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East Fork Owyhee River Salmon and Steelhead Recovery Project

2013 Annual Report

Prepared for:

The Shoshone-Paiute Tribes of the Duck Valley Indian Reservation

Owyhee, NV

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7 March 2014

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EXECUTIVE SUMMARY

The East Fork Owyhee River, located in northeastern Nevada approximately 50 miles north of Elko, was once home to native populations of anadromous fish, including Chinook salmon and steelhead, but fish access to historical spawning and rearing areas are now blocked by dams and diversion structures along the Columbia, Snake, and Owyhee Rivers. In an effort to restore salmon and steelhead populations in the East Fork Owyhee River for the benefit of the Shoshone-Paiute Tribes' fishery resources, the Tribe intends to develop a trap-and-haul program to transport adult fish from dams on the Lower Snake River (either Lower Granite Dam or Hells Canyon Dam) and release these fish into the East Fork Owyhee River above China Diversion Dam to spawn. Emigrating juvenile fish would later be captured and released downstream of passage barriers on the Snake River to complete their migration to the ocean. Upon return, adult fish that originated from the East Fork Owyhee River would be captured in the lower Snake River and transported upstream. Prior to implementation of this program, a complete habitat assessment in the East Fork Owyhee River and its tributaries was deemed necessary to confirm that the watershed still retains the capacity to support natural production of anadromous salmonids.

The assessment described in this report was multi-faceted with three components. The first component was a literature review of water quality conditions and native trout populations in the Basin. The second component involved extensive juvenile rearing and spawning habitat surveys designed to document physical habitat conditions in mainstem and tributary stream segments during the summer of 2013 from Wildhorse Dam downstream to China Dam. Lastly, salmon and steelhead rearing capacity was quantified throughout the Basin using a habitat-based carrying capacity model known as the Unit Characteristic Method (UCM). Hydraulic modeling was also used to extrapolate baseline capacity estimates across a range of stream flow conditions. Ancillary study objectives also included identifying natural and man-made barriers that may impede salmonid migration, evaluating health and genetic structure of resident salmonid populations, and documenting potential locations for a put-and-take salmon and steelhead fishery.

Prior to field surveys, the basin was stratified between mainstem stream segments (reaches) and major tributaries as defined by differences in stream morphology, riparian make up, surrounding anthropogenic practices, and other geomorphological features. Mesohabitat units were classified as a pool, glide, riffle, rapid, or cascade within mainstem and tributary spatial segments. Measurements of length, wetted width, depth, active channel width, and an estimate of stream bed substrate composition were taken within each mesohabitat unit. Upon completion of habitat surveys, the UCM was used to predict carrying capacity for Chinook salmon and steelhead trout spawning and rearing life-stages.

Summer habitat conditions in the East Fork Owyhee River were found to be a mix of large pools with an average depth of 0.8 meters and shallow riffles, typically not deeper than 0.3 meters. Substrates were comprised predominantly of cobbles and boulders at higher elevations in the

watershed, with progressively larger quantities of gravel and fines as distance increased downstream of Wildhorse Dam. Habitat conditions in Skull, Slaughterhouse, and Van Duzer Creeks (the three tributaries surveyed which had flowing water in 2013) had similar mesohabitat composition. Tributaries were dominated by beaver ponds and shallow riffles, with abundant quantities of fine sediments and moderate quantities of gravel.

Carrying capacity estimates calculated using habitat data collected in 2013, were 17,590 juvenile steelhead and 11,442 juvenile Chinook in mainstem reach 1 directly downstream of Wildhorse Dam. Comparatively, juvenile capacity estimates for mainstem reaches 2 and 3 were roughly 65% less for steelhead and 50% less for Chinook. Mainstem spawning capacity estimates indicate more potential for redd deposition at lower elevations, where the stream gradient is reduced and the channel broadens. Mainstem reaches 2 and 3 were estimated to possess steelhead redd capacities greater than 4,000 and Chinook redd capacities greater than 600, while mainstem reach 1 redd capacities were approximately 50% less for both species.

Carrying capacity estimates derived from habitat data collected in 2013 were heavily influenced by drought-like stream flow conditions. In an average water year, summer base flows in the mainstem would be approximately 50 cfs, which would equate to a juvenile rearing capacity estimate roughly twice the baseline values calculated from 2013 survey data. When accounting for the full range of summer flow and temperature conditions (90%-10% exceedance flow, 18-22^{o}C), it is estimated that the annual summer rearing capacity for the entire study area could range between 3,300 and 43,000 juvenile steelhead trout and from 3,600 to 41,000 Chinook salmon.

Our analysis suggested there are three primary factors that limit Chinook salmon and steelhead trout production in the East Fork Owyhee River; these are high summer water temperature, low stream flow, and high volume of fine sediments. Other noteworthy limiting factors include impaired water quality and migration passage conditions at irrigation diversion structures. Restoration activities that address these issues are likely to produce the greatest benefit for anadromous salmonids. Data collection in 2014 will be focused on validating the predicted relationship between stream flow and carrying capacity, assessing unsurveyed tributary streams, monitoring tributary stream flows, estimating redband trout abundance throughout the Basin, developing a genetic baseline for resident salmonids, and documenting migrating or smolting fish derived from resident redband trout populations.

INTRODUCTION

Background

The East Fork Owyhee River was once home to native populations of anadromous fish, including Chinook salmon and steelhead, but fish access to historical spawning and rearing areas are now blocked by dams and diversion structures along the Columbia, Snake, and Owyhee Rivers. To mitigate for the loss of anadromous fish populations, non-native rainbow trout and brown trout were stocked in the East Fork Owyhee River from 1937 to 1972 (Johnson 2000). Surveys conducted in 2000 by the Nevada Department of Wildlife found that both species of trout are still present in the river; with the highest densities of trout found just downstream of Wildhorse Dam (Johnson 2000). The presence of native, non-anadromous redband trout is also expected, though a formal genetic analysis of fish populations in the area has not been conducted and the persistence of native salmonid populations remains uncertain.

In addition to altered fish species assemblages, the East Fork has also sustained changes in water quality and stream flow. Operation of Rio Tinto Mine from 1932 to 1947 introduced toxic levels of heavy metals to Mill Creek (an East Fork Owyhee River tributary), which significantly impacted fish and other aquatic organisms (NDEP 2005). The effects of mining, combined with the naturally iron and phosphorus-rich soils of Nevada, have impaired water quality throughout the stream between Wildhorse Dam and the Duck Valley Indian Reservation (DVIR) (NDEP 2005). Additionally, agricultural activities requiring significant water withdrawals, particularly ranching, reduce stream flows throughout the basin. Ranching has also led to stream bank erosion caused by riparian deforestation, shoreline grazing, and in-stream wading by livestock.

In an effort to restore salmon and steelhead populations in the East Fork Owyhee River for the benefit of the Shoshone-Paiute Tribe's fishery resources, the Tribe intends to develop a trap-and-haul program to transport adult fish from dams on the Lower Snake River (either Lower Granite Dam or Hells Canyon Dam) and release these fish into the East Fork Owyhee River above China Diversion Dam to spawn. Emigrating juvenile fish would later be captured and released downstream of passage barriers on the Snake River to complete their migration to the ocean. Upon return, adult fish that originated from the East Fork Owyhee River would be captured, identified, and transported upstream. Prior to implementation of this program, a complete habitat assessment on the East Fork Owyhee River and its tributaries was deemed necessary to confirm that the watershed still retains the capacity to support natural production of anadromous salmonids, and to determine types of habitat changes needed to increase fish production potential.

Study Area

The Owyhee River is a tributary to the Snake River and drains one of the largest subbasins of the Columbia Basin, with an average discharge of 995 cfs. The headwaters are located in northeastern Nevada, and the river enters the Snake River just outside of Nyssa, Oregon. The largest tributary to the Owyhee River, the East Fork, travels southwest through Wildhorse Reservoir and turns north into the DVIR before reaching Idaho where it joins the mainstem Owyhee River. This study was conducted in the East Fork Owyhee River, from China Diversion Dam, within DVIR boundaries, upstream to Wildhorse Reservoir (Figure 1). China Dam is a few miles south of Owyhee, Nevada and directs water north and west to three DVIR Reservoirs. The East Fork is the main resource for irrigation in the area and is heavily relied upon by a mix of tribal, private, and public landowners for cattle ranching and other agricultural activities. The river is home to a number of fish species including redband trout, redside shiners, speckled dace, sculpin, sucker fish, and historically Mountain Whitefish (Johnson 2000).

Wildhorse Dam was initially constructed in 1937 and then altered in 1969 with a much larger structure that doubled the size of reservoir storage. Wildhorse Dam and is owned by the Bureau of Indian Affairs and leased to the Shoshone-Paiute tribes of Duck Valley Indian Reservation. Before the creation of Wildhorse Dam, the East Fork Owyhee River was a spring snow melt dominated system, but with the creation of the dam came a shift in the flow regime to a system dominated by irrigation, which requires steady water releases for most of the spring and summer months (Figure 2).

The Owyhee Basin maintains many of the same regional climatic and ecological characteristics as neighboring Great Basin watersheds to the south (OSP 2004). The climate is semiarid, with mean annual temperatures of 9^{o}C and average annual precipitation between 10 and 20 cm. The wettest months are November through January, and the driest months are July and August (MSRWMP 1998). January is typically the coldest month of the year, with average daily minimum temperatures near -8^{o}C. As a result, it is not uncommon for the East Fork Owyhee River to experience freezing in the winter months. Maximum temperatures near 33^{o}C typically occur in July, the hottest month. Elevations in the region range from approximately 760 meters to more than 3,260 meters, with the mean elevation near 1,630 meters (BSP 2008). Vegetation in the Subbasins consists mainly of shrub-steppe with intermittent wetland vegetation.

The mouth of the Owyhee River is approximately 1150 kilometers from the ocean, a formidable migration distance. As with most interior Columbia and Snake River tributaries, native anadromous salmonid species and life-histories in this area consist predominantly of spring run Chinook and summer run steelhead. Spring Chinook enter the Columbia Basin between February and May, traveling upstream through the summer and arriving at their natal spawning areas by August-September, with spawning typically occurring October-November. River entry six or more months in advance of spawning affords the fish the time needed to complete their lengthy migration. Similarly, summer steelhead enter the Columbia River well in advance of spawning. River entry typically occurs June-August with spawning occurring February-April.

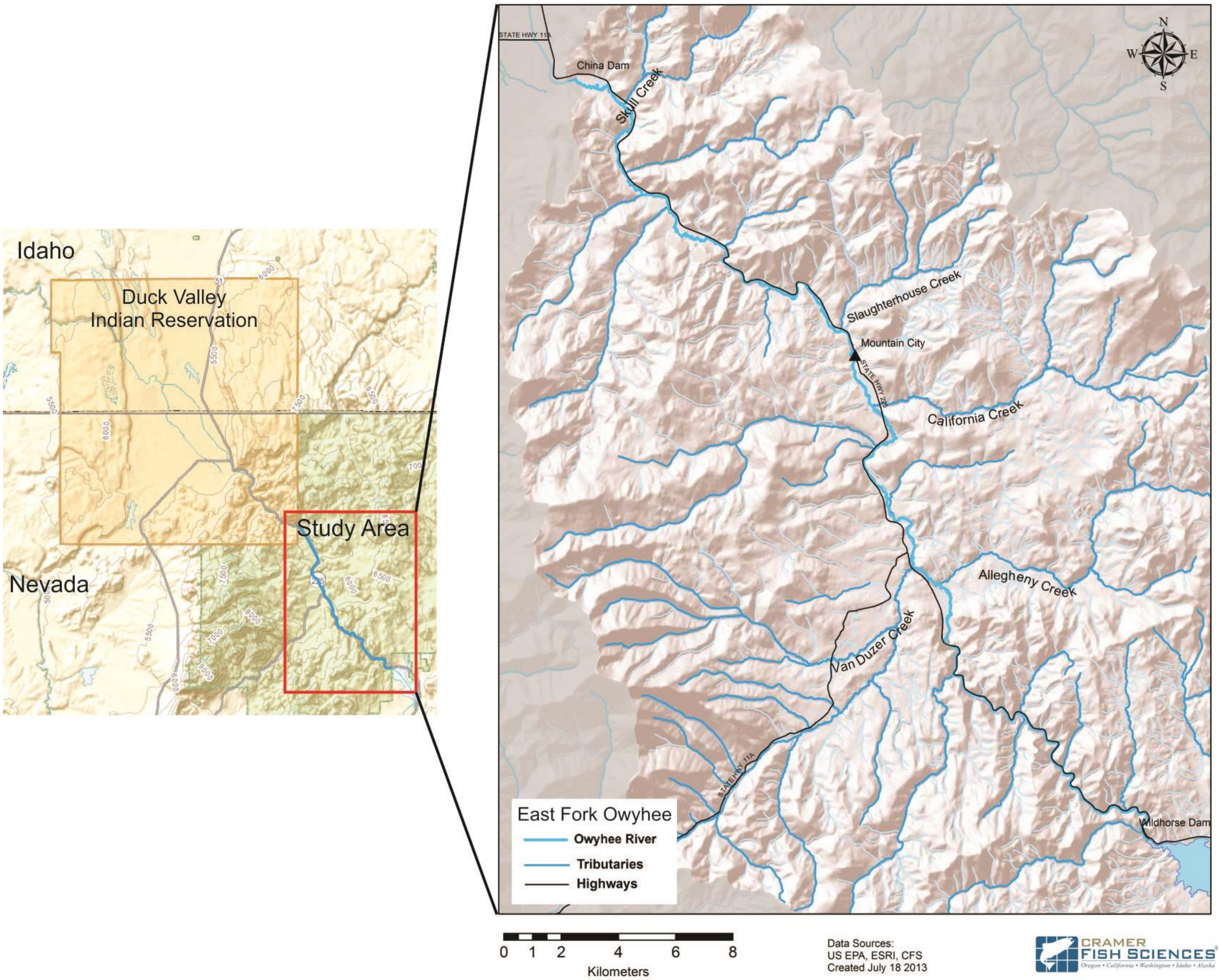

Figure 1. Map of the study area with the East Fork Owyhee River highlighted in blue (both maps) and studied tributaries labeled (main map).

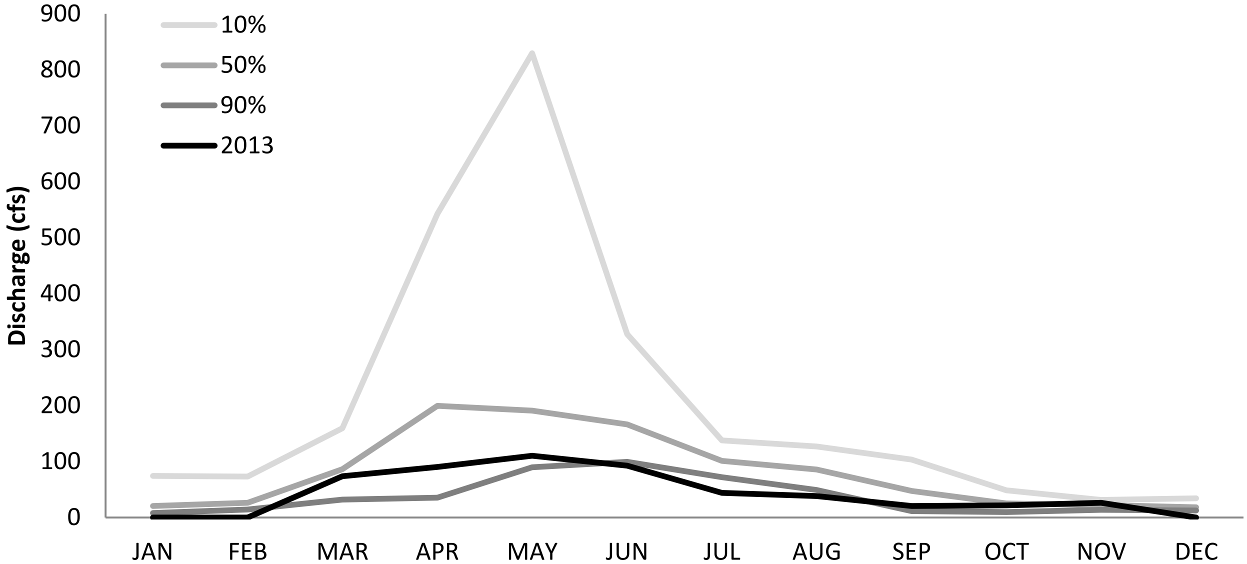

Figure 2. Average flow for 2013 up to the current date at Gold Creek USGS monitoring station, on the East Fork Owyhee River shown with 10%, 50%, and 90% exceedance rates for reference.

Study Purpose and Objectives

The objective of the first phase of the East Fork Owyhee River Salmon and Steelhead Recovery Project is to evaluate the ability of the watershed to support self-sustaining salmon and steelhead populations. To achieve this objective, a number of tasks needed to be completed. These included identifying manmade and natural barriers, establishing overall water quality of the basin, thoroughly categorizing available habitat, and gathering tissue samples to evaluate genetic structure of resident salmonids. Secondarily, the Tribes are also working to determine the most appropriate location for a put-and-take fishery, whereby adult salmon and steelhead would be stocked in a confined area for fishing purposes. These tasks, listed in more detail below, directed study design and field data gathering during the 2013 field season.

1. Identify natural and man-made barriers that may impede salmonid migration.
    a. Determine location and cause of dewatered areas
    b. Identify how current flow regime may be impeding natural migration
    c. Assess water diversion structures to ensure that they are within legal rights and properly equipped for fish safety
2. Characterize the current water quality and potential impacts to salmonid survival and movement.
3. Complete habitat measurements on the East Fork Owyhee River and its tributaries that indicate current ability to support salmon and steelhead populations, and what changes might be needed to enhance their survival.
4. Evaluate health and genetic structure of resident salmonid populations.
    a. Collect fish samples for disease presence
    b. Collect tissue samples from native redband (rainbow) trout for genetic analysis

5. Determine where and how the Tribe can construct weirs to constrain adult fish movements for a put-and-take fishery on the Duck Valley Reservation.

METHODS

Habitat assessments included a combination of literature review and field data collection, literature review was conducted prior to field investigations. Data specific to native redband trout populations and water quality in the East Fork Owyhee Basin were gleaned from existing research reports. Habitat surveys were then systematically carried out following standard stream survey protocols described fully in Appendix A. Habitat data compiled from the literature review and field surveys were then used to populate a fish carrying capacity model to predict the number of juvenile and adult Chinook salmon and steelhead trout the Basin could support when fully seeded. Additional literature review and field surveys were also conducted to document water diversions and characterize the genetic baseline of existing redband trout populations.

Spatial Structure

Prior to field surveys, the Basin was partitioned between mainstem stream segments (reaches) and key tributaries (Figure 3) as defined by specific differences in stream morphology, riparian make up, surrounding anthropogenic practices, and other topographical features. The mainstem of the East Fork was divided into three reaches 1, 2, and 3. Mainstem reach 1 extended from Wildhorse Dam (rkm 196.3) 15km downstream to Rizzi Diversion. This section of river runs through a defined canyon with predominantly pool and riffle habitats. The riparian portion of the stream is dominated by shrubs and bushes along steep canyon walls. Mainstem reach 2 spans from Rizzi diversion to the boundary of the Duck Valley Reservation. This section of the river has a broader floodplain relative to reach 1, with many agricultural sites and grazing areas for cattle. Mainstem reach 3, the last reach along the mainstem, ends at China Diversion south of the town of Owyhee. Mainstem reach 3 is located entirely on Tribal land and is characteristically different than mainstem reach 2 because of the difference in land usage and ownership. Van Duzer, Slaughterhouse, Allegheny, California, and Skull Creeks were identified as potential summer rearing habitat for salmonids and were, therefore, categorized as tributary survey reaches.

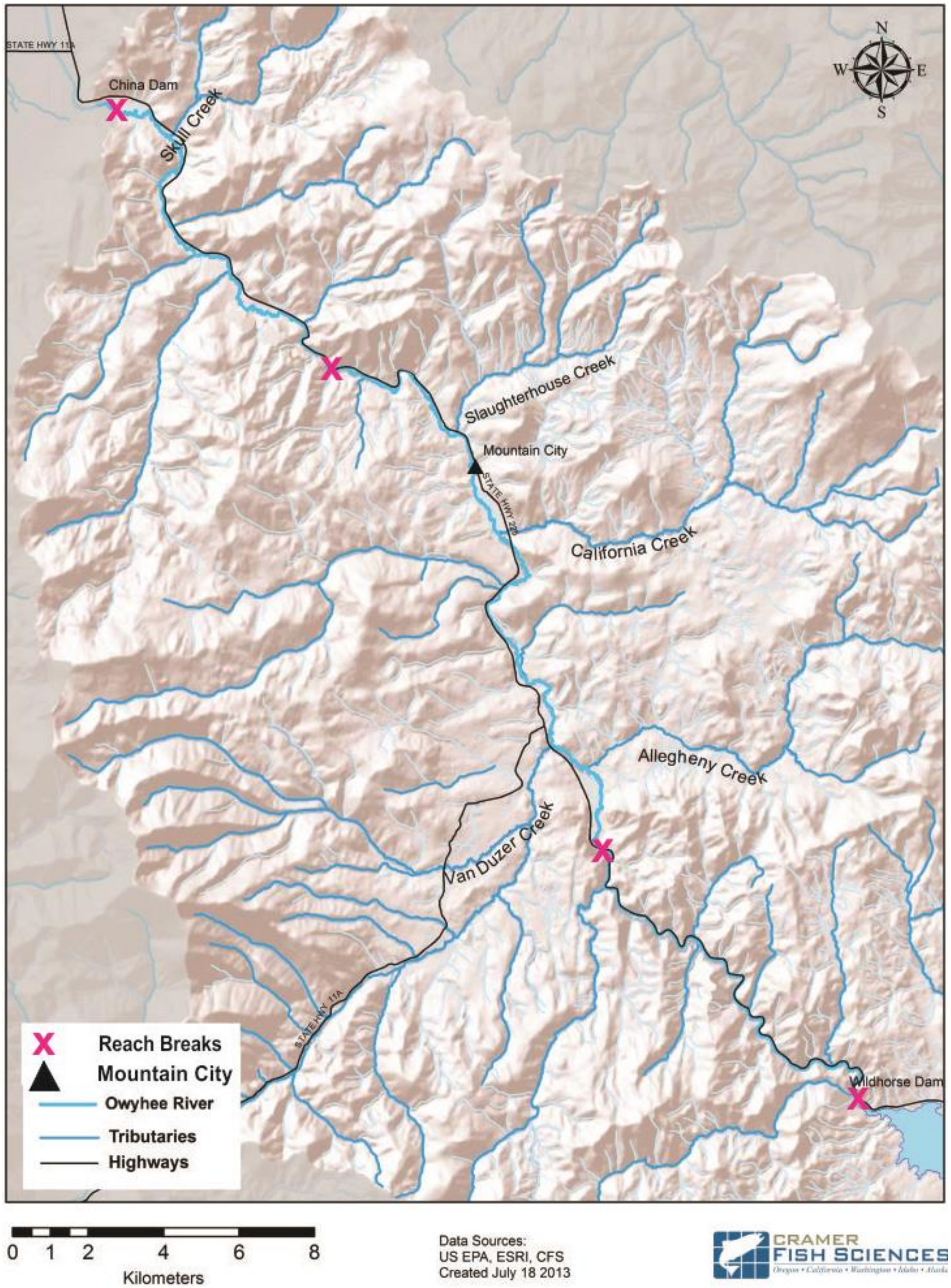

Figure 3. Map of the East Fork Owyhee River depicting reach delineations within the study area. Mainstem study reaches are separated by red X's and labeled by reach number, tributary sample reaches are labeled at the upstream end.

Rearing Habitat Surveys

Once survey reaches were established, a determination was made regarding how much of each section of stream was sufficiently representative of the stream habitat. It was assumed that 20% of the designated reach length would be sufficient to be representative of the entire reach.

In each study reach, channel units were classified as a pool, glide, riffle, rapid, or cascade. Channel geomorphic units are relatively homogeneous lengths of the stream that are classified by channel bed form, flow characteristics, and water surface slope. With some exceptions, channel geomorphic units are defined to be at least as long as the active channel is wide. Individual units are formed by the interaction of discharge and sediment load with the channel resistance (roughness characteristics such as bedrock, boulders, and large woody debris). Each specified channel unit was then measured to include length, wetted widths, depths, active channel width, and an estimate of stream bed substrate composition. The model which was used to determine carrying capacity employs these specific habitat measures and observations to estimate the number of fish each channel unit can potentially support. In addition, data for some water quality parameters were also collected for use in model calculations.

The following is a list of habitat features documented during stream surveys:

Geomorphic Unit Type—Subjectivity defined as a pool, glide, riffle, rapid, or cascade based on stream gradient, water velocity and depth, and channel morphology.

Geomorphic Unit Length – The total geomorphic length of each channel stream unit was determined by the transition between unit types by using a range finder.

Geomorphic Channel Unit Width – Average width should be estimated by observing the wetted width in at least three locations along the longitudinal axis of the unit, and then averaging.

Depth – Depths were measured in all channel units. Maximum depths were determined in pools and beaver ponds and average depth was determined in riffles, glides, and rapids. All depths were recorded with a stadia rod.

Substrate Classification – For each channel unit substrate classifications and estimate were made. Four types of substrate were identified.

Wood Complexity – Wood complexity ratings (1-5) were assigned to each channel unit, 5 being the most complex. See Appendix B for photographic examples of ratings 1-4. (Photographic example is not included for a rating of 5)

Active Channel Width – Active channel width was also recorded for each channel unit. Active channel width is the distance across the channel at “bankfull” flow which is attained every 1.5 years and can often be determined by changes in vegetation or high water marks.

Active Channel Unit Height – The height from streambed to active channel was recorded using a stadia rod.

Spawning Habitat Surveys

In addition to rearing habitat surveys, spawning areas were also assessed. All exposed gravel patches that met requirements for steelhead and Chinook spawning were measured for depth, length, width, height above water surface, and substrate composition. This assessment was conducted simultaneously with rearing surveys, but only accounted for dry gravel patches. Wetted spawning habitat was taken into account via substrate composition estimates recorded for each geomorphic channel unit. Dry gravel patches were included because at higher flows these areas would be expected to be inundated providing potential salmonid spawning habitat.

Fish Sampling

Establishing a genetic baseline of native salmonid populations was considered necessary to effectively evaluate the watershed's suitability to support anadromous fish populations. Caudle fin clips were collected from current redband trout populations throughout the mainstem Owyhee and its tributaries using a Model 12B Smith/Root backpack electrofisher and a team of two field technicians. Fin clips were placed into small manila envelopes, dried, and stored at room temperature for future genetic analysis.

Temperature Monitoring

Summer temperatures were monitored within the study area by the Shoshone-Paiute Tribe using Hobo Pro V2 temperature probes placed along the mainstem and in selected tributaries (Table 1). Temperature probes were programmed to collect data every hour between August and October. Collaboration with Idaho Trout Unlimited (TU) expanded our temperature dataset.

Table 1. Locations of temperature probes placed in the study area in 2013.

River/Creek Probe Location	North	West	Source
Owyhee River	41.69113	-115.8443	Sho-Pai's/CFS
Owyhee River	41.74782	-115.92692	Sho-Pai's/CFS
Owyhee River	41.77186	-115.94061	Sho-Pai's/CFS
Owyhee River	41.82272	-115.9585	Sho-Pai's/CFS
Owyhee River	41.86123	-115.98704	Sho-Pai's/CFS
Owyhee River	41.92458	-116.08644	Sho-Pai's/CFS
Van Duzer Creek	41.75086	-115.95485	Sho-Pai's/CFS
Trail Creek	41.75231	-115.94741	Sho-Pai's/CFS
Van Duzer Creek	41.77142	-115.94115	Sho-Pai's/CFS
Allegheny Creek	41.77055	-115.92289	Sho-Pai's/CFS
Allegheny Creek	41.76681	-115.92956	Sho-Pai's/CFS
California Creek	41.82355	115.94954	Sho-Pai's/CFS
Slaughterhouse Creek	41.86313	-115.96481	Sho-Pai's/CFS
Skull Creek	41.93308	-116.05432	Sho-Pai's/CFS
Skull Creek	41.9174	-116.06241	Sho-Pai's/CFS
Martin Creek	41.750218	-115.675993	Trout Unlimited
Miller Creek	41.889196	-115.948965	Trout Unlimited
EF Owyhee South of DVIR	41.860187	-115.98619	Trout Unlimited
California Creek	41.823412	-115.902149	Trout Unlimited
McCall Creek	41.783876	-116.053936	Trout Unlimited
Van Duzer Creek	41.75507	-115.945642	Trout Unlimited
Badger Creek	41.737466	-115.924375	Trout Unlimited
Trail Creek	41.69317	-116.023022	Trout Unlimited
Sheep Creek	41.691703	-116.022748	Trout Unlimited
Beaver Creek	41.689737	-115.845436	Trout Unlimited
EF Owyhee Below Beaver Creek	41.691094	-115.844361	Trout Unlimited
Owyhee River above WH Reservoir	41.625975	-115.792721	Trout Unlimited

Carrying Capacity Modeling

Carrying capacity (the maximum number of fish that can be supported at a specified life stage under average conditions) is a function of the types of habitat features which fish prefer, and how well those preferences can be satisfied by the habitat conditions available in a given stream (Figure 4). In order to estimate carrying capacity of the East Fork Owyhee River basin to support steelhead trout and Chinook salmon, we first had to describe the seasons and life-stages during which these species would be expected to use available habitat. Production of anadromous salmonids is often limited by the capacity for juvenile rearing (Cramer and Ackerman 2009a; Quinn 2005), but factors constraining production can vary between stream reaches, and migration can enable fish to overcome some of these limitations by moving to another stream reach. Anadromous salmonid rearing capacity throughout the East Fork Owyhee River and its tributaries is likely limited by low summer/fall flows and high summer temperatures, which coincide with the presence of rearing juveniles and Chinook salmon spawning. We assumed that carrying capacity at the emergent fry life stage was not a bottleneck to production, and we did not calculate its carrying capacity. Subyearling Chinook smolts that emigrate to sea in late spring was the first juvenile stage for which capacity was estimated. Steelhead life history includes rearing of parr through the summer, so we calculated summer parr capacity for steelhead. Chinook juveniles were not assumed to remain through the summer.

Patterns of fish habitat use (which we refer to as habitat preferences) determines the proportion of available habitat that is suitable for fish use at a given life stage. So, we quantified the amount of available habitat and documented its features, we projected how these measurements would change across seasons, and then we overlaid the habitat preferences of rearing juveniles and adult spawners with the amount of habitat each fish would need to determine habitat carrying capacity. Data inputs to the model were the measurements of habitat features that are key determinants of the maximum density of fish supportable within mainstem and tributary reaches. Habitat features used to estimate rearing capacity were channel unit composition, surface area, depth, substrate, cover, and temperature. Habitat features used to estimate spawning capacity were gravel availability, area defended per spawning pair, and minimum depth for spawning. A description of the carrying capacity is given in Appendix A.

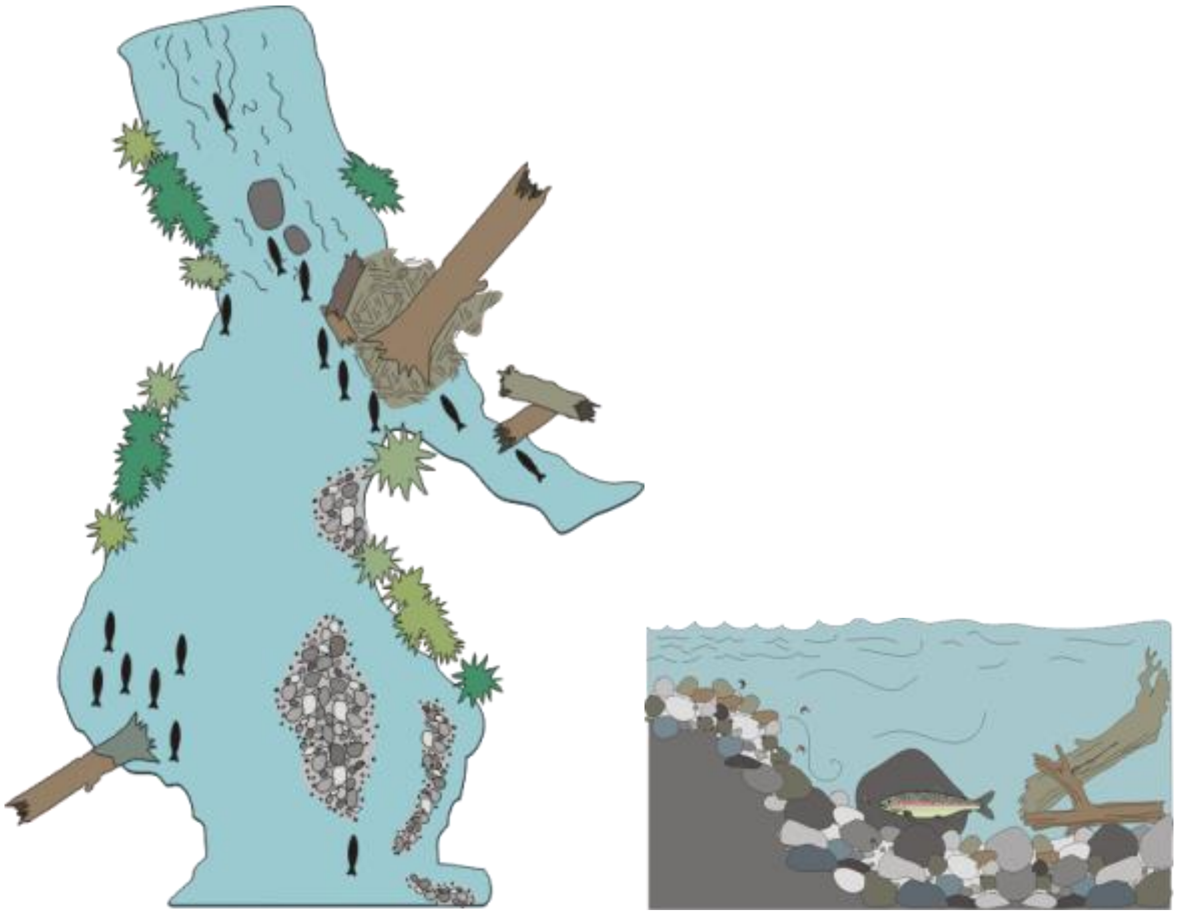

Figure 4. Conceptual depiction of fish utilization of habitat features expected to limit stream carrying capacity.

Hydraulic Modeling

A separate model of hydraulic geometry in the study reaches was used to scale the habitat measurements to flows typical of the rearing and spawning seasons and to those expected in wet water years. Conditions during field measurements in late August to early September 2013 were unusually dry and represent a worst-case example of late summer low-flow bottleneck for rearing. These conditions were used as low-flow baseline in the hydraulic modeling.

Hydraulic modeling was employed to objectively represent how the spawning and rearing capacities for steelhead and spring-run Chinook salmon would change at different levels of flow and to estimate capacity in more typical conditions than the unusually dry conditions observed in 2013. We used the hydraulic geometry relationships recorded in the habitat surveys to predict how width, depth, and velocity would change in each channel unit as flow changed within the surveyed reaches of the East Fork Owyhee River. We did not apply our hydraulic models to the tributaries, but used observed baseline conditions instead. This approach was taken in order to simplify the modeling since our field measurements indicated that the contribution of tributaries to overall carrying capacity is small. Thus, it would be expected that overall carrying capacity in typical and wet water years (i.e., years with flow greater than baseline) would be slightly higher than that predicted by the model. Here, we describe how the model predictions were accomplished.

