Distribution and Abundance of Redband Trout *Oncorhynchus mykiss* in the Malheur River Basin, 2007

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Native Fish Investigations Project

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INTRODUCTION

The Malheur River Basin supports native populations of redband trout *Oncorhynchus mykiss* that consist of resident populations, some isolated upstream of natural barriers, and populations that have likely adopted a resident life history after connectivity to marine environments was severed by the construction of dams. In addition to native populations of redband trout, recreational fisheries in portions of the basin have been supported by stocking of hatchery rainbow trout fingerlings, primarily in reaches of the mainstem and North Fork Malheur River (Hanson et al. 1990). While limited surveys have been conducted to assess relative abundance and distribution of native trout in portions of the basin (Pribyl and Hosford 1985, Fenton et al 2005) no systematic, basin-wide survey of the distribution and abundance of Malheur Basin redband trout exists. This study was conducted to fill this information void. During 2007 we implemented a statistically-based sample design to select representative sample sites across the extent of wadeable streams and obtained a rigorous density estimate of redband trout each site. From these data we inferred spatial patterns of distribution and abundance. Specific objectives of work conducted in 2007 were:

Objective 1. Develop and conduct a statistically based population assessment for Malheur River redband trout.

Sub-objective 1.1. Develop a GIS-based sample frame for the basin.

Task 1.1.1. Assemble 1:24,000 scale stream network coverage for Malheur River Watershed.

Task 1.1.2. With the assistance of regional biologists, define a sample frame that represents the best assessment of potential redband trout summer rearing distribution.

Sub-objective 1.2. Develop a sampling design that provides statistically rigorous estimates of distribution, abundance and biological traits, at the basin level.

Task 1.2.1. Use the EMAP methodology to select a spatially-balanced random sample of points within the sampling frame.

Task 1.2.2. Evaluate sample sites for access and landowner permission and adjust sample selection to accommodate logistical issues.

Sub-objective 1.3. Use electrofishing and calibrated removal methods to estimate fish abundance and size composition at sample sites.

Task 1.3.1. Conduct multi-pass electrofishing at each sample site.

Task 1.3.2. Conduct mark-recapture population estimates at a representative subsample of sites (approximately 10% of sites).

Task 1.3.3. Measure lengths of captured fish.

Objective 2. Using sample data, evaluate species at the basin scale.

Sub-objective 2.1. Produce a final report that describes distribution, estimates abundance, summarizes some biological characteristics, and makes recommendations for future monitoring.

Task 2.1.1. Assess distribution from redband trout presence at sample sites.

Task 2.1.2. Estimate abundance and associated precision at the basin and sample stratum scales.

Task 2.1.3. Examine age class diversity from length frequency data.

Task 2.1.4. Develop recommendations for future population monitoring efforts from results of 2007 sampling.

STUDY AREA

The Malheur River Basin is situated in eastern Oregon bordered on the south by the Owyhee River Basin, on the north by the Burnt River and John Day River Basins, on the west by the Malheur Lakes Basin, and by the Snake River to the east, which it enters near Ontario, Oregon. From its headwaters in the Strawberry Range, at the southern terminus of the Blue Mountains, the Malheur River flows southeasterly for 105 kilometers, turning north for 12 kilometers, then east near the town of Juntura and continuing east to northeast to its confluence with the Snake River near the town of Ontario, a total distance of approximately 306 kilometers. Major tributaries include the South Fork Malheur River, which enters from the west at river kilometer 191; the North Fork Malheur River, which enters at river kilometer 154; Bully Creek, which enters at river kilometer 34; and Willow Creek, which enters at river kilometer 32. The latter three tributaries all enter the mainstem Malheur River from the north. Elevations in the basin range from the highest point on Graham Mountain at 2,613 meters to 610 meters at the mouth of the Malheur River (Hanson *et al.* 1990).

Public ownership accounts for approximately 66 percent of the land in the basin, most of it managed by the U.S. Bureau of Land Management, while 13 percent is managed by the Malheur National Forest and 6 percent is State-owned land. The remainder of the basin is in private or tribal ownership.

The climate in the Malheur River Basin is continental, characterized by hot summers and cold winters. Summer high temperatures average 30^{o} Celsius and winter temperatures average $<0^{o}$ C. Annual precipitation averages from 25 to 30 cm with most occurring during winter as snow. Brief, intense rain events occasionally occur during summer.

Flows in the Malheur River Basin are dominated by meltwater from the mountain snow pack. Peak discharge occurs in the spring (May through June) with low flows in the summer and fall maintained by groundwater inflows. Springs originating in the Strawberry Range maintain year-round flows for streams they feed, while streams originating elsewhere have flows that tend to be ephemeral in nature. Summer storms can influence streamflows with short duration, intense increases in runoff and streamflow. The highly variable annual flows of the Malheur River and its tributaries have been harnessed through construction of storage and flood control facilities and major diversion structures dating from 1881 with construction of the Nevada Diversion Dam at about river kilometer 31 on the lower Malheur River.

