Oregon Department of Fish and Wildlife

Technical Report

2013 Middle Deschutes Fisheries Monitoring Report:
Fish Distribution and Abundance in the Middle Deschutes River

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Abstract

The Middle Deschutes Fisheries Monitoring Project resumed with its second year of sampling in the fall of 2013. Redband trout (*Oncorhynchus mykiss*) were detected at all monitoring sites. However, we discovered limited distribution of the large size class (>250mm) of redband trout versus the more frequently distributed middle size class (>150<250mm). At this time it is unclear what factors may be limiting the large size class distribution of redband trout. Our data suggest a slight but positive relationship between the presence of brown trout (*Salmo Trutta*) and mountain whitefish (*Prosopium williamsoni*) and the presence of redband trout. Continued monitoring will help identify factors limiting the abundance and distribution of large redband trout, and support identification of redband spawning and early rearing areas.

Introduction

The Deschutes River, a tributary of the Columbia River once recognized for its extremely stable interannual flows (Figure 1), has been subjected to significant flow modification since the early 1900's (Figure 2). Currently, from mid-April to mid-October, water is diverted at a series of irrigation canals upstream of the North Canal Dam in Bend (Figure 2, Figure 3). These diversions remove over 90% of stream flow from the Deschutes River in the reach between the City of Bend and Lake Billy Chinook. Low flows during the summer months in the middle Deschutes River result in increased water temperatures. In this reach in 2013, ODFW documented a maximum water temperature of 25.4^{0}Celsius (C). The Deschutes River is currently on the Oregon Department of Environmental Quality 303(d) list for water quality impairment due to excessive temperature.

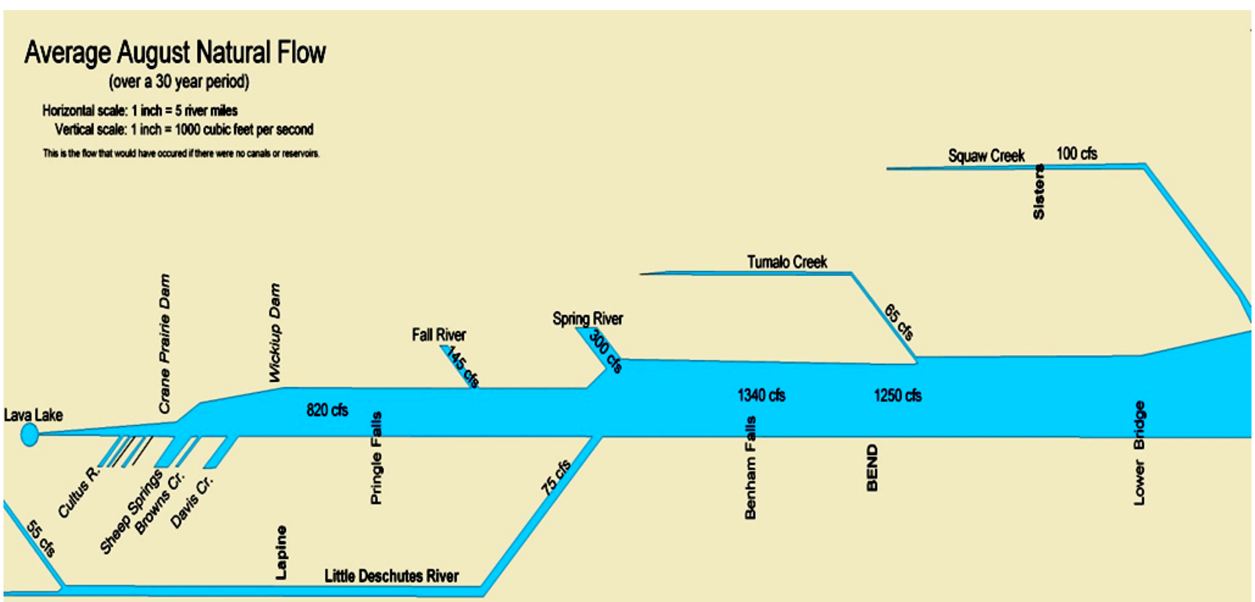

Figure 1. Projected flows in the middle Deschutes River before diversions were installed. Oregon Water Resources Department 2007.

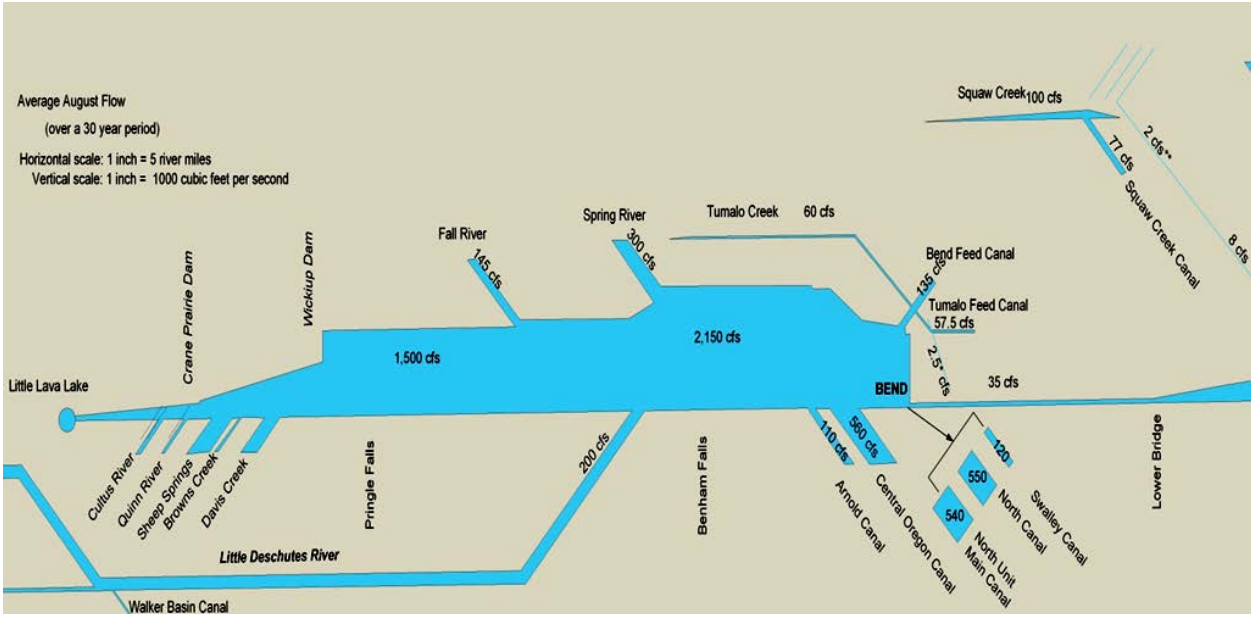

Figure 2. Managed August flows in the Deschutes River. Oregon Water Resources Department 2007

Temperature, flow, and habitat conditions resulting from water management, as well as inter-specific competition and social hierarchy, can influence fish assemblages, abundance and distribution in river systems, specifically trout movement, habitat selection, and migration (Budy et al. 2008, Freeman et al. 2001, McHugh and Budy 2006, Pert and Erman 1994, Starcevich et al. 2006). Irrigation infrastructure often reduces habitat connectivity; flow management affects temperature and reduces access to spawning and rearing habitat (Pringle, 2000; Freeman, 2001). Negative impacts of high temperature on salmonid growth and survival have been well documented (Recsetar et al. 2012). However, McKinney et al. (2001) showed that relative abundance and condition factor increased among rainbow trout in a regulated river after minimum flow increased and variability decreased, providing evidence that flow management that ameliorates stream temperature and reduces flow variability can benefit fish populations.

Local biologists believe flow management and irrigation infrastructure have affected species assemblages (Fies et al. 1996), especially redband trout (*Oncorhynchus mykiss*), in the middle Deschutes River, and climate change and population growth are anticipated to further stress limited water resources. There is also concern that nonnative salmonids have benefited from the current flow regime and further negatively affected the distribution and abundance of redband trout (McHugh & Budy 2006). The native fish assemblage of the middle Deschutes River and Tumalo Creek historically included bull trout (*Salvelinus confluentus*), redband trout, mountain whitefish (*Prosopium williamsoni*), and anadromous Chinook salmon (*O. tshawytscha*) and summer steelhead trout (*O. mykiss*), which were distributed as far upstream as the natural barrier of Big Falls at RM 132 (Nehlsen 1995, Fies et al. 1996). Brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) were introduced into the Deschutes watershed by state and federal agencies in the early 1900's. Artificial barriers, habitat alteration, and changes in water quality have further contributed to changes in the fish assemblage of the middle Deschutes River, which is now limited to two native salmonids, mountain whitefish and redband trout. Life history characteristics and movement patterns of redband trout in the middle Deschutes River were not documented prior to construction of dams in the Deschutes Basin. Recent information on resident fish populations is limited, and it remains unclear how elevated stream temperatures in the summer months may impact redband trout in the middle Deschutes River.