Channel dimensions were measured in the mainstem river while flows averaged 20 cfs. As flows increase and more water flows through the channel, water level increases and the stream spreads out to fill the channel—with the amount of spread being dependent on channel shape. Similarly, as flow decreases water level drops and the stream width narrows. These flow, width, and depth relationships follow laws of fluid dynamics and are predictable using a set of simple models. In the early 1950s Leopold and Maddock (1953) measured flows, widths, average depths, and average velocities in streams. After plotting their measurements in log-log graphs they found linear relationships of flow to each of the following metrics; width, depth, and velocity. This finding led them to develop a hydraulic geometry model to predict stream changes related to flow consisting of three related equations:

$$w = aQ^b$$
$$d = cQ^f$$
$$v = kQ^m$$

Where w is width, d is average depth, v is average velocity, Q is flow, and a, b, c, f, k, and m are coefficients and exponents related to channel size and shape. These relationships also have the property that the sum of the exponents must equal unity (b + f + n = 1), and so must the product of the coefficients (a·c·k = 1).

In recent decades, fisheries researchers have begun to explore the use of hydraulic geometry to predict how fish habitat suitability changes in response to flow changes. Hogan and Church (1989) showed from studies of two coastal streams in British Columbia that slopes of hydraulic geometry relationships consistently differed between pools and riffles, and thus reflected differing responses between types of channel units in the response of habitat characteristics to changes in flow (Figure 5). Further, they found that PHABSIM and hydraulic geometry predictions of habitat quality for salmonids across a range of flows were closely correlated. This hydraulic geometry model has been used to estimate the effects of flow on fish habitat values in streams of California by Rosenfeld et al. (2007) and in high gradient streams in New Zealand by Jowett (1998).

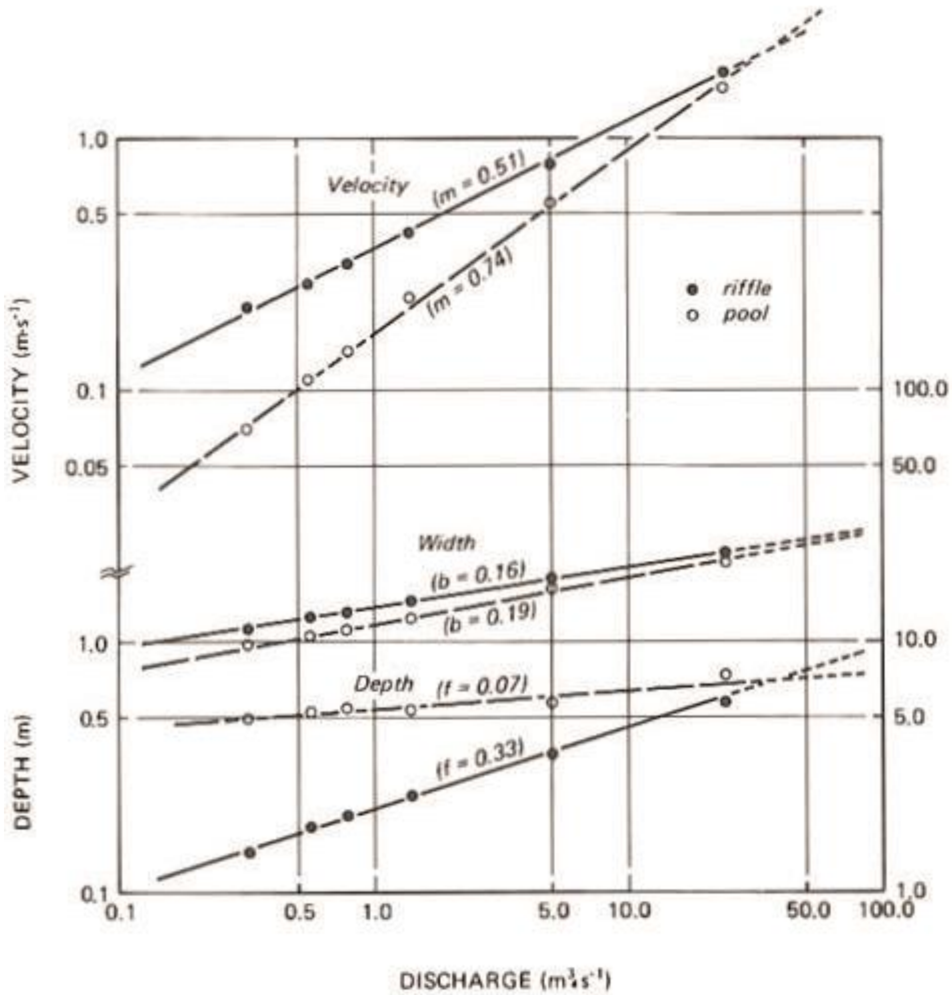

Figure 5. Example of hydraulic geometry relationships fit to field measurements of velocity, depth, and width of a coastal stream in British Columbia. Symbols m, b, and f are exponents of hydraulic geometry equations for the fitted line. From Hogan and Church (1989).

To use the hydraulic geometry model, we needed to estimate the coefficients appropriate for the study reaches of the mainstem East Fork Owyhee River. We applied an approach described by Jowett (1998) in which ratios of width at depth at a low and high flows were used to estimate the needed parameters. We used measurements for width and depth of each channel unit measured at 19-21 cfs during our survey, and the bank-full width and depth measured during the same survey. We assumed that the bank-full (active channel) flow was equal a 2-year return flow event. Data collected from 1992-2013 by USGS stream gauges near Mountain City and Gold Creek on the East Fork Owyhee River was used in flow modeling estimates for the mainstem river reaches.

Using this information, unit-specific coefficients and exponents for the stream change model were calculated using the following equations from Jowett (first four) and Leopold and Maddock (last two).

$$b = \frac{\log\left(\frac{W_1}{W_2}\right)}{\log\left(\frac{Q_1}{Q_2}\right)}$$

$$a = \frac{W_1}{Q_1^b}$$

$$f = \frac{\log\left(\frac{D_1}{D_2}\right)}{\log\left(\frac{Q_1}{Q_2}\right)}$$

$$c = \frac{D_1}{Q_1^f}$$

$$k = 1 - b - f$$

$$m = \frac{1}{a \times c}$$

Where W_1 and D_1 are wetted width and average depth measured at 13 cfs,

Q_1 and W_2 and D_2 are bank-full width and average depth measured at 600 cfs (Q_2)

All of these, except average depth at bank-full flow, were measured. Average depth at bank-full flow is calculated using height to bank-full level using the following equation from Jowett.

$$D_2 = \frac{W_1 \times (D_1 + \Delta L) + \frac{\Delta L \times (W_2 - W_1)}{2}}{W_2}$$

Where ΔL is height to bank-full level and all other variables are the same as above. The values for k and m were calculated in this way to ensure that the output of the equations follow laws of fluid dynamics.

In the few channel units where the active channel dimensions could not be unambiguously determined, we used the average value of each of the calculated a, b, c, and f values for the appropriate channel type (pool, riffle, rapid, or cascade), and the k and m values calculated using the channel type average a, b, c, and f values. For example, if the a value is missing for a pool channel unit, the value used for stream change calculations is the average a value for all pools where that parameter was calculated. Exceptions to this are the c, and f values for the average depth equation for cascades, because height to bank-full level measurements were not made. We assumed bank-full widths and heights for cascades were similar to those for rapids, so we used the coefficient and exponent values from the rapids.

By this approach, the stream change models are channel unit-specific with each channel unit having its own set of coefficient and exponents that allow width and depth at different flows to be calculated. These are used in the calculation of potential spawning production and rearing capacity in the UCM.

Steelhead carrying capacity models will be adjusted to be representative of current trout populations on the East Fork Owyhee River. Current populations consist of a strain of rainbow trout known as Redband Trout. Redband Trout are known to tolerate hotter desert temperatures than other strains of rainbow trout therefore it is important to adjust temperature scalars for steelhead models to those tolerances. Behnke (1992) and Zoellick (1999) found actively feeding redband trout in temperatures of 26-28 ^{o}C suggesting that redband trout may have adapted over time physiologically to withstand high temperatures commonly seen in desert stream systems. Cassinelli and Moffitt (2010) cite numerous sources that report critical temperatures for strains of rainbow trout as 26.9-29.8^{o}C. Temperature scalars for steelhead population modeling will be adjusted two degrees to appropriately account for differences in temperature tolerance; a range of 18-24^{o}C will be used.

RESULTS

Water Quality Analysis

Rio Tinto Mine

Rio Tinto mining site along Mill Creek, a tributary to the East Fork Owyhee River, poses a severe risk to the water quality of the entire Owyhee River system (Figure 6). The mine was operated between 1932 and 1947 (Beltman 2004). Mine tailings were established in sections of Mill Creek and water was diverted from the stream to limit flowing water through the tailing ponds. The original mine was abandoned in 1948. Another mining operation took over in 1966, and efforts were made to recover copper from the Mill Creek tailings (Beltman 2004). Significant leaching occurred into the valley floor during this copper recovery operation. The mine site was sold to the Shoshone-Paiute Tribe in 1975 and remained inactive from 1977 until the 80's (Beltman 2004). The Rio Tinto Working Group (RTWG) conducted site investigations during the 80's and 90's and conducted several remedial projects between 1986 and 2001 (Beltman 2004). RTWG implemented a number of projects to restore the surrounding environment and minimize impact of the current mining conditions (Figure 7). Water testing and water monitoring was introduced in 2002 and 2003 by RTWG along with material removal (Beltman 2004).

Rio Tinto mine site and Mill Creek will likely continue to pose adverse effects to the Owyhee River Basin until pollutants are fully contained. This area will likely not provide rearing habitat for fish due to pollution and lack of sufficient flowing water during summer months. Continued monitoring of Mill Creek and the Rio Tinto Mine is needed, and will likely be carried out by the Nevada Division of Environmental Protection (NDEP).

Figure 6. Aerial view of the Rio Tinto Mine prior to remedial efforts (NDEP).

Figure 7. Current aerial view of the Rio Tinto mine (NDEP).

Nevada Division of Environmental Protection Water Quality Sampling

The NDEP has been monitoring water quality along the East Fork Owyhee River and in Wildhorse Reservoir (Figure 8) from 1966 to 2013. They have collected an extensive data set of water quality parameters. Specific water quality parameters were selected for our assessment from this extensive database according to their relevance to salmonid habitat conditions.

In 2005, Total Daily Maximum Loads (TMDL) were established by the NDEP for the East Fork Owyhee River, and for one of its main tributaries Mill Creek (NDEP 2012). Mill Creek has long been of importance in the monitoring of water quality because of its use in the operation of Rio Tinto Mine, processing mining wastes and providing water for waste treatment ponds. In 2009 a five-year review was released by Idaho Department of Environmental Quality (IDEQ 2009) that reexamined the 2005 TMDL's established by NDEP. An addendum was later released in 2012 (Table 2). The 2012 addendum stated that the water temperature must be <22^{o} C daily maximum or <19^{o} C daily average to support cold water aquatic life and must be <13^{o} C daily maximum or must be <9^{o} C daily average to support salmonid spawning.

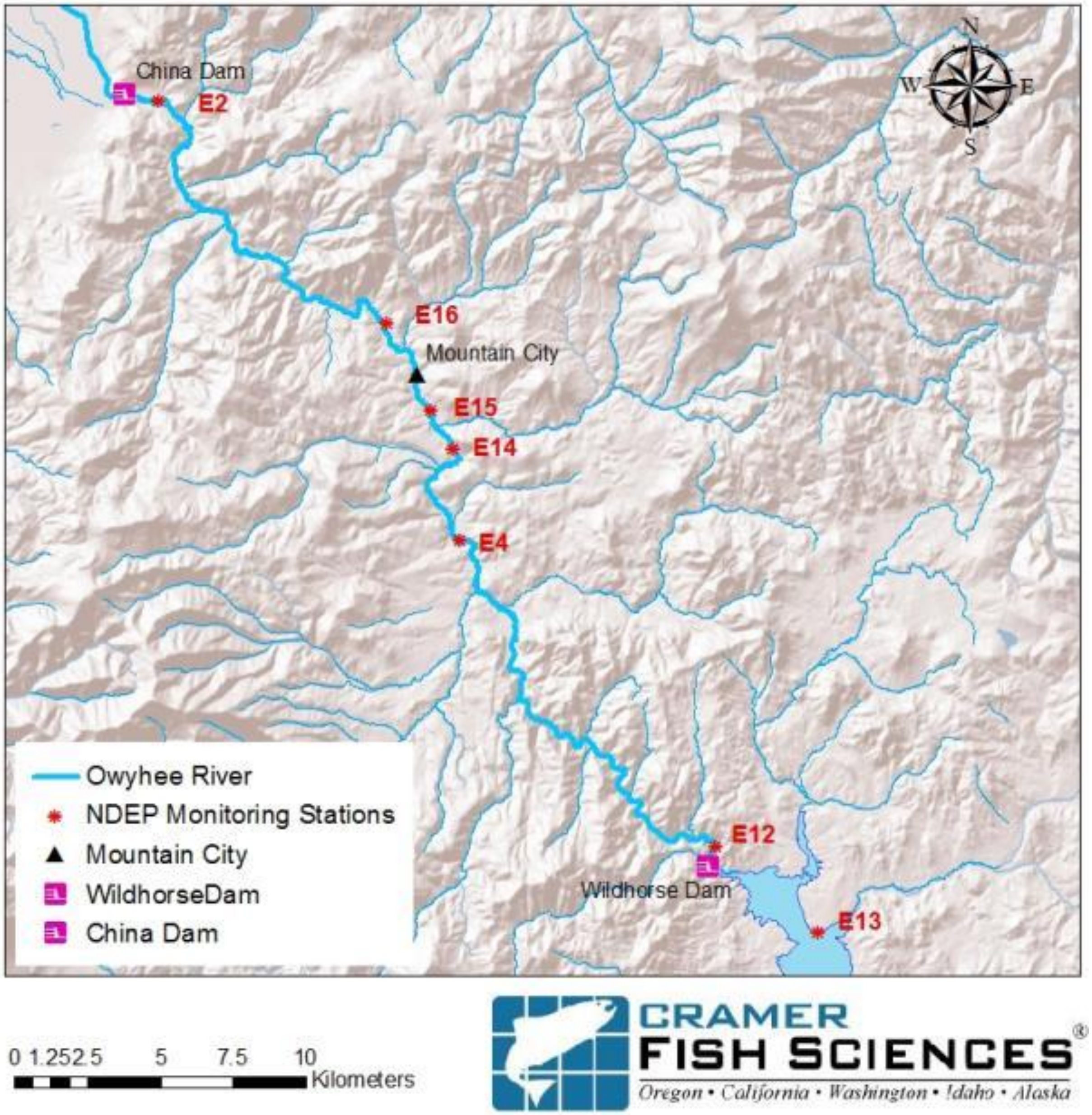

Figure 8. Location of NDEP water sampling sites along the study area used for a preliminary assessment of current water quality. Sites are labeled with NDEP designations.

Table 2. Established TMDLs for the East Fork Owyhee and Mill Creek by the NDEP.

Parameter	Measurement	Notes
Total Dissolved Copper	200 ug/L	
Dissolved Oxygen	>6.0 mg/L	
Total phosphorus	<0.1 mg/L	
Turbidity	<10NTU	
Temperature	<13^{o}C, <9^{o}C	Daily Maximum; Daily Average
pH	6.5-9.0	

NDEP Water Quality Sampling Data Assessment

An analysis of the current water quality within the study area was critical in determining the basin's potential to support anadromous fish populations. We used historical data collected by the NDEP to analyze water quality in the East Fork Owyhee River. To sufficiently support salmon and steelhead populations, water temperatures must remain cool enough for rearing juveniles. Figure 9 shows how temperature changed over the course of one year by averaging the monthly temperature measures over the period of record (1967-2010). Metals including copper, iron, and zinc were examined because of the significant mining activity in the basin (Table 3). Other key parameters included mercury concentration, dissolved oxygen, pH, and phosphorous (Table 3).

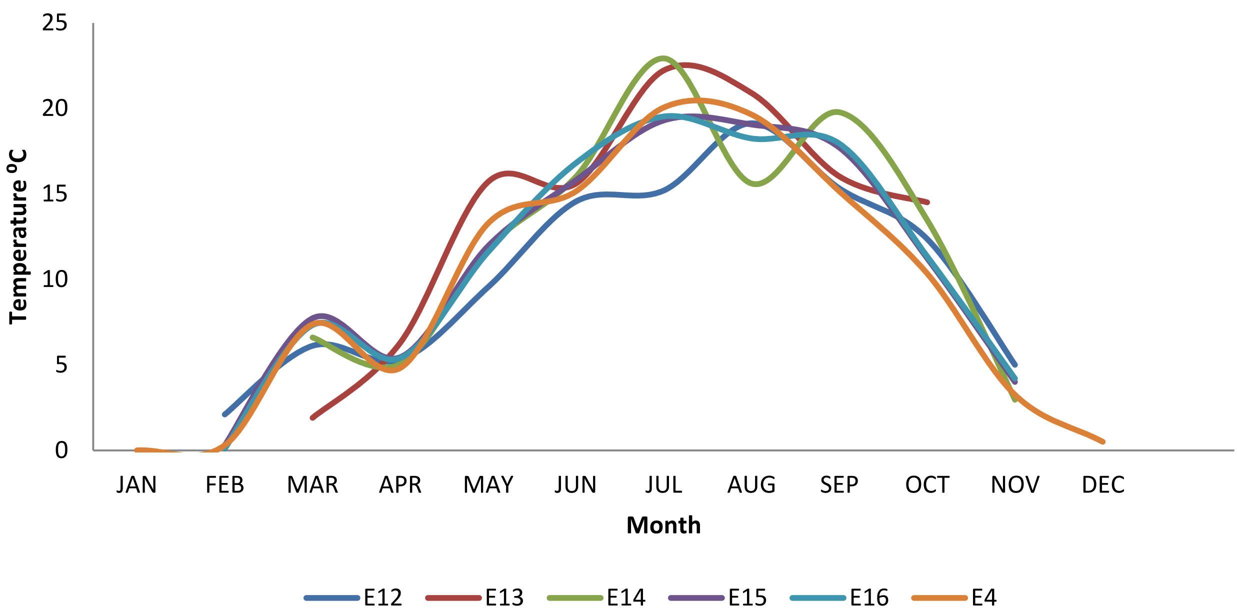

Figure 9. Average monthly temperature for NDEP water quality monitoring sites along the East Fork Owyhee River downstream of Wildhorse Reservoir.

Table 3. Various water quality parameters from NDEP monitoring sites moving downstream of Wildhorse Dam.

Site Averages	E13	E12	E4	E14	E15	E16	E2
Dissolved Oxygen (mg/L)	10.06	9.4	9.5	8.64	9.67	10.37	10.92
pH	8.91	8.27	8.34	6.79	8.31	8.43	8.18
Alkalinity (CaCO3 mg/L)	83.37	67.96	98.86	28.62	92.16	92.71	121.27
Phosphorus (mg/L)	0.15	0.13	0.12	0.08	0.12	0.11	0.1
Turbidity (NTU)	30.06	7.60	12.98	1521.37	11.54	11.64	9.64
Copper (ug/L)	9.93	9.93	9.50	1521.37	33.42	23.5	16.73
Mercury (ug/L)	0.29	0.34	0.37	0.3	0.31	0.31	0.44
Iron (ug/L)	1280.04	543.14	1170.14	19832	1015	929.58	881.95
Zinc (ug/L)	27.8	24.45	23.14	544.67	26.96	25.5	15.87
Distance from Reservoir (km)	0	4.99	25.5	28.93	31	37.8	55.4

Temperature Monitoring Findings

Based on our review of recent monitoring efforts in the Owyhee Basin, it is expected that high summer temperatures will prove to be a significant obstacle for sustaining fish populations, specifically native redband trout. The Shoshone-Paiute Tribe placed Hobo Pro V2 temperature probes along the East Fork Owyhee and its tributaries (Table 1) to obtain additional temperature for August through October 2013. Table 4 shows the designations and locations of each monitoring site to be referenced with Figure 10 and Figure 13. The maximum daily average water temperatures for cold water fisheries specified by the states of Idaho (22^{o} C) and Nevada (21^{o}C) are shown for reference. These criteria reflect the best available science regarding optimal water temperatures for coldwater fisheries in the region where the DVIR is located.

The temperature data collected by the Tribe between the months of August and October indicate that temperatures exceeded 20^{o} C multiple times during this period (Figure 10). Temperatures began to drop in early October and temperature is slightly above 5^{o} C when probes were removed. Tributary temperatures reflected similar readings as to what was observed in the mainstem reaches (Figure 11). Probes were also positioned in California and Allegheny creeks but were not included in temperature analysis because of the lack of flowing water during field investigations.

In addition to the temperature data collected by our study team in 2013, temperature data was received from Idaho's Trout Unlimited program that had been monitoring temperature along the study area since summer 2012. Temperature along the East Fork Owyhee during the period of data collection, July 2012 to October 2013, remained under designated maximum temperature levels for Idaho and Nevada below Wildhorse Dam (Figure 12).

Trout Unlimited temperature data also supports field evidence of limited summer rearing habitat in tributaries. The data collected clearly shows that during low water years many of the tributaries to the mainstem Owyhee experience little to no flow during the summer months. California (Figure 13), Badger, and Beaver Creeks (Figure 14) all exhibit extremely high temperatures between July and September suggesting that these are ephemeral streams and the temperature probes are reading air temperatures rather than water temperatures.

Table 4. Symbols used to identify temperature probes in specific locations of the mainstem Owyhee and its tributaries.

Symbol	Location
M1	Owyhee River Downstream of Wildhorse dam
M2	Owyhee River Rizzi Diversion
M3	Owyhee River confluence with Van Duzer Creek
M4	Owyhee River south of Mountain City
M5	Owyhee River southern boundary of Duck Valley Reservation
M6	Owyhee River China Dam
T2	Trail Creek
T3	Van Duzer Creek
T7	Slaughterhouse Creek
T10	Skull Creek

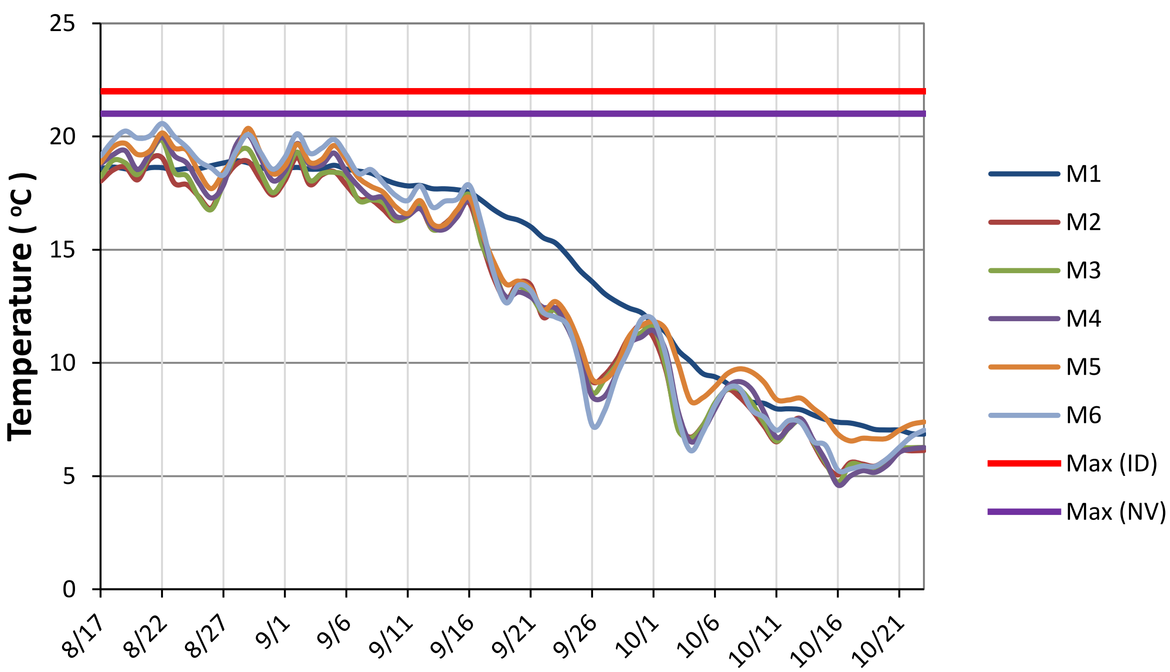

Figure 10. East Fork Owyhee River average daily temperatures from August to October. Maximum salmonid water temperatures for Idaho and Nevada are displayed for reference.

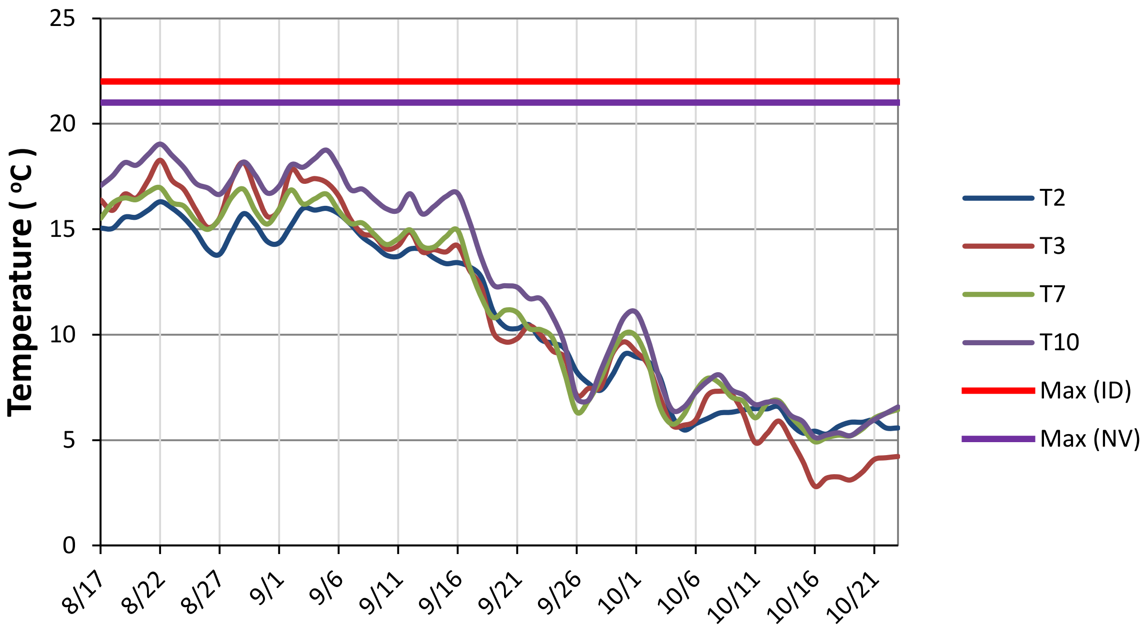

Figure 11. Average daily temperature values for East Fork Owyhee river tributaries during August, September, and October. Maximum daily temperature criteria are displayed for both Idaho and Nevada.

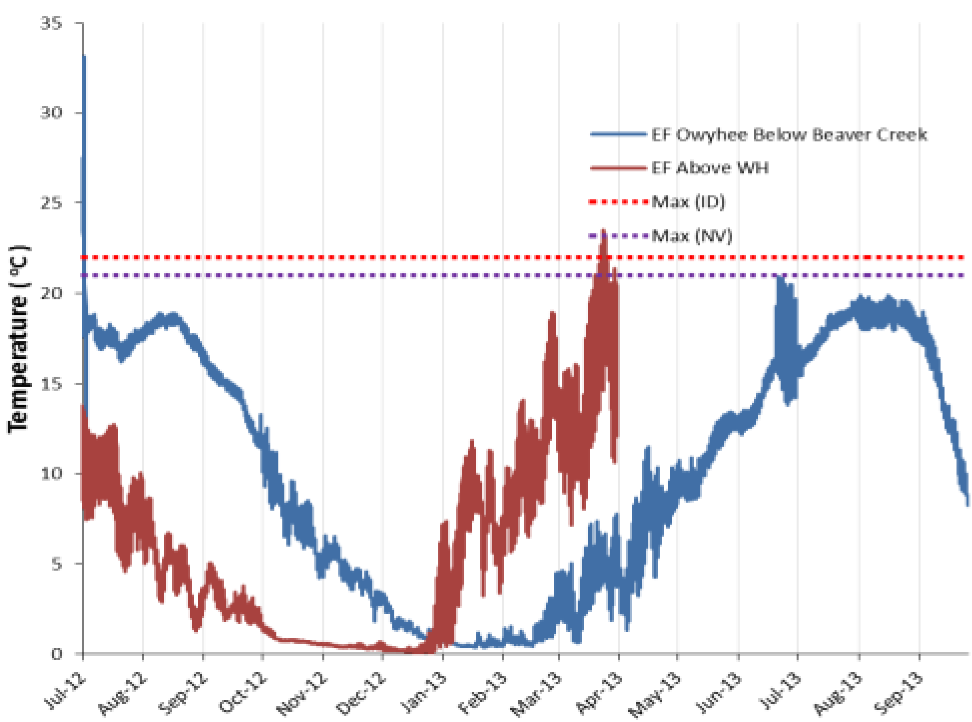

Figure 12. Trout Unlimited temperature monitoring daily readings from July 2012 through October 2013 along the mainstem East Fork Owyhee near Beaver Creek and above Wildhorse Dam.

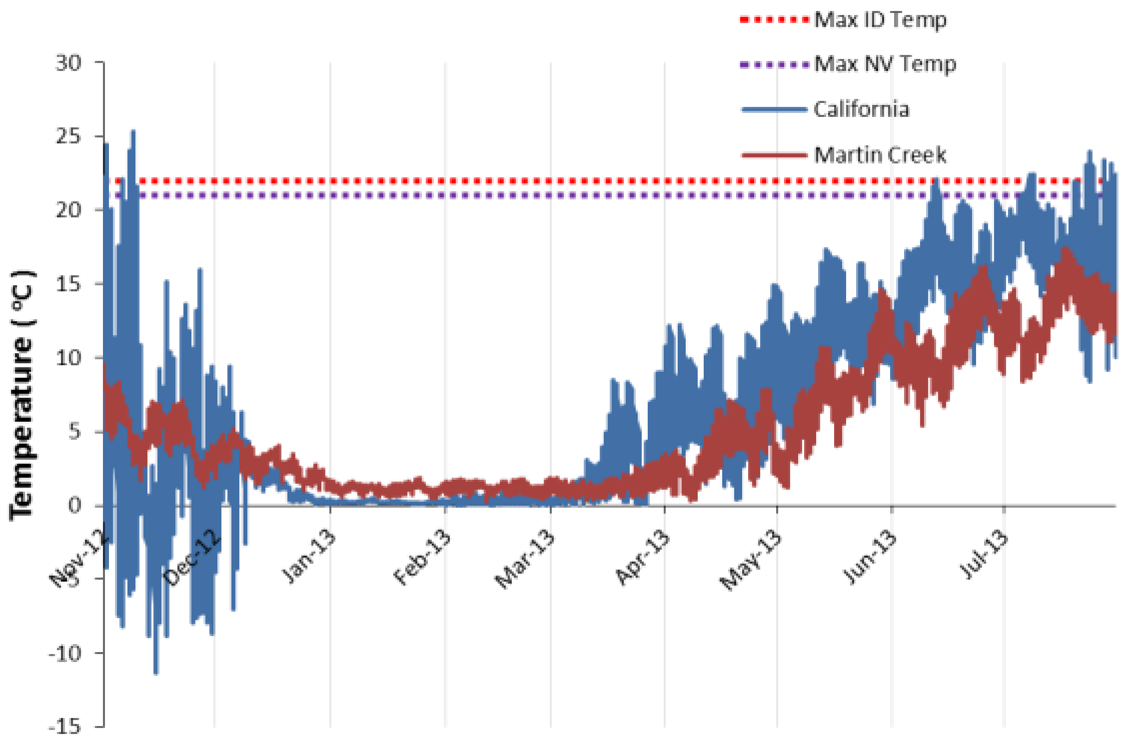

Figure 13. Trout Unlimited temperature monitoring from July 2012 through October 2013 along California and Martin Creeks.

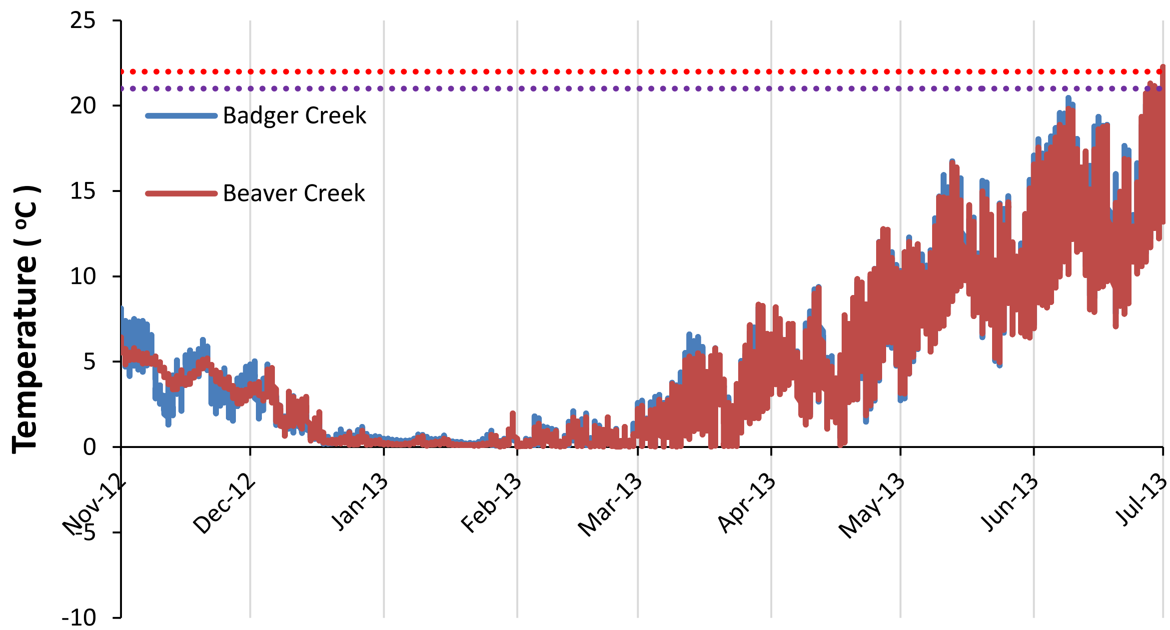

Figure 14. Trout Unlimited temperature monitoring from July 2012 through October 2013 along Badger and Beaver Creeks.

Fry Emergence Predictions

Water temperature has a substantial effect on salmonids and plays a key role initiating spawning behavior and fry emergence. Both life events occur once environmental conditions, largely temperature and flow, reach favorable conditions. Embryo development is dependent on water temperature, and in the case of salmon, warmer temperatures yields faster embryo development. Spawn timing and fry emergence are both predictable with information about the range of temperatures at which spawning occurs, and sufficient information of a given stream or river's thermal regime. The cumulative number of centigrade temperature units (CTUs) that are acquired post-spawn is then used to estimate egg incubation time and the resulting fry emergence.

In Lolo Creek, Idaho, Murrell (2006) estimated that steelhead likely spawn between mid-April and 1 June in most years. Typically, Snake River Basin Steelhead spawn once, holding in deep pools until conditions become favorable. Murrell (2006) noted that Lolo Creek displayed favorable spawning temperatures during the middle of May when observed during 2001, 2003, and 2005 which was within the assumed spawning time indicated for the system. Murrell (2006) cites data from Roberts (1988) and Stack and Bronec (1998) that allowed them to estimate fry emergence dates (average water temperature 7.5^{o}C; 84 days and 632 CTU's and 10.8^{o}C; 41 days and 442 CTU's, respectively).

