Oregon Department of Fish and Wildlife

Technical Report

2012 Middle Deschutes Fisheries Monitoring Report: Fish Distribution and Abundance in the Middle Deschutes River

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Abstract

ODFW sampled the middle Deschutes River during the fall of 2012 to establish a baseline of fish abundances and to identify factors limiting trout production. Although preliminary, we discovered that redband trout (*Oncorhynchus mykiss gairdneri*) numbers and size class presence increases with proximity to cold water sources on the Deschutes River. The result of occupancy models suggests that temperature and flow influence detection; however, an increased sample size is necessary for conclusive results.

Introduction

The Deschutes River, a tributary of the Columbia River, historically was recognized for its extremely stable interannual flows. The river is fed by cold springs and groundwater originating from snowmelt and rainfall percolating into the porous volcanic geology of the Cascades (Jacobson and Jacobs 2010). The springs supplemented flows in the Deschutes River, which ranged from 1250 cubic feet per second (cfs) in August to 1310 cfs in December (Oregon Water Resources Department, 2003). These conditions were optimal for multiple native salmonid species. However, growing human populations resulted in increased extraction of river water for agricultural operations, municipal and industrial use. Logging practices altered the river morphology and flows were steadily diverted by a growing irrigation infrastructure. By 1960, four major diversions and two large reservoirs were in operation, to manipulate flows and facilitate irrigation needs. This disrupted the stable nature of Deschutes River flows downstream of Wickiup Dam, including the middle Deschutes River located between Bend (RM 166) and Lake Billy Chinook (RM 120) (Figure 1).

The largest impoundments on the upper Deschutes River are Wickiup Reservoir (RM 226.5) and Crane Prairie Reservoir (RM 238). Water is stored and released from these water bodies to inflate flows on the upper Deschutes River during irrigation season. Irrigation season typically runs from April 15^{th}, through October 15^{th} and managed flows are diverted at a series of dams near the city of Bend. Arnold Irrigation Dam (RM 174.5) is the first diversion dam encountered below Wickiup Reservoir, followed by Central Oregon Irrigation Dam (RM 171.0), Bend Feed Canal (RM 165.8), and finally North Canal Dam (RM 164.8). These four diversions can divert up to 2000 cfs from the Deschutes River. In 2012, flows directly below the North Canal Dam ranged from 73.5 to 369 cfs during the irrigation season and between 414-1439 cfs in non-irrigation seasons (BOR).

Tumalo Creek is a tributary to the Deschutes River, which contributes cool water to the mainstem just downstream of the North Unit Canal Dam RM 160.2 (Figure 1). According to Water Resources Department (2003), the historic natural average annual flows for Tumalo Creek during a 30 year period was 90 cfs. Unfortunately, Tumalo Creek is also subject to flow manipulation with an irrigation diversion at RM 2 (Figure 1). The Tumalo Irrigation District Dam can divert up to 70 cfs from Tumalo Creek and until recently the lower two miles were frequently dry during peak diversion months. Currently 11 cfs is protected instream below the diversion (Bureau of Reclamation).

Water management has a negative effect on various fish habitat parameters and their corresponding fish assemblages (Shea and Peterson 2007). Irrigation infrastructure reduces habitat connectivity and flow management affects temperature and reduces access to spawning and rearing habitat (Pringle, 2000; Freeman, 2001). The native fish assemblage of the middle Deschutes River and Tumalo Creek historically included bull trout (*Salvelinus confluentus*), redband trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), chinook salmon (*Oncorhnynchus tshawytscha*) and summer steelhead (*Oncorhnynchus mykiss*). Distributions of chinook salmon and steelhead ended at the natural barrier of Big Falls (RM 132) (Nehlsen 1995, Fies et al. 1996). Fish assemblages of the middle Deschutes River are now comprised of redband trout, mountain whitefish, brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*). Brown trout and brook trout were introduced into the Deschutes watershed by state and federal agencies in the early 1900's. Biologists believe flow management and irrigation infrastructure have affected species assemblages (Fies et al. 1996). Low flows during the summer months in the middle Deschutes River results in increased water temperatures. The Upper Deschutes Watershed Council has documented 20.5°C temperatures in this reach in 2012. The Deschutes River is on the Oregon Department of Environmental Quality 303d list for water quality impairment due to excessive temperature. Negative impacts of high temperature on salmonid growth and survival are well documented (Recsetar et al. 2012).

As a result of concern for low flows and exacerbated temperatures on fish populations, aquatic resources and recreational angling, several central Oregon non-profit groups, including the Deschutes River Conservancy and Upper Deschutes Watershed Council (UDWC), began working collaboratively with the irrigation districts and Oregon Water Resources Department to engage in water conservation projects during the past 15 years. This has resulted in flows in the middle Deschutes River incrementally increasing from a summer time low of ~ 30 cfs to an average of 138 cfs in 2012. Conservation project supporters and sponsors would benefit from fisheries monitoring information indicating whether populations are responding favorably to the increase in flow. The UDWC was awarded grant funds from the Oregon Watershed Enhancement Board to fund Oregon Department of Fish and Wildlife staff to conduct a multi-year fish monitoring effort to characterize the fish assemblage in the middle Deschutes River and document changes over time.

Documentation of flow management and its corresponding effects on fish assemblages in the middle Deschutes River subbasin have been difficult to demonstrate. Rough terrain, limited access, and low capture rates limit accuracy and precision of standard population estimates. A methodology that assumes low capture rates, provides unbiased estimates of fish distribution, and calculates the effect of various habitat parameters is ideal. Our goal is to determine which habitat factors were determining the presence of fish species at different life history phases in the middle Deschutes River and its tributaries. Our objectives were to:

1) Develop a sampling methodology that effectively and efficiently measures baseline fish assemblages in the Deschutes River and Tumalo Creek.

2) Measure flow, temperature, and habitat conditions within the study area.

3) Describe the effect of flow, temperature, and habitat conditions on middle Deschutes River and Tumalo Creek fish assemblages.

4) Adapt the study protocol to facilitate future monitoring at a reduced level to document changes in response to further conservation efforts.

