LAND MANAGEMENT AND FLOOD EFFECTS ON THE DISTRIBUTION AND ABUNDANCE OF CUTTHROAT TROUT IN THE COEUR D'ALENE RIVER BASIN, IDAHO

A Thesis

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AUTHORIZATION TO SUBMIT

THESIS

This thesis of Ann M. Abbott, submitted for the degree of Master of Science with a major in Fishery Resources and titled "Land Management and Flood Effects on the Distribution and Abundance of Cutthroat Trout in the Coeur d'Alene River Basin, Idaho," has been reviewed in final form, as indicated by the signatures and dates given below. Permission is now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

In January 1996, the largest flood since 1974 occurred in the Coeur d'Alene River basin, Idaho. In some areas the flood peaks were the second highest ever recorded and exceeded flows that have a 1% chance of occurring during any given year. The focus of this study was to expand the understanding of the influence of biological and physical processes and landscape patterns at the scale of watersheds and subbasins on the distribution, abundance and persistence of westslope cutthroat trout *Oncorhynchus clarki lewisi*. During the summer of 1996, I sampled 62 second and third order tributaries within the Coeur d'Alene River basin using a stratified random sampling design. Streams were divided into three reaches of equal length, and three sites within each reach were randomly chosen for single pass electrofishing. One of the nine sites in each stream was randomly selected for an estimate of absolute abundance using multiple pass electrofishing. Capture efficiency was estimated from the multiple pass sites using a maximum likelihood estimator. Mean capture efficiency was 68% and ranged from 23 to 100%. Single pass catches were adjusted using the average capture efficiency for the basin, and the adjusted catches were used to compute density estimates for all streams. All streams sampled contained westslope cutthroat trout, suggesting that local extinctions did not occur following the January 1996 flood. The mean stream density in 1996 for the entire basin was 0.057 fish/m^2 and ranged from 0.001 to 0.219 fish/m^2. Estimated densities were highest in tributaries to the Main Coeur d'Alene River ($\bar{x} = 0.083$), followed by tributaries to the Upper Coeur d'Alene River ($\bar{x} = 0.048$), tributaries to Shoshone Creek ($\bar{x} = 0.067$) and tributaries to the North Fork Coeur d'Alene

river ($\bar{x} = 0.039$). Mean densities for the Main Coeur d'Alene and North Fork Coeur d'Alene subbasins were not significantly different in 1996 than 1995 (p = 0.868 and p = 0.271). Mean densities in both the Upper Coeur d'Alene and Shoshone Creek subbasins were significantly lower in 1996 than 1995 (p = 0.063 and p = 0.008), but these differences can be accounted for by three streams in the Upper Coeur d'Alene drainage and one stream in the Shoshone Creek drainage. Densities in the North Fork Coeur d'Alene were nearly significantly different from densities in the Main Coeur d'Alene (p = 0.090) and Shoshone Creek (p = 0.108) in 1996, however, no other drainages showed significant differences in densities in 1996. Age-0 cutthroat trout were not found in any streams with wetted widths wider than 8 m. Logistic regression was used to model the probability of encountering cutthroat trout fry, and the best model used gradient to predict the probability of encountering age-0 cutthroat trout (p = 0.0005). Estimated density of westslope cutthroat trout was significantly related to large woody debris counts per 1000 m of channel, and cumulative equivalent clearcut acreage (R^2 = 0.505, p = 0.004). Densities decreased with increased wetted width, increased with increased large woody debris count, and decreased with increased cumulative equivalent clearcut acreage. My results showed that cutthroat trout densities are better predicted by variables measured at the stream or watershed level than at the site or habitat type level. Cutthroat trout in the Coeur d'Alene River basin were able to persist following significant disturbance including disturbance due to land management activities, disturbance due to severe flooding, and the cumulative effects of both.

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INTRODUCTION

Historic records indicate that westslope cutthroat trout *Oncorhynchus clarki lewisi* were abundantly distributed throughout the Coeur d'Alene basin (Maclay 1940). During the 1970's, the Idaho Department of Fish and Game recognized that cutthroat numbers were reduced from previous levels and imposed restrictive angling regulations (Lewynsky 1986). These regulations have not resulted in a substantial increase in the Coeur d'Alene populations, suggesting that other factors are more important in determining abundance in this system. Westslope cutthroat trout are quite sensitive to environmental alteration, exploitation, and competition and hybridization with other fishes (Behnke 1992).

Several authors (Lewynsky 1986; Hunt and Bjornn 1992; Behnke 1992) have suggested that land management practices including logging, mineral extraction, and the associated road construction that have occurred since the mid-1800's (Maclay 1940), and over-fishing, have resulted in a decline in westslope cutthroat trout abundance in the Coeur d'Alene River Basin. Catastrophic forest fires have also occurred within the basin. The physiographic and geomorphic processes characterizing the region are additional contributors to the habitat quality and quantity within the Coeur d'Alene basin.

During the 1980s, the U.S. Forest Service began collecting data on habitat conditions in the Coeur d'Alene River basin. A recent study relating westslope cutthroat trout distribution and abundance to habitat conditions in the Coeur d'Alene basin (Dunnigan 1997) was not able to account for a large amount of the variation in fish abundance. Relationships between habitat and physiographic characteristics, and cutthroat trout distribution have been suggested by several authors (Bozek and Hubert 1992; Platts 1979; Chisholm and Hubert

1986; Lanka et al. 1987; Scarnecchia and Bergerson 1987; Kozel and Hubert 1989; Fausch 1989), although Dunnigan (1997) did not find these factors significant in the Coeur d'Alene basin.

Three general life history strategies have been observed among cutthroat trout populations in the Coeur d'Alene River basin (Bowler 1974; Lewynksy 1986; Hunt and Bjornn 1992): fluvial, adfluvial, and resident. Most of the previous research has focused on the fluvial stock (Bowler 1974; Lewynsky 1986; Hunt and Bjornn 1992), found in the Coeur d'Alene River and larger tributaries. Lewynsky (1986) observed three general patterns of seasonal migration in the fluvial stock, including movements toward low velocity runs and pools in the upper and lower reaches in late fall from spring-summer feeding stations, upstream and downstream spring migration, and upstream and downstream fall migration. The adfluvial stocks, which migrate upriver from Coeur d'Alene Lake and were known to be distributed throughout the basin in the past, are now believed restricted to the lower portion of the main stem of the Coeur d'Alene River (Lewynksy 1986). Juvenile adfluvial cutthroat trout typically spend from 2 to 4 years rearing in the mainstem of the Coeur d'Alene River before migrating into Coeur d'Alene Lake. Hunt and Bjornn (1992) speculated that resident stocks exist in tributaries and headwaters of the Coeur d'Alene River.

In February 1996, a near 100-year flood event occurred in northern Idaho that provided a unique opportunity to investigate the effects of potentially catastrophic disturbance on the persistence and stability of stream fish populations. The Intermountain Research Station in cooperation with the University of Idaho conducted extensive inventories of streams in the Upper Coeur d'Alene River basin from 1993 through 1995 (Rieman, unpublished data; Dunnigan; 1997). Following the flood, streams sampled in previous years were re-sampled to allow examination of effects of both natural and human related disturbances on fishes in those streams.

The goal of this research is to gain a better understanding of effects of cumulative timber harvest and associated road construction along with extensive natural disturbance on westslope cutthroat trout populations in the Coeur d'Alene River Basin.

OBJECTIVES

1. To compare distribution and densities of westslope cutthroat trout in the Coeur d'Alene River basin following the February, 1996 flood to those observed in 1994 and 1995.

2. To determine the influence of physical habitat variables on the distribution of spawning westslope cutthroat trout within the Coeur d'Alene River basin.

3. To fit a model relating timber harvest and road construction to westslope cutthroat trout densities that can be used to predict densities within the Coeur d'Alene River basin.

STUDY AREA

The Coeur d'Alene River originates on the Pend Oreille divide near the Idaho-Montana border and flows southwesterly for approximately 190 km until entering Coeur d'Alene Lake. The study area is entirely within the Panhandle National Forest, encompassing approximately 2,280 km^2, and includes the entire Coeur d'Alene River basin upstream of the confluence of the main Coeur d'Alene River and the North Fork of the Coeur d'Alene River (Figure 1).

Logging and mining activities have altered the Coeur d'Alene River basin since the mid-1800's (Maclay 1940). Roads parallel most of the major streams within the Coeur d'Alene basin with the exception of Independence Creek and portions of the upper Coeur d'Alene River. In some areas, maximum road densities exceed 19 km/km^2 (U.S. Forest Service, unpublished data).

The physiographic and geomorphic characteristics of the Coeur d'Alene River basin, in combination with land management activities, further influence stream habitats. Elevations within the study area range from 700 to 1,850 m above sea level. The dominant geology type within the basin is weathered belt-series (Kappesser 1993). Kappesser (1993) has reported that the amount of bedload material transported on streams surrounded by heavily harvested areas within the Panhandle National Forest can approach 80 to 100% of the substrate present. Stream flows in the Coeur d'Alene River basin follow a snow melt dominated pattern in which flows rise predictably every spring as the snow melts. Since recording began at Enaville, Idaho in 1919, however, approximately every 2 years, rain on snow events resulting in the highest instantaneous flows have occurred between November and February.