Native fish species in the Malheur River include redband/rainbow trout (*Onchorynchus mykiss*), bridgelip sucker (*Catostomus columbianus*), coarse scale sucker (*C. macrocheilus*), redside shiner (*Richardsonius balteatus*), speckled dace (*Rhinichthys osculus*), longnose dace (*R. cataractae*), sculpin (*Cottus spp),* mountain whitefish (*Prosopium williamsoni*), and northern pike minnow (*Ptychocheilus oregonensis*) (Hanson et al. 1990). Anadromous fish including Chinook salmon and steelhead were extirpated from the Malheur River Basin as early as 1919 when Warm Springs Dam was completed. Brownlee Dam, which was constructed on the Snake River in 1958, ended access of the entire Upper Snake Basin to anadromous fish.

METHODS

The sample frame was developed from a 1:24,000 digital stream coverage of the Malheur River watershed. Distribution of redband trout within this coverage was determined from consultation with regional state and tribal biologists who had knowledge of Malheur River redband trout. The resulting sampling frame totaled 1,304 kilometers and consisted of all wadeable streams judged to potentially provide rearing habitat for redband trout during summer base flow (Figure 1).

The sample frame was divided into two similar sized but geographically distinct strata. Stratum 1 comprised 636 km of the sample frame and included portions of the South Fork Malheur River, as well as Cottonwood, Willow and Bully Creeks. Stratum 2 totaled 668 km and contained headwater portions of the Malheur and North Fork Malheur Rivers, the Little Malheur River and tributaries to the portion of mainstem Malheur River between the mouths of Cottonwood Creek and the North Fork Malheur River.

Based on anticipated sampling logistics and sample sizes needed to provide reasonably precise estimates, 60 primary sites were chosen for each sampling stratum. To provide flexibility in our ability to complete sampling, an additional 40 oversample sites were chosen per stratum. Oversample sites provided opportunities to replace primary sites that could not be sampled. We employed the Environmental Protection Agency’s Environmental Monitoring and Assessment Program (EMAP) to draw sample sites. EMAP employs a probabilistic sampling design that allows resource assessment over large areas, based on data from representative sample locations. EMAP uses a sample design called a Generalized Random Tessellation Stratified design (GRTS) (Stevens and Olsen 2004) to achieve a spatially-balanced point distribution that is nonetheless random. The EMAP design takes into account spatial patterns of resource distribution when calculating estimates of variance to provide higher precision for a given level of sampling effort (Stevens and Olsen 2002).

Sampling for redband trout occurred from 25 June to 20 September, 2007. A Native Fish Investigations Project crew from the Oregon Department of Fish and Wildlife sampled Stratum 1. Stratum 2 was sampled by crews from the Burns Paiute Tribe.

Each sample site was approximately 30 wetted channel widths long (or a minimum of 30 m for small streams and a maximum of 100 m for large streams) and included a mix of habitat types. Block nets were set at the upstream and downstream bounds of the site. Two-pass depletion–removal estimates were conducted using backpack electro-shockers. A protocol of a minimum of a 50% reduction in captures between passes for trout >60 mm in fork length was used. A pass consisted of a slow, deliberate progression from the downstream to the upstream net, and a quick return sweep back to the downstream net. If 50% depletion was not achieved between pass 1 and pass 2, two additional passes were completed (passes 3 and 4). The sum of the number of fish caught in the first two passes was used for pass 1, and pass 2 was equal to the sum of the fish caught in the second two passes. In the event that a 50% depletion was not completed after 4 passes, the site was failed. Additionally, in Stratum 1, if no trout were captured after the first pass a second pass was not conducted and an abundance of zero was assumed.

Two passes were always completed for sites in Stratum 2. Captured fish were measured for fork length and released. Most sites were sampled at water temperatures below 21°C, however there were a few sites that were sampled at water temperatures as high as 28°C.

To evaluate the accuracy of removal estimates we calibrated a portion of the sample sites using mark-recapture methods to estimate abundance. To obtain these estimates we set the upstream and downstream block nets and marked all fish >60mm captured during a single upstream electrofishing pass with a partial caudal clip and redistributed them throughout the sample reach. The following day, the site was electrofished according to the protocol for obtaining removal estimates and all fish captured were inspected for caudal fin-clips. The block nets remained in place until the removal estimates were completed.

Removal estimates of population abundance at individual sampling sites were calculated using the methods described by White et al. (1982). Mark-recapture estimates of population abundance at individual sampling sites were calculated using the Petersen formula (Ricker 1975). Estimates of population abundance within strata and associated precision were calculated using local neighborhood estimator methods described by Stevens and Olsen (2002).

Basic habitat data was also collected at each sample site. Habitat data were used to determine effects of habitat complexity on the accuracy of electrofishing removal estimates. These data included classification of riparian vegetation, occurrence of obstructions to electrofishing, and presence of large wood and wood aggregates. In addition, detailed habitat measurements were collected at transects spaced every 10 m throughout the sampled portion of the stream channel. Measurements included water depth, substrate composition, occurrence of undercut banks, presence of aquatic vegetation and occurrence of side channels and backwaters.