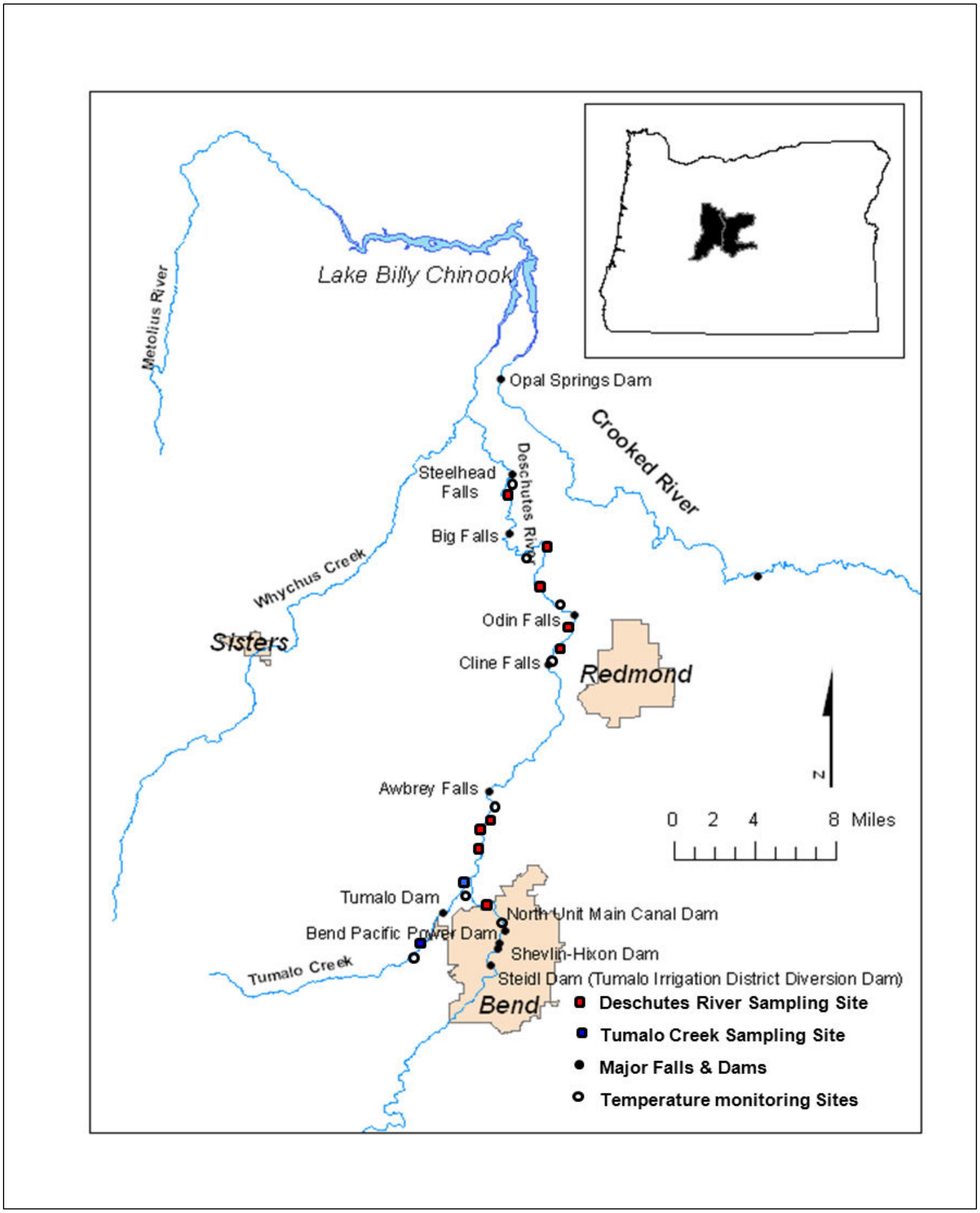

Figure 1. Map of the middle Deschutes River from Bend to Lake Billy Chinook. Red squares represent electrofishing sites on the middle Deschutes River. Blue squares represent sampling sites (electrofishing and snorkeling) in Tumalo Creek. Solid black circles represent major falls and dams. Black circles show temperature logger locations.

Methods

Site Description

The middle Deschutes River runs from the North Canal Dam in Bend to Lake Billy Chinook (Figure 1). This section of river can be generalized by steep canyons and occasional reaches sweeping open to form narrow valleys. The mean gradient from North Canal Dam to Foley Waters is 6.4% and mean width is 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).

The 2012 sampling season was abbreviated between September 5th and October 28th, which limited the number of sampling sites. The rugged topography surrounding the middle Deschutes River and private property also limited access to sampling sites. Once access sites were identified, we used discontinuous sample selection in ArcGIS to select 9 sampling sites on the middle Deschutes River and two sites on Tumalo Creek (Figure 1) (Peterson et al. 2006). All sites were 200 meters (m) in length and GPS coordinates at the upper and lower terminus of each site were recorded to ensure consistency between sampling events; an additional 600 m was added to the Foley Waters site as part of population estimate study. Two seasons were defined, irrigation season and non-irrigation season when in-river flows increased. Each site was monitored three times per season. In order to achieve the maximum amount of sampling in 2012, multiple pass removal on Tumalo Creek and the mark recapture study at the North Canal Dam was postponed.

Our study sites were located from Sawyer Park, downstream of the North Canal Dam to Foley Waters. Sawyer Park is the first site downstream of the North Canal Dam (RM 164) and is comprised of shallow riffles and pools. There are three sites below the city of Tumalo (RM 156.2, 155.5, & 155) that range from shallow riffles to deep pools. The Cline Falls sites (RM 144 & 142) and Odin Falls sites (RM 138 & 137) consist of short rapids followed by glides. Our final site is located at Foley Waters (RM 129), where large spring complexes provide a stable temperature regime year round, and is comprised of shallow riffles and pools.

There are two monitoring sites located on Tumalo Creek. The first site (RM 6) flows through a broad valley near Fremont Park and is comprised of riffles and pool complexes. Site 2 is located 100 meters 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, and terminates into the Deschutes River.

Flow and Temperature Monitoring

Instantaneous flow readings were recorded before the first sampling site daily from the U.S. Bureau of Reclamation Hydromet system. The middle Deschutes River stream gauge is located below the North Canal Dam in Bend (DEBO RM 164.25) and records flows on 15 minute intervals. Tumalo Creek Flows were recorded directly below the Tumalo Feed Canal (TUMO RM 2.05).

Eight temperature loggers were deployed as part of the middle Deschutes monitoring project. Loggers were placed at six sites on the Deschutes River and two sites on Tumalo Creek. Vemco Minilog II-T temperature loggers were used to be consistent with partners and the Oregon Department of Environmental Quality (UDWC 2008). We calibrated all temperature loggers by placing them in two separate baths, the first at 8.1 °C and the second at 23.0 °C for ten minutes each (UDWC 2008). A National Institute of Standards and Technology (NIST) certified thermometer was used to manually recorded temperature every minute. (ODEQ calibrated NIST #52096 Inspected 4.12.12 Expires 4.12.13). Data from each logger was then downloaded and readings were compared to the manual recording from the NIST certified thermometer. Loggers within a difference 0.5°C from the NIST received an A and loggers within 1.0°C received a B. All eight temperature loggers received either an A or a B, none exceeded a difference greater than 0.6°C. ODFW temperature loggers were set to record temperature every hour and were placed in the Deschutes River on September 24th, 2012 (RM 129.0, 139.0, 144.5, 155.0 & 165.9) and on September 25th (RM 141). Temperature loggers with the same settings were placed in Tumalo Creek on October 10th (RM 0 & 6.0). Each logger was secured to the bank with a cable extending 8-12 feet into the water. Loggers were audited every other month and data offloaded onto a Vemco field reader. At the time of audit, the NIST was used to take a manual temperature, recording river temperature to compare with the logger for accuracy. All offloaded data was entered into a database along with the NIST thermometer reading.

We used data from three UDWC Vemco temperature loggers located downstream of Tumalo Creek (RM 160), upstream of Tumalo Creek (RM 160.25) and at the Riverhouse (RM 164.75) located downstream from the North Canal Dam. UDWC temperature loggers recorded temperatures in 2012 from April 23rd to November 7th.

Sampling

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. To reduce the likelihood of incomplete detections, we sampled two longitudinal transects in each reach during irrigation season to ensure full coverage of the river channel (Jacobsen and Jacobs 2010). It was not possible to sample multiple transects at all sites during non-irrigation season due to high flows impeding upstream travel; mean flows were 138 cfs during irrigation season and 615 cfs after irrigation season. The electrofishing unit was set for high-range direct current (DC) with a pulse rate of 120 pulses per second and power ranged from 40-80 percent. All sites were shocked for an average of 187 seconds/transect during irrigation season and 143 seconds/transect after irrigation season. All fish captured were held in a live well until electrofishing was completed. Fish were identified to species, enumerated, measured to the nearest millimeter (total length), weighed to the nearest gram when ≥150mm in length, and then released at end of site. Fish that measured less than 150mm were not weighed due to the inaccuracy of our scales. All data was entered into a Microsoft Access database form on a Trimble Yuma.

We sampled an additional 600 m at the 200 m monitoring site at Foley Waters as part of a population estimate study. All sampling methods were consistent with the nine upstream middle Deschutes River sites; however, mark and recapture methods were also implemented within the 800 m section. Three longitudinal transects were sampled for three consecutive days from September 26th-28th, 2012. Two to three in-stream netters captured fish in front of the raft in addition to the on-boat netters. On September 26, all captured trout were given a lower caudal punch (with exception of fish <150mm) and on September 27th, all unmarked trout were given an upper caudal punch. During the final sampling, fish captured were identified by the type of caudal punch or as unmarked. Fish captured in the 200 meter section were compared to the eight upstream sites and were included in the 800-m population estimate.

Each site on Tumalo Creek was snorkeled once and electrofished with a backpack electrofisher twice between October 10th and October 15th. Snorkelers were trained in fish identification and underwater fish length estimation using various length decoys that ranged from 100mm-300mm (Peterson, 2002). Time restrictions and dangerous conditions due to high flows prevented us from sampling after October 15th.

