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KOOTENAI RIVER FISHERIES INVESTIGATIONS: RAINBOW TROUT RECRUITMENT

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Prepared By
Christopher C. Downs, Fishery Research Biologist
Idaho Department of Fish and Game

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ABSTRACT

The objective of this study was to determine if juvenile production was limiting the rainbow trout *Oncorhynchus mykiss* population in the Idaho reach of the Kootenai River. We used a rotary-screw trap to capture juvenile rainbow trout to estimate total outmigration from the Deep Creek drainage to the Kootenai River. The outmigrant estimate for March through June 1998 was 40,612 juvenile rainbow trout. Age determination based on scales suggests most outmigration from the Deep Creek drainage occurred at age-1 and age-2, during the spring runoff period. Twenty-two adult rainbow trout were captured in Deep Creek during the spawning migration and radio-tagged. Of the 15 radio-tagged rainbow trout that outmigrated from Deep Creek following spawning, 13 traveled downstream to Kootenay Lake, British Columbia, 135 river kilometers downstream of the tagging site. No radio-tagged rainbow trout traveled upstream to the most suitable fluvial salmonid habitat after leaving Deep Creek. For the period 1996–1998, 190 adult rainbow trout were tagged with $10.00 reward T-bar anchor tags. Six of the fifteen tags returned to date have come from Kootenay Lake, BC. Only one reward tag was returned from a section of the Kootenai River upstream of Deep Creek. These data strongly suggest the rainbow trout population spawning in Deep Creek is largely comprised of adfluvial rainbow trout from Kootenay Lake, BC. Aside from straying, the juveniles produced in the Deep Creek drainage will likely recruit to the Kootenay Lake fishery. We estimated a standing stock of 1.6 kg/ha and 29.7 kg/ha for rainbow trout (125-449 mm TL) and mountain whitefish ($\geq$ 220 mm TL), respectively, inhabiting the Hemlock Bar reach of the Kootenai River. Densities of age-0 rainbow trout were low in all tributaries surveyed, but highest in Boulder Creek and the Moyie River. The age-0 abundance estimates suggest reproduction in the Idaho reach of the Kootenai River may be inadequate to produce existing estimated densities of adult rainbow trout. Recruits may be emigrating from upstream areas in Montana.

Author:

Christopher C. Downs
Fishery Research Biologist

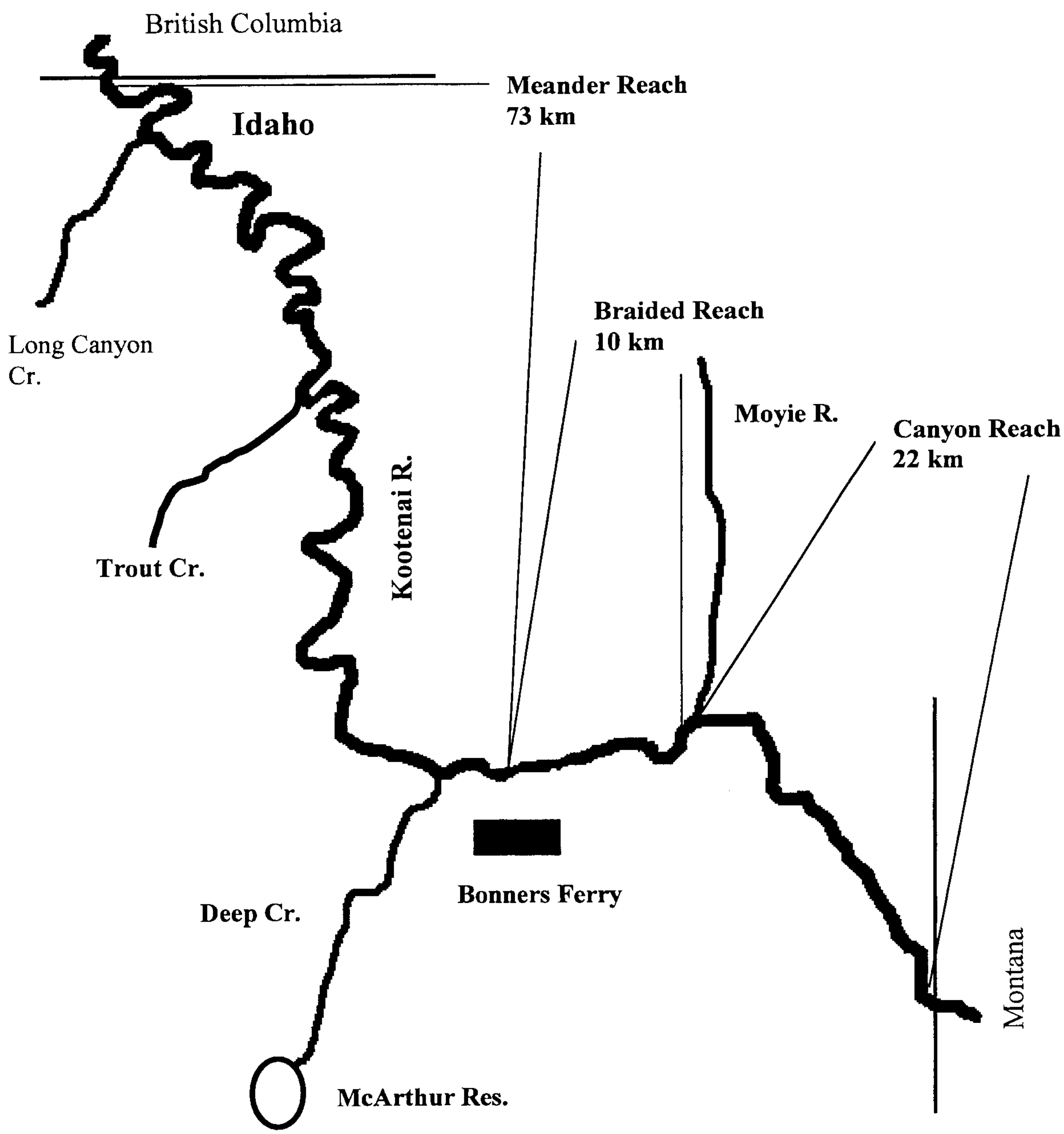
INTRODUCTION

The Kootenai River has undergone the recent loss of several once relatively productive fisheries (white sturgeon *Acipenser transmontanus*, burbot *Lota lota*, bull trout *Salvelinus confluentus*, kokanee *Oncorhynchus nerka*, and mountain whitefish *Prosopium williamsoni*) (Fredericks 1996). Currently, despite low densities, rainbow trout provide the most important fishery in the river. Partridge (1983) estimated angler catch rates of 0.06 trout/h in 1982 and 1983, and Paragamian (1994) reported angler catch rates of 0.02 trout/h over a similar period of time in 1993 and 1994. For comparison, Schill (1991) summarized catch rates for a number of Idaho rivers, which ranged from 0.7 to 1.95 trout/h.

Paragamian (1994) reported that, although poor, the rainbow fishery has remained relatively stable since the work of Partridge (1983). Partridge (1983) and Paragamian (1994) both suggested recruitment is primarily from tributaries. Both authors reported high densities of juvenile trout in Deep Creek tributaries, but noted the limited amount of suitable and/or accessible habitat. Partridge (1983) reported that most of the juvenile production in the Idaho reach of the Kootenai River was probably from Falls, Trail and Ruby Creeks and hypothesized that quantity and quality of spawning and rearing habitat was limiting the rainbow trout population. This hypothesis is largely dependent on the absence or near absence of successful spawning in the mainstem and a lack of recruitment from Montana tributaries. To date, no studies have documented rainbow trout spawning in the mainstem Kootenai River in Idaho. However, researchers with Montana Fish, Wildlife and Parks (MFWP) report counting 20-40 rainbow trout redds each year in the 2.5 km reach directly below Libby Dam (Steve Dalbey, MFWP, personal communication).

There is little information available regarding river habitat use by juvenile or adult rainbow trout in the mainstem Kootenai River in Idaho. There are approximately 105 km of Kootenai River in Idaho with the following three distinct reaches based on habitat types (Figure 1): 1) the Canyon Reach (22 km) from the Montana border to the Moyie River, 2) the Braided Reach (10 km) from the Moyie River to Bonners Ferry, and 3) the Meandering Reach (73 km) from Bonners Ferry to the Canadian border. The meandering reach has been heavily altered by diking and probably has little potential to support fluvial rainbow trout. Based on substrate and depth, the reaches above Bonners Ferry (Braided and Canyon reaches) appear to be the most suitable adult fluvial rainbow trout habitat (Fredericks in press), yet the sources of recruitment to these reaches are unknown. Juveniles produced in the Deep Creek drainage would have to travel upriver after emigrating from Deep Creek to utilize this habitat. Similar migrations have been documented in other salmonid stocks. Cutthroat trout *Oncorhynchus clarki* in Yellowstone Lake spawn, in part, in the outlet area of the Yellowstone River. Progeny from this stock have been shown to migrate upstream to the rearing area, and are evidence of genetically controlled migration patterns (Raleigh and Chapman 1971; Bowler 1975). Other studies have demonstrated upstream migrations of salmonids from natal streams to rearing areas (Brannon 1967; Raleigh 1971).

Figure 1. Map of the Idaho reach of the Kootenai River depicting the three broad habitat types.



The question of whether or not the system is limited by juvenile production can best be answered after we have obtained a numerical estimate of juveniles entering the river, an estimate of in-river survival, and an estimate of the carrying capacity of the Kootenai River for juvenile and adult rainbow trout. Also of importance is an understanding of the river habitat utilized by juvenile and adult rainbow trout. If the fishery is found recruitment limited resulting from insufficient juvenile production, it might be enhanced by improving and/or expanding spawning and rearing habitat in tributaries and the mainstem, or by stocking juvenile trout. If low productivity is reducing survival of juvenile rainbow trout, nutrients could be added to the river.