RESULTS

Site Outcome

From the original sample size of 200 sites between Stratum 1 and Stratum 2, 80 sites were completed. Of the remaining 120 sites, 63 were denied access by the landowner, 55 were dry, and 2 were unsurveyable (Table 1, Figure 1).

Table 1. Site outcomes for selected redband trout EMAP sampling sites in the Malheur River Basin, 2007.

Stratum	Number of Sample Sites			
	Completed	Unsurveyable	Access Denied	Dry Channel
1	27	1	44	28
2	53	1	19	27

Site access denied by landowners limited our ability to obtain a representative sample, determine distribution in portions of stratum 1, and achieve our desired level of precision in Stratum 1. We were denied access to most of the sites on lower Crane Creek, Alder Creek, Coyote Creek, Granite Creek and Swamp Creek on the South Fork Malheur River. We also failed to gain access to the upper South Fork Malheur River between the Crane Creek confluence and South Fork Reservoir. Access was denied on 16 sites in the Bully Creek drainage, leaving only 5 sample points. Access was also denied on some Willow Creek sites, but crews were still able to survey a large portion of the sample frame. Because a majority of stratum 2 was located on public land we were able to evaluate a larger portion of the sample frame that in stratum 1.

Stratum 1 and 2 had similar proportions of dry sites. In stratum 1 most of the sites visited upstream of South Fork Reservoir on the South Fork Malheur River were dry. The sites on mainstem tributaries between Cottonwood Creek and the North Fork Malheur River in Stratum 2 were mostly dry. While dry channels were found throughout the Malheur River system, encountering a dry channel in a downstream reach of a stream didn't rule out the possibility of viable trout habitat in upstream reaches. Springs and areas with subsurface flow were encountered in a number of streams. In some instances changes in valley form altered potential redband trout habitat. Streams in wide open valleys with broad valley floors are often dry or flow subsurface, but when the channel is constrained by hillslopes or bedrock, flowing water and redband trout were encountered. This was common on Cottonwood Creek and other lower Malheur River tributaries, as well as on Crane Creek on the South Fork Malheur River. The summer of 2007 was an extremely low water year in the Malheur River Basin (Malheur County was classified as experiencing severe drought throughout the summer of 2007 by the National Drought Mitigation Center, (http://www.drought.unl.edu/dm/index.html), which likely limited the available redband trout habitat relative to years with higher stream flow.

Density and Population Estimates

Redband trout were observed at 45 of the 80 sites completed. Density estimates were calculated for each site that contained redband trout with lengths greater than 60 mm. Of the 45 sites containing redband trout in the Malheur River basin, 42 yielded trout >60 mm. Densities ranged from 0.002 fish/m² to 1.289 fish/m² (Figure 2). Of the 42 sites where density estimates were obtained, 22 had densities < 0.1 fish/m². There were 16 sites that had densities between 0.1 and 0.4 fish/m², and 4 sites with densities over 0.4 fish/m². The sites with the highest densities were West Fork Wolf Creek, Pine Creek, Squaw Creek, and Canyon Creek. With the exception of Canyon Creek, all of these sites were located in Stratum 2.

We completed depletion estimate calibrations at eight sites (Table 2, Figure 2); however one site was dropped because of mortality associated with high water temperatures. Depletion estimates were negatively biased relative to density estimates derived from mark-recapture. Ratios of depletion estimates to mark-recapture estimates ranged from 0.27 to 0.84 and averaged 0.52.

Table 2. Results of sites where both depletion and mark-recapture methods were used to estimate the abundance of redband trout >60mm in the Malheur River Basin, 2007.

Site No.	Mark-Recapture Estimate	Depletion Estimate	Ratio
36[a]	15	4	27%
117	83	31	37%
168	24	20	83%
6	78	34	44%
10	132	61	46%
14	43	12	28%
46	231	102	44%
158	69	58	84%