Data Analysis

We calculated mean length, weight, relative weight, and absolute length frequency for all fish species by site and for all sites combined. The natural discontinuities in the length frequency histograms for all sites combined were used to assign size classes to each species (Isely, 2007). Length, weight, and relative weight were compared among sampling locations and three size classes assigned to each species (RB & BR; juvenile 60-120, intermediate 121-220, 221-500 reproductive) using two-way analysis of variance. Sampling location variables include river mile, flow variation, and distance to coldwater refuge.

Occupancy modeling was used to determine the effects of flow and temperature on fish distributions in the middle Deschutes River. We queried capture histories (presence/absence) of redband trout, brown trout, and their size classes for each site. We assumed study sites were closed to emigration and immigration during a season; detections were independent; and there was no unexplained heterogeneity in occupancy or detectability. Models related detection estimates to characteristics of the surveys and sites.

We used customized single season, single species models created in Presence and used two sampling covariates. We hypothesized that flow and temperature would have an influence on detection; therefore sampling covariates were instantaneous flow (cfs) and temperature (°C). Detection was modeled as a function of either flow, temperature (temp), or both temperature and flow. We did not model for occupancy probability because a site covariate was necessary and we had no covariates. (Mackenzie, Personal Communication 2013) Models were ranked according to Akaike's Information Criterion (AIC) (USGS, 2005). AIC weight, ΔAIC, and AIC determined the rank of the models. The model with the highest AIC weight and lowest AIC value ranked as the most parsimonious model. The difference between the best fitting model and the selected models AIC value is ΔAIC; models for which the ΔAIC value was within 2.0 units of the best fitting model should not be disregarded when deciphering inferences or parameter estimates (Mackenzie et al. 2006). Covariate data was standardized for the purposes of occupancy modeling.

We used the Schnabel formula for the mark-recapture population estimation at Foley Waters (Kohler and Hubert 1999). Non-game species were not included in this population estimate. The Schnabel estimation formula is:

$$\widehat{N} = \frac{\sum_{t=1}^{n} C_t M_t}{\sum_{t=1}^{n} R_t}$$

Where C refers to number of captures, M is the number marked, N refers to the estimate and R refers to captures without marks. Subscript *t* refers to the individual sample period and *n* is the number of periods.

Results

Flow and Temperature

Flows in the middle Deschutes River were recorded from the Bureau of Reclamation (BOR) (DEBO); 2012 flows ranged from 73.49 cfs to 1439 cfs (Figure 2). Tumalo Creek flows were also recorded from a BOR stream gauge located downstream of Tumalo Irrigation District Canal (TUMO); flows ranged from 13.23 cfs to 313.14 cfs (Figure 3). Temperature loggers began recording data on September 25, 2012 between Pioneer Park and Foley Waters. September 25, 2012 most closely represented a summer-like temperature regime and December 31, 2012 represented a winter temperature regime during this time-period. Maximum temperatures ranged from 13.15 ºC to 15.77 ºC on September 25, and between 0.6 ºC and 1.09 ºC on December 31, 2012 between Sawyer Park and Foley Waters (Figure 4). The overall maximum temperature measured in the middle Deschutes River was 20.48 °C (July 12, 2012) and the overall minimum was -0.04 °C (December 31, 2012). Maximum and minimum temperatures on Tumalo Creek at RM 1 were 12.4 ºC and -0.03 °C between October 10th and December 31 2012 (Figure 5). Maximum and minimum temperatures on Tumalo Creek RM 6 were 9.18 ºC and -0.01 ºC.

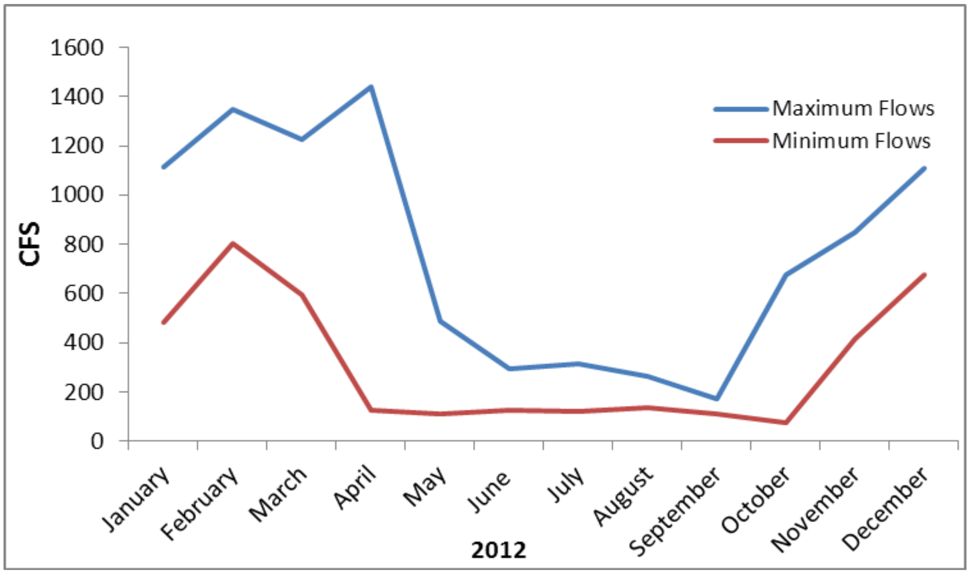

Figure 2. Middle Deschutes River monthly maximum and minimum flows as recorded by BOR for 2012. Stream gauge located at RM 164.25, below North Canal Dam.

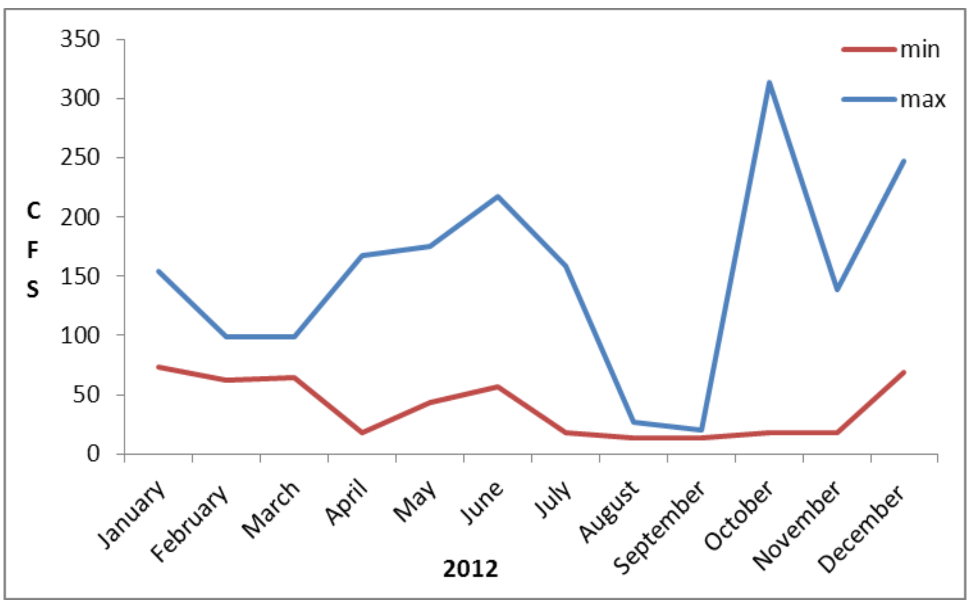

Figure 3. Tumalo Creek minimum and maximum monthly flows as recorded by the stream gauge located below Tumalo Irrigation District Canal. Data was missing before January 18th, 2012. *This graph does not include water diverted from TIDC.