Coeur d'Alene River Basin

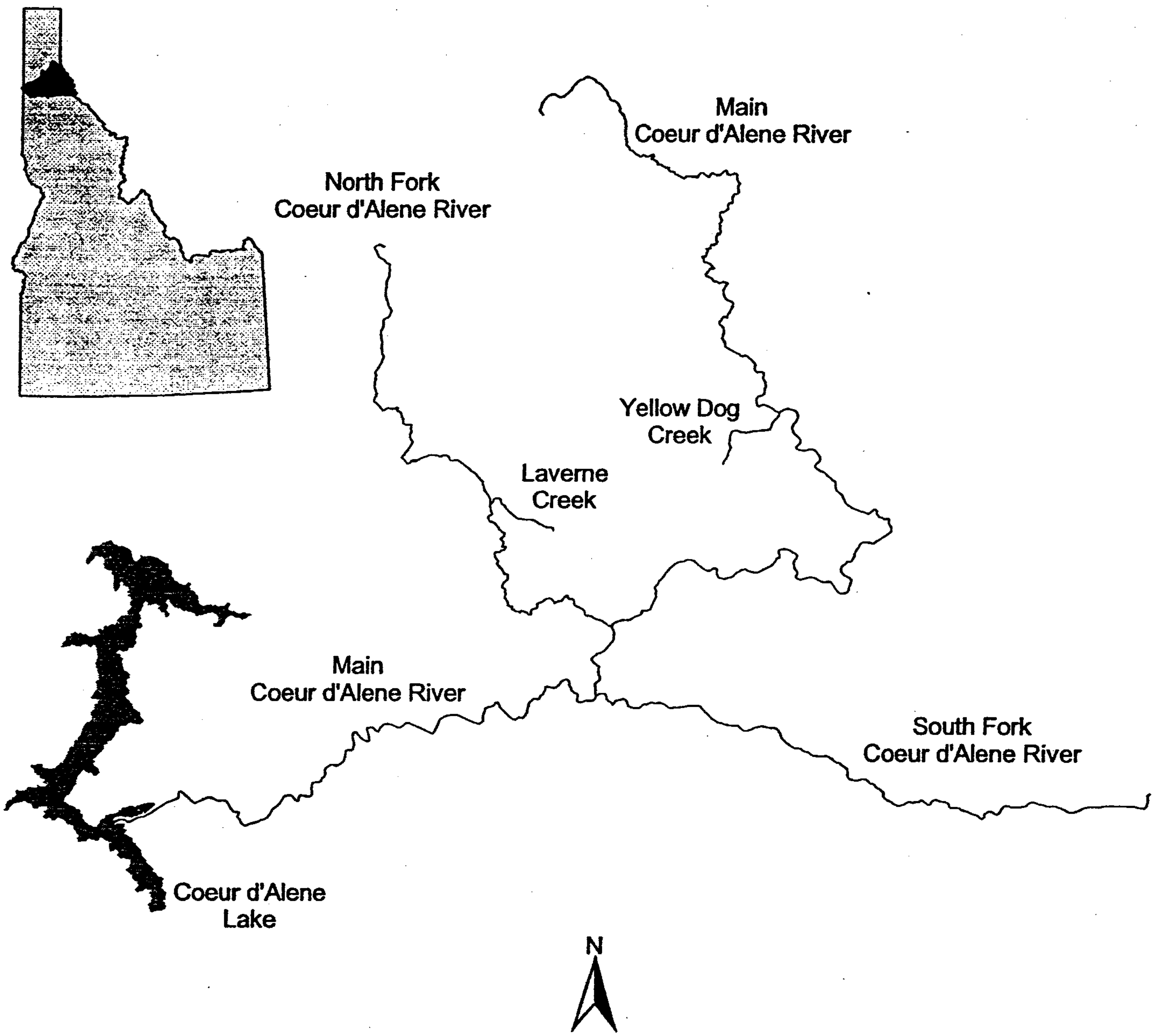


Figure 1. Study area upstream from the confluence of the North Fork of the Coeur d'Alene and main Coeur d'Alene rivers encompassing approximately 2,280 km^2.

In addition to cutthroat trout, fish species found in the Coeur d'Alene River basin include shorthead sculpins *Cottus confusus*, speckled dace *Rhinichthys osculus*, torrent sculpins *Cottus rhotheus*, rainbow trout *Oncorhynchus mykiss*, brook trout *Salvelinus fontinalis*, mountain whitefish *Prosopium williamsoni*, longnose suckers *Catostomus catostomus*, and northern pikeminnow *Ptychocheilus oregonensis*. Historically, bull trout *Salvelinus confluentus* were found within the basin (Maclay 1940), but they are now believed extinct (Lewynsky 1986; Dunnigan 1997).

CHAPTER ONE

COMPARISONS OF CUTTHROAT TROUT DENSITIES OVER TIME AND SPACE

In February 1996, a near 100-year flood event occurred in northern Idaho that provided a unique opportunity to expand the understanding of potentially catastrophic disturbance on the persistence and stability of stream fish populations. Extensive surveys were conducted in the Coeur d'Alene River Basin during 1994 and 1995 to obtain density estimates of westslope cutthroat trout (Dunnigan 1997). During the summer of 1996, I re-sampled streams previously surveyed which allowed comparison of densities before and after the flood under the null hypothesis that no significant differences would be observed in cutthroat trout densities between 1994 - 1995 and 1996.

Methods

Electrofishing surveys were conducted on 62 second and third order streams within the Coeur d'Alene basin between July and October, 1996. Streams sampled during 1994 and 1995 seasons (Dunnigan 1997) were re-sampled to give a comparison of westslope cutthroat trout distribution before and after the 1996 flood event. Streams were selected for sampling according to the following criteria: first, streams with existing flow data to allow quantification of the magnitude of the flood event; second, streams sampled in multiple years; third, streams sampled in 1995; and fourth, streams in the North Fork drainage necessary to complete a broad sampling distribution throughout the entire drainage. Stream lengths were measured on a 7.5-minute quadrangle U.S. Geological Survey topographical map, and then divided into three reaches of equal length. Each reach was divided into 30-m sampling sites, and three sites were randomly chosen from each reach for single pass electrofishing surveys using a Smith Root Model 12 POW backpack electrofisher. To keep the sampling protocols consistent with those used during 1994 and 1995 (Dunnigan 1997), one of the nine sites in each stream was randomly selected for an estimate of absolute abundance using multiple pass electrofishing (Zippin 1958; Lobon-Cervia and Utrilla 1993). All captured fish were counted and identified to species and fork length was measured to the nearest millimeter. Fish were then released downstream of the lower end of the sampling site.

I measured habitat variables for each site sampled, including wetted and bankfull stream width, counts of large organic debris, stream temperatures at approximately 0800, 1200 and 1600, visual estimates of substrate composition and habitat complexity, number and length of pools within sampling sites, and conductivity. Stream temperature was measured with a pocket thermometer and stream gradient was measured at least once at each site with a hand-held clinometer. Additional gradient measurements were taken in sites with obvious gradient changes and/or meanders that did not allow the gradient for the entire site to be determined with one measurement. Habitat complexity was estimated on a scale of 1-10, with 10 being most complex (Dunnigan 1997). Factors contributing to habitat complexity included overall percent of potential cover, diversity of cover and habitat types, and substrate composition. Visual estimates were made of the approximate percentage of each habitat type including pool, run, riffle, cascade, and glide (Overton et al. 1997). A single investigator determined complexity estimates for all locations to minimize subjectivity. Lengths of pools were measured to the nearest 0.5m. Stream conductivity was assessed by taking one 250 ml water sample in the channel thalweg at the first site of each electrofishing reach. Samples were refrigerated until conductivity could be measured in the laboratory using a YSI model SCT conductivity meter ($\mu S/cm^2$).

Statistical Analysis

Capture efficiency estimates were calculated for sites where multiple passes were made using MicroFish 3.0, a maximum likelihood estimator (Van Deventer and Platts 1985). The average capture efficiency for all multiple pass sites was calculated to account for variability among sites. The total number of cutthroat trout captured in each site was divided by the mean capture efficiency for each year to get an estimated total number of fish in each of the nine 30m sections sampled for each stream. The estimated total number of fish per site was then divided by the area of stream sampled in that site, resulting in an estimated density (fish/m^2) for each site sampled. The densities estimated for sites within streams were used to estimate density for each stream. The mean cutthroat trout density for the basin was computed using the density estimates for individual sites and from each stream sampled.

Cutthroat trout densities estimated in 1995 and 1996 were used to compare the distribution and abundance of cutthroat before and after the winter 1996 floods. Analysis for this objective used data collected in the Coeur d'Alene River basin in 1995 (Dunnigan 1997) and 1996. Variation in abundance was examined in several ways using nonparametric statistical methods. Abundance changes among years in which sampling took place were quantified by comparing densities estimated across the basin from 1995 to 1996. Comparisons between years were made both by considering the streams sampled in each year to be independent and by considering only those streams sampled in both 1995 and 1996 to be paired observations. Variation in abundance was explored among the four main drainages within the basin (Main Coeur d'Alene, North Fork Coeur d'Alene, Upper Coeur d'Alene, and Shoshone Creek). Drainages were examined separately to assess changes in density between 1995 and 1996, and pairwise comparisons were made for all drainages. Densities were compared among reaches within streams, and reaches between years.

Length frequency data collected during the 1996 field season were used to examine changes population structure before and after the winter 1996 flood using a three sample Kolmogorov-Smirnov test for homogeneity of distribution functions (Kiefer 1959). The test statistic for the three-sample Kolmogorov-Smirnov test is T_N, where

$$T_N = \sup_x \sum_j n_j \left(F_{n_j}{}^{(j)}(x) - \overline{F}_N(x)^2\right),$$

$F_{n_j}{}^{(j)}(x)$ is the empirical cumulative distribution function of the j^{th} sample, and $\overline{F}_N(x)$ is the sample empirical cumulative distribution function of the three pooled samples. The significance of the test statistic is assessed with Φ_{k-1} (Kiefer 1959), the limiting distribution of $\sqrt{T_N}$, which is provided in Kiefer's (1959) paper.

Results

Cutthroat trout were found in every stream sampled during 1996, indicating that no local extinctions occurred following the winter 1996 flood event. Estimates of capture efficiency of cutthroat trout in 1996 ranged from 23 to 100% (mean = 68%, $s^2 = 0.029$). Dunnigan (1997) reported capture efficiency estimates for 1994 (range = 25 to 100%, mean = 67%, $s^2 = 0.026$, $n = 27$) and 1995 (range = 25 to 100%, mean = 70%, $s^2 = 0.036$, $n = 43$), which were not significantly different from those observed in 1996 ($p > 0.25$).

The overall mean stream density estimated in 1995 for the Coeur d'Alene River basin was 0.099 fish/m^2 (s^2 = 0.007, range = 0.019 to 0.398, n = 55), compared to the mean stream density in 1996 of 0.057 fish/m^2 (range = 0.001 to 0.219, s^2 = 0.002, n = 62). The range of stream densities observed in 1996 was much smaller than in 1995 (Figure 2) due to fewer observations of high densities in 1996. The range of stream densities observed in the Main Coeur d'Alene drainage in 1995 was from 0.019 to 0.195 fish/m^2 (Table 1). The Upper Coeur d'Alene drainage showed the largest range of stream densities, from 0.043 to 0.395 fish/m^2 (Table 2). The smallest range of stream densities, from 0.019 to 0.097 fish/m^2, was observed in the North Fork Coeur d'Alene drainage (Table 3). A range of 0.047 to 0.151 fish/m^2 was observed in the Shoshone Creek drainage (Table 4). The Main Coeur d'Alene drainage showed the most variation in stream density in 1996 with a range of 0.001 to 0.219 fish/m^2 (Table 5). The range of stream densities in the Upper Coeur d'Alene drainage was 0.015 to 0.087 fish/m^2 (Table 6), much smaller than what was observed in 1995 and the lowest range of stream densities for any drainage in 1996 (Figure 3). The North Fork Coeur d'Alene drainage did not have a substantially different range (0.001 to 0.114 fish/m^2) in 1996 than 1995 (Table 7). Densities in the Shoshone Creek drainage in 1996 had a range of 0.029 to 0.107 fish/m^2 (Table 8).