RESEARCH GOAL

Improve the rainbow trout fishery in the Kootenai River.

OBJECTIVE

Determine if the rainbow trout population in the Idaho reach of the Kootenai River is limited by juvenile production and survival.

METHODS

Deep Creek Outmigrants

Population Estimates

We used a rotary-screw trap (Thedinga et al. 1994, Kennen et al. 1994) to capture juvenile rainbow trout outmigrating from the Deep Creek drainage to the Kootenai River. The trap was located on Deep Creek between Twentymile and Caribou creeks (Figure 2).

A mark-recapture technique was employed to estimate trap efficiency (TE) for juvenile rainbow trout (Seelbach et al. 1985; Kennen et al. 1994; Thedinga et al. 1994, Roper 1995). At the beginning of each week (typically Sunday), a minimum of 100 juvenile rainbow trout initially captured in the screw-trap were weighed (g) and measured (total length (TL), mm). These fish were then marked, moved 250 m above the screw trap, and released to estimate TE. If fewer than 100 unmarked juvenile rainbow trout were captured in the trap on Sunday (available for marking and release above the trap), juvenile rainbow trout were marked and released each of the following days until the minimum number of 100 was reached. Two different marks were used on an alternating weekly basis (i.e., adipose/upper caudal – week 1, adipose/lower caudal – week 2, then repeat) in TE tests. This allowed for calculation of TE for individual releases and stratification of efficiencies by date or stream discharge. All fish captured in the screw-trap and not used in efficiency tests were marked with an adipose clip and released 50 m below the trap. These three marks were unique identifiers for juvenile fish emigrating from Deep Creek.

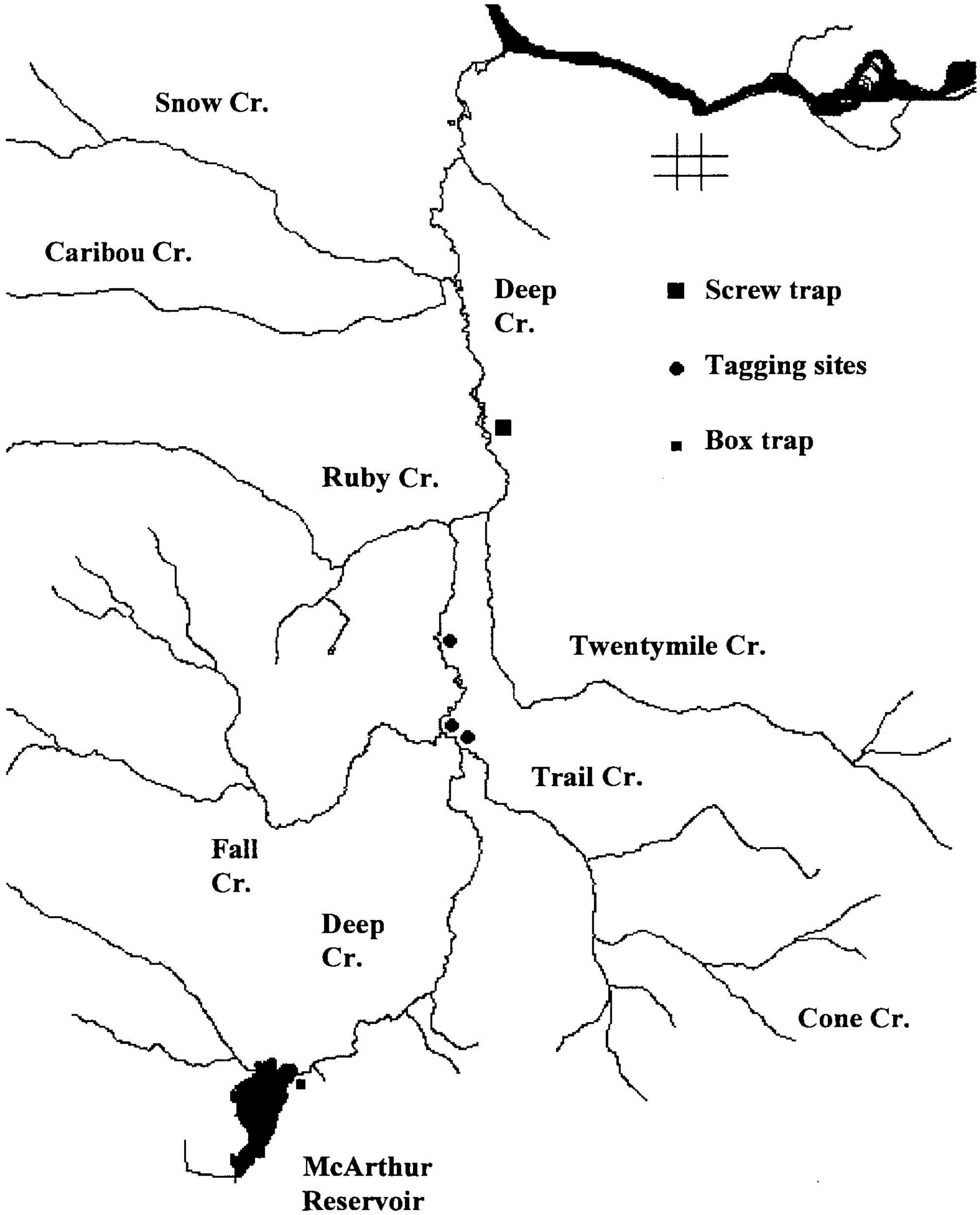


Figure 2. Deep Cr. drainage map depicting major tributaries, rainbow trout tagging sites, and the box trap location in the fishway at McArthur Reservoir.

The proportion of marked fish recaptured provides an estimate of TE. TE was estimated as (Thedinga et al. 1994):

$$TE = R/M \quad (1)$$

Where:

R = number of marked fish recaptured

M = number of marked fish

Upper and lower 95% confidence limits for the TE was estimated using a normal approximation to the binomial distribution for large samples, when TE is small (< 0.3) (Fleiss 1981:14):

$$\text{(2) Lower 95\% CL} = P_L = \frac{(2np + c^2_{\alpha/2} - 1) - c_{\alpha/2}\sqrt{c^2_{\alpha/2} - (2 + 1/n) + 4p(nq + 1)}}{2(n + c^2_{\alpha/2})}$$

$$\text{(3) Upper 95\% CL} = P_U = \frac{(2np + c^2_{\alpha/2} + 1) + c_{\alpha/2}\sqrt{c^2_{\alpha/2} + (2 - 1/n) + 4p(nq - 1)}}{2(n + c^2_{\alpha/2})}$$

Where:

p = proportion in question (TE)

q = 1-p

n = sample size (number of marks released)

$c_{\alpha/2} = c_{.025} = 1.96$ (for df = ∞)

Our sample sizes were appropriate for the large sample approximation as defined by Fleiss (1981:13):

$$np \geq 5 \text{ and } nq \geq 5 \quad (4)$$

TE was used to estimate the total number of outmigrants from the unmarked catch for a given time period as (Thedinga et al. 1994):

$$N_t = U_t/TE_t \quad (5)$$

Where:

N_t = outmigrant estimate for time period t

U_t = unmarked catch for time period t

TE_t = trap efficiency for time period t.

Successful estimates of TE were defined as recovering a minimum of $\geq$ 3 recaptures to minimized bias (Ricker 1975), and operation of the screw trap for four consecutive days post-release of marked fish.

The 95% confidence intervals for the outmigration estimate were derived by substituting the upper and lower boundary of the confidence interval for trap efficiency into the formula used to calculate outmigration (equation 5). Point estimates and confidence limits for daily outmigration were summed to arrive at approximate seasonal estimates of outmigration (Seber 1982, Roper 1995).

Potential biases may arise when calculating TE's if marks are lost. This situation may arise from mortality of marks or residualization of marks above the trap. We tested for the effects of handling mortality on TE by holding marked juvenile rainbow trout for 24 hours prior to release. Two groups each consisting of 15 juvenile rainbow trout were weighed, measured, and marked as usual. These juveniles were then held in Deep Creek near the release site for 24 hours. The holding cars were then inspected for mortalities.

The effect of residualization of marked juvenile rainbow trout on TE was examined. On June 15, we released 121 marked juvenile rainbow trout and on July 2, we released 30 marked juvenile rainbow trout above the screw trap for efficiency estimation. Three to four days post-release we electrofished the reach of Deep Creek between the trap and the upstream release site to look for residualizing marked juvenile rainbow trout. One-pass electrofishing runs were conducted up each bank from the screw trap to the release site. Captured juvenile rainbow trout were examined for marks.

Age Determination

Age at outmigration was estimated from the analysis of scales collected from 10 juvenile rainbow trout/10 mm length group during March and April. Scales were collected from the area immediately dorsal to the lateral line and slightly anterior to the insertion of the adipose fin. Scales were impressed onto plastic slides and aged using a microfiche reader at 42X. An age-length key (Westerheim and Ricker 1978) was developed from the scale sample and applied to a random sample of fish lengths collected during March and April. This likely provided an unbiased estimate of the age composition of the total outmigration for March and April.

Water Temperature

Electronic temperature loggers were used to monitor water temperature in Deep Creek. One temperature logger was located immediately downstream of McArthur Reservoir and the other at the screw trap. Relative stream discharge was monitored with a staff gage located at the screw trap.