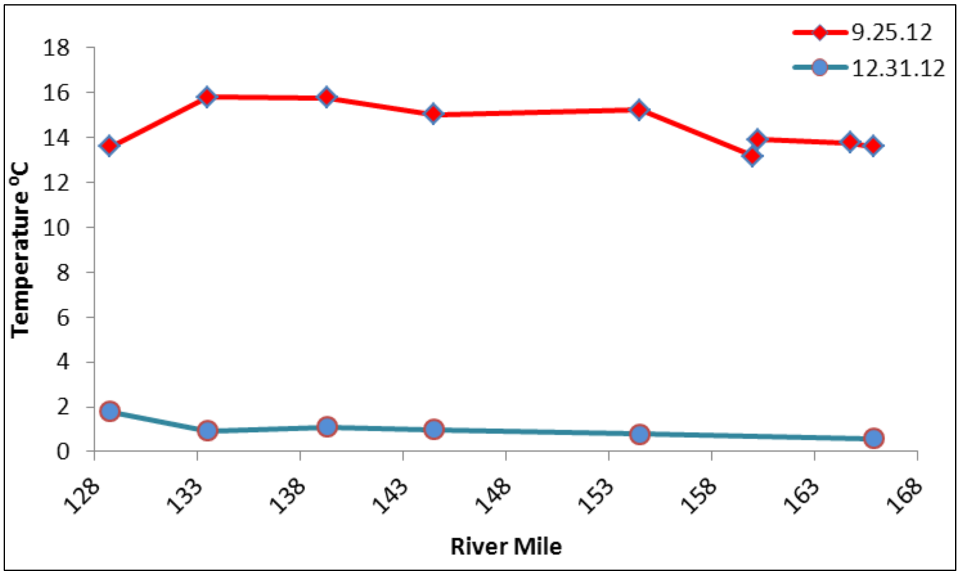

Figure 4. Maximum temperatures recorded on September 25th and December 31st, 2012. Recorded at temperature loggers distributed throughout the middle Deschutes River by UDWC (3 loggers) and ODFW (6 loggers). Logger data for December 31st, 2012 does not include UDWC data. *ODFW temperature loggers were not deployed until September 25th, 2012.

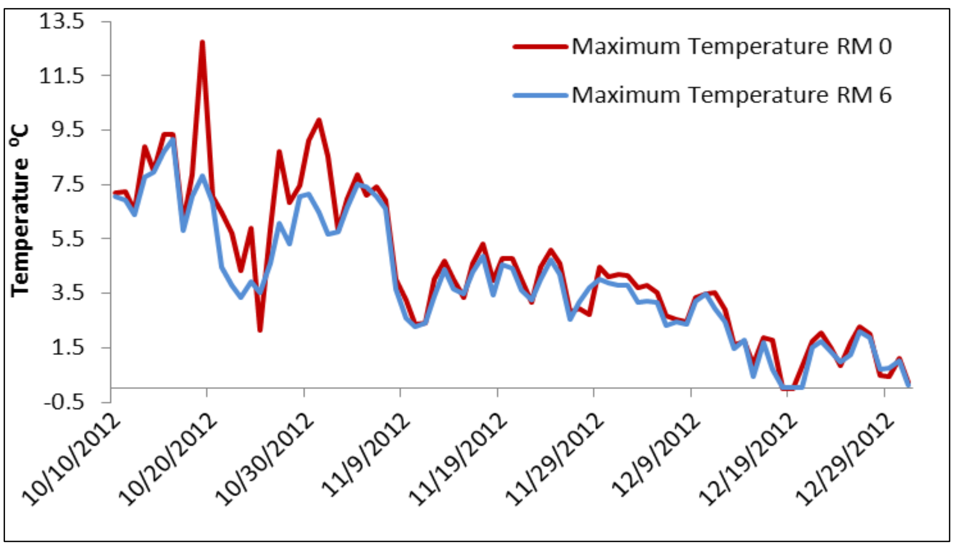

Figure 5. Temperature recorded from Tumalo Creek by ODFW temperature loggers from October 10th, 2012 to December 31st, 2012. Tumalo 1 logger is located at RM 0 (10m upstream from confluence) and Tumalo 2 logger is located at RM 6.

Fish sampling

In the middle Deschutes River we sampled nine sites three times between August 5th, 2012 and October 12th, 2012 and three times between October 15th, 2012 and October 28th, 2012. We captured mountain whitefish, kokanee, redband trout, brown bullhead (*Ameiurus nebulosus*), mottled sculpin (*Cottus bairdii*), brown trout, longnose dace (*Rhinichthys cataractae*), brook trout, tui chub (*Gila bicolor*) and three-spined stickleback (*Gasterosteus aculeatus aculeatus*). Mountain whitefish, brown trout, and redband trout were the dominant species encountered (Figure 6). The mean length and weight of mountain whitefish was 236 mm (SE ± 11.67), brown trout was 237 mm (SE ± 17.7), and redband trout was 189 mm (SE ± 15.3) (Figures 8,9,10). The mean length of redband trout was lowest at Odin Falls 2 and highest at Foley Waters. The mean length of brown trout was lowest at the site below Tumalo Creek and highest at Sawyer Park then Cline Falls 1 and Foley Waters. Mountain whitefish captured at Foley Waters were significantly longer than whitefish captured in all other sites ($P < 0.05$). The mean relative weight of whitefish captured at Foley Waters was also significantly greater than the relative weight of whitefish in all other sites ($P < 0.05$). The sample sizes of redband trout and brown trout were inadequate for statistical comparisons of means among sites.

We sampled two sites three times from October 10th -12th, 2012 on Tumalo Creek. We snorkeled on October 10th, and electrofished on October 11th and October 12th; fish sampled during electrofishing were measured and weighed. Redband trout, brown trout, and brook trout were the only species encountered in Tumalo Creek; redband were the dominant species and brown trout were only captured at the lower site (Figure 7). The mean length of redband trout was 118 mm (SE ± 4.32), brown trout was 104 mm (SE ± 8.27) and brook trout was 123 mm (SE ± 7.42). The mean relative weight of redband was 96.39 grams (SE ± 5.00), brown trout was 86.91 g (SE ± 1.70), and brook trout ranged from 82.14 to 86.84 g (n = 3). Sample sizes of fishes in Tumalo Creek were inadequate for statistical comparisons.

The length frequency of redband was normally distributed (Figure 12). The natural length frequency discontinuities of redband were at 120 mm and 220 mm; the associated size classes were between 60-120 mm (juvenile), 121-220 mm (immature), and 221+ mm (mature) (Figure 12). The brown trout length frequency was also normally distributed (Figure 13). The natural length frequency discontinuities of brown trout were at 150 mm and 270 mm; the associated size classes were between 80-150 mm (juvenile), 151-270 mm (immature), and 270+ (mature) (Figure 13).

All size classes of redband were present at higher frequencies directly downstream of or in cold water inputs; 51% of redband were caught at the site closest to Tumalo Creek and in Foley Waters (Figure 14). The highest frequencies of brown trout were at Foley Waters (Figure 15) and the highest frequencies of juvenile brown trout were located at the first site below Tumalo Creek (Figure 16). Overall frequencies of redband and brown trout among sites had an inverse relationship (Figure 15).

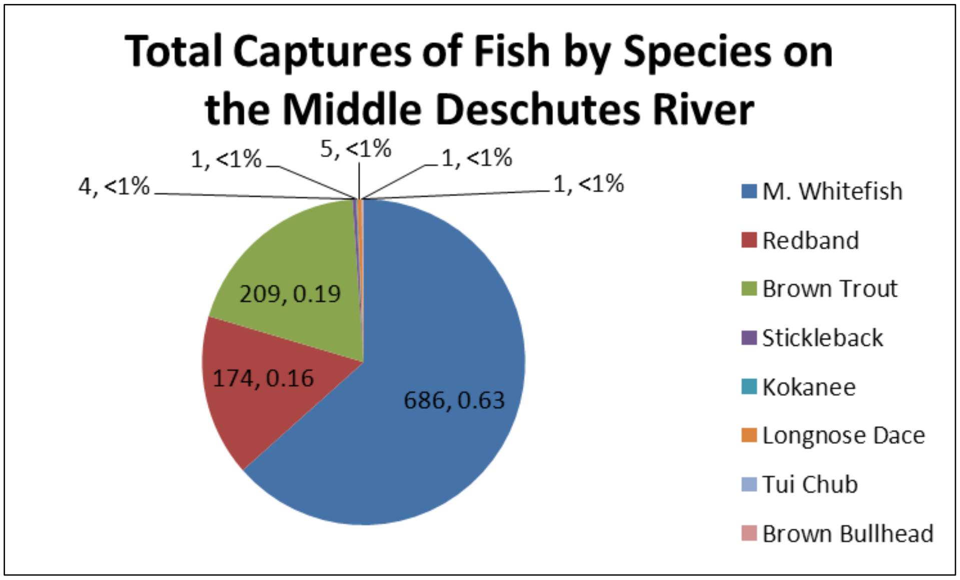

Figure 6. Total captures of fish by species on the middle Deschutes River. Species quantity and percentage is represented.

