

The increased effort to survey all known spawning reaches has provided us with a census of redds that we used to estimate escapement. In years when a sufficient number of John Day origin PIT tagged fish returned to the system and were subsequently detected during spawning surveys, we were able to corroborate those escapement estimates using a mark-recapture technique. In 2012, we estimated escapement to be 5,315 and 5,384, using mark-recapture and redd expansion, respectively.

Extensive surveying has also provided more opportunities to encounter carcasses and gather valuable data, such as age, origin, and disease presence. Using redd counts and age data, stock-recruit analyses for the Mainstem and Middle Fork John Day populations indicate that smolts produced per redd decreases as the number of redds increases, indicating that rearing habitat may be limiting freshwater production. The Middle Fork stock-recruit curve shows the strongest density-dependence, with production decreasing when escapement exceeds 200 redds. Conversely, an adult-to-adult recruitment curve for the North Fork suggests very little decrease in production at higher escapements. Average sustainable yield in the Middle Fork appears to be lower than the Mainstem.

ACKNOWLEDGEMENTS

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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 are not intended to 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 improvement projects.

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

STUDY AREA

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

Spring Chinook salmon primarily spawn in the upper Mainstem John Day River (hereafter called Mainstem; Figure 2) upstream from Indian Creek, in the Middle Fork John Day River (hereafter called Middle Fork; Figure 3) upstream of Armstrong Creek, and the North Fork John Day River (hereafter called North Fork; Figure 4) upstream of Camas Creek. Important spawning tributaries of the North Fork include Granite Creek and its tributaries (Clear Creek and Bull Run Creek; hereafter called Granite Creek System) and Desolation Creek (Figure 4). Spawning has infrequently occurred in the South Fork John Day River (hereafter called South Fork; Figure 5), the North Fork tributaries Camas and Trail creeks, and the Mainstem tributaries Deardorff, Reynolds, and Bridge creeks.

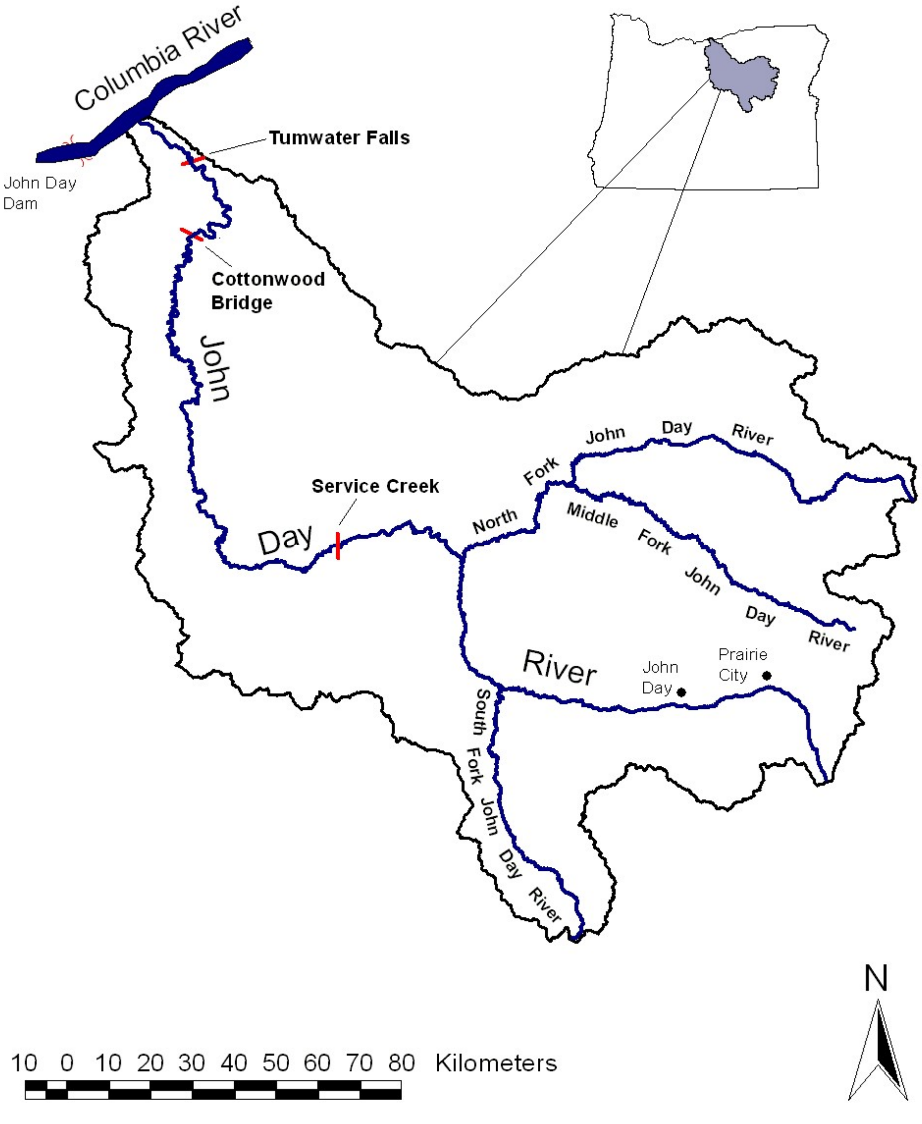

Figure 1. Map of the John Day River basin.

METHODS

Sampling Design

Spring Chinook salmon spawning surveys were conducted during August and September to encompass the temporal distribution of Chinook spawning in the John Day River basin. These surveys included index, census, and random sections. Index sections were defined as locations where redd counts have occurred annually since 1964. Census sections were defined as any location where spring Chinook redds have been previously documented. Random surveys (2 km in length) were defined as surveys located outside of the known spawning universe. The intent of random surveys was to check for range expansion. Our random sampling universe extended 20 km downstream from the most downstream redd observed in each Hydrologic Unit Code (4th level HUC; Mainstem, Middle Fork, and North Fork). A second sampling universe extended 4 km upstream from the most upstream redd observed. Survey sections were selected with a random number generator based on river kilometer. For every one site selected upstream from the census section, two sites were selected downstream from the census section. If redds were observed in a random site, that survey section was added to the census universe for five subsequent years and returned to the random pool of sites if recurring spawning was not observed. 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 on or within five days following the dates listed in Table 1. The number of live fish and occupied redds were recorded during surveys, and surveys were repeated if more live fish than redds were observed or if more than half of the redds were occupied. Pre-index surveys were typically 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, any new redds detected during post-index counts were treated as census counts and not included in the overall index count. During 2018, with the exception of wilderness areas, we surveyed census sections three times on the same dates as the pre-index, index, and post-index surveys. We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork on the day of the index or post-index surveys, or soon thereafter, for their respective streams.

Table 1. Standard index spawning survey dates in the John Day River basin to maximize redd counts.

Stream	**Survey Dates**
Mainstem	Sept 9 – 10
Middle Fork	Sept 17 – 18
Upper North Fork	Sept 15 – 16
Lower North Fork	Sept 19 – 20
Granite Creek System	Sept 11 – 12

Spawning Surveys

Spawning surveys were conducted on foot, and ranged in length from 0.1 to 7.7 km depending on accessibility and difficulty. Typically, teams of two surveyors walked the stream, with one surveyor on each bank to ensure detection and accuracy when distinguishing redds. In each section, surveyors recorded the number of new redds, live fish seen on or off redds, and carcasses. During index and census surveys, the first team marked redds with numbered flagging placed near each redd or group of redds. During subsequent surveys, teams re-identified flagged redds and recorded any new redds. During the last survey in each reach, surveyors geo-referenced redds with a global positioning system receiver and removed flags.

Every carcass we observed was examined unless decomposition or scavenging damage disallowed accurate measures. Medial eye to posterior scale length (MEPS) was measured to the nearest millimeter and carcasses were dissected to verify sex. Volume (in milliliters) of eggs retained was noted for every intact female. Every carcass was scanned for the presence of a passive integrated transponder (PIT tag) unless there were fewer PIT scanners than survey crews. Tag codes from recaptured PIT tags were queried for their tagging and observation history using PTAGIS (data available online at: www.ptoccentral.org). Kidney samples were collected from recently deceased spring Chinook in each of the main spawning areas to determine concentration and prevalence of *Renibacterium salmoninarum* (*Rs*) antigen, the causative agent of bacterial kidney disease (BKD), in the spawning population. Surveyors selected carcasses with intact organs and membranes and non-glazed eyes, indicative of recent mortality, as donors for kidney tissue analyses. Clean disposable plastic knives and spoons were used to collect 1–2 g samples of kidney tissue from each carcass. Samples were placed in sterile 1-ounce Whirl-pack™ bags and stored in a cooler until they could be transferred to a freezer. The enzyme-linked immunosorbent assay (ELISA) was used to obtain optical density (OD) values according to methodology adapted from Pascho and Mulcahy (1987). The *Rs* antigen level is an indication of bacterial infection load of *R. salmoninarum*. Table 2 summarizes the optical density value ranges and standard infection level categories used for BKD. We calculated the mean ELISA OD values for each John Day population, as well for the Imnaha and Minam rivers in the Snake River basin, and used 2-factor analysis of variance (ANOVA) to compare the natural log of *Rs* antigen level among populations and years. Using proportions of fish that were negative, positive, or clinical, we used binomial logistic regression to model the influence of potential explanatory variables such as survey year and population on fish testing negative versus positive for BKD (there were too few kidney samples categorizes as clinical, that we combined these with positive samples). For this test, we also included redd density as another explanatory variable; redd density for each population functioned as a proxy for fish density during summer holding when we hypothesize higher fish abundance results in increased chance of *Rs* transmission and stress as fish compete for limited space. After constructing candidate regression models, we used Akaike's information criterion (AIC) to rank each candidate model.

Table 2. 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**
< 0.10	Negative	Infection not detected by ELISA
≥ 0.10 - 0.99	Positive	Beginning of significant infection, signs of disease absent, rarely a factor in death
≥ 1.00	Clinical	Signs of disease usually present, death probable, fish had BKD

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

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

We marked carcasses that were in good condition (i.e., intact and body cavity not breached) with a uniquely numbered black cable tie passing through the mouth and under the operculum and returned the marked carcasses to their original position in the stream. Tails were removed from carcasses with breached body cavities to prevent repeat sampling. During subsequent surveys, carcasses with cable tie marks were recorded by surveyors. We used these mark-recovery data to estimate carcass detection probability through time (2013–2018) and across populations. We used binomial logistic regression to model the influence of potential explanatory variables such as survey year and population on carcass detection probability. After constructing candidate regression models, we used Akaike's information criterion, corrected for small sample size (AIC_c), to rank each candidate model.

Redd Count Escapement Estimation

All spring Chinook redds in the basin were visually counted with the exception of a few isolated reaches in the Mainstem and Clear Creek (Granite Creek System, GCS) where landowners denied access. If spawning activity was observed in adjacent reaches, we estimated redds for the denied access reaches. In order to estimate the number of redds constructed in the Mainstem we used a spatially stratified reach rank approach. Using the 1:100,000 digital stream network layer, we divided the Mainstem into 65, 500m sections. We then used the number of redds in each section from 2002, the spawning year that provides the only complete dataset, to rank sections based on the number of redds observed. We then used liner regression of section rank versus $\log_e$ (redds [n]) to fit a model to predict redds in sections where we were denied access. 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.

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

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

where:

$\widehat{N}_p$ = Estimated number of spawners in the population

r_p = Number of redds observed in the population

$\hat{f}$ = Estimated fish per redd above Catherine Creek weir located in the adjacent Grande Ronde River basin (ODFW unpublished data)

PIT Tag Detection-Recapture Escapement Estimation

In years where surveys were able to recover sufficient numbers of PIT-tagged carcasses, mark-recapture analysis provided an alternate method for estimating the abundance of adult Chinook returning to the John Day River basin. Several thousand Chinook smolts are intra-peritoneally PIT tagged annually when emigrating from the John Day River basin (DeHart et al. 2012). Some of these 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 100% (n=56) homing to natal spawning areas. Similarly, Narum et al. (2008) analyzed genetic evidence from the three populations and also concluded that homing dominated among these populations. Thus, we assumed a 100% homing rate between Bonneville Dam and spawning grounds for Chinook originally PIT tagged in the John Day River.

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

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

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

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

where:

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

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

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

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

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

$\hat{N}$ = Number of adult Chinook salmon passing the Middle Fork PIT array (rkm 69)
M = Number of PIT tagged adults detected migrating upstream past the Middle Fork PIT array
C = Number of intact carcasses scanned for a PIT tag on Middle Fork spawning ground surveys (inclusive of both males and females)
$\hat{R}$ = Number of fish in group M that were recovered on carcass surveys, including pre-spawn mortality surveys

Redd Distribution Analysis

To statistically analyze trends in spawning distribution across years in the Middle Fork population, we used a subset of the spawning reaches that were consistently surveyed and were typically used by spawning Chinook. We numbered survey sections longitudinally and ranked them based on redd density (redds/km). We then performed Pearson's correlation analysis of section number versus redd density rank to test the longitudinal distribution of redds. Finally, we plotted the correlation coefficients across years to detect any trends in redd distribution.

Population Productivity Analyses

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

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

To estimate smolts per redd, yearling spring Chinook migrants were captured at two rotary screw trap (RST) sites. The RST sites are located downstream of all known spring Chinook spawning habitat within their respective subbasin, with the exception of Bridge Creek that is included in the Mainstem population. A 1.52 m or 2.44 m diameter

RST was fished at the Mainstem (rkm 352) trap site depending on water conditions to optimize capture efficiency. One to two 1.52 m RSTs were fished at the Middle Fork (rkm 24) trap site. Trapping efficiency was estimated separately at each RST site by releasing marked yearling chinook upstream of the trap(s) at civil twilight to mimic natural migration patterns (Tattam et al. 2013). A complete description of smolt collection methods is described by DeHart et al. (2012). Data collected from each of the RSTs were then used to estimate smolt abundance for the Mainstem and Middle Fork populations.

Adult to adult recruitment rates for each population were modeled with Ricker stock-recruitment curves fit to the total redd abundance dataset from 2000 to present. 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:

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

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

RESULTS

Redd Counts

We surveyed 290.8 km of potential Chinook spawning habitat within the John Day River basin in 2018 (Table 3; Figures 2, 3, 4, and 5). From 2000 to present (n=19), average stream length surveyed during Chinook surveys is 292.7 km (SD=19.2 km). A total of 82.4 km of spawning habitat was surveyed within the index area, excluding 2.1 km where we were denied access, and 192.8 km of spawning habitat was surveyed within the census area. We conducted random surveys on the Mainstem, Middle Fork, North Fork, and South Fork for a total length of 15.6 km of stream.

Table 3. Survey location, access status, survey type, and reach length (km) for 2018 spring Chinook spawning survey reaches in the John Day River basin.

		Survey Type		
Stream Name	**Access Status**	**Census**	**Index**	**Random**
Mainstem				
Canyon Creek	Yes			2.0
Deardorff Creek	Yes	2.0		
Mainstem John Day River	*No*	*0.1*	*2.1*	
Mainstem John Day River	Yes	15.9	15.5	2.0
Reynolds Creek	Yes	4.1		
South Fork				
South Fork John Day River	*No*	*3.5*		
South Fork John Day River	Yes	13.8		2.0
Middle Fork				
Bridge Creek	Yes	2.9		
Clear Creek	Yes	4.1		
Granite Boulder Creek	Yes	2.3		
Middle Fork John Day River	Yes	27.7	19.8	4.0
Vinegar Creek	Yes	0.6		
North Fork				
Baldy Creek	Yes	1.1		
Big Creek	Yes	0.1		
Camas Creek	Yes	0.8		2.0
Crawfish Creek	Yes			1.6
North Fork John Day River	Yes	63.2	28.5	2.0
Trail Creek	Yes	3.0		
Granite Creek System				
Bull Run Creek	Yes	2.3	4.9	
Clear Creek	*No*		*1.2*	
Clear Creek	Yes	4.3	4.7	
Granite Creek	Yes	7.5	9.0	
Desolation Creek				
Desolation Creek	Yes	35.3		
South Fork Desolation Creek	Yes	1.8		
Total	**Yes**	**192.8**	**82.4**	**15.6**

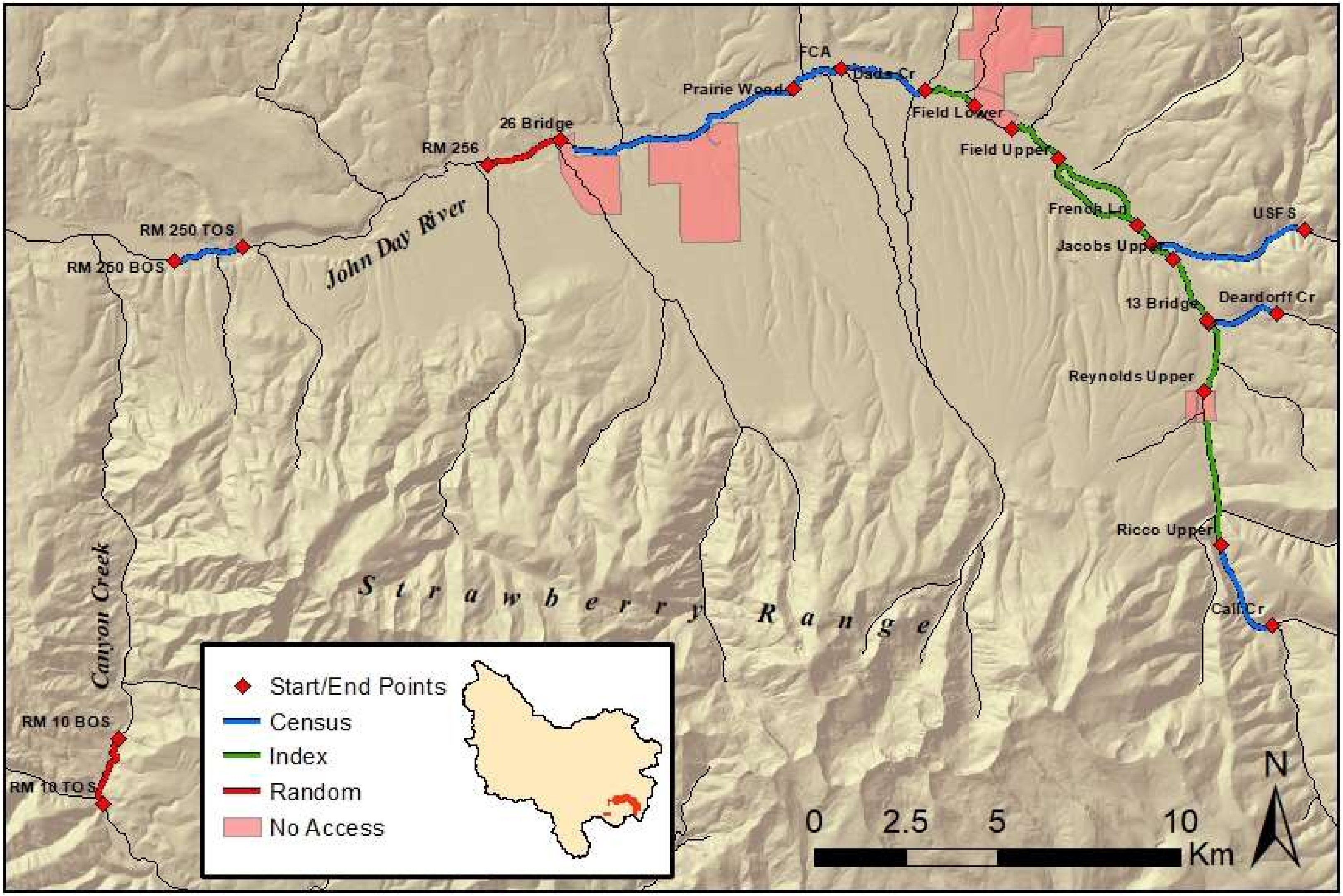

Figure 2. Map of the 2018 Mainstem spring Chinook spawning ground survey sections.