Deep Creek Spawning Population

Radio-telemetry

Twenty-two adult rainbow trout were radio-tagged in the Deep Creek drainage from April 8 to May 14 (Figure 2). Fish were captured by hook-and-line, trapping, and electrofishing. Most fish were captured at the mouths of spawning tributaries in an immediately pre-spawn condition. Captured fish were weighed (g), measured (TL, mm), and anesthetized. The anesthetized fish were placed ventral side up in a wooden surgery cradle. The cradle was lined with 6-mm hardware cloth to minimize damage/removal of the fish's protective mucus layer. The cradle was placed in a 26.5 L cooler containing an anesthetic bath. The cradle is angled downward, partially submerging the gills, while the abdomen (surgical area) remained above the water line. During surgery, an assistant continuously bathed the gills with the anesthetic/water mixture using an oven baster. We used a slightly modified shielded needle technique (Ross and Kleiner 1982) for tag implantation. The shielded needle itself was replaced with a large gauge catheter needle. To prevent internal damage from the catheter, we inserted a small spoon into the abdomen to shield the internal organs during surgery. Surgeries were closed with four or five non-dissolvable polypropylene sutures (3-0 Prolene) using a 24-mm cutting-tip needle. To expedite recovery, the assistant began bathing the gills with fresh water at initiation of wound closure. Radio-tagged rainbow trout were held in live-cars until fully recovered (typically 20 min) and then released at the capture site.

Individuals were selected for radio tagging based on body weight. Tag weight could not exceed 2% of the body weight in air (winter 1992). We used the estimated post-spawn weight of females to determine their suitability for tagging. The estimated post-spawn weight was derived by subtracting the maximum percent body weight of developed ovaries for rainbow trout (8%) (Kaya 1977) from the total weight of the fish at time of capture.

Low frequency (30-31Mhtz) radio-tags were used to maximize signal transmission in the deep, oligotrophic waters of the lower Kootenai River (Winter 1996). We tested radio-tags at various depths and distances to determine the maximum depth and distance from which signals could be received.

Radio-telemetry was conducted daily in the Deep Creek drainage by motor vehicle during the spawning period (April - June). Telemetry was also conducted from fixed-wing aircraft to track the radio-tagged rainbow trout as they began to out-migrate to the mainstem Kootenai River (April – July). Three fixed location-receiving stations served to direct the aerial searches and provide last known locations in the event fish were lost.

Signals remaining in the same location in spawning tributaries for extended periods of time (longer than one month) were assumed to represent mortalities. Mortality dates were approximated as the last date an individual moved. We attempted to confirm mortality by snorkeling and retrieving tags.

Reward-tagging

Adult rainbow trout were captured in Deep Creek by hook-and-line, electrofishing, and trapping from April 8 – June 15, 1998. Fish were weighed (g), measured (TL, mm), and a sample of scales was removed for aging. In addition, all fish >225 mm were marked with $10.00 reward T-bar anchor style tags.

A live-box trap was placed at the upstream end of the fish ladder at McArthur Reservoir to quantify use of the fishway by rainbow trout (Figure 2). Angler exploitation in the reservoir was quantified through angler returns of the reward-tags.

We advertised the reward-tag program in order to reduce angler non-response. Informative signs were posted at fishing access sites on the Kootenai River in Idaho and Kootenay Lake, BC. In addition, press releases were published in local newspapers.

Angler exploitation was estimated as the number of reward-tags returned divided by the number of reward-tags available in the fishery to anglers. The number of reward-tags returned was corrected for non-response by utilizing a linear-logistic model developed for estimating band reporting rates of mallard ducks *Anas platyrhynchos* (Nichols et al. 1991) as:

$$\lambda_i = \exp(-0.0045 + 0.0283i) / [1 + \exp(-0.0045 + 0.0283i)] \quad (6)$$

Where:

λ_i = estimated reporting rate for reward dollar amount i

i = reward dollar amount

Age Determination

Scales were collected from all adult rainbow trout for estimation of age. Scales were impressed onto plastic slides and ages estimated from the impressions using a microfiche reader at 42X. Mean length at capture and the proportion of the run comprised of each age class was estimated.

Kootenai River Tributary Recruitment Assessment

To estimate potential tributary recruitment, we surveyed perennial tributaries to the Kootenai River between Bonners Ferry (rkm 246) and the Idaho/Montana border (rkm 276) (Figure 3). This reach represents the highest quality fluvial trout habitat in the Idaho reach of the Kootenai River (Fredericks in press). Only two tributaries in the reach were excluded from survey. Dawson Creek is inaccessible to migratory salmonids due to a railroad culvert at its mouth, and a combination of small stream size and high gradient likely make Sand Creek unusable to mainstem adults. Linear stream distance was measured (m) from the mouth of each tributary to the first barrier likely capable of blocking the migration of adult salmonids during high flow periods. Natural barrier determination was subjective. Accessible distance was estimated from 1:24,000 scale USGS topographic maps for the Moyie River and Boulder Creek based on the known locations of fish passage barriers.

Multiple-pass depletion estimates were conducted in selected reaches of the tributaries below the barriers to estimate potential recruitment to the Kootenai River. Between three and five removal passes were made for each estimate. Repeated passes were made until the catch was reduced to 20% of the first pass, which typically produces reasonably precise estimates. The estimates were then analyzed using the Microfish software package (Van Deventer and Platts 1989). Where depletion estimates were not possible, 1-pass electrofishing runs were conducted and catch-per-unit-effort was used to index abundance. Each fish was weighed (g), measured (TL, mm), and marked with a fin clip for identification if recaptured in the mainstem Kootenai River.

Kootenai River Rainbow Trout

Population Estimates

Capture-recapture population estimates were conducted for adult rainbow trout and mountain whitefish *Prosopium williamsoni* in the Hemlock Bar reach (rkm 262 – 265) of the Kootenai River (Figure 3). Boom-type electrofishing was conducted at night using a five m-long jet boat. The electrofishing setup consisted of a Coffelt VVP-15 electroshocker powered by a 5000 watt Honda generator. Smooth DC current was employed to minimize risk of injury to rainbow trout (Dalbey et al. 1996). Typically, electrofishing settings were set to generate 6-8 amps at 175-200 volts.

Captured fish were weighed (g), measured (fork length (FL), mm), marked, and released. Fork length was converted to TL using the formula (Carlander 1969):

$$TL = 1.071FL \tag{7}$$

Marking was conducted over a four-night period and the recapture run was conducted over a two-night period the following week.

Estimates were calculated using the modified Petersen method for sampling without replacement (Krebs 1989). Estimates were stratified into five length groups because the size-selective nature of electrofishing (Reynolds 1996) can introduce bias into population estimates (Anderson 1995). Binomial confidence intervals were calculated as recommended by Seber (1982) using the chart provided by Krebs (1989). Relative weights (*Wr*) (Anderson and Neumann 1996) were calculated to assess rainbow trout condition. Proportional stock density (PSD) (Anderson and Neumann 1996) was calculated to examine population size structure. PSD was estimated from the marking sample and separated into two classes; proportion > 305 mm (PSD) and the proportion > 406 mm (QSD) using 200 mm (TL) as stock length (Schill 1991).

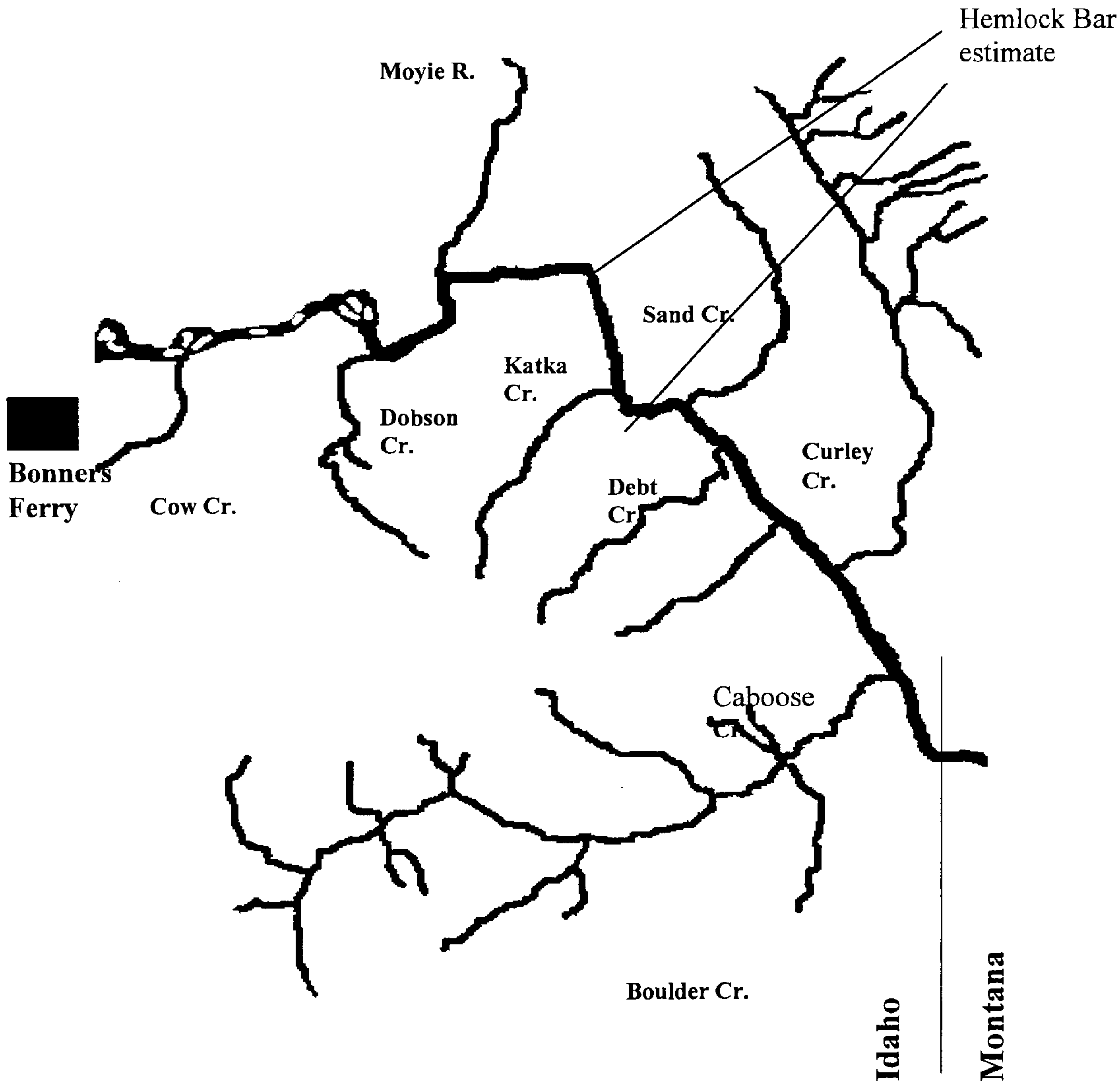


Figure 3. Kootenai River drainage map from Bonners Ferry, Idaho to the Idaho/Montana border (rkms 248.5-276) depicting the Hemlock Bar estimate reach and perennial tributaries.