A significant difference was found between years for overall stream densities (p = 0.004) estimated for 1995 and 1996 when the observations are assumed independent. Using only streams sampled in both years as paired observations under the hypothesis that observed stream densities in 1996 are dependent on 1995 observations, streams were also significantly different between years (p = 0.0001).

Two of the four major drainages in the Coeur d'Alene River Basin showed significant

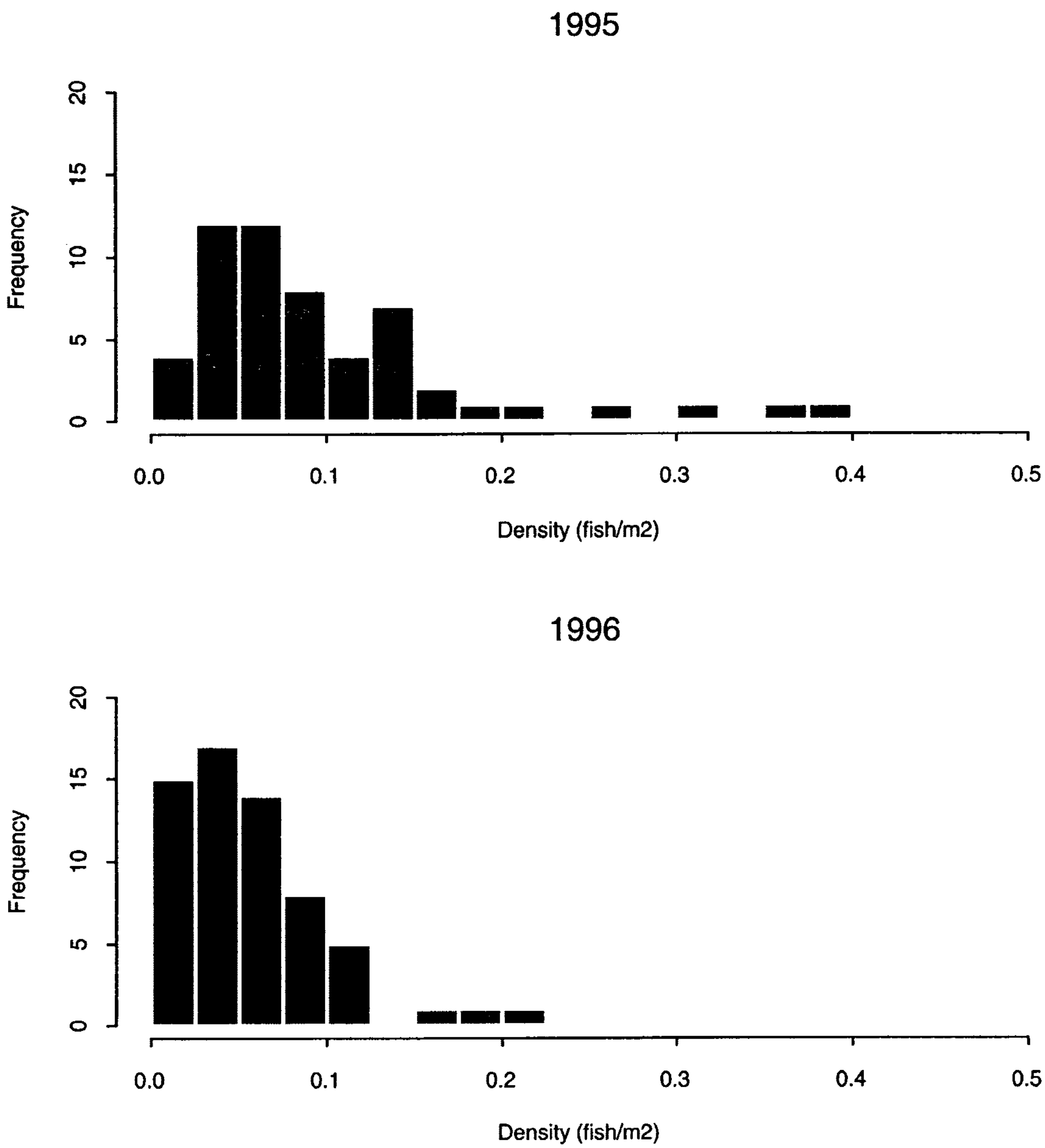


Figure 2. Estimated densities of westslope cutthroat trout in the Coeur d'Alene River Basin.

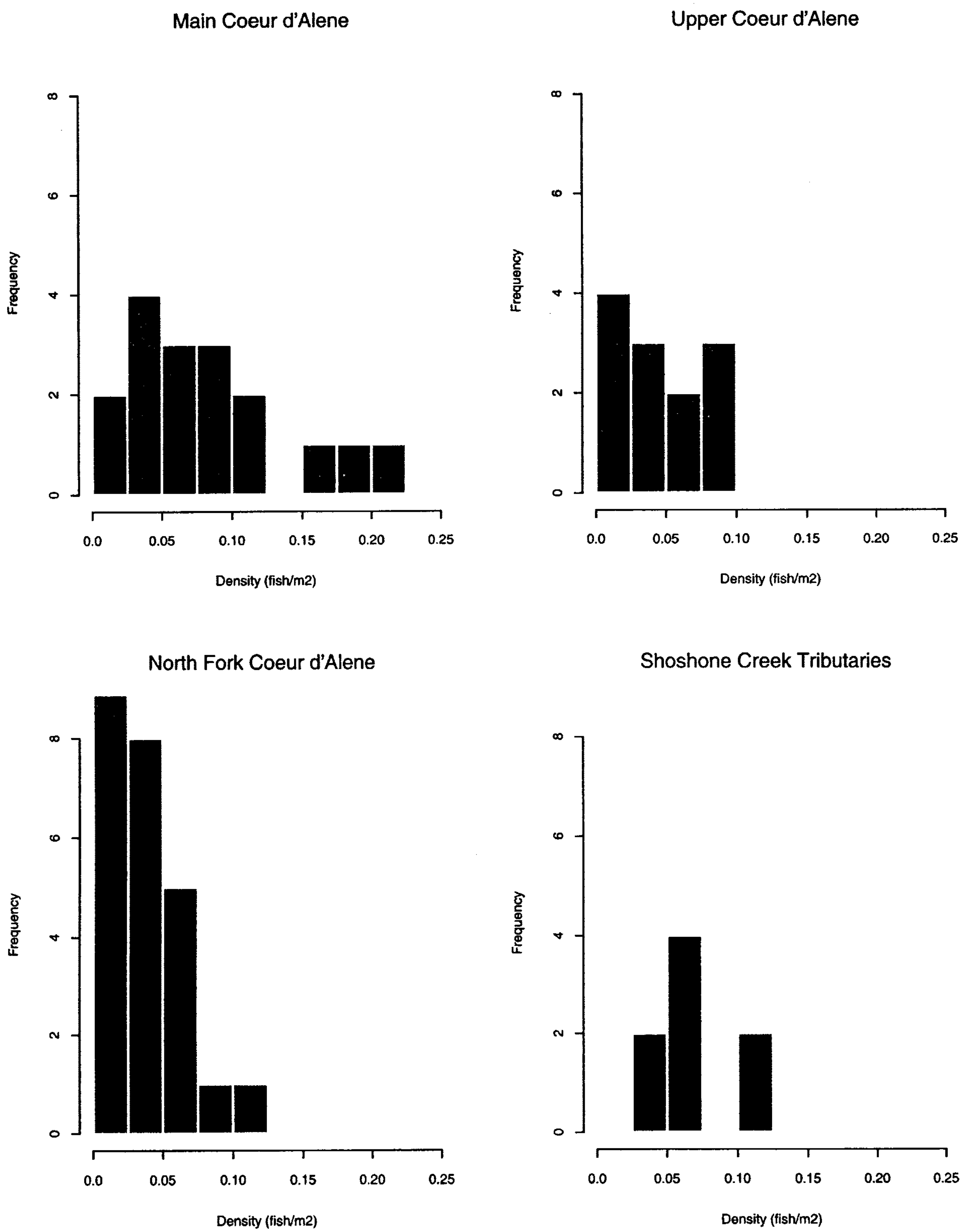


Figure 3. Estimated densities of the four major drainages in the Coeur d'Alene River Basin, 1996.

Table 1. Stream densities in the Main Coeur d'Alene River drainage, 1995.

Stream	N	Mean	Std Dev	Minimum	Maximum
Avery	9	0.1946	0.0967	0.0493	0.3262
Bear	5	0.0414	0.0197	0.0168	0.0635
Big Hank	8	0.0905	0.0885	0.0414	0.3061
Brett	9	0.0402	0.0267	0.0209	0.0876
Browns	5	0.0427	0.0129	0.0251	0.0541
Coal	2	0.0194	0.0055	0.0155	0.0232
Downey	8	0.0311	0.0189	0.0086	0.0577
Falls	6	0.1254	0.0203	0.1036	0.1567
East Fork Steamboat	9	0.1000	0.0796	0.0290	0.2896
Grizzly	8	0.1723	0.0997	0.0431	0.3048
North Grizzly	9	0.1359	0.0695	0.0484	0.2661
Scott	8	0.1006	0.0549	0.0224	0.2078
Svee	5	0.0403	0.0289	0.0128	0.0835
Teddy	9	0.0593	0.0362	0.0224	0.1478
West Fork Steamboat	9	0.1374	0.0919	0.0435	0.3238
Yellowdog	9	0.0405	0.0100	0.0298	0.0586

Overall:	
Mean	0.0857
Minimum	0.0086
Maximum	0.3262

Table 2. Stream densities the Upper Coeur d'Alene River drainage, 1995.

Stream	N	Mean	Std Dev	Minimum	Maximum
Alden	9	0.0646	0.0559	0.0000	0.1852
Blacktail	9	0.0588	0.0292	0.0149	0.1107
Buckskin	9	0.2233	0.1283	0.0835	0.4246
Cateract	1	0.0964	.	0.0964	0.0964
Coeur d'Alene River	9	0.1493	0.1031	0.0323	0.3591
Dahlman	7	0.1402	0.0654	0.0552	0.2484
Deer	8	0.0431	0.0303	0.0143	0.1024
East Alden	8	0.0697	0.0450	0.0247	0.1571
Jordan	9	0.3626	0.2067	0.0508	0.7181
Lost Fork	9	0.3948	0.2697	0.1725	0.9974
Marten	8	0.1038	0.0406	0.0276	0.1524
Mosquito	8	0.1038	0.0879	0.0471	0.3133
Spruce	6	0.3021	0.0869	0.1843	0.4118
West Elk	7	0.0684	0.0472	0.0115	0.1587
Whitetail	9	0.1407	0.1063	0.0529	0.3987

Overall:	
Mean	0.1548
Minimum	0.0000
Maximum	0.9974

Table 3. Stream densities in the North Fork Coeur d'Alene River drainage, 1995.