In 2012, the Deschutes District of Oregon Department of Fish and Wildlife, in collaboration with the Upper Deschutes Watershed Council (UDWC), initiated a study of fish assemblages in the middle Deschutes River with the following objectives:

1) Determine current distribution and relative abundance of three size classes of redband trout, mountain whitefish, and brown trout.

2) Examine how discharge, temperature, nonnative fish presence, and sampling timing influence redband trout detection and occupancy

3) Develop a long-term monitoring protocol by testing occupancy designs and sampling timing for feasibility and effectiveness.

4) Monitor the longitudinal water temperature profile

5) Evaluate fish movement and habitat selection in relation to stream temperature and flow. (ODFW initiated a radio telemetry study in 2013 for this objective; the results are reported in a separate report.)

This project was initiated to obtain baseline information to understand the current status of native and nonnative salmonids, enable managers to monitor the effects of future development and restoration activities, and provide critical information to support fisheries management and strategic restoration planning in the Middle Deschutes River.

Study area

The middle Deschutes River extends from the North Canal Dam in Bend to Lake Billy Chinook (Figure 3). Artificial barriers on the Deschutes River that affect native fish movement include the Round Butte Dam (RM 110), which creates Lake Billy Chinook, and the North Canal Dam (164.8). Fish passage exists over Round Butte Dam in the form of manual transportation of fish around a series of dams to return fish on their natural upstream path. There is no fish passage at North Canal Dam. From Lake Billy Chinook upstream to North Canal Dam, there is a series of falls that can restrict movement depending on flows. These natural barriers include Steelhead Falls (RM 127.75), Big Falls (RM 132.25), Odin Falls (RM 140), Cline Falls (RM144.5), and Awbrey Falls (RM 152.75). This section of river is characterized by steep canyons and occasional reaches sweeping open to narrow valleys. The mean gradient from North Canal Dam to Foley Waters is 6.4% with a mean width of 17.4 meters. Habitat is comprised of 35.7% riffles, 27.6% scour pools, 22.3 % glides, 6.7% rapids, and 1.7% cascades, and 1 % backwater pools (Loerts & Lorz 1994).

Methods

Fish sampling

The 2013 sampling season was conducted between August 1-29 and November 12- 29. We used the same sites used in 2012 (Carrasco et al. 2012); however, we added 16 (N=25) sites on the middle Deschutes River to increase the precision of our modeling results as suggested for occupancy modeling (Mackenzie et al. 2006), selected using discontinuous sample selection in ArcGIS. Rugged topography surrounding the middle Deschutes River and private property limited access to sampling sites. We also added two more sampling sites (N=4) to Tumalo Creek, in addition to the two original sites. In order to meet occupancy modeling criteria (Mackenzie et al. 2006) all Deschutes River sites were changed from 200 m to 100 m in 2013 and visited three times per season. GPS coordinates for the upper and lower terminus of each site were recorded to ensure consistency between sampling events. Two sampling seasons were defined, irrigation season (mid-April through mid-October) and non-irrigation season (mid-October through mid-April) when instream flows increased.

Our study reaches were located downstream of North Canal Dam, from Sawyer Park to Foley Waters (Figure 1). Sawyer Park (RM 164) has two sampling sites, one of which is a glide and the other of which consists of shallow riffles and pools. Gopher Gulch (RM 161.5) has two sites that are sampled by snorkeling, one site is a glide/deep pool and the other consists of large boulders and higher stream velocities/riffles. There are eight sites from Tumalo State Park to Twin Bridges Road. Characteristics in this reach range from shallow riffles to deep pools. Cline Falls and Odin Falls reaches including four and seven sites respectively (RM 138 & 137) consist of short rapids, glides, and shallow riffle areas. Our final sampling reach, consisting of two sites, is located at Foley Waters (RM 129), where large spring complexes upstream provide a stable temperature regime year round and flows do not fluctuate as severely as at sites above the spring complexes. Characteristics found at Foley Waters include shallow riffles and pools. More detail on these river habitat types can be found in the 1993 ODFW Aquatic Inventory Report.

A fourteen foot cataraft equipped with a Smith-Root 2.5 GPP electrofishing unit and 32” array droppers was used to collect fish on the middle Deschutes River. All sampling was conducted with one rower and two netters at the bow of the raft. Single pass electrofishing was used at all sites due to river width and obstacles that restricted coverage. River margins were not able to be effectively sampled due to obstacles, current, and/or lack of ability to control the raft. The electrofishing unit was set for high-range direct current (DC) with a pulse rate of 120 pulses per second and power ranged at sixty percent. All sites were shocked for an average of 110 seconds per transect during irrigation season and 95 seconds per transect after irrigation season. All captured fish were held in a live well until each transect was completed. Fish were identified to species, enumerated, measured to the nearest millimeter (total length), fish ≥150mm in length were weighed to the nearest gram, and then released at the end of the site. All data were entered into a Microsoft Access database form on a Trimble Yuma.

Tumalo Creek monitoring sites were located between RM 6.5 and the mouth of the creek. (Figure 3). The first two sites (RM 6 and 6.5) flow through a broad valley near Fremont Park and are comprised of riffles and shallow pool complexes. Sites three and four are located approximately 100 and 400 meters, respectively, upstream of the confluence with the Deschutes River, but below the Tumalo Irrigation Diversion. This section is narrow and flows rapidly through a steep confined canyon, terminating into the Deschutes River. Data from Tumalo Creek were collected specifically to determine species composition and for baseline monitoring and were not used in occupancy modeling.

Each site on Tumalo Creek was sampled with a Smith Root backpack electrofisher on August 15th, August 19th and September 19th, 2013. Two backpack electrofishing units were used to sample the 100 m transects, each operator covering half of the creek. In addition to two backpack electrofishing operators, there were four netters (two per electrofisher) and two staff members carrying buckets. ODFW staff started sampling at the downstream end of each transect and sampled from downstream to upstream. All captured fish were contained in a bucket equipped with an aerator. At the end of the site, all trout were enumerated, measured to the nearest millimeter (total length), weighed to the nearest gram if ≥150mm in length, and then released at the end of the site. All Tumalo Creek sites were sampled once and were not sampled during non-irrigation season due to high flows.