a. *Not included because of high mortality of fin-marked fish.*

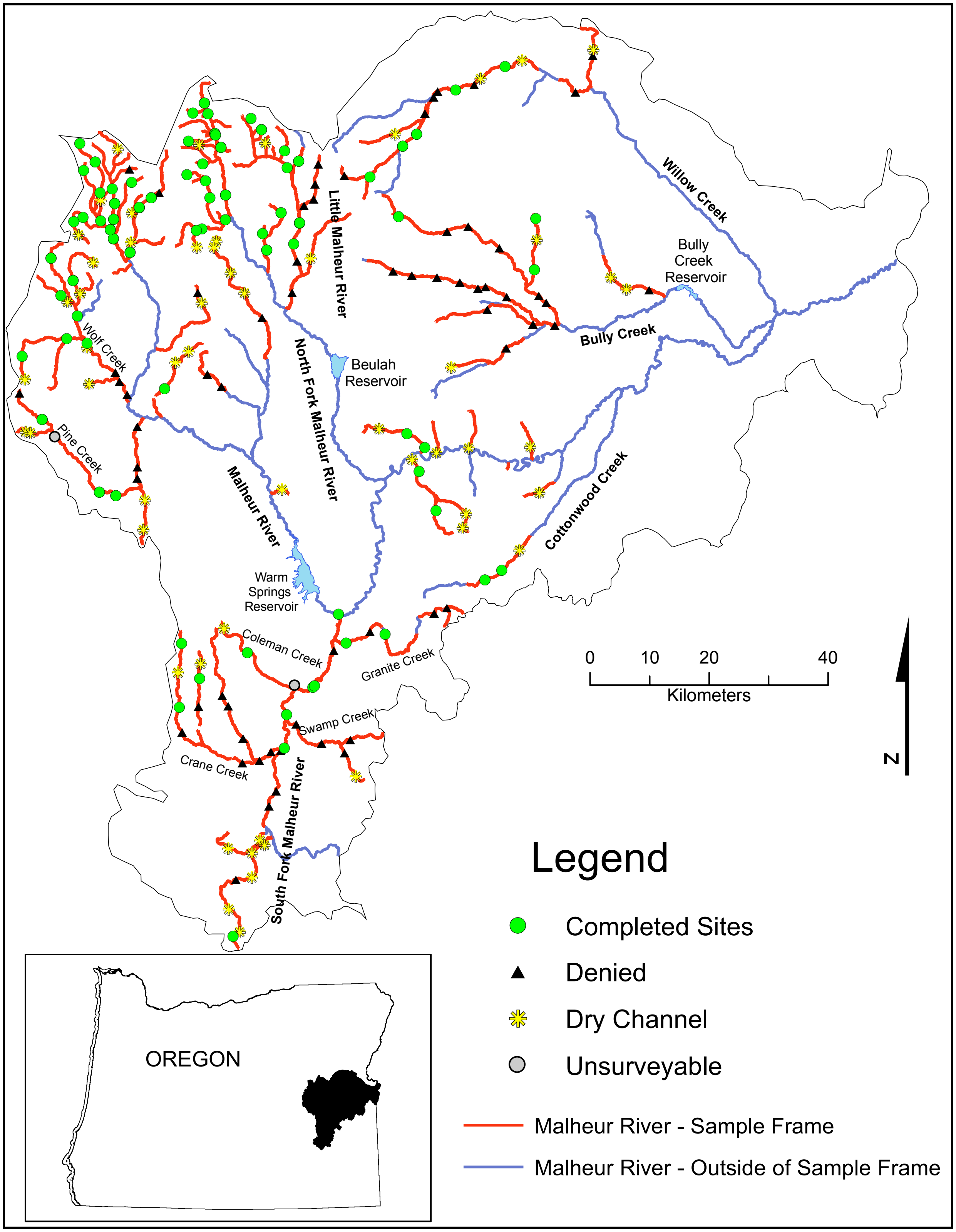

Figure 1. Location and status of sample sites for redband trout in the Malheur River Basin, 2007.