To determine the spawning windows for anadromous steelhead and Chinook in the East Fork Owyhee River, we compiled developmental data, as well as flow and temperature data from the East Fork Owyhee River. We calculated the available thermal units based on daily average water temperature, collected by Trout Unlimited in 2013, to estimate emergence timing. The resulting estimate is suitable for years with similar hydrologic and thermal regimes. In 2013, the average daily water temperature ranged from 19°C in the early fall and fell to 0°C by the winter.

Emergence timing for both Steelhead and Chinook were estimated with the following steps:

> *Task 1.* Estimate the approximate spawning period based on known ideal temperature ranges for spawning and existing temperature data on the East Fork Owyhee River;
>
> *Task 2.* Estimate hatching window by calculating the available CTU's (thermal units) by accumulating the daily temperature averages to a known critical hatching threshold evaluated with literature review; and
>
> *Task 3.* Estimate emergence time by adding an average "gravel wait time" based on literature review.

Steelhead

Task 1. We estimated the minimum and maximum steelhead spawn timing window in the East Fork based on a combination of literature review for ideal spawning temperatures and existing thermal data from the East Fork Owyhee River. We selected one 'early' spawn time and one 'late' spawn time at either end of the spawning runs. Steelhead have been observed spawning in water between 3.9-21.1^{o}C (WDOE 2002; cited in Carter 2005). However the reported optimum temperature range for steelhead spawning is 7.8°C–11.1°C (U.S. Fish and Wildlife Service 1995). Since steelhead eggs mature very slowly below 7.2°C (Murrell 2006), this study used the USFWS optimum range to estimate the onset of spawning,. Ideal temperature ranges for steelhead spawning (7.8-11.1°C) occurred in the East Fork Owyhee River from 5 April through 30 May.

Task 2. We estimated how many CTUs were available in the East Fork following the spawning period to determine the length of the egg incubation period. After spawning, the preferred steelhead egg incubation temperatures occur between 8.9°C and 11.1°C (IEP 1998). Based on an average of 10°C during egg incubation in the East Fork, we assume steelhead need 310 CTUs for eggs to hatch. Table 5 indicates the number of days to hatch and CTU's associated with specific temperature intervals. We estimate that the yolk-sac alevins hatch from 5 to 23 June, after achieving approximately 310 CTUs.

Task 3. We estimated the amount of time that steelhead spent post-hatch to absorb their yolk sacs, and applied it to each estimate. Newly hatched steelhead alevins remain in the gravel for around 2 to 6 weeks (Moyle 2002; DWR et al. 2000), and then emerge as fry 2 to 8 weeks later (U.S. Fish and Wildlife Service 1995). For this analysis, we assume an average gravel period of 5 weeks (35 days) prior to emergence. We estimate that steelhead fry emerge from 10 July though 28 July, after 35 days in the gravel (Table 6).

Chinook

Task 1. We estimated the timing period that would provide ideal thermal conditions for Chinook spawning by reviewing existing average daily water temperature. We selected one 'early' spawn time and one 'late' spawn time at either end of the spawning run. The Oregon Department of Environmental Quality (2005) determined that Chinook spawn between 5.6^{o}C and 12.8^{o}C (Carter 2005). Chinook spawning temperatures were ideal (5.6 – 12.8°C) in the East Fork Owyhee River from 21 April through 8 June.

Task 2. We estimated how many CTUs were available in the East Fork post-spawn to estimate the length of the egg incubation period. Egg survival is highest at temperatures between 5^{o}C and 13^{o}C (Beacham et al. 1989, Moyle 2002b). Temperatures in the East Fork exceeded 13°C on 18 June, and again from 20 June through 27 September, indicating that perhaps the early Chinook spawners would have higher survival. Once Chinook have spawned, the egg incubation period ranges from 40-60 days (Moyle 2002b) to 42-63 days (U.S. Fish and Wildlife Service 1995), dependent on temperature. Controlled laboratory experiments indicate that British Columbia Chinook egg incubation ranges from 35 days to 129 days and a range of 516 to 560 CTUs (Table 5); however, others have estimated that Chinook required up to 900 – 1,000 CTUs to hatch (Raleign et al. 1986). For this analysis we assume that Chinook eggs required 530 CTUs to hatch. Based on the available 2013 temperature data for the East Fork Owyhee River, Chinook would achieve 530 CTUs and hatch from their eggs from 15 June to 14 July.

Task 3. We estimated the amount of time that Chinook spent post-hatch to absorb their yolk sacs. After hatching, Chinook larvae remain in the gravel for approximately 4-6 weeks (28–42 days) until the yolk sac is absorbed and alevins emerge (Moyle 2002b; Yoshiyama et al. 1998). For the purpose of this analysis, we used an average period of 5 weeks (35 days) between hatching and emergence, which would range from 20 July and 18 August, depending on early or late spawning (Table 6).

Both species are thought to spawn around high flow events, which occurred from approximately 4 April - 1 July, peaking from 17 June to 22 June in 2013 (87 cfs). Temperature optimums for steelhead and Chinook were achieved by May 5 and April 21, respectively. By the time either species were estimated to hatch (5 and 15 June for the early spawners), flows were peaking at approximately 84-86 CFS. Offspring of late steelhead spawners would likely hatch by 23 June, when flows remain relatively high (~86 CFS). For the late Chinook spawners, flows could be as low as 27 cfs. In 2013, there was a brief reduction in flow rates from 12 through 16 July, but then flows picked back up to about 70 cfs through 6 August.

Table 5. Number of days and CTU's required for steelhead and Chinook eggs to hatch. 1 CTU= 1°C above freezing x 24 hours; 5 CTU = 5°C above freezing x 24 hours.

Water Temp °C	Days to Hatch	CTU's	Reference
Steelhead			
4.4	88	356	Leitritz and Lewis 1976 (by Murrell 2006)
4.4	80	352	USFWS 1995
7.2	48	346	Leitritz and Lewis 1976 (by Murrell 2006)
8.9-11.1	21	249.2-310.8	DWR et al. 2000
10-15	21-28	210-420	Moyle 2002
10	31	310	Leitritz and Lewis 1976 (by Murrell 2006)
10.6	30	328.6	McEwan et al. 1996
12.8	24	306	Leitritz and Lewis 1976 (by Murrell 2006)
15.6	19	296	Leitritz and Lewis 1976 (by Murrell 2006)
15.6	19	296.4	USWS 1995
Chinook			
4	129	516	Beacham et al. 1989
8	70	560	Beacham et al. 1989
12	44	528	Beacham et al. 1989
15	35	525	Beacham et al. 1989

Table 6. Estimated range for Steelhead spawning, hatching and emergence based on 2013 temperatures.

Life Event	Early spawners	Late spawners
Steelhead		
Spawn	May 5	30 May
Hatch	5 June	23 June
Emerge	10 July	28 July
Chinook		
Spawn	April 21	June 8
Hatch	15 June	14 July
Emerge	20 July	18 August

Habitat Morphology

Surveys of the mainstem Owyhee and its tributaries were initially summarized before UCM model predictions were calculated. Approximately 11 km (Table 9) of stream was surveyed between all seven spatial reaches. Each reach is summarized in detail below.

Mainstem

Reach 1

Observed Morphology

As expected prior to field surveys, reach 1, the upper basin, consisted predominately of riffles, rapids, and pools with an occasional glide and beaver pond (Figure 15). Substrate consisted heavily of boulder and cobble and very little area was observed with fine sediments. Throughout the Owyhee basin extensive beaver activity and pond networks were observed, except in reach 1 and reach 3, only one beaver pond was observed and none were observed respectively. Table 9 displays various summary statistics for the section of stream surveyed along mainstem reach 1, specific to each channel unit type.

Reach 2

Observed Morphology

Reach #2 of the field study differed quite significantly from the upper canyon reach. This section of the river exhibited mostly pool and riffle morphology (Figure 16). Rapids were not observed in the surveyed section of reach 2. The substrate consisted primarily of fines, gravel, and cobble. With the large presence of pool units, the high observed amounts of fines are to be expected. Multiple gravel patches were observed in this reach and will be important in quantifying salmonid suitability in carrying capacity modeling. Table 10 summarizes various statistics for the section of stream surveyed along mainstem reach 2, specific to each channel unit type.

Reach 3

Observed Morphology

The lower reservation reach of the mainstem was characteristically similar to the middle reach and was dominated by pools and riffles. However, this reach contained more frequently larger substrate of cobble and gravel when compared to the middle section of the river (Figure 17). Interestingly little beaver activity was observed in this section. Table 11 summarizes various statistics for the section of stream surveyed along mainstem reach 3, specific to each channel unit type.

Table 7. Summaries of the total distance survey for each stream reach.

Reach ID	Distance Surveyed (km)	Reach Length (km)	Notes
1	2.3	13.78	
2	3.5	22.69	
3	3.2	15.13	
Slaughter	0.33	3.16	
Skull	0.65	5.8	
Van Duzer	0.71	4.5	
Trail	0.41	2.7	Dry stream
Allegheny	0.16	7.8	Dry, stagnant pools
California	0	8.5	Dry not surveyed
Total	**11.26**	**83.96**	

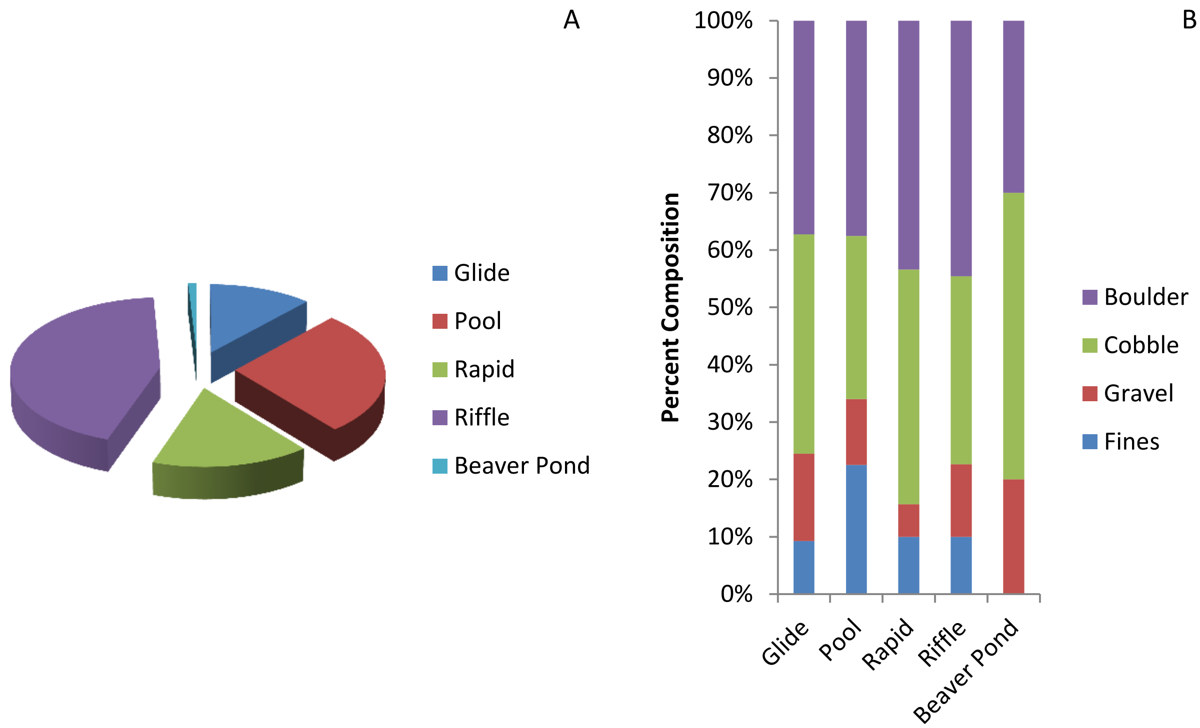

Figure 15. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for reach 1.

Table 8. Summary of channel unit measurements for mainstem reach 1.

	Mainstem Reach 1					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	21	21	21	21	1	NA
Glide	11	25.9	20.5	52	10	16
Pool	6	30.4	23.5	70	20	21.02
Riffle	3	19.83	17	43	18	10.48
Rapid	10	38.88	30	124	25	31.24
	Width					
Beaver Pond	8	8	8	8	1	NA
Glide	2.73	6.04	5.79	38	10	2.33
Pool	3.25	8.56	7	11.5	20	7.15
Riffle	2.25	5.57	6.08	12.5	18	1.85

Rapid	3.5	7.65	7.4	7.75	25	2.43
	Depth					
Beaver Pond	1	1	1	1	1	NA
Glide	0.2	0.35	0.34	2	10	0.08
Pool	0.44	0.81	0.8	0.46	20	0.33
Riffle	0.09	0.23	0.21	0.5	18	0.08
Rapid	0.13	0.31	0.31	0.33	25	0.1

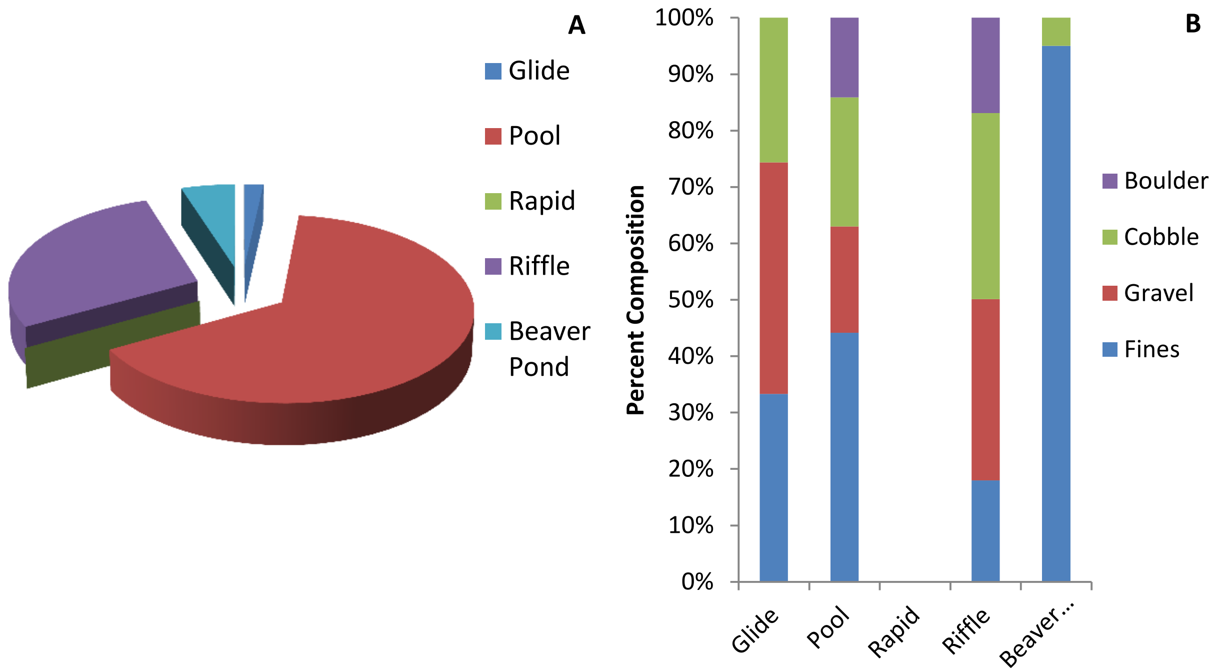

Figure 16. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for reach 2.

Table 9. Summary of channel unit measurements for mainstem reach 2.

	Mainstem Reach 2					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	161	161	161	161	1	NA
Glide	35	35	35	35	1	NA
Pool	11	56.78	42	356	37	60.18
Riffle	9	23.23	22	70	40	13.7
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Width					
Beaver Pond	12	12	12	12	1	NA
Glide	7	7	7	7	1	NA
Pool	5	8.7	8	14.6	37	1.98
Riffle	4	8.57	8.9	13.5	40	2.22

Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Depth					
Beaver Pond	1.4	1.4	1.4	1.4	1	NA
Glide	7.31	7.31	7.31	7.31	1	NA
Pool	0.4	0.74	0.7	1.2	37	0.19
Riffle	0.13	0.33	0.29	1.64	40	0.23
Rapid	N/A	N/A	N/A	N/A	N/A	N/A

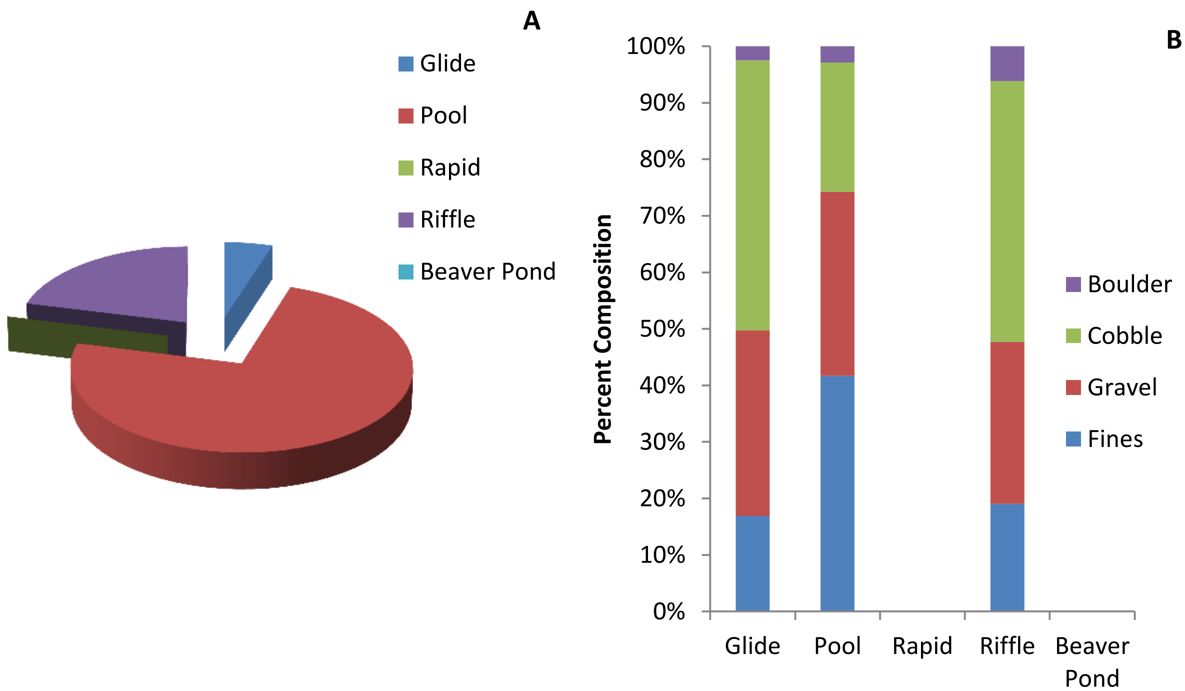

Figure 17. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for reach 3.

Table 10. Summary of channel unit measurements for mainstem reach 3.

	Mainstem 3					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	N/A	N/A	N/A	N/A	N/A	N/A
Glide	9	27.8	19	70	5	24.28
Pool	9	89.87	50	809	23	161.52
Riffle	8	26.86	17	83	22	20.11
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Width					
Beaver Pond	N/A	N/A	N/A	N/A	N/A	N/A
Glide	3.35	6.39	5	11.67	5	3.25
Pool	5.5	10	10.33	16.5	23	2.84

Riffle	4.5	9.68	9.68	14.5	22	3.08
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Depth					
Beaver Pond	N/A	N/A	N/A	N/A	N/A	N/A
Glide	0.17	0.24	0.24	0.29	5	0.05
Pool	0.4	0.89	0.9	1.5	23	0.25
Riffle	0.12	0.2	0.2	0.36	22	0.05
Rapid	N/A	N/A	N/A	N/A	N/A	N/A

Tributaries

Slaughterhouse Creek

Slaughterhouse Creek proved to be a tributary that supported flowing water through the summer time providing habitat for juvenile and young of the year. This tributary was dominated by extensive beaver pond networks, small pools and riffles (Figure 18) and consisted of smaller substrate (i.e. fines). Table 12 summarizes various statistics for the section of stream surveyed along Slaughterhouse Creek, specific to each channel unit type.

Skull Creek

Consisting mainly of large beaver ponds, small pools, and riffles (Figure 19) Skull Creek is another tributary that that proved to have populations of juvenile redband trout. These ponds, pools, and riffles were covered primarily in fines and gravel with slightly more cobble than observed in Slaughterhouse Creek. Table 13 summarizes various statistics for the section of stream surveyed along Skull Creek, specific to each channel unit type.

Van Duzer Creek

Van Duzer Creek, one of the most highly accessed streams for irrigation purposes was primarily dominated by beaver ponds. A section located above initial beaver ponds contained few small riffles and pools. Fines and gravel were largely observed in this tributary and very few larger substrates (Figure 20). Table 14 summarizes various statistics for the section of stream surveyed along Van Duzer Creek, specific to each channel unit type.

California, Trail, and Allegheny Creeks were found to be dry streams during 2013 field surveys; thus, they were not included in full habitat assessments. Observations and basic measurements were made of some gravel patches in Allegheny Creek but will not be included in habitat summaries or capacity estimates due to the absence of flowing water. Trail Creek was surveyed about a half a kilometer upstream from its confluence with Van Duzer Creek. It was at this point upstream that we found Trail Creek to be also without flowing water. We encountered scattered stagnant pools and dry gravel patches in the section of Trail Creek we did survey. Trail Creek stream bed is fairly substantial with potential for both spawning and rearing capacity during a year with increased water flow and snow melt. Trail Creek will also be excluded from capacity estimates due to the absence of flowing water. All three of these tributaries should be reexamined during future habitat assessment surveys with higher observed flows.

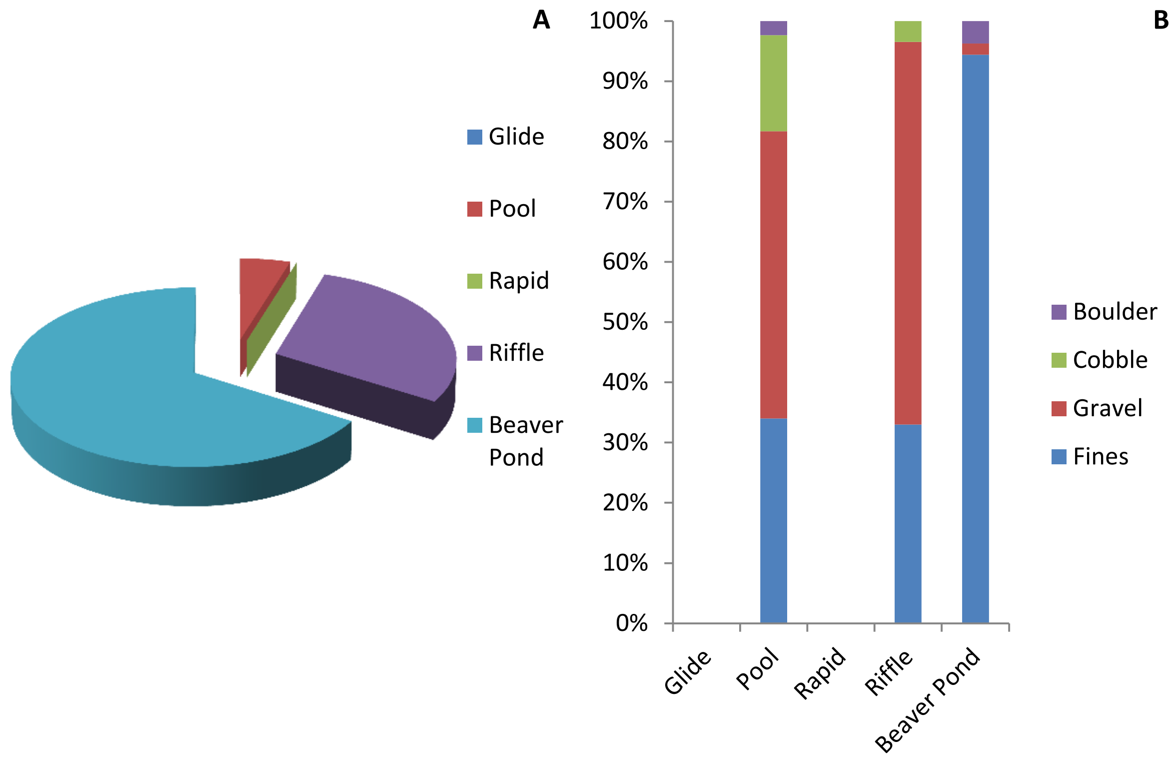

Figure 18. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for Slaughterhouse Creek.

Table 11. Summary of channel unit measurements for Slaughterhouse Creek.

	Slaughterhouse Creek					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	10	24.11	24	46	9	12.28
Glide	N/A	N/A	N/A	N/A	N/A	N/A
Pool	0.76	1.97	1.55	3.6	8	1
Riffle	0.8	9.55	7	26	10	7.43
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Width					
Beaver Pond	6.28	13.98	9.67	23.67	9	7.04
Glide	N/A	N/A	N/A	N/A	N/A	N/A
Pool	0.8	1.8	1.7	2.77	8	0.78
Riffle	0.9	1.39	1.21	2.8	10	0.57

Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Depth					
Beaver Pond	0.5	1.01	1	1.5	9	0.43
Glide	N/A	N/A	N/A	N/A	N/A	N/A
Pool	0.1	0.2	0.2	0.3	8	0.07
Riffle	0.04	0.07	0.07	0.09	10	0.01
Rapid	N/A	N/A	N/A	N/A	N/A	N/A

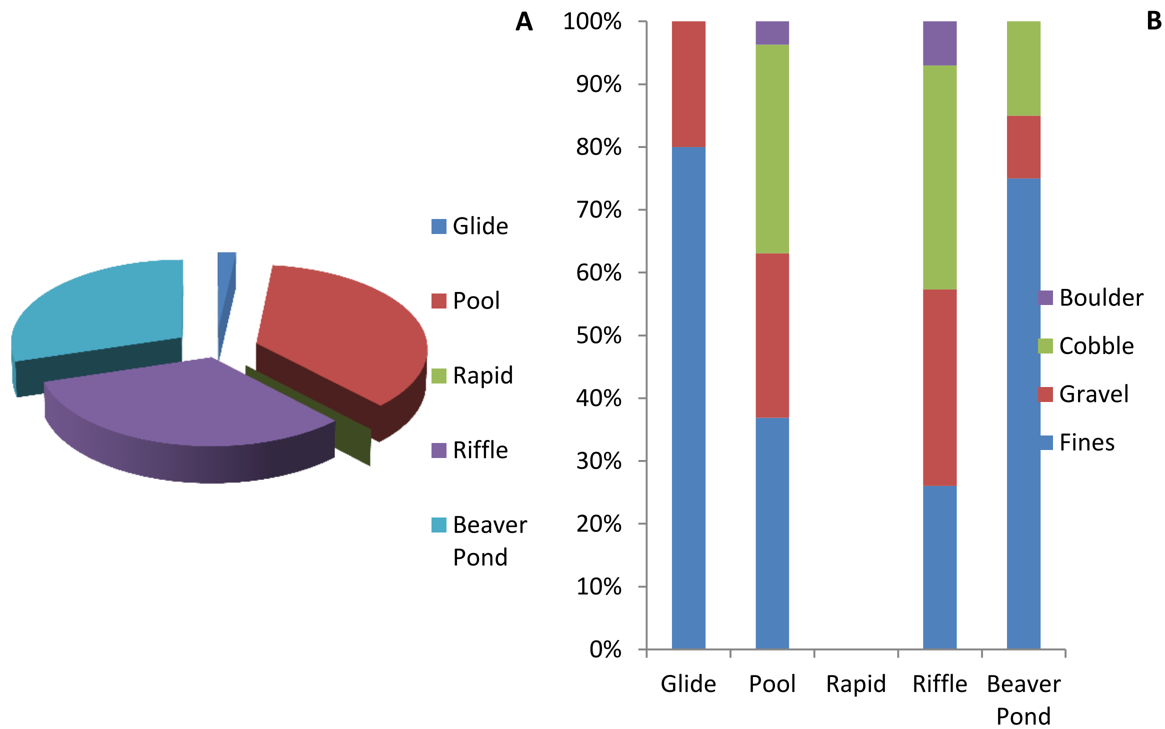

Figure 19. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for Skull Creek.

Table 12. Summary of channel unit measurements for Skull Creek.

	Skull Creek					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	38	60	42	100	3	34.7
Glide	11	11	11	11	1	NA
Pool	4	9.12	7	21	24	4.7
Riffle	3	8.56	9	18	23	4.32
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Width					
Beaver Pond	14.25	48.86	43	89.33	3	37.88
Glide	0.9	0.9	0.9	0.9	1	NA
Pool	1.5	2.83	2.46	8.5	24	1.39

Riffle	1.05	2.43	1.95	15.33	23	2.88
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Depth					
Beaver Pond	1	1	1	1	3	NA
Glide	0.13	0.13	0.13	0.13	1	NA
Pool	0.16	0.29	0.29	0.5	24	0.08
Riffle	0.06	0.1	0.1	0.16	23	0.03
Rapid	N/A	N/A	N/A	N/A	N/A	N/A

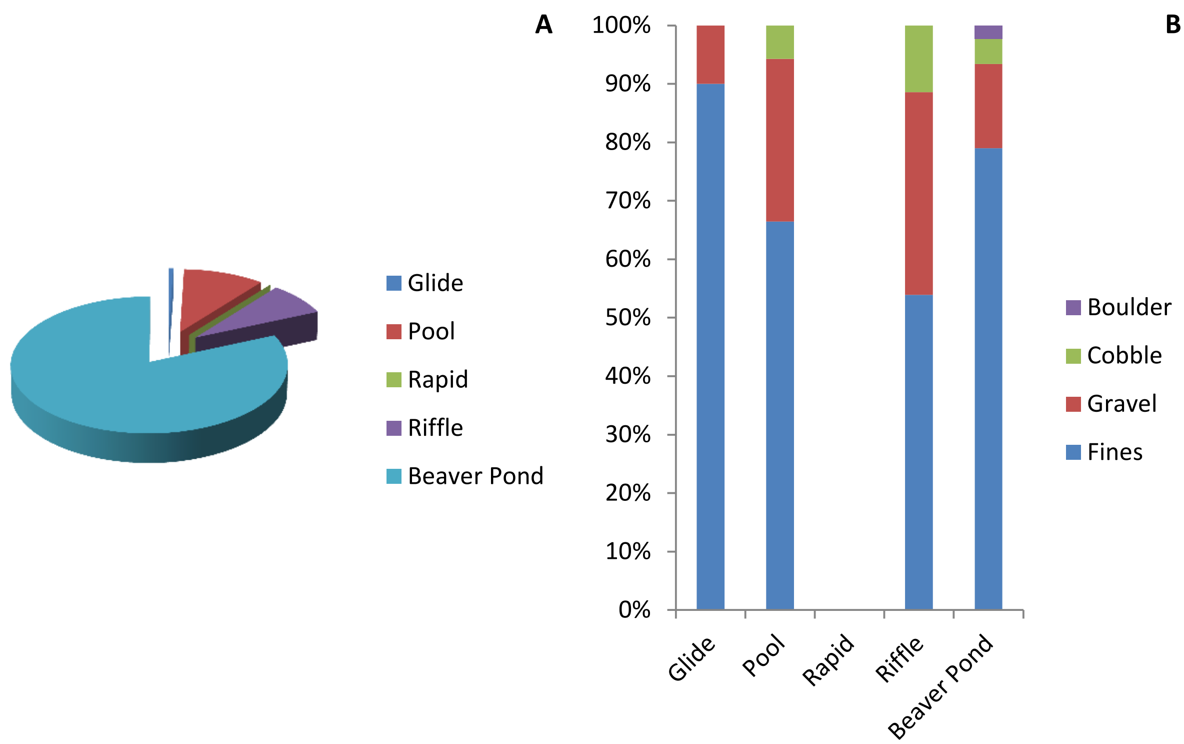

Figure 20. Habitat data summarized based on channel unit make up (A) and substrate composition of those channel units (B) for Van Duzer Creek.

Table 13. Summary of channel unit measurements for Van Duzer Creek.

	Van Duzer Creek					
Habitat Type	**Min**	**Mean**	**Median**	**Max**	**N**	**SD**
	Length					
Beaver Pond	11	45	35	105	14	28.5
Glide	4	4	4	4	1	NA
Pool	1.5	5.17	4.45	13	14	3.02
Riffle	1	4.03	3.75	8.6	14	2
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Width					
Beaver Pond	2.87	7.34	4.12	20.8	14	6.27
Glide	1.15	1.15	1.15	1.15	1	NA
Pool	0.4	1.44	1.42	2.23	14	0.51

Riffle	0.55	1.04	0.88	2.45	14	0.47
Rapid	N/A	N/A	N/A	N/A	N/A	N/A
	Depth					
Beaver Pond	0.6	0.92	0.9	1.3	14	0.2
Glide	0.06	0.06	0.06	0.06	1	NA
Pool	0.09	0.3	0.3	0.5	14	0.12
Riffle	0.02	0.06	0.04	0.33	14	0.08
Rapid	N/A	N/A	N/A	N/A	N/A	N/A

Diversions

The East Fork Owyhee watershed is highly utilized for irrigating pastures and watering livestock. The Office of the State Engineer of the State of Nevada in 2010 addressed the water removal rights for the East Fork and its tributaries. The Preliminary Order of Determination signed by State Engineer Jason King on April 29th, 2010, addresses and categorizes each withdrawal and identifies the owner of operator based on use and permits filed. The Final Order of Determination has yet to be released.

Water withdrawals can drastically influence stream flow, water levels, and fish passage in a watershed dominated by irrigation. The list of recorded permitted diversions along the East Fork Owyhee was quite extensive requiring specific criteria be defined to eliminate those permits outside the area of interest. The list below has been created with local knowledge of specific withdrawals from Tribal members and with the support and knowledge of Nevada Division of Water Resources Water Specialist Steve Shell. Steve was a resource to effectively navigate the NDWR's extensive website and to efficiently narrow down the search based on descriptions provided by tribal experts. The list of diversions of interest is as follows (Figure 21):

1. *V05191*- Located off of Slaughterhouse creek this permit has a diversion rate of 3 cfs, and is used for irrigation. Owner of record: Dale Hoover and Rebecca Delaney
2. *V02650, 23604, 1529, V05184*- Four permits of interest exist off of Van Duzer creek. The cfs of these four permits is 2.5, 2, 1.6, and 3.5 respectively. Owner of Record (respectively): Wade and Cara Small, Dennis and Marcia Bieroth, John Angell, Shoshone-Paiute Tribes of the Duck Valley Indian Reservation.
3. *V05186*- This permit has a diversion rate of 2 cfs. Owner of record: Shoshone-Paiute Tribes of the Duck Valley Indian Reservation.
4. *V06522*-Devils Gate Draw with a diversion rate of .008 cfs and is used for stock watering livestock. Owner of Record: Shoshone-Paiute Tribes of the Duck Valley Indian Reservation.
5. *V06520* this particular diversion uses 0.008 cfs from Haystack Creek. Owner of Record: Shoshone-Paiute Tribes of the Duck Valley Indian Reservation.
6. *1841*-The permit of interest has a rate of .24 cfs on Allegheny Creek. Owner of Record: Grover F. West.
7. *V06712*- Ross Gulch- This particular permit pulls 0.028 cfs of water. Owner of Record: Simplot Livestock Company.

8. *V03707, V02277, V02276*- East Fork Owyhee River- These three permits are located directly off the East Fork Owyhee River pull off 2.5, 0.1, 0.353 cfs respectively. Owner of Record: Casey W. Bieroth, Shoshone-Paiute Tribe, and Shoshone-Paiute Tribe respectively.