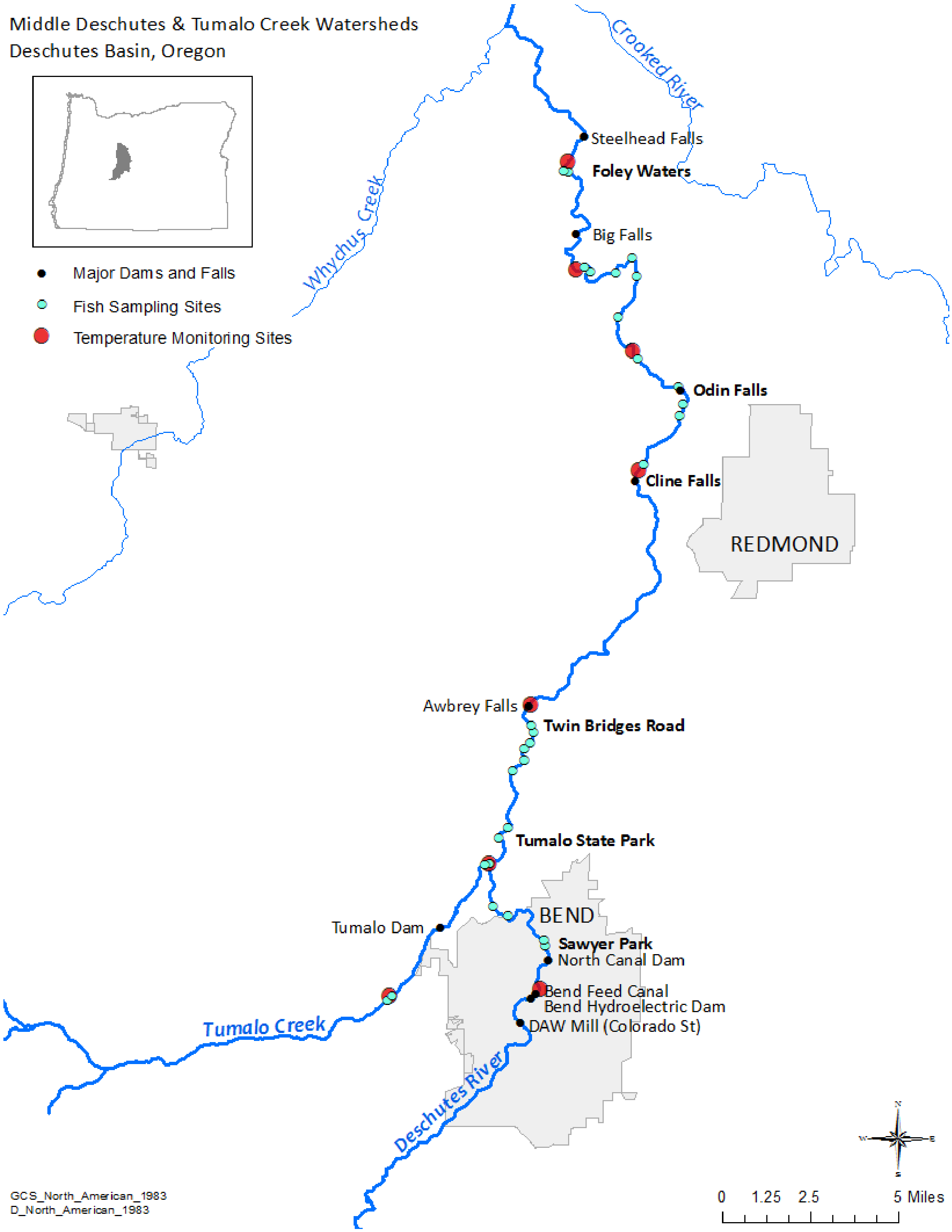

Figure 3. Middle Deschutes Fish Monitoring Study Area. Turquoise circles represent electrofishing sites on the Deschutes River and Tumalo Creek (bold labels). Red circles represent temperature monitoring sites. Solid black circles represent major falls and dams.

Flow and temperature monitoring

Instantaneous flow readings were recorded each day before sampling from the U.S. Bureau of Reclamation Hydromet system. The middle Deschutes River stream gauge is located below North Canal Dam in Bend (DEBO RM 164.25) and records flows at 15 minute intervals. Tumalo Creek Flows were recorded directly below the Tumalo Feed Canal (TUMO RM 2.05). The stream gauge below North Canal Dam is the only gauge for 44.3 miles on the middle Deschutes River; the next downstream gauging station is located in Culver which is outside our study area. Flows can fluctuate significantly between North Canal Dam and Foley Waters due to natural loss from the channel (losing reaches), withdrawals for irrigation, and gains from springs fed by groundwater (gaining reaches). According to OWRD (1992), there is a gain of 150 cfs between RM 128.7 and 129.7 (Foley Waters) and a loss of 24 cfs from Cline Falls (145.3) to Tethrow Bridge (RM 141.2). Other points of gain are at Cline Falls (RM145.3, +12.2 cfs), Lower Bridge (RM 134, +19.8 cfs) and just above Big Falls (RM 130.5, +15.5 cfs). Other areas experienced gains that were within the measurement of error and were consequently disregarded.

Temperature loggers are located in the middle Deschutes River (N=6) and in Tumalo Creek (N=2) (Figure 3). Vemco Minilog II-T temperature loggers were used to be consistent with partners and the Oregon Department of Environmental Quality [ODEQ] (UDWC 2008). Before deployment, we calibrated temperature loggers following ODEQ guidelines. Loggers recorded water temperature hourly and were deployed in five locations in the Deschutes River (RM 129.0, 139.0, 144.5, 155.0, 165.9) on the 24^{th} and 25^{th} of September in 2012, and in two locations in Tumalo Creek (RM 0 & 6.0) on the 10^{th} of October in 2012. Each logger was secured to the bank with a cable extending 8-12 feet into the water to accommodate high and low flows. Loggers were audited every other month and data downloaded onto a Vemco field reader. At the time of audit, a temperature grab sample was taken manually using an ODEQ calibrated thermometer to compare with the logger for accuracy. Downloaded data and calibration readings were entered into an ODFW database.

We used data from three UDWC Vemco temperature loggers located on the Deschutes downstream of Tumalo Creek (RM 160), upstream of Tumalo Creek (RM 160.25) and at the Riverhouse Hotel (RM 164.75) downstream from North Canal Dam. UDWC temperature loggers recorded temperatures in 2013 from March 30^{th} to November 26^{th}. Daily average flow data was obtained from the BOR gauge below North Canal Dam.

Data analysis

To obtain data on salmonid distribution and effectiveness of our capture method (boat electrofishing), we used a single-season occupancy model (MacKenzie et al. 2006) to estimate detectability (ρ) and occupancy (ψ), for three size classes of redband trout, brown trout, and mountain whitefish. Each species was modeled separately and size classes were as follows: <151 mm, 151-250 mm, and >250 mm. Season was used as a factor to explore differences in occupancy and detection in different time periods.

Covariates used in the modeling were selected a priori. For detectability, all models contained the ψ-intercept parameter and detection was assumed to be the same for all three visits. The covariates evaluated were season, size class, segment, site discharge, site water temperature, and visit seconds (i.e., electrofishing time by each visit to a site). Detection was assumed to be constant during an individual season. The occupancy covariates evaluated were season and size class. Only single-covariate models were evaluated because of a relatively small sample size. It was assumed that site occupancy by any species and size class did not change during the study. We used the best fitting detection model as the baseline for modeling occupancy. Prior to analysis, all continuous covariates were standardized into z-scores.

Akaike information criterion model selection procedures with a correction factor for low sample size [AICc] were used to select the models of best fit. Models were ranked by AICc values and evaluated using the ΔAIC (i.e., the difference in AICc values between a given model and the highest ranked model) and Akaike weight (w_i), which is a relative measure of the weight of evidence for a model given the data (Burnham and Anderson 2002). The best fitting model had the lowest AICc and the greatest weight. The analysis was conducted using Program MARK.

We evaluated relative abundance relationships between the three species in two ways. First, linear regression was used to evaluate the relationship between relative site abundance of mountain whitefish, brown trout, and redband trout. The maximum number of each species captured during a sampling visit to a site in the first season was used as the measure of relative abundance. We evaluated two size classes: >150 and >250 mm FL. Second, the Royle N-mixture model for repeated counts (Royle 2004) was used to estimate mean site abundance (λ –lambda) and detectability (ρ) across sample sites during the first season. This model assumes: 1) demographic closure of sites during the sample season, i.e. fish are not moving in or out of sampling sites; 2) the distribution of animals across sample sites follows the Poisson distribution; and 3) the detection probability at a site represents a binomial trial of the true number of animals at that site. Since the closure assumption was likely not met, these Royle abundance estimates are used here to compare relative abundance among the species for an average site within the study area. Because of our interest in catchable fish, count data for the largest size class (i.e., >250 mm) of each salmonid species was analyzed separately using the computer software Program PRESENCE 6.4.

Results

Fish Sampling

We captured mountain whitefish (*Prosopium williamsoni*), 69% (N=607); redband trout (*Oncorhynchus mykiss*), 13% (N=117); brown bullhead (*Ameiurus nebulosus*), 0% (N=4); mottled sculpin (*Cottus bairdii*) 1% (N=7); brown trout (*Salmo trutta*), 17% (N=146); tui chub (*Gila bicolor*), 0% (N=2); and bridgelip sucker (*Catostomus columbianus*), 0% (N=1) on the middle Deschutes River. Mountain whitefish, brown trout and redband trout were the dominant species on the middle Deschutes River (Figure 4).