Age and Growth

A sample of scales was collected from each rainbow trout captured for estimation of age and growth. Scales were impressed onto plastic slides and viewed on a microfiche reader at 42X. A regression of TL at capture on scale radius (Y = 5.04(X) + 43.88; R^2 = 0.90) was used with a refined Whitney and Carlander (1956) "body proportional" method (Francis 1990) to back-calculate TL at age. The Francis (1990) method uses:

$$L_i = [\,(c + dS_i) / (c + dS_c)\,]\, L_c$$

Where:

L_i = TL
S_i = radius measurement at time of formation of the *i*th annulus
L_c = the TL at capture
S_c = total scale radius
c = the y-intercept from the regression equation
d = slope derived from the regression equation.

Mean length at age and annual growth increments were estimated from the back-calculation data.

Water Temperature

An electronic temperature logger was used to monitor water temperature in the Kootenai River. The temperature logger was located immediately upriver of the confluence of the Moyie River.

Kootenai River Shoreline Abundance Index

Single-pass electrofishing runs were conducted to index the abundance of juvenile rainbow trout in the mainstem Kootenai River. Electrofishing was conducted in a stratified pattern along the shoreline between Cow Creek and the Idaho/Montana border (Figure 3). We sampled the downstream most 120 m of shoreline habitat on each bank within each rkm. We defined "shoreline" as the zone extending out from the riverbank into the river for a distance of one m.

Electrofishing was conducted using a mobile electrofishing system consisting of a hand-held anode, Coffelt VVP-15 electrofisher, and a 5000w Honda generator. The shocking equipment was placed in an aluminum jetboat, which served as the cathode. Two individuals walked downstream with the mobile anode and a dip net, capturing fish as they were stunned. A third individual held the boat, walking it downstream as needed. Smooth DC current, generating between two and four amps at 200-250 volts was used to stun the fish. Captured juvenile rainbow trout were weighed (g), measured (TL, mm), and examined for marks.

RESULTS

Deep Creek Outmigrants

Population Estimates

Although marked fish were released on a weekly basis, we were only able to estimate TE's for 12 time-periods. During peak runoff, debris jammed the trap on several occasions invalidating the estimates of trap efficiency for the respective releases. TE varied considerably over the trapping period (Table 1). Neither gage height or water temperature was significant linear predictor of TE ($p > 0.1$) .

Two groups of 15 juvenile rainbow trout each were held in Deep Creek for 24 hours prior to release to test the effect of marking on survival. No mortality was observed in either of the test groups.

Residualization above the screw trap was not detected in marked juvenile rainbow trout. No marked juvenile rainbow trout were recaptured during electrofishing runs in the reach of Deep Creek between the screw trap and the release site.

Size-selective recapture of marked fish could also bias the estimate of outmigration. A plot of TE by length group revealed size selection in the recapture of juvenile rainbow trout (Figure 4). The TE averaged 14% for rainbow trout < 100 mm and 25% for rainbow trout ≥100 mm. To account for the size selection bias in the estimate of outmigration, marks and recaptures were pooled into monthly estimates of TE stratified by fish length (≥/< 100 mm).

The rotary-screw trap was operated from March 10–July 19, 1998. By July 20, flows in Deep Creek were too low to turn the trap. An estimated 40,615 juvenile rainbow trout outmigrated from the Deep Creek drainage during the trapping period (Table 2). By July, outmigration had dropped to levels too low for an unbiased estimate.

Age Determination

We estimated mean length and age at outmigration for the period March through April 1998 (Table 3). Assuming the proportion of ages outmigrating in March and April are representative of the remainder of the outmigration period (May through July), outmigration was dominated by age-1 and age-2 rainbow trout.

Table 1. Individual trap efficiencies (TE) for the 1998 season estimated from recaptured juvenile rainbow trout in Deep Creek, Idaho.

Date	Mean daily water T (^0C)	Gage height (cm)	Number of marks	Number of recaptures	TE
3/18	3.5	59	18	3	0.167
3/30	4.1	65	135	25	0.185
4/6	6.7	66	109	13	0.119
4/13	5.2	64	47	5	0.106
4/27	7.5	75	164	24	0.146
5/7	10.0	76	186	40	0.215
5/11	10.1	66	166	49	0.295
5/18	8.2	61	204	53	0.259
6/2	12.4	71	94	17	0.181
6/8	13.0	59	128	29	0.226
6/15	14.3	56	121	40	0.331
6/27	14.6	48	40	6	0.150

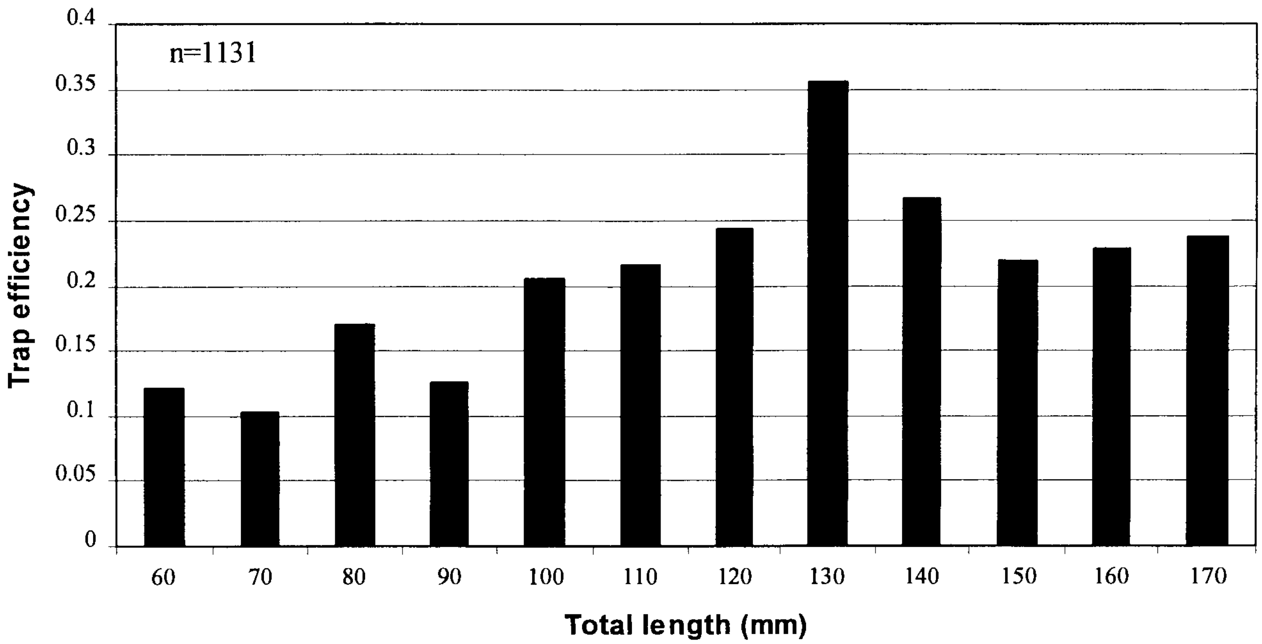


Figure 4. Plot of season-long trap efficiencies by total length group.

Water Temperature

Weekly mean water temperature in Deep Creek varied between the upper and lower sites (Figure 5). Water temperature ranged from 2 – 9°C higher at the upper site than the lower site for any given week. Mean weekly water temperatures exceeded 22°C for a six-week period at the upper site versus only one-week at the lower site.

Deep Creek Spawning Population

Radio-telemetry

Twenty-two adult rainbow trout were captured for radio tagging as they ascended the Deep Creek drainage to spawn. The majority of these were captured by hook-and-line at the mouth of Trail Creek (Figure 2). Radio-tag weight never exceeded the recommended 2% of body weight, and averaged less than 1.5%. All rainbow trout survived the initial surgical procedure as evidenced by changing signal locations following implantation.

Radio-tagged rainbow trout remained in the Deep Creek drainage for a maximum of 47 days. Although most (93%) out-migrated by May 20, a single radio-tagged fish remained in Deep Creek as late as June 8. Using the date of earliest capture of adult rainbow trout at the mouth of Trail Creek as the start of spawning, we approximated the spawning period to extend from April 11 to May 20. Point values of water temperature recorded during this time period in Trail Creek ranged from 4.5°C–13 °C. Based on the telemetry movements of 11 individuals, rainbow trout spawned in Trail Creek from its mouth, upstream to the confluence of Cone Creek (Figure 2). Based on juvenile rainbow trout densities observed in previous Deep Creek studies (Fredericks in press, Downs in press), rainbow trout also use Snow, Caribou, Twentymile, Ruby, Fall, and Dodge creeks for spawning.

Mortality began to occur in radio-tagged rainbow trout as early as nine days and continued out to 59 days post-implantation. Fifteen of the twenty-two radio-tagged rainbow trout survived spawning and outmigrated from Deep Creek (Table 4). Of the 15 fish that outmigrated, 13 were eventually located in Kootenay Lake or the immediate vicinity of its delta. One of the two remaining outmigrants set up a river home range near the Idaho/BC border and the other was lost as it migrated downstream towards Kootenay Lake.

