FISHERY RESEARCH

Assessment of Native Salmonids Above Hells Canyon Dam, Idaho

1998 Annual Progress Report

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Fisheries Research Biologist

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By

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To

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ABSTRACT

Native resident salmonids in the western United States are in decline throughout much of their range. The purpose of this multi-phased project is to restore native salmonids in the upper Snake River basin to self-sustaining, harvestable levels. As a first step, the Idaho Department of Fish and Game (IDFG) began in 1998 by inventorying native salmonid populations in 75 streams in the upper North Fork Payette and upper Weiser river basins. We also counted bull trout *Salvelinus confluentus* redds in the upper Boise River basin and began a study to analyze the population dynamics of a brook trout *S. fontinalis* population being eradicated from a bull trout stream by the Southwest Basin Native Fish Watershed Advisory Group (SBNFWAG), to test whether eradication is possible and whether compensation occurs.

Redband trout *Oncorhynchus mykiss gairdneri* were found in 49 of the 75 North Fork Payette and Weiser rivers. A total of only four bull trout were found in two streams, and both streams contained brook trout. There was a strong positive relationship between the number of trout caught in the first pass and the corresponding population estimates; this relationship was used to estimate abundance in streams with only a single removal pass.

Five adfluvial and four resident bull trout redds were located in 220 hours of redd counting in the upper Boise River basin. In South Fork Boise River tributaries, incessant kokanee *O. nerka* spawning activity may have obscured redds constructed by bull trout.

Brook trout removal efficiency in reaches of the Pike's Fork of the Crooked River were extremely high, but we estimate that approximately 11 age-1+ and 83 age-0 fish escaped removal, in addition to the brook trout that existed above the removal area. In a comparison of aging methods, otolith reading was not only more accurate than scales, but also required less time. No brook trout that we aged were older than age-3. Within any given age class, mature fish were larger than immature fish. Mortality between the oldest age classes was extremely high (94.2% ± 4.8). Both sexes first reached maturity at age-1, but a higher proportion of males than females were mature for each age class. Females outnumbered males in each age class. These demographics parameters will be monitored throughout the project to assess whether continued removal triggers a compensatory response in the brook trout population, and whether the bull trout population increases after brook trout have been removed.

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INTRODUCTION

Bonneville Power Administration (BPA) Project 98-002 was established with the IDFG under the Northwest Power Planning Council's 1998 Fish and Wildlife Program. The overall project goal is to protect and restore native resident salmonid populations in Idaho's Snake River basin above Hells Canyon Dam to self-sustaining, harvestable levels. In the upper Snake River basin, quantified data on the status and trends of native salmonids is generally lacking for many populations (Thurow et al. 1997). The project has multiple phases. The first phase is a basin-wide, systematic inventory of native salmonids to determine the current status and trends of the populations. The second phase is to identify factors limiting population size and threats to future persistence. Once limiting factors and threats to persistence are identified, recovery and restoration plans will be developed and implemented.

The North Fork Payette River and Weiser River, tributaries of the Snake River in west central Idaho, historically contained bull trout *Salvelinus confluentus*, though bull trout were more abundant in the Weiser River (D. Anderson, IDFG, personal communication). In recent years, bull trout, which in 1998 were listed in the Columbia River basin as threatened under the Endangered Species Act (ESA), have declined across much of their range; the extent of the decline, however, is not well defined (Rieman et al. 1997). Redband trout *Oncorhynchus mykiss gairdneri*, also native to the North Fork Payette River and Weiser River, are more widely distributed across their range and in these drainages. Nevertheless, populations have declined and a petition was filed in 1995 to list them under the ESA.

There exists a strong adfluvial component to the Boise River bull trout population that migrates from Arrowrock and Anderson Ranch reservoirs into headwater tributaries to spawn (Flatter 1998). Smaller, resident bull trout also occur throughout the upper Boise River basin. The size of the bull trout population in the Boise River basin, however, is not well defined. An index of bull trout abundance would be helpful in monitoring population strength and trends over time. One of the simplest methods of monitoring trends in population abundance is to establish stream index reaches for counting redds (Bonar et al. 1997). Using redd counts to follow trends in upper Boise River basin bull trout may be easier than attempting to estimate the overall population size because of the difficulty in capturing these cryptic, highly mobile fish.

The introduction of non-native brook trout *S. fontinalis* has had deleterious effects on bull trout through competitive interactions and hybridization between the two species (Rieman and McIntyre 1993). Though brook trout have been documented in only 14 of the 108 sub-watersheds of the upper Boise River basin, they are considered to pose a serious risk to some current populations of bull trout in the upper Boise River watershed (SBNFWAG 1998). Removal or suppression of brook trout where they coexist with bull trout has been recommended as a conservation action in six Priority 1 sub-watersheds of the Boise River basin, including Pike's Fork of the Crooked River. However, the effectiveness of removing brook trout where rare native salmonids occur has not been fully evaluated, especially with respect to bull trout conservation. Thompson and Rahel (1996) effectively removed 73% to 100% of age-0 and 59% to 100% of age-1 brook trout from three study streams, but failed to completely eradicate brook trout from any of them. Furthermore, the remaining trout may compensate after the fish population is reduced through increased growth and fecundity and decreased natural mortality (McFadden 1961, 1976), negating some or all of the effect of the removal. Before brook trout removal or suppression is considered on a wider scale, the population-level effects should be more thoroughly studied.

OBJECTIVES

1) To inventory native salmonid distribution and abundance in the North Fork Payette River and Weiser River basins;

2) To assess the effectiveness of locating bull trout redds in the upper Boise River basin and of establishing index reaches for future trend analysis; and

3) To assess whether an intensive brook trout removal effort over three years in a small stream can effectively eliminate brook trout and lead to an increase in bull trout numbers in subsequent years.

METHODS

Payette/Weiser Fish and Habitat Surveys

The North Fork Payette River basin lies in west-central Idaho and flows from the Sawtooth and Salmon River mountains at elevations over 3,000 m to an elevation of 648 m where the mainstem Payette River enters the Snake River (Figure 1). The North Fork Payette River drains about 2,460 km², and the geology is mostly highly erosive granitic soils. The Weiser River watershed lies to the west of the North Fork Payette River (Figure 1) and enters the Snake River less than 30 km downstream of the Payette River. The Weiser River drains 4,300 km² from the headwaters to where it enters the Snake River. Elevation at the headwaters is about 2,500 m, and much of the drainage is rolling foothills dissected by many small streams.

In an attempt to quantify the distribution and densities of bull trout, redband trout, and other non-native trout and non-game fishes in the upper reaches of the North Fork Payette River and Weiser River basins, numerous streams were sampled from each drainage. Sample streams were selected based on the potential of the stream to contain native salmonids. Coordination with IDFG regional biologists and U.S. Forest Service biologists was conducted to prioritize streams and avoid sampling where analogous information had recently been gathered.

One or two sampling reaches were selected for each stream, usually 100 m long but ranging from 25 to 104 m. Reaches were selected, not at random, but to be as representative of the rest of the stream as possible. Sampling sites tended to be located near roadside access to maximize time efficiency. Following the IDFG Standard Stream Survey (IDFG 1994, modified 1996) procedures, a crew of two to three persons collected stream habitat and fish abundance data. Habitat variables collected from the reach included mean depth, mean wetted width, channel type, gradient, conductivity (with a conductivity meter), water temperature (with a hand-held thermometer), ocular estimates of substrate particle size distribution (sand through bedrock), percentage of habitat type (pool, riffle, run, pocketwater), and unstable banks.

Once habitat data was collected, fish were sampled using either electroshocking or snorkeling techniques. When electroshocking, the operator worked slowly in an upstream direction, searching all available habitat. At least one netter assisted the operator in capturing fish. Single or multiple passes were made to collect fish, and captured fish were held in

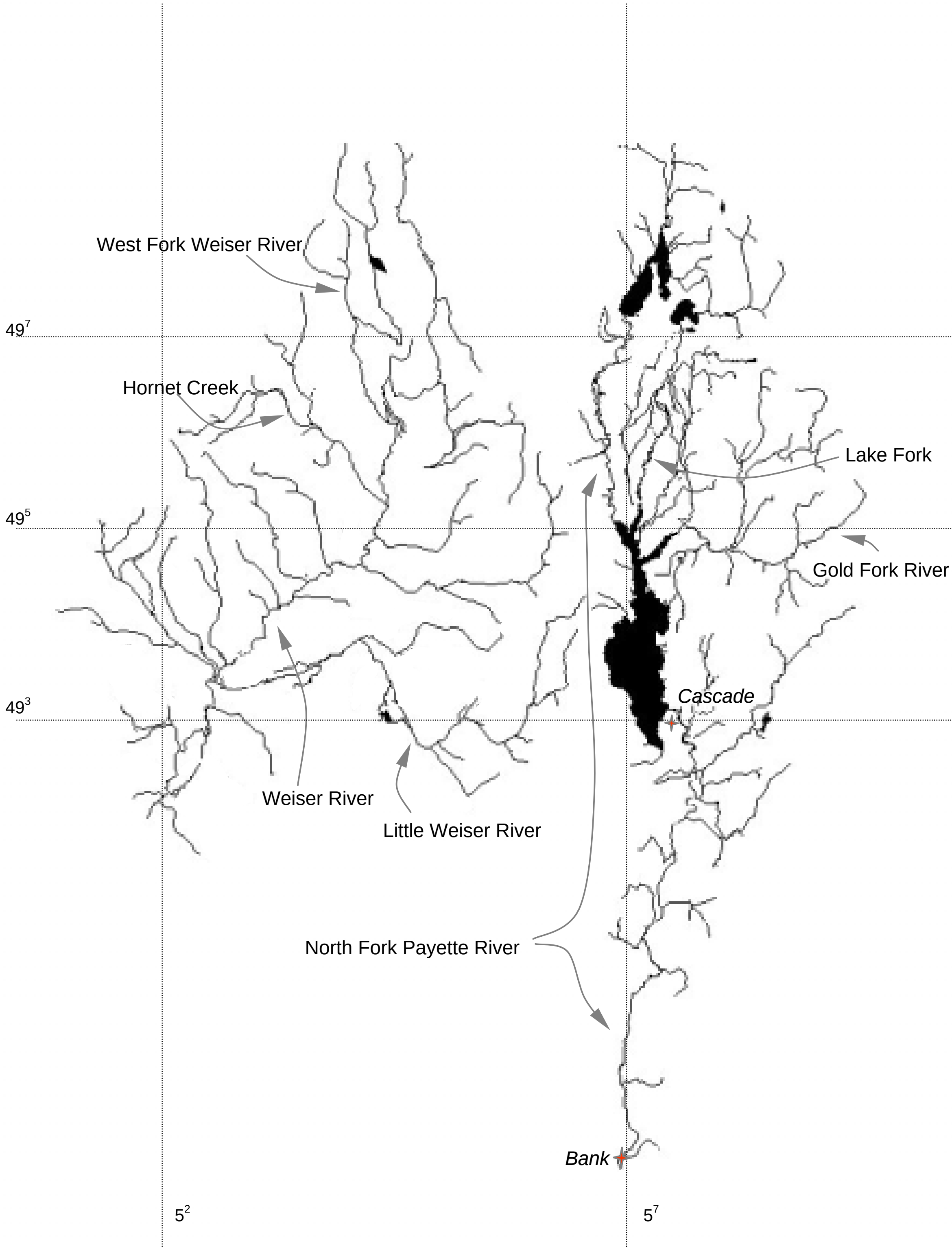

Figure 1. Map of the Upper North Fork Payette River and Upper Weiser River areas where stream surveys were conducted in 1998. UTM coordinates are shown as reference markers for Tables 1-3.

separate livewells for each pass. Upper and lower end points were chosen in riffles to minimize fish movements, but blocknets were not used. Fish were separated to species, measured to the nearest millimeter for total length, and weighed to the nearest gram. After all passes were completed, fish were released unharmed. In North Fork Payette River streams, weight was measured only for fish greater than 20 g.