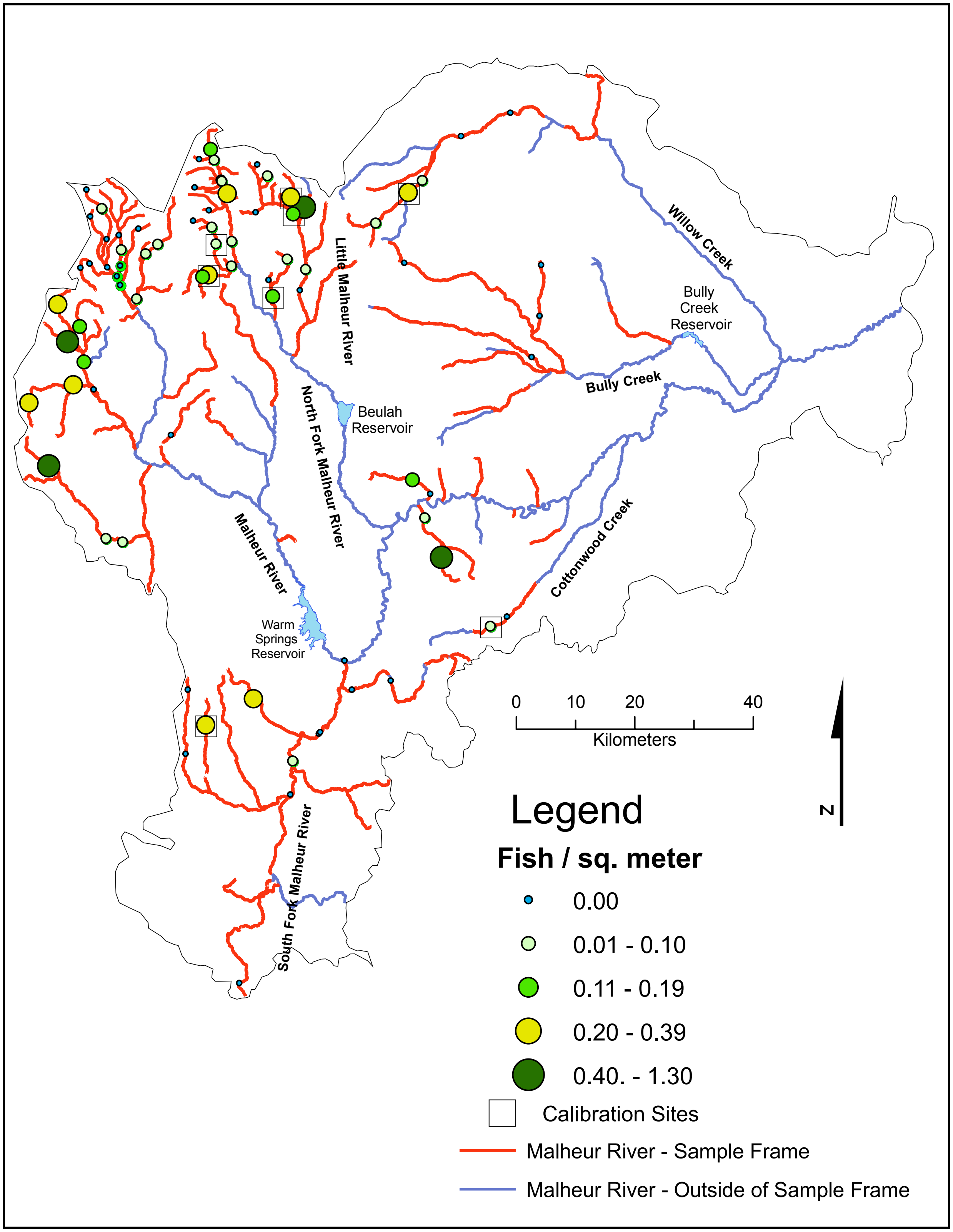

Figure 2. Density (fish/m^2) of redband trout at sample sites in the Malheur River Basin, 2007. Also shown are sites where removal estimates were calibrated using mark-recapture.

Population estimates were generated by the methods developed by Stevens and Olsen (2004) using scripts written for R Statistical Software (http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm#methods). This procedure extrapolates densities estimated at sample sites to the extent of the sample frame that is judged to comprise target rearing habitat for redband trout. Therefore the length of sample frame was adjusted to account for dry segments in the sample. Frame adjustments were made by applying results of sample outcomes as follows:

$$F_a = \frac{F_i(S_c + S_u + S_d)}{S_c}$$

where:

F_a = Adjusted frame extent in kilometers
F_i = Initial frame extent in kilometers
S_c = Number of sites completed
S_u = Number of sites that were unsureyable
S_d = Number of sites where access was denied

This adjustment assumed that none of the sites where access was denied had dry channels.

Based on the methodology described above and densities derived by electrofishing-removal we estimated the overall abundance of age 1+ redband trout in the Malheur River basin in the summer of 2007 to be 156,200 ± 29% (relative 95% C.I.). Approximately 60% of the population occurred in Stratum 2 (Table 3). Further, the precision of the abundance estimate for Stratum 2 was twice as high as it was for Stratum 1, likely because of a higher number of completed samples and lower between-site variability in fish densities.

Table 3. Estimated abundance of redband trout >60mm in the Malheur River Basin derived from electrofishing, 2007.

Stratum	Estimate	Standard Error	Lower 95% CI	Upper 95% CI	Relative CI
Stratum 1	58,003	17,646	23,418	92,589	60%
Stratum 2	98,196	15,175	68,455	127,938	30%
Total Estimate	156,200	23,273	110,584	201,815	29%

To adjust for biases associated with removal electrofishing we divided parameter estimates in Table 1 by calibration ratios. The adjusted population estimates for Stratum 1 was 96,125, for Stratum 2, 199,648 and for the entire basin, 298,250 (Table 4).

Table 4. Estimated abundance of redband trout >60mm in the Malheur River Basin derived from electrofishing and adjusted for biases in depletion methods, 2007.

Stratum	Calibration	Estimate	Standard Error	Lower 95% CI	Upper 95% CI
Stratum 1	60.3%	96,125	29,244	38,807	153,442
Stratum 2	49.2%	199,648	30,853	139,176	260,120
Total Estimate	52.4%	298,250	44,438	211,152	385,348

Length Frequency Analysis

Fork lengths were measured on all redband trout captured. Redband trout ranged in length from 26 to 295 mm. However, the majority of the encountered fish measured between 45 and 195 mm.

While a thorough analysis of the age structure was not a component of this project, there is an indication of separate year classes based on the length frequency histogram (Figure 4). The peak at 45–55 mm most likely represents age-0 fish, while the peak at 80–120 mm most likely represents a mixture of age-1 and age-2 fish. Fish with lengths greater than 120 mm most likely represent fish age-2 and older. Only 3% of the sample consisted of fish large enough for legal harvest (200 mm). Fish lengths from both strata were compared to elevation and temperature. Neither temperature nor elevation showed any relationship to fish length.