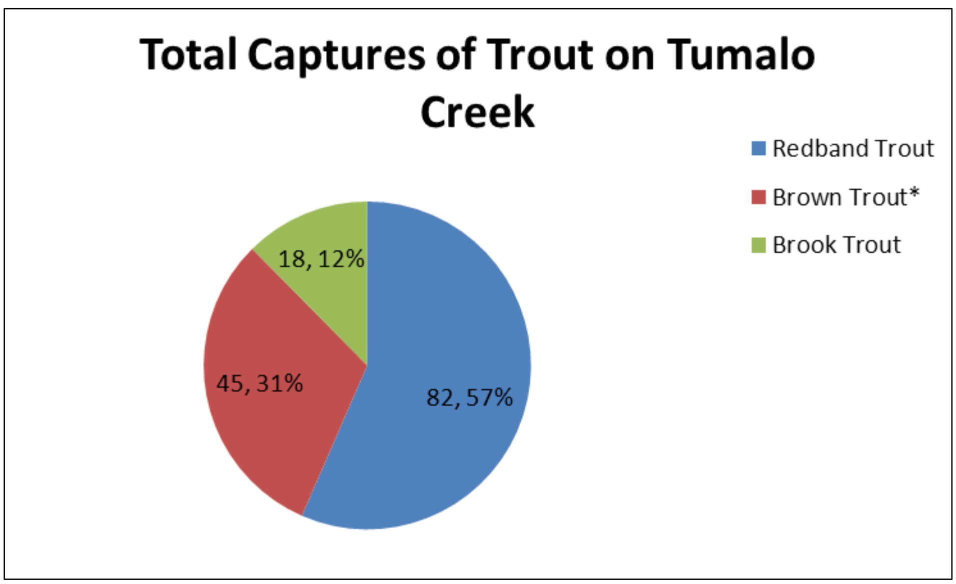

Figure 7. Total captures by species on two sites on Tumalo Creek in 2012.
*Brown trout were not captured at upper site near Fremont Meadows. Species quantity and percentage is represented.

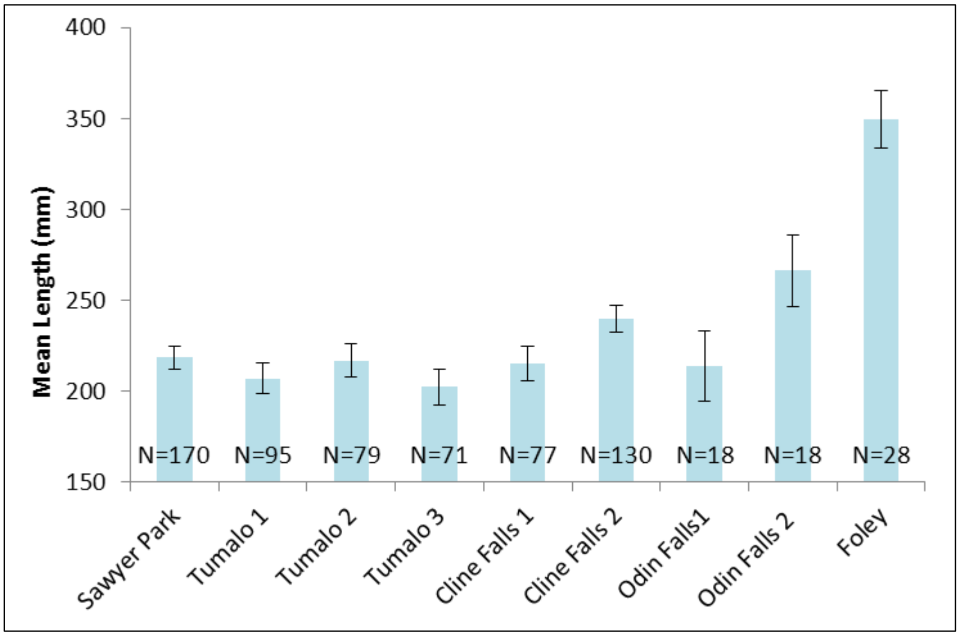

Figure 8. Mean length (mm) and standard error for mountain whitefish captured on the middle Deschutes River.

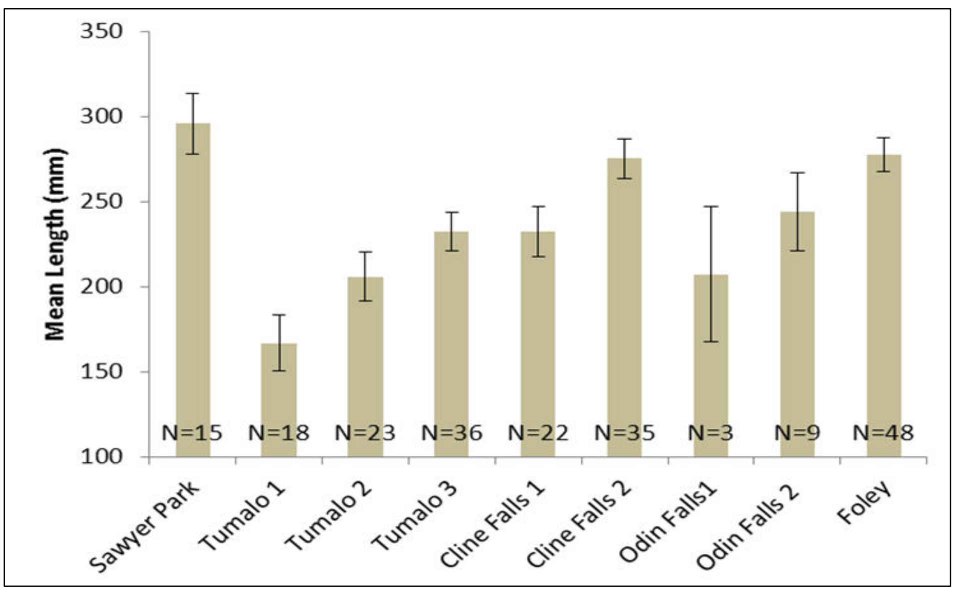

Figure 9. Brown trout mean length in millimeters with standard errors bars that were captured on the middle Deschutes River.

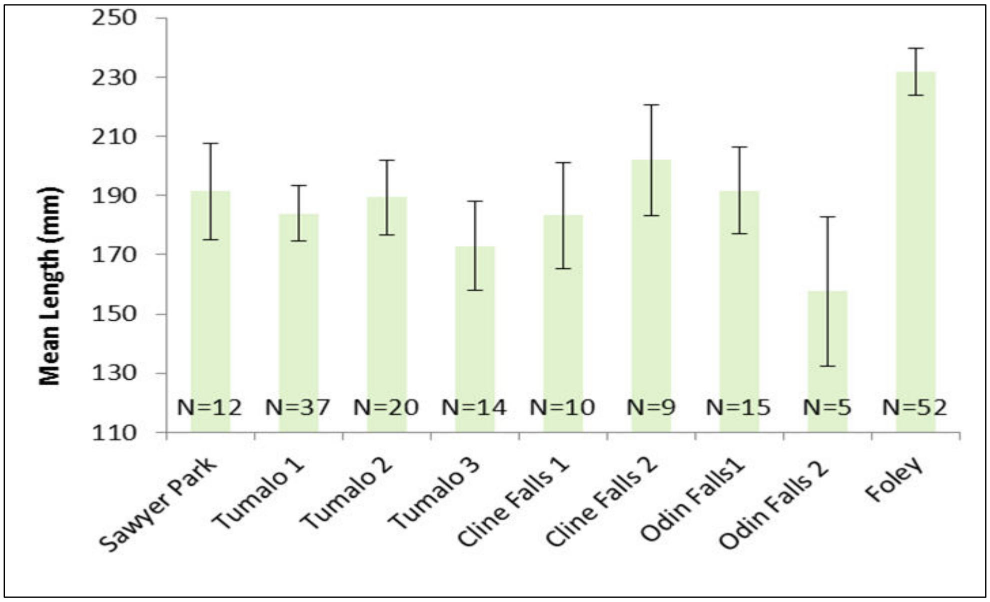

Figure 10. Redband trout mean length in millimeters with standard errors bars that were captured on the middle Deschutes River.