Originally we had intended to visit and assess each diversion from the above stated list for compliance with requirements for proper fish passage and water withdrawals. This was not completed during 2013 summer surveys and should be thoroughly examined pending 2014 summer field investigations approval. Evaluating these water withdrawals at peak irrigation periods is important to understand the full effects these diversions have on fish population potential. This period was missed by field crews during the summer of 2013. The above described list of diversions should be further discussed with region experts to further identify and rule out sites for further investigation.

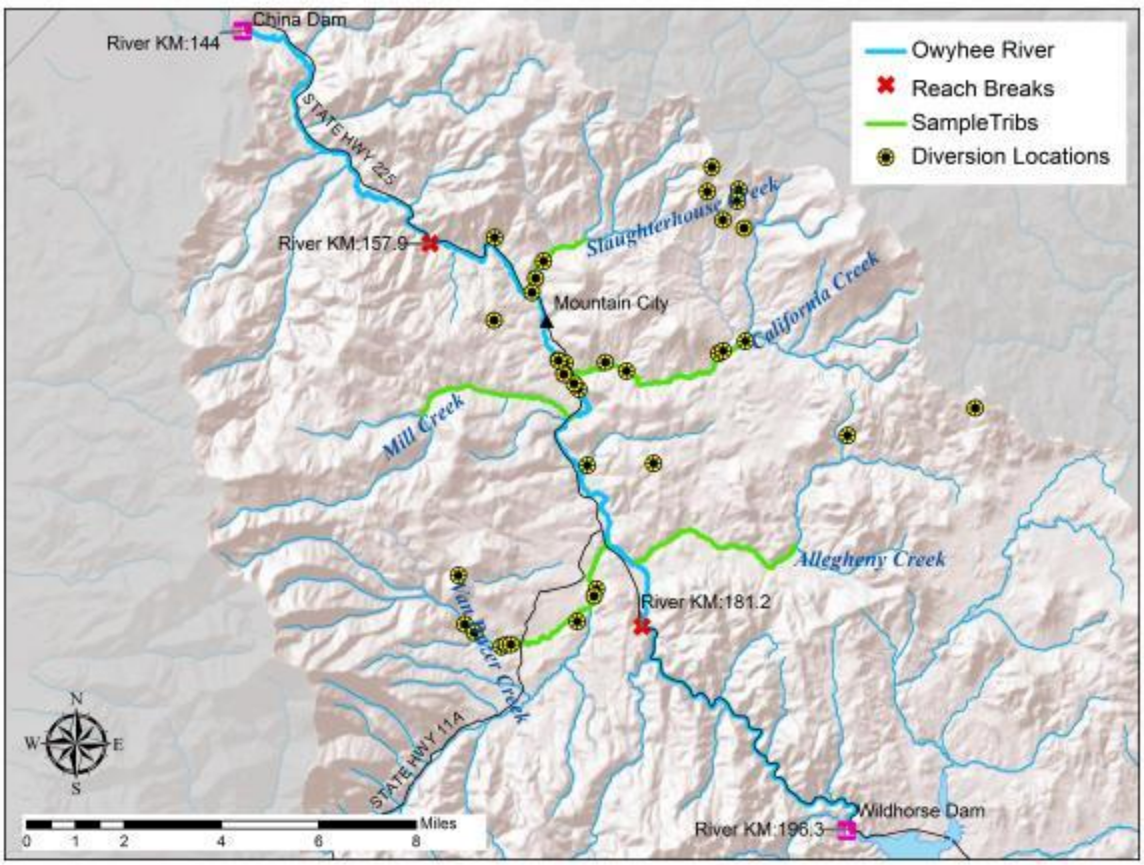

Figure 21. Locations of water withdrawals within study area. Locations provided by Steve Shell at NDWR.

Carrying Capacity Estimates

Baseline Capacity

Baseline juvenile rearing capacity estimates indicate the highest rearing capacity in mainstem reach 1, 17,590 steelhead and 11,442 Chinook. Modest rearing capacity was also estimated for mainstem reaches 2 and 3, as well as Skull Creek (Figure 22, Figure 23; Table 15). Maximum weekly average temperatures (MWAT) used to calculate rearing capacity in each spatial reach were all between 17 and 20^{o}C, which had an effect on estimates of rearing potential (Table 16).

Potential redd deposition and resulting juvenile parr production were also estimated for each survey reach. Redd estimates were highest in mainstem reaches 2 and 3 for both steelhead trout and Chinook salmon (Figure 24). Of the three tributaries surveyed in 2013, only Skull Creek was predicted to possess the habitat requirements necessary for spawning steelhead (Figure 25). Very little Chinook spawning capacity was predicted in tributary streams.

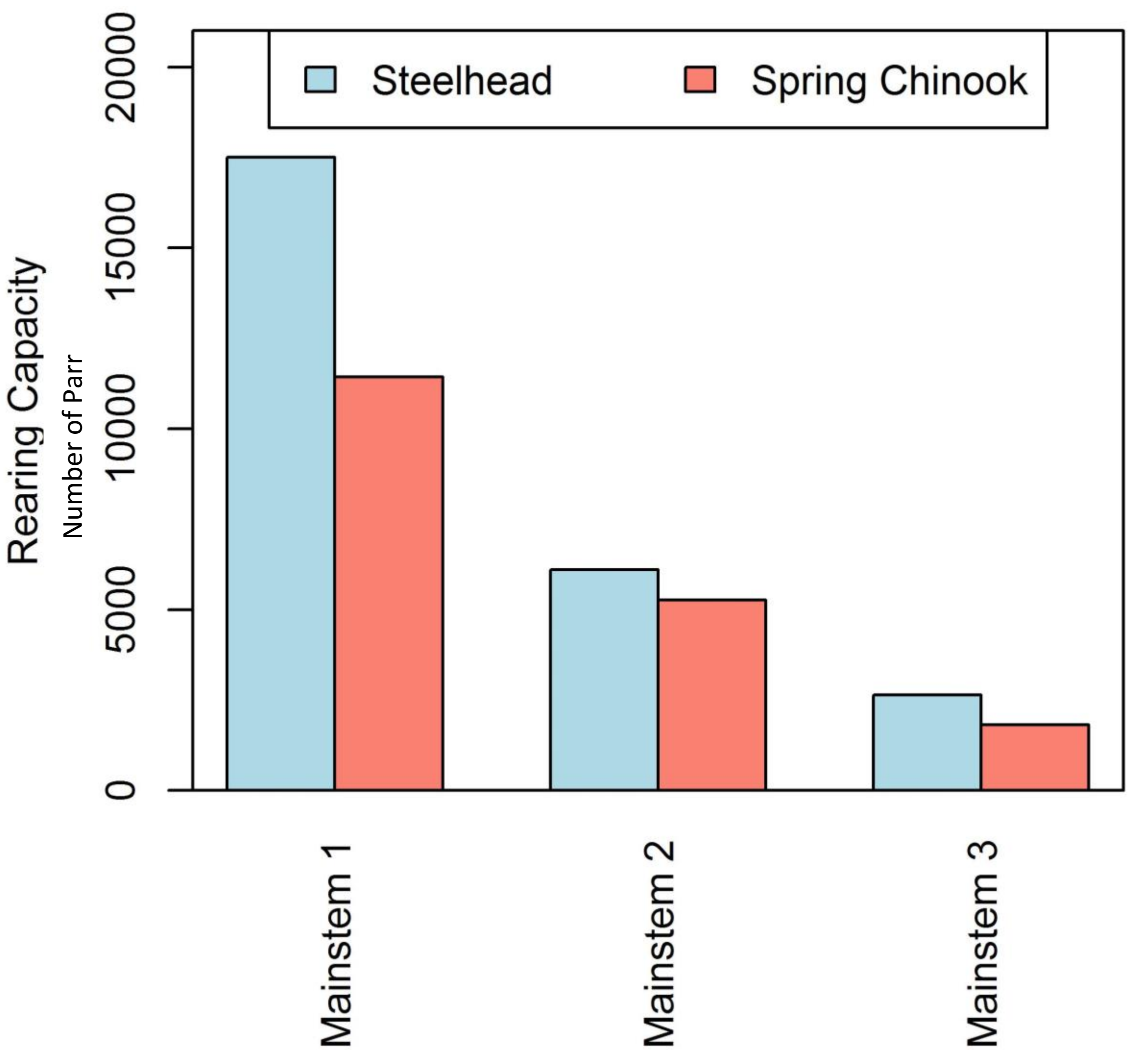

Figure 22. Estimated rearing capacity in mainstem reaches during 2013.

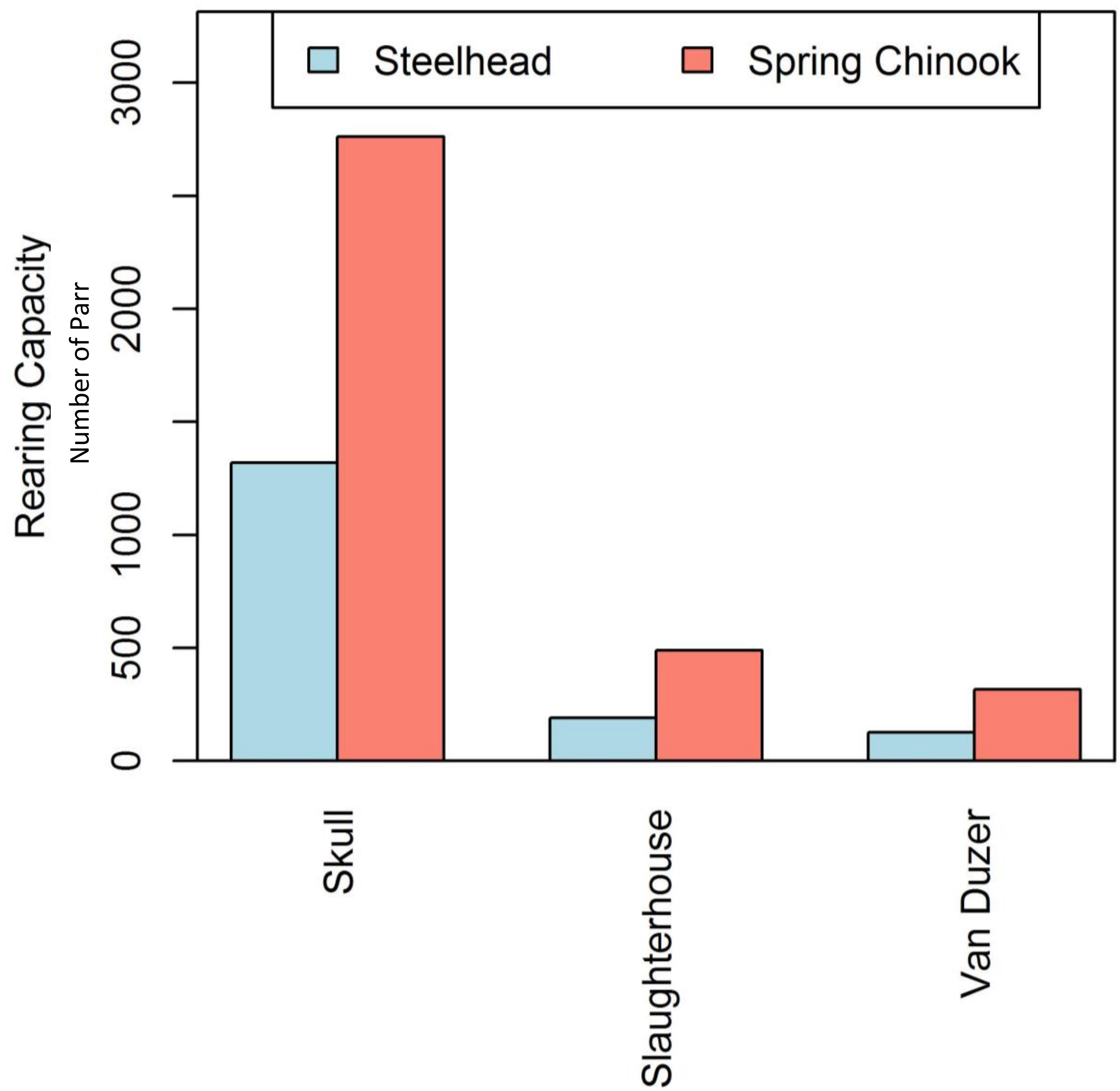

Figure 23. Estimated rearing capacity in tributaries during 2013.

Table 14. Rearing capacity estimates for mainstem and tributary reaches during 2013.

Reach	Redband Steelhead	Spring Chinook
Mainstem 1	17,509	11,442
Mainstem 2	6,112	5,275
Mainstem 3	2,645	1,817
Skull	1,319	2,762
Slaughterhouse	192	490
Van Duzer	128	316
Totals	27,905	22,108

Table 15. Maximum weekly average temperature (MWAT) by temperature probe location.

Symbol	MWAT	Location	Reach ID
M1	18.7	EF Owyhee River Wildhorse	1
M2	18.5	EF Owyhee River Rizzi Diversion	1/2
M3	18.8	EF Owyhee River Van Duzer	2
M4	19.1	EF Owyhee River South of Mountain City	2
M5	19.5	EF Owyhee River Duck Valley Sign	Reach 2/3
M6	20	EF Owyhee River China Dam	3
T3	17	Van Duzer Creek	Van Duzer Creek
T7	16.6	Slaughter House Creek	Slaughterhouse Creek
T10	18.2	Skull Creek	Skull Creek

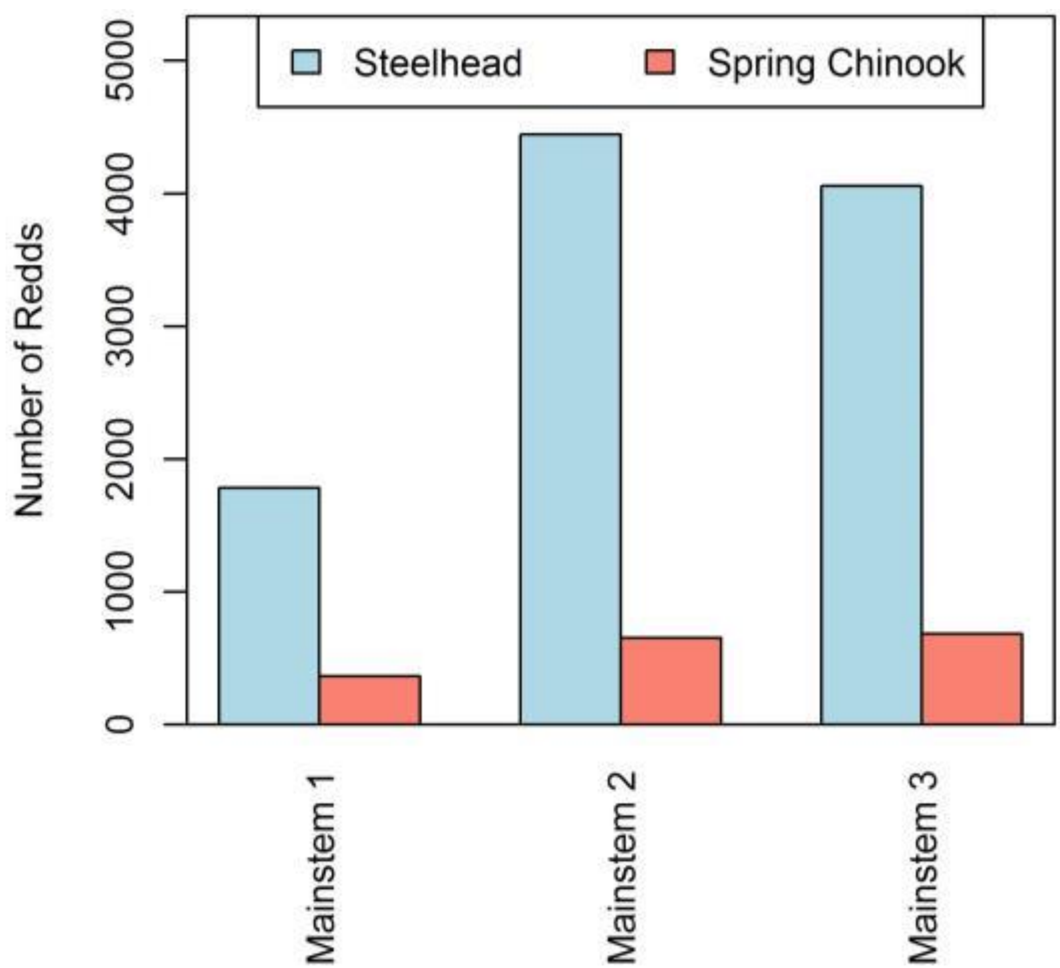

Figure 24. Estimated number of redds in mainstem reaches during 2013.

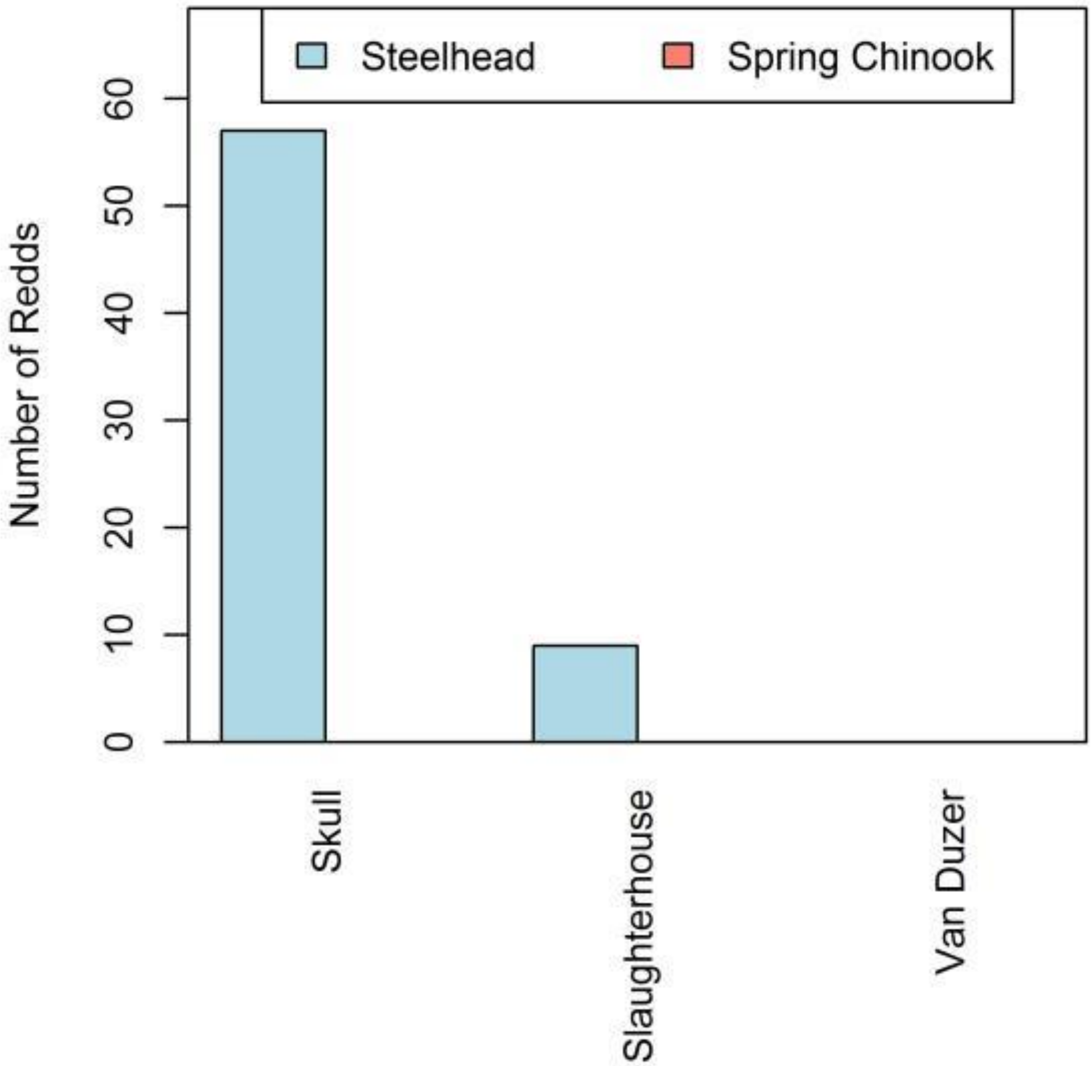

Figure 25. Estimated number of redds in tributaries during 2013.

Capacity Changes in Response to Flow and Temperature

Rearing capacity modeled across a range of flow conditions indicated a large effect of flow in mainstem reach 1, with nearly 25,000 more parr possible at 100 cfs given an average of 16°C than 22°C. Flow had a lesser effect in mainstem reaches 2 and 3 (Figure 26, Figure 27). Modeled changes in carrying capacity were sensitive to temperature changes in all three mainstem reaches. Similarly, spawning habitat estimates increased substantially with increasing flows (Figure 28, Figure 29). However, the most notable increases in spawning habitat occurred in mainstem reaches 2 and 3, where baseline capacity estimates were highest. When comparing both spawning and rearing capacity estimates it is apparent that rearing habitat would be expected to limit salmon and steelhead production across the full range of flows simulated.

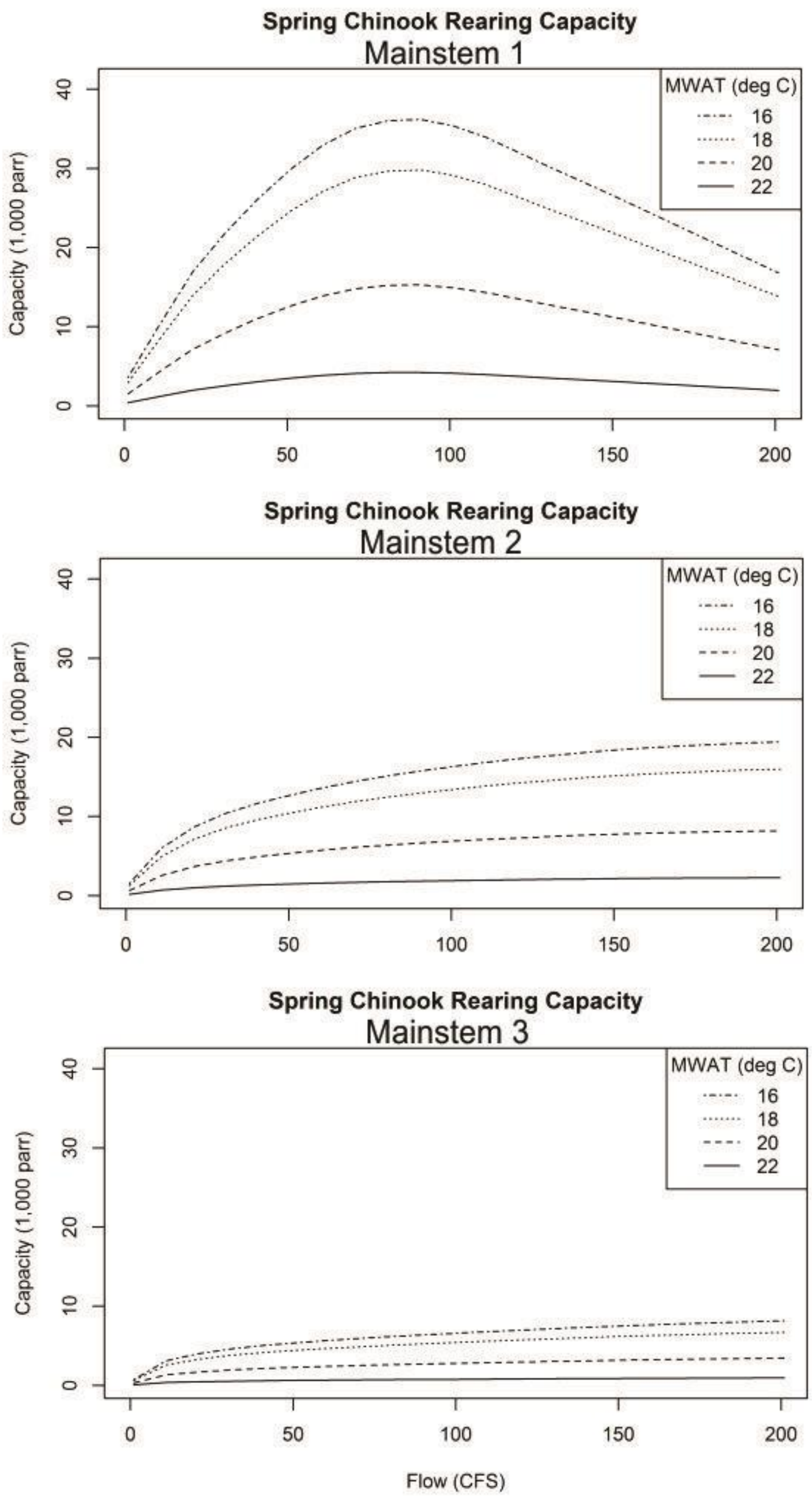

Figure 26. Spring Chinook rearing capacity potential in each mainstem reach when compared to increasing flow and increasing MWATs.

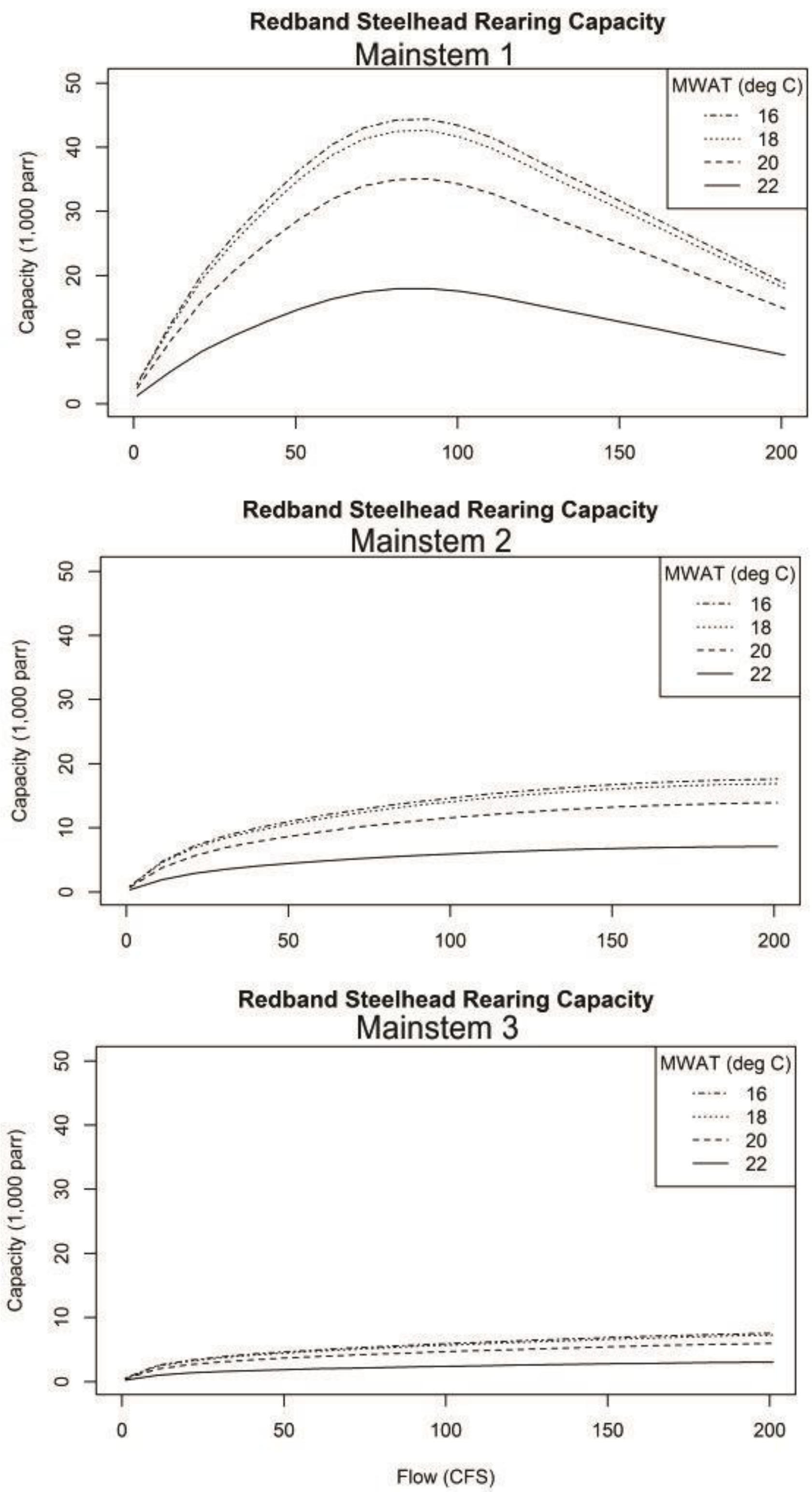

Figure 27. Steelhead rearing capacity potential in each mainstem reach when compared to increasing flow and increasing MWATs.

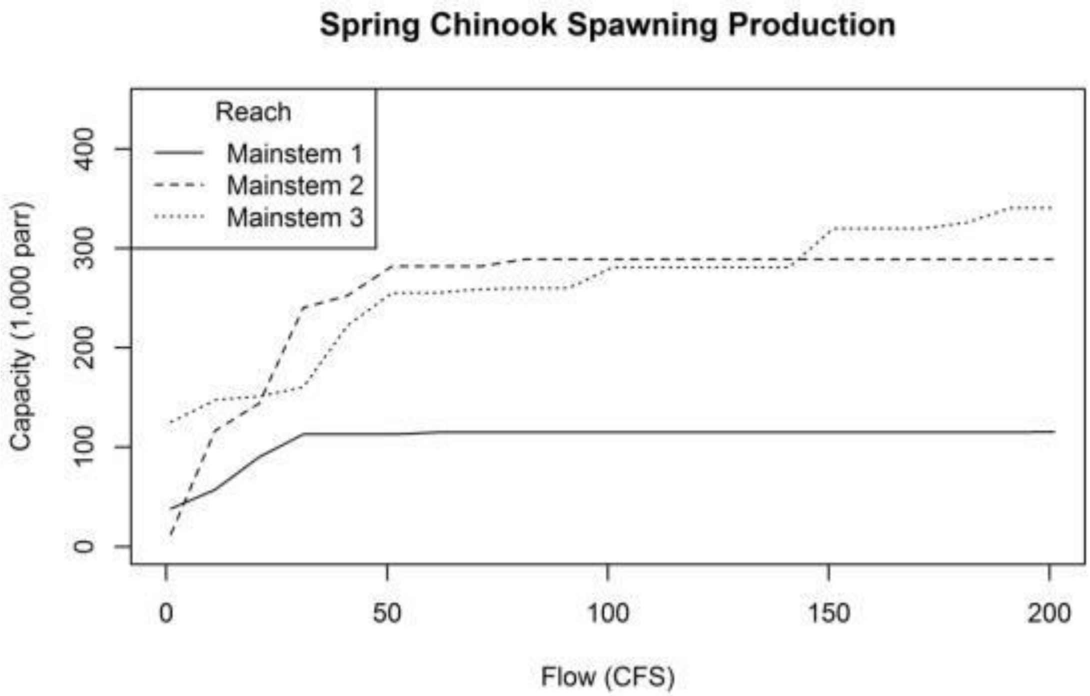

Figure 28. Modeled Spring Chinook spawning production when flow is increased in each mainstem reach.

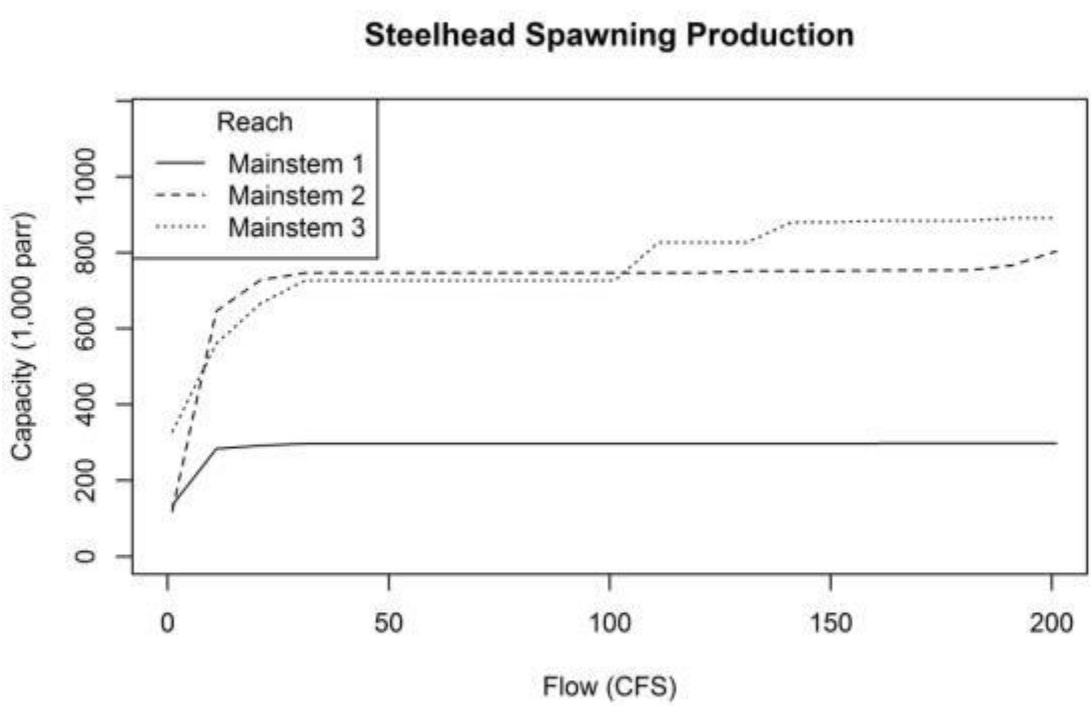

Figure 29. Modeled steelhead spawning production when flow is increased in each mainstem reach.

CURRENT FISH POPULATIONS

Redband Trout

Redband trout (*Oncorhynchus mykiss gairdneri*) are a subspecies of rainbow trout that thrive in desert streams and are common in interior Columbia Basin tributaries such as the East Fork Owyhee River. Redband trout require many of the same habitat features as salmon and steelhead and, therefore, provide a reasonable indicator of habitat suitability in this system. Johnson (2000) estimated density (Table 17) of redband trout from Wildhorse Dam to the DVIR and found the largest density of trout in the upper portion of the watershed near the confluence of Beaver Creek just below Wildhorse Dam. The lower section of the survey revealed significantly lower numbers of redband trout per mile than the upper canyon section and increased number of redside shiner, sculpin, and sucker fish most likely due to the change in channel unit morphology and composition.

Zoellick et. al. (2005) calculated density estimates of Redband Trout per 100 m^2 between the periods of 1977-1982 and between 1993-2000 for areas along the North Fork Owyhee and a number of its tributaries (Table 18). Based on their results the authors concluded that redband trout populations have remained relatively stable in the past 15-20 years, occupying similar areas during the first sampling period as the second and appearing to increase in density in some streams. However, in 2012, a redband trout status review was distributed by Wild Trout Enterprises, updating previous broad-scale assessments. This project was constructed with the involvement of over 150 biologists and data entry personnel (May 2012). The authors estimated that the upper Owyhee redband trout distribution has declined by 80% compared with historic conditions (Table 18 & Table 20).

Table 16. East Fork Owyhee River Redband trout abundance estimates for upper and lower river reaches. (Adapted from Johnson 2000).

Species	Upper Reach Fish/mile	Lower Reach Fish/mile
Rainbow (Redband)	298.1	68.6
Brown	192.1	10.6
Yellow Perch	18.9	0
Redside Shiner	17.7	2576.6
Sculpin	374.4	1140.5
Sucker	28.8	121.4

Table 17. Zoellick et. al. (2005) density estimates of Redband Trout for the North Fork Owyhee and tributaries.