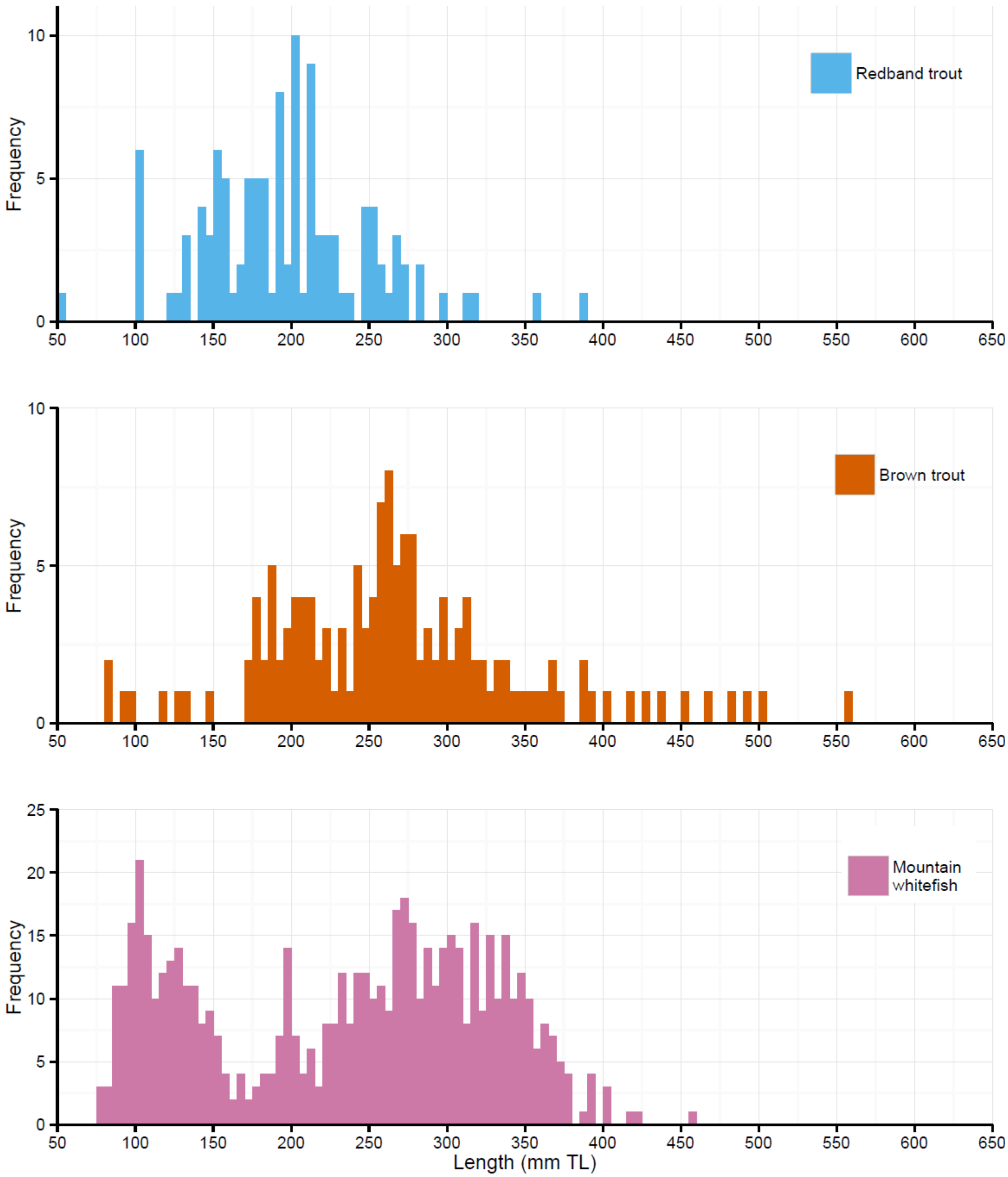

Figure 4. Length frequency distribution for salmonids captured at all sites on the middle Deschutes River.

Modeling occupancy and detectability

The best-fitting detection model included "season" as a factor. Modeled detection probabilities differed between seasons (Table 1), suggesting that detection was significantly better for all size classes during the first sampling season (irrigation season, mid-April through mid-October). There was little support for size class or other covariates influencing detection. The best-fitting occupancy model contained the size class covariate (Table 2). The best models for both detection and occupancy were at least two orders of magnitude more likely than the next best models. In the best linear model (Table 3), the confidence interval around the beta for season (i.e., -2.018) did not overlap zero, suggesting that there was a significantly lower probability of detecting any size class of redband trout in the second season (non-irrigation season, mid-October through mid-April).

The best-fitting occupancy model contained size class as a covariate, suggesting that occupancy differed among the size classes. The best linear model suggested that redband trout in the second size class (151-250 mm) had significantly higher occupancy of the study area than the other size classes (Table 3). Assuming perfect detection of species at individual sites in the study area, the "naïve" estimates of occupancy for redband trout size classes were 0.20, 0.57, and 0.30 (Table 4). Put another way, there was a 30% probability that large redband trout (i.e., >250 mm) occupy a given site within our sample frame. The modeled detection probability for all size classes was 0.51 in the first season and 0.12 in the second. By factoring in this imperfect detection, modeled occupancy was substantially greater than the naïve estimates (Table 4). These results showed there was a high occupancy probability for medium-sized (151-250 mm) redband trout and significantly lower occupancy for the other size classes in this study area.

The best fitting linear model for estimating detectability and occupancy of brown trout was composed of size classes (Table 4). For whitefish, the model was composed of size classes for detectability and season for occupancy (Table 4). Modeled occupancy probabilities for brown trout were similar to redband trout, except for the largest size class, in which large brown trout (ψ =0.88) were more likely to occupy a site than large redband trout (ψ =0.49). All size classes of whitefish were highly likely to occupy individual sites in the study area (Table 4).

Comparing relative abundance among species

There was slight support for a positive relationship between the relative abundance of redband trout (>150 mm TL) and that of other salmonids (>150 mm TL) in the study area (Figure 5). However, the effect was small (i.e., slope of relationship <0.23) and less than 13% of the variation among sites was explained by these regression lines (Table 5). Relative abundance of brown trout and mountain whitefish showed a stronger positive relationship (slope range, 0.28-0.29) with more of the variation explained by the regression.

Across the sample sites, mean site abundance for the largest size class of brown trout and mountain whitefish was higher than that of redband trout (Table 6). Low sample size, and especially low detection of large brown trout (i.e., high variability in the count among the three visits at particular sites), led to high standard errors for the estimates and low confidence in the statistical significance of these results (Table 6).

Figures 6, 7, and 8 show the maximum count at each site on any single sampling visit during either season, for three size classes. The middle size class was best represented (Figure 7), followed by the large size class (Figure 8) and the least represented was the small size class (Figure 6).

Table 1. Detection modeling results for redband trout in the middle Deschutes based on 3 visits, during 2 seasons, at 25 sites sampled by boat electrofishing. "Visit seconds" represents the number of seconds electrofished at each site visit. All continuous covariates were standardized as z-scores prior to modeling.

Model	AICc	ΔAIC	w_i	Model Likelihood	Parameters	Deviance
Season	327.09	0.00	1.00	0.999	3	320.91
Size classes	341.28	14.19	0.00	0.001	4	332.98
Segment	345.30	18.21	0.00	0.000	3	339.12
Visit seconds	346.94	19.85	0.00	0.000	2	342.85
No covariates	349.40	22.31	0.00	0.000	2	345.31

Table 2. Occupancy modeling results for redband trout in the middle Deschutes River based on 3 visits, during 2 seasons, at 25 sites sampled by boat electrofishing. As "Season" provided the best model for detection, this factor was used in all occupancy models.

Model	AICc	ΔAIC	w_i	Model Likelihood	Parameters	Deviance
Size classes	314.86	0.00	1.00	0.998	5	306.31
No covariates	327.09	12.23	0.00	0.002	3	318.86
Season	328.93	14.07	0.00	0.001	4	325.16

Table 3. The best linear model results for redband trout in the Middle Deschutes River study area. Betas represent the slope of the linear relationship of individual covariates and are considered significant if their confidence interval (CI) does not overlap zero.

			95% CI	
Parameter	Beta	SE	Lower	Upper
p-intercept	0.038	0.257	-0.466	0.543
Season	-2.018	0.386	-2.775	-1.262
Psi-intercept	-0.714	0.448	-1.593	0.164
Size class 2 (151-250 mm)	2.974	1.212	0.599	5.350
Size class 3 (>250 mm)	0.681	0.600	-0.494	1.857

Table 4. Detectability and occupancy estimates and 95% confidence intervals (CI) for three salmonid species in the middle reach (Foley Waters to Sawyer Park in Bend) of the Deschutes River. Boat electrofishing was used in 3 visits to 25 sites during two seasons.