We classified any rainbow/redband trout captured as redband trout. However, the purity of the redband trout encountered was not known, and no genetic samples were collected in this, the first partial year of the project. Where bull trout and brook trout were found in sympatry, hybrids were determined by dorsal fin color pattern—banded spots in brook trout, clear in bull trout, spotted and irregular in bull/brook hybrids (Markle 1992).

More electrofishing effort was expended on capturing trout than non-game species; thus, population estimates were made only for trout. Fish were separated into age-0 (<80 mm) and age-1+ (> 80 mm) categories for population estimation. Such a size separation applied more to brook trout age differentiation than for redband trout, which were smaller at age-0 and presumably age-1 as well. This size separation may have biased trout population estimates, but many streams contained only a few fish of one trout species, making estimates of all trout species more useful. We assumed capture efficiency was equal between all trout species. The maximum-likelihood model was used to estimate population size, upper and lower 95% confidence intervals, and capture probabilities (CP) over all passes, for streams with multiple removals using the MicroFish software package (Van Deventer and Platts 1989).

In all streams in the upper Weiser River basin and most in the upper North Fork Payette River basin, two or three pass removal efforts were used to obtain population estimates for each stream. However, in certain North Fork Payette River streams, a single electrofishing pass was made. To estimate population size in these streams, we regressed the number of fish captured in the first pass against the population estimate made from streams with multiple removals on North Fork Payette River streams and applied the relationship to other North Fork Payette River streams with single pass removals. Only streams with CP above 0.5 were used in this analysis, since population size is underestimated when CP is low (Riley and Fausch 1992). Ninety-five percent confidence intervals were calculated around each single pass estimate (Zar 1996). From the multiple pass removal streams, we regressed CP, abundance (number of fish/m of stream), and density (number of fish/100 m^2) against stream gradient, average width, average depth, conductivity, and water temperature to assess whether certain habitat conditions influenced population size or our ability to capture trout.

Snorkeling was used in streams that were too large to be effectively electrofished. One snorkeler worked upstream, zigzagging to cover the entire channel and relaying the species and estimated total length of encountered fish to a bank recorder. Care was taken to avoid duplicating counts by moving slowly and disturbing fish as little as possible. Fish length was categorized into intervals of 2.5 cm. Only trout species were counted during snorkeling.

Boise River Bull Trout Redd Counts

The upper Boise River basin in southwestern Idaho consists of three main branches, the South Fork, Middle Fork, and North Fork (Figure 2); all are located above Arrowrock Dam, an impassable fish barrier. Anderson Ranch Dam on the South Fork (Figure 2) is also impassable to fish. The entire basin covers approximately 5,700 km^2 and has a lower elevation of 975 m and upper elevation above 3,000 m. Bull trout reside throughout the basin, in both the migratory and resident form. Other native fish present in the basin include rainbow trout, mountain whitefish *Prosopium williamsoni*, sculpins *Cottus sp.*, and several catastomid and cyprinid species. Non-native brook trout, which can hybridize with bull trout, were introduced in the basin through past fish plants.

During 1998, IDFG regional biologists radio-tracked tagged bull trout making spawning migrations from Arrowrock Reservoir into the Middle Fork and North Fork and from Anderson Ranch Reservoir into the South Fork (Flatter 1998). We used these results to determine where the highest concentrations of bull trout spawning activity were most likely occurring and where redd count efforts should be focused. Once most radio-tagged fish had chosen a spawning location in a particular stream, we determined the reaches most likely to have a sufficient amount of spawning activity that index reaches could be established. By revisiting the reaches in subsequent years, trends in population abundance might be detected. We divided our searching efforts between Middle Fork, North Fork, and South Fork tributaries. In the Middle Fork we counted redds in Queens, Little Queens, and Yuba rivers; in the North Fork we counted redds in Johnson and Ballentyne creeks, and in the South Fork we counted redds in Willow, Skeleton, Boardman, Paradise, Beaver, and Big Smokey creeks (Figure 2). Redds were located by wading the stream and looking for redds using Polaroid sunglasses (with a pit and tailspill) and fish exhibiting spawning behavior.

<u>Pike's Fork Brook Trout Removal</u>

In August 1998, the SBNFWAG planned a brook trout removal project on Pike's Fork of the Crooked River (Figure 2), about seven to eight miles southeast of Lowman, Idaho. The plan outlined the removal of brook trout from the stream by electrofishing from immediately above the Banner Creek confluence and upstream 7.1 km. A wire gabion barrier was constructed just above the Banner Creek confluence soon after the removal efforts were completed to block brook trout recolonization of the stream. The stream was divided into six sections roughly equal in length, which were further divided into three reaches each (approximately 400 m long). Three crews (comprised mostly of SBNFWAG personnel or volunteers), each consisting of between six to eight members with two backpack electrofishing units, were established for each day, and each crew covered one reach at a time. Four 100 m "index sites" were established within the longer reaches, but no overlapping occurred. The crews made two electroshocking passes in the 400 m reaches and three in the 100 m reaches. Passes in the 400 m reaches were made with one electroshocking operator proceeding upstream in front of the other by about 20 m, whereas the operators in the 100 m reaches worked upstream in tandem.

From two 100 m reaches and two 400 m reaches, all brook trout captured were retained for population dynamics analysis; these reaches are hereafter referred to as the demographics reaches. Brook trout from the remaining reaches were also removed from the stream. A subsample of redband trout and all bull trout were measured for total length (to nearest millimeter) and weight (to nearest gram) to form a length-weight relationship; no other information was collected for redband or bull trout. The removal-depletion maximum-likelihood model was used to estimate population size, upper and lower 95% confidence intervals, and CP for each reach using the MicroFish software package (Van Deventer and Platts 1989). Lower 95% confidence intervals were always less than the total catch, and thus are not presented. Brook trout removal efficiency was calculated by comparing the total catch to the overall population estimate.

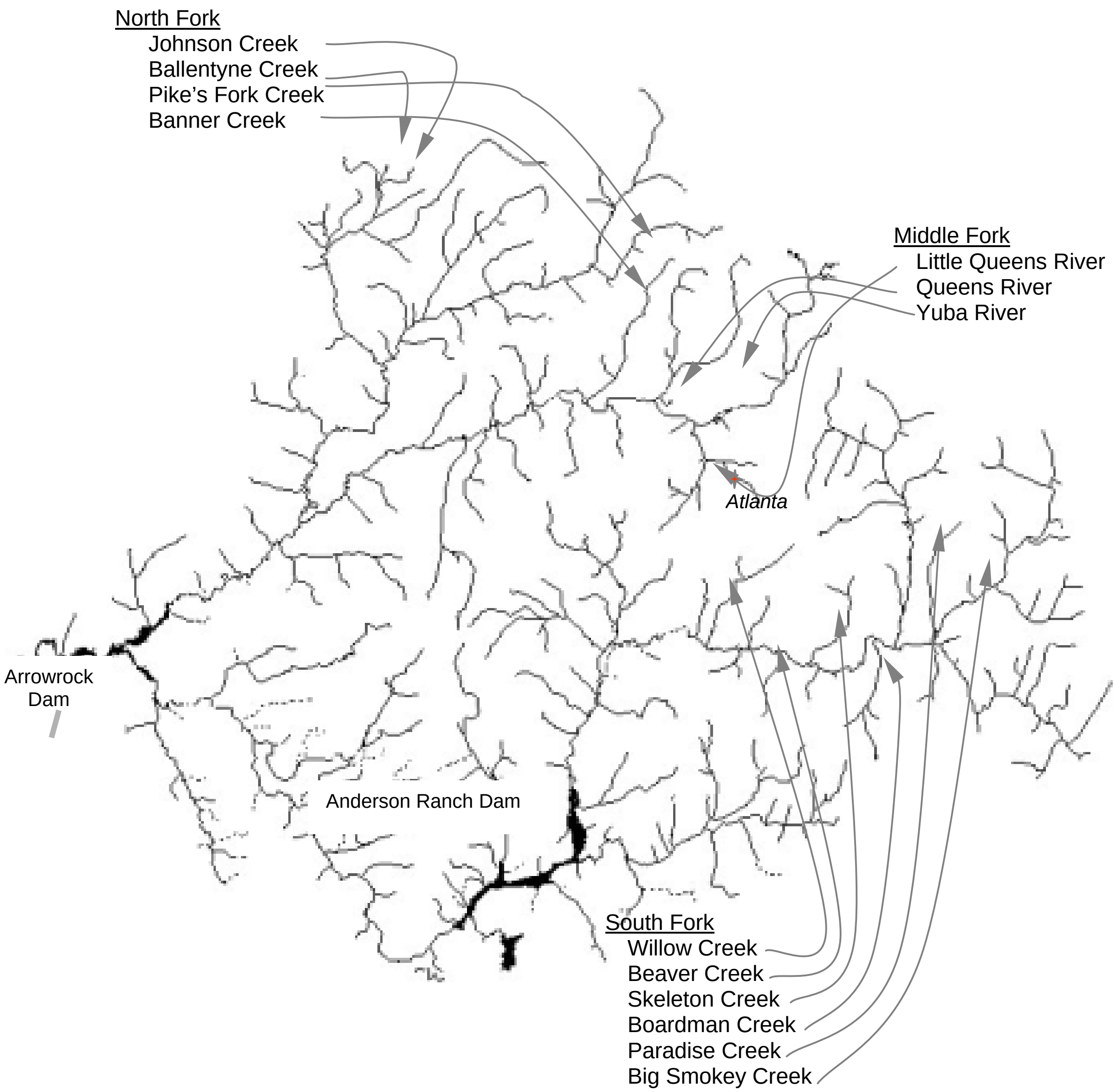

Figure 2. Map showing the upper Boise River basin, including Pike's Fork, and streams where bull trout redd counts were made in 1988.

Our electrofishing efforts indicated that age-0 and age-1 brook trout were probably not fully recruited to the sampling gear and thus the assumption of equal catchability was violated. This should be kept in mind when considering our abundance, removal efficiency, and age-frequency estimates. We assumed that within each age class, capture ability was equal and thus the remaining parameter estimates should be unbiased.