Density trout/100m^2

	1977-1982			1993-2000		
Owyhee River Drainage	Estimate	95% CI	Year	Estimate	95% CI	Year
North Fork Owyhee River	0		1977	0		2002
North Fork Owyhee River	0		1977	0		1997
Juniper Creek	0		1977	4.1	4.1-4.6	1996
Cabin Creek	0		1977	52.3	52.3-53.1	1996
Corral Creek	0.7		1977	15.2	15.2-16.8	2001
Pole Creek	0		1979	0		2000
Deep Creek	12.5	11.8-15.1	1977	0		1997

Table 18. Historical vs. Current Redband occupied habitat in Owyhee River Basin. Adapted from May (2012).

Watershed	**Historical Occupied Habitat**	**Current Occupied Habitat**
	Stream Length	Stream Length
Upper Owyhee	1427	292
South Fork Owyhee	800	188
Middle Owyhee	518	387
Lower Owyhee	278	151

Table 19. Fish density intervals and length of streams at those density intervals occupy. Adapted from May (2012).

Fish Density (fish/km)	**Stream km**	**% Occupied**
0-35	9,040	36
36-100	2,997	12
101-250	1,565	6
251-625	1,125	4
626-1250	451	2
>1250	158	<1
Unknown	10,081	40
Totals	25,417	100

Fish Sampling

An important component of our study involved the collection of tissue samples from native redband trout. These tissue samples were collected to establish a genetic baseline for native salmonids in the Basin prior to salmon and steelhead reintroduction. Though not intended for use as a measure of relative abundance, field crews observed similar distribution patterns to those observed by Johnson (2000). Table 20 summarizes the numbers of fin clips collected in each survey reach; sampling efforts were not equivalent between reaches because of variable weather conditions and timing. Prior to field sampling CFS had planned on collecting full bodied fish for disease analysis later in 2014. Disease collection did not take place in 2013 and will occur during summer 2014.

Table 20. Total number of fin clips sampled from each designated stream reach.

Reach ID	Fin clips collected	Effort (seconds)
1	4	9000
2	9	10800
3	20	18000
Slaughter	18	5400
Skull	13	7200
Van Duzer	2	7200
Trail	0	0
Allegheny	0	0
California	0	0
Total	**66**	**57600**

Weir Placement

Criteria used to identify and select potential locations for the installation of weirs for a put-and-take-fishery will be taken into account when making this designation in 2014. The following guidelines will be used:

1. Flat and uniform river bottom with small gravel of cobble substrate;
2. Even flow dynamics and stream velocities less than 1.0 cubic meter per second; and
3. Straight stream reach less than 1 meter in depth

Other factors that will be taken into account when selecting the best location for a weir include ease of access and tribal land ownership. Based on habitat type, channel morphology, and the above stated criteria, the ideal placement of weirs in support of a put-and-take fishery would be on tribal land from the southernmost reservation boundary to China Dam. Although a more in-depth discussion with tribal experts and CFS weir experts will be conducted prior to a finalized placement decision.

DISCUSSION

The first phase of the East Fork Owyhee River Salmon and Steelhead Recovery Project was designed to assess habitat conditions and determine the Basin's ability to support self-sustaining anadromous salmonid populations following initiation of a truck-and-haul program. Literature review, habitat surveys, carrying capacity modeling, and hydraulic modeling were utilized to accomplish this task. Results of our assessment were also used to identify factors expected to limit salmon and steelhead production, which provided a basis for prioritizing habitat restoration actions in the Basin.

Summer habitat conditions in the East Fork Owyhee River were found to be a mix of large pools with an average depth of 0.8 meters and shallow riffles, typically not deeper than 0.3 meters. Substrates were comprised predominantly of cobble and boulder at higher elevations in the watershed with progressively larger quantities of gravel and fines as distance increased downstream of Wildhorse Dam. Water temperature did not vary longitudinally in the mainstem. MWATs calculated from temperature monitoring in 2013 ranged between 18.5^{o}C and 20^{o}C in all three mainstem reaches.

Habitat conditions in Skull, Slaughterhouse, and Van Duzer Creeks (the three tributaries surveyed with water flow in 2013) had similar mesohabitat composition. Tributaries were dominated by beaver ponds and shallow riffles with abundant quantities of fine sediment substrates and moderate quantities of gravel. Tributary water temperatures were generally cooler those observed in the main stem.

A fairly steep rocky canyon confines the main stem of the East Fork Owyhee below Wildhorse Dam which is expected to support the highest salmonid densities of all mainstem sites assessed (Johnson 2000). Habitat-based capacity estimates support this assertion with a baseline estimate from habitat data collected in 2013 of 17,509 juvenile steelhead and 11,442 juvenile Chinook in reach 1. Compared to mainstem reach 1, juvenile capacity estimates for mainstem reaches 2 and 3 were roughly 65% less for steelhead and 50% less for Chinook. Conversely, mainstem spawning capacity estimates indicate more potential for redd deposition at lower elevations, where the stream gradient is reduced and the channel broadens. Mainstem reaches 2 and 3 were estimated to possess steelhead redd capacities greater than 4,000 and Chinook redd capacities greater than 600, while mainstem reach 1 redd capacities were approximately 50% less for both species. Skull Creek and Slaughterhouse Creek both exhibited rearing capacity of significance for both steelhead and Chinook. Skull Creek was predicted to have spawning and rearing habitat capacity, with capacity estimates of about 60 steelhead redds and juvenile rearing capacities of 1,319 and 2,762 for steelhead and Chinook respectively. Slaughterhouse Creek had predicted capacity that was slightly less than Skull Creek of 490 and 192 Chinook and Steelhead respectively. Given the abundance of available spawning gravels in the Basin, it appears that rearing habitat is likely to be the limiting factor for salmon and steelhead production. However, the impact of fine sediment on redds site selection and egg survival was not quantified during our assessment and may be important variables to examine prior to concluding that spawning habitat is not limiting.

Carrying capacity estimates derived from habitat data collected in 2013 were heavily influenced by stream flow conditions at the time of the survey which were extremely low, reflective of a drought. Summer flows measured at the USGS Gold Creek gauge below Wildhorse Dam (20 cfs) were equivalent to the 90% exceedance value for the period of record (1991-2012). We modeled habitat changes associated with alterations in stream flow conditions to derive estimates of salmon and steelhead capacity across a range of flow and temperature conditions, which had a large impact on predicted production potential. For example, in an average water year, summer base flows in the main stem would be approximately 50 cfs, which we predicted would equate to a juvenile rearing capacity estimate roughly twice the baseline values calculated from 2013 survey data. When accounting for the full range of summer flow and temperature conditions (90%-10% exceedance flow, 18-22^{o}C), we estimated that the annual summer rearing capacity for the entire study area could range between 3,300 and 43,000 juvenile steelhead trout and from 3,600 to 41,000 Chinook salmon, dependent upon meteorological conditions in the watershed.

There are three factors that appear to limit Chinook and steelhead production in the East Fork Owyhee River based on summer 2013 findings. These are high summer water temperatures, low flow conditions, and high volumes of fine sediments. Other noteworthy limiting factors include impaired water quality and migration passage conditions at irrigation diversion structures. Restoration activities that address these issues are likely to produce the greatest benefit for anadromous fish.

High summer water temperatures are a significant limiting factor for salmonids in high desert streams like the East Fork Owyhee River due to the combination of low flow conditions and warm air temperatures. We measured temperatures greater than 20^{o}C at multiple locations while monitoring in 2013. Similarly, monitoring activities carried out by Trout Unlimited in 2012 also measured summer water temperatures in the 20s along the mainstem and tributaries. Maximum Weekly Average Temperatures (MWAT) were calculated for all surveyed areas during our assessment, all of which exceeded 18^{o}C along the mainstem river which is above the temperature requirements for optimal salmonid growth (~16^{o}C). Salmonids are known to seek out thermal refugia at 19^{o}C (Sutton 2012) and fish unable to find cooler water typically begin to experience reduced growth and eventually mortality at sustained temperatures between 18^{o}C and 25^{o}C (Ackerman 2007). According to Hicks (2000) temperatures greater than 21^{o}C and 23^{o}C expose Chinook and steelhead, respectively, to acute lethality (cited in Sutton 2007). Conversely numerous studies have cited upper critical temperatures for Redband trout to 26.9^{o}C-29.8^{o}C (Cassinelli and Moffitt 2010). Continued temperature monitoring is recommended in the East Fork Owyhee River, and activities that reduce summer water temperatures, such as riparian plantings and mobilization of embedded course sediments (gravels and cobbles) would likely be effective temperature mitigation measures.

Low summer flows are another important limiting factor for salmon and steelhead production in the East Fork Owyhee River. Seasonal low flows are caused by the arid climate in the region, as well as irrigation practices. Flows frequently drop to less than 20 cfs in the mainstem during summer months, at which point fish become confined to pools and beaver ponds. Though the river likely historically dropped to very low summer flow levels prior to irrigation development, it is possible with present-day management to artificially increase flows in the summer via water releases from Wildhorse Reservoir, and/or reduced downstream water withdrawals. We would expect similar results from reduced withdrawals in tributary habitats, such as Van Duzer, Slaughterhouse, and Skull Creeks. We predicted that increasing in-stream flow during the summer would result in steadily increasing juvenile salmonid rearing capacity in mainstem reach 1 up to about 90 cfs. Flows higher than 90 cfs would be expected to have minimal effects on rearing capacity. Mainstem reaches 2 and 3 exhibited a less pronounced response to flow due to the composition of geomorphic habitat units and large quantities of fine sediment substrates that resulted in suboptimal juvenile rearing conditions.

Composition of streambed substrate is an important determinant of salmonid production; influencing availability of spawning habitat, cover for rearing juveniles, and invertebrate nursery areas. Scientists have shown that salmonid rearing densities decline as the percentage of fines rises above 10% of the streambed sediment composition (Platts 1979). Increases in fines can be caused by bank erosion from a variety of sources, including grazing and riparian degradation. We observed large deposits of fine sediments in lower elevation mainstem reaches, and in tributaries. Bank erosion, the primary cause of sedimentation, is common throughout the basin. Free range cattle practices can be linked to increased levels of fines in river systems due to increased bank erosion and riparian deforestation (Platts 1979). Studies that examined aquatic and riparian habitats that excluded domestic cattle grazing were able to support and sustain greater numbers of salmonids than streams with dominate grazing activity. Similarly, a study in the Deschutes Basin demonstrated that restricted grazing changed the fish assemblage from predominantly dace to rainbow trout (Platts 1979). Limiting grazing in riparian areas would be expected to reduce the amount of fines found in the river, increase riparian cover, and increase stream bank stability. Identifying or establishing a “demonstration” area along the East Fork Owyhee River that restricts grazing practices could provide a useful site for studying the effects of grazing on stream habitat.

Beavers and salmonids have co-existed for millennia throughout the Columbia Basin. Beavers can play an important role in the life-cycle of salmonids, providing pool habitat for rearing juveniles. Beaver ponds also promote riparian vegetation growth by slowing stream flow and preventing widespread flooding events. In turn, riparian vegetation provides shade and bank support, which prevents erosion. Although we observed ample evidence of beaver activity during our habitat surveys, particularly in tributaries, beaver dams were uncommon in the mainstem East Fork Owyhee River. This is likely related to the higher spring flows occurring in the mainstem, which would make permanent dams more difficult for the beavers to maintain. Encouraging beaver activity throughout the watershed would be beneficial to salmonid production.

Lastly, stream contamination from mining sites, pesticide application, urban development, and transportation activities along Nevada Highway 225 should be noted as possible threats to water quality conditions in the East Fork Owyhee River. Contaminated runoff is most likely to occur during the first large precipitation event, which would transport contaminants accumulated in the basin into tributaries and the mainstem. Though pollutant concentrations were not directly measured during our 2013 habitat survey, water quality data available from the NDEP indicate that concentrations of heavy metals, such as copper and iron, reach levels toxic to salmonids in the East Fork downstream of Mill Creek. Therefore, activities that reduce contamination in Mill Creek would be expected to increase salmon and steelhead production potential in the Basin.

2014 Study Objectives

Data collection in 2014 will be designed to address critical data gaps identified in 2013. These include:

1. additional water quality and temperature monitoring;
2. habitat surveys in tributaries that could not be adequately surveyed in 2013, such as California, Allegheny, and Trail Creeks;
3. secondary habitat surveys at higher flow conditions in mainstem and tributary sites;
4. tributary flow assessments;
5. measures of redband trout densities throughout the Basin;
6. documentation of migrating or smolting fish derived from native redband trout populations;
7. and genetic analysis of salmonid tissue samples collected in 2013 and 2014

Additional water quality and temperature monitoring will allow us to build on the data collected from 2013. As a general practice, water quality, and particularly temperature monitoring, should become a regular part of the Tribes research program before and after salmon and steelhead reintroduction occurs.

A second summer rearing and spawning habitat survey will be conducted at flow rates comparable to average or wet water year conditions. This data will be used to validate predicted increases in carrying capacity associated with modeled flow increases. We recommend survey reaches remain the same, so that habitat data from 2013 and 2014 are directly compatible, with the only difference being flow volume. Tributaries that could not be assessed due to low water conditions in 2013 should be included during the 2014 habitat survey.

Developing production and capacity estimates in response to flow changes in major tributaries will also be an important component of our research in 2014. Flow modeling was not conducted in tributaries during 2013 because of the lack of flow data available for these streams. During the summer of 2014, we will monitor flows in tributaries to acquire the data necessary to develop these models by placing in-stream monitoring gauges, or collecting weekly flow measurements.

A more extensive fish sampling effort throughout the basin will need to be conducted. During the summer of 2013, fish were sampled sparingly to collect tissue for genetic analysis of resident redband trout populations to be performed at a later date. A more thorough sampling effort should be carried out in 2014 to establish a trout abundance estimate and collect more tissue samples. A backpack electrofisher and block nets would be used to capture fish, facilitating a mark-recapture population estimate within select stream segments in the Basin. Stratified sampling reaches would be strategically selected to ensure that each distinct habitat area within the watershed is represented in the dataset.

Genetic analysis remains a priority during the second year of study. A minimum of fifty tissue samples are needed to establish a genetic baseline for native redband trout in the Basin. In the summer 2013, over sixty samples were collected. Samples from unsurveyed sites may be added to this number prior to lab analysis, contingent on resource limitations.

Finally, establishing whether or not smoltification is occurring within existing redband trout populations has been identified as a priority in 2014. A demonstration of migratory behavior or smoltification would provide evidence of remnant populations of redband steelhead and validation that the watershed still possesses the habitat necessary to sustain anadromous fish. We propose placement of a screw trap in the lower river to capture migrating fish. A combination of visual identification and biochemical techniques will be used to identify smolting fish.

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APPENDIX A: CARRYING CAPACITY MODEL

The Unit Characteristic Method (UCM) estimates rearing capacity by using the standard density of fish in a channel unit based on fish species and habitat type, scaling by habitat features, and summing across channel units in a reach. Standard values used for steelhead are from Cramer and Ackerman (2009) and for Chinook from Cramer *et al.* (2012) (Table A-1). In the first calculation step, these values were scaled at the channel unit level based on unit area, depth for pools and riffles, wood complexity in pools and glides, and boulders in riffles to give a channel unit capacity. Unit area was calculated as average length times average width, except in the case of pools. Longer pools tend to have a calm mid-section which receives little or no fish use. Therefore, if the length of a pool was greater than four times its width, the length used in the area calculation was set as equal to four times the width. If the length of the pool was less than four times its width, then length multiplied by width was used. For simplification, channel unit capacity will be referred to as "unit capacity".

In the next calculation step, unit capacity was scaled by reach level attributes, including mean riffle depth, percent riffles, percent rapids, percent fines, percent cobbles, alkalinity, turbidity, and maximum weekly average temperature (MWAT) (Table A-2). All values except alkalinity and turbidity were calculated from 2013 field data (see Cramer and Ackerman 2009 for details regarding capacity computations). Alkalinity and turbidity were assumed to be similar to other interior Columbia Basin rivers, and average values for a typical interior Columbia Basin river were used (Ackerman *et al.* 2007).

Table A-1. Standard densities for steelhead and Chinook salmon by UCM habitat type.

Habitat Type	*Steelhead*	*Chinook*
Pool	0.17	0.24
Beaver pond	0.07	0.19
Glide	0.08	0.07
Rapid	0.07	0.024
Riffle	0.03	0.024

Table A-2. Reach level attributes for Owyhee rearing capacity UCM runs. Mean riffle depth, percent riffles, percent rapids, percent fines, percent cobbles, and MWAT were calculated from 2013 field measurements for each reach. Alkalinity and turbidity values are average values for a typical interior Columbia Basin river (Ackerman *et al.* 2007).

Reach	*Mean Riffle Depth (m)*	*Percent Riffles*	*Percent Rapids*	*Percent Fines*	*Percent Cobbles*	*Alkalinity*	*Turbidity*	*MWAT*

Mainstem 1	0.31	44	16	14	30	25	2.5	18.6
Mainstem 2	0.33	29	0	46	24	25	2.5	18.95
Mainstem 3	0.20	21	0	32	34	25	2.5	19.75
Skull	0.10	32	0	8	5	25	2.5	18.2
Slaughter House	0.07	29	0	87	0	25	2.5	16.6
Van Duzer	0.06	8	0	83	4	25	2.5	17

Capacity is the reach unit capacity (Area * dens * chnl * dep * cvr * Prod).
Area is length multiplied by width with the exception of pools which have a maximum effective length of four times the width,
dens is the standard density for the species and habitat type,
chnl is the unit-level channel scalar based on the width of pools, glides, and riffles,
dep is the unit-level depth scalar for pools and riffles,
cvr[1] is the unit-level cover scalar based on wood complexity in pools and glides and boulders in riffles,
turb[2] is the reach-level turbidity scalar
drift is the reach-level drift scalar
fines is the reach-level fines scalar
alk is the reach-level alkalinity scalar
winter is the reach-level winter cover scalar
mwat is the reach-level temperature scalar (modification of the function in Ackerman et al. 2007)
Prod[3] is the productivity scalar (turb*drift*fines*alk*winter*mwat)

- [1] cvr values are usually 0.58 because of a lack of wood. Since this is a desert river system it may be worth reconsidering. For the East Fork Owyhee River we eliminated the wood cover scalar.
- [2] turb is 1 for Allegheny Creek because there are no riffles. Since there are no riffles in the sampled reach the scalar calculation is inappropriate.
- [3] Prod scalar is very small for all the tribs. This is driven primarily by the drift, winter scalars through lack of riffles, high fine sediment loads, low amounts of fast water habitats, and lack of cobbles.

The primary life stages that a given reach supports may be juvenile rearing during spring, spawning during seasons of cooler, higher flows, or winter refuge for rearing. We define the juvenile life stages as follows:

fry Juveniles in their first 30 days of life prior to establishing territories. Maximum fork lengths of fry are assumed to be: Chinook ≤45 mm fork length, steelhead ≤35mm.

parr Juveniles rearing and defending territories. Fork lengths assumed to be Chinook 45 to 80 mm and steelhead 35 to 150 mm.

presmolt Parr at the conclusion of summer and through overwintering until they smolt in the spring.

smolt Juveniles that have undergone the physiological transformation to live in salt water and are actively migrating to sea.

In cases where spawning is the principal life stage supported, successful juveniles would be those that migrate downstream to find suitable habitat for rearing. In our modeling, we directly estimate carrying capacity within East Fork Owyhee Watershed, and we assume that suitable rearing habitat is available and not limiting outside the watershed. However, we assign extra mortality during the act of migrating to find that habitat, because migrating fish expose themselves to ambush predators such as pike minnow and larger salmonid juveniles.

In the following paragraphs, we describe the life history pathways we anticipated and modeled in the East Fork Owyhee River.

Chinook Salmon

Chinook are large bodied fish that spawn in large channels and do not penetrate as far upstream to spawn as steelhead. The upstream limit of their spawning is likely limited by the year-to-year consistency with which they can find suitable depths for holding and spawning. Large bodied fish spawning in small streams are highly vulnerable to predators (including people), so pre-spawning mortality may limit success of Chinook in the East Fork Owyhee. Typically upon emergence of juveniles in early spring, many of the fry would migrate downstream to rear, while most would rear to smolt size (≥ 80 mm) and then emigrate to sea during mid-May to mid-June in their first year of life (Figure A-1); but in the East Fork Owyhee, emigration is limited by the creations of dams, so assuming that a fish could emigrate to the ocean is incorrect unless truck and haul practices are implemented. There are too many obstacles that stand in the way for anadromous passage.

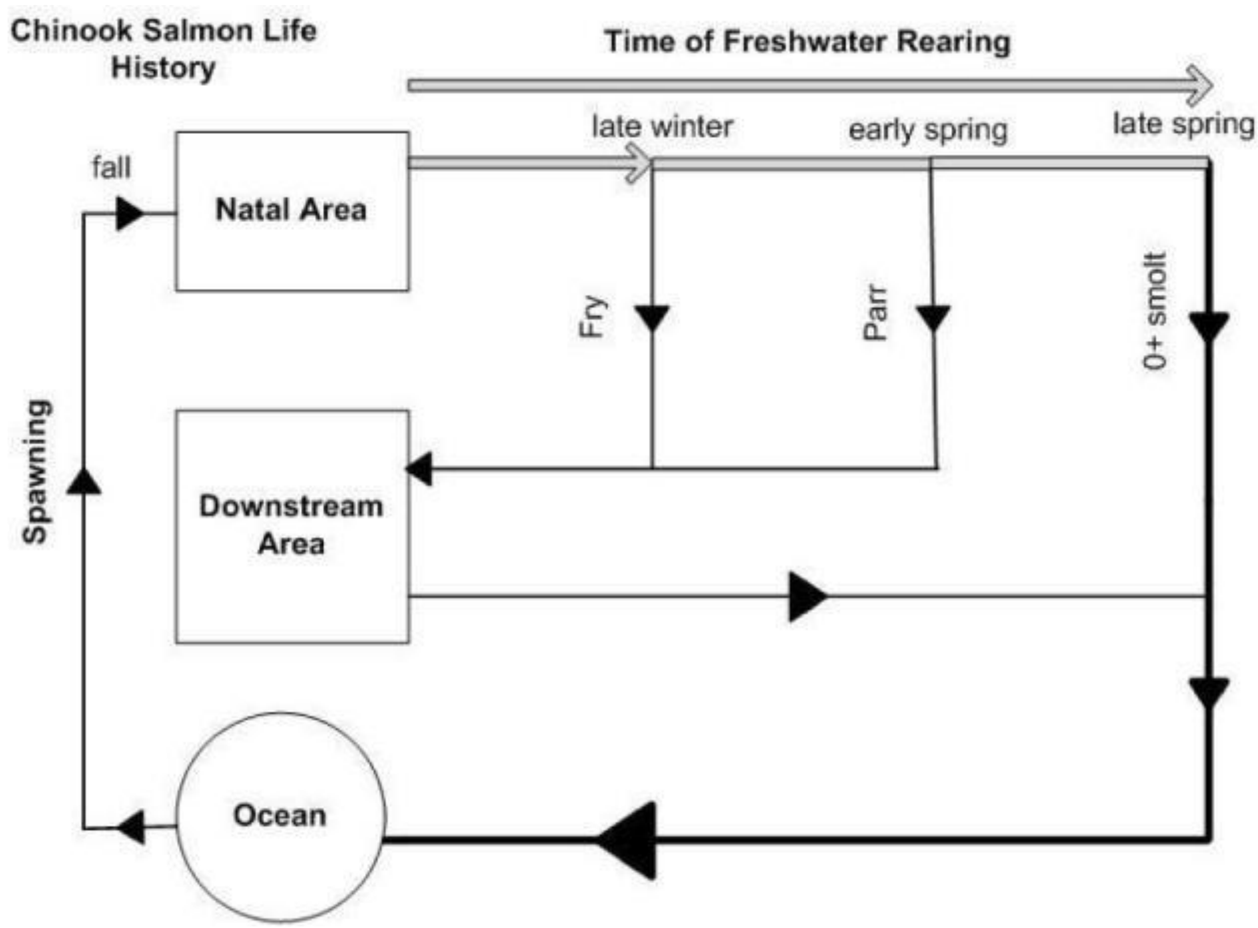


Figure A-1. Conceptual model of life-history pathways for Chinook salmon in the East Fork Owyhee.

Steelhead Trout

Steelhead trout spawn in the late winter into spring, emerge as fry in late spring to early summer, and typically rear through one or two summers in freshwater before smolting in the spring at age 1+ or 2+ (Figure A-2). Rearing capacity for parr in the summer is typically the limiting factor (Cramer and Ackerman 2009b). Given the limited rearing opportunities in East Fork Owyhee River during the summer months it would be expected for most age 0 steelhead to migrate to find rearing opportunities farther downstream, but given damming activity along the Owyhee this behavior will be inhibited and young fish will have to find rearing habitat within the East Fork.

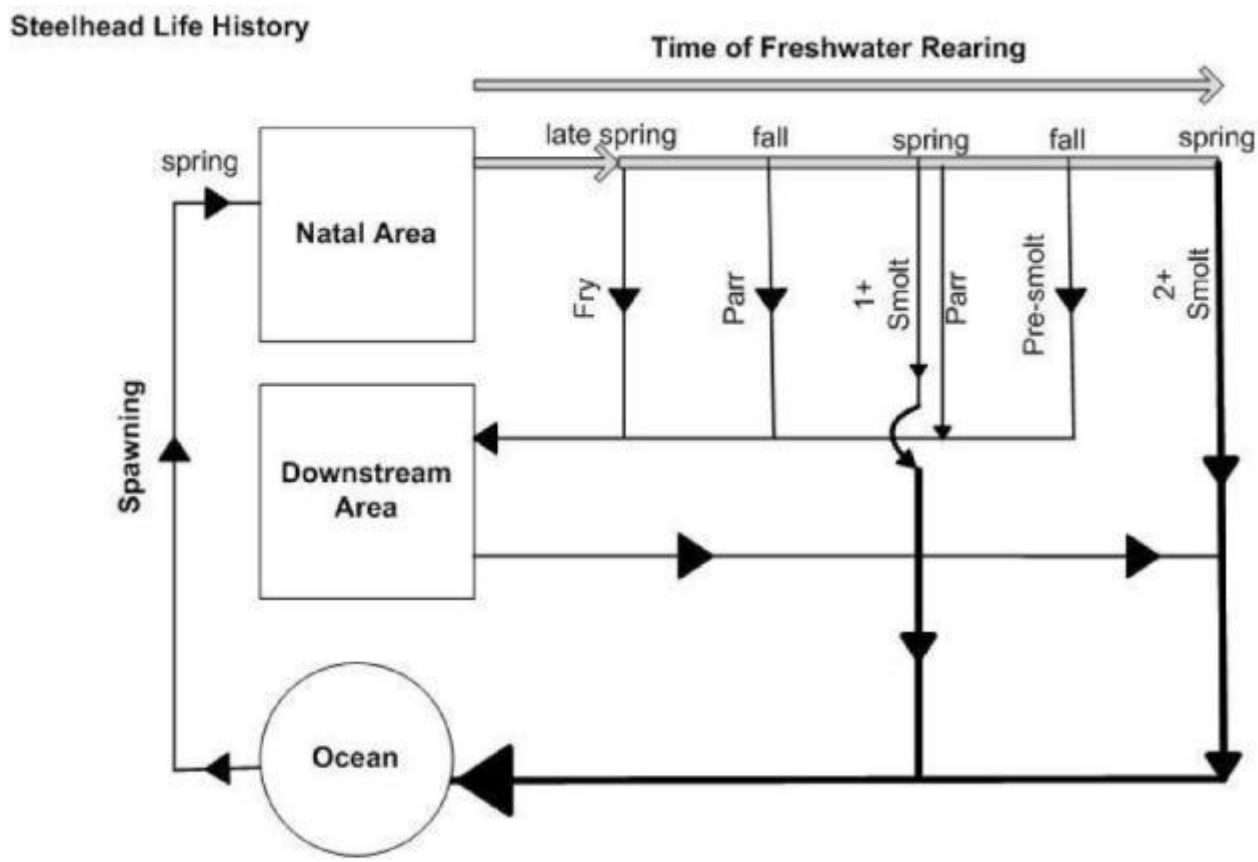


Figure A-2. Conceptual model of life-history pathways for steelhead in East Fork Owyhee River.

Life Stages Modeled

Based on these conceptual models, we determined that habitat capacity across all species of interest could be a limiting factor for four life stages: (1) spawning, (2) rearing through spring for juveniles that smolt as sub-yearlings, (3) summer rearing for parr, and (4) overwintering refuge for juveniles. Accordingly, our approach included an accounting for stream features that determine suitability to support each of these life stages.

Relationship of Fish Use to Habitat Features

Carrying capacity is a function of the types of habitat features for which fish consistently exercise preference and how well those preferences can be satisfied by the types of habitat that are available in a given stream.

Spawning Habitat Preferences

There is commonality of preferred spawning habitat features across anadromous salmonid species, so that we used the same generalized model to predict spawner carrying capacity for all species. Species specific influences on spawner distribution can be found under our separate descriptions of the rearing capacity models for each species.

Anadromous salmonids show broad overlap in the range of depths, velocities, and substrate composition they choose to spawn in (Burner 1951; Kondolf and Wolman 1993; Keeley and Slaney 1996) and studies have generally revealed that predictable differences in preferred spawning habitat are related to the size of the spawning fish rather than its species (Figure A-3). Fish of different species but similar size would tend to spawn in the same type of habitat. Larger fish tend to spawn in deeper, faster water with larger diameter substrate than their smaller cohorts choose (Keeley and Slaney 1996) (Figure A-3 and Figure A-4). The data presented by Kondolf (2000) show that salmonids can spawn in gravels with median diameters up to 10% of their body length (Figure A-4), although movement of such large particles would also likely correspond to spawning in water velocities at the maximum of the observed range.

As an apparent consequence of these habitat preferences, few anadromous salmonids spawn in third order streams and most spawn in fourth and fifth order streams (Platts 1979; House and Boehen 1985). Data compiled by Platts 1979 in Idaho streams, and House and Boehen (1985) in Oregon streams showed that as stream order increased, gradient decreased while width and depth decreased. These factors, combined with spawner preferences for depth, velocity, and substrate result in most anadromous salmonids spawning in higher order stream reaches of low gradient with pool-riffle combinations composing most of the channel length (Isaak and Thurow 2006; Montgomery et al. 1999). Buffington et al. (2004) found from extensive surveys in three river basins of Washington that suitable gravel size for salmon spawning was seldom produced in channel reaches with gradients >3%. Gradient and flow are key factors that drive where spawnable size substrate will settle out. Researchers consistently report that salmon and steelhead most frequently spawn in pool tailouts and heads of riffles below a pool (Bjornn and Reiser 1991; Mull and Wilzbach 2007; Keeley and Slaney 1996), because these are the zones where depth, velocity and substrate most frequently are met in combination.

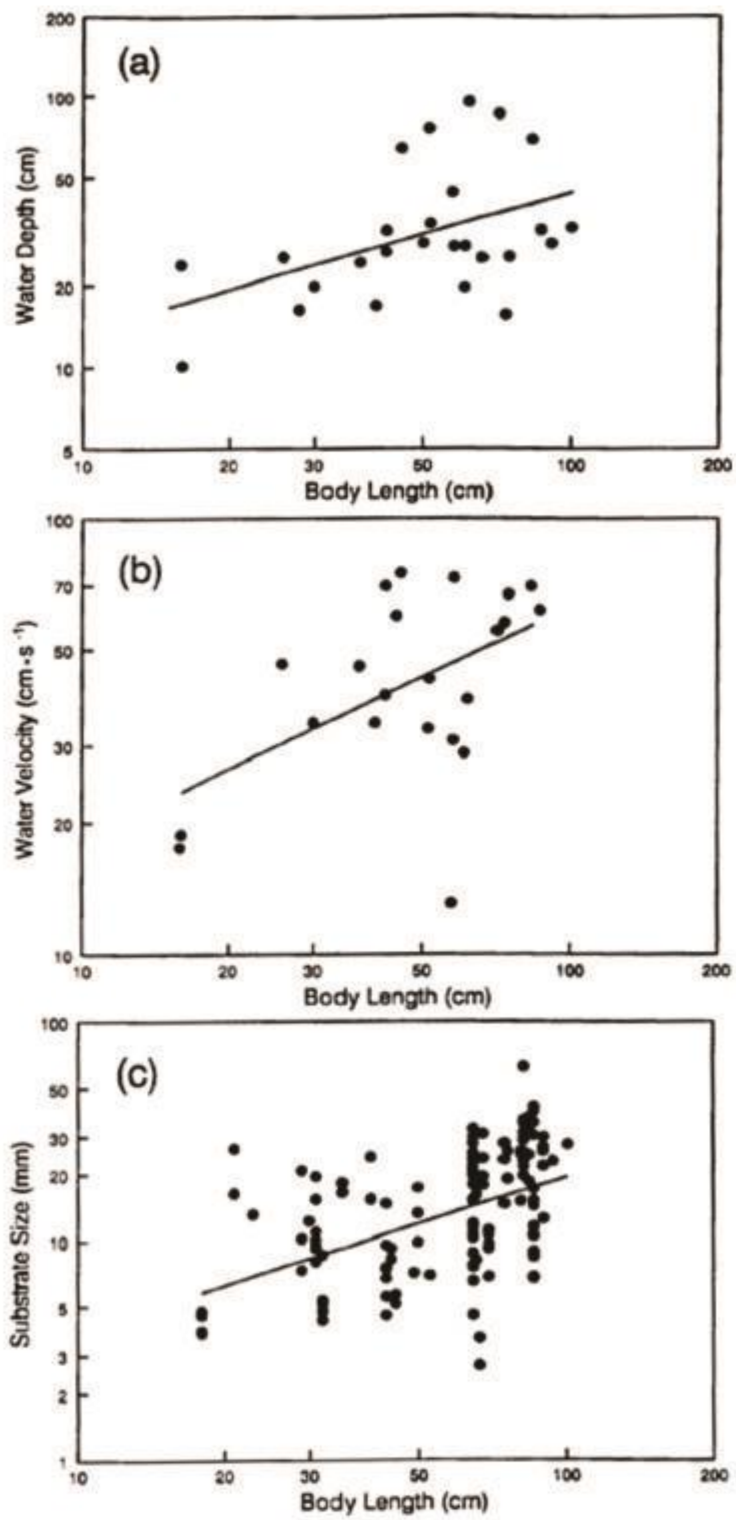


Figure A-3. Spawning microhabitats selected by salmonid fishes in relation to body size. From Keeley and Slaney (1996).

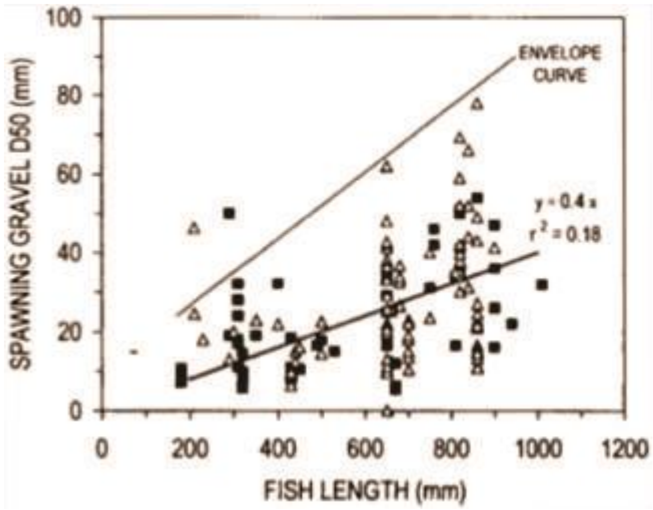


Figure A-4. Median diameter (D50) of gravel used by salmonids for spawning plotted against spawner body length. Solid squares are samples from redds, and open triangles are potential spawning gravel nearby. From Kondolf (2000).