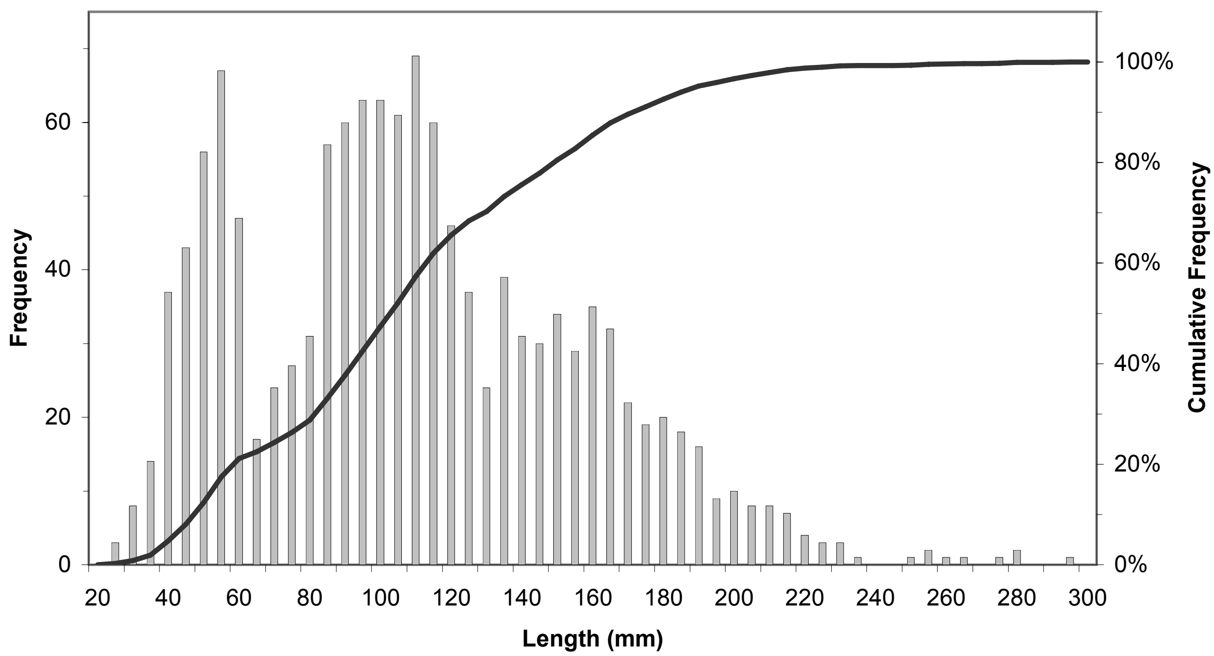

Figure 4. Length frequency histogram (5 mm intervals) of redband trout captured by electrofishing in the Malheur River Basin, 2007. N = 1,301.

Physical Habitat

The physical habitat data collected has yet to be analyzed for any relationship between habitat characteristics and redband density or capture efficiency. With only seven valid calibration samples it will be difficult to develop definitive relationships between capture efficiency and habitat complexity for the Malheur River Basin. Additional data collected at sample sites for redband trout in Great Basin streams can be used to help develop these relationships at a region-wide scale once these data are available.

Despite the small sample size, there were some patterns that emerged between channel complexity and redband trout capture efficiency. Among the seven calibration sites there was a marked difference in capture efficiency of two of the sites compared to the remainder of the sites. Sites 158 and 168 had capture efficiencies exceeding 80%, whereas the other five other sites had capture efficiencies ranging between 28% and 46%. Some features of stream complexity varied between these two groups of sites (Table 5). Sites 158 and 168 had low concentrations of instream wood and wood aggregates. In contrast, four of the other five sites contained wood aggregates and had relatively high concentrations of instream wood. The one exception, site 117, did not contain any wood but was markedly deeper than any of the other calibration sites. Although cursory, this analysis suggests that our capture efficiency was influenced by the volume of instream wood and the depth of the channel at sample sites. With only seven calibration sites, we are limited to applying a mean capture efficiency to adjust abundance estimates, however the accuracy of these estimates would be improved by applying site-specific adjustments based on channel features.

Table 5. Physical habitat features occurring at sites in 2007 in the Malheur River Basin where electrofishing depletion estimates of redband trout were calibrated with mark-recapture.

Site Number	Ratio of abundance estimates	Site Length (m)	Mean Wetted Channel Width (m)	Mean Thalweg Depth (m)	Number of Obstructions	Number of Wood Pieces in Channel	Number of Wood Aggregates	Percent of Substrate With Cobble or Boulder	Volume of Undercut Channel (m^3)
6	44%	91.0	2.4	0.33	2	29	2	58%	0.02
10	46%	76.0	2.5	0.25	6	45	3	46%	0.01
14	28%	100.0	4.2	0.35	3	37	3	46%	0.32
46	44%	103.0	2.5	0.30	9	49	3	53%	0.00
117	37%	62.5	1.8	0.65	0	0	0	0%	0.00
158	84%	100.0	4.8	0.28	0	0	0	59%	0.47
168	83%	45.0	1.6	0.27	3	3	0	0%	0.00

Water temperatures were warmer in Stratum 1 than in Stratum 2 (Figure 5). Cooler water temperatures could have been a contributing factor to the higher densities of redband trout observed in Stratum 1 compared to those observed in Stratum 2.