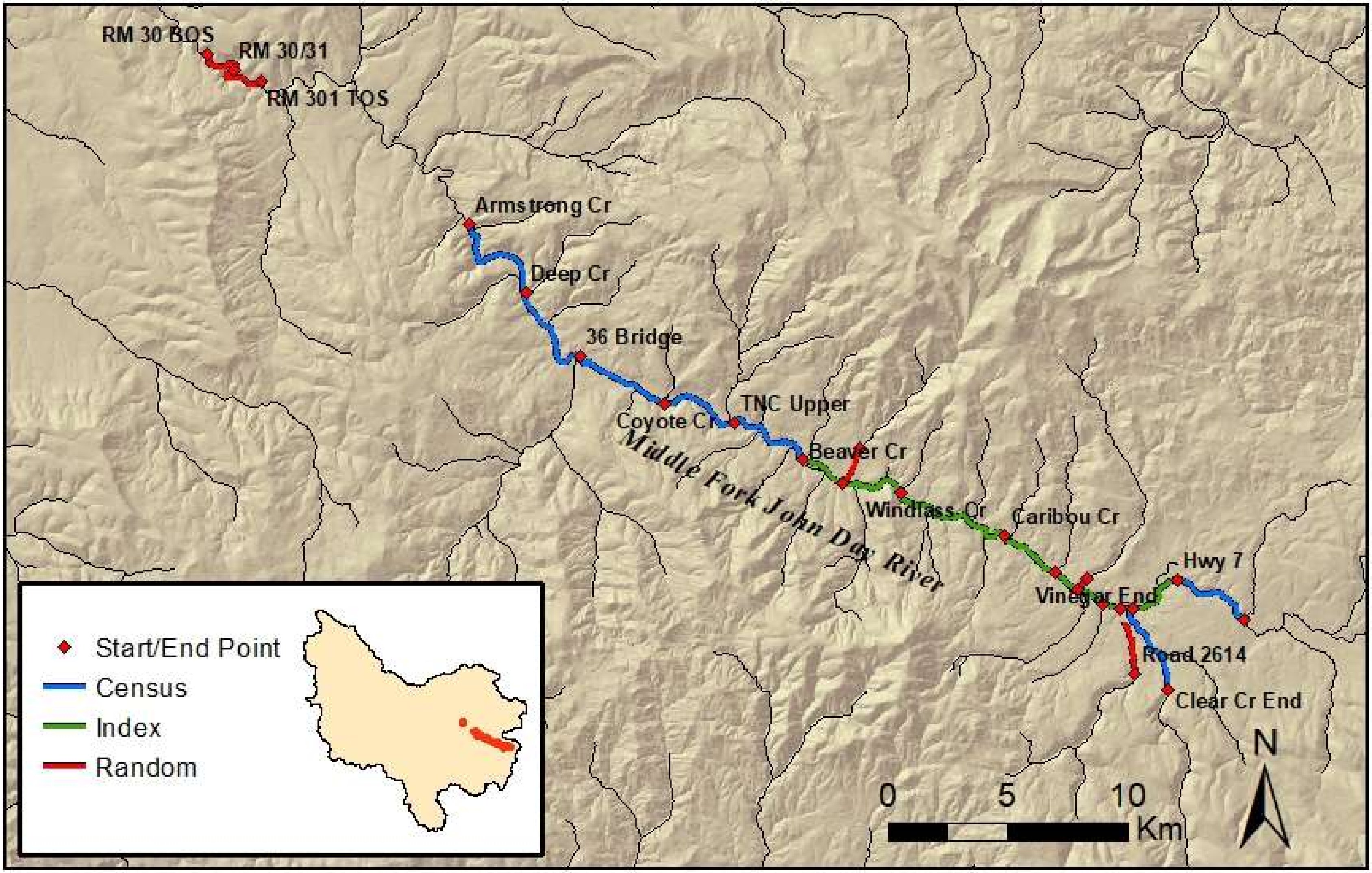

Figure 3. Map of the 2018 Middle Fork spring Chinook spawning ground survey sections.

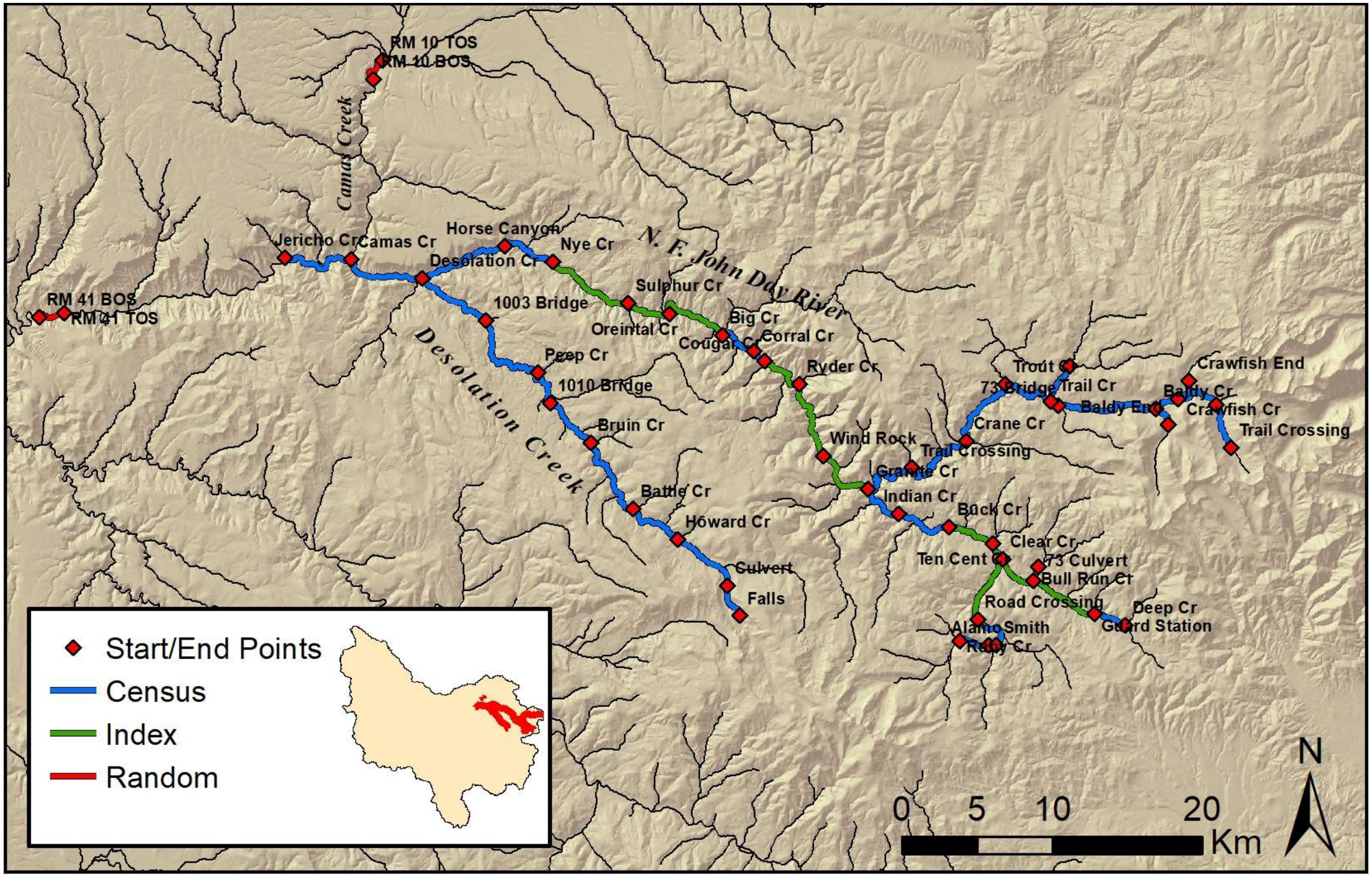

Figure 4. Map of the 2018 North Fork spring Chinook spawning ground survey sections.

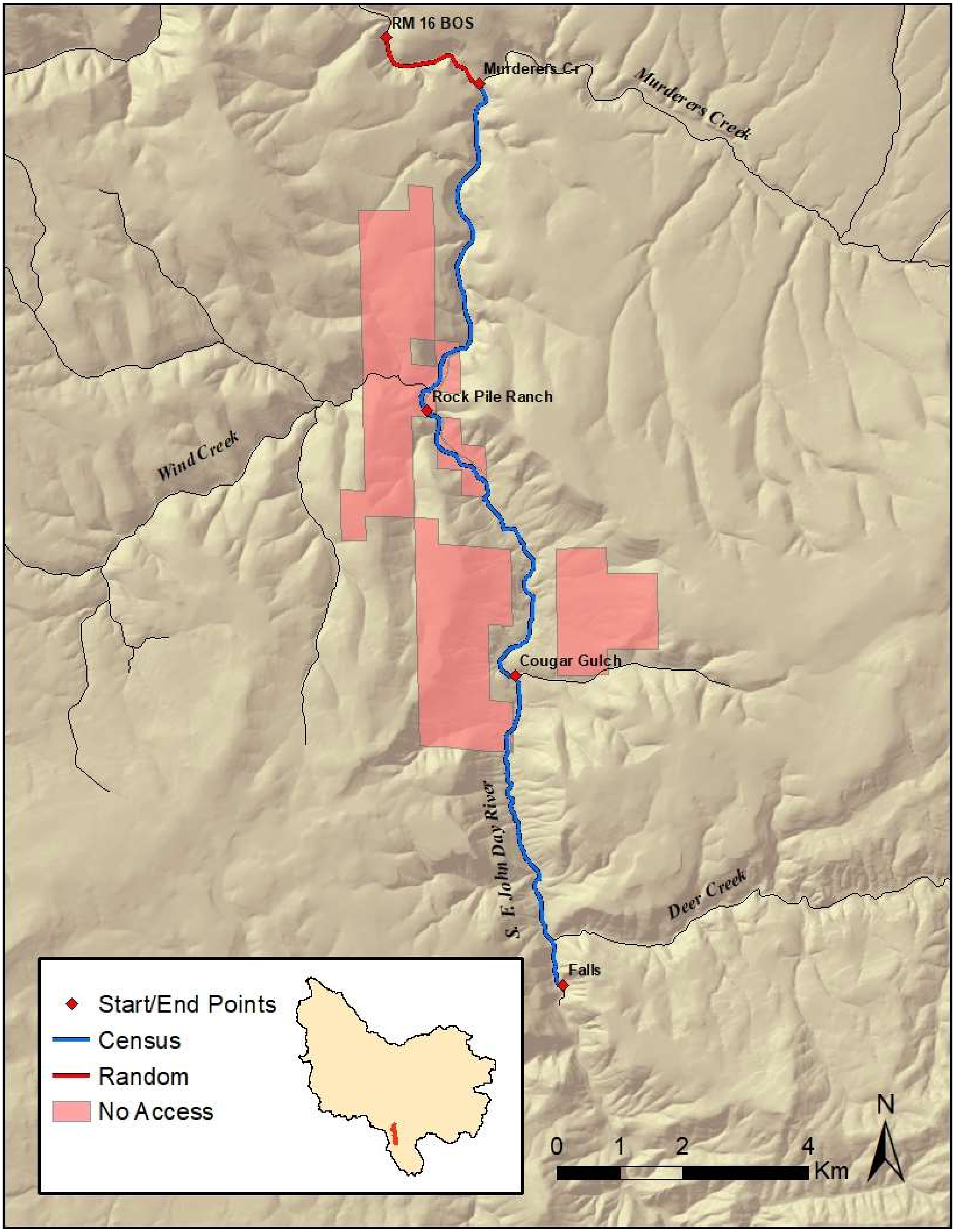

Figure 5. Map of the 2018 South Fork spring Chinook spawning ground survey sections

We observed 539 spring Chinook redds within the John Day River basin in 2018 (Tables 4 and 5). Including an estimated 29 redds where we were denied access in the Mainstem, total redds in the basin was 568. We estimated an overall density of 2.1 redds/km for the entire survey area, excluding random reaches where spawning was not present (Table 4). Of the 568 total redds, 411 were observed during index surveys at a density of 5.0 redds/km. The ratio of index to census redds, with post-index redds treated as census redds, was 2.6 (Figure 6). One redd was observed in a Mainstem random reach. The Mainstem accounted for 59.9% of the total redds observed in 2018, the Middle Fork had 13.2%, and the North Fork had 26.9%. We did not observe any redds in the South Fork. The Mainstem had the highest density of redds with 9.1 redds/km, followed by the Middle Fork with 1.3 redds/km, and the North Fork with 0.9 redds/km (Figures 7, 8, and 9).

Table 4. 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 through 2018.

Year	**Distance (km)**	**Redds**	**Redds/km**	**Adults/Redd**	**Jacks and Adults/Redd**	**Adult Escapement**	**Total Escapement**
2000	236.1	1,869	7.9	1.54	1.69	2,875	3,163
2001	243.2	1,863	7.7	2.92	4.19	5,447	7,808
2002	255.9	1,959	7.7	2.71	2.90	5,299	5,689
2003	243.0	1,354	5.6	2.76	2.92	3,742	3,955
2004	260.0	1,531	5.9	2.13	2.24	3,257	3,437
2005	267.5	878	3.3	1.92	2.07	1,683	1,817
2006	264.6	909	3.4	2.29	2.41	2,079	2,190
2007	267.5	746	2.8	2.77	2.93	2,068	2,186
2008	264.6	963	3.6	1.99	2.15	1,916	2,072
2009	265.9	1,221	4.6	2.24	3.23	2,737	3,944
2010	268.2	1,440	5.4	2.55	2.71	3,671	3,905
2011	287.7[a]	1,846	6.4	2.62	3.90	4,844	7,205
2012	276.7[a]	1,787	6.5	2.91	3.01	5,202	5,384
2013	267.9[a]	995	3.7	3.81	4.68	3,795	4,663
2014	267.9[a]	2,195	7.6	2.70	2.89	5,920	6,349
2015	289.8[a]	1,628	5.6	2.19	2.35	3,565	3,826
2016	289.8[a]	893	3.1	2.73	2.91	2,438	2,599
2017	289.6[a]	339	1.2	2.54	2.76	861	936
2018	277.2[a]	568	2.1	1.88	2.00	1,070	1,136

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

Table 5. Total number of redds and carcasses observed during spring Chinook salmon spawning surveys in the John Day River basin, 2018.