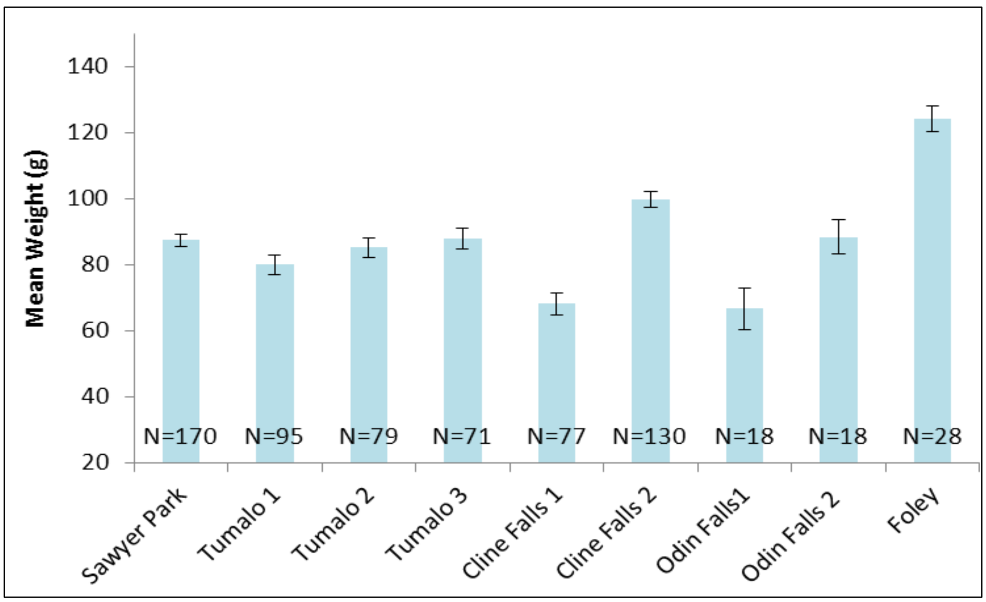

Figure 11. Mean relative weights of mountain whitefish captured in the middle Deschutes, errors bars represent standard error.

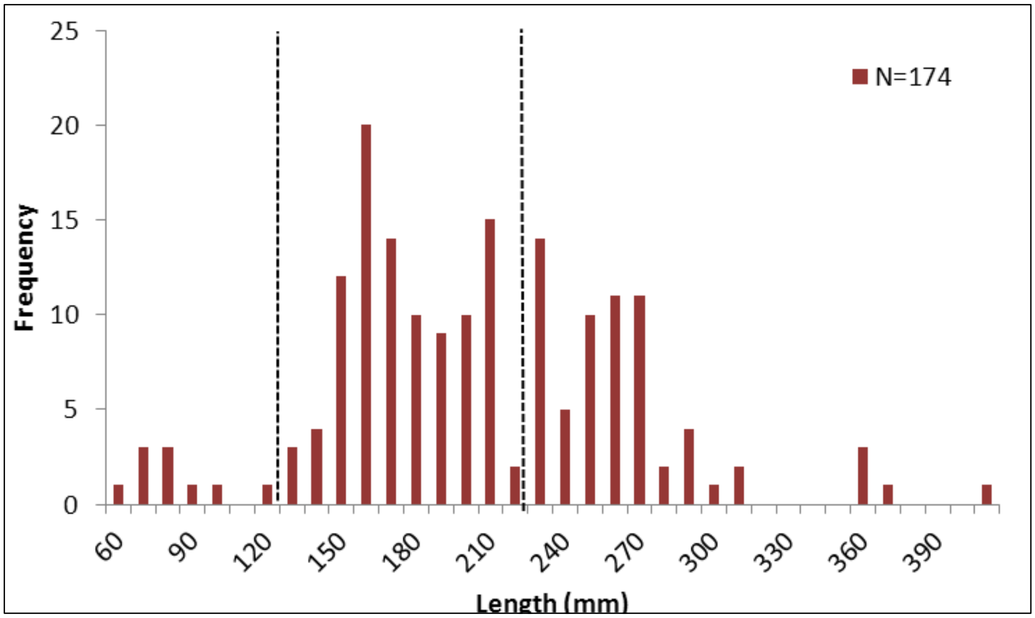

Figure 12. Length frequency distributions of redband trout captured on the middle Deschutes River. Dotted lines represent natural discontinuities in size class distributions. 30% of all redband were captured at Foley Waters.

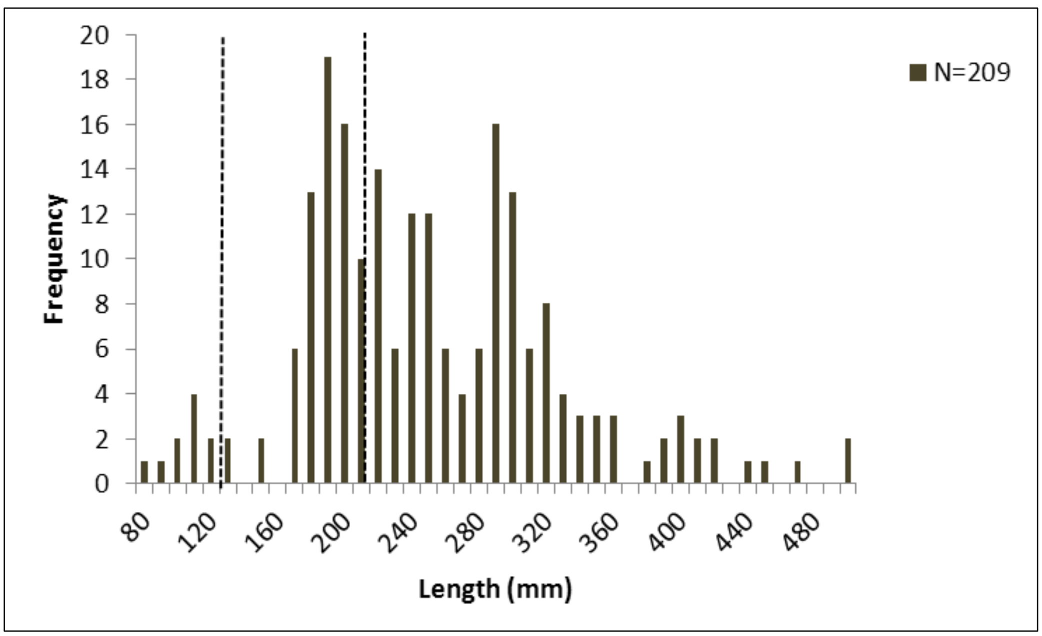

Figure 13. Length frequency distributions of brown trout captured on the middle Deschutes River. 23% of all brown trout were captured at Foley Waters.