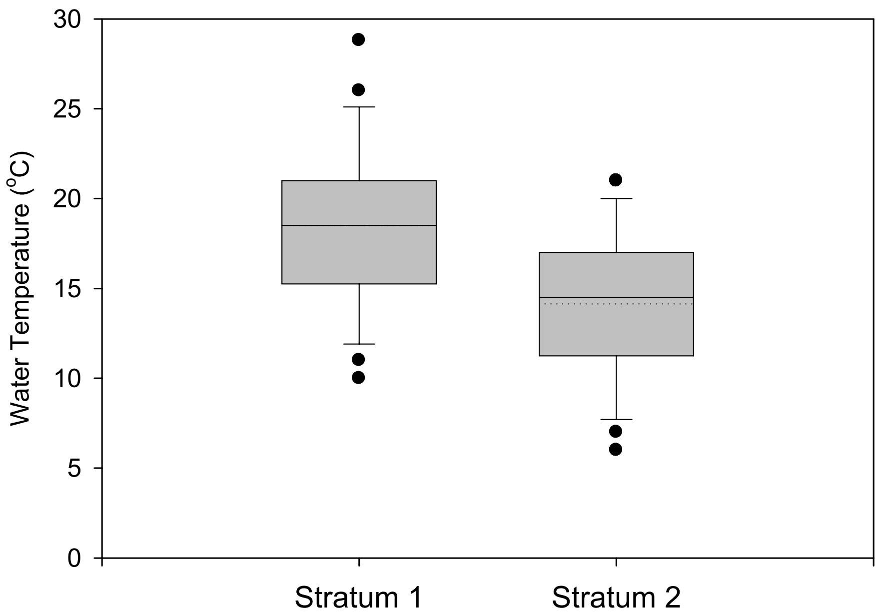

Figure 5. Box plots of water temperatures measured at the onset of sampling for redband trout in sites located in Stratum 1 and 2, Malheur River 2007.

Occurrence of Other Fish Species

Bull trout, brook trout and smallmouth bass were encountered during redband surveys (Figure 6). Bull trout and brook trout were encountered on the upper Malheur River, from the headwaters downstream to Summit Creek. Bull trout were also encountered on the upper North Fork Malheur River from the headwaters downstream to Little Crane Creek. In stratum 2 all sites containing bull trout also contained redband trout. However, there were four sites sampled in Stratum 2 where brook trout were present but no redband trout were captured. Smallmouth bass were encountered in three locations on the South Fork Malheur River. The range of smallmouth bass is likely extensive in the low elevation reaches of the Malheur River.

Other species encountered during surveying included bluegill, bridgelip sucker, chiselmouth, large scale sucker, longnose dace, mountain whitefish, northern pikeminnow, redside shiner, sculpin and speckled dace. Lists of fish species captured in major subbasins within each stratum are shown in Table 6.

Table 6. Occurrence of fish species other than redband trout in sample sites within major subasins for each sample strata. Values shown in table are number of sample sites where a given fish species was captured.

	Number of Sample Sites					
	Stratum 1				Stratum 2	
Fish Species	Bully Creek	Lower Malheur R. Tributaries	S. Fk. Malheur River	Willow Creek	N. Fk. Malheur River	Upper Malheur River
			Native			
bull trout	0	0	0	0	7	2
mountain whitefish	0	0	0	0	1	0
chiselmouth	0	0	0	0	0	1
longnose dace	0	0	0	0	3	5
speckled dace	0	0	0	0	6	15
unidentified dace	1	6	5	5	0	0
northern pikeminnow	0	1	1	0	1	1
redside shiner	1	4	4	3	3	11
largscale sucker	0	0	0	0	1	1
bridgelip sucker	0	0	0	0	2	9
unidentified sucker	1	5	5	3	0	0
unidentified sculpin	0	0	0	0	12	11
			Exotic			
brook trout	0	0	0	0	0	10
smallmouth bass	0	0	3	0	0	0
bluegill	0	0	1	0	0	0