Measurements of depth, velocity, and substrate size at salmon redds lead to the conclusion that minimum depth and velocity are the factors that limit use of appropriate sized gravels. Keeley and Slaney (1996) concluded that across a range of salmon species, water flows greater than 10 cm/sec velocity and 10 cm deep were the minimum amounts of water fish would spawn in. Swift (1979) summarized relationships between spawnable area for salmon and flow in 84 reaches of 28 streams in Washington, and deduced that minimum depths in which salmon would spawn were 30.5 cm for Chinook salmon. Further, he concluded that Chinook needed a minimum velocity of 0.31 m/sec.

Where minimum depth, velocity and appropriate substrate sizes occur, salmonids also need a minimum amount of territory in which to construct and defend their redd. The most widely cited study for determining spawning territory size is that of Burner (1951) who measured characteristics for a large number of redds for several salmon species in the Lower Columbia basin. Burner found that inter-redd spacing was proportional to redd size, which in turn was proportion to spawner size. Burner concluded that the total average area necessary for a pair of spawning fish was about four times the area of the average redd. Burner obtained his measurements of redd sizes in the lower Columbia Basin, and he reported minimum area required per spawning pair was of spring Chinook was 16 square yards. Forty-five years after the work of Burner (1951), Keeley and Slaney (1996) reviewed 33 studies of microhabitat selected at spawning by 13 species of salmonids, and concluded that available data continued to support Burner's conclusion; territory size for spawning salmonids is roughly four times that of the redd area. Accordingly, we used Burner's estimates for area needed per spawning pair in our model.

The amount of fine sediment mixed with the gravels can have a strong effect on egg survival. Even when depth, velocity and substrate criteria preferences are satisfied, egg survival is reduced when fines compose more than 25% of the substrate. Bjornn and Reiser (1991) summarized research showing that egg survival begins to decline at 25% fines in otherwise suitably-sized gravel, and approaches zero when fines exceed 55%. Thus, we scaled egg capacity to decline directly proportional to this survival effect wherever a suitable GP had fines greater than 25%.

Spawner Carrying Capacity

We used the functional relationships of fish use to habitat features to develop a protocol for calculating spawner carrying capacity, because spawning habitat could potentially be a limiting factor for all anadromous salmonids.

A list of calculation steps to estimate spawning capacity follows:

1. Identify the pools, riffles and glides that contain potentially suitable gravels for spawning
2. Exclude units where suitable gravel has noticeable lateral slope
3. Exclude units where the gravels contain greater than 40% fines
4. Exclude units with less than 15 cm depth for steelhead and with less than 30 cm depth for Chinook. Assume depth of pool tailout is 1/3 of pool max depth
5. Pool spawnable area is the tail out, and is assigned length equal to one channel width (area upstream of tail out is assumed unsuitable)
6. Glide spawnable area is assumed to be half of the glide area with suitable substrate
7. Riffle spawnable area is the full area of the riffle with suitable substrate.
8. Multiply spawnable area in each unit by the scalar for fines exceeding 25%
9. Sum qualifying suitable area across all units
10. Redd capacity = qualifying suitable area/(4 * avg redd area)

Rearing Habitat Preferences

Stream carrying capacity for anadromous salmonids that rear to the smolting stage in freshwater can be predicted from a sequence of cause-response functions that describe fish preferences for macro-habitat features. The channel unit (e.g., pool, glide, and riffle) is a useful stratum for quantifying rearing capacity for salmonids, and is a hydrologically meaningful unit for predicting the response of stream morphology to watershed processes. Thus, channel units are the natural link between habitat-forming processes and habitat requirements of salmonids. Maximum densities of juvenile salmonids that can be supported in a channel unit are related to availability of preferred habitat features including velocity, depth, cover, and substrate. Within channel unit types, maximum densities of salmonid parr will shift predictably as availability of cover from wood and boulders increases.

Cramer and Ackerman (2009a) summarized a number of studies demonstrating that rearing densities (fish/m^2) of juvenile salmonids consistently differ between channel unit types (pool, riffle, glide, etc.), and that stratification of parr densities by channel unit type was a useful starting point for estimating habitat capacity to rear parr. We used the fish rearing densities reported by Cramer and Ackerman (2009a) in our models of rearing capacity. For all species of anadromous salmonids, pools supported the highest fish densities and riffles supported the lowest (Table A-3). Cramer (2001) also found evidence that use by steelhead and spring Chinook drops to near zero in the calm mid-section of pools longer than 4 channel widths. Therefore, we assigned a density of 0 to the midsection of such large pools.

Channel Unit Definitions:

Pool: a unit with no surface turbulence, except at the inflow, and has depth extending below the plane of the streambed

Riffle: a unit with discernible gradient and surface turbulence

Glide: a unit that has relatively uniform velocity down the channel, little surface turbulence, and no depth below the plane of the streambed

Table A-3. Standard parr densities (fish/100m^2) used in the UCM for each channel unit type. Derivation of these values has been described for steelhead by Cramer and Ackerman 2009b and for Chinook by Underwood et al. 2003.

Unit Type	Steelhead	Chinook
Backwater	5.0	13.0
Beaver Pond	7.0	19.0
Cascade	3.0	2.4
Glide	8.0	7.0
Pool	17.0	24.0
Rapid	7.0	2.4
Riffle	3.0	2.4

As salmonids grow, their habitat preferences change and the preferred habitat associated with their increasing size becomes less and less available. Further, territory size of salmonids increases exponentially with fish length, such that the demand for territory to support surviving members of a cohort increases at least through their first year of life. Changing habitat preferences and space demands, juxtaposed against shrinking habitat availability with the onset of summer low flows often results in a bottleneck to rearing capacity in wadable streams for salmonids greater than age 1. Additional habitat factors accounted for within each habitat unit are described below.

Influence of Depth

Densities within each unit type were strongly influenced by depth and cover. Combined observations from several experiments indicate that steelhead exercise habitat preferences in the priority order of depth first, velocity second, and cover third. Parr of all salmonid species strongly avoided areas with depths <0.2 m, and a variety of studies showed that parr densities increased as unit depths increased up to at least 1 m. Everest and Chapman (1972) found a highly significant correlation between fish size and the depth or velocity at which juvenile Chinook and steelhead choose to position.

Influence of Cover

A study by Johnson et al. (1993) was able to quantify the benefit of cover by assigning a cover complexity score to the pools in which fish were sampled. Parr density in pools for both steelhead and cutthroat increased about three fold as woody debris complexity increased from none to high complexity. Similar effects have been demonstrated for Chinook. Boulders provide a form of cover in streams, particularly in riffles. Steelhead and spring Chinook show strong preference to hold adjacent to much faster velocities, and their densities in boulder dominated riffles, where they held behind boulders, are several times greater than in riffles dominated by other substrate types.

Influence of Substrate

Substrate embeddedness with fines is a key factor that influences both the production of invertebrate drift and the cover for juvenile salmonids. Hawkins et al. (1983) found that increasing percentages of fines in riffles across reaches in 13 coastal streams of Oregon was correlated to reduced production of both invertebrates and juvenile salmonids. Bjornn and Reiser (1991) summarize data from several studies on the effects of fines, and show that rearing densities decline as fines rise above 10% of the substrate in riffles. The measurement of fines in riffles is used an index for the effect on fish in the entire reach rather than just in riffles.

Stream Temperature

In order to scale down the rearing capacity as temperatures reaches stressful levels (> 16°C) we estimated the proportionate effect based on densities of salmon parr in 44 Oregon coastal survey sites where temperatures were also measured. Sites were selected based on the criteria that the sampling location and the temperature monitoring location were within 2 km of each other on a single stream segment. Further, the two sampling activities needed to be conducted in the same year. For each site, we calculated the MWAT from the continuous temperature monitoring data and examined the relationship between the MWAT temperature and juvenile rearing densities.

The analysis suggests that juvenile rearing densities are highest at MWAT temperatures between 14-16°C. The highest MWAT at which rearing were observed was 23°C. Low sample size and variability in the data make the form of the decreasing slope in densities between the lower and upper thresholds difficult to ascertain, but the data suggest that mean densities at an MWAT of 20°C are approximately 30% of those at optimal temperatures.

We found several studies of fish assemblages in streams spread over a broad geographic area that showed salmon and trout were consistently found at highest densities where stream temperatures in summer were near their physiological optimum of 12 to 16°C (Huff et al. 2005; Ott and Marret 2003; Waite and Carpenter 2000). These studies showed that salmonids still persisted, but at lower densities, in stream reaches with temperatures above this range. Although densities declined with increasing temperature, we did not find consistent evidence that mortality rate of rearing fish increased until temperatures reached incipient lethal levels.

Field studies of the foods and feeding strategies of salmon and trout in streams indicate that the amount of preferred habitat decreases as stream temperature increases. Because salmonids like other fishes are poikilotherms, their metabolic demands increase as temperature increases, so their feeding rates also increase (Brett 1971). Salmonids feed on drifting macro-invertebrates in streams (Rader 1997), and the volume of drift at any point in a stream is generally greater where velocity is greater (Smith and Li 1983). Therefore, salmonids tend to seek positions of increasing velocity in a stream as temperature increases (Smith and Li 1983). However, the strategy of moving to higher velocities is only effective as long as the net energetic gain to the fish stays positive. Swimming performance declines above optimum temperature (Brett 1971), while performance of warmer-adapted competitors, such as redside shiners, improves. Reeves et al. (1987) found in a laboratory stream that water temperature affected the outcomes of competition between age 1+ juvenile steelhead and redside shiners. In experiments with cool water (12-15°C) trout abundance and distribution was unaffected by the presence of shiners. However, in warmer waters (19-22°C), juvenile steelhead abundance decreased by 54%, and their distribution was altered when shiners were present. Conversely, at cooler temperatures shiners were negatively affected by trout, but not at warmer temperatures. Thus, temperature forces fish to compete for a decreasing number of stream positions that will satisfy their bioenergetic needs. Increased competition results in migration of those that do not win satisfactory stream positions. The overall effect of temperature above the optimum range for salmonids is thus that it decreases carrying capacity of habitat that is otherwise suitable.

Rearing Capacity Prediction

The UCM predicts a stream's carrying capacity under average conditions by multiplying fish density by surface area in each unit, and then adjusts for differences between stream reaches in factors that influence food supply, as described in the section below. The general form of the predictor for a given species in a specific stream reach is:

$$Capacity_i = (\Sigma\ area_k \cdot den_j \cdot chnl_{jk} \cdot dep_{jk} \cdot cvr_{jk})$$

Where;
i = stream reach. "Reach" is a sequence of channel units that compose a geomorphically homogenous segment of the stream network,
j = channel unit type,
k = measured channel unit,
area = area (m2) of channel unit *k*,
den = standard fish density (fish/m2) for a given species in unit type *j*,
dep = depth scalar with expected value of 1.0,
cvr = cover scalar with expected value of 1.0,
chnl = discount scalar for unproductive portions of large channels with expected value of 1.0

We used scalars to represent the proportionate change in standard fish densities that would occur if habitats differed from the standard in their depth, cover, substrate, or nutrients. For steelhead, we used the functions described by Cramer and Ackerman (2009b), and for Chinook we used the factors as described in the following paragraphs. For Chinook, we scaled capacity down when the maximum of weekly average stream temperatures (MWAT) during the period of rearing exceeded 16°C. Steelhead capacity was scaled down when MWAT exceeded 18°C during the period of rearing. We first describe the temperature scalar that we applied to both species.

Temperature Scalar

Ackerman et al. (2007) conducted an extensive literature review on the effects of temperature on capacity and independently carried out analyses of state agencies data to explain this effect. The literature review concluded that capacity begins to decrement at 16°C (MWAT) and at 23°C (MWAT) streams lose the ability to rear juvenile salmonids unless thermal refuge is available (Ackerman et al. 2007). Low sample size and variability in the data make the form of the decreasing slope in densities between the lower and upper thresholds difficult to ascertain, but the data suggest that mean densities at an MWAT of 20°C are approximately 30% of those at optimal temperatures. We chose a logistic function (Equation 3) to fit the decrease in maximum observed densities by fitting it through values of 0.95 at WAT = 16°C and 0.05 at WAT = 23°C for Chinook salmon. Steelhead temperature scalars were adjusted slightly higher from Chinook parameters to mirror the native populations of trout in the East Owyhee River. Redband Trout can withstand higher temperatures and have been observed actively feeding by Zoellick (1999) and Behnke (1992) at 26-28 °C (Cited by Cassinelli and Moffit 2010). Temperature scalars were adjusted conservatively two degrees higher for steelhead models, so that the beginning of the decrementing density curve began at 18°C (Figure A-5). A logistic function (Equation 3) was fit through values of 0.95 at WAT=18 and 0.05 at WAT=25°C. This function is: *Equation 3:*

$$Tsi = \frac{1}{1 + e^{-a-bTi}}$$

Where:

Tsi = Temperature scalar for capacity for reach *i* in a given week.

a = intercept of logit(*Tsi*) = 16.4 (Chinook), ; 18.1 (steelhead)

b = slope of logit(*Tsi*) = -0.84 (Chinook), ; -0.84(steelhead)

T = WAT for reach *i* in a given week.

This scalar is then multiplied by the habitat capacity for rearing in the reach.

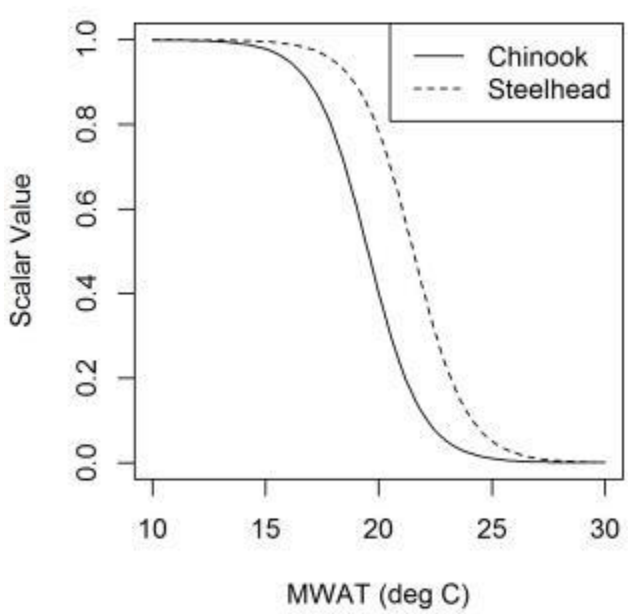


Figure A-5. Chinook and steelhead temperature scalar values.

Chinook

The scaling factors for Chinook rearing, were derived from data from the Coldwater River, B.C. Relationships were developed by comparing the geometric mean of Chinook densities in strata of each variable. The number of strata were maximized while maximizing sample size and testing for significant differences between mean densities in those strata ($p<0.05$). We pooled strata that were not significantly different until all strata had significantly different geometric means. Scaling factors were determined using the following equation:

Scaling Factor = Geo MeanS/Geo. MeanT

where: Geo. MeanS = Geometric mean of units within the strata

Geo. MeanT = Geometric mean of all units within that unit type

and: Geo. MeanT Pools = 24 Chinook/100m^2

Geo. MeanT Glides = 7 Chinook/100m^2

Geo. MeanT Riffles = 2 Chinook/100m^2

Scaling factors were multiplied by the capacity to obtain the adjusted capacity. The adjustment proportions and the level at which each adjustment applies for all the habitat variables analyzed can be seen in Table A-4.

Table A-4. Scaling factors and levels at which the factors apply in Chinook parr.

	% Boulder Cover Adjustments						
	Pools		Glides			Riffles	
	<2%	> 2%	0%	1-6%	> 6%	<11%	<11%
Geo. Mean Density	11	29.5	4	6	11	2	4
Adjustment factor	0.46	1.23	0.57	0.86	1.57	1.00	2.00
	% Non-Boulder Cover						
	Pools						
	<2%	> 2%					
Geo. Mean Density	11	27					
Adjustment Factor	0.46	1.13					
	Avg. Depth (cm)						
	Glides		Riffles				
	<30	>30	<10	10-15	15-24	24-35	<35
Geo. Mean Density	4	14	0	1	2	7	15
Adjustment Factor	0.57	2.00	0.00	0.50	1.00	3.50	7.50

A list of calculation steps for estimating Chinook and steelhead parr capacity follows:

Channel Units

- Surface area was determined for each pool, glide, riffle, rapid, cascade, beaver pond and backwater unit within each reach.
- Surface area was deducted for calm, mid-sections of pools. No credit for length greater than 4 widths.
- Raw parr capacity in each unit was calculated by multiplying the area for each unit by the average maximum parr density for that unit type.
- Raw capacity was adjusted up or down in each unit according to whether depth was more or less than average.
- Capacity for each unit was further adjusted up or down in each unit according to whether cover complexity was more or less than average. Cover in pools was derived from wood complexity and boulder abundance. Cover in glides and riffles were derived from boulders abundance.

Reaches

- Reaches of homogenous flow, gradient and turbidity were separated.
- Raw capacity for each reach was calculated by summing the adjusted capacities for all of its component units.
- Capacity for each reach was discounted further, if embeddedness in riffles averages greater than 10%.
- Capacity was reduced in accord with the temperature scalar in reaches where MWAT temperature exceeded 16°C for Chinook and 18°C.

Stream

- Raw capacity for the stream was calculated by summing the adjusted capacities for all reaches.

<u>Steelhead</u>

The steelhead UCM calculated the capacity of a stream, or reaches in a basin, to produce age 1+ parr. The UCM for steelhead operates in the same manner as the UCM for Chinook, except that densities assigned to each habitat unit type were different, and the response to deviations in habitat features from average was specific to steelhead. Raw parr capacity was derived from the surface area of different unit types, and it was subsequently adjusted up or down based on cover and depth (Figure A-7 and Figure A-8). The utility of UCM for predicting steelhead carrying capacity has previously been corroborated against actual smolt production in several river basins spread throughout Oregon (Cramer and Ackerman 2009b). The functional relationships between habitat features and parr densities, as used in the UCM, are presented in Figure A-6. The calculation steps for estimating steelhead parr capacity followed the same sequence as described for Chinook, but the densities for each unit type differ, as do some of the coefficients for functions the scale the effects of depth, cover and substrate.

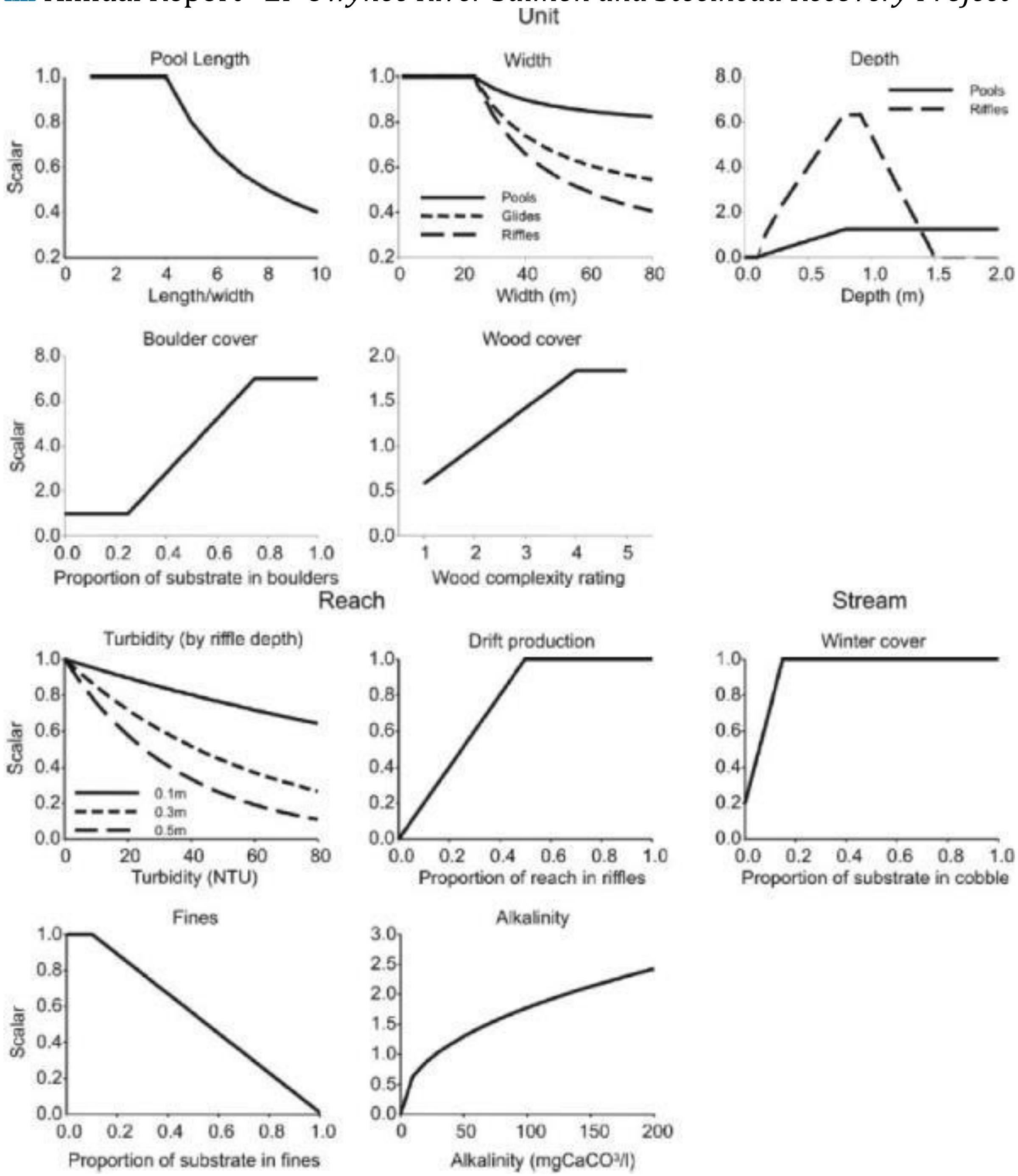


Figure A-6. The functional relationships between habitat features and parr densities, as used in the UCM to predict rearing capacity for steelhead. From Cramer and Ackerman (2009b)

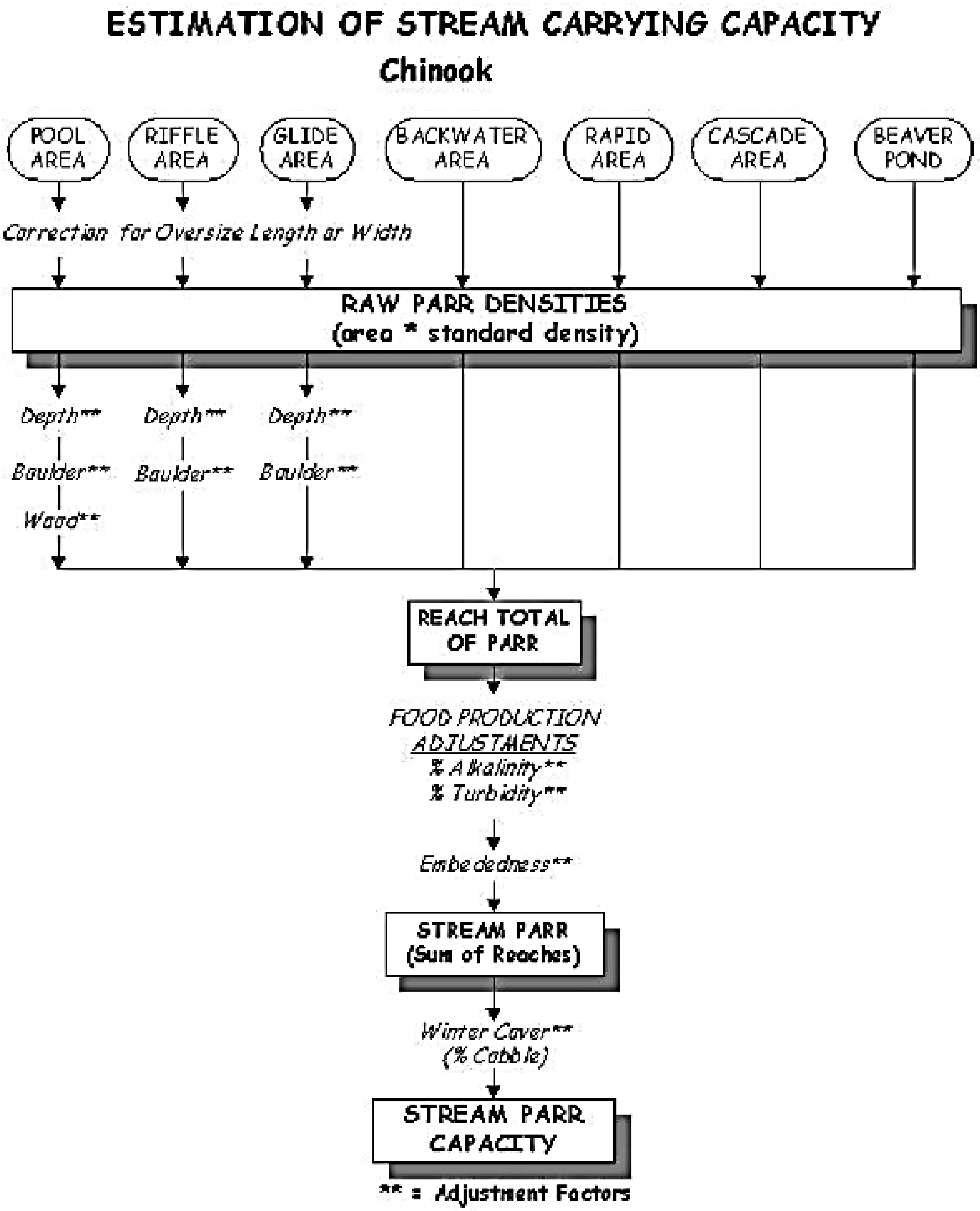


Figure A-7. Diagram of data input and calculation steps used in the UCM to estimate stream carrying capacity for Chinook parr.

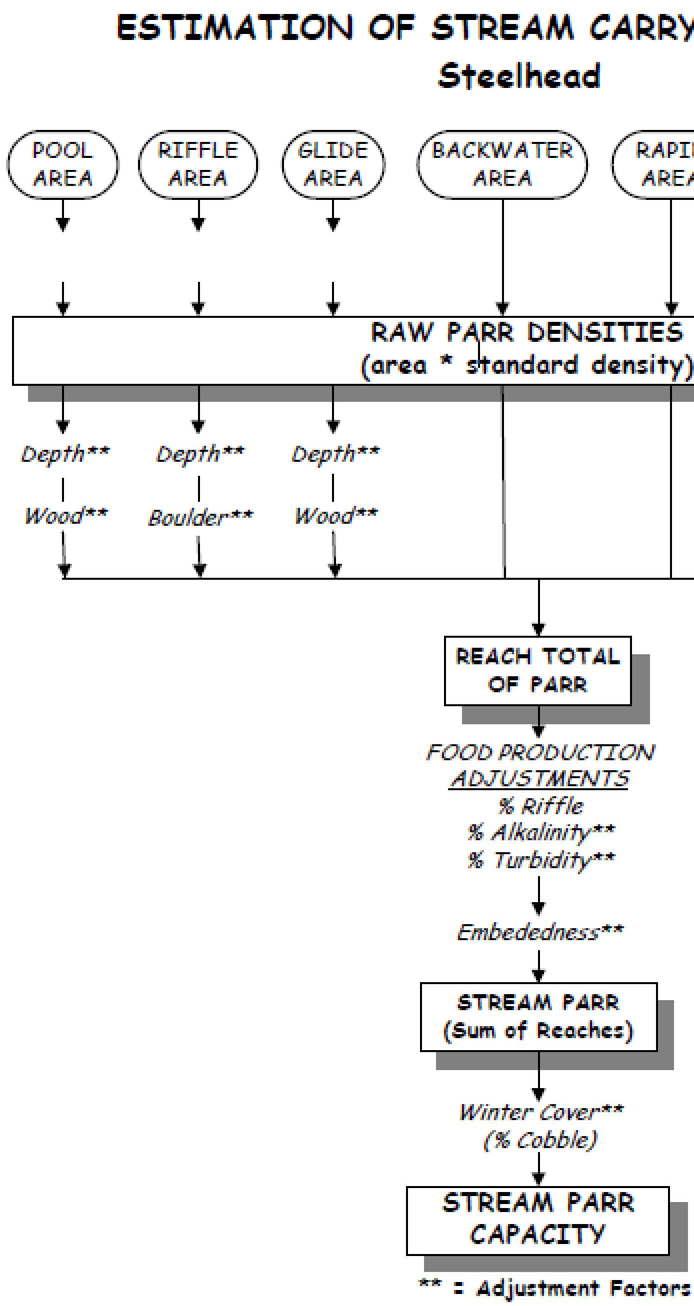


Figure A-8. Diagram of data input and calculation steps used in the UCM to estimate stream carrying capacity for steelhead parr.

APPENDIX B: CARRYING CAPACITY PARAMETER DEFINITIONS

Geomorphic Channel Unit Type	Description
Pool	A section of stream channel where water is impounded within a closed topographical depression. A pool would still have residual water depth if flow ceased. Pools are typically created when fluvial processes such as scour associated with a channel obstruction form depressions in the channel bed. The scour forms a depression which acts as a basin that would continue to hold water if there was no flow. Some pools are created by impoundments at the tail end, such as boulders, a debris flow, a log jam, or a beaver dam.
Glide	An area with generally uniform depth and flow with no surface turbulence. Low gradient; 0-1 % slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Generally deeper than riffles with few major flow obstructions and low habitat complexity. There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993).
Riffle	Fast, shallow flow with surface turbulence over submerged or partially submerged substrates. Generally broad, uniform cross section. Low gradient; usually 0.5-2.0% slope, rarely up to 6%. Some riffles may contain numerous sub-unit sized pools or pocket water created by scour associated with boulders, wood, or stream bed dunes and ridges. In these instances, sub-unit sized pools comprise 20% or more of the total unit area. Other protocols might classify these as pocket water, but in our case, these are boulder riffles (i.e. riffles with boulders as dominant substrate).
Rapid	Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders; exposed substrate composed of individual boulders, boulder clusters, and partial bars. Moderate gradient; usually 2.0-4.0% slope, occasionally 7.0-8.0%. Rapids over bedrock may appear as swift, turbulent, "sheeting" flow over smooth bedrock. Sometimes called chutes. Little or no exposed substrate. Moderate to steep gradient; 2.0-30.0% slope.
Beaver Pond	Pool formed by a beaver dam.

Substrate Size Class	Size Range (mm)
Fines	<2
Gravel	2-60
Cobble	60-256
Boulders	>256

Wood Complexity Rating	Definition
1	Wood debris absent or very low
2	Wood present, but contributes little to habitat complexity. Small pieces creating little cover.
3	Wood present as combination of single pieces and small accumulations. Providing cover and some complex habitat at low to moderate discharge.
4	Wood present with medium and large pieces comprising accumulations and debris jams that incorporate smaller root wads and branches. Good cover for fish over most flow levels.
5	Wood present as large single pieces, accumulations, and jams that trap large amounts of additional material and create a variety of cover and refuge habitats. Woody debris providing excellent persistent and complex habitat. Complex flow patterns will exist at all discharge levels.