Retained brook trout were transported to the IDFG Nampa research station. Specific objectives were to assess age, mortality, growth, age at sexual maturity, fecundity, longevity, and sex ratio of brook trout in Pike's Fork. We collected paired scale and otolith samples from 241 fish in the demographics reaches to age brook trout and to examine scale and otolith aging accuracy and precision. Scales were removed from the area immediately dorsal to the lateral line and posterior to the dorsal fin, placed on paper strips in envelopes, and subsequently mounted on acetate slides using a scale press. Both otoliths were removed and stored in vials in glycerin. One or two readers estimated fish age using scales, but two readers always estimated age using otoliths. Readers had no knowledge of fish length during readings. A final determination of age for each fish was made by comparing results between readers and methods and resolving any differences with additional readings. Aging accuracy was the percentage of initial readings for each method that matched the final determination.

To further guide future aging efforts and to determine which method was most cost effective, we compared the amount of time required to determine age by scales or otoliths from a subsample of 72 fish. Cost was defined as the total time required to determine age; differences between methods in the costs of materials needed to determine age were considered negligible. Total time for each method was the sum total of the seconds required for labeling, collection, preparation, and reading time for each fish.

Labeling was the time required to label all envelopes (scales) or vials (otoliths) with a fish ID number, which was divided by 72 to obtain labeling time per fish for each method. Scale collection included picking up the fish, scraping scales from the fish, wiping the scales onto a paper strip, and folding and placing the strip into a labeled envelope. Scale preparation included removing the paper strip from the envelope, scraping the scales onto an acetate slide, pressing the slide between two metal plates in a scale press for 25 s, and removing the slide and returning it and the paper strip to the labeled envelope. Scale reading was the time required to remove the slide from the envelope, insert it into a microfiche reader, locate a readable scale on the slide, determine age, and return the slide to the envelope. For otoliths, collection consisted of picking up the fish, removing both otoliths, and placing the otoliths into a labeled vial and filling the vial with glycerin for storage. There was no preparation time for otoliths. Reading time was the number of seconds required to remove the otoliths from the vial, place them into a petri dish of saline solution, determine age under a dissecting microscope, and return the otoliths to the vial. Age was determined using reflected and/or transmitted light.

Time was recorded with a stopwatch, which was stopped at the end of each individual step. Fish were separated into age-0 ($n = 19$) and age-1+ ($n = 53$) for analysis, because age-0 fish could usually be distinguished by length-frequency analysis, and scale or otolith reading was generally unnecessary. Paired *t*-tests were used for each age category to test whether one method of age determination was more cost effective (i.e., faster) than another.

Once age was determined for the 241 fish in the demographics reaches, the age of the remaining 1,160 brook trout was assigned using age-frequency distribution (DeVries and Frie 1996) and professional judgement. All demographics parameters, however, were estimated only from the demographics fish. Mortality estimates followed Robson and Chapman (1961) and used catch curves (age frequency) and Heincke's estimate ($(n - N_o)/n$, where n = total sample size and N_o = number occurring in youngest age group). Growth was assessed by comparing average length of brook trout between sexes and age groups. Sexual maturity was rated as immature or mature by laboratory examination of ovaries and testes. Mature males were those with large extended testes, whereas immature males had minute, strand-like testes. Mature females contained large, developed eggs, whereas immature females contained granular eggs that obviously would not reach ripeness by fall. Immature fish could not be sexed. Maturity percentages were calculated for each age class. Sex ratio was expressed as the proportion of the population that was female. Comparisons between sexes and age classes were made for each parameter when possible. Ninety-five percent confidence intervals around the estimates were calculated from Robson and Chapman (1961) for mortality and from McFadden (1961) for all other parameters.

Three 100 m sections were established in Banner Creek to obtain demographics data from an adjacent control stream. However, it became apparent that the overall brook trout population in Banner Creek was too small to remove fish for demographics estimates without affecting the population. Based on removal-depletion results, we estimated age-1+ brook trout abundance in Banner Creek at about 19 bkt/100 m of stream, or about 580 brook trout in the entire creek. Consequently, we assumed that brook trout population dynamics between the two adjacent streams are currently equivalent. Next year, brook trout will again be removed from Pike's Fork. In 2000, the final year of the project, a large portion of the brook trout will be removed from Banner Creek and Pike's Fork. At that time we will compare the brook trout populations in each stream and assume that any differences are due to the removal of brook trout from Pike's Fork.

RESULTS AND DISCUSSION

Payette/Weiser Fish and Habitat Surveys

Project personnel electrofished 48 and snorkeled 13 streams in the upper North Fork Payette River basin and electrofished 14 streams in the upper Weiser River basin (Tables 1-3). A total of only four bull trout and two bull trout x brook trout hybrids were found in two streams. In the upper East Fork Weiser River, one bull trout and two hybrids were captured, and three bull trout were captured in two reaches of the North Fork Lakefork Creek in the upper North Fork Payette River basin. At each site containing bull trout, brook trout were also captured.

Redband trout were found in 35 and brook trout in 40 of 61 upper North Fork Payette River streams (Tables 1-2). In the upper Weiser River streams, redband and brook trout were found in 14 and 11 of the 14 streams sampled, respectively (Table 3). The percent composition of trout was similar between basins; redband trout made up 36% and brook trout 64% of the trout captured in Weiser River streams, and in the upper North Fork Payette River redband trout made up 32% and brook trout 67% of the trout captured. Sculpins were rare in the upper North Fork Payette River streams, but were common in the upper Weiser River streams. Cutthroat trout, mountain whitefish, and other non-game fishes (i.e., dace, suckers, or shiners) were rarely found in either basin. Four streams contained no fish (Table 2).

Mean densities (number/100 m^2) from multiple pass removals of trout were similar between basins (Tables 1-3). Age-0 density averaged 18.9 (range 0.5-100.8) in upper Weiser River streams and 15.7 (range 0-61.6) in upper North Fork Payette River streams, while age-1+ density averaged 16.2 (range 1.4-40.4) in upper Weiser River streams and 16.6 (range 0-54.3) in upper North Fork Payette River streams. The CP from multiple pass removal efforts for age-0 and age-1+ in Weiser and Payette streams averaged 0.63 (range 0.30-0.80) and 0.67

Table 1. Trout abundance, confidence intervals (CI), and total number of fish captured with removal electrofishing in upper North Fork Payette River streams in 1998.

	UTM		Trout young-of-year			Trout subadults and adults			Number of fish caught						
Stream name	Northing	Easting	Density (fish/100m²)	Lower 95% CI	Upper 95% CI	Density (fish/100m²)	Lower 95% CI	Upper 95% CI	Brook trout	Bull trout	Redband trout	Cutthroat Trout	Rbt/Cut hybrid	Mountain whitefish	Sculpin
Two or Three Pass Removals															
Arling Trail Creek tributary	49.417	5.683	8.4	8.4	10.5	5.3	5.3	6.8	1		12				
Bacon Creek	49.012	5.802	12.5	11.7	16.6	30.0	11.7	128.3			29				
Bogus Creek	49.112	5.726	32.3	28.6	38.0	12.0	12.0	12.7			78				
Camp Creek	49.588	5.828	21.3	19.7	25.0	6.4	6.4	7.8	49						11
Clear Creek upper, upper reach.	49.293	5.934	19.0	18.3	21.8	40.8	40.8	42.1	78		6				
Clear Creek, upper reach.	49.279	5.932	32.2	21.3	51.3	48.3	16.5	159.9	47		40				
Cloochman Creek	50.056	5.804	11.2	10.9	12.6	5.8	5.8	6.5	49						
Deep Creek	49.944	5.757	0.4	-	-	0.9	-	-			3				
Deep Creek, tributary to Big Creek	49.373	5.867	11.2	8.9	17.3	12.9	9.8	21.0	51						
Fall Creek	49.779	5.763	3.7	3.7	4.1	14.7	13.2	17.0			78				
Hargrave Creek	49.388	5.912	34.7	29.3	44.1	23.1	22.4	25.8	76						
Lake Creek, trib to Granite Lake	49.951	5.720	36.8	28.6	46.3	54.3	49.6	59.0	245						
Lemah Creek	49.811	5.746	0	-	-	4.9	4.9	5.2			9	7	3		
Louie Creek	49.672	5.792	1.9	1.9	2.9	4.5	3.9	7.2			18				
Murray Creek	49.018	5.748	9.6	8.9	11.7	18.9	18.9	19.4			78				
NF Lakefork Creek, middle reach	49.845	5.831	11.0	10.1	12.7	9.7	8.5	11.7	81	2	15				
No Business Cr.	49.551	5.674	0.5	-	-	7.4	7.4	7.9	15		1			9	69
Paddy Creek.	49.594	5.814	17.0	16.5	18.3	14.8	13.9	17.1	70						5
2nd Unnamed tributary to Clear Creek	49.204	5.858	3.0	-	-	15.4	14.0	19.0	24		9				
SF Fawn Creek	49.167	5.737	8.9	8.3	11.0	21.5	19.5	24.7			84				
Skunk Creek	49.123	5.824	42.8	38.1	49.1	6.2	6.2	7.3			86				
Sloan Creek	49.512	5.839	61.6	59.5	64.7	10.8	9.9	13.4	161						27
Trail Creek	50.023	5.807	16.4	16.0	18.3	31.0	31.0	31.9	100						
Tripod Creek	49.051	5.707	20.8	19.8	23.4	51.5	50.0	54.0	37		104				
Wagon Bay Cr.	49.809	5.701	10.8	10.8	11.5	47.9	43.7	52.3	156						
WF Beaver Cr.	49.387	5.795	30.3	28.4	33.9	11.0	10.6	12.8			85				
One Pass vs. Three Pass Regression Model Predictions															
Brush Creek	49.220	5.734	3.0	1.5	9.4	1.0	1.0	11.2			5				
Copet Creek	49.874	5.740	0.8	0.3	4.4	0.8	0.8	6.5	1		3				1
Ditch Creek	49.165	5.839	0	-	-	5.3	4.5	21.0	6						
EF Fisher Creek	49.930	5.714	0	-	-	2.2	1.7	6.6	8						
1st Unnamed tributary to Clear Creek	49.195	5.854	68.3	52.7	84.0	0	-	-	34		4				
1st Unnamed tributary to Fischer Creek	49.936	5.704	0	-	-	4	3.1	10.2	10			1			
Landing Creek	49.839	5.719	2.0	0.7	11.1	19.8	13.0	33.7	20						
Little Creek	49.379	5.894	5.3	2.6	16.7	17.8	12.2	35.6	17						
NF Lakefork Creek, upper reach	49.856	5.848	0.8	0.3	4.1	0.8	0.8	6.1	2	1	1				
Olson Creek	49.222	5.750	9.1	5.2	17.6	15.6	10.5	28.9	12		12				1
Willow Creek	49.244	5.721	2.5	0.8	13.6	15.8	10.9	33.0	12			2			
Wilson Creek	50.018	5.783	-	-	-	9.1	6.0	15.5	19		3				

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Table 2. Total number of fish captured with presence/absence electrofishing and snorkeling in upper North Fork Payette River streams in 1998.