	Redds (n)			Carcasses (n)		
Stream Name	**Census**	**Index**	**Random**	**Wild**	**Hatchery**	**Unknown**
Mainstem Population						
Deardorff Creek						
Mainstem John Day River	42	263	1	55		1
Reynolds Creek	5			1		
Middle Fork Population						
Bridge Creek						
Clear Creek						
Granite Boulder Creek						
Middle Fork John Day River	30	45		24		1
Vinegar Creek						
North Fork Population						
Baldy Creek						
Bull Run Creek		7		1		
Clear Creek	9	16		20		1
Desolation Creek	26			10		
Granite Creek	5	26		32		
North Fork John Day River	39	25		7		2
Total	**156**	**382**	**1**	**150**	**0**	**5**

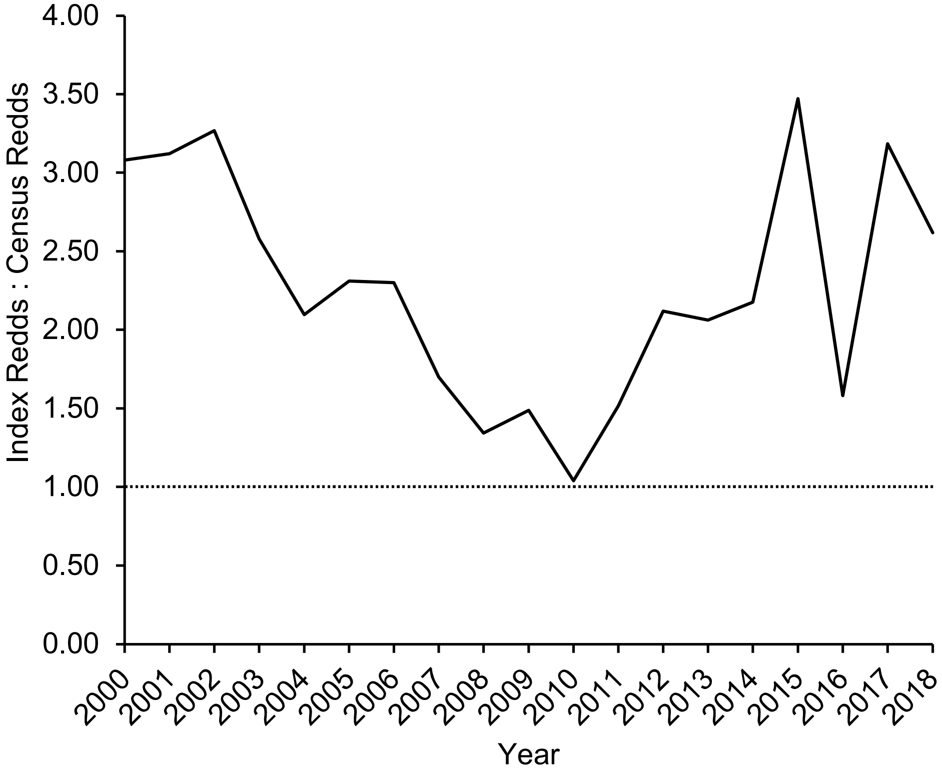

Figure 6. Ratio of index to census redd count totals from 2000 through 2018 for the John Day River basin. The dotted line indicates a ratio of 1:1 between the number of index redds and the number of census redds.

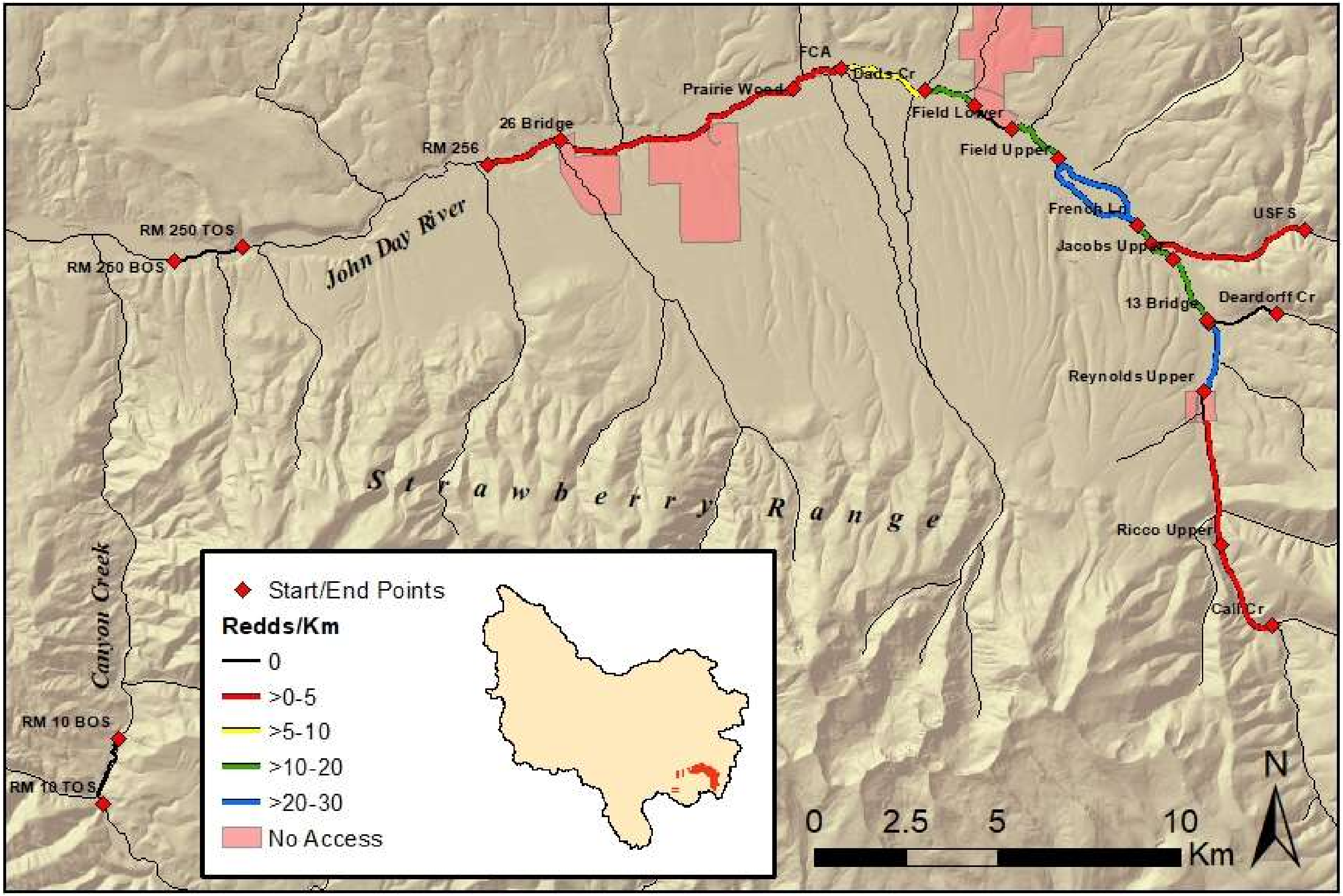

Figure 7. 2018 spring Chinook spawning survey sites and redd densities in the Mainstem John Day River.

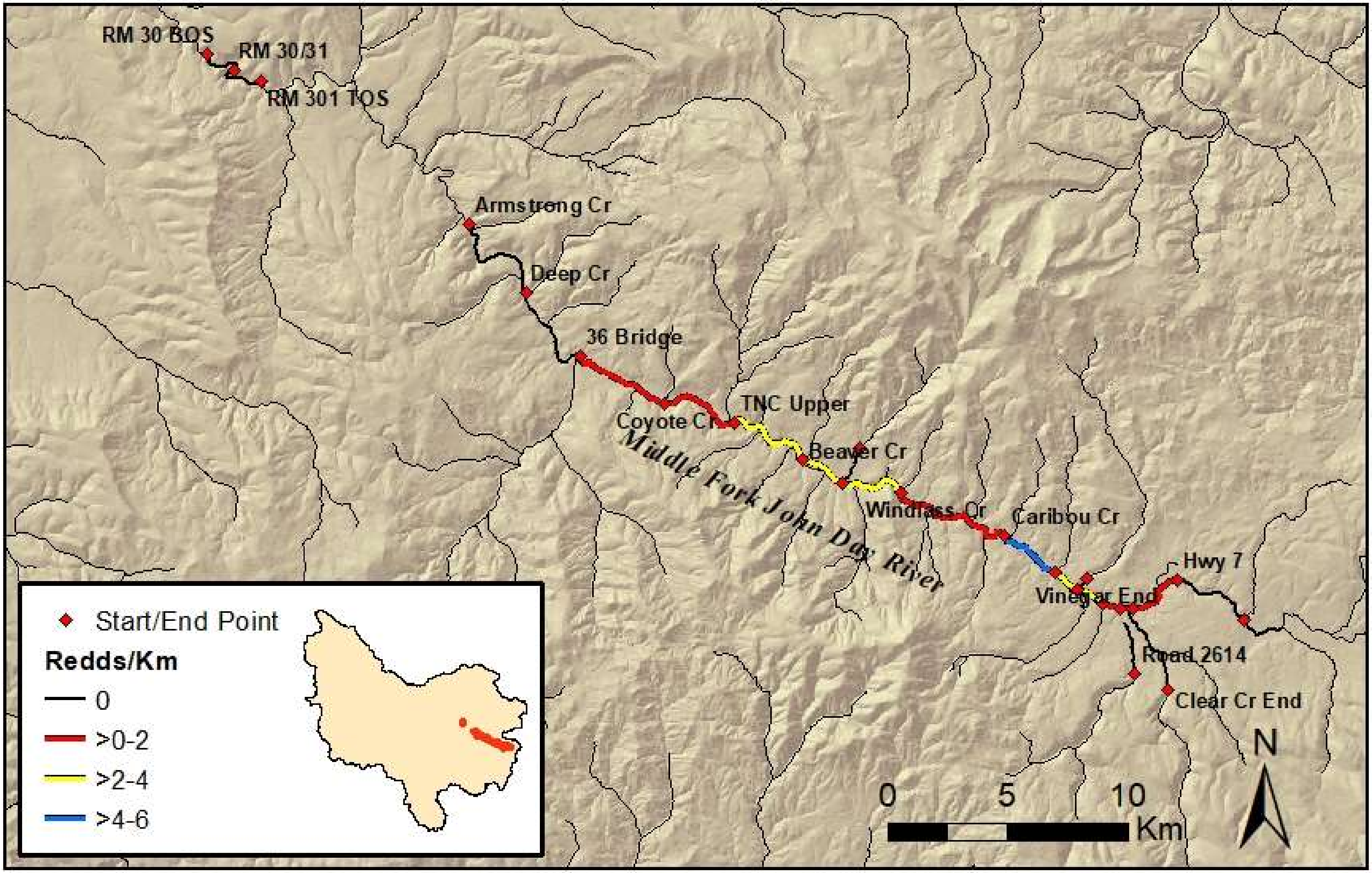

Figure 8. 2018 spring Chinook spawning survey sites and redd densities in the Middle Fork John Day River.

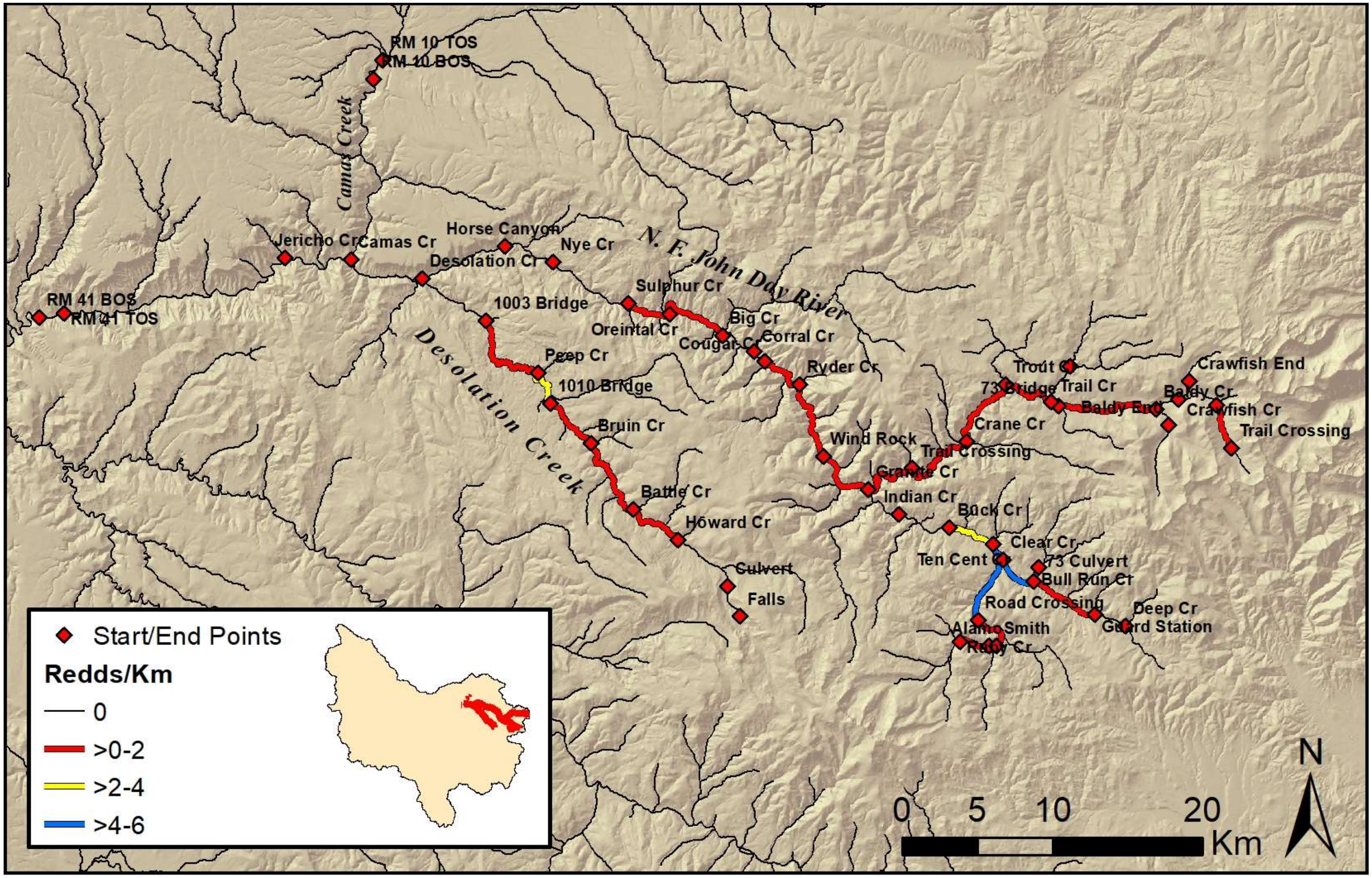

Figure 9. 2018 spring Chinook spawning survey sites and redd densities in the North Fork John Day River.

Redd Count Expansion Escapement Estimation

The 2.00 fish per redd ratio generated from Catherine Creek spawning surveys in 2018 is lower than the past eighteen year average (2.89). Applying the ratio to the John Day River basin, we estimated an escapement of 1,136 spring Chinook in the John Day River basin for 2018 (Table 4). We estimate that 680 fish spawned in the Mainstem, 150 spawned in the Middle Fork, and 306 spawned in the North Fork.

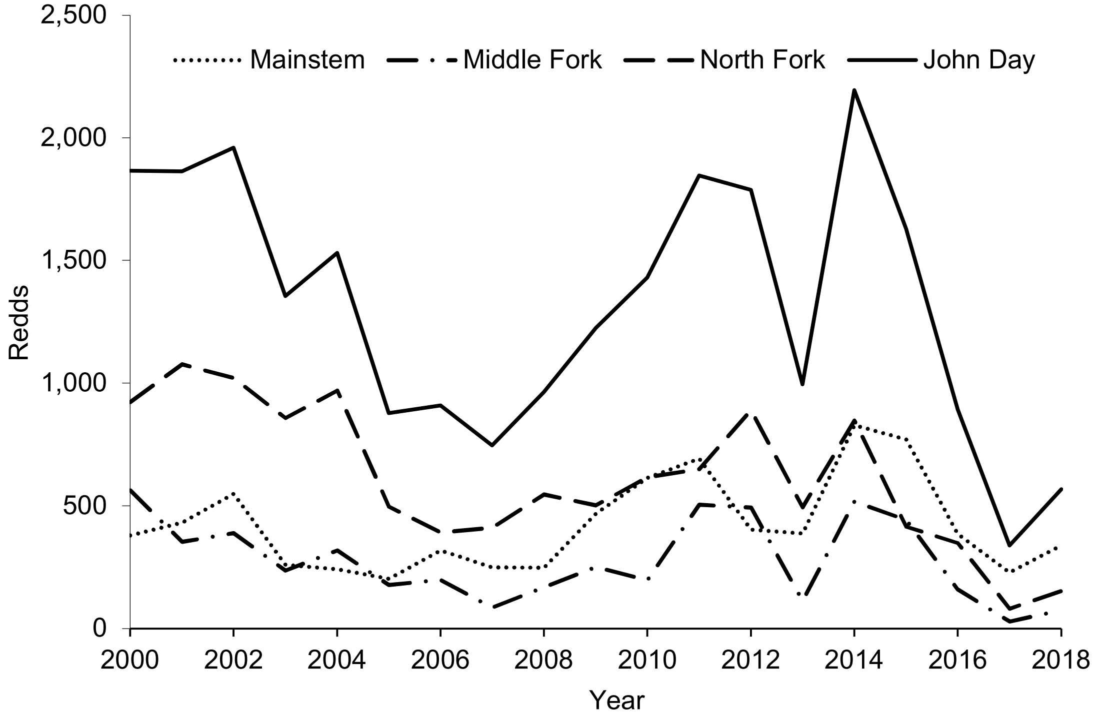

Figure 10. Redd totals from 2000 through 2018 for John Day River basin spring Chinook salmon populations and the basinwide total.