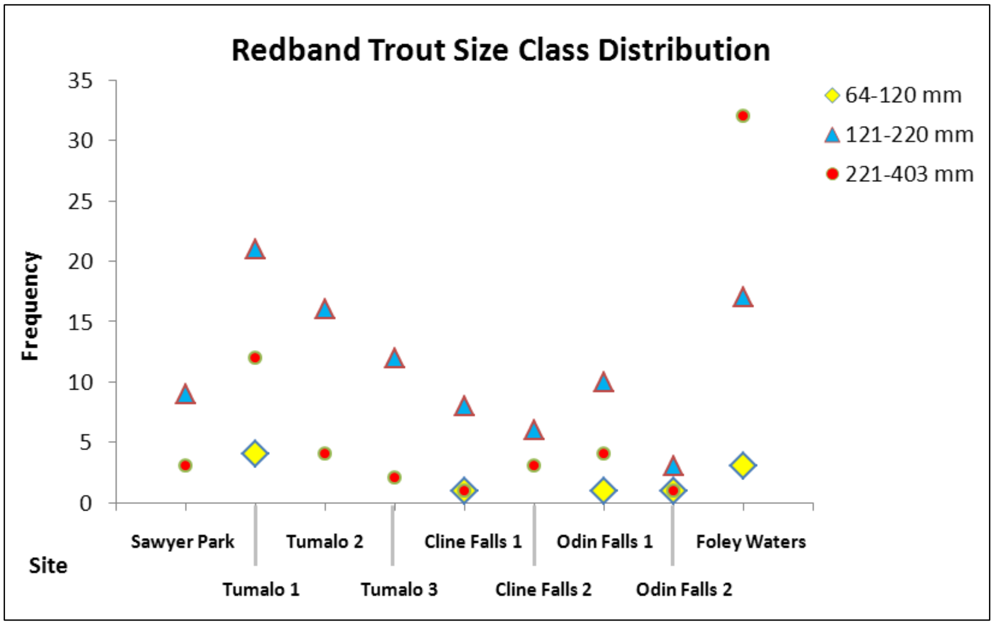

Figure 14. Middle Deschutes River size class distribution according to site, from Sawyer Park downstream to Foley Waters. Size classes are grouped from 64-120mm, 121-220mm and 221-403mm.

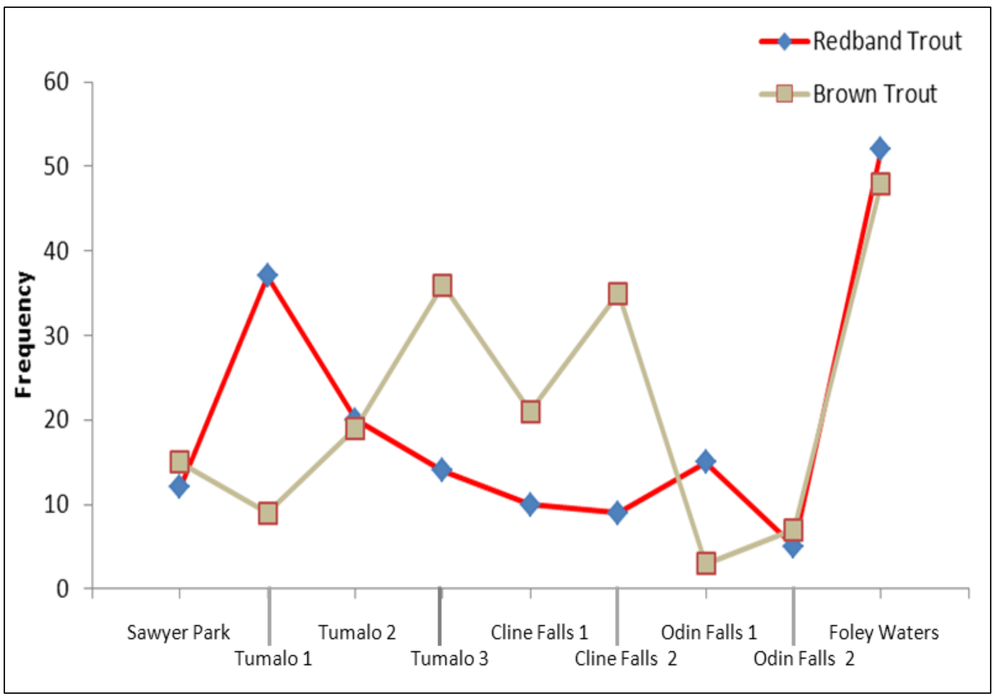

Figure 15. Distribution of brown trout and redband trout at sites sampled in the middle Deschutes River. Includes all size classes.

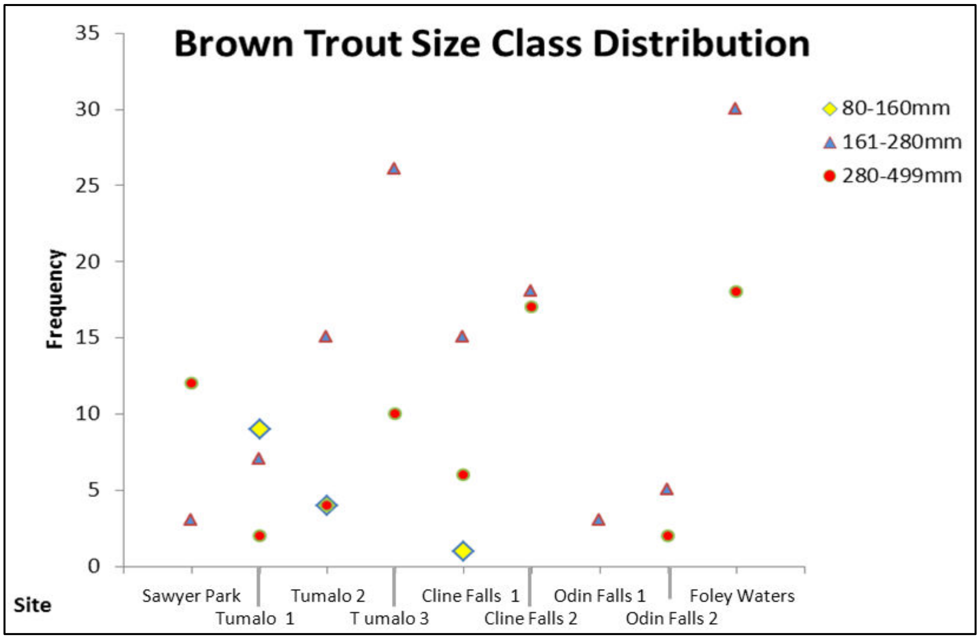

Figure 16. Distribution of brown trout size classes sampled in the middle Deschutes River. Size classes were grouped from 80-160mm, 161-280mm, and 280-499mm.

Population modeling

Four models were run in Presence to estimate occupancy probabilities of the redband trout total population, juvenile redband trout, mature redband trout, and the total population of brown trout. Each model was run with three arrangements of sampling covariates to estimate detection probabilities; temperature, flow (cfs), and temperature and flow. The occupancy parameter was held constant because no covariates remained constant throughout all sites during each sampling season.

Flow was the most likely sampling covariate affecting the presence of the redband trout total population, juvenile redband trout population, and the brown trout total population; temperature was the sampling covariate most likely to affect the presence of mature redband trout (Table 1A). The second most likely sampling covariate affecting the presence of the redband trout total population, juvenile redband, and mature redband was a combination of temperature and flow (Table 1A). The second most likely sampling covariate affecting the presence of the brown trout total population was temperature (Table 1). However, it is important to note that the four models have a high standard error (SE ± 0.75-1.00).

Table 1. Results for all Presence models run for the middle Deschutes River.
Column A indicates all four models run, with three variations of detection as a function of flow, temperature (temp), and temperature and flow. The occupancy parameter remained constant for all models. AIC, ΔAIC and AIC weights are all listed in column A for each of the models. Column B shows the results of occupancy estimates and standard errors and the corresponding covariate that was in the best selected model, which was flow, with the exception of the +250mm redband trout model.