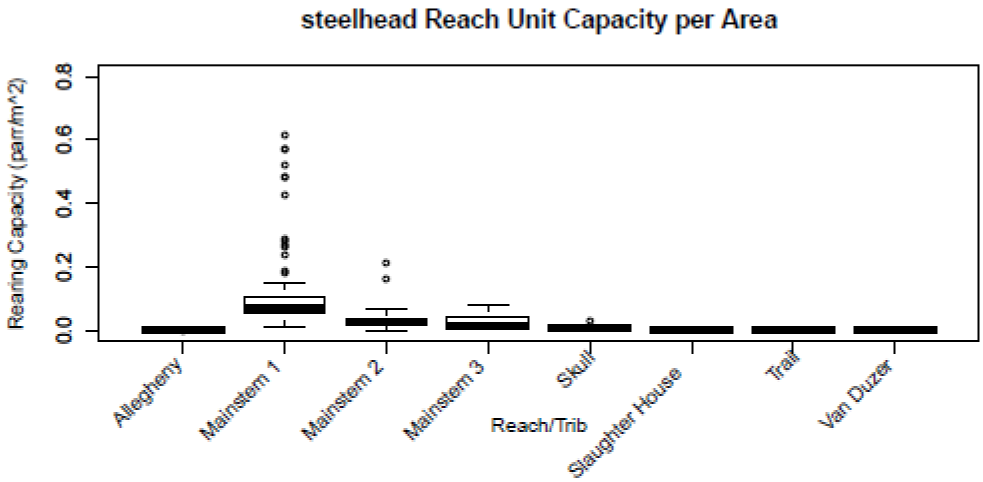
Wood complexity 1

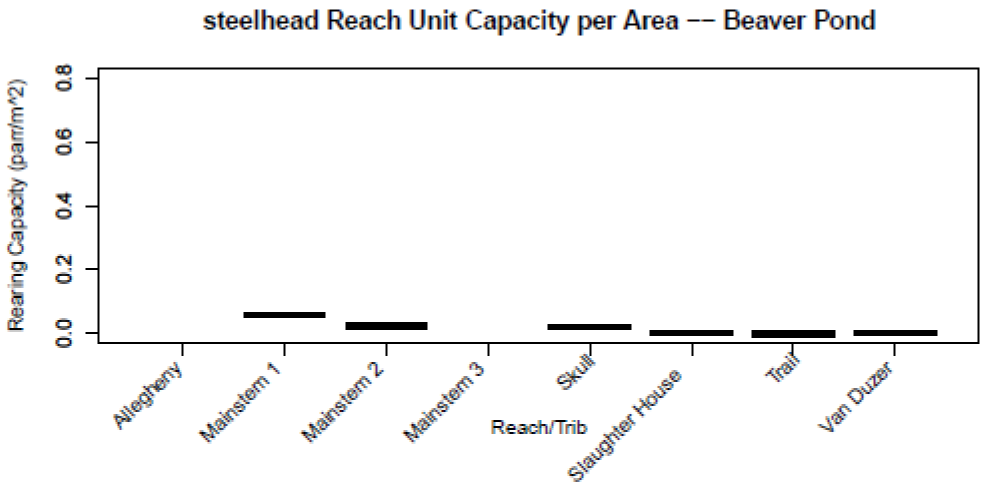
Wood complexity 2

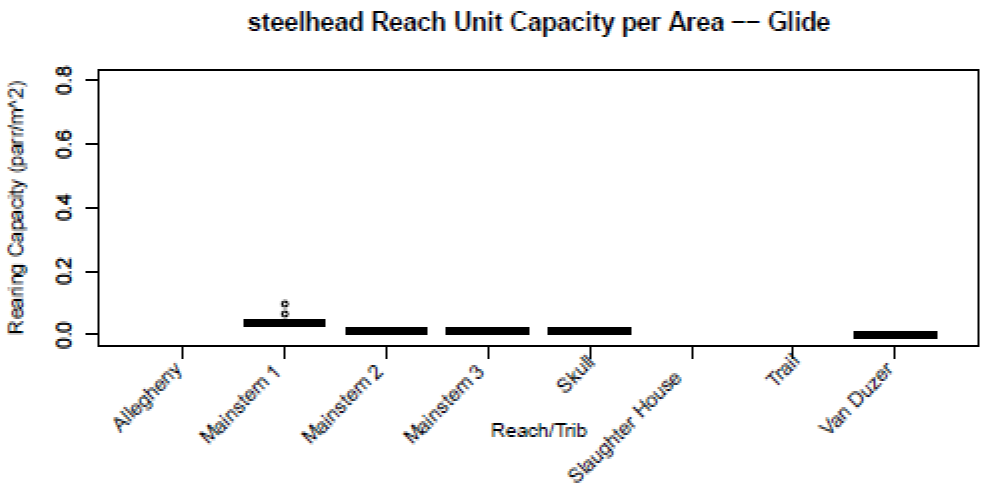
Wood complexity 3

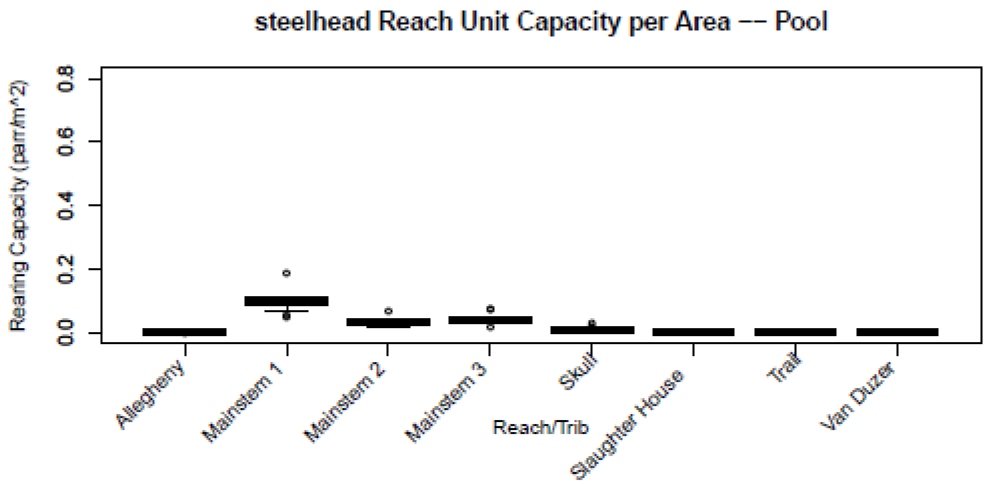
Wood complexity 4

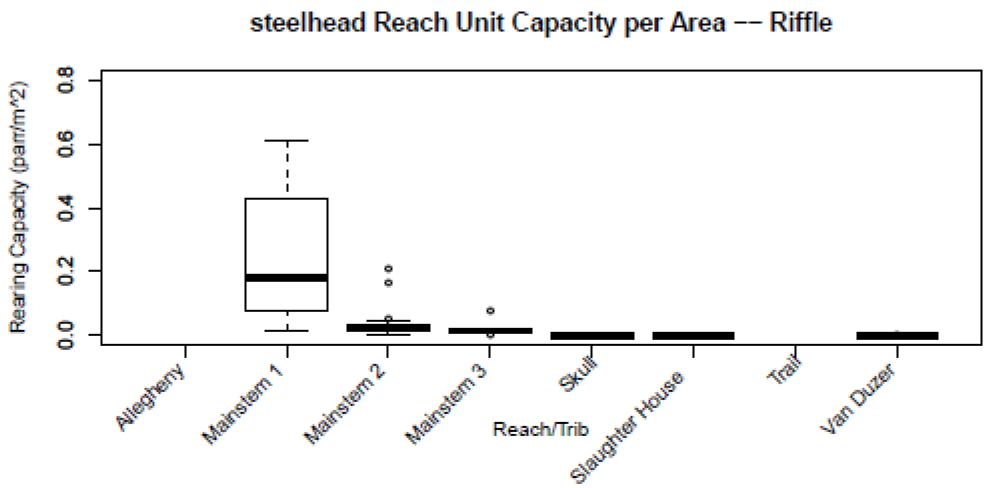
APPENDIX C: REARING CAPACITY ESTIMATES AT SURVEYED FLOWS








steelhead Reach Unit Capacity per Area -- Pool
Rearing Capacity (parr/m^2)
0.0
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


steelhead Reach Unit Capacity per Area -- Riffle
Rearing Capacity (parr/m^2)
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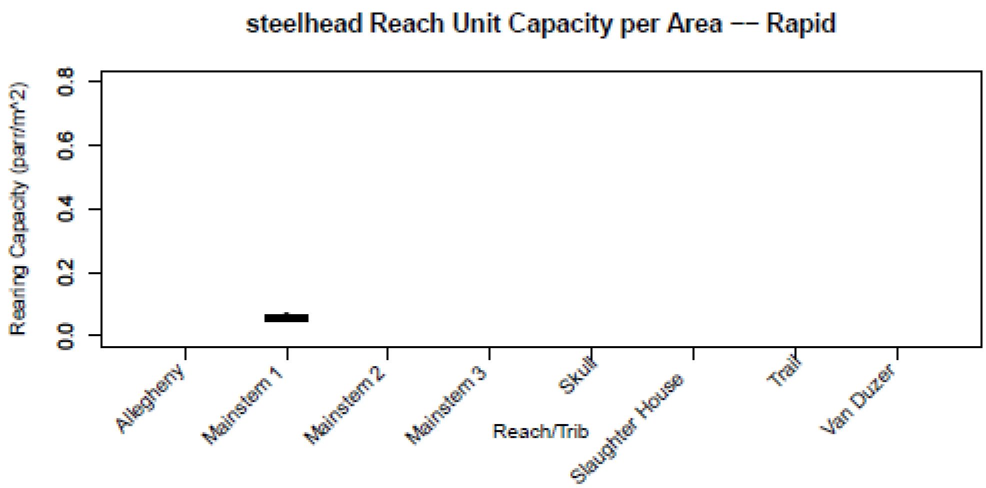
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


steelhead Reach Unit Capacity per Area -- Rapid
Rearing Capacity (parr/m^2)
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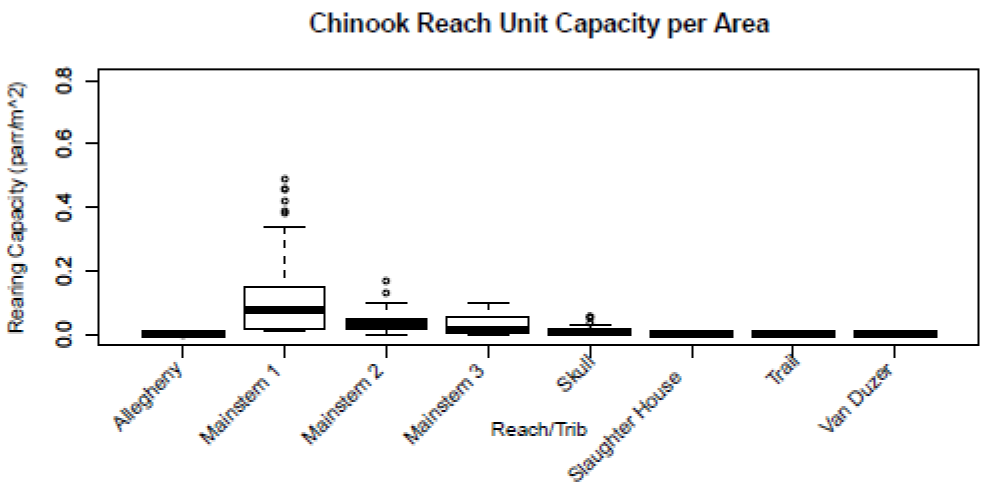
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


Chinook Reach Unit Capacity per Area
Rearing Capacity (parr/m^2)
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0.2
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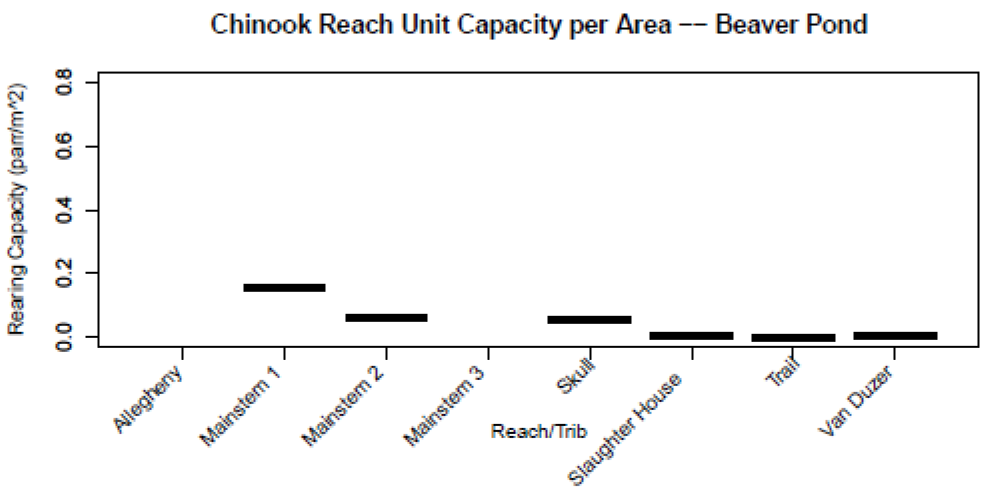
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


Chinook Reach Unit Capacity per Area -- Beaver Pond
Rearing Capacity (parr/m^2)
0.0
0.2
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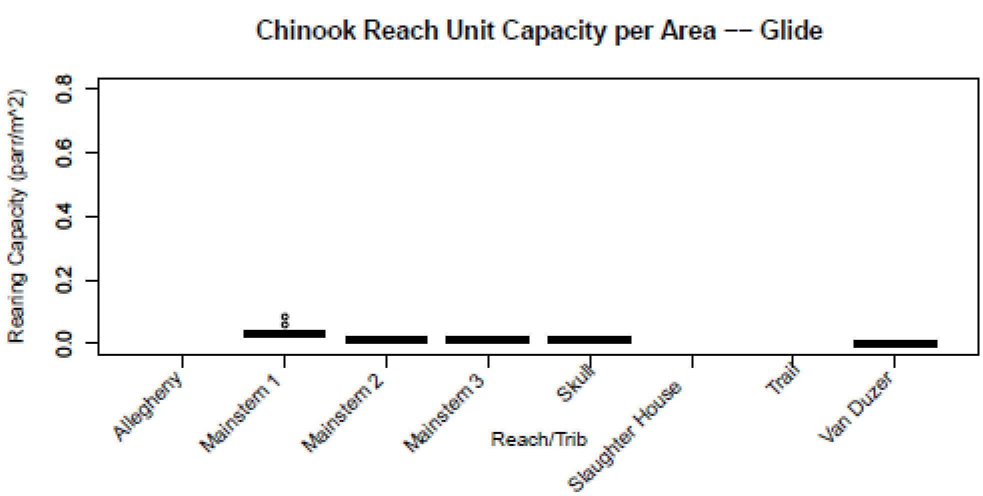
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib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Rearing Capacity (parr/m^2)
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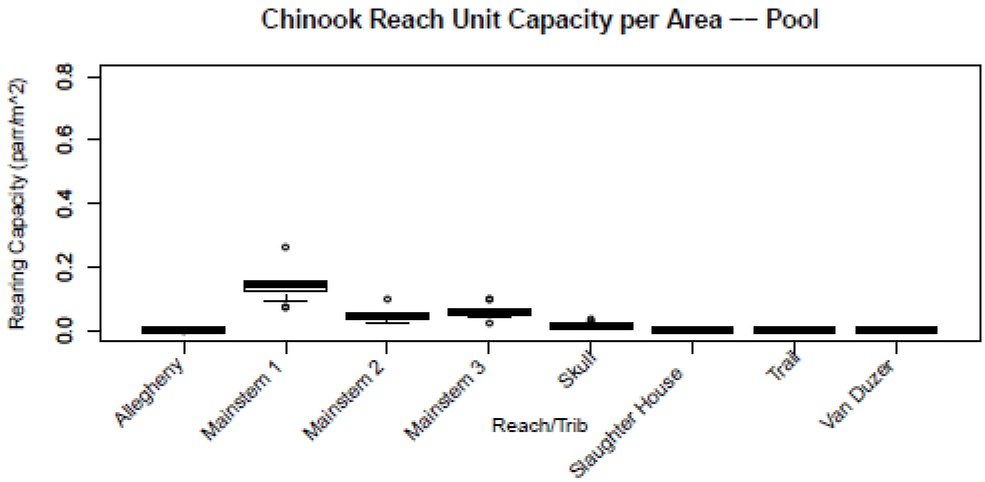
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


Chinook Reach Unit Capacity per Area -- Pool
Rearing Capacity (parr/m^2)
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Mainstem 1
Mainstem 2
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Skull
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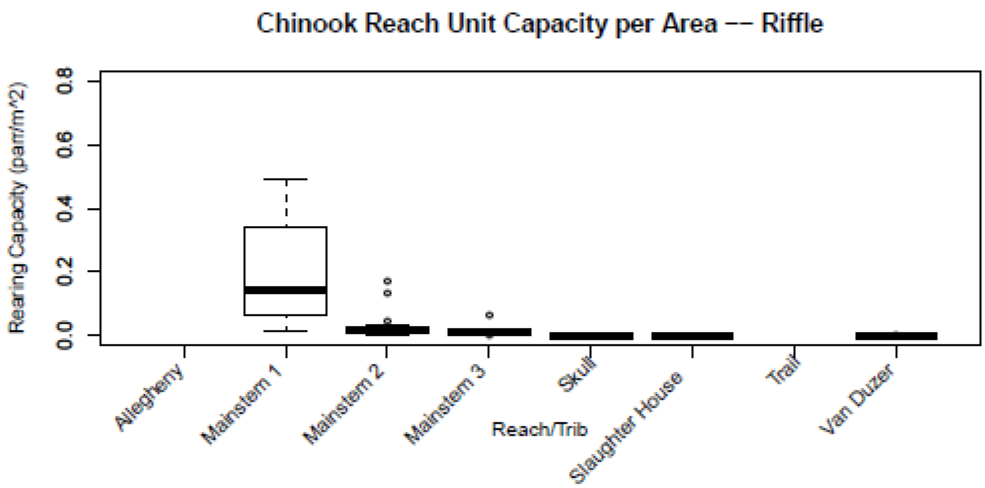
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Rearing Capacity (parr/m^2)
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Mainstem 1
Mainstem 2
Mainstem 3
Skull
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Van Duzer
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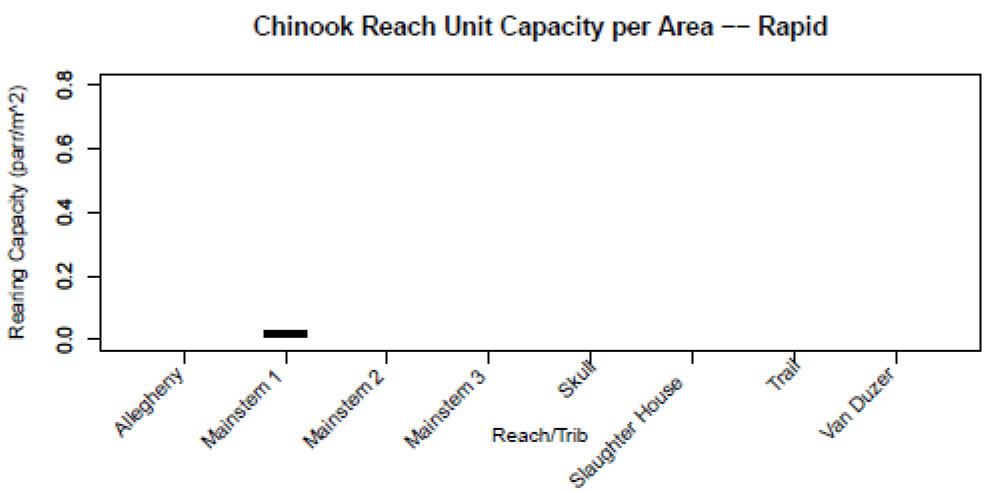
Chinook Reach Unit Capacity per Area -- Rapid
Rearing Capacity (parr/m^2)
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Skull
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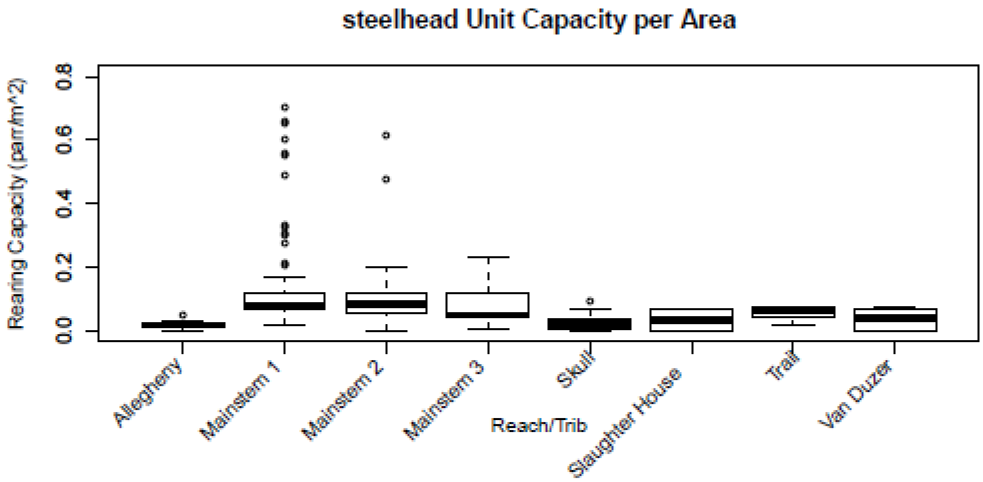
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Rearing Capacity (parr/m^2)
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Allegheny
Mainstem 1
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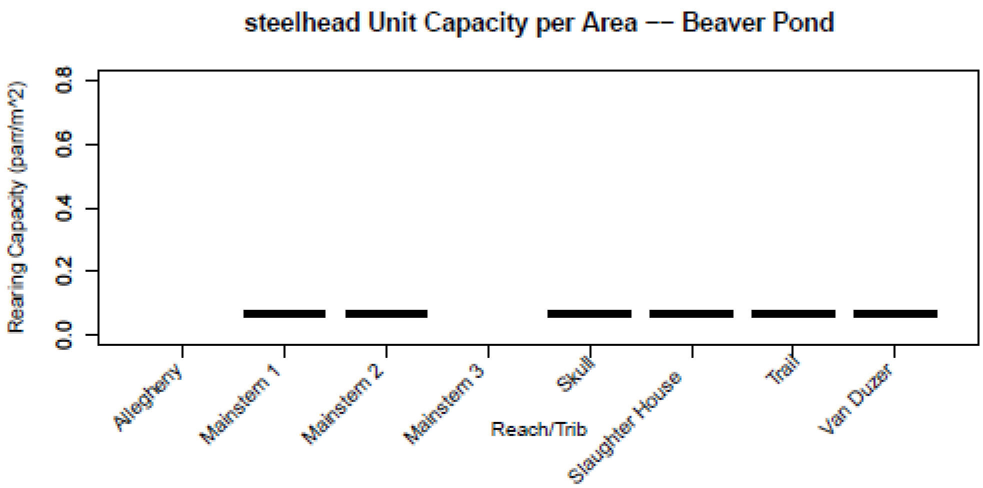
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Rearing Capacity (parr/m^2)
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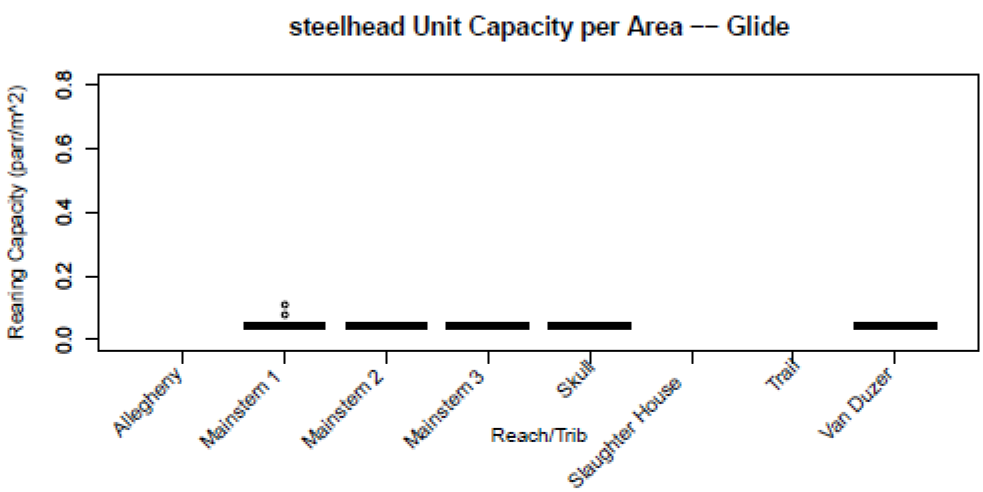
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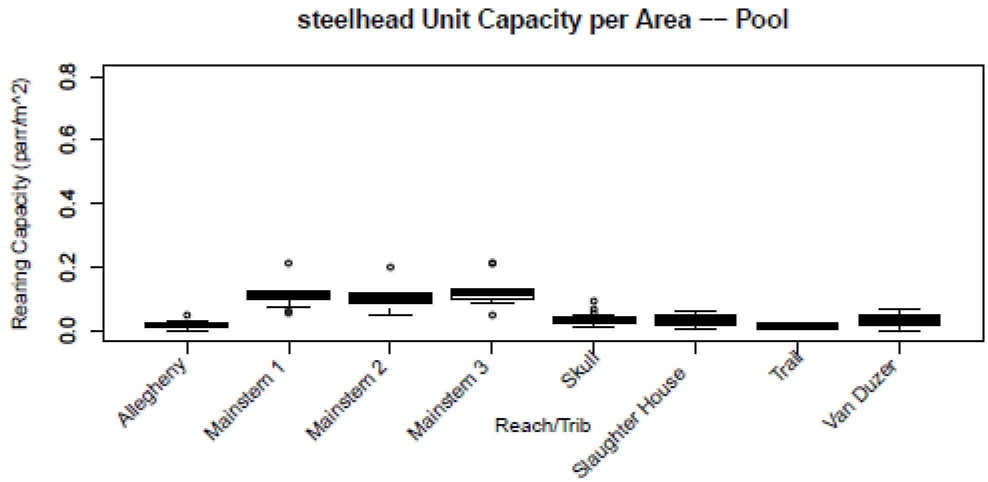
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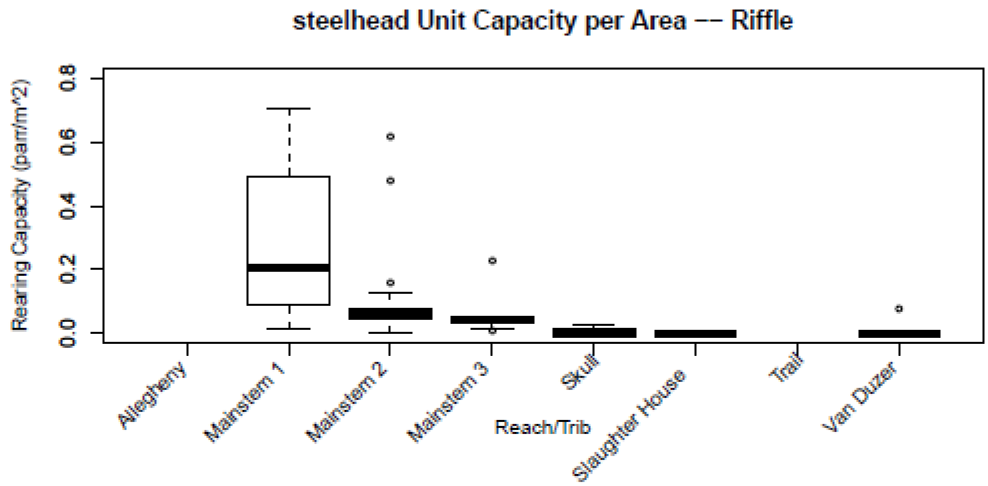
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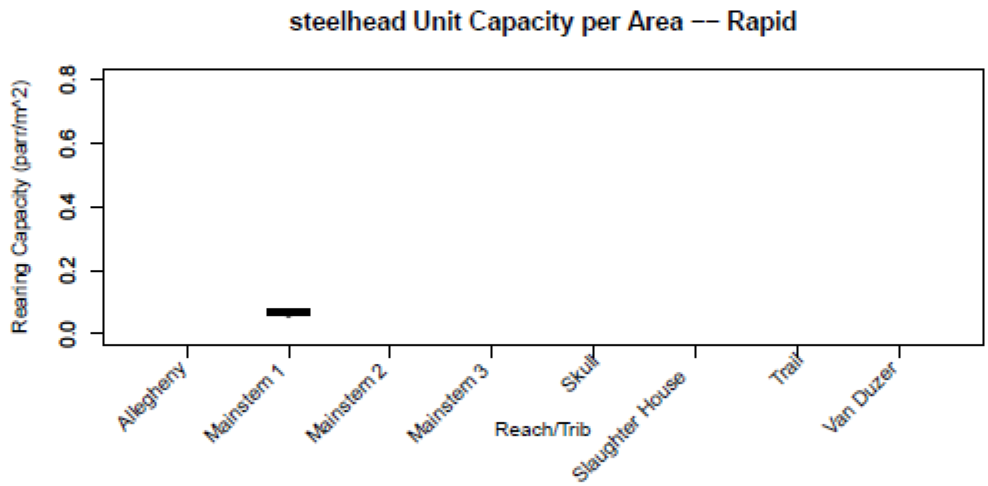
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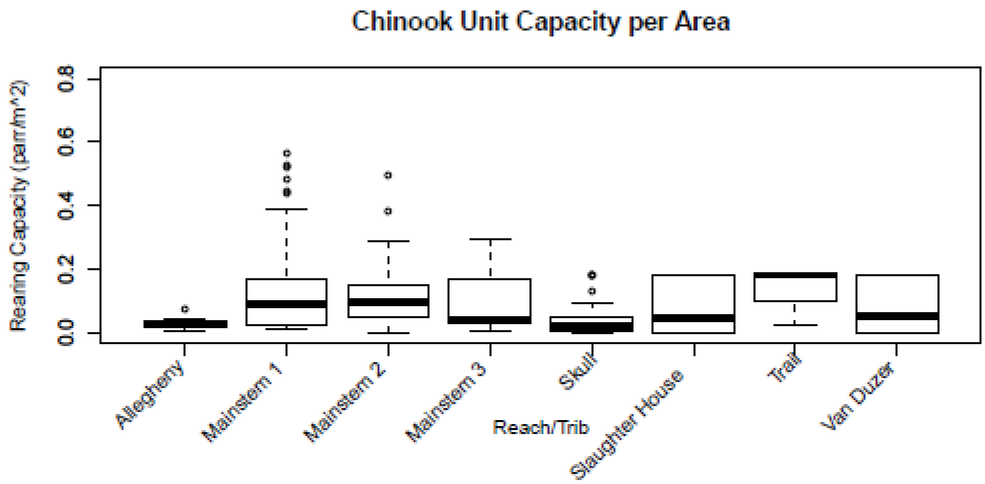
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Rearing Capacity (parr/m^2)
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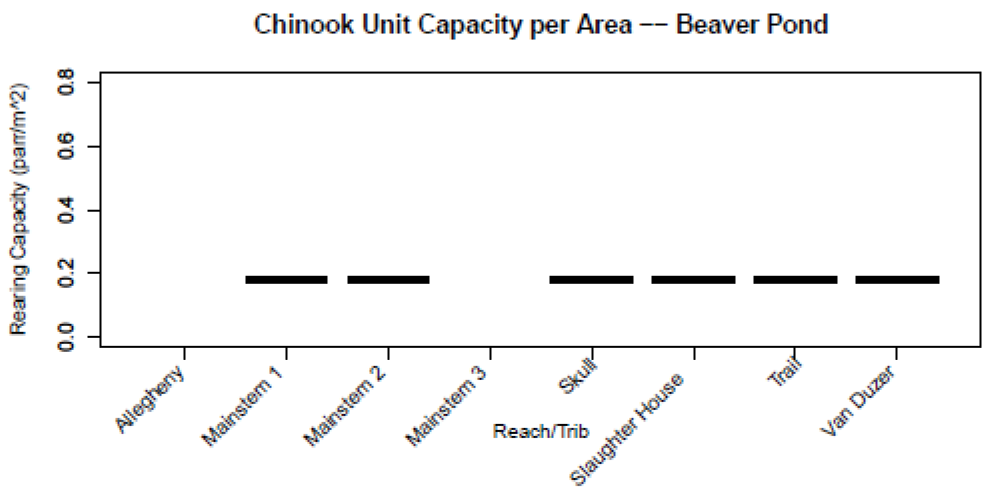
Reach/Trib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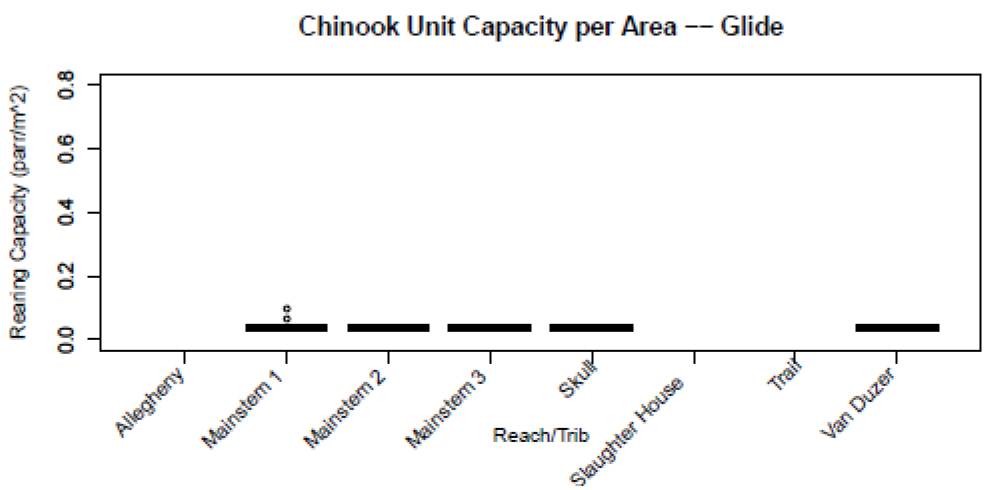
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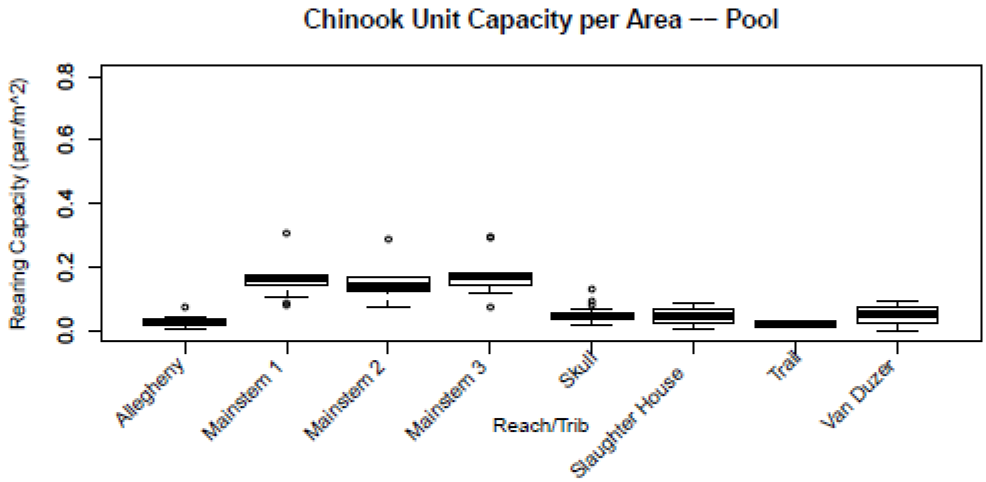
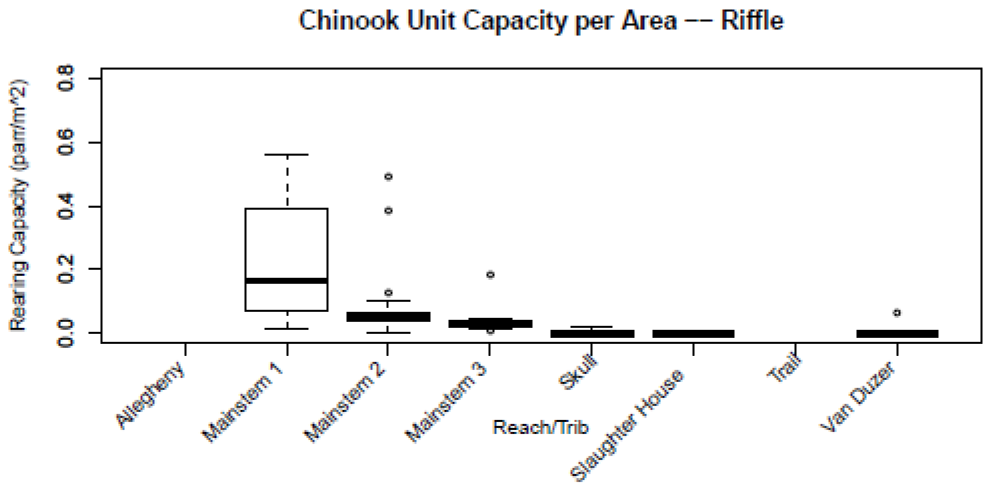
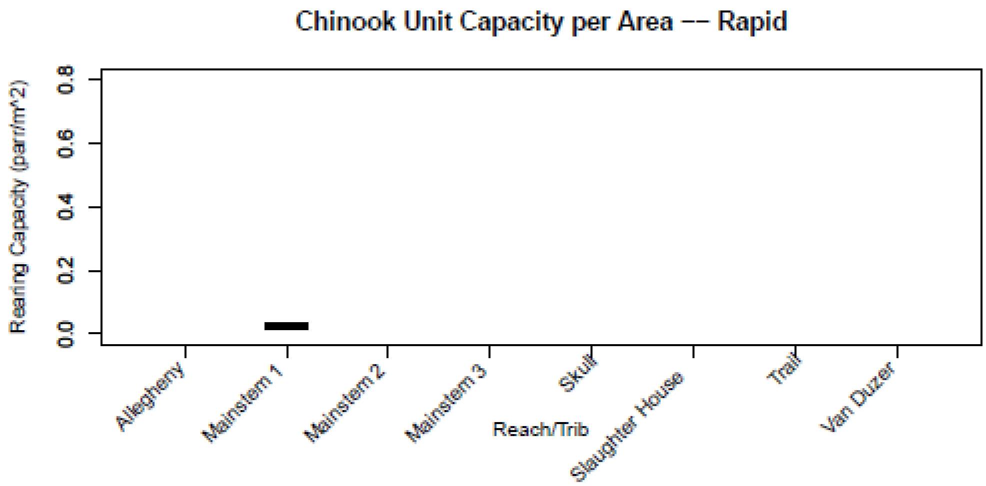
Van Duzer
Reach/Trib


Chinook Unit Capacity per Area -- Pool
Rearing Capacity (parr/m^2)
0.0
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


Chinook Unit Capacity per Area -- Riffle
Rearing Capacity (parr/m^2)
0.0
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib


Chinook Unit Capacity per Area -- Rapid
Rearing Capacity (parr/m^2)
0.0
0.2
0.4
0.6
0.8
Allegheny
Mainstem 1
Mainstem 2
Mainstem 3
Skull
Slaughter House
Trail
Van Duzer
Reach/Trib