Redd abundance at the John Day River basin scale during 2018 was up 68% from 2017 (Figure 10), yet is still well below the average redd count of 1,356. At the population scale, the Mainstem showed a 49% increase, the Middle Fork rose 159%, and the North Fork produced 89% more redds in 2018 than we observed in 2017. Summer stream flows were below average, although it is not known if any of the populations experienced a pre-spawn mortality event like the ones we observed in 2007, 2013, and 2015 that resulted from elevated water temperatures. Grande Ronde River basin redd counts increased 28% and Imnaha River basin redds went down 6% from 2017 to 2018 (Figure 11). Annual Middle Fork redd counts are significantly correlated with counts in both Mainstem and North Fork populations (Table 6), however, the Mainstem is not significantly correlated with the North Fork. Redd counts for the Mainstem, as well as the Middle Fork, were significantly correlated to both Grande Ronde and Imnaha river populations. The North Fork was nearly significantly correlated with Imnaha counts (Table 6 and Appendix Table IX). The similar trends in redd totals observed across northeast Oregon populations appear to be inversely related to PDO values for the summer those spawners entered the ocean (Figure 11). Redd counts for every population in the John Day basin were significantly correlated with PDO values during the summer two years prior to the redd count (Table 6, Figure 12).

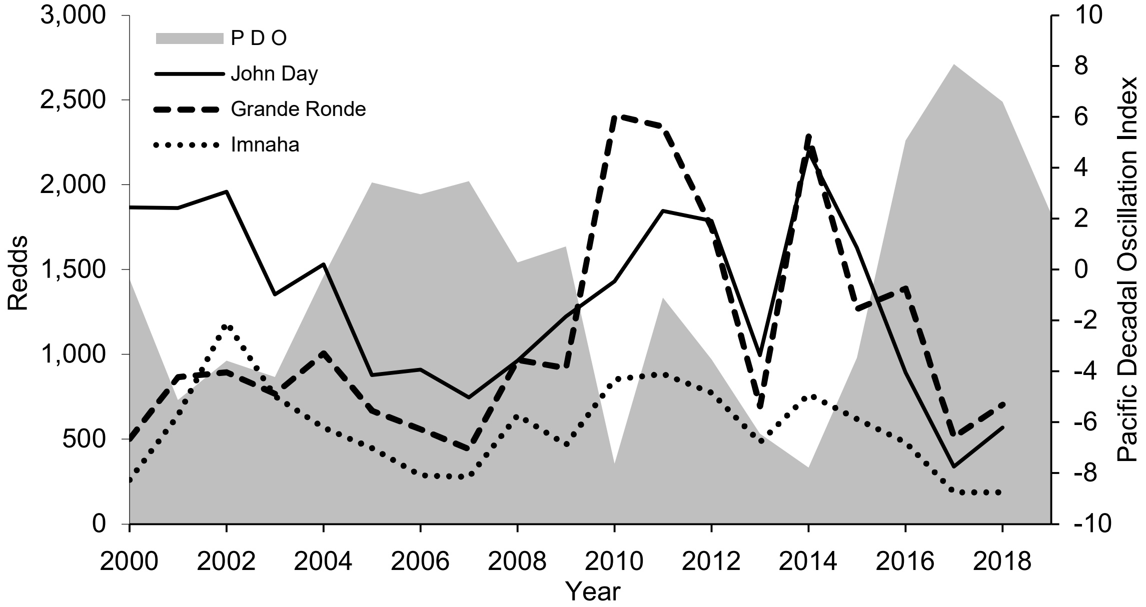

Figure 11. Redd totals from 2000 through 2018 for the John Day, Grande Ronde, and Imnaha river basins plotted with summer values of the Pacific decadal oscillation index corresponding with summer of entry for age-4 Chinook.

Table 6. Matrix of correlation coefficients (Pearson's R) between Mainstem, Middle Fork, North Fork, Grande Ronde, and Imnaha Chinook redd counts from 2000 through 2018 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	North Fork	Grande Ronde	Imnaha	PDO
Mainstem	**0.63**	0.22	**0.74**	**0.55**	**-0.60**
Middle Fork	-	**0.70**	**0.48**	**0.52**	**-0.55**
North Fork	-	-	0.23	**0.64**	**-0.68**
Grande Ronde	-	-	-	**0.62**	*-0.53*
Imnaha	-	-	-	-	**-0.71**

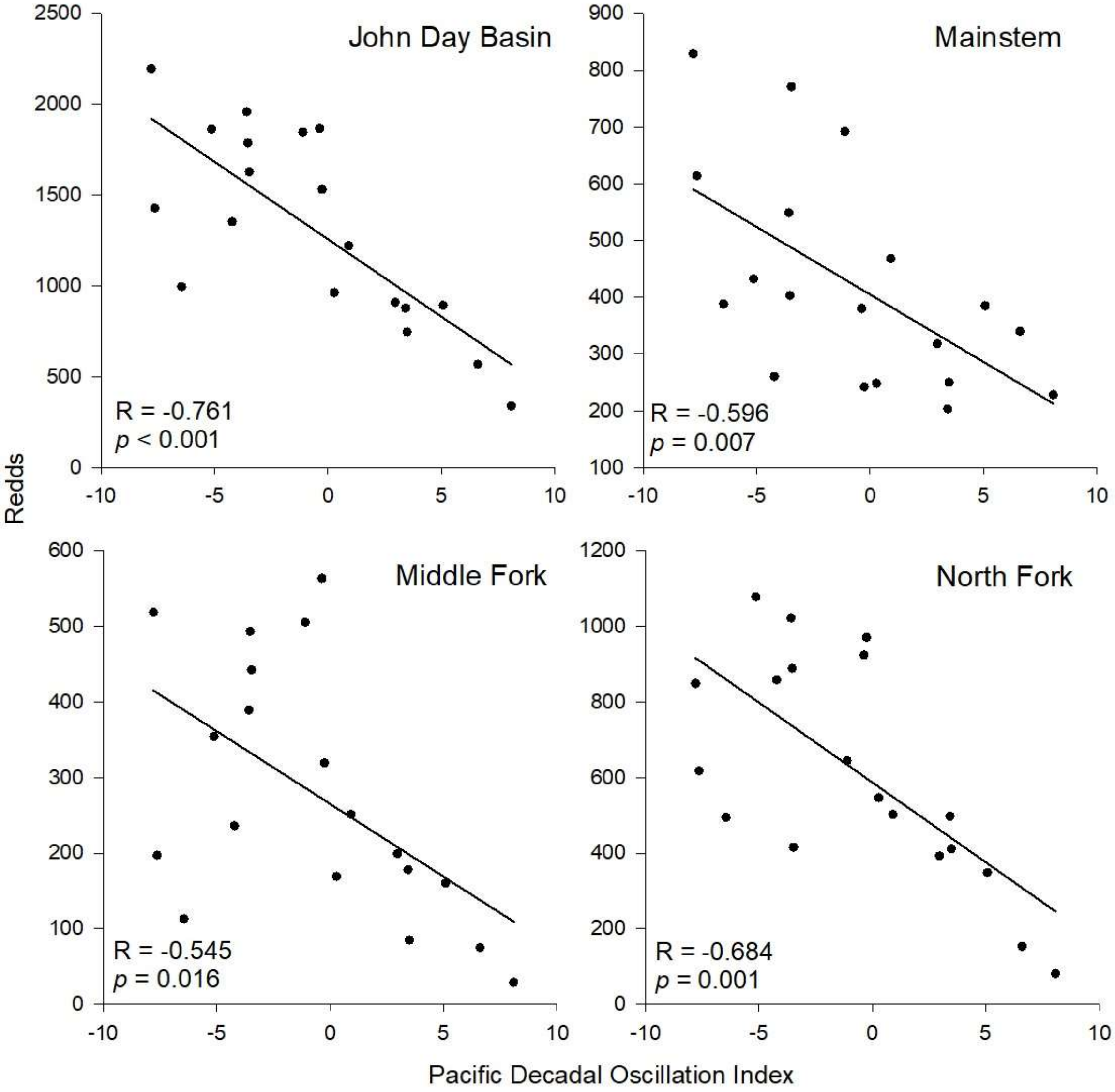

Figure 12. Pearson's correlation between Pacific decadal oscillation values and total redd counts from 2000 through 2018 spawning ground surveys in the John Day basin, Mainstem, Middle Fork, and North Fork.

Carcass Recovery

In 2018, we recovered 153 carcasses throughout the John Day River basin. Of the 148 carcasses that we were able to determine their origin, all appeared to be wild. Since this study began in 2000, 2017 and 2018 are the only years that have not resulted in a hatchery origin Chinook being observed in any of the populations (Figure 13). Mean percent hatchery-origin spawners from 1998 to 2018 was highest in the North Fork (2.4%), then the Mainstem (1.8%), and lowest in the Middle Fork (0.7%). The declining proportion of hatchery origin spawners we have been observing in the John Day River basin is somewhat mirrored by the reduction in percentage of Snake River hatchery yearling Chinook being transported downstream on barges (Figures 14 and 15).

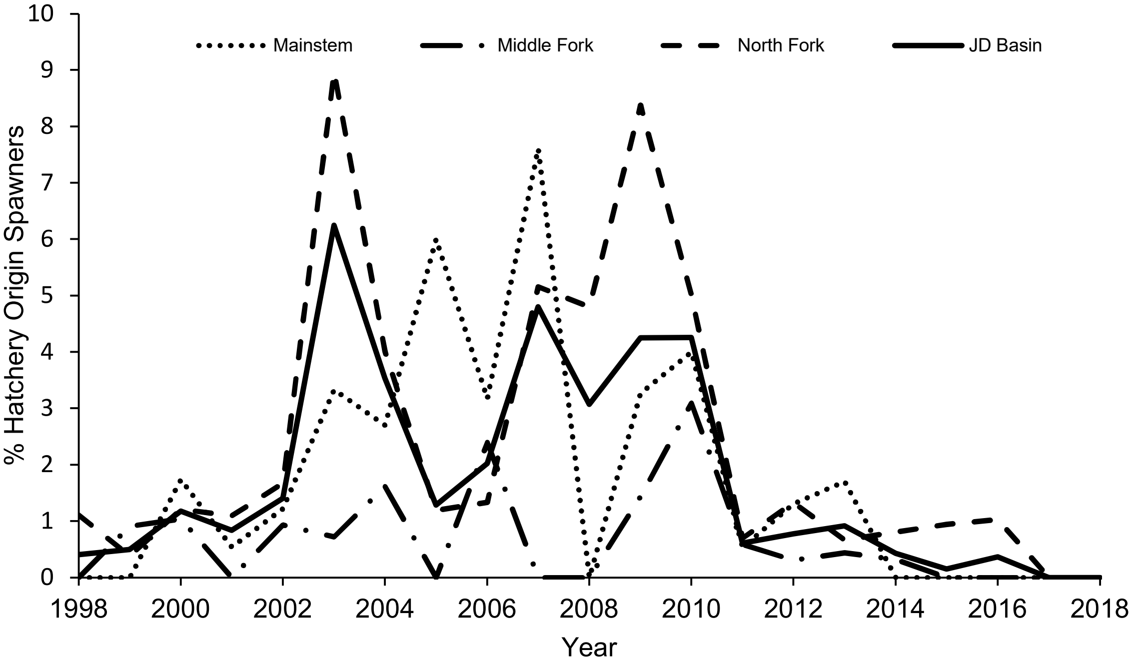

Figure 13. Percent hatchery origin spawners from 1998 through 2018 for three John Day River basin spring Chinook salmon populations and the entire basin.

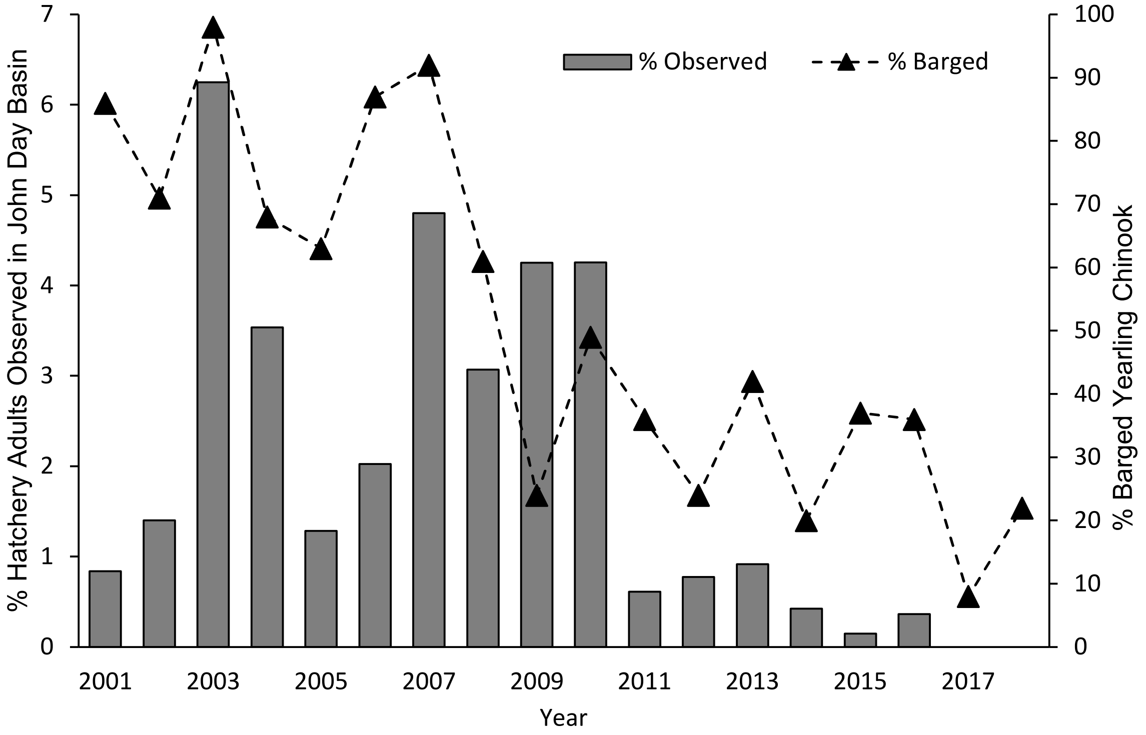

Figure 14. Proportion of hatchery origin spawners in the John Day River basin and the percentage of hatchery yearling Chinook transported from Lower Granite Dam (Snake River) two years prior to spawning year from 2001 through 2018.

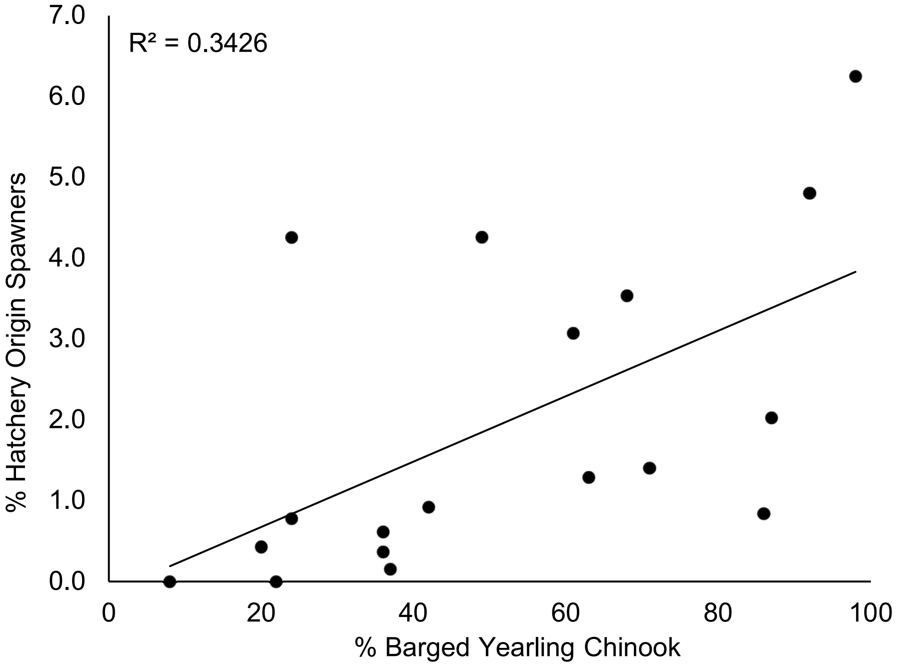

Figure 15. Pearson's correlation between % barged yearling Chinook and % hatchery origin spawners observed in the John Day basin from 2001 through 2018.

We determined the sex of 140 carcasses, 51 (36.4%) were male and 89 (63.6%) were female. We determined age for 129 carcasses using scale pattern analysis. There was a total of 8 age-3 (6.2%), 119 age-4 (92.2%), and 2 age-5 (1.6%) fish (Figure 16; Tables 7 and 8). None of the scale samples was found to have sub-yearling smolt growth patterns (i.e., age-1 freshwater). Mean ages of fish from the past sixteen years suggest older salmon return to the North Fork (Figure 17). Mainstem carcass recoveries in 2008 and 2013 appear to have had increased numbers of jacks; the slight drop in mean ages was also present in those PIT tagged individuals detected at Bonneville and The Dalles dams.

Table 7. Age, mean MEPS length (mm), standard error (SE), sample size (n), range (mm), and percentage of total known-sex aged Chinook from 2018 carcass recovery. Two fish of unknown sex were also aged.

	Male					Female				
Age	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**	**Length (mm)**	**SE**	**n**	**Range (mm)**	**%**
3	440.4	32.4	8	345 - 584	6.2%			0	-	0.0%
4	580.8	6.4	33	490 - 649	25.6%	586.4	4.6	80	477-700	62.0%
5	715.0	20.0	2	695 - 735	1.6%			0	-	0.0%

Table 8. Percentage of known-sex aged Chinook carcasses by population for 2018.