	Detectability (p)					Occupancy (ψ)					
Species	Covariate	Modeled	SE	CI:Lower	CI:Upper	Covariate	Naïve	Modeled	SE	CI:Lower	CI:Upper
Redband	Season 1	0.51	0.06	0.38	0.64	≤150	0.20	0.33	0.10	0.13	0.52
	Season 2	0.12	0.04	0.05	0.19	151-250	0.57	0.91	0.10	0.71	1.00
						>250	0.30	0.49	0.11	0.28	0.71
Brown	≤150	0.14	0.13	0.00	0.39	≤150	0.13	0.37	0.32	0.00	1.00
	151-250	0.38	0.08	0.24	0.53	151-250	0.61	0.81	0.13	0.55	1.00
	>250	0.45	0.07	0.32	0.58	>250	0.72	0.88	0.11	0.67	1.00
Whitefish	≤150	0.63	0.06	0.52	0.74	Season 1	0.80	0.90	0.05	0.80	1.00
	151-250	0.48	0.06	0.37	0.60	Season 2	0.73	0.79	0.06	0.67	0.91
	>250	0.75	0.04	0.66	0.83						

Table 5. Linear regressions (y ~ x) of maximum count during a single sampling visit for each study site between two salmonid species. Two size classes were evaluated. Data were from the first (irrigation) sampling season in 2012 and 2013.

	Intercept			Slope				
Regression	Estimate	SE	P-value	Estimate	SE	P-value	R^2	P-value
>250 mm FL								
Redband trout ~ Brown trout	0.68	0.39	0.090	0.22	0.11	0.056	0.11	0.06
Redband trout ~ Whitefish	0.88	0.41	0.041	0.07	0.06	0.245	0.04	0.24
Brown trout ~ Whitefish	0.96	0.50	0.064	0.29	0.07	0.000	0.37	<0.001
>150 mm FL								
Redband trout ~ Brown trout	2.71	0.66	<0.001	0.23	0.10	0.035	0.13	0.04
Redband trout ~ Whitefish	3.29	0.65	<0.001	0.06	0.05	0.283	0.04	0.28
Brown trout ~ Whitefish	2.31	0.86	0.011	0.28	0.07	<0.001	0.33	<0.001

Table 6. Mean site abundance (λ -lambda) and detection probability, estimated using the Royle repeated count model, for fish greater than 250 mm in the middle Deschutes River. Sample sites (N=25) were replicated 3 times during a single season by boat electrofishing.

			95% CI				95% CI	
Species	λ	SE	Lower	Upper	p	SE	Lower	Upper
Brown trout	8.7	13.5	0.4	180.8	0.08	0.12	0.00	0.70
Redband trout	1.2	0.9	0.2	5.6	0.20	0.16	0.03	0.65
Mountain whitefish	8.7	2.9	4.6	16.7	0.23	0.08	0.11	0.42

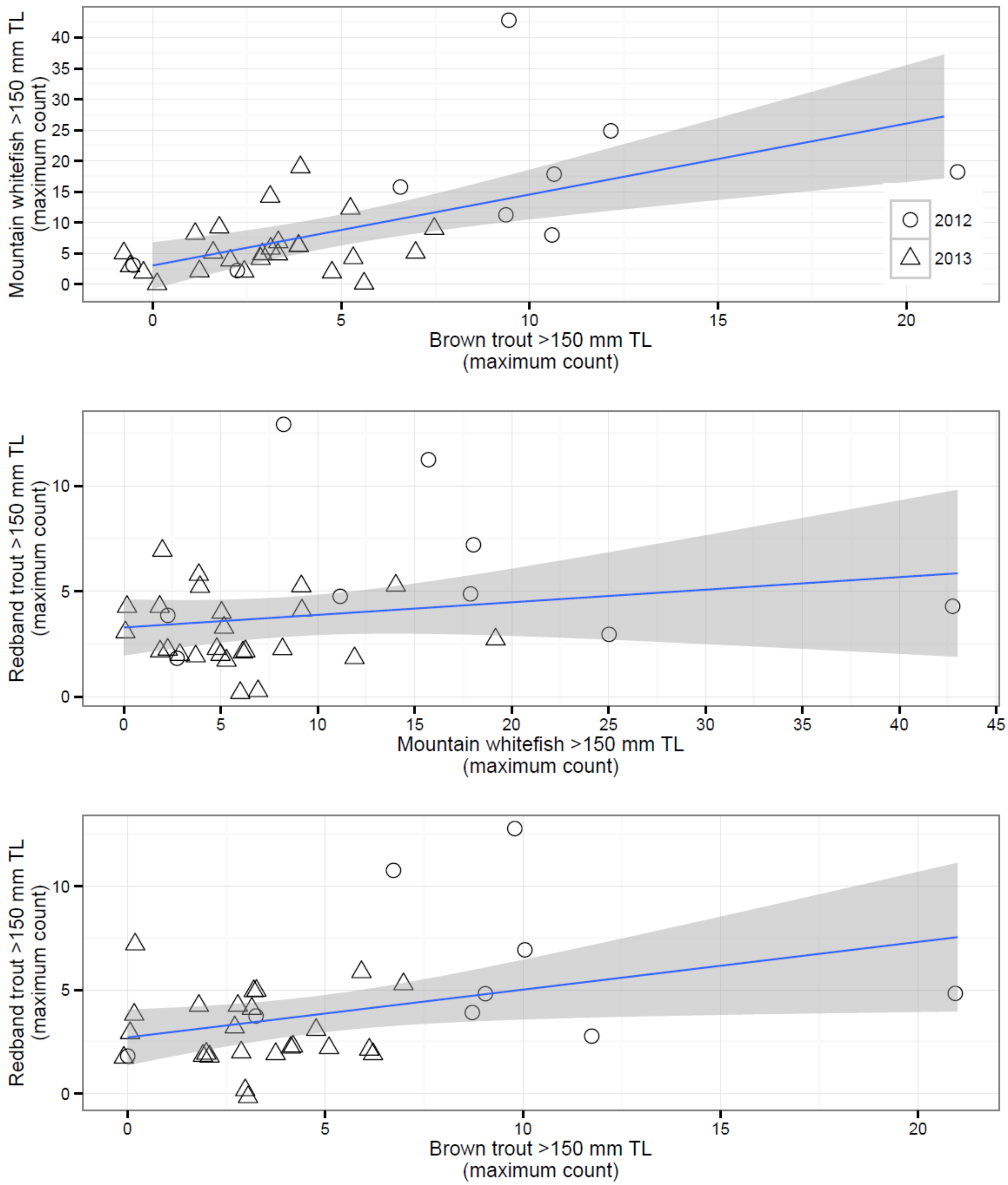

Figure 5. Linear regression showing relationship among salmonids in the middle Deschutes River.

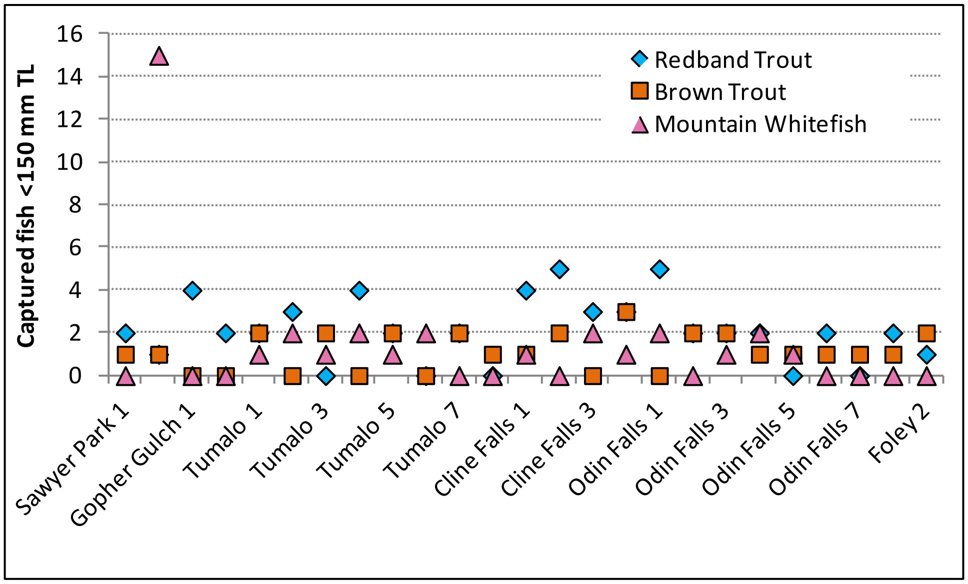

Figure 6. Maximum count from each site on any single sampling visit during either season for salmonids <150 mm TL. Data from Foley Waters was not collected during non-irrigation season.