APPENDIX D: HABITAT SURVEY SHEETS

Reach 1

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Vegetation	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull height)
1	GL	18	7	7	7	8	.	0.2	0.3	0.27	0.3	0.5			0	25	35	35	0	1	0	10	1.2
2	RI	43	7	9	11	11		0.2	0.2	0.23	0.2	0.3			20	20	40	20	15	1	0	13	1
3	P	63	7	11	10			0.9							30	15	25	30	40	1	0	28	1.4
4	RA	25	10	9	7	5		0.3	0.3	0.35	0.2				0	20	50	30	0	1	0	11	1.3
5	BP	21	6	10				1							0	20	50	30	0	1	0	13	1.25
6	RI	12	7	7	6			0.2	0.3	0.3					0	20	50	30	0	1	0	11	1.3
7	RA	43	7	6	5			0.4	0.3	0.3	0.4	0.3			0	10	40	50	0	1	0	11	1.5
8	RI	19	7	7				0.4	0.4	0.4	0.7				0	10	50	40	15	1	0	13	1.4
9	P	19	7	7				0.7							30	40	30	0	25	1	0	11	1.4
10	RI	16	12	13				0.4	0.3	0.25					0	30	45	25	0	1	0	14	1.3
11	P	45	8	8	7			0.9							40	20	40	0	30	1	0	13	1.7
12	RI	27	13	12				0.2	0.2	0.25					0	20	60	20	20	1	0	13	1.4
13	GL	40	11	12				0.4	0.4	0.45	0.4				25	25	50	0	35	1	0	13	1.3
14	RI	26	12	10				0.4	0.4	0.31					20	20	40	20	30	1	0	15	1.5
15	GL	51	8	7	6			0.5	0.5	0.4	0.5	0.6	0.3		10	10	45	35	30	1	0	16	1.5
16	RI	32	8	8	6			0.3	0.2	0.32					10	20	30	40	55	1	0	10	1.3
17	P	25	12	10	11			0.6							30	10	40	20	35	1	0	13	1.5
18	RI	20	6	4				0.3	0.2	0.2					15	15	35	35	30	1	4	10	1.3
19	GL	13	5	4				0.3	0.5	0.21	0.3					20	20	60	0	3	9	7	1.3
20	RI	17	5	4.2				0.2	0.2	0.4					5	15	20	60	20	1	1	6.5	1.4
21	GL	14	5	4.5				0.3	0.3						0	30	30	40	20	1	0	8	1.3
22	RI	20	4	5	4.5			0.9	0.3	0.25	0.5				0	20	60	20	15	1	0	6	1.4
23	RA	15	6	6.5	5			0.3	0.2	0.19	0.2				0	10	70	20	0	3	4	9	1.4

24	RA	12	6	3				0.1	0.2						10	0	70	20	5	1	0	7	1.1
25	P	8	3	3.5				0.5							10	0	70	20	15	1	0	6	1.2
26	RA	7	2	2.3				0.1	0.1						0	0	70	30	0	1	0	10	1.1
27	GL	12	2	2.7	3.3			0.3	0.2	0.17					0	0	70	30	15	1	0	10	1.3
28	RI	10	4	4				0.1	0.1	0.17					0	10	70	20	40	1	0	7	0.9
29	P	12	4	3.5	3			0.4							50	0	50	0	50	1	0	7	1.3
30	RA	3	2	2.9				0.1	0.1	0.19					10	0	90	0	5	1	0	6	1.1
31	GP	10	4	3.9	3.7	2									50	50	0	0	0				1.1
32	GP	6.5	1	1.3	1.2										30	70	0	0	0				0.9
33	RA	21	8	6				0.3	0.3								50	50	0	1	0	8	1.2
34	P	33	6	7	6			0.7							20		40	40	20	1	0	11	1.9
35	RI	88	12	12	11	9	7	0.3	0.3	0.3	0.3	0.3	0.4	0.4	20		40	40	30	1	0	16	1.3
36	P	20	8	7				0.8									40	60	40	1	0	11	1.5
37	RA	24	6	7	5.5			0.3	0.3								30	70		2	3	12	1.5
38	GP	1.5	1	0.6											50	10	40						0.7
39	RI	98	8	8	9	9	8	0.3	0.4	0.34	0.2	0.3			5		20	75	0	1	0	13	1.4
40	P	24	5	7				0.8							15	10	15	60		1	0	8	1.5
41	RI	16	7	7				0.4	0.4						5	5		90	0	1	0	11	1.4
42	P	51	7	8	9			0.8							20	0	40	40	40	1	0	14	1.6
43	RA	38	9	6	6			0.2	0.4	0.29	0.4				0	0	15	85	0	1	0	11	1.5
44	RI	30	7	7.5	8			0.4	0.5						5	0	20	75	5	1	0	11	1.4
45	RA	18	7	7	6			0.3	0.3						0	0	20	80	0	1	0	9	1
46	RI	31	6	7	8			0.4	0.5	0.27					10	0	20	70	0	1	0	10	1.4
47	P	70	9	8	8			1							20	20	30	30	50	1	0	10	2
48	RA	11	4	1.4				0.2	0.2	0.22					30		50	20		1	0	20	1.5
49	P	6	6	5	6			0.5									55	45		4	5	25	1.2
50	RI	13	8					0.1	0.3	0.17					10		50	40		4	2	25	1.2
51	GL	11	5	5.5	4.5			0.3	0.4						0	0	60	40	30	1	0	25	1.4
52	RA	16	5	6	5			0.2	0.2	0.26					0	0	60	40		1	0	25	1.3
53	P	9	7	7				1.2							40		20	40	20	1	0	13	1.8
54	RI	38	12	11	9	9		0.2	0.2	0.2	0.3				35		25	40	35	1	0	14	1.3

55	RA	14	6	7	8			0.2	0.2						30		30	40	30	2	2	10	1.6
56	RI	96	8	7	8	6	8	0.3	0.3	0.55	0.4	0.6			20		40	40	30	1	0	11	2.3
57	P	66	8	8	9			0.8							20		10	60	40	1	0	11	1.5
58	RA	22	8	7				0.2	0.2	0.25					20		20	60	10	1	0	11	1.4
59	GL	23	6	7	6			0.6	0.5	0.3					10		30	60	5	1	0	12	1.5
60	P	16	6	7				2							20		20	60	15	1	0	8	2.4
61	RA	34	6	7	7			0.3	0.3	0.31					0	0	15	85	0	1	0	11	0.9
62	P	10	7	7				0.9								0	20	80	0	1	0	9	1.6
63	RI	32	7	10				0.4	0.4	0.27					5	0	20	75	0	2	1	8	1.4
64	P	23	9	8	7			0.7							10	0	10	80	0	1	0	11	1.6
65	RI	124	6	7	9	7	7	0.5	0.4	0.63	0.4	0.3	0.4	0.2	10	0	15	75	10	1	0	11	1.5
66	GL	52	6	5	7	6		0.5	0.4	0.39					10	0	25	65	10	1	0	8	1.5
67	RA	25	7	9	7			0.3	0.4	0.31					20		20	60	0	1	0	14	1.5
68	RI	30	9	8				0.5	0.5	0.29					20		10	70	0	2	2	10	1.4
69	GP	3	2	1	1.4										10	40	50						0.7
70	P	51	8	7	99			0.6							15	20	25	40	20	1	0	10	1.4
71	RA	13	5	4.5				0.2							30	15	40	15	0	1	0	8	1.5
72	GL	25	4	5	7	6		0.4	0.3	0.33	0.2				30	30	25	15		2	2	7	1.2
73	RI	17	4	4	3			0.1	0.2	0.1					20	20	30	30	20	1	0	6	0.9
74	RA	16	3	3.2				0.2	0.1						15	15	20	50	0	1	0	8	0.8
75	RI	47	7	8	8			0.2	0.5	0.2					15	10	15	60	0	1	1	11	1.5
76	P	12	6	7				0.7							40	30		30	0	1	0	9	1.5
77	RI	70	7	6	5	5		0.3	0.4	0.2	0.6	0.4				15	15	50	20	1	0	9	1.5
78	P	45	6	6	7			0.8							5	10	5	80	15	1	0	8	1.7

Reach 2

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Vegetation	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull height)
1	RI	25	9	10	12				0.6	4	0.33			10	50	40			1	0	14	2.2
2	BP	161	14	12	10	12	12		1.4					95		5		85	1	0	17	2.9
3	RI	17	11	9					0.14	0.2	0.25			30	20	30	20		1	0	11	0.75
4	P	59	9	10					0.4					45	55				1	0	13	1.7
5	RI	10	11						0.14	0.3	0.25			5	95			65	1	0	15	2.3
6	P	165	12	9	9	10			0.8					20	20	40	20	65	1	0	17	2.5
7	RI	23	12	8					0.1	0.15	0.17	0.2	0.25	40	60			45	1	0	15	1.9
8	P	17	12	17					0.5					50	50			35	1	0	15	1.7
9	GP	20	2.3	1.9	2.4	5.6	4.5							40	60				1	0		0.6
10	RI	17	10	5					0.11	0.15	0.14			35	65				1	0	16	1
11	GP	26	27	2.4	2.8	4								40	60							0.7
12	P	38	6	4					0.6					30	20		50		1	0	12	1.6
13	RI	11	6						0.33	0.3	0.33	0.4		20	40	40			1	0	14	1
14	GP	9	2.3	3.2	2.8									25	75							0.5
15	P	63	12	11	9				0.8					30	40	20	10		1	0	17	1.6
16	RI	14	7						0.25	0.2	0.22	0.3		5	35	40	20	0	1	0	11	2.3
17	P	54	7	7	8				0.7					30	15	35	20	45	1	0	13	1.2
18	RI	29	8	7					0.3	0.35	0.4	0.4	0.32	10	15	45	30	0	1	0	17	1.4
19	Cp	25	2.6	2.1	3.3	3	1.3							15		85		0	1	0		0.9
20	RI	31	12	12	14				0.6	0.7	0.5	0.4		25	75	35			1	0	15	1.2
21	RI	14	9						0.3	0.2	0.18	0.2		15	15	70			1	0	12	1.3
22	P	49	7	7					0.7					70		30		35	1	0	15	1.7
23	RI	17	5						0.28	0.25	0.2	0.2		15	10	75		0	1	0	13	1.1
24	P	14	11						0.5					85		15		15	1	0	23	1.3

25	RI	12	10					0.24	0.2	0.32			20	70	10		0	1	0	22	1.2
26	P	11	11					0.5					50	20	20	10		1	0	22	1.5
27	RI	12	5					0.18	0.19	0.3	0.4	0.38	10	20	60	10	0	1	0	17	1.5
28	P	35	7	8	9			0.7					15	45	25	15	0	1	0	15	1.4
29	RI	65	10	12	8	8	6	0.28	0.2	0.23	0.3	0.26	5	15	80	0	25	1	0	11	1.2
30	P	55	6	9	6	8		0.8					30	10	60		15	1	0	20	1.5
31	P	74	8	7	7			1.1					70	10	20		25	1	0	16	1.6
32	RI	24	7	7				0.22	0.12	0.23			30	10	60			1	0	15	1.5
33	P	42	8	7	12	7	6	0.9					40	10	50		0	1	0	16	1.5
34	RI	14	5	6	4.5	5.6		0.2	0.17	0.18	0.3		30	40	30		0	1	0	17	1.4
35	P	24	8	9	8			1.2					50	20	20		0	1	0	19	1.6
36	RI	31	13	9				0.2	0.18	0.26	0.4	0.31	30	30	40	0	35	1	0	26	1.5
37	GP	23	6	8	7	4								75	25						1.1
38	P	45	6	7	9			0.8					30	70	25					26	1.2
39	RI	24	11	12				0.12	0.16	0.17	0.2	0.24	15	65	20		10	1	0	28	1.5
40	GP	8	2.1	1										100							1.1
41	P	17	5	6	7			0.62					20	40	40			1	0	20	1.2
42	GP	9	3.6	3.6	4.2								40	40	20						0.9
43	GP	17	3	3.4	2.1								20	40	40						0.55
44	RI	9	6					0.32	0.49	0.59			10	30	60			1	0	20	1.88
45	P	65	5	10	10			0.58					20	20	60			1	0	16	1.8
46	RI	22	11	7				0.22	0.24	0.25	0.2	0.51	30	10	60			1	0	26	1.75
47	P	13	8	8				0.62					45	10	40	5		1	0	43	1.79
48	GP	10	4	6									40	60							1.1
49	GP	26	3.5										40	60							1.1
50	RI	23	7	9	9			0.25	0.24	0.28	0.31	0.29	10	70	10	10		1	0	16	1.72
51	P	60	9	12	8			0.85					40	15	40	5		1	0	22	1.5
52	RI	28	7	6	5			0.35	0.29	0.27	0.3	0.34	15	5	70	10		1	0	17	1.1
53	P	47	8	8				0.67					50	5	40	5		1	0	13	1.6
54	RI	9	8	8				0.37	0.52				25	15	60		20	1	0	16	1.3
55	P	32	8	7				0.82					80	20				1	0	21	1.7

56	RI	11	4	4					0.33	0.3	0.39			10	80	10			1	0	5.5	1.7
57	GP	13	5	5	1									10	90				1	0		0.8
58	P	48	6	8	12	9			0.62					25	5	40	30		1	0	16	1.9
59	RI	30	9	10					0.33	0.45	0.52	0.5	0.35	20	10	60	10		1	0	16	1.75
60	P	18	12	9	10				0.59					50	10	30	10		1	0	22	2.55
61	RI	25	12	13	13				0.31	0.24	0.25	0.35		25	45	20	10	10	1	0	21	1.1
62	P	18	7	9	8				0.71					70		15	15	30	1	0	20	1.4
63	RI	70	12	10	8	9			0.38	0.47	0.6	0.4	0.34	15	10	65	10	5	1	0	15	1.1
64	P	36	9	8	11	9			0.46					30	10	40	20		1	0	13	1.65
65	GP	6	2.6	2.1										40	60							0.6
66	RI	30	9	6	8				0.37	0.38	0.27	0.4		20	30	40	10		1	0	15	1.55
67	P	356	9	10	9	10	7	9	1.2					75	10	10	5	15	1	0	16	1.8
68	RI	16	7	12					0.4	0.27	0.31					30	70		1	0	18	1.3
69	P	99	16	6	9				0.9					55	10	10	25	10	1	0	15	1.6
70	RI	42	12	15					0.39	0.22	0.25			10	80	10			1	0	17	1.4
71	GP	12	23	1.9										10	90							
72	P	110	7	8	8	6	8	11	0.9					65	30		5		1	0	13	1.8
73	RI	11	8	11	11				0.28	0.12	0.26			30	60	10			1	0	13	1
74	P	73	8	7	7	9			0.8					75	20	5			1	0	16	1.3
75	RI	38	7	8	8	9			0.33	0.29	0.18	0.4	0.42	30	60	10			1	0	12	1.3
76	GP	26	1.5	2	1.7	1	2.3	2.1						20	65	15						0.4
77	GP	4.5	1	1.7	1.9									5	95							0.35
78	P	36	9	8	9				0.69					70	15	10	5		1	0	13	1.4
79	RI	14	7	12	6				0.32	0.31				30	20	50			1	0	16	1.2
80	P	16	7	6					0.77					80	15	5			1	0	12	1.5
81	GP	10	4	3	1.6	2.2								40	55	5						1.3
82	RI	14	9	8	10				0.29	0.19	0.1			40	40	20			1	0	12	0.95
83	Run	35	8	7	7	6			28	0.41	0.42	0.4		35	30	30		5	1	0	17	1.2
84	GP	9	2	2.1	1.6	2	1.7							40	60							0.6
85	GP	12	6	6	7	6	4								90	10						1.2
86	P	36	7	10	7				0.87					75	15	5	5	10	1	0	11	1.3

87	RI	13	9.5	11					0.27	0.3			50	30	10	10		1	0	11	1.2
88	P	42	9	7	7	6			0.85				75	10	15		10	1	0	12	1.5
89	RI	31	5	7	8				0.15	0.3	0.33	0.2	30	60	10			1	0	11	1.2
90	P	17	12	9	9				0.51				20	30	30	20		1	0	17	1.4
91	R	22	7	7	6				0.35	0.3	0.37		30	50	20			1	0	17	1.4
92	GP	14	3.5	5.2	4.4	2.9	1.7						50	50							0.8
93	P	106	6	7	7	8	10	11	0.61				65	15	10	10		1	0	13	1.4
94	RI	27	9	11	7				0.26	0.18	0.31		15	20	65		5	1	0	12	1.3
95	P	83	12	12	16	23	10		0.7				70	10	10	10	5	1	0	14	1.4
96	RI	12	8	6					0.66	0.36				20	20	60		1	0	10	1.1
97	P	28	7	7	7				1				40		10	50	5	1	0	9	1.3
98	RI	42	9	6	6	11	14		0.36	0.2	0.28	0.21		20	40	40		1	0	14	1.3

Reach 3

Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Bedrock	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull
34	10	12	11				0.8				75	5	10	5	30	1	0	15	1.4
70	11	11	13				0.19	0.32	0.24	0.23	25	25	40	10	35	1	0	16	1.2
18	9	8	9.5				0.13	0.2	0.19		25	40	35	0	15	1	0	13	1.2
58	11	11	10				0.9				40	20	40	0	35	1	0	15	1.5
13	12	10					0.15	0.32	0.2		30	30	40	0	20	1	0	27	0.9
15	12	11	11				0.6				30	30	40	0	30	1	0	27	1.1
13	7	8					0.2	0.27	0.21		20	30	50	0	20	1	0	18	1
809	11	9	13				0.7				30	20	50	0	30	1	0	15	1.1
14	12	14					0.2	0.2	0.21		50	10	40		15	1	0	19	1.4
77	7	8	9				1				95	5	0	0	15	1	0	17	1.6
11	6	6.6	3.6	2.5							75	25	0	0	0	1	0		1.7
30	14	17	13	14			0.37	0.27	0.17	0.21	30	10	60	0	25	1	0	19	0.9
42	16	15	14				0.7				75	5	20	0	30	1	0	18	1.3
12	6	4					0.19	0.11			30	30	40	0	0	1	0	13	0.7
11	8	6	8				0.4				30	30	40	0	0	1	0	12	0.9
13	5	4					0.16	0.17			25	30	45	0	0	1	0	8	0.8
16	4	5.5					0.31	0.27			30	20	50	0	20	1	0	7	0.9
57	5	6	6				0.5	0.9			30	10	60	0	25	1	0	8	0.8
83	5.5	6	6	5	5		0.7				75	25	0	0	0	1	0	8	1.1
4.5	1.1	1.2	1								25	75	0	0	0	1	0		0.7
8	2	2.4	2.5	2							25	30	45	0					1.2
48	5	5	4	12			0.12	0.17	0.2	0.06	15	40	45	0	0	1	0	10	0.7
28	4.5	3.5	4.3	2.9	0.7	2					10	20	70	0	0	1	0		0.5
24	16	12	13				0.21	0.12	0.27		30	40	30	0	15	1	0	21	1
12	3.4	7.4	8.4	7							40	30	30	0	0	1	0		1
84	7.8	8.6	7	10	13	12	1				70	10	20	0	15	1	0	17	1.6

6	3.6	4.2	4.5								60	40							
64	14	17	15	12	13		0.31	0.14	0.27	0.19	25	20	50	15	15	1	0	18	1
15	5.45	4.1	4.9								5	35	60	0	0	1	0		0.6
38	11	11	13				0.9				85	5	10	0	30	1	0	17	1.4
42	13	11	12	9			0.19	0.2	0.27	0.18	35	10	35	20	25	1	0	14	1
104	13	17	18	18			1.2				45	55	0	0	30	1	0	23	1.9
8	10	13					0.19	0.18	0.21		10	20	70	0	15	1	0	17	1.9
140	14	11	9.9	10.2	15	13.6	1.5				20	75	5	0	35	1	0	17	1.9
83	10	9	7	13	9		0.25	0.12	0.21	0.31	0	50	50	0	15	1	0	15	1.4
19	7	7	7.5				0.23	0.27	0.17		10	30	60	0	0	1	0	9	1.5
23	1.7	3	9	9	5	3.5					15	55	30	0	0	1	0		1.1
13	6	5					0.7				20	50	30	0	0	1	1	8	1.4
9	4	3.5	3.2	2.7			0.1	0.15	0.27		0	50	50	0	0	1	0	10	0.6
40	2.7	7	9	8.5	11		0.11	0.12	0.13	0.15	0	50	50	0	5	1	0	11	0.8
75	8	3	1.3	2	5	3					10	60	30	0	0	1	0		0.5
24	8	8					0.8				25	60	5	0	0	1	0	21	1.5
4	2.6	2.2	1.8								20	60	20	0	0	1	0		0.6
40	17	9	12				0.22	0.17	0.13		10	50	40	0	15	1	0	26	1.9
6.7	3.5	3	2.6								10	50	40	0	0	1	0		0.7
9	2	1.9	1.3								10	60	30						0.5
50	7	8	9				1				0	50	50	0	0	1	0	18	1.9
50	3.7	5.8	4.76	3.97								15	75	10					0.6
7	4.8	5.24	4								15	75	10	0	0	1	0		0.7
10	6	7					0.17	0.25			0	40	60			1	0	17	1.8
157	15	9.5	12	9	17	12	1.2				20	60	20		20	1	0	21	1.4
7	3.5	3.12	3.2								60	40							0.65
12	9	8					0.13	0.23			0	40	60			1	0	15	1.2
5.6	3.6	2.7	2.7								10	50	40						0.5
42	9	10	8.5				1.1				10	60	30					15	1.5
26	7	6	6				0.22	0.2	0.21		25	30	20	25		1	0	18	1.3
5.3	2.3	1.9	2.2								5	55	40						0.7

26	8	10	7	1.5						5	30	65						0.6
9	8	8	9				1			30	40	30	0	0	1	0	21	2
16	6	7	6.5				0.12	0.11		30	20	50	4	0	1	0	17	1.5
25	5	5	5				0.32	0.24	0.25	20	40	40		25	1	0	9	1.1
27	2.3	3.5	4	2						20	40	40						1
69	7	6	8	11	11		1.1			45	35	10	10	35	1	0	11	1.9
12	12	11	11.5				0.25	0.17		15	20	50	15				20	1.1
9	4	5	5	2						40	60							0.6
26	8	10	13				0.8			40	25	15	20	0	1	0	13	1.4
8	12	13					0.12	0.16		15	20	65	0	20	1	0	14	1.3
80	9	10	16	11			1.1			15	30	30	25	0	2	3	18	1.7
21	3	7	5	5.5	4	2.5				30	60	10	0					0.6
45	7	11	8	13			0.27	0.6	0.2	5	10	45	40	0	1	0	16	1.1
45	12	12	13				0.6			50	40	10	0	0	1	0	15	1.2
8	2	2.2	1														15	85

Slaughterhouse Creek

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg
1	BP	24	21	17	22					1.5							80	15		5	1	0	30	3
2	BP	46	24	17	15	15				1.3							80	15		5	1	0	32	2.3
3	BP	11	12	9	9	8				0.6							100				1	0	33	1.4
4	BP	10	12	9	8					0.5							100				1	0	33	1.3
5	BP	18	25	25	21					0.5							100				1	0	40	1.3
6	BP	31	21	23	29	23	19			1.4							100				1	0	38	2.1
7	BP	14	8	8	6					1							100				1	0	20	1.3
8	BP	26	7	7	12					0.8							85			15	1	0	30	2.4
9	BP	37	10	7	3.6	5.8	5			1.5							90			10	1	0	17	1.9
																					1	0		
Upper Slaughterhouse after culvert GPS (41.85815, 115.96135)																								
10	R	18	3.2	3.2	2					0.06	0.05	0.05					40	60			1	0	7	1.3
11	P	3	3.1	3.2	1.7					0.23							40	60			1	0	5.9	1.7
12	R	6	1	1.1	0.9	0.9				0.06	0.06	0.07	0.05				40	60			1	0	4.2	1.2
13	P	2.7	2.3	2.8						0.2							35	65			1	0	4.5	1.4
14	R	6	1.3	1.3	1.3	2.9				0.06	0.07	0.02	0.02				35	65			1	0	3.1	1.5
15	R	26	2.2	1.8	1.8	1.5	2	1.7	1.4	0.1	0.06	0.03	0.1	0.06	0.06	0.07	35	65			1	0	4.5	1.4
16	P	3.6	2.5	3.2	2.6					0.15							45		55		1	0		
17	R	6	1.3	1.1	1.3					0.15	0.04	0.05						75	25		1	0	2.5	0.8
18	P	1.2	1.9							0.3								75	25		1	0	2.6	1.1
19	R	10.2	1	1.2	1.1	1.1	1			0.1	0.12	0.11	0.06	0.08			20	80			1	0	1.5	0.6
20	P	1.7	1.1	1.2						0.3							30	70			1	0	1.9	0.69
21	R	10.9	1.4	1	1	0.5	0.9	1.6	1	0.08	0.04	0.07	0.1	0.16	0.06	0.07	40	60			1	0	2.5	0.76
22	R	3.6	1.7	1.4	0.9	0.9				0.11	0.04	0.06	0.04				30	70			1	0	2	0.78

23	P	1.4	0.8							0.1							60	40			1	0	1.9	0.67
24	R	8	1.1	1.1	1	1.4	1.2	1.3	1.3	0.13	0.1	0.05	0.05	0.05	0.04	0.06	20	70	10		1	0	1.45	0.9
25	P	0.76	1.1							0.21							25	40	20	15	1	0	1.5	0.95
26	R	0.8	0.9							0.07							70	30			1	0	3.3	1.1
27	P	1.4	1.5							0.15							50	50			1	0	2.8	0.95

Skull Creek

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Vegetation	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull
1	BP	42	89	87	92			>2				Too deep to determine					1	0	94	0.4
2	P	12	8	9				>2				Too deep to determine					1	0	12	2.4
3	BP	100	136	40	14	18	7	>1				Too deep to determine					1	0		0.6
4	BP	38	31	9	12	5		1				75	10	15	0		1	0	40	1.3
5	RI	11	2	23	21			0.11	0.12	0.1		40	20	40		20	1	0	6	0.5
6	P	21	3	4	4	2		0.3				30	5	65			1	0	14	0.7
7	GP	8	4	4	1.8							30	20	50						0.5
8	RI	18	1	0.8	1.3	1.7		0.1	0.17	0.08		20	20	40	20		1	0	4	0.5
9	P	7	2	2.7	2.4			0.3				25	35	20	20		1	0	3.2	0.6
10	RI	4	1	1.2	1.4			0.07	0.05			20	35	35	10		1	0	3.5	0.5
11	P	5	2.4	2				0.22				25	40	30	5	15	1	0	3.7	0.4
12	RI	12	2	2.2	2.1			0.04	0.12	0.11		25	50	25			1	0	6	0.4
13	P	15	1.7	1.8	2.2	2.1		0.3				20	40	40			1	0	7	0.5
14	RI	11	1.7	1.2	0.6			0.11	0.2	0.11		30	60	10			1	0	11	1
15	P	9	2.2	2				0.28				30	60	10			1	0	11	1.2
16	GP	6	1	2.4	2.2							30	60	10			1	0		0.7
17	RI	4	1.6	1.2				0.09	0.05			40	50	10			1	0	9	1
18	P	13	5	4				0.37				50	20	30			1	0	7	1
19	RI	6	2	2.1				0.08	0.05			30	25	45		5	1	0	8	0.9
20	P	7	2	2.1				0.32				30	30	40			1	0	6	1.1
21	RI	10	2.2	4	3			0.1	0.08	0.07		20	40	40			1	0	5	0.7
22	P	12	2.4	3.3				0.19				30	10	60			1	0	4.2	0.6
23	RI	3.8	1.3	1.5				0.08				40	10	50			1	0	5	0.5
24	P	5	2.3	2				0.17				40	10	50			1	0	15	0.6
25	RI	15	2.2	2.5	2.1	1.1		0.11	0.17	0.15	0.14	35	15	50			1	0	5	0.8

26	P	4	2.3	2.3				0.3				35	15	50			1	0	5	0.8
27	RI	13	2	2.7				0.1	0.17	0.15		35	15	50			1	0	5	0.6
28	P	9	2.6	3				0.3				40	10	50			1	0	6	0.9
29	RI	10	1.2	1.8	1.9			0.13	0.12			20	40	40			1	0	5	0.7
30	P	7	3	4.2	3.2			0.25				60	20	20			1	0	6	0.9
31	RI	5	2	1.5				0.12	0.2			20	40	40			1	0	5	0.8
32	GL	11	1	0.9	0.8			0.12	0.16	0.1		80	20			15	1	0	7	0.9
33	P	10	1.8	1.4	1.5			0.26				55	10	30	5	15	1	0	2.4	0.6
34	RI	15	1.7	1.2	3.5			0.08	0.19	0.13		20	40	30	10	10	1	0	37	0.7
35	P	6	2.4	2.1	2.3			0.25				55	30	15		30	1	0	7	1.1
36	RI	11	2.3	1.6	2			0.12	0.08	0.13		15	30	50	5		1	0	8	0.7
37	P	8	3	2.9				0.32				35	15	30	20		1	0	10	1.2
38	GP	15	2	5	9	13	2					40	60							0.8
39	RI	9	1.6	1.7	2.2			0.09	0.14			30	50	10	10	15	1	0	13	1.1
40	P	5	2.2	2.8				0.29				40	30	15	5	20	1	0	6	0.6
41	RI	5	1.3	1				0.09	0.07			70	10	20	10		1	0	8	0.9
42	P	6	2.24	2.6				0.5				45	40	15		25	1	0	6	1.2
43	RI	9	1	3.3				0.09	0.1			25	25	30	10	60	1	0	9	1
44	P	6	3	3	3.1			0.16				60	40			80	1	0	7	0.7
45	RI	4	2	1.9				0.1	0.08			40	30	30		60	1	0	6	0.7
46	P	5	1.2	1.8				0.21				50	30	20		15	1	0	7	0.8
47	RI	6	0.9	1.3	1.4				0.12	0.11	0.03		35	40	25	30	1	0	7	0.8
48	GP	4	2.5	2.6	1.7							10	50	40						0.5
49	P	18	3	1.9	2.1	3.8		0.43				40	30	30		25	1	0	8	1.1
50	RI	9	2.3	2.4					0.08	0.04			30	30	25	15	1	0	5	0.7
51	GP	2.5	0.8	1.1									80	20						0.2
52	P	17	4	4.5	3.1			0.32				35	40	20	5		1	0	6	0.7
53	RI	3	4	3.5	2.9			0.1	0.05				45	40	15		1	0	5	0.6
54	P	5	2	2.3				0.27					40	50	10		1	0	8	0.8
55	RI	3	1.2	0.9				0.17	0.1	0.11		20		60	20		1	0	9	0.8
56	P	7	3	2.6	2.4	2.1		0.26				15		70	15	25	1	0	10	0.9

Van Duzer Creek

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Depth (m)	Depth (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Vegetation	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull	Notes
1	BP	25	48	48	2	3	3				0.8				100					1	0		1.1	
2	BP	80	2.7	2.8	2.7	3.6	2.5	2.9			0.8				50	20	10	20		1	0	4.92	1.7	
3	RI	1	2	1.1	0.9						0.03	0.02			40	20	40			1	0	3.5	1	
4	P	13	1.5	1.2	2.2	4					0.28				60	20	20			1	0	4.2	1.5	
5	RI	4.8	2.7	2.2							0.03	0.02			50	10	40			1	0	2.3	0.9	
6	P	4	1.4	1.8							0.15				50	40	10			1	0	2.4	1	
7	RI	3.5	0.6	1							0.4	0.3	0.3		50	40	10			1	0	3.31	0.8	
8	P	4.5	0.8	1.1	1.5						0.16				50	40	10			1	0	3.5	1.2	
9	RI	2.5	1.1	1.2							0.01	0.03	0.04		50	20	30			1	0	6	1.2	
10	P	3	0.9	0.9							0.09				50	20	30			1	0	6	1.2	
11	RI	5	1.7	0.9							0.06	0.05	0.03		50	10	40			1	0	5	1.1	
12	P	6	1.2	0.8							0.18				70	20	10			1	0	4.4	1.1	
13	BP	25	2.8	3.8	4.3	3.8	2.7				0.9				60	30	10		35	1	0	7.68	1.6	
14	BP	21	4.3	3.9	3	2.7					0.8				60	30	10			1	0	6.6	1.3	
15	BP	48	10	3.3	4.5	3.6					1.1				75	5	10			1	0	8.7	1.8	
16	BP	26	3.6	2	4.3						0.8				80	10	5		5	1	0	3.6	1.4	
17	BP	17	12	18	20						1.2				80	10		10		1	0	6.5	1.6	
18	BP	70	28	25	9	4.1					1.1				90	5	5			1	0	37	1.4	
19	BP	105	6.4	4.7	3.9	4.2	3.5	3.5			0.6				90	5	5			1	0	7.3	1.2	
20	BP	Greater than 60m and very deep. Marshy with extensive channels. Significant amounts of vegetation in the pond. Mostly fines. Very difficult to survey due to deep water, mud, and extensive size																						
21	BP	61	4	3	7	2				1.3			90	10			5			1	0	7	1.6	

22	BP	35	3	5	3.9	2.6	3.2				0.9				80	20	1	0	4	1.6	
23	BP	11	3.2	2.8	4						0.8				80	20			5.3	1.5	
24	BP	61	10	5	15	5	7	8	6	4.5	0.9				80	20	1	0	25	1.5	Large Marshy, multiple channels
Middle Flowing water section. Beg. @ bridge 41.75037, W115.95493; End at 41.75031, 115.95522																					
1	**P**	**4.4**	**1.4**	**1.2**							**0.31**				**70**	**30**	**1**	**0**	**2.2**	**1.3**	
2	RI	4	0.8	0.9							0.02	0.03	0.02		70	30	1	0	4	1	
3	P	3.5	1	1.1	1.4						0.35				70	30	1	0	3.5	1.2	
4	RI	3.5	0.8	0.9							0.02	0.04	0.02		70	30	1	0	2	1.2	
5	P	7	1.2	1.4							0.42				70	30	1	0	4	1.4	
6	RI	2	0.9	0.8							0.08	0.06			70	30	1	0	2.5	0.9	
7	P	8	1.5	2	1.3						0.24				70	30	1	0	4.5	1	
8	RI	2.5	1	1							0.04	0.03			70	30	1	0	3.5	0.9	
9	P	7	1.8	2.2	1.5						0.37				70	30	1	0	3.7	1.2	
10	RI	8.6	1.7	0.8	0.9						0.07	0.07	0.06	0.03	70	30	1	0	2.7	0.9	
11	P	1.5	2	1.9							0.4				70	30	1	0	3	1.4	
12	RI	4	0.9	0.9							0.05	0.05			70	30	1	0	5	0.9	
13	P	1.5	1.9	2.5							0.4				70	30	1	0	4	1.3	
14	RI	7	0.7	0.7	0.9						0.03	0.04	0.02		35	65	1	0	4.5	1	
15	P	3	0.4	0.4							0.3				80	20	1	0	1.2	3	
16	RI	3	0.6	0.5							0.04	0.05			30	70	1	0	6	1.1	
17	P	6	1.5	1.6							0.5				80	20	1	0	5	1.4	
18	RI	5	0.4	0.6	0.8						0.07	0.08	0.06		30	70	1	0	3.7	1	
19	GP	1.2	1.1	1											30	70				0.25	Thalwag to Gravel Surface
20	GL	4	1	1.3							0.07	0.06			90	10	1	0	5	1.2	

Trail Creek

Unit #	Habitat Type	Length (m)	Width (m)	Width (m)	Width (m)	Width (m)	Depth (m)	Fines	Gravel	Cobble	Boulder	Bedrock	Wood Complexity	LWD Count	Active Channel Width	Cross section depth (thalweg to bankfull height)
1	BP	31	3.9	2.9	4.1	5	0.57	100					1	0	7.5	1.2
2	Dry Patch	12						100							6	
3	P	3.4	2.3	2.1			0.18	100					1	0	4.5	1
4	Dry Patch	6.6						100					1	0	6	
5	BP	5.7	1.4	5.7			0.1	100					1	0	6	1.2