		% Males by Age				% Females by Age		
	n	**3**	**4**	**5**	**n**	**3**	**4**	**5**
Mainstem	16	37.5	56.3	6.3	24	0.0	100.0	0.0
Middle Fork	7	28.6	71.4	0.0	12	0.0	100.0	0.0
North Fork	20	0.0	95.0	5.0	44	0.0	100.0	0.0
South Fork	0	0.0	0.0	0.0	0	0.0	0.0	0.0
Basin Total	43	18.6	76.7	4.7	80	0.0	100.0	0.0

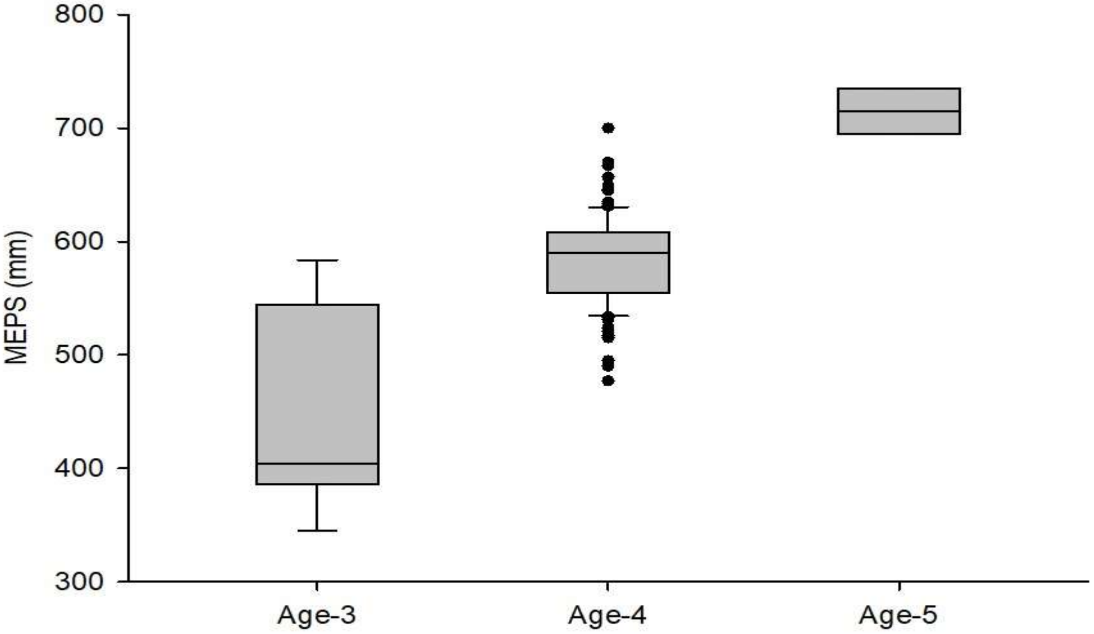

Figure 16. Age versus MEPS length for all Chinook recovered in 2018. Boxes indicate 25th percentile, median, and 75th percentile. Error bars indicate 10th and 90th percentiles.

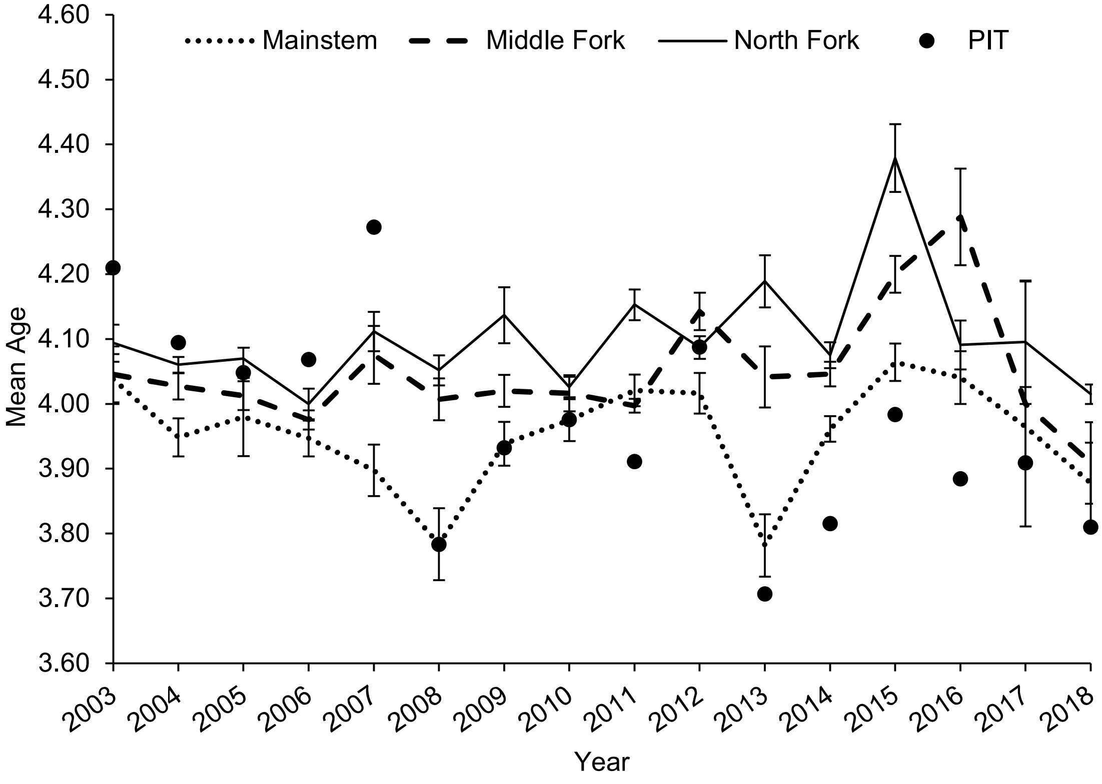

Figure 17. Mean ages with standard errors determined from scales of carcasses in John Day River basin spring Chinook salmon populations, as well as mean ages of PIT tagged fish from 2003 through 2018.

In 2016, laboratory analysis produced optical density values for kidney samples taken from 30 carcasses and Rs antigen levels revealed 7 samples were negative or very low, 23 samples were positive (Appendix Table VI). In 2017, results from seven samples revealed 3 were negative and 4 were positive. In 2018, results from 25 fish revealed 4 negative and 21 positive samples. Mean ELISA optical density values for kidney samples collected from carcasses in the John Day, Imnaha, and Minam populations from 2000–2018 indicate overall low ELISA OD values with sporadic increases in the Mainstem, Middle Fork, and Minam fish (Figure 18). Two-factor ANOVA revealed significant differences among basins (i.e., lack of correlation between populations), with the Middle Fork having a higher prevalence of positive fish. Information theoretic selection of four candidate logistic regression models (Table 9) indicated that the "Population + Density" was the best fit model.

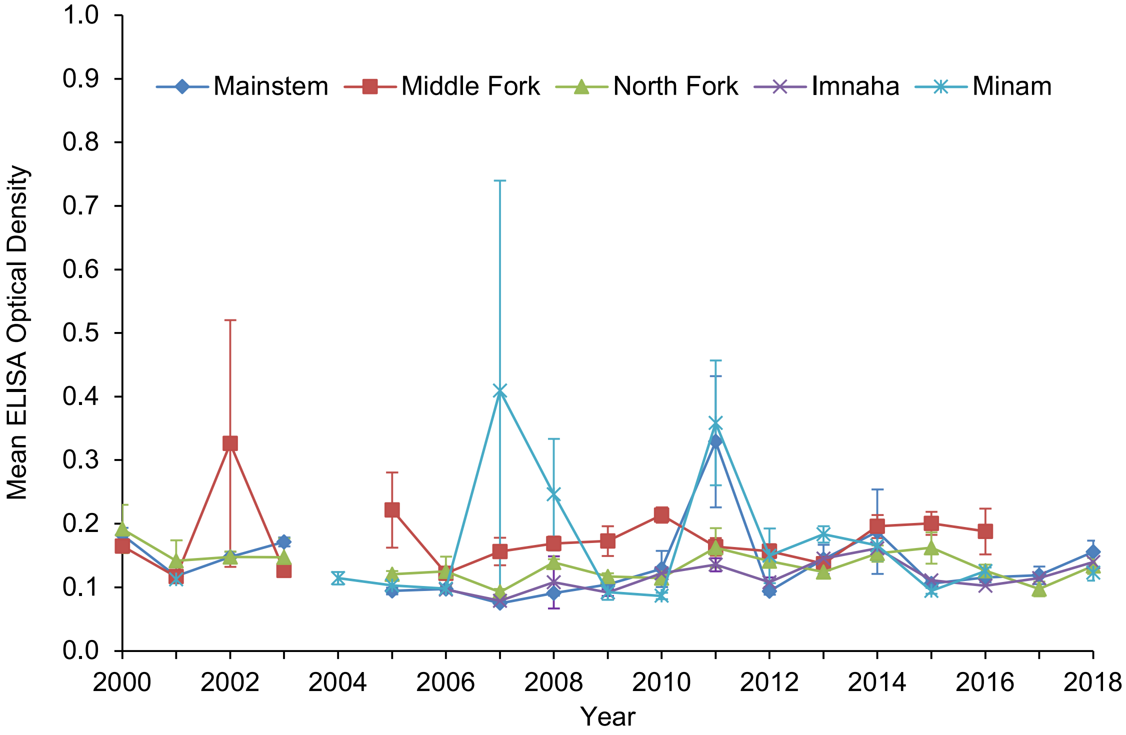

Figure 18. Mean ELISA optical density values with standard errors for kidney samples collected from carcasses in John Day River basin spring Chinook salmon populations from 2000 through 2018.

Table 9. Akaike's information criterion (AIC) model selection results for binomial logistic regressions of ELISA OD values versus different explanatory variables. Explanatory variables included: population, year, and density.

Model	K	AIC	ΔAIC	w_i
Population + Density		413	0	0.8808
Population * Density		417	4	0.1192
Population + Year		435	22	< 0.000
Population		441	28	< 0.000

Of the 36 female carcasses for which we estimated egg retention, 31 (86%) were completely spawned. The 5 females that were partially spawned contained an average of 265 ml (SD = 268) of egg

PIT Tag Detection-Recapture Escapement Estimation

In 2018, a total of 137 carcasses, including those that had been scavenged, were scanned for PIT tags during spawning ground surveys and four tags were recovered (Appendix Table V). Two of the recaptured fish were males and two were females, all were of wild origin. One of the carcasses we recovered in the Mainstem was originally tagged as a juvenile at the Mainstem RST on 11 April 2017. The other PIT tagged fish recovered in the Mainstem was tagged at Bonneville Dam on 30 May 2018. The only PIT recapture in the North Fork was also tagged at Bonneville Dam (24 May 2018). The lone Middle Fork PIT recapture was tagged as an adult at Lower Granite Dam (Snake River, Idaho) on 31 May 2018. Earlier PIT detections reveal that it is not uncommon for an occasional John Day Chinook to stray into the Snake River and later find their way into the John Day River. Detections at Bonneville Dam indicated that 61 John Day origin PIT-tagged returning adult Chinook passed the dam in 2018. Surveyors scanned a total of 111 intact wild origin carcasses for PIT tags. Given the low number of recaptured John Day origin PIT-tagged fish in 2017 and 2018, we were unable to estimate wild escapement at Bonneville Dam (Figure 19) and the Middle Fork Array (Figure 20). A matrix of all in-basin PIT tag recoveries (n=134), including antenna detections and carcass examinations, reveals 100% homing among Mainstem and Middle Fork adults (Table 10).

Table 10. Total passive integrated transponder (PIT) tags implanted in juvenile Chinook and subsequently detected in returning jacks and adults in John Day River subbasins during 2009 through 2018.

		Recapture Location		
		Mainstem	Middle Fork	North Fork
Marking Location	Mainstem	44	0	0
	Middle Fork	0	90	0
	North Fork	0	0	0

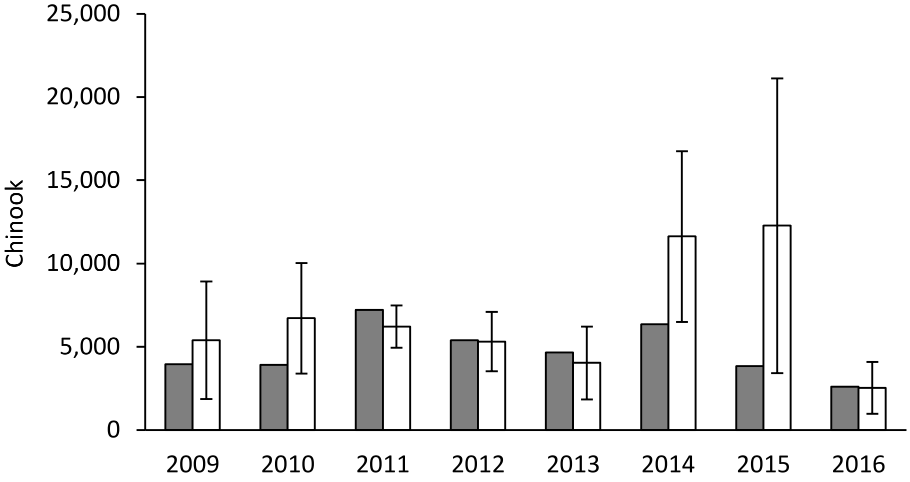

Figure 19. John Day River basin mark-recapture abundance estimates (white) with 95% confidence intervals and redd count escapement estimates (gray) for spawning years 2009 through 2016.

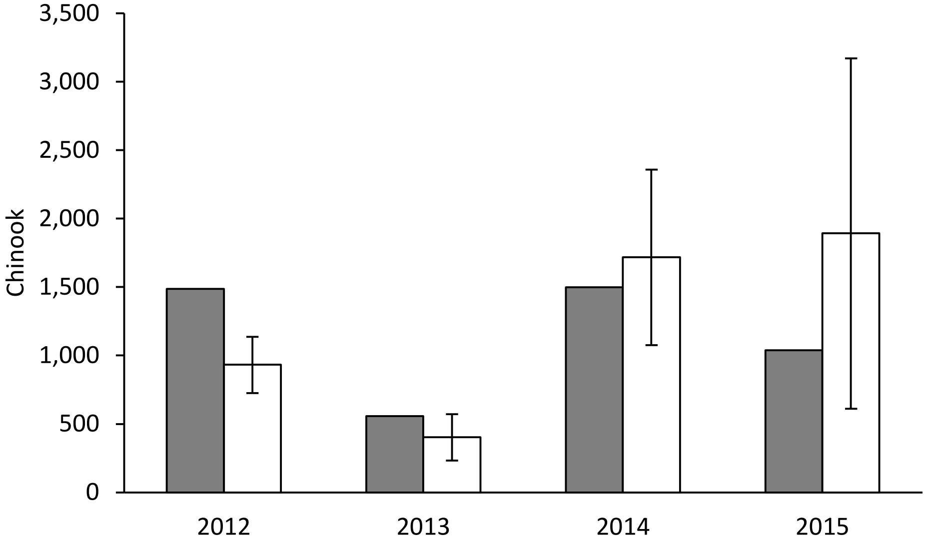

Figure 20. Middle Fork John Day River mark-recapture abundance estimates (white) with 95% confidence intervals and redd count escapement estimates (gray) for spawning years 2012 through 2015.

Redd Distribution Analysis

Analysis of the relationship between reach location and redd density in the three populations produced mixed results. In the Mainstem, we used seven sections, starting at Prairie Wood Products and continuing upstream to Reynolds Upper Fence, from spawning years 2008 through 2018. Eight of the eleven years had correlation values of 0.80 or higher, indicating that higher redd densities tended to occur in upstream reaches (Figure 21; Mainstem). The Middle Fork analysis included ten reaches, from Armstrong

Creek upstream to Highway 7, from 2001 through 2018. The first twelve years revealed correlation coefficients of 0.77 or higher, excluding an outlier of 0.38 in 2004 that we cannot explain (Figure 21; Middle Fork). Five of the last six years, however, produced lower and more varied correlation coefficients; spawners appear to be increasing the use of downstream reaches relative to upstream reaches. In the North Fork, we used redd densities from sixteen reaches, from Camas Creek up to Trail Crossing, from 2004 through 2018. The relationship between site location and redd density in the North Fork during this period is more variable, with positive and negative correlation coefficients (Figure 21; North Fork).