	UTM		Number of fish caught							
Stream name	Northing	Easting	Brook trout	Bull trout	Redband trout	Cutthroat Trout	Rbt/Cut hybrid	Mountain whitefish	Sculpin	other non-game
Electrofishing										
Camp Creek (Round Valley)	49.063	5.793			1					31
Cougar Creek	49.982	5.693	1						1	
Hurd Creek	49.366	5.674			7					
Jug Creek	49.645	5.807				no fish				
Unnamed Tributary of EF Clear Creek	49.256	5.917				no fish				
NF Pearl Creek	49.918	5.799				no fish				
Pearl Creek	49.928	5.776				2				
Round Valley Creek	49.093	5.765			1					31
Sater Creek	49.918	5.703	25							
Snag Creek	49.374	5.903	13							
Snorkeling										
Big Creek	49.383	5.903	31							
Boulder Creek	49.694	5.775	8		20					
Box Creek	49.869	5.749	42		40					
Brush Creek	49.903	5.755			29					
Clear Creek	49.259	5.907	24		35					
Fischer Creek	49.940	5.703	93		5					
Fischer Creek, middle section	49.940	5.703	123						not counted	
Fischer Creek, upper section	49.998	5.698				no fish				
NF Payette River	50.037	5.783	117							
Powelson Creek	49.589	5.868	11		5					
Rapid Creek, middle reach	49.631	5.844	7		5					
Rapid Creek, lower reach	49.586	5.838	6		2					
Twah Creek	49.840	5.746			5					

Table 3. Trout abundance, confidence intervals (CI), and total number captured with removal electrofishing in upper Weiser River streams in 1998.

	UTM		Trout young-of-year			Trout subadults and adults			Number of fish caught					
Stream name	Northing	Easting	Density (fish/100m²)	Lower 95% CI	Upper 95% CI	Density (fish/100m²)	Lower 95% CI	Upper 95% CI	Brook trout	Bull trout	Bkt/but hybrid	Redband trout	Sculpin	other non-game
Beaver Creek	49.705	5.515	12.5	11.8	15.6	40.4	39.7	42.6	29			41	94	
East Branch Weiser River	49.900	5.452	15.4	14.6	16.9	13.5	12.7	15.2	91			10	71	
EF Lost Creek	49.828	5.419	100.8	73.1	128.4	28.2	13.5	60.2	270			37		
EF Lost Creek, upper reach	49.886	5.415	3.1	2.7	4.4	7.8	6.9	9.6	46			7	61	
EF Weiser River, lower reach	49.655	5.499	4.4	4.4	4.8	10.1	10.1	10.8				33	1	
EF Weiser River, upper reach	49.577	5.584	0.5	-	-	3.2	-	-	3	1	2	2		
Grouse Creek	49.776	5.387	6.7	6.7	7.7	27.5	27.1	28.7	2			84	60	
Joker Creek	49.626	5.576	19.0	18.6	20.2	19.0	19.0	19.8				97		
Lost Creek, main stem	49.837	5.405	80.4	74.2	86.7	17.2	16.5	18.6	338			31		
Lower E. Branch Weiser River	49.863	5.452	4.8	4.4	6.7	9.9	8.8	12.8	25			11	6	
Main Weiser River	49.755	5.489	0.5	-	-	1.4	-	-	2			9	2	54
NF Hornet Creek	49.707	5.343	1.8	1.8	2.1	18.5	17.3	20.6				61	72	
West Branch Weiser Rver	49.865	5.441	9.0	8.5	11.3	16.5	15.5	19.3	46			2	86	
WF Weiser River	49.778	5.391	6.4	6.2	7.3	14.0	13.3	15.3	13			72	81	

Table 4. Mean and range in stream attributes and their correlation with capture probability, population abundance, and population density.

			Capture probability		Population abundance		Population density (fish/100m²)	
Habitat variable	mean	range	*r*	*P*	*r*	*P*	*r*	*P*
Width (m)	3.0	1.4-6.3	0.071	0.704	0.138	0.426	0.095	0.592
Depth (m)	0.17	0.06-0.38	0.110	0.533	0.122	0.484	0.370	0.137
Slope (%)	2.8	0.5-5.5	0.105	0.548	0.255	0.131	0.355	0.126
Conductivity (µS/cm)	56	10-110	0.063	0.731	0.243	0.179	0.095	0.600
Water temperature (°C)	6.8	1.5-15.5	0.130	0.465	0.155	0.371	0.017	0.923

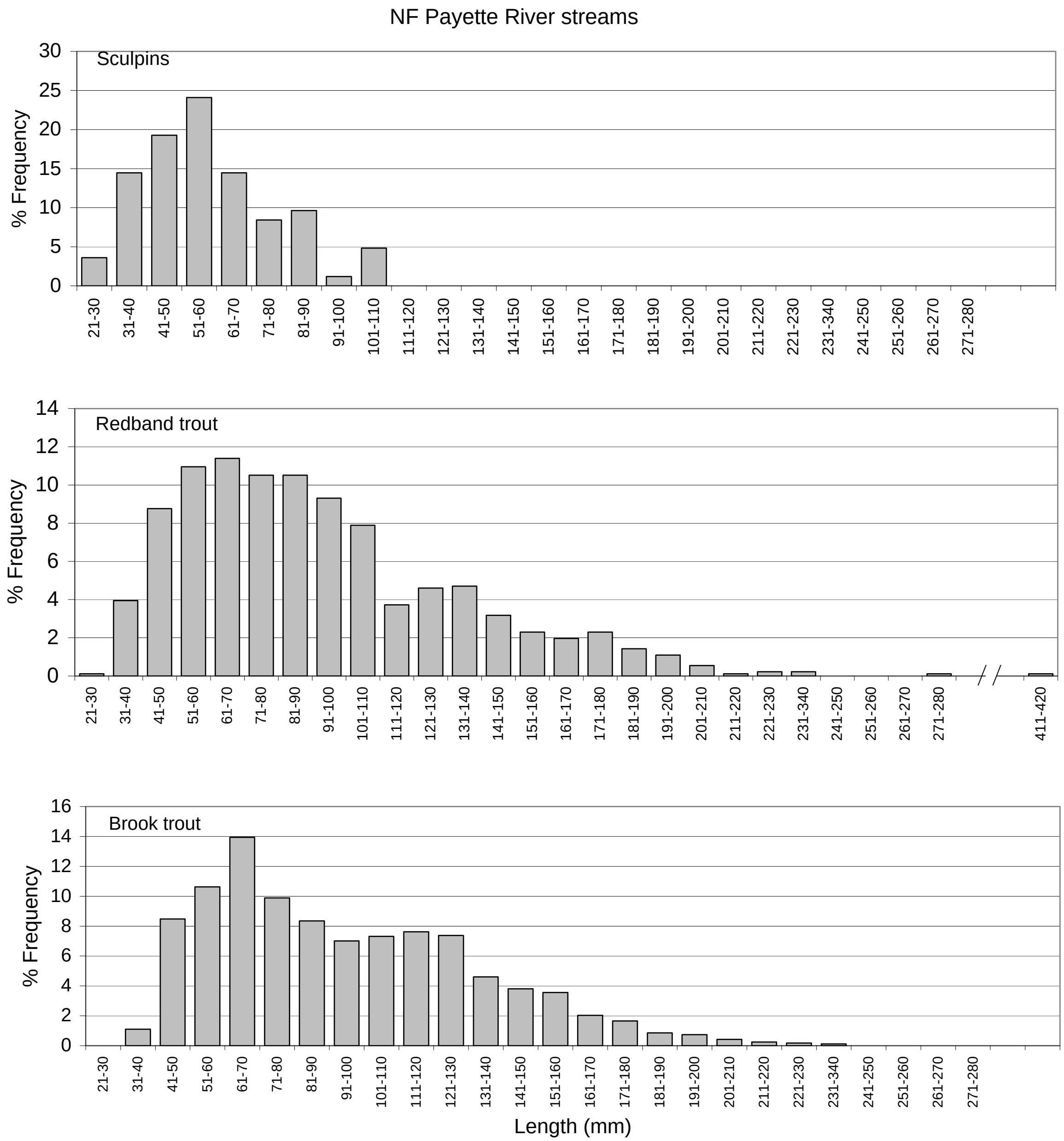


Figure 3. Length frequency of sculpins, redband trout, and brook trout caught in upper North Fork Payette River streams in 1998.

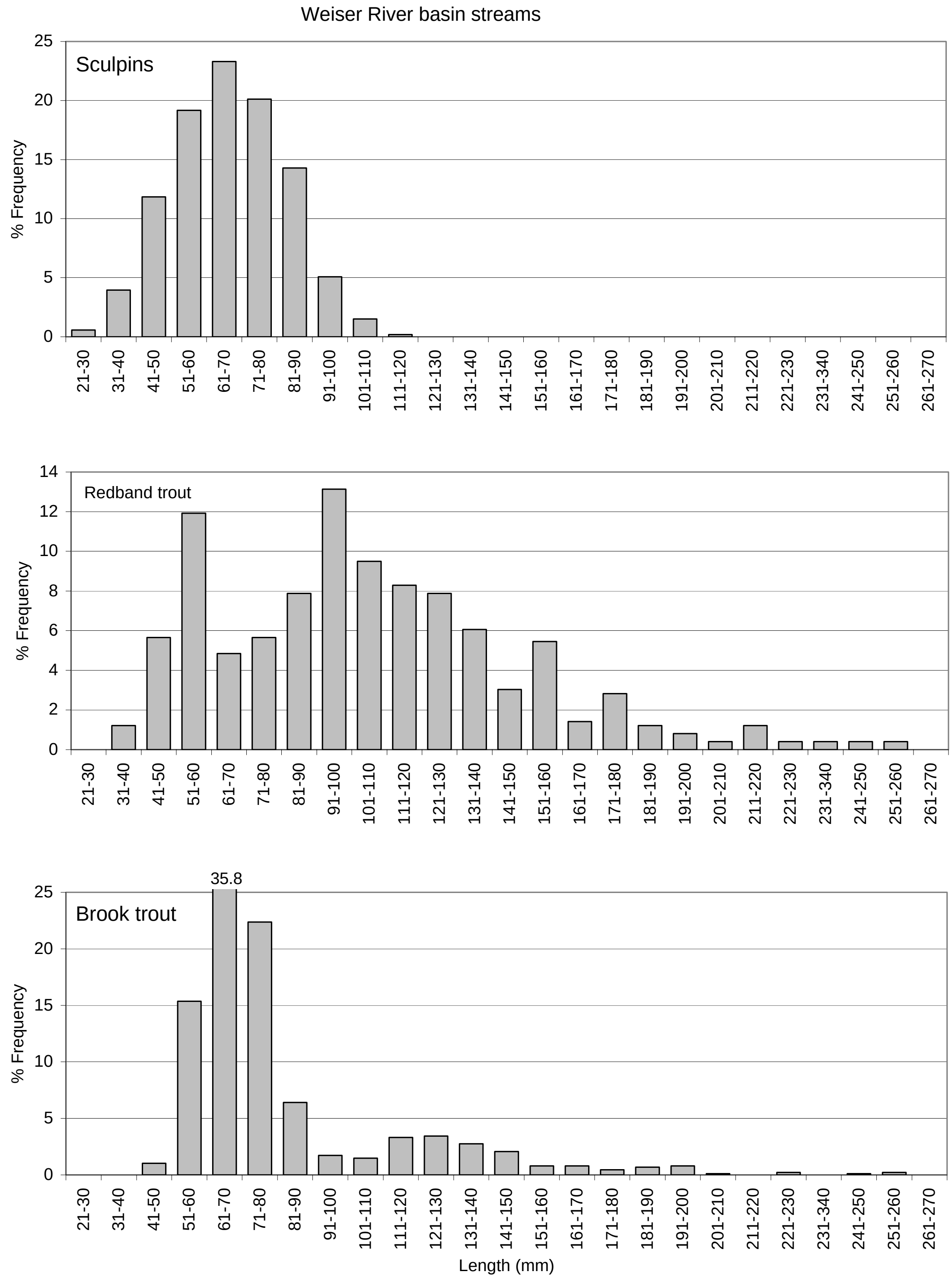


Figure 4. Length frequency of sculpins, redband trout, and brook trout caught in upper Weiser River streams in 1998.