Stream	N	Mean	Std Dev	Minimum	Maximum
Bootjack	2	0.0190	0.0037	0.0164	0.0216
Bottom	7	0.0686	0.0514	0.0157	0.1681
Bumblebee	3	0.0612	0.0631	0.0138	0.1329
Burnt Cabin	3	0.0290	0.0077	0.0207	0.0361
Cascade	6	0.0795	0.0450	0.0284	0.1568
Deception	3	0.0226	0.0036	0.0185	0.0251
Hemlock	8	0.0588	0.0617	0.0152	0.1633
Little Tepee	4	0.0966	0.1528	0.0130	0.3256
Laverne	6	0.0196	0.0093	0.0112	0.0317
Lavin	6	0.0482	0.0363	0.0181	0.1154
Lewelling	5	0.0569	0.0385	0.0234	0.1152
Lone Cabin	8	0.0261	0.0105	0.0164	0.0507
Nicholas	7	0.0367	0.0226	0.0170	0.0765
Picnic	7	0.0750	0.0588	0.0246	0.1993
Tie	8	0.0777	0.0557	0.0220	0.1958

Overall:	
Mean	0.0517
Minimum	0.0112
Maximum	0.3256

Table 4. Stream densities in the Shoshone Creek drainage, 1995.

Stream	N	Mean	Std Dev	Minimum	Maximum
Cabin	8	0.2636	0.1391	0.0265	0.4037
Clinton	5	0.1348	0.1042	0.0582	0.3114
Haystack	9	0.0470	0.0242	0.0229	0.0866
Hemlock	9	0.0878	0.0540	0.0154	0.1772
Little Lost Fork	7	0.0777	0.0609	0.0232	0.2081
Pine Flat	7	0.0769	0.0438	0.0192	0.1345
Rampike	9	0.1513	0.0640	0.0687	0.2360
Sentinel	8	0.0691	0.0456	0.0286	0.1587
Ulm	5	0.0710	0.0454	0.0225	0.1223

Overall:	
Mean	0.1088
Minimum	0.0154
Maximum	0.4037

Table 5. Stream densities in the Main Coeur d'Alene River drainage, 1996.

Stream	N	Mean	Std Dev	Minimum	Maximum
Avery	9	0.1171	0.0631	0.0201	0.2036
Bear	9	0.1783	0.1355	0.0473	0.4412
Big Elk	9	0.0364	0.0221	0.0000	0.0714
Big Hank	6	0.0752	0.0431	0.0000	0.1161
Brett	9	0.0014	0.0041	0.0000	0.0123
Browns	9	0.0414	0.0276	0.0000	0.0858
Coal	4	0.0321	0.0238	0.0000	0.0577
Downey	9	0.0469	0.0421	0.0000	0.1176
East Fork Steamboat	9	0.0993	0.1007	0.0189	0.2717
Grizzly	9	0.2185	0.2338	0.0460	0.7516
Halsey	9	0.0581	0.0291	0.0315	0.1225
North Grizzly	9	0.1140	0.0991	0.0267	0.3088
Scott	9	0.0588	0.0317	0.0000	0.1036
Svee	6	0.0631	0.0294	0.0126	0.0932
Teddy	9	0.0916	0.0463	0.0516	0.1733
West Fork Steamboat	9	0.1623	0.2147	0.0163	0.6863
Yellowdog	9	0.0207	0.0158	0.0000	0.0410

Overall:	
Mean	0.0832
Minimum	0.0000
Maximum	0.7516

Table 6. Stream densities in the Upper Coeur d'Alene River drainage, 1996.

Stream	N	Mean	Std Dev	Minimum	Maximum
Alden	9	0.0797	0.0903	0.0000	0.2647
Blacktail	9	0.0761	0.0657	0.0000	0.1838
Buckskin	9	0.0367	0.0592	0.0000	0.1891
Coeur d'Alene River	9	0.0193	0.0158	0.0000	0.0427
Dahlman	8	0.0243	0.0255	0.0000	0.0735
Deer	9	0.0154	0.0206	0.0000	0.0630
East Alden	8	0.0261	0.0247	0.0000	0.0630
Jordan	8	0.0487	0.0394	0.0000	0.1203
Lost Fork	9	0.0227	0.0166	0.0000	0.0551
Marten	9	0.0765	0.0378	0.0000	0.1261
Mosquito	7	0.0666	0.0575	0.0000	0.1604
Spruce	6	0.0527	0.0413	0.0083	0.1188
Whitetail	9	0.0868	0.0756	0.0000	0.2101

Overall:	
Mean	0.0486
Minimum	0.0000
Maximum	0.2647

Table 7. Stream densities in the North Fork Coeur d'Alene River drainage, 1996.

Stream	N	Mean	Std Dev	Minimum	Maximum
Barney	9	0.0471	0.0457	0.0000	0.1379
Bootjack	8	0.0013	0.0038	0.0000	0.0108
Bottom	9	0.0283	0.0280	0.0000	0.0882
Bumblebee	9	0.0110	0.0158	0.0000	0.0401
Burnt Cabin	9	0.0413	0.0306	0.0000	0.0913
Cascade	9	0.0296	0.0312	0.0000	0.0817
Deception	9	0.0248	0.0296	0.0000	0.0735
Hemlock	9	0.0459	0.0530	0.0000	0.1471
Honey	9	0.0091	0.0109	0.0000	0.0221
Iron	9	0.0681	0.0551	0.0000	0.1471
Laverne	9	0.0152	0.0127	0.0000	0.0401
Lavin	9	0.1139	0.1261	0.0000	0.3501
Leiburg	9	0.0037	0.0064	0.0000	0.0184
Lewelling	7	0.0571	0.0654	0.0000	0.1716
Little Tepee	9	0.0470	0.0482	0.0000	0.1225
Lone Cabin	9	0.0385	0.0361	0.0000	0.1003
Middle Fork Hudlow	7	0.0606	0.0296	0.0000	0.0882
Nicholas	9	0.0685	0.0560	0.0000	0.1471
Picnic	7	0.0244	0.0186	0.0000	0.0580
Sob	3	0.0100	0.0174	0.0000	0.0301
Solitaire	9	0.0432	0.0289	0.0000	0.0863
Tie	9	0.0799	0.0870	0.0000	0.2704
Tom Lavin	9	0.0529	0.0577	0.0000	0.1733
West Fork Hudlow	9	0.0179	0.0203	0.0000	0.0477

Overall:	
Mean	0.0392
Minimum	0.0000
Maximum	0.3501

Table 8. Stream densities in the Shoshone Creek drainage, 1996.

Stream	N	Mean	Std Dev	Minimum	Maximum
Cabin	9	0.1072	0.0694	0.0324	0.2022
Clinton	9	0.0668	0.0510	0.0000	0.1471
Hemlock	9	0.0633	0.0332	0.0184	0.1103
Little Lost Fork	9	0.0294	0.0184	0.0000	0.0572
Pine Flat	8	0.0533	0.0367	0.0094	0.1203
Rampike	6	0.1064	0.1296	0.0000	0.3595
Sentinel	6	0.0443	0.0203	0.0212	0.0788
Ulm	9	0.0611	0.0421	0.0142	0.1235

Overall:	
Mean	0.0665
Minimum	0.0000
Maximum	0.3595

differences in density between 1995 and 1996. Mean densities for each of the four drainages ranged from 0.052 to 0.155 fish/m^2 in 1995, and from 0.039 to 0.083 fish/m^2 in 1996 (Table 9). When the four large drainages within the Coeur d'Alene basin are examined individually to explore changes in density between 1995 and 1996, the Main Coeur d'Alene was not significantly different when using streams ($p = 0.868$) as independent samples. Paired differences also were not significant for streams ($p = 0.607$) in the Main Coeur d'Alene. Streams in the Upper Coeur d'Alene drainage showed a significant decrease from 1995 to 1996 using independent ($p = 0.063$) and paired observations ($p = 0.023$). No significant differences were observed in the North Fork Coeur d'Alene streams ($p = 0.271$) when the observations are assumed to arise from independent samples. When differences are assumed paired, however, a significant difference was observed between streams ($p = 0.026$). Estimated densities in Shoshone Creek were significantly lower in 1996 than 1995 using streams as independent observations ($p = 0.096$) and using paired observations ($p = 0.008$).

Significant differences in cutthroat trout densities were observed between drainages in 1996 ($p = 0.055$), however, not all drainages were different from each other. Pairwise comparisons between mean stream density among drainages in 1996 showed that the mean stream density in the Main Coeur d'Alene was not different from the Upper Coeur d'Alene ($p = 0.277$), nearly significantly different from the North Fork Coeur d'Alene ($p = 0.090$), and not different from Shoshone Creek ($p = 0.893$). Mean stream density in the Upper Coeur d'Alene was not different from the North Fork Coeur d'Alene ($p = 0.646$) or from Shoshone Creek ($p = 0.296$). The North Fork Coeur d'Alene was nearly significantly different in mean stream density from Shoshone Creek ($p = 0.108$).

Table 9. Mean cutthroat trout stream density by drainage.

Drainage	Year	N	Mean	Std Dev	Minimum	Maximum
Main Coeur d'Alene	95	16	0.0857	0.0546	0.0194	0.1946
Upper Coeur d'Alene	95	15	0.1548	0.1136	0.0431	0.3948
North Fork Coeur d'Alene	95	15	0.0517	0.0251	0.0190	0.0966
Shoshone Creek	95	9	0.1088	0.0668	0.0470	0.2636
Main Coeur d'Alene	96	17	0.0832	0.0593	0.0014	0.2185
Upper Coeur d'Alene	96	13	0.0486	0.0261	0.0154	0.0868
North Fork Coeur d'Alene	96	24	0.0392	0.0272	0.0013	0.1139
Shoshone Creek	96	8	0.0665	0.0276	0.0294	0.1072

Differences in stream densities among drainages for only streams sampled in both 1995 and 1996 were not significant ($p = 0.117$).