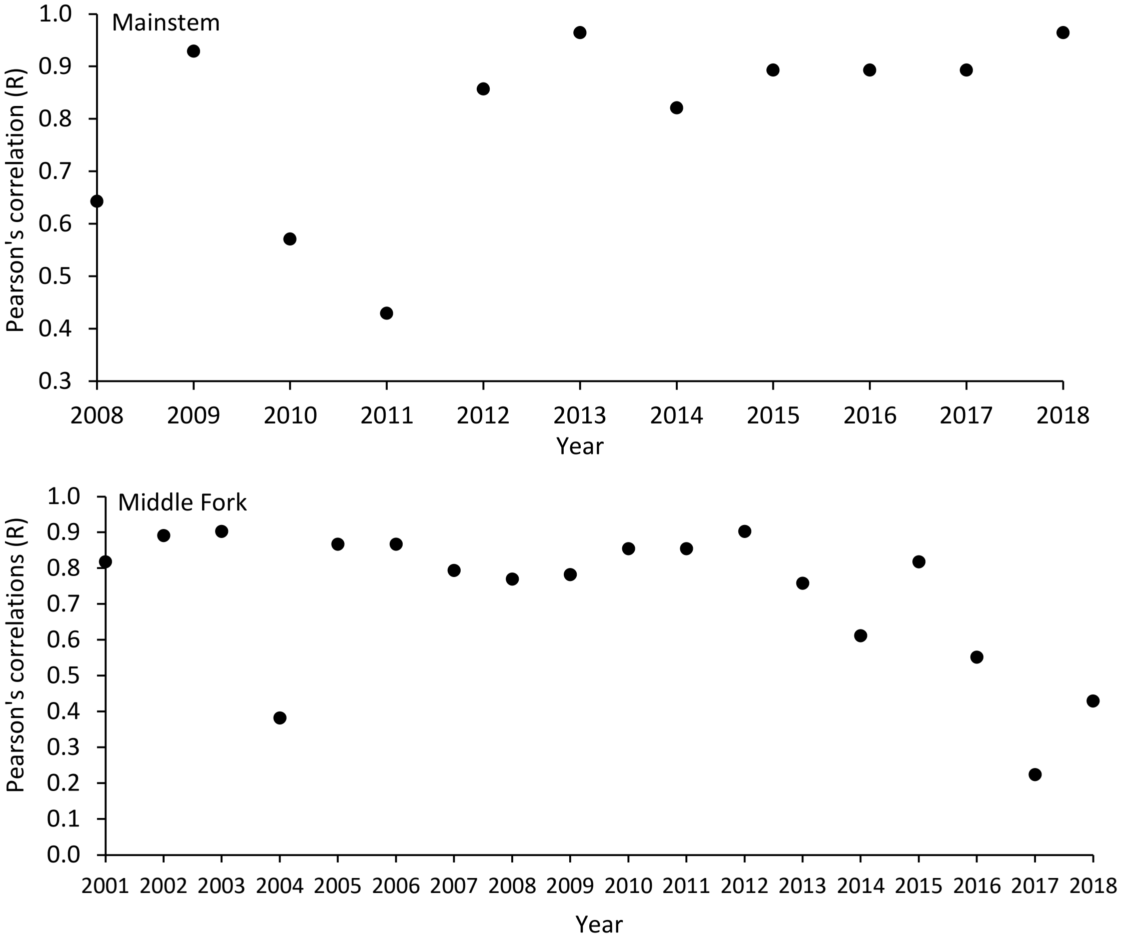

Figure 21. Pearson's correlations for spawning reach versus rank based on density (redds/km) in the Mainstem, Middle Fork, and North Fork.

Carcass Detection Probabilities

Since 2013, we have marked 945 carcasses with uniquely numbered cable-ties before replacing them in the stream. We have recovered 422 of these marked carcasses at least once during subsequent surveys. The probability of a marked carcass being recovered was highest in the Middle Fork (0.37; *n* = 477 marked carcasses), intermediate in the North Fork (0.32; *n* = 319), and lowest in the Mainstem (0.30; *n* = 149). Information theoretic selection of four candidate logistic regression models (Table 10) indicated that the "year + population" was the best fit model. Logistic regression models which incorporated population and year alone, or no explanatory variables (i.e., intercept), did not fit the data as well.

Table 11. 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 year. The intercept model is a null model with no explanatory variables.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	***w$_i$***
Year + Population	8	91.19	0	
Population	3	105.96	14.77	0.13
Year	6	171.23	65.27	0.57
Intercept	1	206.69	35.46	0.31

Population Productivity Analyses

We estimated that freshwater productivity for the 2016 brood year was 153 smolts per redd (95% CI: 148–159) in the Mainstem and 121 smolts per redd (95% CI: 112−132) in the Middle Fork. The estimated number of smolts produced per redd declines with increasing redd abundance for both the Mainstem and Middle Fork populations (Figures 22 and 23).

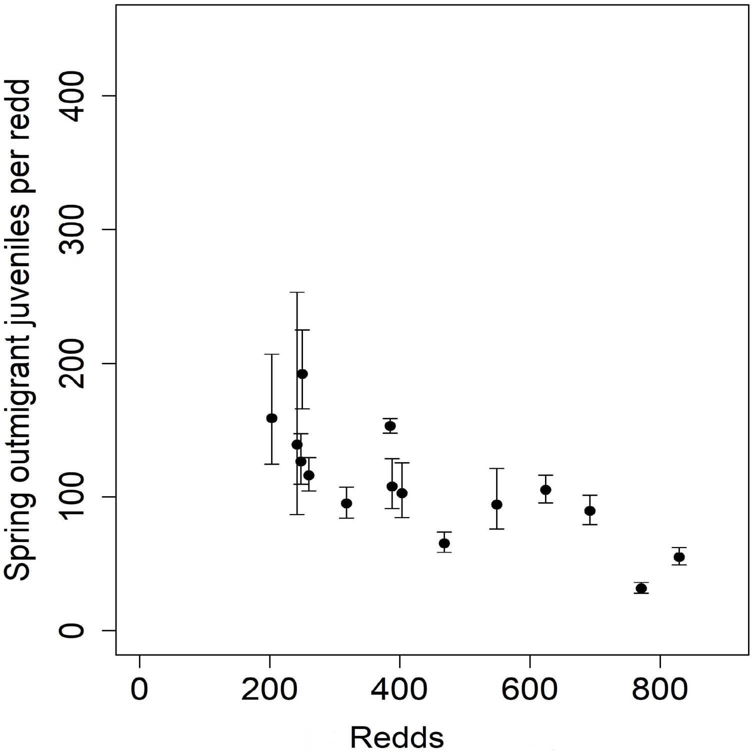

Figure 22. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2016 for the Mainstem population. Error bars are 95% Confidence Intervals.

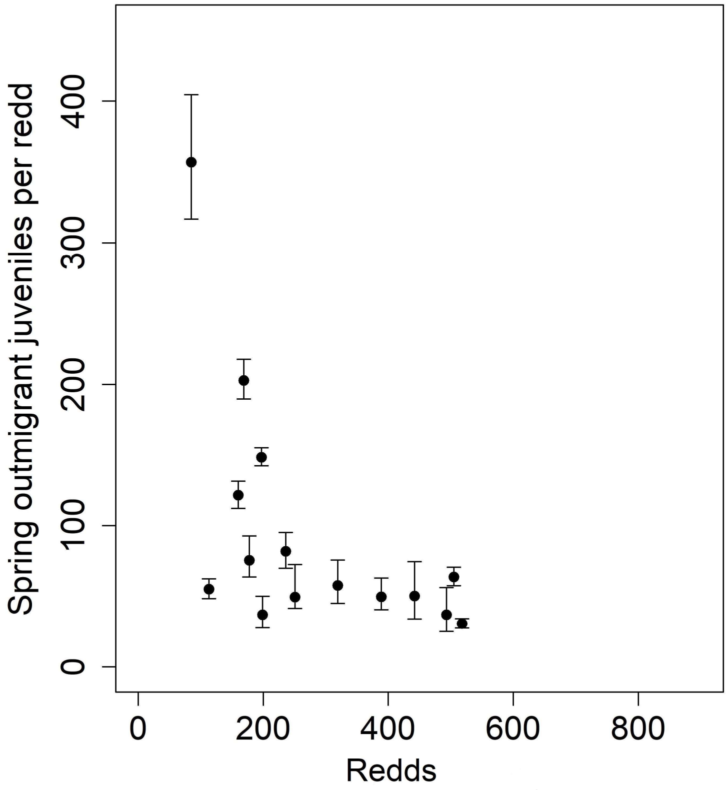

Figure 23. Estimated yearling spring Chinook salmon smolts produced per redd for brood years 2002 through 2016 for the Middle Fork population. Error bars are 95% Confidence Intervals.

Stock-recruitment analysis for the Mainstem population suggests a replacement level (unexploited equilibrium) of 420 redds (Figure 24a). The Middle Fork population appears to have a replacement level of 220 redds (Figure 24c). Replacement level for the North Fork population is 320 redds (Figure 24e).

Plots of residuals from the stock-recruitment regressions suggest an upward trend for the Mainstem population; the first five brood years for the Mainstem had negative residuals, while six of the most recent seven brood years had positive residuals (Figure 24b). The Middle Fork and North Fork residuals indicate downward trends. The sharp decline in redd totals in 2017 and 2018, appear to have had larger negative residuals in both of these populations (Figures 24d and 24f).

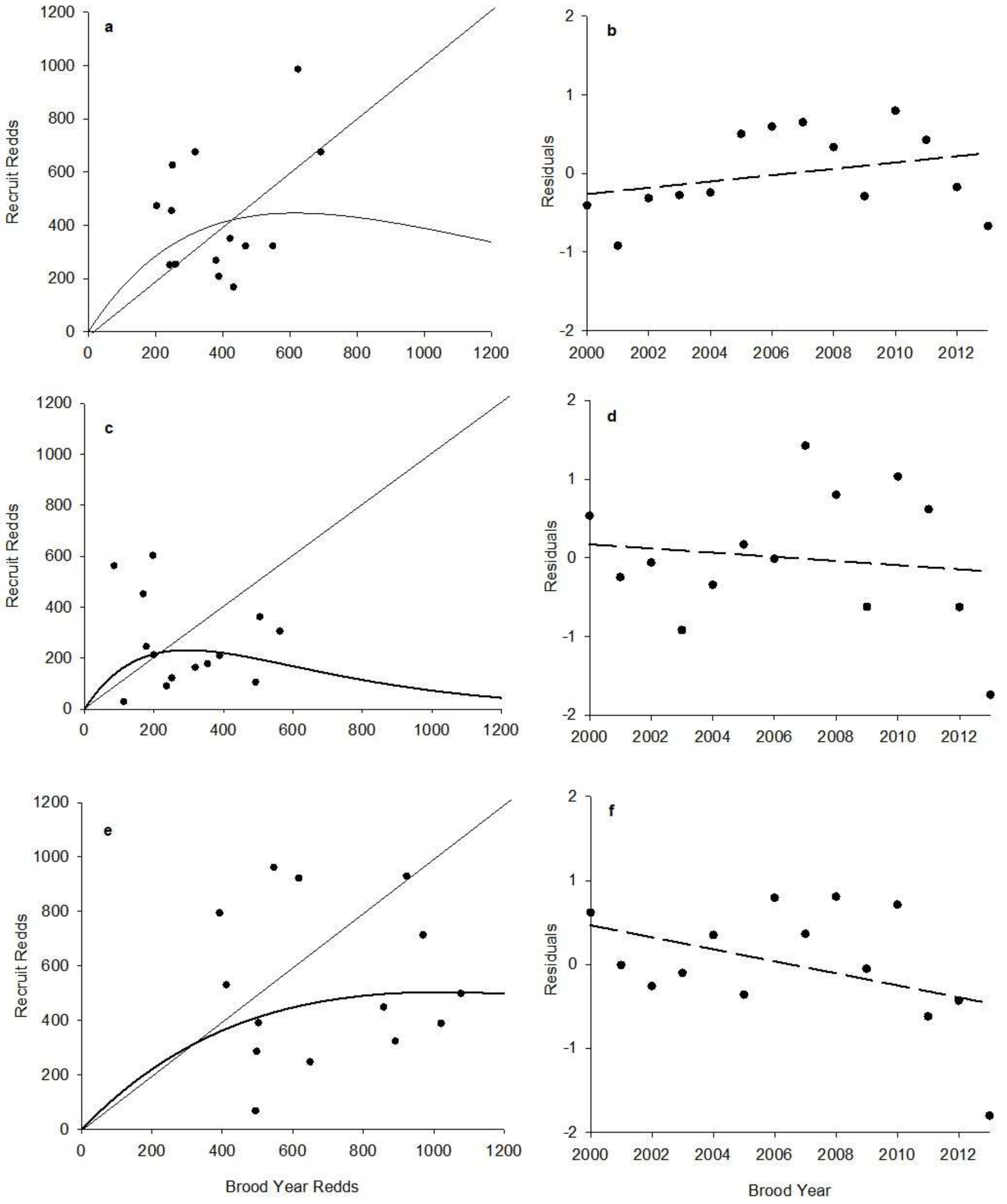

Figure 24. Comparison of Ricker stock-recruitment curves for 2000 through 2013 brood years and associated residual versus brood year plots for Chinook spawning populations in the Mainstem (a and b), Middle Fork (c and d), and North Fork (e and f) of the John Day River. Diagonal lines in panels a, c, and e are 1:1 replacement lines. Dashed lines in panels b, d, and f are linear regression lines fit to the residuals to illustrate trends over time.

DISCUSSION

Status of John Day River Spring Chinook Salmon

Chinook redd counts for 2018 rebounded slightly from those of 2017, which produced the lowest totals observed during the nineteen-year monitoring period. The Grande Ronde basin experienced a rise in redd counts as well. Although, the Imnaha basin did not experience a rebound, covariation among redd counts in northeast Oregon populations over the past nineteen years is significant and suggests a large-scale environmental effect is occurring across these populations. Such ecological responses to large-scale changes in the physical environment are known to occur with Pacific salmon (Hare et al. 1999). Once again, higher ocean-entry PDO values (indicating warmer sea surface temperatures) appear to correspond with lower escapement. The majority of this latest cohort, that entered the ocean as smolts in 2016, experienced the second highest PDO value measured since 1998. Consequently, 2018 escapement was the second lowest we have observed since 2000. Significant inverse relationships between PDO values during the summer of smolt ocean-entry and adult returns to all John Day basin populations, the Grande Ronde, and Imnaha River populations suggest that ocean conditions are a driving factor influencing smolt survival. For returning adult Chinook, lower stream flow and higher water temperatures during summer months may have resulted in higher pre-spawn mortality rates in these populations, and have further diminished adult abundance on spawning grounds. This may have gone undocumented in the remote reaches of the North Fork, where we observed fewer than half the redds counted in the Mainstem.

Given the effect of ocean conditions on adult abundance, trends in freshwater productivity provide a more appropriate measure of population status than simple adult abundance (e.g., Lawson 1993). Mainstem and Middle Fork smolts produced per redd decrease as the number of redds increase, indicating that juvenile rearing areas are fully seeded at recent escapement levels and rearing habitat may be limiting freshwater production. Stock-recruit analyses for the John Day populations illustrate the effect of density-dependence. The Mainstem stock-recruit curve shows a density-dependent effect, production decreases once escapement exceeds 600 redds. Conversely, the curve for the North Fork indicates no immediate concern about decreased production at higher escapements. In the Mainstem population, there is also a broad range of escapement that produced a positive sustainable yield and a large yield when brood redds approach 200. Average sustainable yield in the Middle Fork, however, is low and extends over a shorter range of brood year redds. In the North Fork, sustainable yield is roughly constant for a comparatively broader range of brood year redds.

The Mainstem now comprises more of the basinwide adult escapement than the North Fork. For the first eleven years of census counts, the North Fork contributed 41–63% of the basinwide totals. During 2015, however, the North Fork counts were just 25% of the total redd count and in 2017 and 2018 the population contributed less than

27% of the basinwide redd total. Residuals from the Mainstem stock-recruitment curve suggest non-stationarity because a positive slope is apparent through the years in the Mainstem (Figure 24 b), while the Middle Fork and North Fork are beginning to exhibit negative slopes (Figures 24 d and f). Spatial connectivity may explain the trends we see in productivity; many habitat improvement projects have been completed in the upper Mainstem and Middle Fork in recent years, which have presumably increased fish passage and juvenile rearing habitat. Removing barriers and allowing juvenile and adult Chinook access to additional spawning and rearing habitat may be increasing population productivity (Sharma and Hilborn 2001). Conversely, the transition from the North Fork being the most abundant population to the Mainstem being the most abundant population may also be natural population asynchrony (i.e., "portfolio-effect"). Productivity of neighboring populations can oscillate on decadal scales, even in the absence of habitat changes (Hilborn et al. 2003). Continued monitoring will allow us to discern whether this abundance and productivity shift from the North Fork to the Mainstem is a natural "portfolio-effect" oscillation, or a response to habitat changes in the Mainstem.

Monitoring BKD throughout the basin may provide additional insight to the effects environmental stressors have on Chinook. Although opportunistic collection has provided inconsistent and limited numbers of mortalities for kidney sampling—especially in juveniles—we were able to see significant differences in the prevalence of infected fish among John Day populations and two other northeast Oregon basins. Furthermore, population and density were both significantly related to the probability of a carcass having positive-clinical levels. In the John Day River basin, the probability of a positive-clinical BKD score is significantly greater in the Middle Fork than either the Mainstem or North Fork. Absence of correlation between these populations suggests the lack of an out-of-basin effect (i.e., ocean or Columbia River). If local factors, such as habitat quality and abundance, are driving this difference among basins, BKD occurrence could potentially be used as a restoration tracking metric.

Straying of adipose-clipped hatchery Chinook into the John Day River basin has decreased recently, and we did not detect any hatchery fish or wild strays during 2017 and 2018. Reduced barging of smolts collected at Lower Granite Dam in the Snake River basin, which impairs homing ability (Keefer et al. 2008), may be contributing to the reduced level of hatchery straying and lack of wild straying we have observed in the past four years. Numerous wild Chinook juveniles in Snake and Upper Columbia River populations are marked with PIT tags, creating the possibility of re-detection in the John Day River. Although Narum et al. (2008) suggested that wild strays may be more prevalent than hatchery strays in the John Day River basin, we did not recover or passively detect any wild strays. Continued emphasis on scanning carcasses for PIT tags will improve our understanding of straying by wild and hatchery Chinook. Installation of PIT detection arrays on the North Fork John Day would also improve our ability to detect stray wild adults.