(range 0.13-0.80), respectively. For each age category, only four streams had probabilities less than 0.50. There was no relationship between any combination of stream gradient, width, depth, conductivity, or temperature with CP, trout abundance, or trout density ($r^2 < 0.14$; $P > 0.13$; Table 4). The fact that our sites were located mostly in headwater sections that varied little in habitat complexity probably contributed to the lack of any relationship between these variables. Our findings concur with Kruse et al. (1998), who found that in small mountain streams in Wyoming, there was little correlation between stream attributes they measured and CP, population estimates, or density estimates.

Length-frequencies were also similar between basins for redband trout, brook trout, and sculpins (Figures 3 and 4). Few fish of either salmonid species exceeded 250 mm. Age-0 brook trout were large enough to capture with some regularity, but age-0 redband trout were typically less than 50 mm and were not captured with any regularity. Length-weight relationships were stronger in the Weiser River than the Payette River streams (Figures 5 and 6), probably because a more accurate spring-scale was used for most of the fish less than 50 g in the Weiser River streams.

The number of fish caught in the first pass was strongly related to the population estimates for both age-0 ($P = 1.08E^{-15}$; $r^2 = 0.968$; n = 21) and age-1+ trout ($P = 9.25E^{-15}$; $r^2 = 0.953$; n = 22) (Figure 7). Despite the strong relationships, the 95% confidence limits around the predicted densities from single-pass vs. multiple-pass removal model were much wider than the confidence limits calculated from the removal-depletion maximum-likelihood model (Table 1).

Several researchers have demonstrated that one-pass sampling may not provide a reliable index of fish abundance due to stream channel complexity (Peterson and Cederholm 1984), changing capture probability due to behavioral avoidance by fish (Riley and Fausch 1992), or differential catchability of length classes among multiple passes (Mahon 1980). However, the method we used was effective in streams that in general were narrow (less than 6 m mean width), shallow (less than 0.5 m mean depth), and contained minimal instream cover such as large woody debris complexes, thick macrophyte beds, or deep undercut banks. These findings concur with Kruse et al. (1998), who found that in streams with minimal habitat complexity, one pass provided an accurate estimate of trout abundance. The technique may be less effective in streams that are wider or have more complex habitat, because CP is usually reduced under those circumstances. We removed only 4 of the 26 multi-pass streams from the regression analysis because CP was less than 0.50.

Kruse et al. (1998) combined data across drainages and over multiple years to form a regression model. However, differences between basins or years may affect a crew's ability to capture trout and thus alter the relationship. Thus, we believe that caution must be used in this regard, and any application of a one-pass vs. three-pass regression model over more than one year should be validated by multi-pass sampling in each year the model is used. A minimum of 20 multi-pass streams (with CP values > 0.5) will probably be needed for predicting estimates in the remaining one-pass streams that are sampled. Length frequencies should be used to separate age-0 fish captured from older fish to reduce the bias inherent in modeling densities of the more difficult-to-capture juvenile fish, though the results of this study demonstrate that the method is useful not only for larger trout but for age-0 as well. If a high percentage of streams within a basin have to be removed from the model because of low CP values, this technique will probably be inadequate to predict density estimates in one-pass streams, and we recommend that it not be used under such conditions. We also emphasize the fact that confidence intervals will be wider for one-pass predictions than multi-pass removal-depletion estimates, and management goals should be weighed when considering the tradeoff between reduced effort and reduced confidence in the predicted population estimate. Nevertheless, we believe this approach is useful for watershed-scale assessments of trout population as a method of reducing the amount of effort needed to obtain trout density estimates.

Boise River Bull Trout Redd Counts

We spent approximately 90, 60, and 70 man-hours surveying 23, 17, and 46 km of stream for bull trout redds in the Middle Fork, North Fork, and South Fork of the Boise River, respectively. Water clarity was good on all days.

Queens River—Project personnel surveyed for redds on September 17 and 18 from the confluence of Little Queens River upstream 5.6 km and from river-kilometer (Rkm) 8.7 upstream 8.8 km. The Queens River contained steep gradient sections interspersed with lower gradient areas where spawning gravels were plentiful. Four bull trout redds were located in one long glide (UTM 48.578N, 06.506E); two were obviously redds from large, adfluvial females, while the other two were most likely constructed by small, resident bull trout. No other redds were found in Queens River, although many sections looked adequate for spawning. Potential migration barriers (waterfalls) 3 m and 5 m high were located approximately 11 km (48.604N, 06.520E) and 16 km (48.651N, 06.520E) upstream from the confluence with Little Queens River, respectively. However, migrating bull trout were apparently radio-tracked to positions upstream of both barriers, to about 18 km above the confluence with Little Queens River (B. Flatter, IDFG, personal communication). Bull trout passing such waterfalls would be exceptional, though fish in Rapid River, Idaho, have been observed passing immense barriers (D. Schill, IDFG, personal communication). Future efforts to summarize existing barrier locations and bull trout distribution may be fruitful in determining possible limiting factors to the Middle Fork/North Fork metapopulation.

Little Queens River—On September 18, project personnel surveyed the Little Queens River from its confluence with Queens River upstream 2.5 km in the area where radio-tracked fish had been located. No fish or redds were observed. Stream gradient was relatively steep and low-gradient spawning areas were generally absent.

Yuba River—On October 8, project personnel surveyed 6 km of stream from the mouth to about 1 km above Trail Creek and found only one bull trout redd (48.469N, 06.492 E). Based on the size of the redd (approximately 0.3 m wide), it was most likely formed by a resident bull trout or a small adfluvial fish. Very little of the stream appeared to be suitable for spawning. No migration barriers were observed.

Johnson Creek—Johnson Creek was surveyed on September 29 from the confluence with the North Fork Boise River upstream 12.8 km. The best spawning areas were from the Cahhah Creek tributary upstream about 1 km, and most of the areas below Cahhah Creek had accumulated fine sediments in the lower gradient areas. One adfluvial bull trout redd was noted above Cahhah Creek about 10 km from the mouth (48.704N, 06.444E), and one resident bull trout redd was located below Cahhah Creek's confluence. No fish migration barriers were observed.

Ballentyne Creek—On September 30, we surveyed from the mouth upstream 4.1 km, and located one adfluvial bull trout redd near the upper end of the survey (48.751N, 06.451E). No fish migration barriers were found.

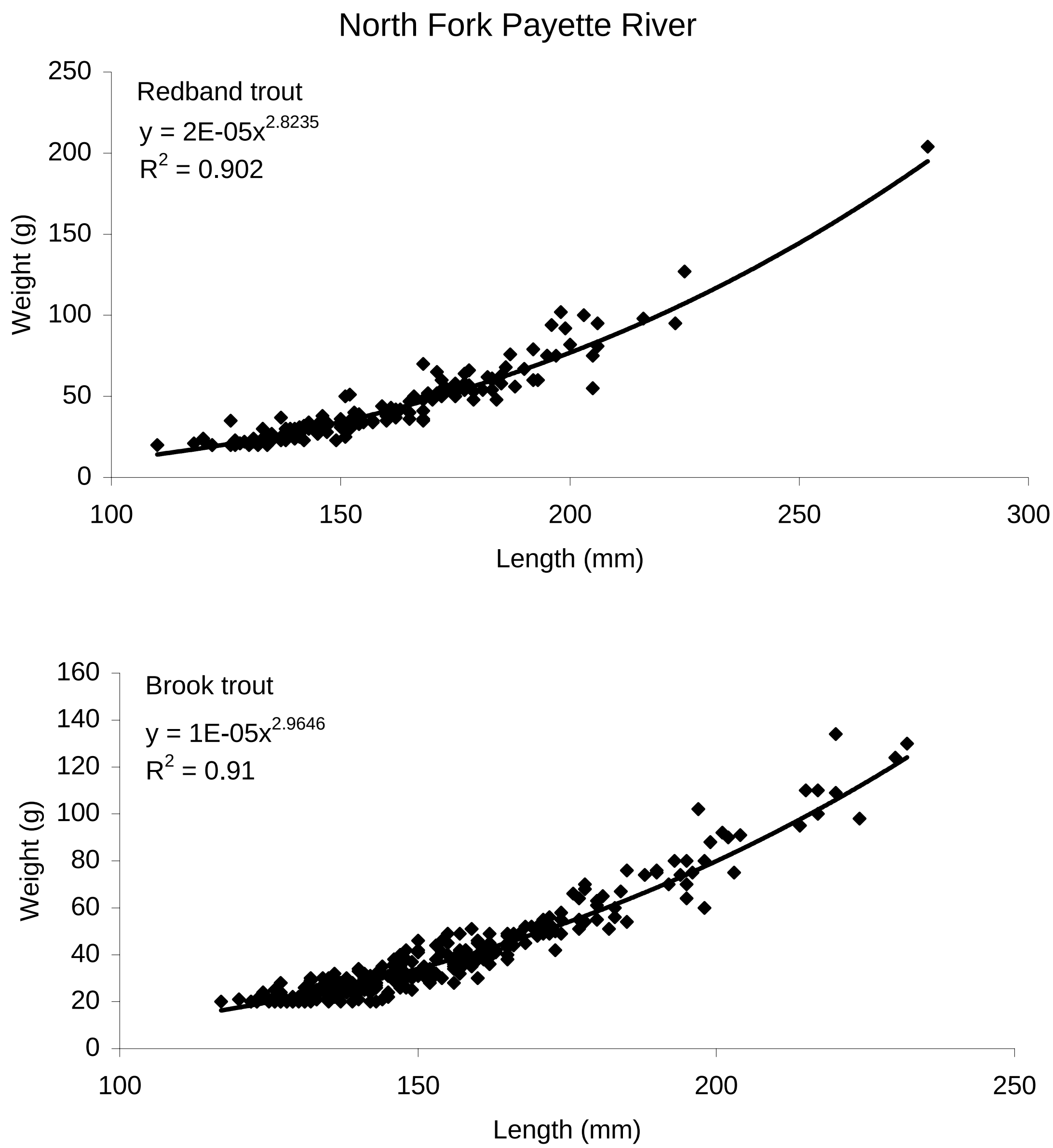


Figure 5. Length-weight relationship for redband trout and brook trout in upper North Fork Payette River streams in 1998.