Column A

Presence Model Results for Redband Trout

Model	AIC	ΔAIC	AIC Weight
Flow	52.64	0	0.5685
Temp, Flow	53.75	1.11	0.3263
Temp	56.06	3.42	0.1028

Presence Model Results for Brown Trout

Model	AIC	ΔAIC	AIC Weight
Flow	64.03	0.42	0.287
Temp	64.34	0.73	0.2458
Temp, Flow	65.89	2.28	0.1132

Presence Model Results for ≥250mm Redband Trout

Model	AIC	ΔAIC	AIC Weight
Temp	61.96	0	0.6039
Temp, Flow	63.3	1.34	0.309
Flow	65.9	3.94	0.0842

Presence Model Results for Juvenile Redband Trout

Model	AIC	ΔAIC	AIC Weight
Flow	34.72	0	0.5229
Temp, Flow	35.52	0.8	0.3505
Temp	37.83	3.11	0.1104

Column B

Redband Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-2.263844	0.781645

Brown Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-0.415265	0.336354

≥250mm Redband Trout	**Estimate**	**Std.Error**
Occupancy	88%	73%
Temp	1.480697	0.498389

Juvenile Redband Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-2.960738	2.706747

Foley Waters Mark-Recapture Results

Fish captured at Foley Waters included mountain whitefish, redband trout, longnose dace and brown trout. Using the Schnabel equation, the redband trout population was estimated to be 645 fish/800 m with a 95% confidence interval ranging from 250 to 1776 (figure 8). The brown trout population was estimated to be 854 fish/800 m with a 95% confidence interval ranging from 476 to 1531.

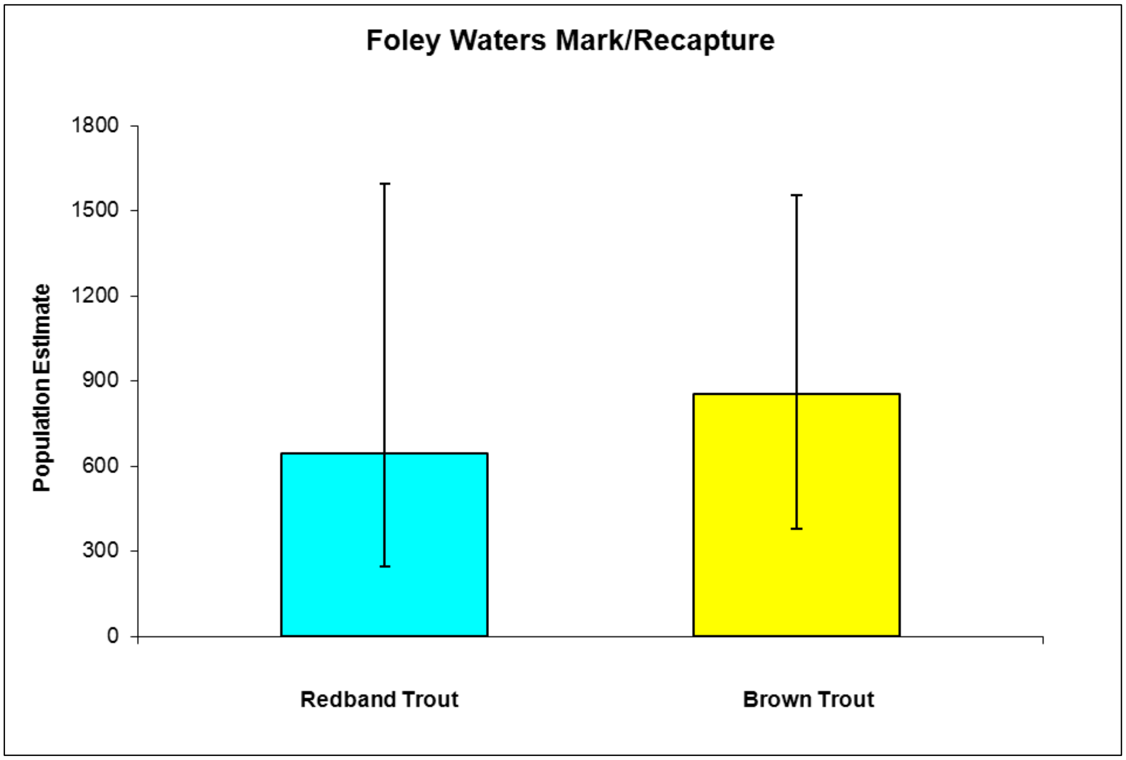

Figure 15. Foley Waters Schnabel population estimates for 800 meters for redband and brown trout with error bars representing 95% confidence intervals.

Discussion

In the middle Deschutes, the Oregon Water Resources Department estimates natural annual flows averaged 1350 cfs with an approximate annual variation of 60 cfs. In 2012, the annual average flow for the middle Deschutes was 756 cfs and it varied by 1366 cfs. In Tumalo Creek natural late summer flows averaged 65 cfs; however, late summer flows reached a minimum of 13 cfs in 2012 (OWRD 2003). Variations in flow limit habitat availability and can potentially conflict with fish spawning. Freeman et al. (2001) demonstrated that young of the year were affected significantly by alterations in flows and fish directly benefit from stable flows by an increase in reproduction. Our models supported this finding, suggesting flows affect presence of juvenile redband trout and redband trout and brown trout of all size classes combined. However, the altered flow regimes in Tumalo Creek and the Deschutes are likely to benefit brown trout and harm native redband. Native redband trout typically spawn between December and May in the Deschutes watershed and their fry emerge from the gravel between May and late July, which corresponds with the period of low flows and high temperatures. Non-native brown trout typically spawn between October and December and their fry emerge from the gravel before flows decline. Redband spawning redds are potentially subjected to dewatering while brown trout fry are allowed to emerge. Additionally, brown trout young of the year gain a size advantage over redband trout young of the year by emerging from the gravel months earlier. Both variables could result in a greater frequency of brown trout over redband trout. In Tumalo Creek, brown trout were not detected in the site unaffected by irrigation withdrawals and they were present in high numbers in the Tumalo Creek reach affected by irrigation withdrawals. Results in the middle Deschutes were not as conclusive due to low sample sizes; however, inverse distributions of redband and brown trout by sampling site suggest that the two species are affected by habitat conditions differently.

Due to time of deployment of temperature loggers, we were unable to demonstrate maximum and minimum temperatures for one year throughout our sampling sites. However, we recorded temperatures with a hand held thermometer on each sampling occasion. Our model suggests that temperature affects adult redband presence more than flow. Our distribution data also suggests fish concentrate near areas of cold-water inputs and average fish lengths and average relative weights are greater in these areas. Another point of interest was juvenile brown trout were only found in the three sites directly below Tumalo Creek and their frequency decreased with distance from Tumalo Creek. There are several explanations for this that are related to either structural habitat in the sites or a temperature effect caused by Tumalo Creek. It is important to collect more information to explain this phenomenon.

Unfortunately, our sample sizes were too small to say that flows and temperature affect fish presence, distribution, or growth with statistical certainty. Our small sample size resulted in a standard error of 100% in our occupancy model and we were unable to make other important statistical comparisons. In 2013, we will adjust the 2012 sampling protocol to increase statistical power and strengthen the models. Increasing the number of sampling sites will reduce standard error within our occupancy model and precision and accuracy will increase as annual data is added. We will shift from multiple longitudinal electrofishing transects to single longitudinal transects and will sample 30 randomly selected sites as opposed to 10. The sampling season will also be shifted from September and October to August and November to allow fish to respond to seasonal fluctuations of flow and temperature. We will also implant radio transmitters in redband trout to track movements of fish between irrigation seasons, which we suspect will support the assertions of the occupancy models. Although our data is limited it suggests that flow management and temperature affect fish presence and growth in the middle Deschutes River; it is essential to collect additional years of data to confirm this hypothesis.

Glossary

Akaike Information Criterion (AIC): a measure of goodness of fit of a statistical model.

Detectability: the probability of detecting a species during a single survey visit, given it is present at the site.

Discontinuous Sampling Frame: a type of random sampling used to locate sites in an area that has constraints that prevent access to a entire stream or basin. ie. road access, land ownership, or safety concerns that may limit access.

Heterogeneity: synonymous with variation. Used here to refer to unexplained variation in parameters.

Logit function: an equation that converts a sigmoid relationship (logistic) between two factors to a linear relationship. The logit function involving detectability may be: $logit(p)=ln(p/(1-p))=y$.

Maximum likelihood estimate: method of estimating the parameters of a statistical model.

Occupancy: the proportion of sites, patches or habitat occupied by a species

Parameters: quantities to be estimated, such as occupancy or detectability, under an assumed model structure.

Sampling Covariate (survey specific): a unit that can be measured and have a direct influence over detection and varies between sampling events.

Site Covariate: a unit that can be measured and varies between sites, but must remain constant for entire season.

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