When comparisons of reach densities (Appendix A) were made between years, significant decreases in density were observed for all three reaches. The largest decrease was in the lower reaches ($p = 0.0006$), followed by the middle reach ($p = 0.014$) and the upper reach ($p = 0.055$). Density also was not equal for all reaches in 1996. The lowest reach was nearly significantly lower than the middle reach ($p = 0.085$) but was significantly lower than the upper reach ($p = 0.003$). The middle and upper reaches were not significantly different from each other ($p = 0.65$).

Length frequency distributions for all years followed the same general pattern, but the distributions for 1995 and 1996 were more similar to each other than to the 1994 distribution. The mean length of cutthroat trout captured in 1996 was 102 mm, and ranged from 19 mm to 250 mm (Figure 4). Fish from individual streams, with more than 25 length observations, had length frequency distributions similar in overall shape to the combined distribution for 1996 (Appendix B). Mean length for 1994 was 97 mm (range = 23 - 280 mm), and 95 mm (range = 19 - 305 mm) for 1995. At least one of the three length distributions was significantly different from another ($p = 0.0009$). The empirical cumulative distribution functions for the 3 years were all significantly different from each other, suggesting that the length frequency distribution functions are not constant. Pairwise comparisons of the three length distributions showed that the 1994 length distribution was significantly different than 1995 ($p = 0.0001$), 1994 was significantly different than 1996 ($p = 0.0001$), and 1995 was significantly different than 1996 ($p = 0.0001$). The length frequency distribution for 1994 appears to be smoother than those for 1995 and 1996, both of which show a decrease in

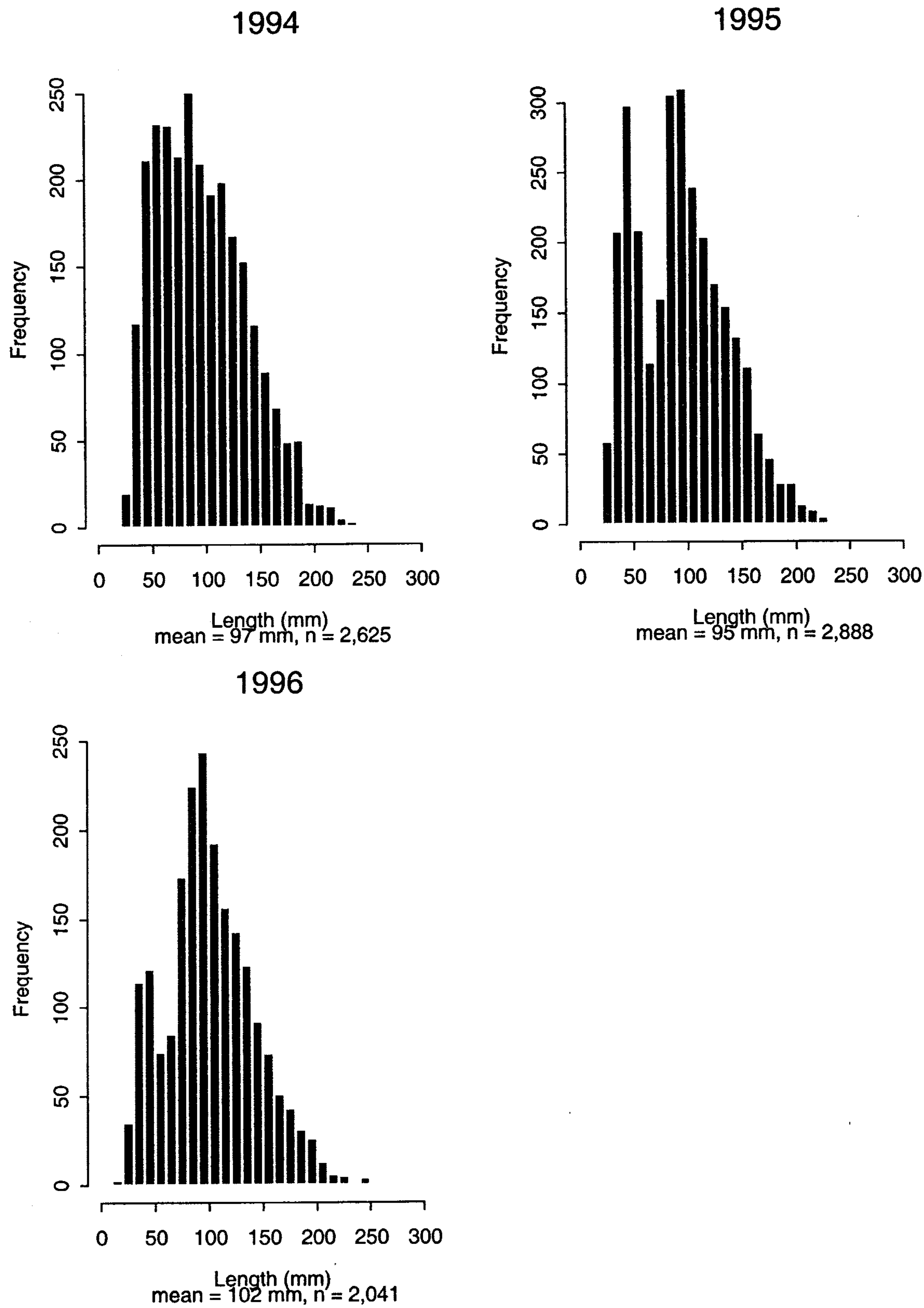


Figure 4. Length frequency distributions of Westslope Cutthroat Trout in the Coeur d'Alene River Basin.

number of cutthroat trout with lengths between 50 and 100 mm (Figure 4). The length frequency distributions for each of the two drainages sampled in 1994 (Figure 5) and the four sampled in 1995 (Figure 6) show that the decrease occurred in all drainages except the North Fork Coeur d'Alene in 1995, but is evident in all four drainages in 1996 (Figure 7). When the length distributions are examined by drainage, the distributions for both the Main Coeur d'Alene and North Fork Coeur d'Alene drainages appear similar to the combined length distribution in 1994. In 1995, although the North Fork Coeur d'Alene follows a similar pattern to that of 1994, all three of the other drainages show a large decrease in numbers between 50 and 100 mm. The drainage distributions are similar in 1996 to those of 1995, but the decrease in number of fish with lengths between 50 and 100 mm is evident in the North Fork Coeur d'Alene drainage.

Discussion

I found cutthroat trout in every stream sampled during the 1996 field season, indicating that no local extinctions have occurred as a direct response to the high flows during the winter 1996 floods. The change in estimated density could be a response to the floods, however. The capture efficiencies reported by Dunnigan (1997) for the Coeur d'Alene basin in 1994 and 1995 were not significantly different from what I estimated in 1996, indicating that comparisons using these data between the 3 years are valid. Although density estimates varied across the basin, the range of densities was not as wide as had been observed in the previous 2 years (Dunnigan 1997), and I observed more streams with lower densities (Figure 2). In 1996, the highest individual stream density observed was 0.219 fish/m^2 compared to 0.446 fish/m^2 in 1994 and 0.398 fish/m^2 in 1995. Effects of

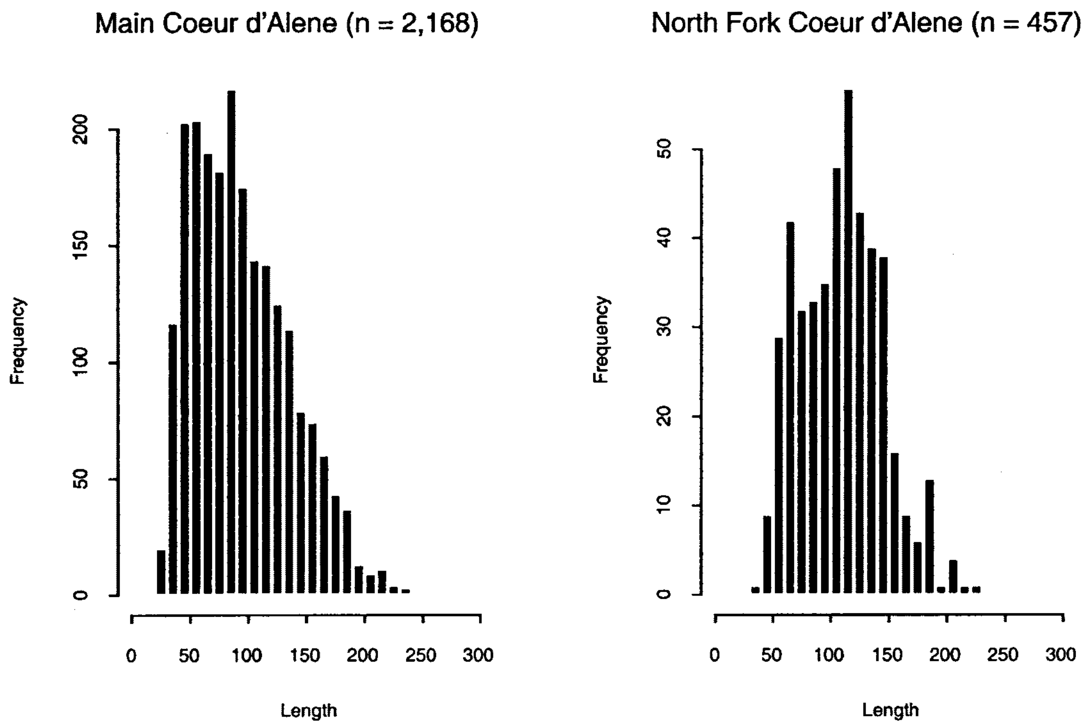


Figure 5. Length frequency histograms for two major drainages in the Coeur d'Alene River Basin, 1994.