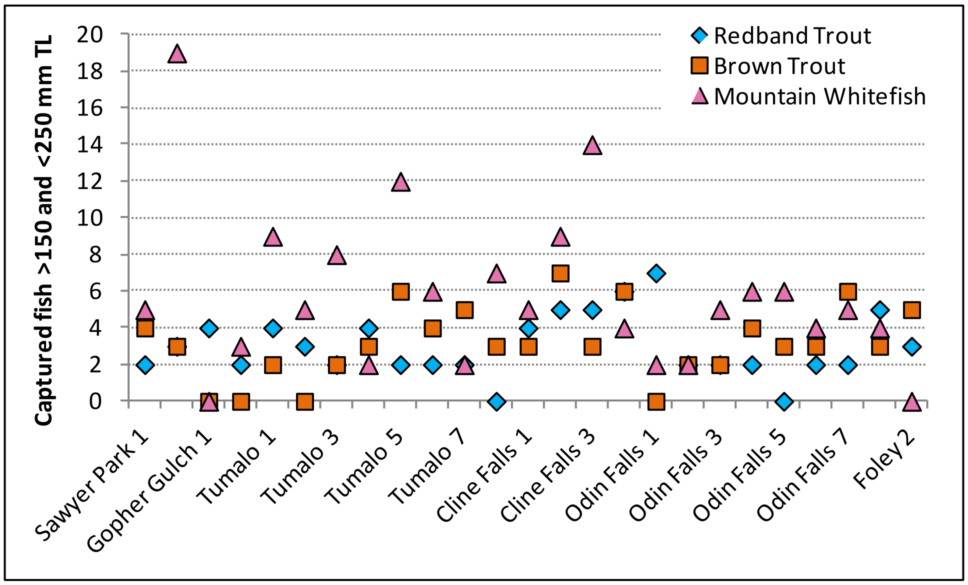

Figure 7 Maximum count from each site on any single sampling visit during either season for salmonids >150 and <250 mm TL. Data from Foley Waters was not collected during non-irrigation season.

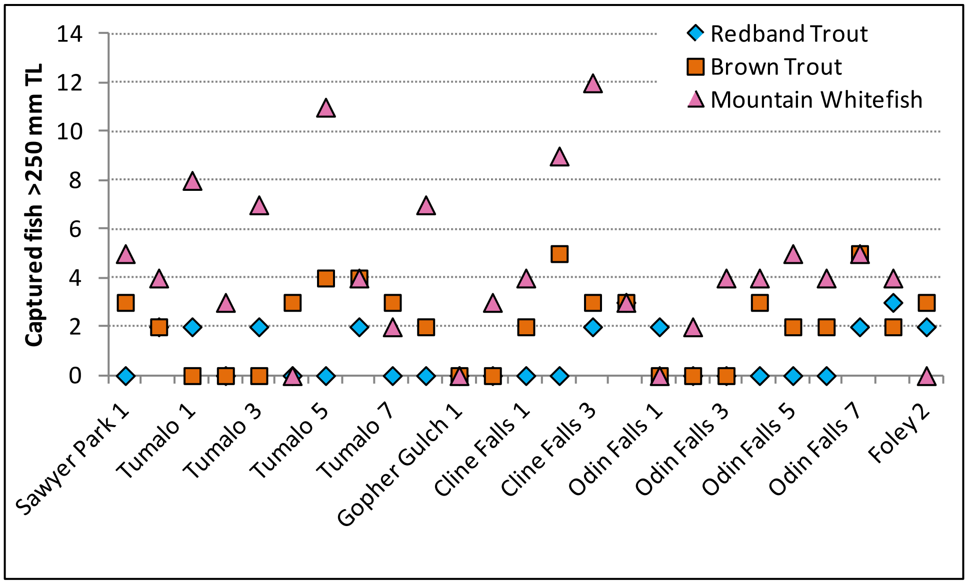

Figure 8. Maximum count from each site on any single sampling visit during either season for salmonids >250mm TL. Data from Foley Waters was not collected during non-irrigation season.

Flow and Temperature

Flows in the middle Deschutes River in 2013 ranged from 82 cfs to 1280 cfs with a median flow of 262 cfs (Figure 9). Irrigation season flows during fish sampling from August 1st through 29th ranged from 114 to 353 cfs with a median flow of 134 cfs; non-irrigation season flows during sampling from November 12th through 29th ranged from 242 to 458 cfs with a median flow of 426 cfs (Table 7). Temperature loggers continuously recorded temperature data every hour throughout the year (Figure 10). Temperatures ranged from -0.05°C to 25.42°C in 2013; both these minimum and maximum temperatures were recorded at Lower Bridge. Irrigation season maximum daily stream temperature at Lower Bridge during fish sampling dates ranged from 17.8 to 23.6°C, with a median of 21.3°C; stream temperature at Lower Bridge during non-irrigation season sampling dates ranged from 0 to 6.6°C, with a median of 3.4°C.

Table 7. 2013 sampling seasons and dates, and median, maximum, and minimum maximum daily temperature and average daily flow for the Middle Deschutes River and for Tumalo Creek. Maximum daily temperatures are from Lower Bridge on the Deschutes and the mouth of Tumalo Creek, respectively, representing the most impaired sites on the two waterways during irrigation season.

	Middle Deschutes River			Tumalo Creek		
Season	2013 Sampling Dates	Maximum Daily Temperature (°C: median; min-max)	Average Daily Flow (cfs: median; min-max)	2013 Sampling Dates	Maximum Daily Temperature (°C: median; min-max)	Average Daily Flow (cfs: median; min-max)
Irrigation: mid-April - mid-October	Aug 1-29	23;17.8-23.6	134; 114-353	Aug 15, 19; Sep 19	18.3;11.2-18.5	15.8;14-17.2
Non-Irrigation: mid-October - mid-April	Nov 12-29	4;0-6.6	256; 242-458	-	-	-

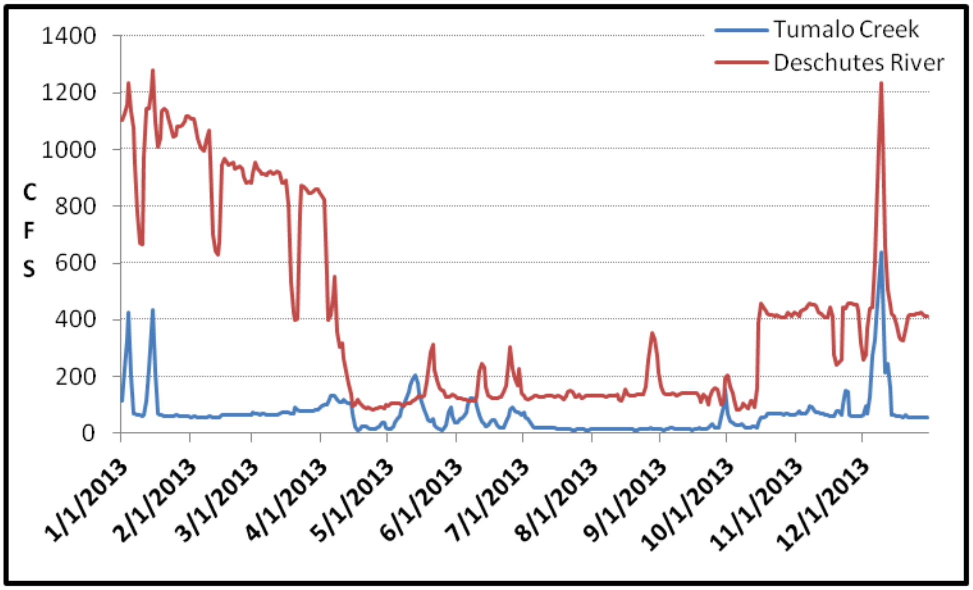

Figure 9. Daily average flows on the middle Deschutes River and Tumalo Creek as recorded by BOR for 2013. River gauges are located at RM 164.25 on the Deschutes and below the diversion on Tumalo Creek.