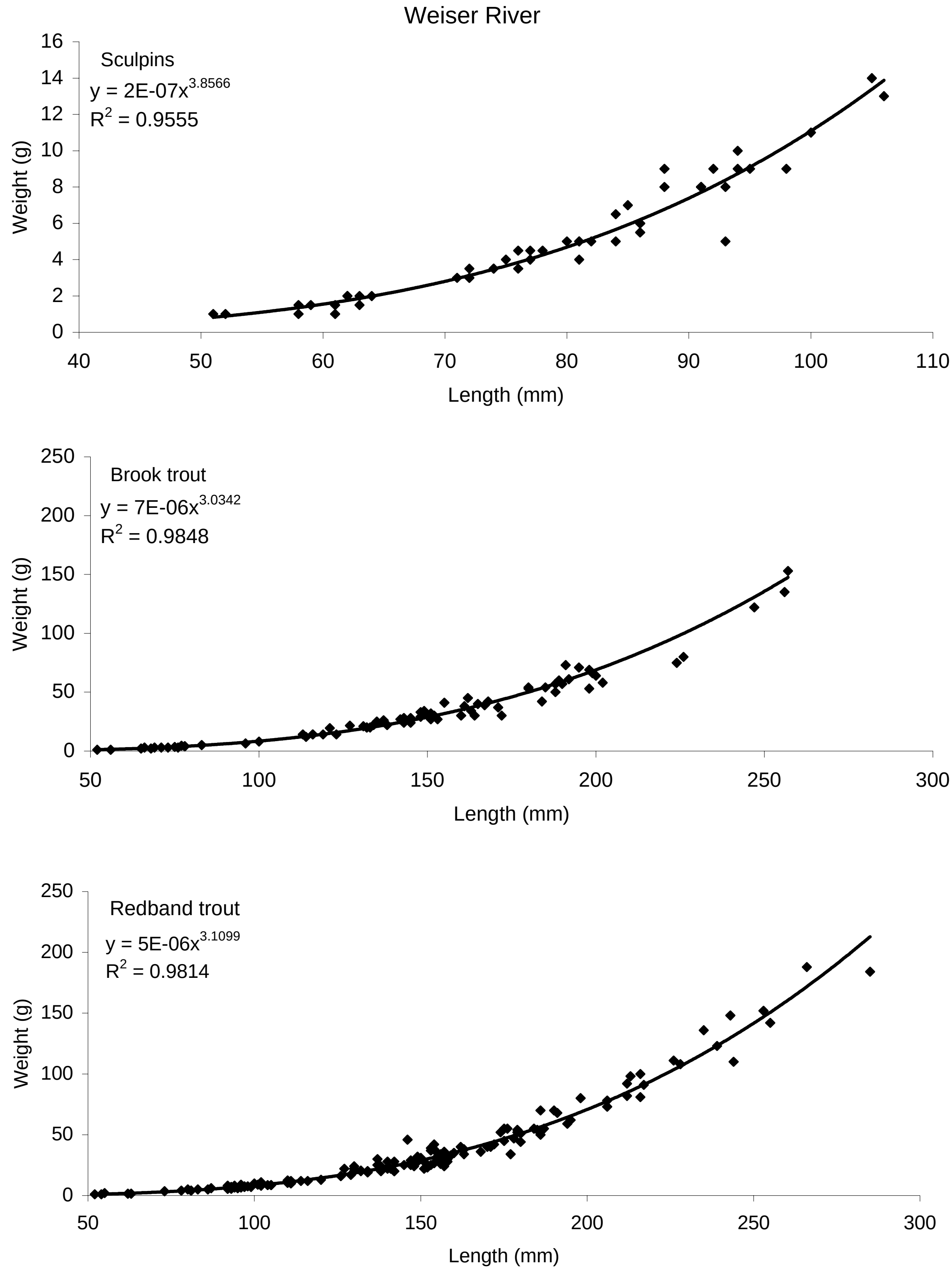


Figure 6. Length-weight relationship for sculpins, redband trout, and brook trout in upper Weiser River streams in 1998.

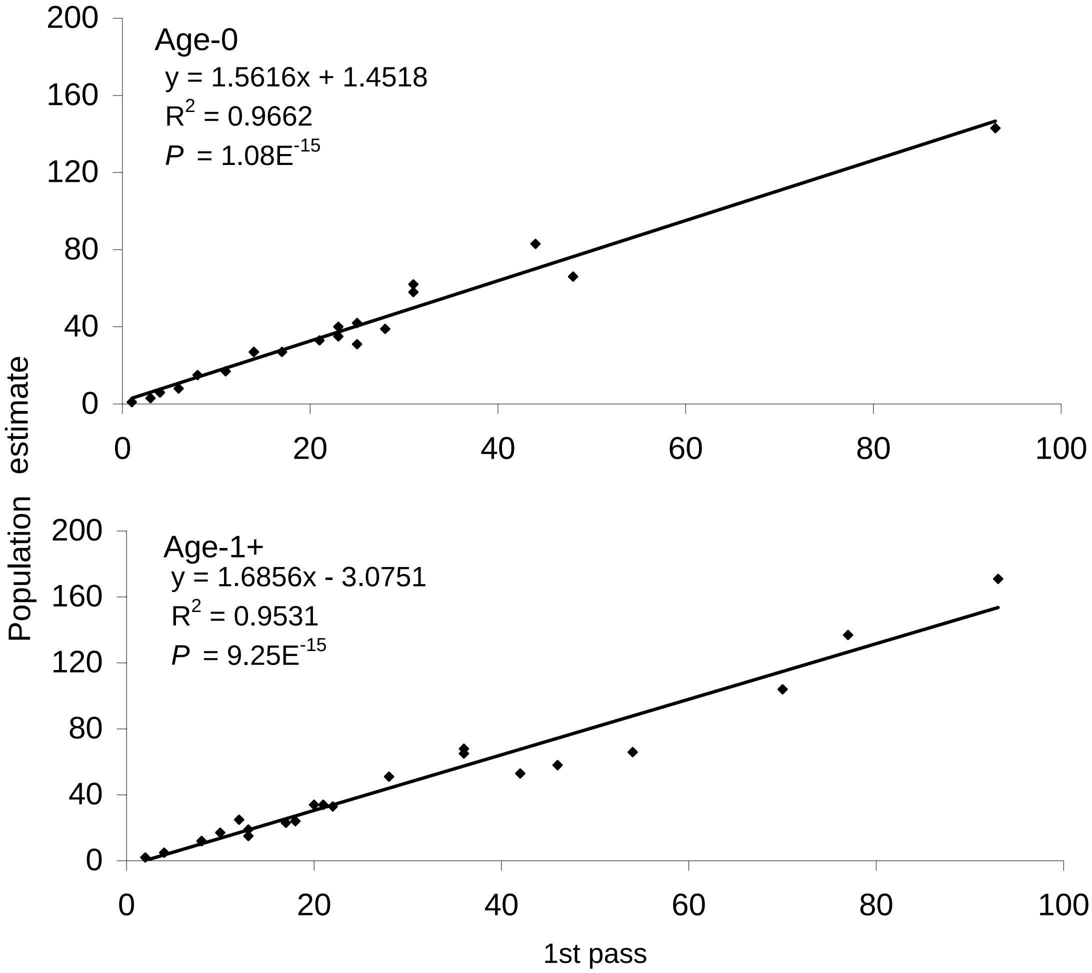


Figure 7. The relationship between the first pass and the population estimates of age-0 and age-1+ brook trout from upper North Fork Payette River streams in 1998.

Willow Creek—Two sections of Willow Creek were surveyed on October 7, from the mouth upstream 5.1 km and from Haypress Creek upstream approximately 2 km. The lower section was lower gradient and contained more spawning habitat, which was being heavily utilized by kokanee and may have impeded bull trout redd identification. The upper section contained little spawning habitat. Some large logjams were located but none appeared to function as adfluvial bull trout barriers. No bull trout redds were positively identified.

Skeleton Creek—On October 7, project personnel surveyed from the mouth upstream 13.3 km to Burnt Log Creek. Most of the channel was steep with only pockets of spawning habitat, and no bull trout redds were located.

Big Smokey—Redd counts were made on October 6 from the campground upstream 12.1 km to just below Narrow Creek. Bull trout redd counts were hindered by kokanee spawning activity occurring on most of the spawning gravels up to the North Fork of Big Smokey Creek. The incessant kokanee activity may have obscured any bull trout redds that had been made. No adfluvial bull trout redds were positively identified, and any resident bull trout redds would have been indistinguishable from kokanee redds. Spawning gravels that were available were interspersed with large expanses of stream with little or no spawning habitat. No fish migration barriers were encountered.

Boardman Creek—Redd counts were made on October 6 from the mouth to 5.9 km upstream. About midway through the survey, the stream gradient became more steep and spawning habitat decreased substantially. One adfluvial bull trout redd was located approximately 1.5 km from the mouth (48.290N, 06.665E). Any resident bull trout redds would have been indistinguishable from kokanee redds. No fish migration barriers were encountered.

Paradise Creek—On October 6, project personnel surveyed from the mouth to approximately 6 km upstream, and no redds were observed. Gradient was low and spawning gravels were present throughout the reach.

Beaver Creek—The lower 1.8 km of stream was surveyed, and no redds were observed. Very little spawning habitat was available in this lower portion of the stream.

Redd counts proved ineffective in assessing bull trout spawning activity in the Boise River drainage. Overall, we counted five adfluvial and four resident bull trout redds in 220 man-hours over 85 km of stream. This corroborates the findings of Rohrer (1991), who also had difficulties locating bull trout redds in the upper Boise River basin, finding only six adfluvial redds in 280 man-hours covering 40 km of stream in three Middle Fork Boise River tributaries. Rieman and Myers (1997) found that year-to-year variation in redd counts makes detection of changes in abundance in individual streams unlikely with limited data sets. A more effective method of monitoring adfluvial bull trout population size and trends may be to use weir traps to capture adults during their spawning migrations and screw traps to capture out-migrating subadults (Bonar et al. 1997). Planning is under way to determine the amount of effort that would be needed to undertake an effective trapping scheme in the upper Boise River basin.