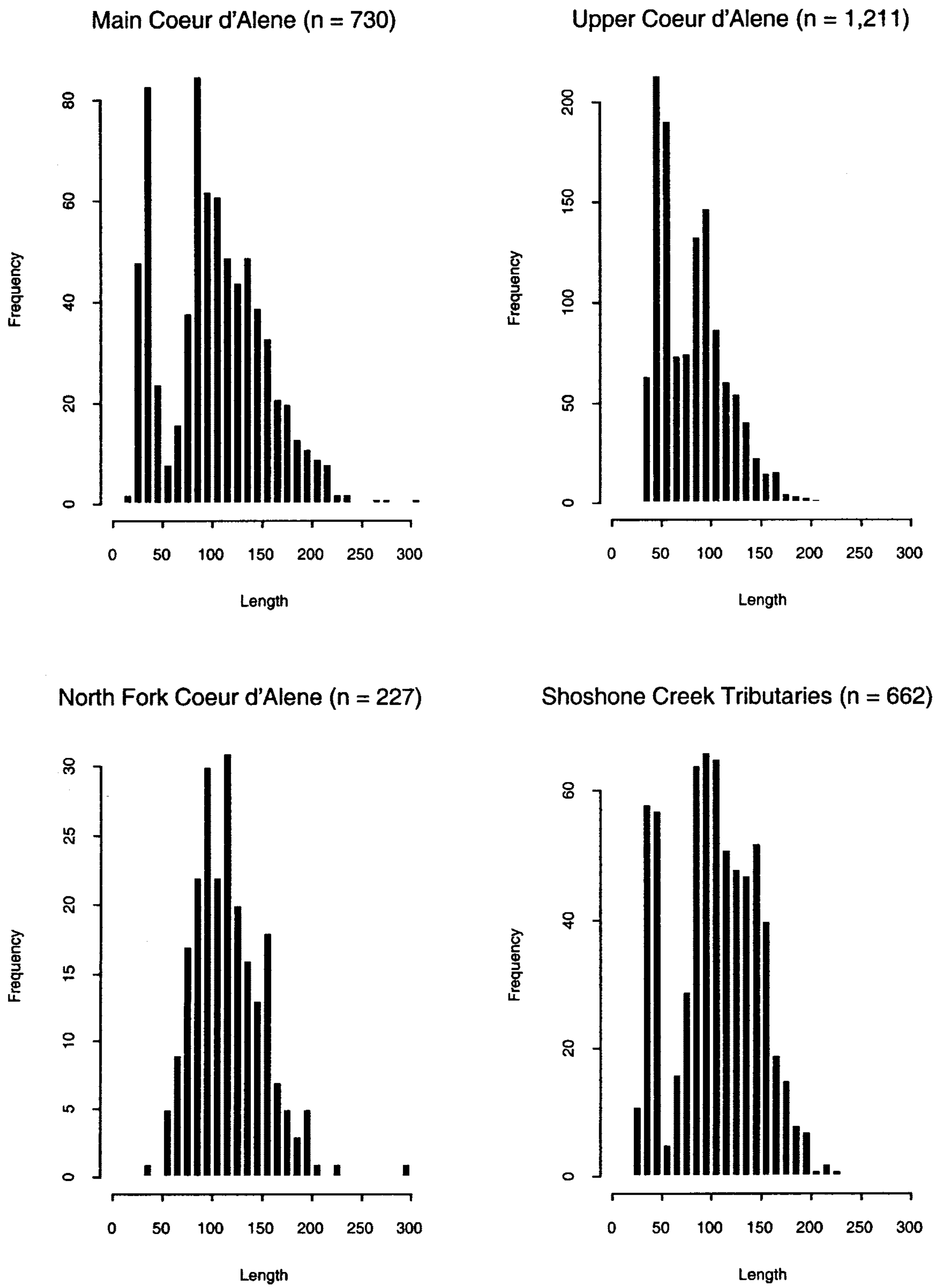


Figure 6. Length frequency histograms for four major drainages in the Coeur d'Alene River Basin, 1995

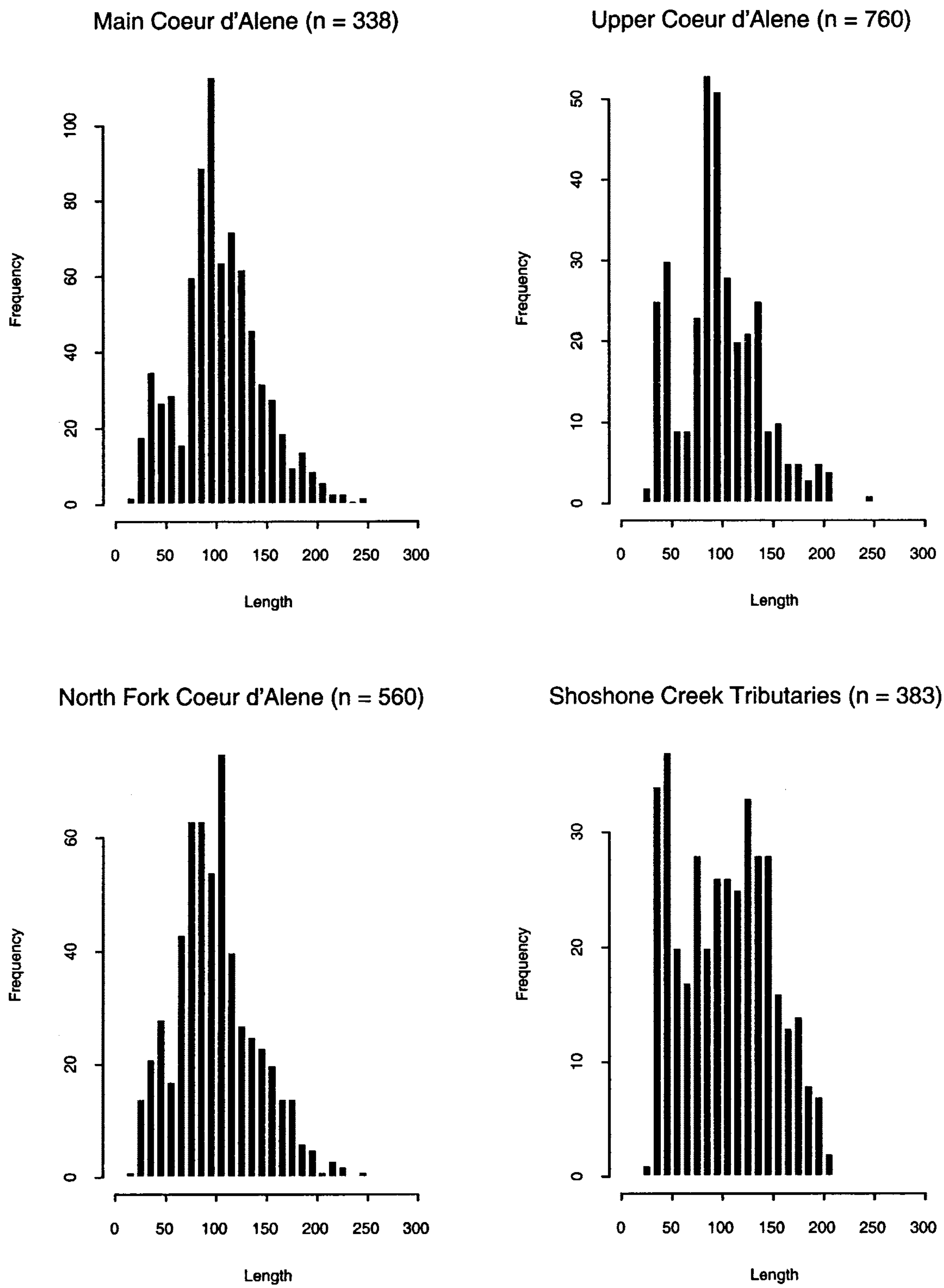


Figure 7. Length frequency histograms for four major drainages in the Coeur d'Alene River Basin, 1996.

gravel movement, increased large woody debris jams, siltation of spawning gravels, disturbance of side-channel rearing areas, and filling and scouring of pools and riffles (Swanston 1991). Significant bedload movement was evident in many of the streams sampled following the winter floods, thus it is possible that some of these changes could account for some of the decrease in cutthroat trout abundance between 1995 and 1996. Channel changes such as increased movement of sediment and woody debris into the channels, movement and redistribution of coarse sediments and large woody debris probably further contributed to the change in abundance between years.

Changes in hydraulic complexity could also account for some of the change in estimated abundance of cutthroat trout between 1995 and 1996. Pearsons et al. (1992) reported that hydraulically more complex stream reaches lost fewer fish than hydraulically simple reaches in response to flooding, where hydraulic complexity is a measure of hydraulic retention. Although my research did not include a measure of hydraulic retention, my visual observations in streams sampled included large woody debris counts and estimated percentages of substrate types that could potentially relate to hydraulic retention. The reduction in estimated cutthroat trout density in the Shoshone Creek and Upper Coeur d'Alene drainages could potentially be explained by a reduction in hydraulic complexity. The streams in the Upper Coeur d'Alene drainage with the highest densities in 1995 contained little large woody debris in 1996, possibly explaining the large reduction in cutthroat trout density observed in 1996. Many streams in the Coeur d'Alene Basin were used in the early part of this century to transport timber with chutes and splash dams (Strong and Webb 1970; Russell 1984). According to Strong and Webb (1970), there were hundreds of miles of log chutes in the Coeur d'Alenes and about 25 flume projects with a total mileage in excess of 150. At least seven splash dams were constructed on the North Fork Coeur d'Alene River, and others were used in the Shoshone Creek and Independence Creek drainages. Before log transport could begin, "improvements" were necessary which included blocking off swamps, low meadows and banks along wider parts of the streams with log cribbing, and removal of boulders, leaning trees, sunken logs or any other obstructions (Brown 1936). All of these modifications had the effect of reducing the hydraulic complexity of streams. Wendler and Deschamps (1955) reported that effects of splash dams on salmon (*Oncorhynchus* spp.) runs in the Gray's Harbor-Willapa Bay area of southwestern Washington included driving spawning fish away from redds and scouring or moving gravel bars to leave bedrock or heavy boulders. The splash dams employed in the Coeur d'Alene basin probably had similar effects on cutthroat trout populations.

The range of cutthroat trout densities that I estimated for second and third order tributaries in the Coeur d'Alene River Basin was within the range observed by other investigators for westslope cutthroat trout (Table 10). Estimated densities in the St. Joe River (B. Rieman, Intermountain Research Stations, U.S. Forest Service, Boise, Idaho, unpublished data; Thurow, 1976) are similar to what I observed in the Coeur d'Alene basin. Lukens (1978) reported densities for Wolf Lodge Creek, Idaho that were generally higher, and Pratt's (1984) results indicate that maximum densities in the upper Flathead River basin, Montana are higher than in the Coeur d'Alene River basin overall.

The Upper Coeur d'Alene tributaries showed the largest change in cutthroat abundance between 1995 and 1996 of the four main drainages, where stream density estimates were consistently lower in 1996 than in 1995 for every stream sampled. Significant changes in abundance were not observed in the tributaries to the Main Coeur d'Alene River

Table 10. Estimated densities (fish/m2) of cutthroat trout in other systems.