Survey Methodology

Continuing to monitor index reaches allows us to see trends in redd density from 1964 to present, yet these reaches only comprise a portion of the spawning range in the basin. Index reaches were not chosen using a non-biased random process. Furthermore, index sites are based on redd distributions that were established five decades ago in reaches that may no longer provide the most suitable spawning habitat nor the highest redd densities. Although index counts constituted 72% of redds observed in 2018, our more extensive census efforts reveal an overall downward trend in index representation since 2000 (Figure 6). For example, the 2011 index:census redd count ratio equaled 0.5 (index representation of 33%). Although our census area has expanded over time, our analyses suggest spawner distribution shifts toward census reaches as run size increases, possibly resulting from competition for spawning gravel among adult females. Our data also suggest a greater percentage of fish utilize census areas during higher flow conditions. This may be the result of managers in the 1950s selecting index sites based on redd distribution during normal flow conditions, thereby excluding spawning reaches made available by above average discharge. Hence, our data indicate that index counts alone are not an accurate method for estimating escapement. Although it is necessary to continue monitoring index reaches to maintain long-term trend data, the interannual variation in distribution of redds (Figure 6) indicates it is also necessary to monitor census sites to achieve an accurate measure of escapement.

The 2018 spawning season was the sixth consecutive year that we conducted a carcass detection study. Through the course of monitoring 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. The detection probability in the Mainstem is typically lower than the rates observed in the Middle and North forks. 2018 was the exception, with the one Mainstem carcass that was marked being subsequently recovered. The typical lower carcass detection probability in the Mainstem is likely the result of the dense riparian cover, higher turbidity, more frequent log jams and undercut banks, and a moderate amount of scavenging. In the North Fork population, scavenging appears to be a major limitation to carcass recovery; evidence of black bears and eagles feeding upon salmon carcasses is abundant on streambanks within roadless reaches. Given the decline in escapement over the last four years, opportunities to mark carcasses has also declined. Despite the limitations, marking and resighting carcasses throughout the spawning grounds improved our understanding of factors influencing carcass recovery probability and the data derived from carcasses we do recover.

During certain years, 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. This can be problematic, as demonstrated during the 2013 spawning season, when rain events resulted in turbidity likely affecting the final redd count in Catherine Creek, although not in the John Day basin. Unlike the redd expansion estimate that uses out-of-basin fish per redd estimates, the PIT tag mark-recovery escapement estimation relies solely on John Day spring Chinook data. Although results from the first five years of mark-recovery data (2009-2013) and 2016 suggest that this approach is feasible, the 2014 and 2015 escapement estimates demonstrate that the estimate is sensitive to even slight differences in the number of marked and recovered fish. Therefore, a minimum number of returning marked fish is necessary to generate an estimate with acceptable confidence and greater effort must be made to scan and detect as many PIT tagged carcasses as possible. With low numbers of returning adults in 2017 and 2018, we were not able to generate an estimate. During years when both approaches were feasible, the concordance of escapement estimates generated by these discrete methodologies increases our confidence in the suitability of both methods for estimating John Day spring Chinook salmon escapement and we intend to continue both estimations for immediate future years.

Management Implications

Our extensive monitoring of Chinook spawning locations has allowed us to detect changes in redd distribution throughout the spawning grounds. Chinook salmon are known to use the same spawning areas year after year. Klett et al. (2013) statistically evaluated spatiotemporal consistency in the spawning patterns of Chinook in the Cowlitz River, located in southwestern Washington. In the Oxbow area of the Middle Fork, stream restoration efforts created 1.8 km of new river channel and enhanced 1.7 km of river channel with flow restoration and habitat improvements. Prior to this restoration, redd densities along the river consistently indicated a longitudinal distribution with more upstream spawning activity. Following the restoration work, however, redd density appears to be increasing in the newly restored reaches.

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

Adult escapements in recent years are at or above the current capacity of freshwater habitat to produce yearling smolts. While freshwater habitat is already limiting salmonid production, increases in stream temperature resulting from climate change may result in extensive loss of habitat throughout the John Day basin (Ruesch et al. 2012). 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 24) is a cautious approach that should allow for sufficient production of all juvenile life-history types. Managing for replacement levels of escapement will provide "cushion" in the event of unanticipated ocean or freshwater environmental changes. With opportunities for recreational fisheries targeting wild populations being scarce for Columbia River Chinook populations, improvements to rearing habitat in the John Day River basin would increase the potential of future fisheries for these wild populations.

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APPENDIX

Appendix Table I. Spring Chinook total redd counts in the John Day River basin, 2000 through 2018. Includes redds observed in index, census, and random sections.

				North Fork Subbasin					
					Granite Creek System				
Year	**Mainstem**	**South Fork**	**Middle Fork**	**North Fork**	**Granite Creek**	**Clear Creek**	**Bull Run Creek**	**Desolation Creek**	**Basin Total**
2000	380	3	563	612	198	96	12	5	1,869
2001	432	0	354	803	126	80	45	23	1,863
2002	549	0	389	707	163	64	31	56	1,959
2003	260	0	236	668	118	32	1	39	1,354
2004	242	0	319	806	72	38	8	46	1,531
2005	203	0	178	420	43	15	4	15	878
2006	318	0	199	262	55	28	14	33	909
2007	250	0	85	358	19	9	2	23	746
2008	248	0	169	432	57	16	10	31	963
2009	468	0	251	360	47	53	4	38	1,221
2010	624	2	197	386	93	50	18	70	1,440
2011	692	0	505	475	67	44	14	49	1,846
2012	403	0	493	595	139	69	37	51	1,787
2013	388	0	113	494	53	37	7	44	995
2014	829	0	518	848	124	103	33	77	2,195
2015	771	0	442	415	32	16	11	33	1,628
2016	385	0	160	158	30	19	5	51	893
2017	228	1	29	55	9	3	6	8	339
2018	340	0	75	153	31	25	7	26	568

Appendix Table II. Census and index survey lengths (km) for spring Chinook salmon spawning surveys in the John Day River basin, 2000 through 2018. Includes stream lengths in areas where we were denied access.

				North Fork Subbasin					
					Granite Creek System				
Year	**Mainstem**	**South Fork**	**Middle Fork**	**North Fork**	**Granite Creek**	**Clear Creek**	**Bull Run Creek**	**Desolation Creek**	**Basin Total**
2000	32.2	17.3	51.5	83.9	16.5	7.6	5.7	21.4	236.1
2001	32.2	17.3	51.5	83.9	16.5	7.6	5.7	28.5	243.2
2002	32.2	17.3	51.5	86.9	16.5	10.3	7.2	34.0	255.9
2003	32.2	0.2	51.5	86.9	16.5	10.3	7.2	38.2	243.0
2004	34.3	17.3	51.5	88.3	16.5	10.3	7.2	34.6	260.0
2005	34.3	17.3	51.5	92.2	16.5	10.3	7.2	38.2	267.5
2006	34.3	17.3	51.5	92.2	16.5	10.3	7.2	35.3	264.6
2007	34.3	17.3	51.5	92.2	16.5	10.3	7.2	38.2	267.5
2008	34.3	17.3	51.5	92.2	16.5	10.3	7.2	35.3	264.6
2009	34.3	17.3	51.5	94.8	16.5	10.2	7.2	34.0	265.9
2010	34.3	17.3	51.5	97.5	16.5	10.2	7.2	34.0	268.6
2011	43.9	17.3	57.4	95.8	16.5	10.3	7.2	37.1	285.6
2012	45.3	17.3	59.4	96.0	16.5	10.3	7.2	37.1	290.8
2013	43.6	17.3	59.4	96.7	16.5	10.3	7.2	37.1	287.2
2014	43.6	17.3	59.4	96.7	16.5	10.3	7.2	37.1	287.2
2015	48.5	17.3	57.4	96.7	16.5	9.0	7.2	37.1	289.8
2016	48.5	17.3	57.4	96.7	16.5	9.0	7.2	37.1	289.8
2017	46.3	17.3	57.4	96.7	16.5	9.0	7.2	37.1	287.6
2018	37.4	13.8	57.4	96.7	16.5	9.0	7.2	37.1	275.2

Appendix Table III. Spawning density (redds/km) in the John Day River basin, 2000 through 2018. Includes density estimates for areas where we were denied access.

				North Fork Subbasin					
					Granite Creek System				
Year	**Mainstem**	**South Fork**	**Middle Fork**	**North Fork**	**Granite Creek**	**Clear Creek**	**Bull Run Creek**	**Desolation Creek**	**Basin Total**
2000	11.8	0.2	10.9	7.3	12.0	12.6	2.1	0.2	7.9
2001	13.4	0.0	6.9	9.6	7.6	10.5	7.9	0.8	7.7
2002	17.0	0.0	7.6	8.1	9.9	6.2	4.3	1.6	7.7
2003	8.1	0.0	4.6	7.7	7.2	3.1	0.1	1.0	5.6
2004	7.1	0.0	6.2	9.1	4.4	3.7	1.1	1.3	5.9
2005	5.9	0.0	3.5	4.6	2.6	1.5	0.6	0.4	3.3
2006	9.3	0.0	3.9	2.8	3.3	2.7	1.9	0.9	3.4
2007	7.3	0.0	1.7	3.9	1.2	0.9	0.3	0.6	2.8
2008	7.2	0.0	3.3	4.7	3.5	1.6	1.4	0.9	3.6
2009	13.6	0.0	4.9	3.8	2.8	5.2	0.6	1.1	4.6
2010	18.2	0.1	3.8	4.0	5.6	4.9	2.5	2.1	5.4
2011	15.8	0.0	7.8	5.0	4.1	4.3	1.9	1.3	6.3
2012	12.4	0.0	8.3	6.2	8.4	6.7	5.1	1.4	6.1
2013	8.9	0.0	1.9	3.6	3.2	3.6	1.0	1.2	3.9
2014	19.0	0.0	8.7	5.1	7.5	10.0	4.6	2.1	7.6
2015	15.9	0.0	7.7	3.3	1.9	1.8	1.5	0.9	5.6
2016	7.9	0.0	2.8	2.1	1.8	2.1	0.7	1.4	3.1
2017	4.9	0.1	0.5	0.6	0.5	0.3	0.8	0.2	1.2
2018	6.1	0.0	1.3	0.7	1.9	2.8	1.0	0.7	1.7

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 through 2016 brood years.

		Mainstem				**Middle Fork**			
				95% CI				**95% CI**	
Brood Year	**Smolt Year**	**Redds (n)**	**Smolts/ redd**	**Lower**	**Upper**	**Redds (n)**	**Smolts/ redd**	**Lower**	**Upper**
2002	2004	549	94	76	121	389	50	41	63
2003	2005	260	116	105	129	236	82	70	95
2004	2006	242	139	87	253	319	58	45	76
2005	2007	203	159	124	207	178	76	64	93
2006	2008	318	95	84	107	199	37	28	50
2007	2009	250	192	166	225	85	357	317	404
2008	2010	248	126	109	147	169	203	190	218
2009	2011	468	65	59	74	251	50	42	73
2010	2012	624	105	96	116	197	148	142	155
2011	2013	692	90	79	101	505	64	58	71
2012	2014	403	103	85	125	493	37	25	56
2013	2015	388	108	91	129	113	55	49	63
2014	2016	829	55	49	62	518	31	28	34
2015	2017	771	31	28	36	442	51	34	75
2016	2018	385	153	148	159	160	121	112	132

[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. Spring Chinook passive integrated transponder (PIT) tags recovered on John Day River spawning ground surveys during 2009 through 2018. U = unknown sex.

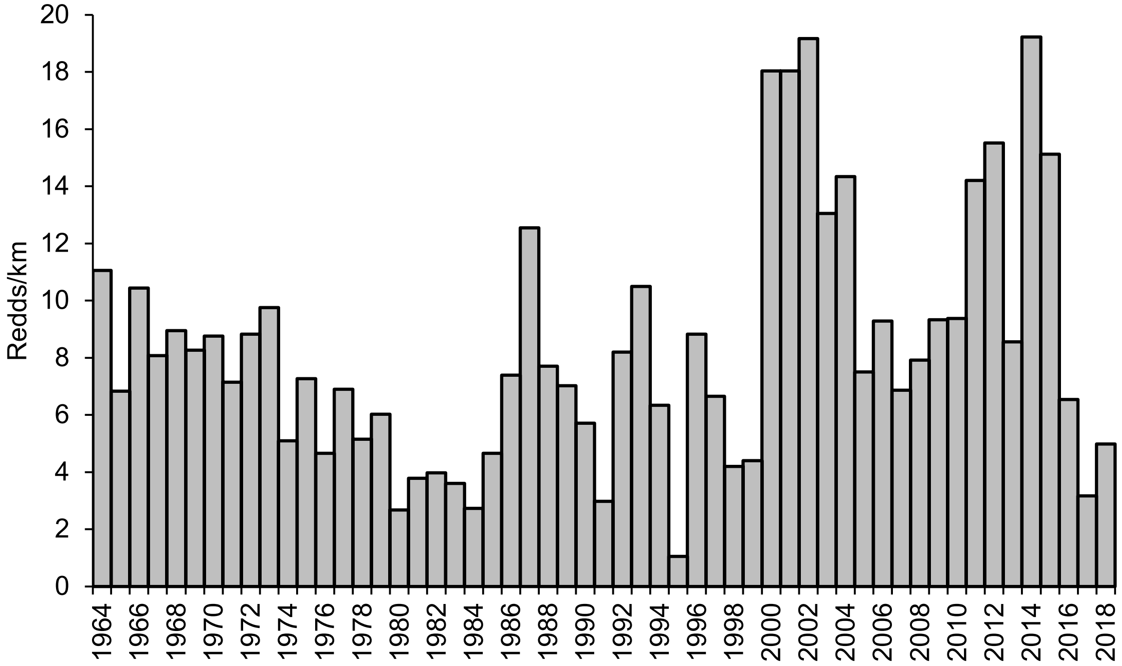
	Intact Wild Carcasses Scanned			**Carcasses with John Day Origin PIT Tags**[b]			**Carcasses with Out of Basin Origin PIT Tags**		
Year	**Male**	**Female**	**U**	**Male**	**Female**	**U**	**Male**	**Female**	**U**
2009	114	137	2	3	1	0	1	0	0
2010	259	233	24	7	0	1	3	1	0
2011	746	759	42	31	4	0	6	5	0
2012	228	318	619	8	1	5	3	6	5
2013	319	245	4	6	0	0	6	3	0
2014	549	685	38	7	1	0	6	7	0
2015	238	263	22	2	1	0	1	2	0
2016	78	103	1	3	0	0	2	0	0
2017	26	25	0	0	0	0	0	0	0
2018	37	73	1	1	0	0	1	2	0

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

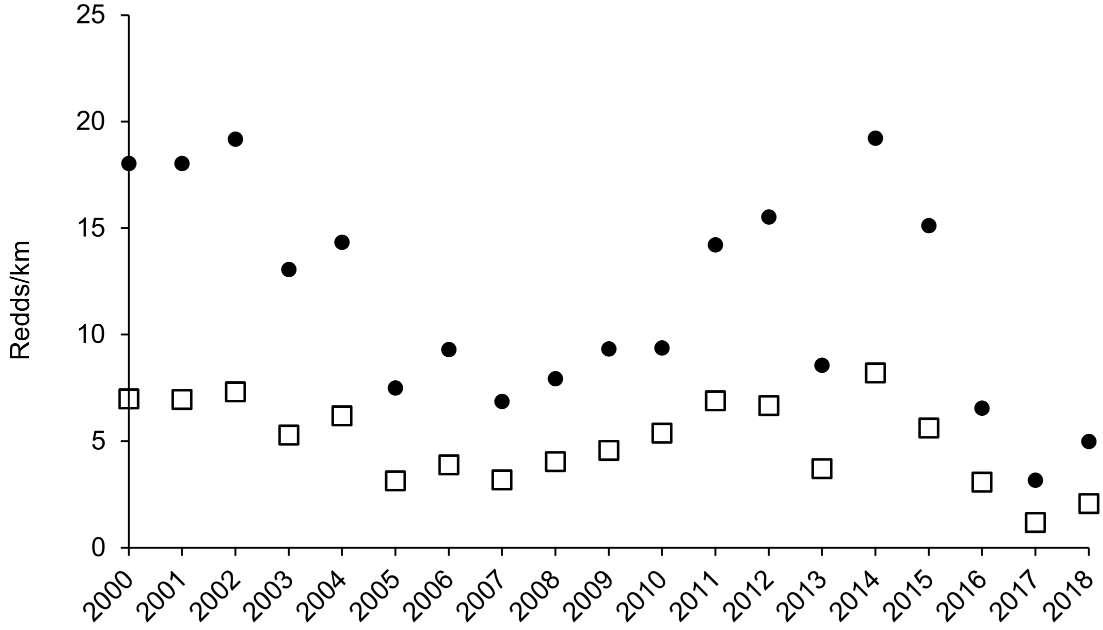
Appendix Table VI. Egg retention and ELISA optical density values for adult spring Chinook kidneys sampled from carcasses in the John Day River basin, 2016, 2017, and 2018.