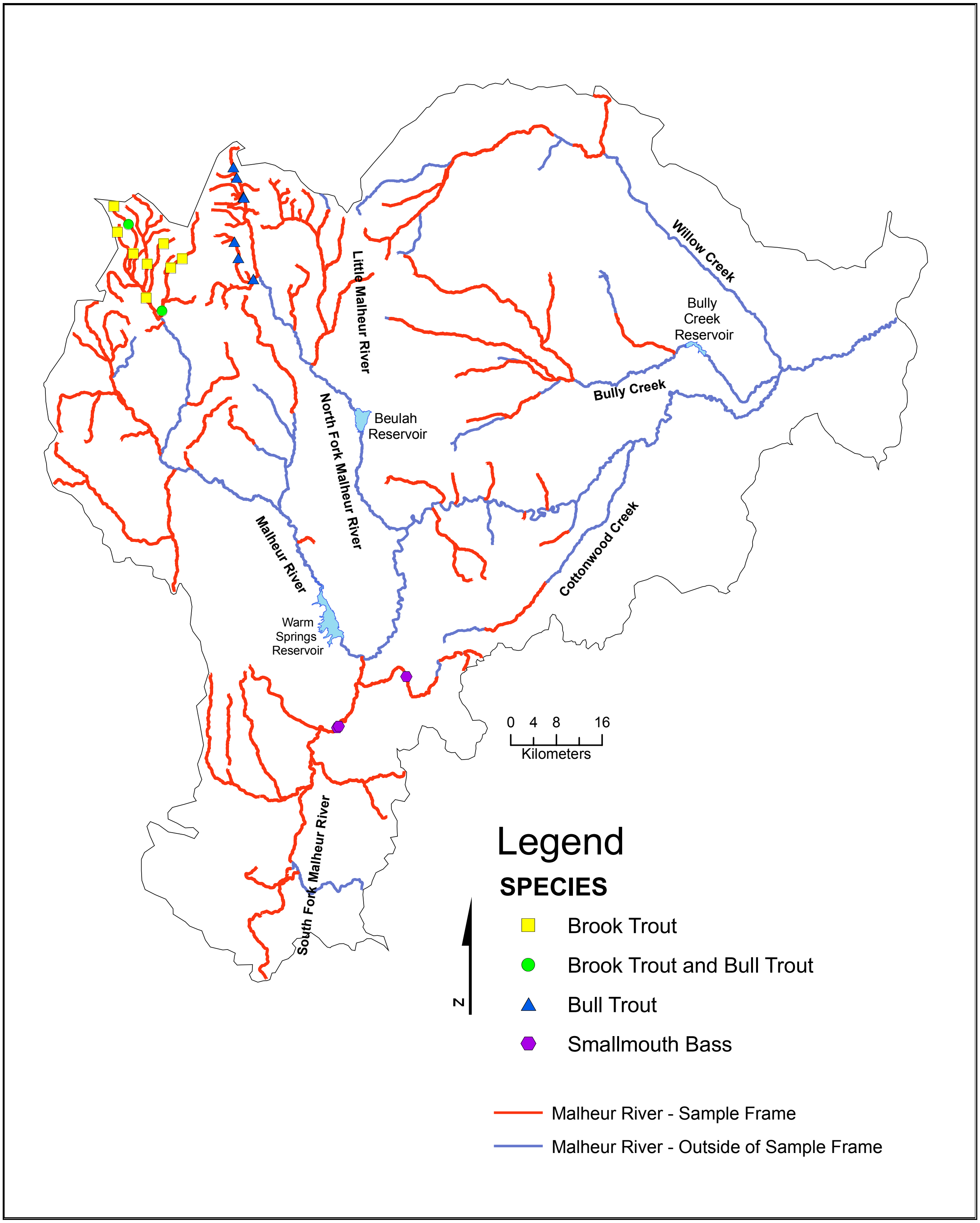

Figure 6. Occurrence of selected other fish species captured at redband trout sites in the Malheur River, 2007.

DISCUSSION

Redband trout were abundant in the Malheur River sample frame; however, their distribution was patchy, particularly in portions of the drainage located in Stratum 1. While redband trout were distributed throughout Stratum 1, there were few streams where they were found at more than a single sample site. However, redband trout were found in relatively high densities at some sites in Stratum 1. Redband trout were well distributed throughout Stratum 2 and were found at a number of adjacent sites on the same streams. It is likely that higher stream flow and cooler water temperatures provided more widespread habitat in Stratum 2 than was available in Stratum 1. Distribution patterns could be different in years having greater base summer flow.

Stratum 1 contained a high number of sites that were dry and sites where access was denied by private landowners. This was especially true in the Bully Creek and South Fork Malheur River drainages. Our inability to access all selected sites because of a lack of landowner permission may have biased our estimate of redband trout abundance in Stratum 1. For example, if densities in denied sites were higher than densities in sites where samples were obtained our estimates may be negatively biased. Further, our inability to meet our target of sampling 60 sites in Stratum 1 because of landowner denials reduced the precision of the population estimate. Nevertheless, the overall estimate of redband trout density in the Malheur River Basin had relatively high precision. Relative precision within ±30% is sufficient to detect changes in population abundance of within 50%. Future sampling should consider further partitioning Stratum 1 into multiple sample strata and selecting additional sites for each of these strata. This approach would allow greater flexibility to adjust sampling effort in the face of landowner denials and increase the success of obtaining density estimates.

Although not yet fully analyzed, the results from calibration sites indicate that depletion-electrofishing underestimates redband trout abundance by about 48%. This estimate of bias should be included in future estimates of population abundance. Preliminary analysis suggests that wood volume and channel depth may predict electrofishing capture efficiency. We plan to look further at this source of bias by analyzing the influence of stream channel complexity and also increasing the sample of calibration sites by including sites sampled outside the Malheur River basin.

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