River	Mean	Minimum	Maximum	Reference
St. Joe	0.061	n/a	n/a	Rieman (unpublished)
Flathead	n/a	0.03	0.6	Pratt (1984)
St. Joe	n/a	0.03	0.06	Thurow (1976)
Wolf Lodge Creek	n/a	1	2	Lukens (1978)
Coeur d'Alene	0.099	0.019	0.3984	Dunnigan (1997)
Coeur d'Alene	n/a	0	0.53	Lewynksy (1986)
Coeur d'Alene	0.0567	0.0013	0.2185	Abbott (this research)

or the North Fork Coeur d'Alene River between 1995 and 1996, although densities estimated in Shoshone Creek and the Upper Coeur d'Alene River were significantly lower in 1996 than 1995. The relatively high average density in the Main Coeur d'Alene drainage in 1996 (0.083) was largely a result of high densities observed in three streams (Bear, Grizzly and West Fork Steamboat). When these streams are excluded from analyses, densities are similar in all four basins. The large decrease in estimated densities in the Upper Coeur d'Alene River between 1995 and 1996 was a result of high densities observed in 1995 that were not observed in 1996. Three streams with high densities in 1995 (Jordan, Lost Fork, and Spruce) were largely responsible for the decrease between years. Significant gravel movement was evident in these three streams, indicating that the decrease in abundance could be a result of flood related habitat changes. Although the Upper Coeur d'Alene drainage is largely roadless and little timber harvest has occurred, it was heavily influenced by the 1910 fire. Extremely hot fires can retard timber regeneration when seeds are burned, and it is possible that the effects of the fire are still affecting fish populations and habitat, particularly with the lack of large woody debris following the January 1996 flood. Elevated peak flows as a result of increased water yields after fire can result in channel alteration, sediment transport and deposition, and loss of habitat complexity and cover (Minshall et al. 1989; Minshall and Robinson, 1993).

Although in some individual streams, estimated stream densities were higher in 1996 than in 1995, all mean drainage densities were lower in 1996 than 1995, further suggesting that the flood affected cutthroat trout. Abundance was also lower in 1996 for all drainages when only streams sampled in both years were compared as paired observations. The decrease in abundance between 1995 and 1996 was smaller in the Main Coeur d'Alene and

North Fork Coeur d'Alene drainages than in the Upper Coeur d'Alene and Shoshone Creek drainages. The Main Coeur d'Alene and North Fork Coeur d'Alene drainages had significantly lower average densities in 1995 than the Upper Coeur d'Alene and Shoshone Creek drainages, suggesting that streams with higher densities were more affected by the flood. Three streams in the Upper Coeur d'Alene and one in Shoshone Creek (Cabin) are largely responsible for the overall difference in those drainages. The Upper Coeur d'Alene and Shoshone Creek drainages were not included in the 1994 sampling effort (Dunnigan 1997), so it is impossible to determine the true nature of the change in abundance between 1995 and 1996. Two possibilities are either there truly was a decrease in the 1996 densities, or the 1995 densities were abnormally high in the four streams with the most significant changes in abundance. Another possibility could be that changes are simply too difficult to detect in small populations.

I found cutthroat trout densities in tributaries to the Main Coeur d'Alene River were significantly higher than in tributaries to the North Fork of the Coeur d'Alene River, consistent with findings by Hunt and Bjornn (1992) using snorkeling. Dunnigan (1997) also observed higher densities in the mainstem tributaries, although the difference that he saw in 1994 and 1995 was more highly significant ($p = 0.001$) than what I estimated for 1996. The variability in estimated density was not constant between years across the basin, possibly resulting from variation in either the low flows observed in 1994 or the 1996 flooding. Flows are not recorded in all areas of the Coeur d'Alene Basin, and it is not known if the magnitude of the winter, 1996, flood was similar across all areas or if the low flows in 1994 were consistent across the basin.

Densities in all reaches were lower in 1996 than in 1995. I observed the highest densities in the upper reaches and lowest densities in the lower reaches, consistent with Dunnigan's (1997) results. These data suggest that while the overall abundance appears to have been negatively impacted by the winter, 1996 floods, population structures within streams were probably uniformly affected.

Composite frequency distributions of length frequencies for 1995 (Figure 4) and 1996 were similar. When compared to the distribution of lengths observed in 1994, however, there was an obvious decrease in fish with lengths from 50-70 mm between 1994 and 1995, suggesting that these fish were negatively affected by some other factor than those measured in this study. One possible explanation could be that the extremely low flows observed in 1994 were more detrimental to these fish (age-0 in 1994) than the high flows in the winter, 1996 flood. Dunnigan (1997) found a significant decrease in densities from 1994 to 1995 and hypothesized that the decrease could be due to the 10-year flood event that occurred between the 2 years. The interaction of the low flows in 1994 and subsequent flooding could account for the varying change in densities among drainages observed in 1996. Several authors (Harvey 1987; Pearsons et al 1992; Seegrist and Gard 1972; Hanson and Waters 1974) have suggested that young of the year fishes may be particularly vulnerable to floods because of their poor swimming ability and small size.

Although all pairwise differences between the cumulative length frequency distributions are highly significant, I could not determine whether those differences are truly present or whether they are a function of the large sample size. Based on a graphical analysis of the distributions, I believe that the difference between 1994 and 1995 is larger than the difference between 1995 and 1996. Distributions for both 1995 and 1996 have a decreased abundance of fish in the 50 – 80 mm range, while the 1994 length distribution does not have a lower abundance of fish in that range.

CHAPTER TWO

INFLUENCE OF PHYSICAL HABITAT VARIABLES ON THE DISTRIBUTION OF SPAWNING CUTTHROAT TROUT

Conservation biologists consider populations to be spatially structured when habitat is non-continuously distributed and local populations inhabit patches of habitat, surrounded by a matrix of hostile uninhabitated habitat (Hanski and Gilpin 1991; Harrison 1991; Hanski and Gyllenberg 1993). Cutthroat trout populations could be considered spatially structured if successful spawning locations were not continuously distributed, regardless of the spatial distribution of adults during other times. Beginning when fry were first observed in the electrofishing catch, streams were surveyed across a gradient of stream orders to determine whether cutthroat trout spawning locations were continuously distributed or spatially structured.

Methods

Presence or absence of age-0 cutthroat trout was determined from the electrofishing data (Chapter One) and by visual observations while walking the banks of predetermined streams. Sampling began when age-0 fish began appearing in the electrofishing catch. Data on age-0 cutthroat trout distribution in the Coeur d'Alene Basin from the 1994 and 1995 sampling (Dunnigan 1997) were used to determine streams to be surveyed in 1996. Streams were sampled across a gradient of size, elevation, channel gradient, and known fish abundance and included larger systems such as the Main Coeur d'Alene, North Fork Coeur d'Alene, and Shoshone Creek.

Sampling began at the mouth of the stream to be surveyed and continued upstream for 100 m. Observers on each of the streams looked for recently emerged juvenile cutthroat trout in calm, shallow, lateral habitat commonly inhabited by age-0 cutthroat trout (Kelly et al. 1989). Locations of age-0 fish were recorded on a 1:24,000 scale U.S.G.S. topographical map, and physical habitat data (Chapter One) were recorded. If no fish were observed within the first 100 m, the second sampling site began approximately 1000 m upstream from the mouth. If fish were observed in the second site, the location was marked and a third site was located approximately halfway between the first and second sites. If no fish were observed in the second site, the third site was located approximately 1000 m upstream from the second site. This procedure was repeated until the first occurrence of age-0 cutthroat trout was located, within 500 m.

Statistical Analysis

Nonparametric tests were used to determine significant differences in medians of the independent variables between sampling sites where fry were observed and sites where fry were not observed. Logistic regression was used to model the probability of observing age-0 cutthroat trout at a sampling site using wetted stream width at the site, average stream temperature (Objective One), gradient of the site, distance from the mouth of the stream, complexity, elevation, aspect, percent of pool habitat, pool volume, conductivity, large woody debris counts, equivalent clearcut acreage, watershed area, cumulative equivalent clearcut acreage, and road density per square mile as independent variables. Visually observed cutthroat trout were not included in the logistic regression procedures to correct for any difference in sampling efficiency between observations made while walking the streambank and electrofishing. Sites with wetted widths greater than the maximum width at which fry were observed were not included in the analyses. Models were examined individually as a result of missing values for independent variables, using the independent variables with significant differences in the presence or absence of fry.

Results

No age-0 cutthroat trout were found in any stream with wetted width larger than 7.7m, either by visual observation or electrofishing catch. In streams where age-0 fish were observed, they were always found in calm, shallow water.

Statistically significant differences were found in distance from the stream mouth (p = 0.03), gradient of the site (p = 0.003), average stream gradient (p = 0.004), percent of pool habitat (p = 0.076), and watershed size (p = 0.071) depending on the presence or absence of fry. No other independent variables examined in this objective were significantly different when fry were present or absent (Table 11).

The stepwise logistic regression procedure found the best model that could significantly predict the probability ($\hat{P}$) of encountering fry (p = 0.0009, n = 27) including the single independent variable of gradient at the sampling site. The model was

$$\hat{P} = \frac{1}{1 + e^{(-4.78 + 0.62 \times gradient)}},$$

and suggests that fry are more likely to occur in sites with lower gradients. No other single variable was as significant as site gradient in predicting the probability of encountering fry.

Table 11. P-values from median tests that physical habitat variables are equal when fry are present or absent.

Variable	Median		P-value	N
	Fry present	Fry absent		
Distance from stream mouth	1080.0	2125.0	0.0295	49
Wetted width	3.4	3.3	0.9429	49
Average stream temperature	9.5	9.7	0.6621	47
Site gradient	2.5	7.3	0.0029	49
Complexity	4.1	4.0	0.5286	49
Large woody debris count	7.9	5.6	0.5302	14
Elevation	3220.0	3480.0	0.7043	49
Aspect	180.0	180.0	0.5939	49
Percent pool habitat	34.1	23.4	0.3657	28
Pool volume	23.9	18.0	0.4190	27
Conductivity	47.5	33.7	0.0705	49
Equivalent clearcut acreage	14.9	7.3	0.0705	36
Watershed area	2530.5	1736.0	0.0705	35
Cumulative equivalent clearcut acreage	12.7	6.7	0.2956	35
Road density	2.6	1.6	0.2956	35

When the distance from the stream mouth to the first observation of fry is included, the model is slightly more significant (p = 0.0001), however, distance is not significant (p = 0.41). A model containing site gradient and watershed size was also significant in predicting the probability of encountering fry (p = 0.0003), but watershed size is not significant (p = 0.878). The only two variable model in which all of the independent variables were significant was one including site gradient (p = 0.036) and percent pool habitat (p =0.074). The overall model was significant (p = 0.0005), and was

$$\hat{P} = \frac{1}{1 + e^{(-1.22 - 0.76 \times gradient + 0.23 \times pools)}}.$$

This model suggests that the probability of encountering age-0 cutthroat trout increased with decreased gradient, but decreased with increased percent of pool habitat. No other more significant models were found; addition of other independent variables generally yielded less significant models due to a reduced sample size from missing values.