The one-way migration distance between Kootenay Lake and the spawning tributaries of the Deep Creek drainage is approximately 135 river kilometers (rkms). Several fish moved as far as 180 rkms one-way from the tagging site in Deep Creek to locations in the West Arm of Kootenay Lake. Post-spawn rainbow trout traveled approximately 123.5 rkms between the spawning tributaries and the fixed location receiving station near the delta of Kootenay Lake in as little as five days.

Table 2. Estimates and associated 95% confidence limits (CL) of outmigrating juvenile rainbow trout in Deep Creek, Idaho, during 1998.

Month	Mean daily catch	Estimate	Upper CL	Lower CL
March	10	1,309	1,357	899
April	33	10,007	20,365	6,853
May	122	23,683	41,752	16,735
June	54	5,613	7,622	4,554
July	3	N/A	--	--
Totals		40,612	71,096	29,041

Table 3. Mean total length (TL, mm) at capture (n = 132), and proportion (*P*) of total outmigrants by age class for juvenile rainbow trout from Deep Creek, Idaho during March and April 1998.

Age class	Mean TL (SE)	*P*
1	89.8 (2.2)	.493
2	151.1 (3.9)	.479
3	218.3 (6.9)	.028

Table 4. Disposition and mortality of 22 radio-tagged rainbow trout from Deep Creek, Idaho, 1998.

Disposition	Number of fish
Kootenay Lake / vicinity	13
Pre-outmigration mortality	7
River home-range	1
Disappearance in river	1

Reward-Tagging

Ninety-two adult rainbow trout were reward-tagged in the Deep Creek drainage during 1998. Using the observed 32% post-spawn mortality rate for radio-tagged rainbow trout, I adjusted the number of reward-tagged rainbow trout available to anglers. Fourteen percent of the reward-tagged rainbow trout were harvested by anglers. The estimated reporting rate for the $10.00 reward-tags based on equation 6 is 57%. When corrected for non-response, the estimated annual angler exploitation rate of the spawning population is approximately 25%.

For the period 1996 through 1998, an estimated 129 reward-tagged rainbow trout were available for harvest. A total of 15 tags have been returned to date, and six of these have come from Kootenay Lake, BC. Only one tag was returned from the Kootenai River upstream of the confluence with Deep Creek.

The box trap was operated at McArthur Reservoir from March 23 through May 11, 1998. Thirteen adult rainbow trout were captured in the trap. Twelve of these fish received reward-tags and were placed above the trap in the lake. Only one reward-tag was returned from this group. This rainbow trout was originally tagged at the trap on March 31, 1998 and was harvested in McArthur Reservoir on August 28, 1998. After adjusting the number of tags available to anglers by the mortality rate of radio-tagged fish, the single tag return results in a minimum estimated annual angler exploitation rate of 12.5% (95% CI; 0 – 40.5%).

Age Determination

Age and growth data were obtained from analysis of 70 scale samples collected during the Deep Creek spawning run (Table 5). The majority of the spawning run was comprised of age-4 and older individuals.

Kootenai River Tributary Recruitment Assessment

A combination of natural and anthropogenic factors severely limit adfluvial or fluvial spawning access to Kootenai River tributaries (Table 6). The Moyie River and Boulder Creek contain the greatest amount of accessible habitat. However, cursory observation of substrates in both tributaries suggests dominance by cobble size and larger material.

Table 5. Mean total length at capture (TL, mm) of adult rainbow trout captured during the spawning migration in Deep Creek, Idaho, 1998.

Age class	n	Mean TL (SE)
2	6	270 (10)
3	18	321 (10)
4	12	373 (7)
5	24	385 (7)
6	10	421 (7)

Table 6. Stream survey results for segments of tributaries accessible to Kootenai River salmonids between Bonners Ferry and the Idaho/Montana border.

Stream	Rkm[a]	Accessible distance (m)[b]	Barrier type
Boulder Cr.	275.3	1,500	Falls
Caboose Cr.	270.6	37[c]	Culvert
Cow Cr.	250.0	425	Culvert
Curley Cr.	272.3	237	Falls
Debt Cr.	268.5	600[c]	Cascade
Dobson Cr.	255.9	0	Culvert
Katka Cr.	265.0	50	Falls
Moyie R	258.6	2,100	Falls

[a] Kootenai River kilometer at the confluence with the tributary.
[b] Survey conducted from 6/24-7/10/98.
[c] By early-August, streams flowed subsurface through alluvial fans preventing access by salmonids.

Depletion population estimates were conducted for salmonids in the accessible reaches of Caboose, Debt, and Katka creeks. The remaining tributaries were too large to effectively deplete with a single backpack electrofishing unit, and catch-per-unit-effort (CPUE) based on single electrofishing passes was calculated to index the abundance of salmonids in the accessible reaches. Based on comparisons of CPUE, Boulder Creek supported the highest density of rainbow trout (Table 7), the majority of which (67%) were age-0. Although the CPUE calculated for the Moyie River was lower than other tributaries, almost the entire catch of rainbow trout (98%) was comprised of age-0 individuals. The only other tributaries in which age-0 rainbow trout were captured were Curley (three age-0) and Katka (one age-0) creeks.

Kootenai River Rainbow Trout

Population Estimates

We estimated a total of 219 rainbow trout 125 to 449 mm (TL) and 4,044 mountain whitefish $\geq$ 220 mm (TL) in the 3,000 m-long Hemlock Bar reach of the Kootenai River (Table 8). Standing stocks of rainbow trout and mountain whitefish were 1.6 and 29.7 kg/ha, respectively.

Age and Growth

Length at age was estimated from back-calculation of scales for 105 rainbow trout captured during the population estimate (Table 9). Ages ranged from 1 to 6 years, with 98% of the rainbow trout captured being $\leq$ age-4.

Estimated W_r's for rainbow trout > 200 mm, >305 mm, and >406 mm were 85 (SE = 1.2), 83 (SE = 1.0) and 83 (SE = 2.2), respectively. The PSD was estimated at 42% and QSD at 5.0% for the population.

Water Temperature

Mean weekly water temperatures in the Kootenai River peaked at 16.4°C during the week of July 26 (Figure 6). Temperatures gradually declined thereafter and the thermograph was removed on October 15.

Kootenai River Shoreline Abundance Index

We sampled approximately 6,240 m^2 of the estimated 52,000 m^2 of available shoreline habitat from rkm 250 – 275. A length-frequency histogram was used to discriminate age-0 from age-1 rainbow trout (Figure 7). All rainbow trout captured <70 mm (TL) were classified as age-0. This decision rule was supported by comparison of juvenile rainbow trout lengths with the length ranges of other age-0 fall spawning salmonid species captured (Table 10). Although age-0 rainbow trout abundance was low throughout the study area, they were the most abundant juvenile salmonid captured. No juvenile rainbow trout marked in tributaries, including Deep Creek, were recaptured during the shoreline population indexing.

By expanding the CPUE of age-0 rainbow trout captured in the mainstem Kootenai River ($0.04/m^2$) to the total amount of habitat available (52,000 m^2 of shoreline), we estimate a total catch of 208 age-0 rainbow trout. Assuming a modest 25% electrofishing efficiency, we estimate approximately 1,000 juvenile rainbow trout in the study reach. Using a hypothetical 10% survival rate from age-0 to age-1, the mainstem can produce 100 age-1 rainbow trout annually.

DISCUSSION

Deep Creek Outmigrants

Population Estimate

Peak outmigration of juvenile rainbow trout occurred during April and May in 1998. Outmigration declined dramatically by early July. This peak outmigration period is similar to that reported in 1997, when approximately 88% of the total annual outmigration occurred from March through June (Downs in press). The trap could not be operated beyond mid-July due to low flows in 1998, but it is reasonable to assume a similar outmigration pattern as in 1997. The outmigration estimate for 1997 (33,784) is similar to the 1998 estimate (40,612) for the peak migration period.

Mortality and residualization did not appear to bias our estimates of trap efficiencies. Failure to stratify TE by size groups (≥/< 100 mm) would have resulted in a substantial underestimate of outmigration. The non-stratified estimate of outmigration was 32,241 (95% CI, 26,685-39,698) compared to the stratified estimate of 40,612 (95% CI, 29,041-71,096). Estimating future outmigration in Deep Creek need only be conducted during the months of peak outmigration (typically March through June) to monitor changes.

Stream morphology influenced the location of the screw trap. Below Snow and Caribou creeks, low stream gradient and the backwater influence of the mainstem Kootenai River reduce water velocities. Placement of the screw trap above these two Deep Creek tributaries did not result in a significant bias in the total outmigration estimate because these tributaries do not support high densities of juvenile rainbow trout (Downs in press).

Table 7. Abundance indices for all age classes combined of salmonid species captured in tributaries to the Kootenai River located between Bonners Ferry and the Idaho/Montana border. The indices were estimated for the reaches of tributaries accessible to fluvial Kootenai River salmonids.

Stream	Species	No. captured first pass	m^2 sampled	Population est.	Upper 95% CI	Lower 95% CI	CPUE (n/m^2)
Boulder Creek[a]	Rb	128	2,203	1,050	1,629	471	0.06
Caboose Creek	Rb	4	135	17	28	15	0.03
	Ebt	1	135	--	--	--	< 0.01
	Bull	1	135	--	--	--	< 0.01
Cow Creek	None	--	1,275	--	--	--	--
Curley Creek	Rb	2	1,050	--	--	--	<0.01
	Ebt	6	1,050	--	--	--	<0.01
	Bull	1	1,050	--	--	--	<0.01
	Mwf	1	1,050	--	--	--	<0.01
Debt Creek	Rb	14[b]	260	21	23	21	0.05
	Eb	1	260	--	--	--	< 0.01
Katka Creek	Rb	5	100	5	5	5	0.05
	Eb	5	100	8	11	8	0.05
Moyie River	Rb	49	1,753	--	--	--	0.03
	Eb	5	1,753	--	--	--	< 0.01
	Mwf	5	1,753	--	--	--	<0.01

[a] 1996 single-pass snorkel data (Fredericks in press).
[b] Includes two westslope cuuthroat trout x Rb hybrids.
Rb-Rainbow trout.
Ebt-Brook trout.
Bull-Bull trout.
Mwf-Mountain whitefish

Table 8. Population estimates for the 3,000 m-long Hemlock Bar reach of the Kootenai River conducted during September 1998.