Pike's Fork Brook Trout Removal

Densities in the four index sites for age-1+ redband trout and brook trout averaged 6.3/100 m^2 and 2.8/100 m^2, respectively. Because individual reach lengths were not measured in the longer reaches, density estimates were not possible. In the entire area sampled, 713 age-0 and 688 age-1+ brook trout were captured and removed (Table 5). In comparison, 25 age-0 and 1470 age-1+ redband trout were captured. That many more age-1+ but many fewer age-0 redband trout were caught is probably the result of a difference in the ability of our sampling gear to capture the smaller, spring-hatching age-0 redband trout compared to the fall-hatching age-0 brook trout. Electrofishing efficiency is highly dependent on size (Reynolds 1996), and small age-0 trout are difficult to capture with consistency.

Brook trout removal efficiency (i.e., total catch ÷ population estimate) was high not only for age-1+ (98.4%) but also for age-0 (89.6%) (Table 5). Nevertheless, we estimate that 11 or as many as 37 age-1+ brook trout were not removed from the 7.1 km long study area. For age-0 brook trout, we estimate that 83 or as many as 177 fish were missed. The estimated CP tended to be slightly higher in the two-pass than three-pass removal reaches for both age-0 (mean 0.70 vs. 0.67) and age-1+ (mean 0.86 vs. 0.70), but all of the 94 estimated "missed" brook trout came from the two-pass reaches (Table 5). Age-0 brook trout that were not removed are less critical because they could not have spawned in fall 1998, but the adult brook trout that went uncaptured likely spawned, adding another year class that will need to be removed. Additionally, brook trout still existed at the uppermost reaches, and presumably, a portion of the population was not removed above Rkm 7.1. In 1999, a concerted effort will be necessary to remove brook trout from the entire stream, including reaches above the uppermost removal reaches in 1998.

Only four bull trout (1 < 80 mm, 3 > 180 mm) and one bull trout x brook trout hybrid were captured. Thus, brook trout probably still outnumber bull trout in Pike's Fork, depending on the composition of trout above the removal reaches. It may be necessary, after the brook trout removal efforts have ceased, to reintroduce bull trout or add to those that remain by transferring bull trout from a nearby drainage into Pike's Fork. Though the barrier (built soon after the removal efforts) was constructed to allow adfluvial spawning bull trout to access and re-seed Pike's Fork, it is uncertain whether any migratory bull trout are currently utilizing this stream.

Of the brook trout analyzed in the demographics reaches, 42% were age-0, 17% age-1, 39% age-2, and 2% age-3; none were older than age-3. These percentages were only slightly altered after using age-frequency distribution and professional judgement to distribute the remaining brook trout to specific age classes (Table 6). Except for the break between age-0 and age-1, there was extensive overlap in length-at-age (Table 6). Only age-2 and older brook trout were fully recruited to the sampling gear, and thus are the only fish that can be used for mortality estimates. Using catch curve data, we estimated mortality at 94.2% (±4.6) from age-2 to age-3. Heincke's estimate of 93.9% corroborated this estimate. That only two age classes were used to produce these estimates makes them more subject to bias and less reliable. Nevertheless, such a high mortality rate in the oldest age groups is not uncommon in brook trout populations (Meehan and Bjornn 1991).

Very few small redband trout were captured compared to brook trout, but the size distribution of the larger fish was similar between species (Figure 8). Brook trout length vs. weight fit a power curve well, but redband trout length vs. weight appeared to fit a more exponential relationship at the upper end of the data (Figure 9).

Individual otolith readings were more accurate than scale readings for both readers. Combining readers, otolith aging for age-1+ agreed with the final age assessment 89% of the time, compared to 78% for scales. In addition, it took less time to read otoliths from age-1+ brook trout (mean 269 s, range 176-472) than scales (mean 303 s, range 218-432) ($P = 0.001$; Table 7). For age-0 fish, both techniques resulted in correct readings 100% of the time, and there was no difference in the time it took to read otoliths (mean 254, range 204-324) vs. scales (mean 256, range 190-326) ($P = 0.902$; Table 7). From these results we conclude that otoliths are more useful for aging brook trout and will be used in subsequent years over scale reading. However, it may be impractical to use otoliths to age native salmonids in many upper Snake River basin tributaries, especially where their numbers are extremely depressed. The readers in this study were novices to aging techniques, probably reducing their accuracy; with more practice, it is likely that scale reading will be adequate to age native trout when populations are too small to obtain enough otoliths to characterize the population. Nevertheless, lack of first-year annuli on scales is common in Snake River tributaries (Lentsch and Griffith 1987), and that is probably the reason scale reading was less accurate in this study.

The average length of age-0 brook trout was 59 mm, compared to 115 mm for age-1, 148 for age-2, and 203 mm for age-3. Within each sex/age class category, mature fish grew faster than immature fish (Table 8). The average length of male brook trout of age-1, age-2, and age-3 exceeded that of females, but the difference was only significant for age-2 fish

Table 5. Total catch, population estimates, and removal efficiency of redband trout and brook trout in Pike's Fork of the Crooked River in 1998.

	Redband age-1+				Brook trout age-1+				Brook trout age-0			
Reach name	Total catch	Population estimate	Upper CI	Capture probability	Total catch	Population estimate	Upper CI	Capture probability	Total catch	Population estimate	Upper CI	Capture probability
0.0 A	34	34	36	0.87	15	15	16	0.88	12	13	19	0.67
0.0 B	43	44	47	0.83	17	17	20	0.81	22	22	23	0.92
0.0 C	73	80	91	0.70	35	35	37	0.88	58	63	72	0.71
0.5 A	28	28	28	0.97	28	28	29	0.90	29	36	52	0.55
0.5 B	109	110	113	0.89	72	73	76	0.87	21	21	22	0.91
0.5 C	67	68	71	0.85	36	36	38	0.88	28	31	39	0.67
1.0 A	72	112	175	0.40	38	45	59	0.59	19	28	57	0.42
1.0 B	97	106	118	0.70	45	46	49	0.83	19	19	21	0.86
1.0 C	100	100	101	0.95	49	49	50	0.94	24	31	50	0.51
1.5 A	44	47	54	0.73	32	32	34	0.89	48	63	90	0.51
1.5 B	76	85	98	0.67	38	38	39	0.93	35	41	54	0.60
1.5 C	65	65	67	0.89	29	29	31	0.88	16	16	18	0.84
2.0 A	81	82	85	0.87	31	31	32	0.94	29	29	31	0.85
2.0 B	98	98	102	0.88	34	34	36	0.90	9	9	10	0.90
2.0 C	109	114	121	0.78	27	27	27[a]	NA	90	90	90[a]	NA
2.5 A	93	97	104	0.78	45	46	49	0.83	78	88	102	0.66
2.5 B	132	134	138	0.86	50	51	55	0.82	108	123	140	0.65
2.5 C	67	69	74	0.81	31	31	33	0.86	28	33	45	0.60
Index site 1	33	34	38	0.65	11	11	12	0.79	7	7	9	0.64
Index site 2	17	17	17	0.90	11	11	12	0.73	28	28	30	0.72
Index site 3	14	14	15	0.74	8	8	9	0.73	2	2	7	0.67
Index site 4	18	18	18	0.90	6	6	10	0.55	3	3	3[a]	NA
Total	1470	1556	1712	0.80[b]	688	699	725	0.83[b]	713	796	890	0.69[b]
Removal efficiency (%)		NA	NA			98.4	94.9			89.6	80.1	

[a] All fish captured on first run, thus CI could not be calculated.

[b] Average, not total

Table 6. Size-age structure of all brook trout removed from Pike's Fork of the Crooked River in 1998. Age-frequency distribution was computed by using an age-length key from a subsample of aged fish (n = 241) and professional judgement.

Total length (mm)	Age group 0	1	2	3	Total
40	6				6
50	160				160
60	387				387
70	160				160
80		20			20
90		15			15
100		47	19		66
110		44	57		101
120		27	57		84
130		17	45	3	65
140		10	52	3	65
150		7	56	4	67
160		6	66	3	75
170		2	51	3	56
180			28	3	31
190			14	4	18
200			5	5	10
210				6	6
220				1	1
230				6	6
240				1	1
250					
260				1	1
Total	713	195	450	43	1401
Percent	50.9	13.9	32.1	3.1	100.0

(Table 8). Both sexes reached maturity at age-1, and a higher proportion of males than females were mature for each age class (Figure 10). The smallest mature male was 95 mm, and the largest immature male was 157 mm, whereas for females the smallest mature and largest immature were 133 mm and 169 mm, respectively. In comparison, brook trout in Lawrence Creek, Wisconsin, were between 41-91 mm larger than our fish for each age class from age-0 to age-3, but length at maturity, age at maturity, and the smallest mature and largest immature fish of each sex were comparable (McFadden 1961).

Of the brook trout whose sex could be determined, females outnumbered males for each year class, and the ratio increased as age increased (Table 8). The proportion of brook trout that were females was 0.56 (SE ±0.17) for age-1, 0.60 (±0.05) for age-2, and 0.67 (±0.19) for age-3; over all age classes, the proportion was 0.59 (±0.05). McFadden (1961) also observed that the proportion of females becomes greater in successively older age groups of brook trout, and attributed the phenomenon to selective angling pressure and harvest on the faster-growing, more aggressive males.

Total length of females was strongly related to fecundity (Figure 11). The number of eggs produced per fish was less than 300 for all but two of the 16 females sampled. Average fecundity was 235 eggs per female. If even one female brook trout spawns successfully, and mortality is low due to a drastic reduction in competition, there could be a substantial number of age-1 brook trout to remove in August 2000.

Whether or not the remaining brook trout in Pike's Fork undergo a compensatory response via decreased natural mortality and increased growth and fecundity remains to be seen. Additionally, though this BPA project is bearing little of the cost of this removal, a serious consideration of the cost being incurred while performing such removals will be examined in 1999. These factors, as well as the ability to completely or effectively remove brook trout from streams with bull trout or other native trout, will dictate whether or not removals can be considered an effective method for future use in other Snake River tributaries to reduce the risk that brook trout or other non-native trout pose on native resident salmonids.