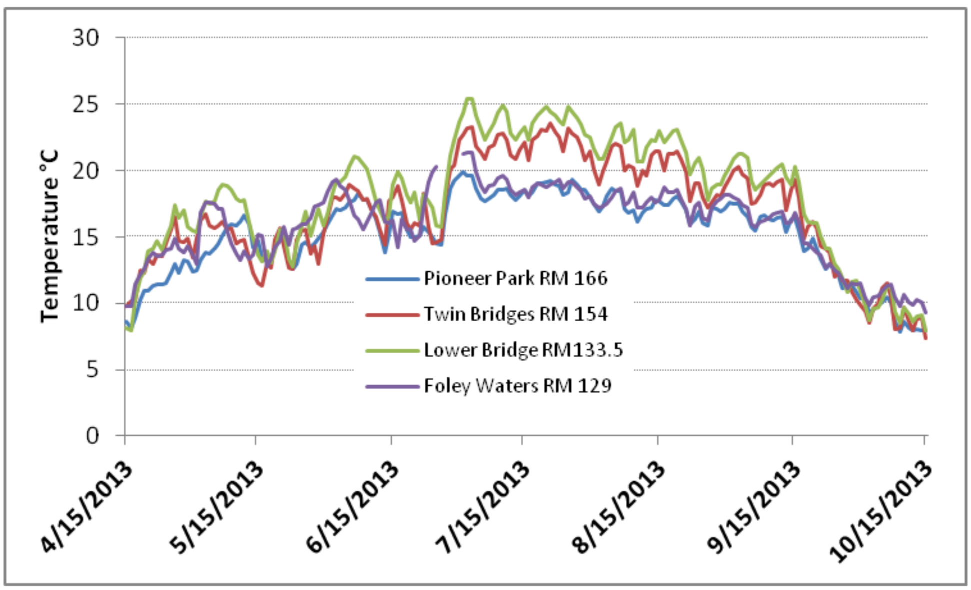

Figure 10. Maximum daily temperatures recorded from April 15- October 15th 2013. For clarity, data from 4 other loggers has been omitted. Sites with maximum fluctuations are shown here.

Tumalo Creek

ODFW staff sampled four Tumalo Creek sites on August 15th, 19th and on September 19th. Species captured included brown trout, redband trout and brook trout (Figure 11). Brook & brown trout were found above and below the Tumalo diversion; however only two brook trout were captured downstream of the diversion and four brown trout were captured upstream of the diversion.

Tumalo Creek flows were recorded from a BOR stream gauge located downstream of Tumalo Irrigation District Canal (TUMO). Tumalo Creek flows ranged from 9.2 to 640 cfs, with a median flow of 59.7 cfs. Flows on sampling dates ranged from 9.3 cfs to 640 cfs with a median of 15.8 cfs (Figure 9). Maximum and minimum temperatures on Tumalo Creek were recorded just upstream of the confluence of the Deschutes River and were 20.66 ºC and -0.04°C (Figure 12). Maximum and minimum temperatures on Tumalo Creek at RM 6 were 16.6ºC and -0.01ºC.

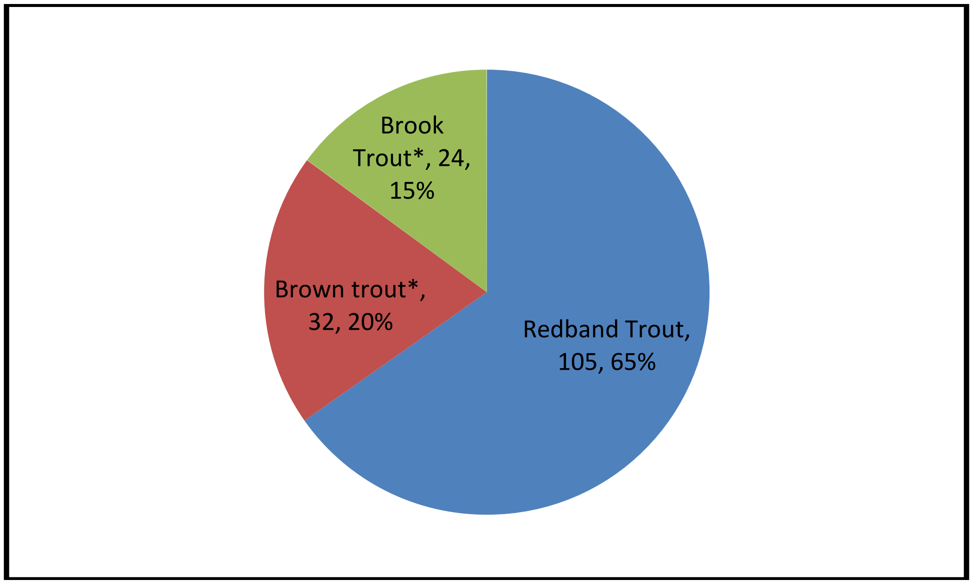

Figure 11. Total captures on Tumalo Creek. *Only two brook trout were captured downstream of the diversion and four brown trout were captured above the diversion.

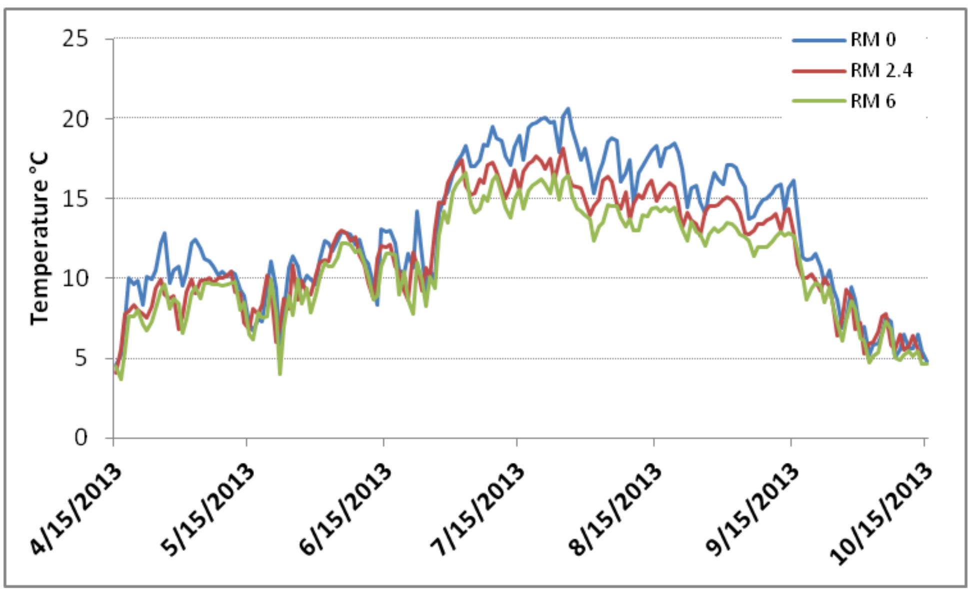

Figure 12. Maximum daily temperature data recorded at the mouth of Tumalo Creek (RM 0), below the diversion (RM 2.4) and at Fremont Meadows (RM 6) in Shevlin Park. Data at RM 2.4 obtained from BOR. Data is from April15th-October 15th 2013.

Discussion

Distribution and abundance

In this study, redband trout, brown trout, and mountain whitefish were distributed throughout the Middle Deschutes River; although, the trout distribution differed among the size classes. One main difference was that the smallest size class of both trout species (50-150 mm TL) was relatively limited in its distribution. Spawning areas for these species are not known in this study area, but since early rearing of juveniles often occurs near spawning locations, this limited rearing distribution has at least two possible explanations. First, it may reflect a limited spawning distribution. The relatively extensive distribution of small whitefish may suggest that their spawning habitat is distributed through more of this reach. Second, only one age-0+ (i.e., young-of-the-year) redband trout was captured and detection was lowest for the smallest size-class of brown trout, which suggests that the sampling methodology was biased against capturing small rearing trout.

Another important difference was the relatively limited distribution of large redband trout (i.e., >250 mm TL). This was surprising given that redband trout of the middle size class (i.e., 151-250mm TL) were distributed throughout most of the study area. One would expect, as shown by brown trout in this study, that extensive distribution of the middle size class would lead to recruitment and the large size class would be present throughout the study area. Large brown trout and mountain whitefish were both present in the study area in greater relative abundance than large redband trout.

It is not clear what factors may be limiting the distribution and abundance of large redband trout in the middle Deschutes River. Discharge and water temperature differed dramatically during the two sampling seasons in this study. We evaluated the effect of "season" on species occupancy and found no support that it affected redband trout distribution, which suggests that the accompanying seasonal differences in discharge and water temperature did not have a measurable effect on redband trout occupancy using this sampling protocol and level of effort. We also hypothesized that high relative abundance of large brown trout and whitefish at a site would competitively exclude or reduce in relative abundance redband trout. We found no support for this hypothesis either. Instead, we found suggestive evidence that there was a slight positive relationship among these species. In other words, rather than competitive exclusion among the species, when brown trout or whitefish were present at a site, it was more likely that redband trout were also present at that site. There are few studies examining redband trout and brown trout interactions. Large populations of redband trout and brown trout have coexisted for decades in the Wood River, an Upper Klamath Lake tributary (ODFW, unpublished data). This occurs in part through habitat partitioning, with brown trout foraging mainly in the Wood River and redband trout foraging mainly in the lakes (Steve Starcevich, ODFW, personal communication). Since the trout species in the middle Deschutes River probably have similar fluvial life history, there may be substantial overlap in their niches. If so, competition may be limiting abundance of both species.