Species	Length group (TL, mm)	M	R	Population estimate	Upper 95% CL	Lower 95% CL	n/ha	kg/ha
Rb	125 - 179	13	6	15	32	14	0.51	0.02
Rb	180 - 249	35	7	98	250	62	3.3	0.34
Rb	250 - 349	42	13	73	124	64	2.5	0.64
Rb	350 - 449	14	3	33	175	18	1.1	0.62
Rb	≥ 450	2	0	--	--	--	--	--
Mwf	≥220	462	48	4,044	6,600	3,080	135	29.2

Rb-Rainbow trout
Mwf-Mountain whitefish

Table 9. Mean back-calculated total length (mm) at age for adult rainbow trout captured in the Hemlock Bar reach of the Kootenai River, Idaho, during September 1998.

Age	n	Mean length at capture (SE)	Length range at capture	Mean back-calculated length at each age (SE)					
				1	2	3	4	5	6
1	38	192 (3.7)	150 – 230	134 (2.3)					
2	28	248 (4.9)	209 – 304	128 (3.0)	203 (3.6)				
3	24	316 (8.6)	237 – 374	126 (3.0)	213 (5.4)	277 (5.9)			
4	13	384 (9.6)	330 – 451	134 (4.4)	207 (4.2)	288 (5.3)	354 (8.8)		
5	1	472	N/A	112	196	290	403	443	
6	1	478	N/A	129	202	306	384	436	462
Weighted mean (SE)				130 (1.5)	207 (2.6)	282 (4.3)	359 (8.3)	439 (3.4)	462
Increment				130	77	75	68	80	23
n				105	67	39	15	2	1

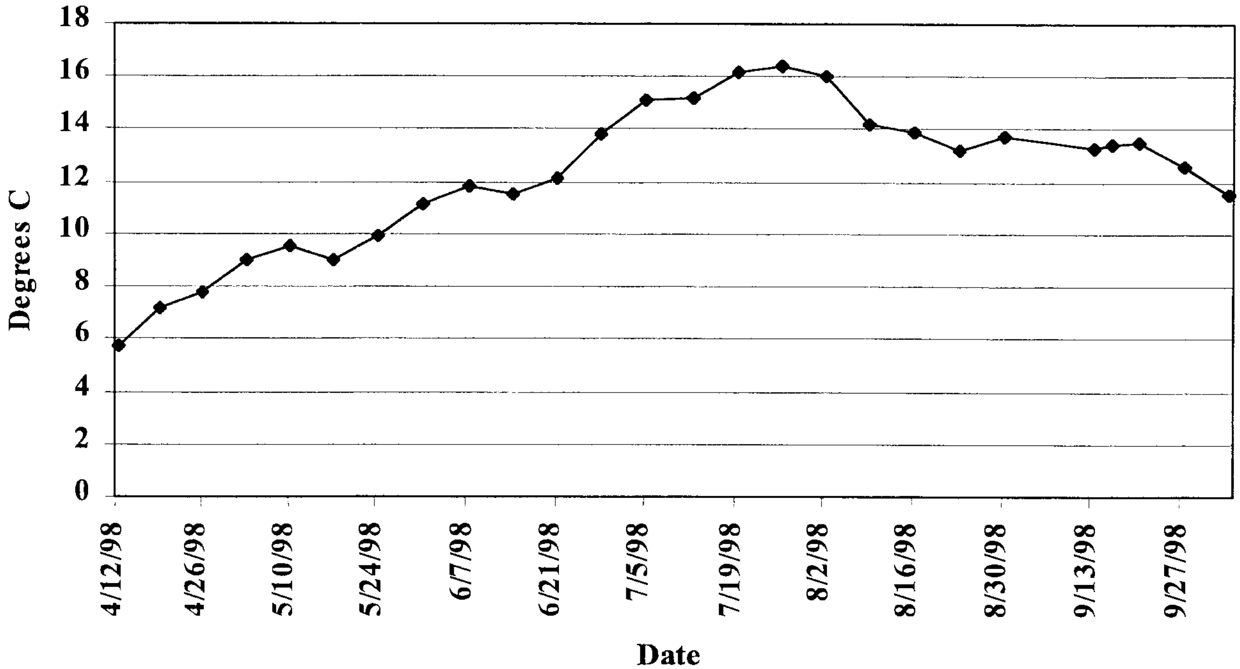


Figure 6. Mean weekly water temperatures for the Idaho reach of the Kootenai River, upstream of the confluence of the Moyie River during 1998.

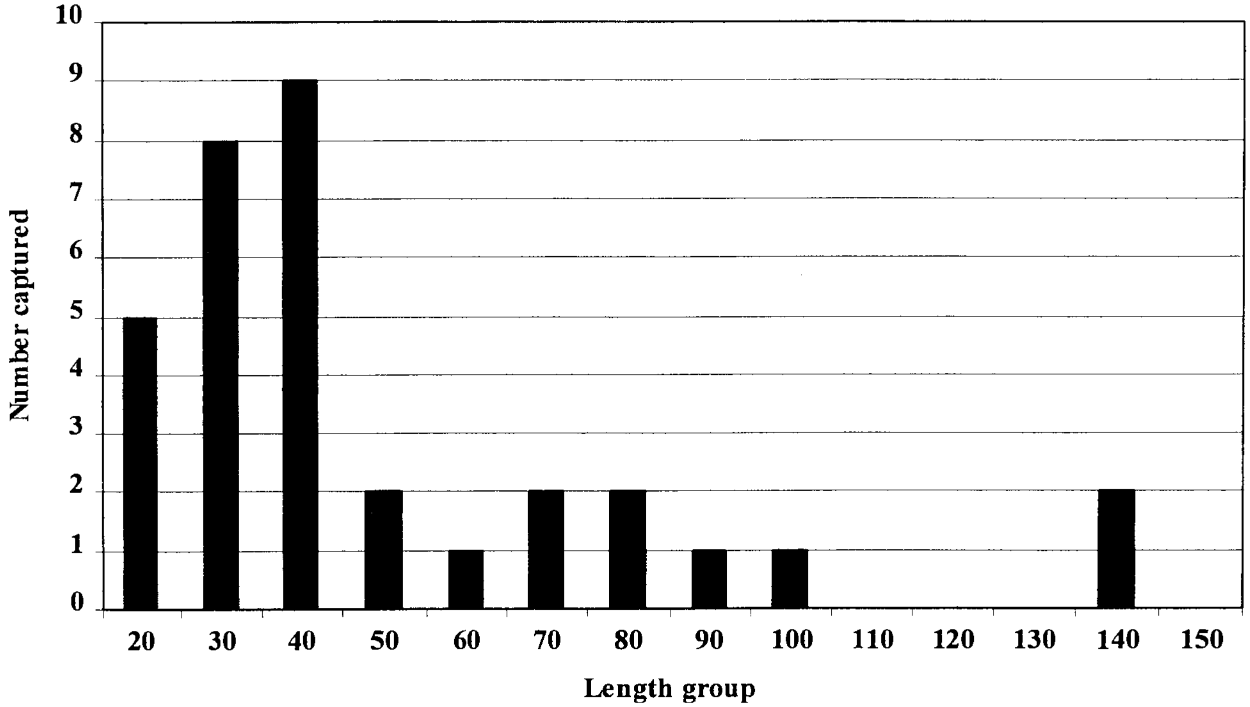


Figure 7. Length-frequency histogram of juvenile rainbow trout captured in mainstem Kootenai River, Idaho, during July 1998.

Table 10. Relative abundance, mean total length (TL, mm) and length ranges for age-0 salmonids captured in the mainstem Kootenai River, Idaho, during July, 1998.

Species	Number captured	Mean TL (SE)	Length range
Bull	3	62 (2.2)	59 – 66
Bkt	4	69 (3.3)	63 – 78
Bnt	1	69	--
Mwf	20	77 (2.1)	56 – 97
Rb	25	42 (1.9)	29 – 64

Bull-Bull trout
Ebt-Brook trout
Bnt-Brown trout
Mwf-Mountain whitefish
Rb-Rainbow trout

Age Determination

Age at outmigration for the March through April period suggested equal proportions of age-1 and age-2 rainbow trout, with few fish outmigrating as age-3. The possibility of substantial outmigration as age-0 exists during the un-trapped late summer/fall period, however results from 1997 trapping (Downs in press) indicate this is unlikely. The ratio of age-1 to age-2 outmigrants during March and April in 1998 is smaller than estimated for June 1997 (Downs in press). However, it is similar to that reported for the entire outmigration period in 1996 (Fredericks in press). Variation in year-class strength and differences in timing of outmigration of age-1 and age-2 rainbow trout are the most probable explanations for the differences.

Water Temperature

Water temperatures in Deep Creek are largely determined by the surface temperature of McArthur Reservoir. The reservoir warms upper Deep Creek during the summer to levels unsuitable for rainbow trout. Lower Deep Creek receives some tributary inflow serving to reduce temperatures to levels tolerable for rainbow trout. High summer water temperatures and embedded substrates (Fredericks in press) likely act together to reduce habitat quality in Deep Creek.

Deep Creek Spawning Population

Radio-telemetry

Of the 15 radio-tagged rainbow trout that outmigrated from the Deep Creek drainage, 13 were later located in Kootenay Lake or within 13 rkms of its delta. Of the remaining two fish, only one appeared to use a home range within the river itself. The other was lost while migrating downstream towards Kootenay Lake.