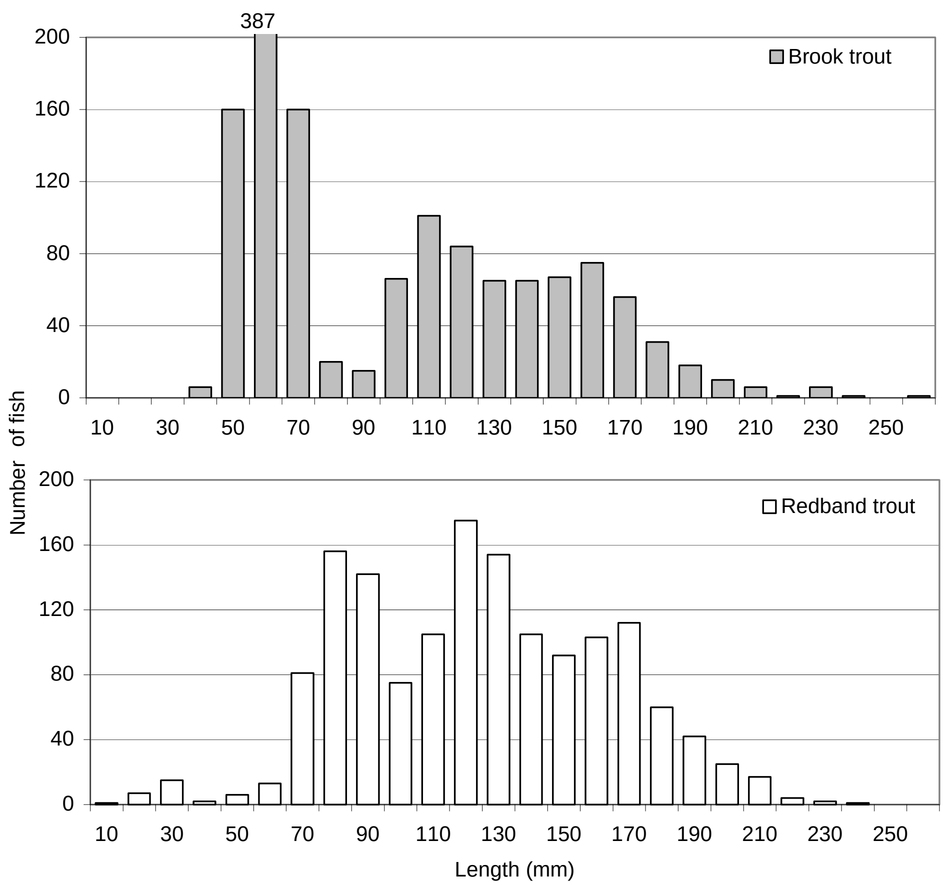
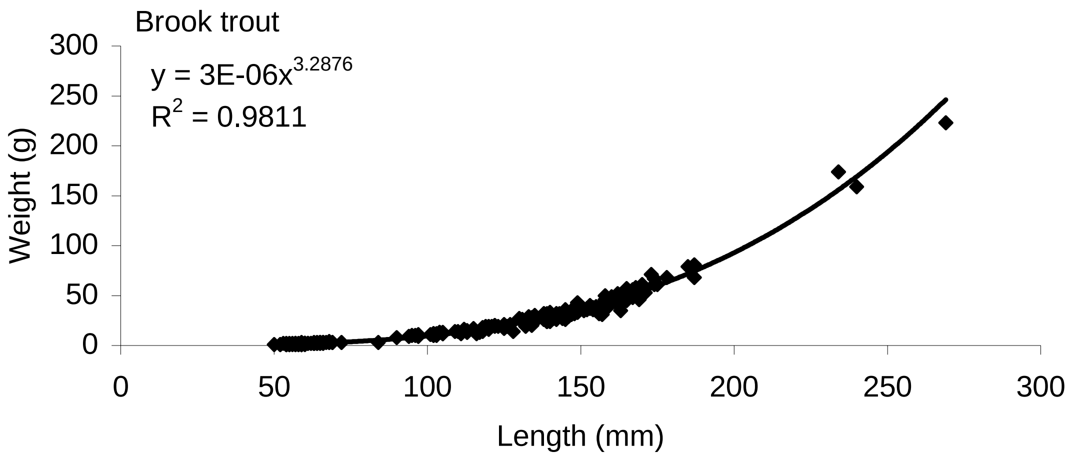


Figure 8. Length frequency of brook trout and redband trout caught in Pike’s Fork of the Crooked River in 1998.



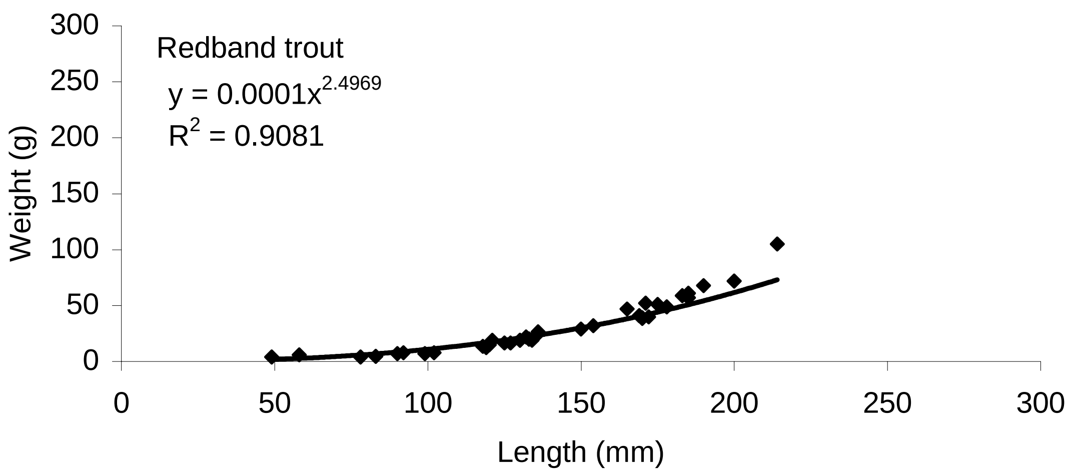


Figure 9. Length-weight relationship for redband trout and brook trout in Pike's Fork of the Crooked River in 1998.

Table 7. Mean (SE) time (in seconds) to age scales v. otoliths for brook trout in Pike's Fork of the Crooked River in 1998.

Age	Method	n	Removal	Labeling	Preparation	Reading	Total	*P*-value
0	Scale	19	56.4 (1.8)	9	117.7 (4.7)	72.1 (5.0)	255.6 (8.1)	0.902
	Otolith	19	95.5 (5.7)	44	0.0	114.3 (11.3)	254.0 (8.7)	
1+	Scale	53	48.5 (1.0)	9	130.3 (2.7)	114.5 (6.2)	302.6 (6.7)	0.001
	Otolith	53	108.8 (6.4)	44	0.0	115.8 (6.1)	268.8 (9.4)	

Table 8. The length of male and female brook trout at age in the Pike's Fork of the Crooked River in 1998.

			Fish length (mm)				*P*-value	
Age	Sex	Maturity	n	Mean	SE	Range	Maturity	Sex
1	F	I	8	118.8	6.2	97-146	0.272	
		M	2	134.0	1.0	133-135		
		combined	10	121.8	5.3			
								0.671
	M	I	5	109.0	7.7	95-139	0.027	
		M	3	156.7	17.3	122-175		
		combined	8	126.9	11.4			
2	F	I	31	137.1	2.8	109-169	0.00005	
		M	18	156.3	2.9	139-187		
		combined	49	144.1	2.5			
								0.003
	M	I	6	137.5	7.2	155-157	0.002	
		M	27	159.7	2.6	131-187		
		combined	33	155.7	2.9			
3	F	I	1	138.0	0.0		NA	
		M	3	202.3	34.6	153-269		
		combined	4	186.3	29.3			
								0.312
	M	I					NA	
		M	2	237.0	3.0	234-240		
		combined	"	"	"	"		

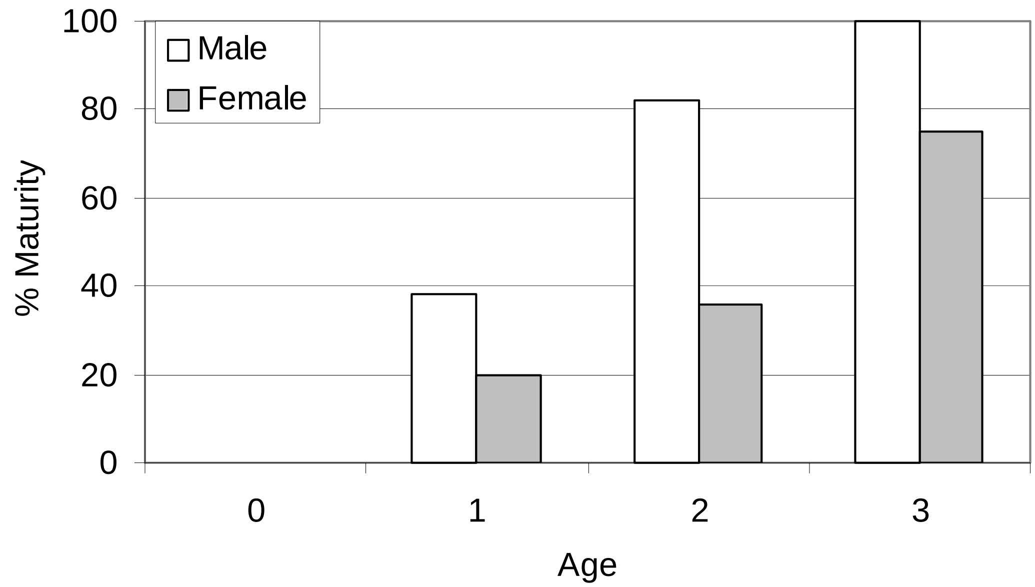


Figure 10. Proportion of male and female brook trout mature at age in Pike's Fork of the Crooked River in 1998.

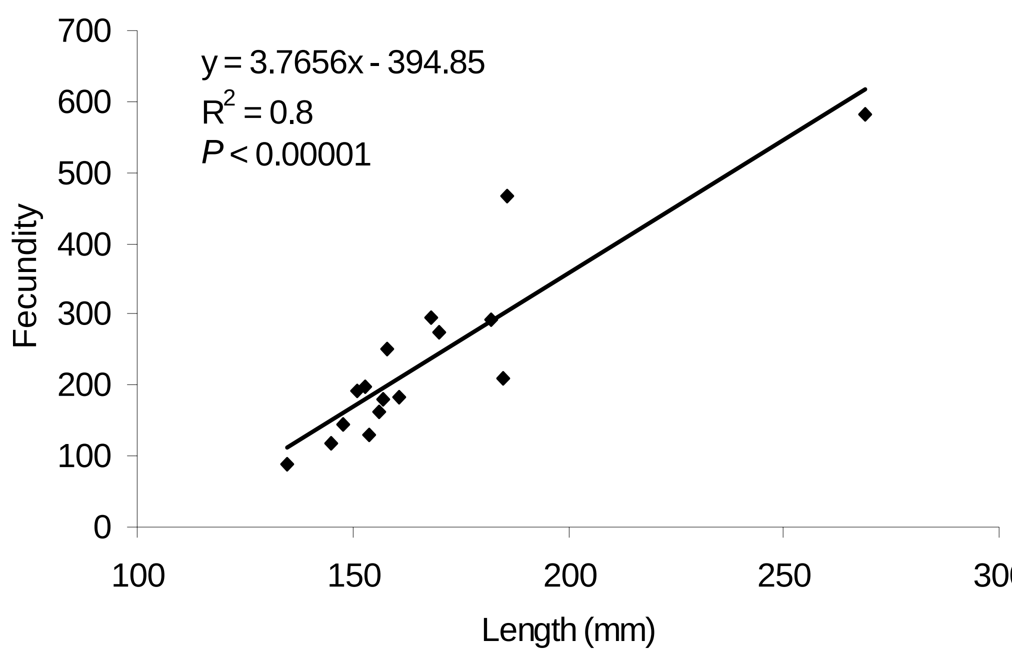


Figure 11. The relationship between length and fecundity of female brook trout in Pike's Fork of the Crooked River in 1998.

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