McHugh and Budy (2006) have shown that the presence of brown trout can influence feeding patterns, habitat selection, movement, and growth of cutthroat trout in a closed population. In addition, Gatz et al. (1987) discovered that rainbow trout habitat selection differed when brown trout were present. Although brown trout were not shown to affect survival, there could be an indirect negative impact on survival of native trout entering the winter period without a suitable amount of lipids to sustain the winter (McHugh and Budy 2006).

Monitoring protocol

This monitoring protocol was most effective during the low managed flows of the first season. It is not clear why the sampling method resulted in such relatively low detection in the second season for redband trout but not the other species. Sampling seasons were scheduled to examine differences in redband trout occupancy and detection during two distinct flow management periods. However, there was little support for discharge or water temperature as individual covariates influencing redband trout distribution or detection. One hypothesis for the difference in detectability between seasons may be that redband trout behavior changed during the second (non-irrigation) season. The timing of the second season corresponds to the transition period from a feeding home range to staging for spawning. This hypothesis could be examined through radio telemetry.

The monitoring protocol was not effective at capturing small trout. Detectability of the smallest size class of brown trout was relatively low and distribution of both trout species was relatively low. Furthermore, very few trout smaller than 120 mm TL were captured, which suggests that young of the year and age-1 fish were almost completely missed during the sampling. Thus the apparent limited distribution may be biased in part by the sampling method, in which a single pass in an electrofishing boat downstream mostly along the thalweg had limited access to early rearing habitats in the shallower margins and off-channel areas. Therefore, this protocol cannot be used to accurately predict where early rearing is occurring and, indirectly, where spawning typically occurs, in the middle Deschutes River. If increasing detection of trout less than 120 mm TL is an important monitoring goal, then using an additional equipment type (e.g., backpack electrofishing) and sampling shallower and marginal habitats must be added to the protocol.

The occupancy and "Royle repeated count abundance" estimates from this study have large confidence intervals and may be biased if the assumptions of the statistical models were violated, which reduces the effectiveness of this protocol as a long-term monitoring tool. The high variance and associated uncertainty in the estimates will cause difficulty in detecting long-term changes (i.e., trends) in trout populations. Some of the sources of variance include low detectability of target species or size class, small number of sampling sites, and high variation in counts among visits within a site. These variance sources can be at least partially ameliorated by increasing overall sample size or sampling effort at each site; however, this requires more resources (i.e. time and money) to accomplish, and does not guarantee acceptable estimates for monitoring population trends.

In large river settings, the most difficult assumption to meet is population closure at a sample site. Since these sample sites are too wide or water velocity and discharge too high for active closure of a site (e.g., the use of blocknets), an assumption is made that one may sample over a short time period to ensure no loss or gain of individuals at site during the study (Pine et al. 2003). In this study, the first season (with three electrofishing visits) was conducted over a month and the actual degree to which the population closure assumption was violated was not known. To reduce bias and obtain adequate precision, future sample design should account for this population closure issue (Gwinn et al. 2011).

Stream temperature

Water management on the middle Deschutes River not only restricts habitat availability and forage production, but also affects the temperature of reduced downstream flow, which is more strongly influenced by ambient summer air temperature than are higher flows, and can quickly exceed the ODEQ standard for redband trout (Dimick and Campbell 1947). Water diversion from both the middle Deschutes River and Tumalo Creek has a profound effect on river temperatures. Figure 10 shows daily maximum temperature on the middle Deschutes River slightly increases longitudinally from upstream to downstream sites, until RM 130 where springs can add an additional 150 cfs of stream flow. In "good" water years, flows from Tumalo Creek can help stabilize rising temperatures in the middle Deschutes River. However, on July 26th, 2013, minimum Tumalo Creek flows were recorded at 14.1cfs and the corresponding maximum temperature was 20.66°C. The cooling effect of this cold water recharge system is thus negated at low flows. In contrast, in 2012 minimum flows on Tumalo Creek were recorded at 28.9

cfs and maximum temperature was recorded at 14.7°C (at TCID, BOR). Redband trout home ranges are small in comparison to locations of cold water sites in the middle Deschutes River (Young et. al 1997, Carrasco and Moberly 2013), such that redband trout may not discover cold water sites. The telemetry portion of this project will help to describe trout behavior under elevated stream temperature conditions.

References

Bureau of Reclamation. Historical daily stream flow values for Deschutes River and Tumalo Creek, Oregon Available: http://www.usbr.gov/pn/hydromet/arcread.html. (January 2014).

Carrasco, R., Harrington, M., and Hodgson, B. (2013) 2012 Middle Deschutes Fisheries Monitoring Report. Oregon Department of Fish and Wildlife.

Carrasco, R., Moberly, E. (2014) 2013 Middle Deschutes Fisheries MonitoringReport: Redband Trout Movement in the Middle Deschutes River. Oregon Department of Fish and Wildlife.

Dimick, J.B. and Campbell, C.J. (1947) Recommended Minimum Flows Below Wickiup Reservoir. Oregon State Game Commission.

Freeman,M.C., Z.H. Bowen. Boyee,K.D., Irwin,E.R., 2001. Flow and Habitat Effects on Juvenile Abundance in Natural and Altered Flow Regimes. Ecological Applications 11:179-190

Gatz, A.J., M.J.Sale, L.J. Loar. (1987) Habitat Shifts in Rainbow Trout: Competitive Influences of Brown Trout. Oecologia Vol. 74, No. 1 p. 7-19

Gwinn, D. C., P. Brown, J. C, Tetzlaff, and M. S. Allen. 2011. Evaluating mark-recapture sampling designs for fish in an open riverine system. Marine and Freshwater Research 62:835-840. doi: 10.1071/MF10217 1323-1650/11/070835.

Loerts, S., T. Lorz. ODFW Aquatic Inventory Project Stream Report. Oregon Department of Fish & Wildlife. 1994.

MacKenzie,D.L., J.D. Nichols, J.A. Royle, K.H. Pollack. L.L. Bailey, J.E. Hines. Occupancy Estimation and Modeling: Inferring patterns and dynamics of species occurrence. Academic Press, New York. 2006.

McHugh, P. & Budy, P. (2006) Experimental Effects of Nonnative Brown Trout on the Individual- and Population-Level Performance of Native Bonneville Cutthroat Trout. Transactions of the American Fisheries Society, 135:6, 1441-1455.

McKinney, T., Speas, D.W., Rogers, R.S., & Persons, W.R. (2001): Rainbow Trout in a Regulated River below Glen Canyon Dam, Arizona, following Increased Minimum Flows and Reduced Discharge Variability. North American Journal of Fisheries Management, 21:1, 216-222.

Oregon Department of Water Resources. 1992. Deschutes Streamflow Investigations.

Pine, W. E., Pollock, K. H., Hightower, J. E., Kwak, T. J., and Rice, J. A. (2003). A review of tagging methods for estimating fish population size and components of mortality. Fisheries 28, 10–23. doi:10.1577/1548-8446(2003)28[10:AROTMF]2.0.CO;2

Recsetar, M.S., S.M., Zeigler, M.P., Ward, D.L., Bonar, S.A., & Caldwell, C.A.

(2012): Relationship between Fish Size and Upper Thermal Tolerance, Transactions of the American Fisheries Society, 141:6, 1433-1438

Shea, C., Peterson, J. 2007. An Evaluation of the Relative Influence of Habitat Complexity and Habitat Stability on Fish Assemblage Structure in Unregulated and Regulated Reaches of a Large Southeastern Warmwater Stream. Transaction of the American Fisheries Society 136:943-945

Starcevich,S., Jacobs, S., Tinniswood, B. 2006. Effects of Dams on Redband Trout Life History in the Upper Klamath River: A Summery and Synthesis of Past and Recent Studies. Oregon Department of Fish and Wildlife.

Upper Deschutes Watershed Council. Water Quality Monitoring Program. Standard Operating Procedure. November 2008.

United States Geological Survey. 2005. Occupancy Models to Study Wildlife.

Young, M.K., Wilkison, R.A., Phelps, J.R., and Griffith, J.S. Contrasting Movement and Activity of Large Brown Trout and Rainbow Trout in Silver Creek Idaho. Great Basin Naturalist. 1997. 238-244.