Year	Population	Egg Retention (ml)	Optical Density (OD_{405})
2016			
	Mainstem John Day River		0.091
	Mainstem John Day River		0.095
	Mainstem John Day River		0.097
	Mainstem John Day River	0	0.098
	Mainstem John Day River		0.099
	Mainstem John Day River	0	0.102
	Mainstem John Day River	0	0.103
	Mainstem John Day River	0	0.105
	Mainstem John Day River		0.105
	Mainstem John Day River	0	0.108
	Mainstem John Day River		0.118
	Mainstem John Day River		0.123
	Mainstem John Day River		0.133
	Mainstem John Day River		0.171
	Mainstem John Day River		0.197
	Middle Fork John Day River	0	0.138
	Middle Fork John Day River	0	0.146
	Middle Fork John Day River		0.161
	Middle Fork John Day River	25	0.163
	Middle Fork John Day River		0.331
	North Fork John Day River		0.084
	North Fork John Day River		0.089
	North Fork John Day River		0.106
	North Fork John Day River		0.119
	North Fork John Day River	0	0.121
	North Fork John Day River		0.124
	North Fork John Day River		0.126
	North Fork John Day River		0.141
	North Fork John Day River		0.175
	North Fork John Day River	0	0.176
2017			
	Mainstem John Day River	0	0.091
	Mainstem John Day River		0.097
	Mainstem John Day River	0	0.109
	Mainstem John Day River		0.130
	Mainstem John Day River		0.168
	North Fork John Day River		0.086
	North Fork John Day River		0.109
2018			
	Mainstem John Day River	0	0.084
	Mainstem John Day River	0	0.087
	Mainstem John Day River		0.101
	Mainstem John Day River		0.105
	Mainstem John Day River	0	0.115
	Mainstem John Day River	0	0.129
	Mainstem John Day River		0.134
	Mainstem John Day River		0.138
	Mainstem John Day River		0.139
	Mainstem John Day River		0.153
	Mainstem John Day River		0.179
	Mainstem John Day River		0.24
	North Fork John Day River	0	0.087
	North Fork John Day River		0.098
	North Fork John Day River		0.107

North Fork John Day River	725	0.108
North Fork John Day River	0	0.111
North Fork John Day River		0.139
North Fork John Day River	0	0.149
North Fork John Day River		0.152
North Fork John Day River	0	0.196
North Fork John Day River		0.204
North Fork John Day River		0.227
North Fork John Day River	225	0.291



Appendix Figure I. Spring Chinook index redd densities in the John Day River basin, 1964 through 2018. Densities include estimated redd counts in areas where we were denied access. Data from 1959 through 1963 are not presented because they do not represent the same spatial extent.



Appendix Figure II. Spring Chinook index (black circles) and census (open squares) redd densities in the John Day River basin, 2000 through 2018. Densities include estimated redd counts in areas where we were denied access.

Appendix Table VII. Index redd density (redds/km) in the John Day River basin 1998 through 2018. Includes estimated redd densities in areas where we were denied access. GCS = Granite Creek system (tributary to North Fork John Day).

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

2013	13.8	4.1	6.1	3.0	6.6
2014	27.3	17.0	14.5	11.0	16.1
2015	22.4	13.5	4.1	2.8	10.0
2016	16.9	5.4	3.4	2.3	6.5
2017	13.9	1.0	0.6	1.0	3.2
2018	18.8	2.7	0.9	2.6	5.1

Appendix Table VIII. 2018 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	River Mile 250	44.415336	-118.931297	44.418567	-118.907272
Mainstem John Day River	Indian Creek to Prairie Wood Products	44.443455	-118.797648	44.454705	-118.717714
Mainstem John Day River	Prairie Wood to Forrest Conservation Area	44.453559	-118.722180	44.459277	-118.701083
Mainstem John Day River	Forrest Conservation Area to Dads Creek	44.459277	-118.701083	44.453506	-118.672481
Mainstem John Day River	Dads Creek to Emmel Upper Fence	44.453506	-118.672481	44.449536	-118.655137
Mainstem John Day River	Field Lower Fence to Field Upper Fence	44.443609	-118.642786	44.435896	-118.627021
Mainstem John Day River	Field Upper Fence to French Lane	44.435896	-118.627021	44.419336	-118.600508
Mainstem John Day River	French Lane to Jacobs Upper Fence	44.419336	-118.600508	44.410514	-118.588248
Mainstem John Day River	Jacobs Upper Fence to Rd 13 Bridge	44.410514	-118.588248	44.395640	-118.577286
Mainstem John Day River	Rd 13 Bridge to Reynolds Fence	44.395640	-118.577286	44.377879	-118.579106
Mainstem John Day River	Reynolds Fence to Ricco Upper	44.377879	-118.579106	44.340011	-118.574012
Mainstem John Day River	Ricco Upper to Call Creek	44.340011	-118.574012	44.320119	-118.55734
Mainstem John Day River	River Mile 256 (Random)	44.437660	-118.822847	44.443455	-118.797648
Canyon Creek	River Mile 10 (Random)	44.298389	-118.953072	44.282398	-118.958864
Reynolds Creek	Mouth to U.S. Forest Boundary	44.412546	-118.588818	44.417049	-118.543229
Deardorff Creek	Mouth to 2.0 km upstream	44.394786	-118.576509	44.396724	-118.553344
Middle Fork John Day River	Armstrong Creek to Deep Creek	44.743248	-118.851359	44.716848	-118.821969
Middle Fork John Day River	Deep Creek to Rd 36 Bridge	44.716848	-118.821969	44.692588	-118.794073
Middle Fork John Day River	Rd 36 Bridge to Coyote Creek	44.692588	-118.794073	44.674525	-118.750240
Middle Fork John Day River	Coyote Creek to Upper TNC Boundary	44.674525	-118.750240	44.666466	-118.713502
Middle Fork John Day River	Upper TNC Boundary to Beaver Creek	44.666466	-118.713502	44.652418	-118.677977
Middle Fork John Day River	Beaver Creek to Windlass Creek	44.652418	-118.677977	44.638962	-118.627342
Middle Fork John Day River	Windlass Creek to Caribou Creek	44.638962	-118.627342	44.622012	-118.573089
Middle Fork John Day River	Caribou Creek to Dead Cow Bridge	44.622012	-118.627342	44.622012	-118.573089
Middle Fork John Day River	Dead Cow Bridge to Placer Gulch	44.607644	-118.547349	44.595637	-118.522586

Appendix Table VIII. Continued.

System	Description	Start Latitude	Start Longitude	End Latitude	End Longitude
Middle Fork John Day River	Placer Gulch to Highway 7	44.595637	-118.522586	44.603958	-118.483250
Middle Fork John Day River	Highway 7 to Crawford Creek	44.603958	-118.483250	44.588330	-118.448254
Middle Fork John Day River	River Mile 30 (Random)	44.808674	-118.987067	44.802598	-118.973479
Middle Fork John Day River	River Mile 31 (Random)	44.802598	-118.973479	44.797907	-118.958774
Granite Boulder Creek	Mouth to 4550 Road	44.647386	-118.665057	44.655800	-118.647961
Vinegar Creek	Mouth upstream 0.62km	44.601232	-118.535686	44.604931	-118.530114
Bridge Creek	Mouth to Road 2614	44.593407	-118.513618	44.569226	-118.506281
Clear Creek	Mouth to 1.6 km upstream of Hwy 26 Bridge	44.593743	-118.506834	44.562465	-118.488907
North Fork John Day River	Trail Crossing to Cunningham Creek	44.885060	-118.254856	44.910764	-118.266677
North Fork John Day River	Cunningham Creek to Baldy Creek	44.910764	-118.266677	44.909619	-118.317805
North Fork John Day River	Baldy Creek to Road 73 Bridge	44.909619	-118.317805	44.912888	-118.400227
North Fork John Day River	Road 73 Bridge to Trout Creek	44.912888	-118.400227	44.926657	-118.444597
North Fork John Day River	Trout Creek to Crane Creek	44.926657	-118.444597	44.893568	-118.477699
North Fork John Day River	Crane Creek to Trail Crossing	44.893568	-118.477699	44.874560	-118.520736
North Fork John Day River	Trail Crossing to Granite Creek	44.874560	-118.520736	44.865611	-118.562299
North Fork John Day River	Granite Creek to Wind Rock	44.865611	-118.562299	44.885947	-118.599879
North Fork John Day River	Wind Rock to Ryder Creek	44.885947	-118.599879	44.929562	-118.618474
North Fork John Day River	Ryder Creek to Cougar Creek	44.929562	-118.618474	44.944108	-118.647593
North Fork John Day River	Cougar Creek to Big Creek	44.944108	-118.647593	44.960194	-118.682884
North Fork John Day River	Big Creek to Oriental Creek	44.960194	-118.682884	44.973791	-118.726782
North Fork John Day River	Oriental Creek to Sulphur Creek	44.973791	-118.726782	44.980441	-118.761786
North Fork John Day River	Sulphur Creek to Nye Creek	44.980441	-118.761786	45.006291	-118.824657
North Fork John Day River	Nye Creek to Horse Canyon	45.006291	-118.824657	45.016381	-118.865414
North Fork John Day River	Horse Canyon to Desolation Creek	45.016381	-118.865414	44.997921	-118.935827
North Fork John Day River	Desolation Creek to Camas Creek	44.997921	-118.935827	45.010210	-118.995950
North Fork John Day River	Camas Creek to Jericho Creek	45.010210	-118.995950	45.011857	-119.051625

Appendix Table VIII. Continued.

System	Description	Start Latitude	Start Longitude	End Latitude	End Longitude
North Fork John Day River	River Mile 41 (Random)	44.978586	-119.260932	44.980843	-119.239867
Camas Creek	River Mile 10 (Random)	45.118192	-118.974400	45.129423	-118.965938
Camas Creek	0.4 km above and below Fivemile Creek	45.068389	-118.982213	45.079725	-118.987688
Crawfish Creek	Mouth to 1 mi upstream (Random)	44.914949	-118.298285	44.925824	-118.288679
Big Creek	Footbridge to mouth	44.960922	-118.682390	44.960194	-118.682884
Trail Creek	Mouth to Forks	44.915541	-118.406310	44.820401	-118.689409
Baldy Creek	Mouth to 1 mi upstream	44.909619	-118.317805	44.899615	-118.307586
Granite Creek	73 Road Culvert to Ten Cent Creek	44.816141	-118.420549	44.831070	-118.458033
Granite Creek	Ten Cent Creek to Buck Creek	44.831070	-118.458033	44.841373	-118.494582
Granite Creek	Buck Creek to Indian Creek	44.841373	-118.494582	44.850403	-118.537324
Granite Creek	Indian Creek to Mouth of Granite Creek	44.850403	-118.537324	44.865611	-118.562299
Clear Creek	Ruby Creek to Alamo Road	44.772950	-118.488480	44.769600	-118.473293
Clear Creek	Alamo Road to Smith Lower Boundary	44.769600	-118.473293	44.769969	-118.457903
Clear Creek	Smith Lower Boundary to Old Road Crossing	44.769969	-118.457903	44.785595	-118.472676
Clear Creek	Old Road Crossing to Clear Creek Mouth	44.785595	-118.472676	44.821483	-118.450278
Bull Run Creek	Deep Creek to the Guard Station	44.779916	-118.348625	44.787182	-118.374203
Bull Run Creek	Guard Station to Mouth	44.787182	-118.374203	44.807964	-118.425153
Desolation Creek	Road 45 Culvert to Falls	44.809318	-118.683428	44.791032	-118.673187
Desolation Creek	Forks to Howard Creek	44.820401	-118.689409	44.838014	-118.724023
Desolation Creek	Howard Creek to Battle Creek	44.838014	-118.724023	44.856763	-118.761268
Desolation Creek	Battle Creek to Bruin Creek	44.856763	-118.761268	44.896974	-118.796166
Desolation Creek	Bruin Creek to Road 1010 Bridge	44.896974	-118.796166	44.921231	-118.829258
Desolation Creek	Road 1010 Bridge to Peep Creek	44.921231	-118.829258	44.940121	-118.839682
Desolation Creek	Peep Creek to Road 1003 Bridge	44.940121	-118.839682	44.971799	-118.882862
Desolation Creek	Road 1003 Bridge to Mouth	44.971799	-118.882862	44.997921	-118.935827
South Fork John Day River	Murderers Creek To Rock Pile Bridge	44.314554	-119.539573	44.267652	-119.550757

Appendix Table VIII. Continued.

System	Description	Start Latitude	Start Longitude	End Latitude	End Longitude
South Fork John Day River	Rock Pile Bridge to Cougar Gulch	44.267652	-119.550757	44.229578	-119.533785
South Fork John Day River	Cougar Gulch to Izee Falls	44.229578	-119.533785	44.185104	-119.524821
South Fork John Day River	River Mile 16 (Random)	44.321223	-119.557854	44.314555	-119.539574

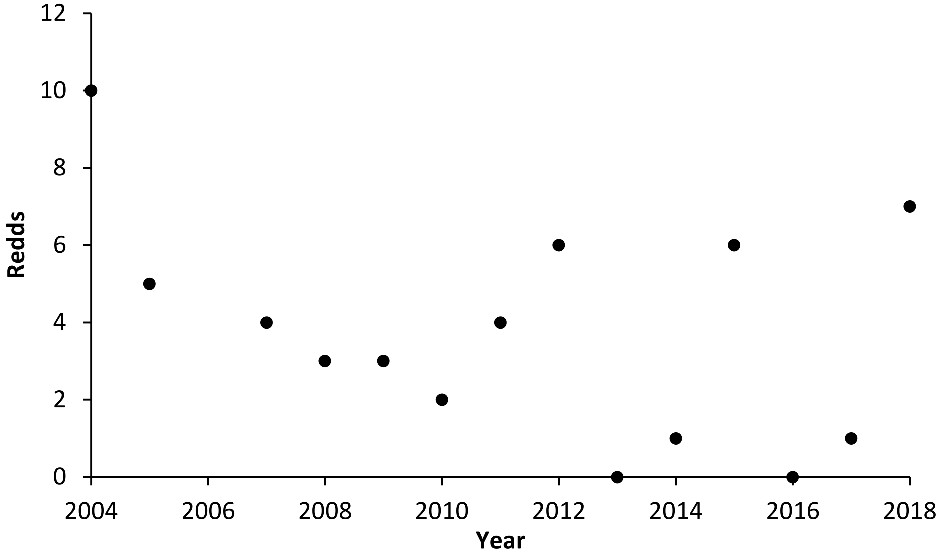
Appendix Table IX. Correlation matrix for census John Day River population Chinook redd counts from 2000 through 2018 and Chinook redd counts observed in other northeast Oregon streams. Significant correlations (α = 0.05) are indicated in bold.

John Day Population	Catherine Creek	Lookingglass Creek	Minam River	Wallowa-Lostine System	Wenaha* River	Imnaha River	Grande Ronde River
Mainstem	**0.794**	**0.565**	**0.847**	**0.644**	**0.675**	**0.572**	**0.613**
Middle Fork	**0.509**	0.439	**0.580**	0.353	**0.561**	**0.546**	0.338
North Fork	0.256	0.025	0.447	0.138	**0.524**	**0.667**	0.163

* 2015 data for the Wenaha River were excluded from analyses because the stream was only partially surveyed that year.

Appendix Table X. Summary of Chinook coded wire tag recoveries by John Day River population from 2000 through 2018.

Year	Population	Tags (n)	Hatchery	Release Location
2000	Middle Fork	1	Round Butte, Oregon	West Fork Hood River
	North Fork	2	Lookingglass, Oregon	Grande Ronde River
	North Fork	2	Rapid River, Idaho	Rapid River
	North Fork	1	McCall, Idaho	South Fork Salmon River
2001	North Fork	1	Lookingglass, Oregon	Imnaha River
	North Fork	1	Rapid River, Idaho	Rapid River
2002	*No Recoveries*			
2003	North Fork	1	Lookingglass, Oregon	Catherine Creek
2004	Mainstem	1	Lookingglass, Oregon	Imnaha River
	Middle Fork	1	Lookingglass, Oregon	Grande Ronde River
	North Fork	6	Lookingglass, Oregon	Grande Ronde River
	North Fork	1	Lookingglass, Oregon	Catherine Creek
	North Fork	1	Lookingglass, Oregon	Lostine River
	North Fork	2	Rapid River, Idaho	Rapid River
2005	Mainstem	1	Lookingglass, Oregon	Grande Ronde River
	Mainstem	1	Round Butte, Oregon	Deschutes River
2006	Middle Fork	1	McCall, Idaho	South Fork Salmon River
	North Fork	1	McCall, Idaho	South Fork Salmon River
	North Fork	1	Lookingglass, Oregon	Grande Ronde River
2007	North Fork	1	Rapid River, Idaho	Rapid River
2008	North Fork	1	Lookingglass, Oregon	Lookingglass Creek
	North Fork	1	Lookingglass, Oregon	Catherine Creek
2009	North Fork	1	Lookingglass, Oregon	Catherine Creek
	North Fork	1	Wallowa, Oregon	Grande Ronde River
2010	North Fork	2	Rapid River, Idaho	Rapid River
2011	Middle Fork	1	Lostine, Oregon	Lostine River
	North Fork	1		Grande Ronde River
2012	North Fork	2	Lookingglass, Oregon	Lookingglass Creek
	North Fork	3		Grande Ronde River
2013	*No Recoveries*			
2014	North Fork	1	Lookingglass, Oregon	Grande Ronde River
2015	*No Recoveries*			
2016	*No Recoveries*			
2017	*No Recoveries*			
2018	*No Recoveries*			



Appendix Figure III. Fall Chinook redd counts in the lower John Day River, 2004 through 2018 (survey was not conducted in 2006).

Appendix Table XI. Summary of 2018 fall Chinook spawning surveys conducted in the lower John Day River.

				Fish	
Date	**Survey Reach**	**Length (km)**	**Redds**	**Live**	**Dead**
07-Nov-18	RKM 64 to RKM 35	31	0	0	0
14-Nov-18	RKM 64 to RKM 35	31	2	0	0
28-Nov-18	RKM 64 to RKM 35	31	3	1	0
29-Nov-18	RKM 36 to RKM 16	20	2	0	0