The minimum one-way migration distance from the spawning tributaries of Deep Creek to the inlet of Kootenay Lake is approximately 135 rkms. Several individuals moved as far as 180 rkms to locations in the West Arm of Kootenay Lake. The migration distances observed for this adfluvial stock of rainbow trout are among the longest documented in the literature. VanVelson (1974) documented adfluvial rainbow trout migrating as far as 145 km from McConaughy Reservoir to spawn in tributaries of the North Platte River in Nebraska. Hockersmith et al. (1995) documented spawning movements as great as 87 km for rainbow trout in the upper Yakima River Basin, Washington.

The spawning run in Deep Creek was comprised mainly of age-4 and -5 rainbow trout. Lesser numbers of age-2, -3, and 6-year old fish were also captured. This is consistent with rainbow trout age at maturity in Kootenay Lake for the non-Gerrard strain (B. Lindsay, BC Ministry of Environment, Lands and Parks, personal communication).

Reward-tagging

Forty percent of the reward-tag returns have come from Kootenay Lake, BC. Only one tag return came from an area upstream of the Deep Creek drainage. Assuming the radio and reward-tagged rainbow trout represent a random sample of all adult spawners in the Deep Creek drainage and tag implantation did not effect post-spawn movements, it appears the migratory spawning population of Deep Creek is largely comprised of adfluvial rainbow trout from Kootenay Lake, BC. The progeny of these spawners will, aside from straying, likely recruit to the Kootenay Lake fishery.

Angler exploitation of adult rainbow trout migrating through McArthur Reservoir has been of concern to fish managers in North Idaho. Results of this study suggest the number of rainbow trout migrating through the reservoir is small. In addition, angler exploitation appears to be low. Although our sample size of reward-tagged rainbow trout was small, I believe angling in McArthur Reservoir does not pose a serious risk to the stock.

Kootenai River Tributary Assessment

The amount of tributary habitat accessible to migratory salmonids in the Kootenai River is severely limited by natural and anthropogenic factors. The two tributaries with the most available habitat (Moyie River and Boulder Creek) also supported the highest densities of age-0 rainbow trout. Overall, reproduction in the accessible reaches of Idaho tributaries upstream of Bonners Ferry appears minimal, with the exception of Boulder Creek. Fredericks (in press) estimated 1,050 age-0 rainbow trout during late summer in Boulder Creek. This estimate was conducted over approximately 66% of the accessible stream habitat. Assuming a total age-0 population of approximately 1,500 age-0 rainbow trout and a 10% survival rate age-0 to age-1, Boulder Creek could produce an estimated 150 age-1 rainbow trout recruiting to the Kootenai River.

Kootenai River Rainbow Trout

Population Estimates

Densities of rainbow trout 125 to 449 mm (TL) (0.08/100 m^2) in the Hemlock Bar reach of the Kootenai River are low in comparison to other fluvial wild trout fisheries in Idaho. Schill (1991) reported densities in other large Idaho rivers ranging from almost 0 trout/100 m^2 in the Snake River near Shelly, Idaho to near 7 trout/100m^2 in the special regulation section of the Henrys Fork River, Idaho. Four of the seven streams he compared supported densities in excess of 1 fish/100m^2.

Age and Growth

Estimated ages indicate rainbow trout in the Hemlock Bar reach of the Kootenai River can reach ages of six years. However, our electrofishing surveys indicate few fish remain in the reach older than age-4. Possible explanations include high natural mortality, movement out of the study section, or high angler mortality. Future reward tagging will provide the answer to this question.

Growth rates of rainbow trout in the Hemlock Bar reach of the Kootenai River remained fairly constant through the first four years of life. The back-calculated length at age-4 falls in the middle of the range reported for other fluvial Idaho populations (Figure 8) (adapted from Schill 1991). The estimated QSD of 5.0% is similar to the QSD of 4.0% estimated for the Big Wood River (Thurow 1990) which has a similar length at age-4 (Schill 1991). Neither QSD estimate was corrected for size selection however.

Kootenai River Shoreline Abundance Index

Electrofishing results indicate age-0 rainbow trout abundance was low throughout the study reach. CPUE was higher in the lower rkms, downstream of the Moyie River. The Braided Reach may currently provide the best mainstem spawning habitat in the study reach. Although extremely limited, the Canyon Reach contains the majority of the tributary spawning and rearing habitat available in Idaho upstream of Bonners Ferry.

If we combine the hypothetical recruitment from the mainstem with the hypothetical recruitment from Boulder Creek, we arrive at a year class consisting of 250 individuals by age-1. When this year class is distributed across the 26 rkms of the study area, we arrive at an estimate of approximately 10 age-1 rainbow trout/rkm produced annually. Using constant recruitment of 10 fish/km, a conditional natural mortality rate of 30% [a conservative value compared to estimates for other wild rainbow trout populations in Idaho (Schill 1991)], and no angling mortality, we arrive at a hypothetical population of 28 age-1 and older rainbow trout/rkm in the study reach. Currently, we estimate 73 rainbow trout/rkm (125-449 mm, TL) in the study reach. The study reach may be drawing recruits from outside of its boundaries.

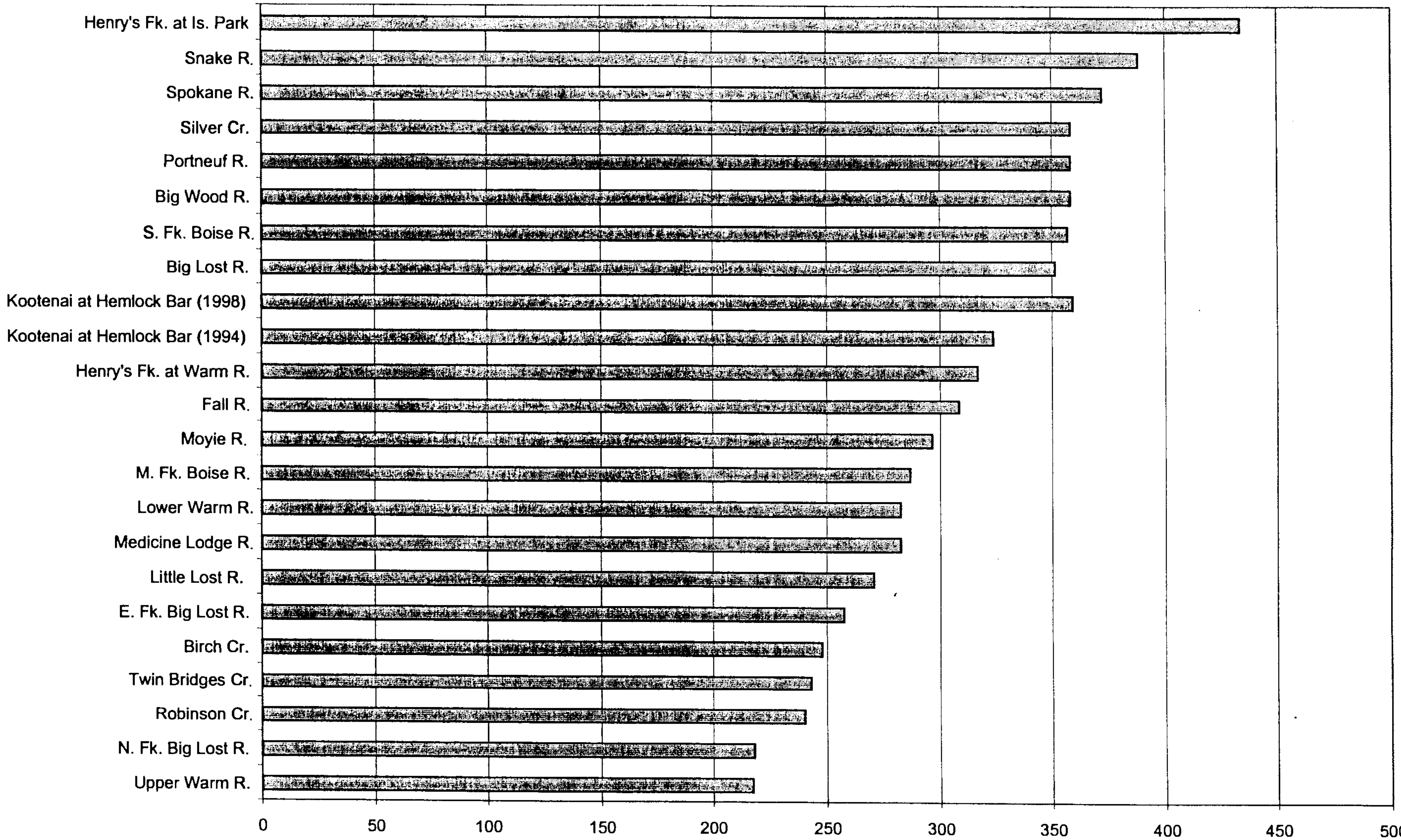


Figure 8. Length at age-4 (mm) for rainbow trout from the Hemlock Bar reach of the Kootenai River, Idaho, compared to 21 fluvial rainbow trout populations in Idaho (adapted from Schill 1991).

Recruitment Overview

The idea of food limitation for fish in the Kootenai River has been proposed as a mechanism behind declining fish populations. Koocanusa Reservoir acts as a nutrient sink, retaining approximately 63% of the total phosphorus entering it (Woods 1982). The Canyon and Braided reaches of the Kootenai River are currently classified as ultra-oligotrophic (Richards 1997). Snyder and Minshall (1996) concluded that ambient phosphorus levels limited periphyton growth in the Idaho portion of the Kootenai River. Periphyton is a major autotrophic component in river systems and is at the base of the food web (Snyder and Minshall 1996). The authors created an energy budget based on autotrophic (periphyton) production and the input of transported organic matter. They concluded that macroinvertebrates were limited by autotrophic production. The energy budget indicated there were periods during the year (June, July and August) when autotrophic production could support increased densities of macroinvertebrates, but these periods were too short for the macroinvertebrates to capitalize and increase their biomass. This energy budget also indicated that ultimately, fish were limited at all times by autotrophic production. The authors proposed bottom-up food limitation (Carpenter et al. 1985, McQueen et al. 1989), caused by low nutrient levels, as the mechanism behind declining fish populations.

Mountain whitefish and rainbow trout condition data provide evidence in support and against a food limitation theory. The estimated W_r's for Kootenai River rainbow trout equaled or exceeded 83 across all size groups. A W_r of 100 across all size groups is thought to reflect ecological and physiological optimality for populations (Andersen and Neuman 1996). The W_r's for the Kootenai River rainbow trout fall near the 25th percentile of the cumulative frequency distribution of population-mean W_r values of 81 lotic populations examined (Simkins and Hubert 1996). This suggests that across all size groups, Kootenai River rainbow trout are in below average condition. This below average condition suggests insufficient food resources.

Partridge (1983) and Paragamian (1994) reported mean Fulton-type condition factors (K) (Anderson and Neumann 1996) ranging from 0.97 to 1.15 for rainbow trout in the Hemlock Bar reach during September. Although these previous K values are higher than those observed in 1998 (K=0.94) suggesting lower mean fish condition, they may simply reflect the natural range in variation in condition from one year to the next.

Mean K values reported by Partridge (1983) and Paragamian (1994) for mountain whitefish ranged from 0.81 to 0.94, which is similar to the mean K of 0.84 documented in this study. The consistency in mountain whitefish condition factors over time is unexpected under a scenario of food limitation. In 1980 and 1981, mountain whitefish densities were estimated at 1,533 and 1,331 individuals/305 m of river, respectively. By 1993, densities had declined to an estimated 351 mountain whitefish/305 m of river (Paragamian 1994). The number of mountain whitefish estimated in this study was 413 mountain whitefish/305 m of river. If the population of mountain whitefish was food limited, condition factor should have increased with the reduction in fish density.

Productivity could potentially be limiting fish populations as a whole, but may not be responsible for low rainbow trout density. Other factors, such as shifts in invertebrate species composition resulting from Libby Dam operation (Perry and Huston 1983), low mainstem habitat diversity, and the limited availability of spawning habitat downstream of Kootenai Falls (Partridge 1983, May and Huston 1983) are all likely adversely affecting the rainbow trout population in Idaho.

Substantial recruitment to the study reach from tributaries downstream of Bonners Ferry is unlikely. We sampled approximately 12% of the available shoreline habitat in the study reach and did not recapture any juvenile rainbow trout from Deep Creek marked in 1998. Nor did we observe upstream movement by radio-tagged adult rainbow trout leaving the Deep Creek drainage. However, our shoreline sampling technique may have been inadequate to capture age-1 and age-2 juvenile rainbow trout emigrating from the Deep Creek drainage because of shifts in habitat use. Juvenile rainbow trout production from tributaries within the study reach appears inadequate to support observed adult rainbow trout densities in the study reach. The most likely explanation is recruitment from upstream sources in Montana.

RECOMMENDATIONS

1. Radio-tag adult rainbow trout inhabiting the study reach (Braided and Canyon reaches) and use radio-telemetry to identify current spawning areas.
2. Reward-tag adult rainbow trout inhabiting the Kootenai River upstream of Bonners Ferry to estimate angler exploitation.
3. Repeat rainbow trout and mountain whitefish population estimates in the Hemlock Bar reach.
4. Deploy electronic temperature loggers in perennial tributaries to determine temperature suitability for rainbow trout reproduction.
5. Evaluate instream flow needs for fluvial Kootenai River salmonid mainstem spawning and rearing.

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LITERATURE CITED

Anderson, C.S. 1995. Measuring and correcting for size selection in electrofishing mark-recapture experiments. Transactions of the American Fisheries Society 124:663-676.

Anderson, R.O. and R.M. Neuman. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* Fisheries Techniques, 2nd Edition, American Fisheries Society, Bethesda, Maryland.

Bowler, B. 1975. Factors influencing genetic control in lakeward migrations of cutthroat trout fry. Transactions of the American Fisheries Society 104:474-482.

Brannon, E.L. 1967. Genetic control of migrating behavior of newly emerged sockeye salmon fry. International Pacific Salmon Fisheries Commission. Progress Report Number 16.

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Volume 1. Iowa State University Press, Ames, Iowa.

Carpenter, S.R., and J.F. Kitchell, and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioScience 35:634-639.

Dalbey, S.R., T.E. McMahon, and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing induced spinal injury on long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management 16:560-569.

Downs, C.C. 1997. Kootenai River fisheries investigations: Rainbow trout recruitment. Annual report to Bonneville Power Administration. Project 88-65. Idaho Department of Fish and Game, Boise.

Fleiss, J.L. 1981. Statistical Methods for Rates and Proportions, 2nd Edition. John Wiley and Sons, Inc. New York, New York.

Francis, R.I.C.C. 1990. Back-calculation of fish length: a critical review. Journal of Fish Biology 36:883-902.

Fredericks, J. In press. Kootenai River fisheries investigations: Rainbow trout recruitment investigations. Annual report to Bonneville Power Administration, Project 88-65. Idaho Department of Fish and Game, Boise.

Hockersmith, E., J. Vella, and L. Stuehrenberg. 1995. Yakima River Rainbow Trout. Annual Report to Bonneville Power Administration. Project 89-089. National Marine Fisheries Service, Seattle.

LITERATURE CITED (continued)

Kaya, C.M. 1977. Reproductive Biology of rainbow and brown trout in a geothermally heated stream: The Firehole River of Yellowstone National Park. Transactions of the American Fisheries Society 106:354-361.

Kennen, J.G., S.J. Wisniewski, and N.H. Ringler. 1994. Application and modification of an auger trap to quantify emigrating fishes in Lake Ontario tributaries. North American Journal of Fisheries Management 14:828-836.

Krebbs, C.J. 1989. Ecological Methodology. Harper-Collins Publishers, Inc. New York, New York.

May, B. and J. Huston. 1983. Kootenai River investigations final report. Section C. Fisheries investigations. Montana Fish, Wildlife, and Parks, Helena. 112 p.

McQueen, D.J., M.R.S. Johannes, J.R. Post, T.J. Stewart, and D.R.S. Lean. 1989. Bottom-up and top-down impacts on freshwater pelagic community structure. Ecological Monographs 59:289-309.

Nichols, J.D., R.J. Blohm, R.E. Reynolds, R.E. Trost, J.E. Hines, and J.P. Bladen. 1991. Band reporting rates for mallards with reward bands of different dollar values. Journal of Wildlife Management 55(1):119-126.

Paragamian, V.L. 1994. Kootenai River fisheries inventory: Stock status of burbot and rainbow trout and fisheries inventory. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Project 88-65. Boise.

Partridge, F. 1983. Kootenai River fisheries investigations. Idaho Department of Fish and Game. Job Completion Report, Project F-73-R-5, Boise.

Perry, S. and J. Huston. 1983. Kootenai River investigations final report. Section A. Aquatic insect study. Montana Fish, Wildlife, and Parks, Helena. 112 p.

Raleigh, R.F. 1971. Innate control of migrations of salmon and trout fry from natal gravel to rearing areas. Ecology 52:291-297.

Raleigh, R.F. and D.W. Chapman. 1971. Genetic control in lakeward migrations of cutthroat trout fry. Transactions of the American Fisheries Society 100:33-40.

Reynolds, J.B. 1996. Electrofishing. Pages 221-251 *in* B.R. Murphy and D.W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Richards, D. 1997. Kootenai River biological baseline status report. Bonneville Power Administration project number 94-49, contract number 95BI40364. Kootenai Tribe of Idaho, Bonners Ferry.

LITERATURE CITED (continued)

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research board of Canada Bulletin 171.

Roper, B.B. 1995. Ecology of anadromous salmonids within the Upper South Umpqua River Basin, Oregon. Doctoral dissertation, University of Idaho, Moscow.

Ross, M.J. and C.F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish Culturist 44:41-43.

Schill, D.J. 1991. Wild trout investigations. Idaho Department of Fish and Game. Job Performance Report. Project F-73-R-13, Job 1. Boise.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Griffin, London.

Seelbach, P.W., R.N. Lockwood, and G.R. Alexander. 1985. A modified inclined-screen trap for catching salmonid smolts in large rivers. North American Journal of Fisheries Management 5:494-498.

Simkins, D.G., and W.A. Hubert. 1996. Proposed revision of the standard-weight equation for rainbow trout. Journal of Freshwater Ecology (11)3: 319-325.

Snyder, E.B. and G.W. Minshall. 1996. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Final Report. Stream Ecology Center, Idaho State University, Pocatello.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Thurow, R. 1990. River and stream investigations: Wood River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-12, Boise.

Van Deventer, J.S. and W. S. Platts. 1986. Microfish 3.0. A computer software package for processing electrofishing data using the removal method. USDA Forest Service, Forestry Sciences Laboratory, Boise, Idaho.

Van Velson, R.C. 1974. Self-sustaining rainbow trout (Salmo gairdneri) population in McConaghy Reservoir, Nebraska. Transactions of the American Fisheries Society 103:59-64.

LITERATURE CITED (continued)

Westerheim, S.J. and W.E. Ricker. 1978. Bias in using an age-length key to estimate age-frequency distributions. Journal of the Fishery Research Board of Canada 35:184-189.

Whitney, R.R. and K.D. Carlander. 1956. Interpretation of body-scale regression for computing body length of fish. Journal of Wildlife Management. 20: 21-27.

Winter, J. 1996. Advances in underwater biotelemetry. Pages 555-585 *in* Fisheries Techniques, 2nd edition. American Fisheries Society. Bethesda, Maryland.

Woods, P.F. 1982. Annual nutrient loadings, primary productivity, and trophic state of Lake Koocanusa, Montana and British Columbia, 1972-1980. Geological Survey Professional Paper 1283, United States Government Printing Office.

Submitted by:

Christopher C. Downs
Fishery Research Biologist

Approved by:

Virgil K. Moore, Chief
Bureau of Fisheries

Steve P. Yundt
Fish Research Manager