Discussion

My results indicate that cutthroat trout reproduction in the Coeur d'Alene River basin is most successful in third order and smaller tributaries with wetted widths smaller than 8 m, similar to Lewynsky's (1986) observations in the lower Coeur d'Alene River and to Dunnigan's (1997) observations. Other researchers (Johnson 1963; Lukens 1978; Shepard et al.1984; Apperson et al. 1988) have also found that most cutthroat trout spawning and rearing occurs in small tributaries.

Bozek and Rahel (1991) found that age-0 cutthroat trout were primarily associated with specific stream locations with slow water velocities (less than 0.06 m/s) and in water deeper than 3 cm, however, streams with hydraulic and geomorphologic characteristics different than these were also capable of providing suitable rearing habitat. In steep headwater streams with large boulders and plunge pools, as well as streams consisting primarily of lateral scour pools, successful reproduction was evident. Young fish used small backwater and upstream dam pools associated with the plunge for rearing when the slow, calm, lateral habitat generally associated with cutthroat trout rearing was not present. Juvenile cutthroat trout were also found in small pools within larger habitat units in such streams (Bozek and Rahel 1991). My results suggest that age-0 cutthroat trout in the Coeur d'Alene system are frequently using small pools within larger habitat units for rearing, since young fish were found in many streams that did not appear to be ideal.

In the Coeur d'Alene system, stream with widths greater than 8 m often did not contain locations with both water velocities and depths suitable for rearing cutthroat trout. Depth and velocity in the larger tributaries were usually deeper and faster than the typical rearing habitat (Bozek and Rahel 1991), which might explain the lack of apparent reproduction in the larger systems. Lewynsky (1986) also found no evidence of cutthroat trout reproduction in higher order streams in the Coeur d'Alene River basin. Water temperature in the large systems was also higher than in the tributaries, particularly in those areas that did have both slow velocities and shallow depths. I believe that the interaction of depth, velocity and water temperature could explain the lack of fry observations in large streams. My results are similar to what others (Johnson 1963; Lukens 1978; Shepard et al. 1984; Apperson et al. 1988) have found indicating that cutthroat trout spawning and initial rearing is mainly restricted to small tributaries. No juvenile cutthroat trout were observed in any stream wider than 7.7 m, suggesting that spatial structuring could be a factor in population dynamics in the Coeur d'Alene basin (Rieman, unpublished; Dunnigan 1997).

Regardless of the spatial distribution of adult cutthroat trout, it seems likely that, since spawning locations are not continuously distributed as my results indicate, metapopulation processes may be important in the Coeur d'Alene system (Hanski and Gyllenberg 1993).

Of the two most significant models for predicting the probability of encountering age-0 cutthroat trout, the model that only contained site gradient appears to be the best. The two variable model that also included percent pool habitat is not biologically feasible, probably because gradient alone is so important. In contrast to Dunnigan's (1997) results, watershed area was not significant in predicting the presence of age-0 cutthroat trout. I believe that this is a result of not including the visual observations from the larger streams in the logistic regression analysis. Had electrofishing been effective in the larger systems and such observations been included in the analyses, watershed area could have been more important in the models.

CHAPTER THREE

EFFECTS OF LAND MANAGEMENT ACTIVITIES ON THE DISTRIBUTION AND ABUNDANCE OF CUTTHROAT TROUT

Cutthroat trout were historically abundant in the Coeur d'Alene River basin (Maclay 1940). Today, the combined effects of over-fishing, logging activities, road construction, and mineral extraction have reduced numbers of cutthroat trout within the drainage (Lewynsky 1986; Hunt and Bjornn 1992; Dunnigan 1997). Several authors have suggested a relationship between habitat characteristics, physiographic characteristics, and trout distribution (Bozek and Hubert 1989; Platts 1979; Chisholm and Hubert 1986; Lanka et al. 1987; Kozel and Hubert 1989; Fausch 1989). Relationships between fish habitat and timber harvesting and road construction have also been described (Chamberlain et al. 1991; Furniss et al. 1991). The purpose of this objective was to quantify effects of land management activities in the Coeur d'Alene River Basin on the distribution and abundance of cutthroat trout.

Methods

Electrofishing and habitat data collected for Chapter 1 were used to quantify the effects of land management activities on cutthroat trout abundance and habitat. Physical habitat data collected by the U.S. Forest Service (Chapter 1) including habitat typing inventory (Hankin and Reeves 1988), riffle stability indices (RSI: Kappesser 1993), and large woody debris counts (LWD: woody debris larger than 30 cm in diameter and 1 m long) were included in the analyses. Dunnigan (1997) calculated road densities (km/km^2) used in my analyses with a geographic information system. Records were provided by the U.S. Forest Service of all timber harvest occurring during the past 30 years within each watershed. Total watershed clearcut activity was estimated by summing the area of all timber harvest activity, then dividing by the total watershed area.

Statistical Analysis

Capture efficiency and cutthroat trout density estimates calculated in Chapter 1 were used as dependent variables in the analyses for this objective. Since biomass can also be an effective measure of population abundance, cutthroat trout biomass (g/m^2) was calculated for each stream by estimating the weight of each fish captured using the allometric growth equation (Rieman and Apperson, 1989):

$$\hat{W} = (4.5 \times 10^{-6}) L^{3.14}$$

where $\hat{W}$ is the estimated weight (g) and L is the fork length (mm). Mean biomass (g/m^2) for each site was computed by summing the biomass estimated for each fish in the site, then dividing by the total area in each site. Mean biomass for each stream was estimated using the following equation:

$$\bar{y} = \frac{1}{N} \sum_{i=1}^{N} \bar{y}_i$$

where N is the total number of sampling sites in the stream and $\bar{y}_i$ is the mean biomass in each site. To find a model useful to predict cutthroat trout biomass, the square root of the biomass was used in analyses to meet the assumptions for multiple linear regression.

To prevent the instability in estimated regression parameters that can result from independent variables measured on widely differing scales, all independent variables used in this analysis were rescaled (Box and Draper 1987). A linear transformation was used due to non-normal distributions of the independent variables. The transformed variables all ranged from –1 to 1 after subtracting the midpoint from each observation, then dividing the difference by the half-range.

Principal components and factor analyses were used to reduce the dimensionality of the dataset, and correlation analysis was used to examine effects of multicollinearity on the parameter estimates. Multiple linear regression techniques were used to model the relationship between cutthroat density and physical habitat variables. Multiple regression also was used to examine the relationship between the square root of cutthroat trout biomass and physical habitat variables. Missing values reduced the data set to 10 streams with observations for all independent variables, so the standard model selection procedures were not appropriate. Models were examined individually using the criteria of highest R^2 in a significant model with all parameters significant, the smallest number of predictor variables, and lowest root mean square error.

Results

Principal components and factor analyses were unable to reduce the number of independent variables in the data due to missing values. Correlation analysis showed that although most of the independent variables were not strongly related, some were highly correlated with each other. Separate models were examined using each of the correlated variables individually so only those most significantly related to the dependent variables could be included in analyses.

A significant ($p = 0.001$) model containing wetted width (*width*), large woody debris (*lwd*) and cumulative equivalent clearcut acreage (*cumeca*) accounted for nearly 64% of the variability in cutthroat trout density ($R^2 = 0.6379$). This model was

$$\hat{y} = 0.047 - 3.86 \times width + 16.90 \times lwd - 32.85 \times cumeca$$

and suggests that densities decreased with increased wetted width and cumulative equivalent clearcut acreage, and increased with increased amounts of large woody debris per 1000m of channel. Although this model had the highest R^2 of any model examined, it is limited by missing values for large woody debris counts ($n = 19$), and cumulative equivalent clearcut acreage is not significant within the model.

Wetted width, large woody debris per 1000 m channel and watershed area (*acres*) were also significantly related to cutthroat trout density ($p = 0.002$). The model was

$$\hat{y} = 0.059 - 3.91 \times width + 16.83 \times lwd + 4336.08 \times acres$$

indicating that densities decrease with increased wetted widths and increase with increased large woody debris counts and increased watershed size ($R^2 = 0.619$). This model is similar to the first model listed above in that densities appear to vary similarly with wetted width and large woody debris, and it is also limited by missing values for large woody debris to 19 streams. Watershed area is not significant within this model ($p = 0.220$), but wetted width ($p = 0.004$) and large woody debris ($p = 0.006$) are both significant.

The best two variable model for predicting cutthroat trout density included wetted width and large woody debris as independent variables. This model was

$$\hat{y} = 0.053 - 3.88 \times width + 16.70 \times lwd$$

and continues to indicate a negative relationship between density and wetted width and a positive relationship between density and large woody debris. The model was highly significant ($p = 0.001$) and was able to account for nearly as much variability in density as the best three variable models ($R^2 = 0.578$). All independent variables were significant in this model.

The second best two variable model relating cutthroat trout density ($\hat{y}$) to the independent variables in this objective used only large woody debris and cumulative equivalent clearcut acreage to predict density. This model accounts for over 50% of the variability in density ($R^2 = 0.505$) and was highly significant ($p = 0.004$). This model was

$$\hat{y} = 0.04 + 17.05 \times lwd - 33.36 \times cumeca,$$

and suggests that density increased with increased numbers of large woody debris but decreased with increased cumulative equivalent clearcut acreage.

Of the four independent variables included in these models, only large woody debris had a nearly significant relationship individually with cutthroat trout density ($p = 0.077$). Large woody debris alone could account for 17% of the variability in density, while no other independent variable alone was able to account for more than 10% of the variability.

To predict estimated biomass, the best fitting model included wetted width, large woody debris counts per 1000 m channel, and cumulative equivalent clearcut acreage. This model was able to account for 47% of the variability in biomass and was significant overall ($p = 0.02$), however, neither wetted width nor cumulative equivalent clearcut acreage were individually significant. This model was

$$\hat{y} = 0.54 - 4.26 \times width + 22.36 \times lwd - 39.57 \times cumeca,$$

suggesting that biomass, like density, decreased with increased wetted width and cumulative equivalent clearcut acreage but increased with increased amounts of large woody debris.

The second best three variable model for biomass included large woody debris, cumulative equivalent clearcut acreage, and road density was also significant in predicting biomass ($p = 0.026$). Large woody debris was the only significant predictor variable ($p = 0.005$) and missing values for large woody debris reduced the sample size to only 19 streams.

Wetted width and large woody debris together were able to account for nearly 36% of the variation in biomass. Although the model only included 20 streams, it was significant overall ($p = 0.023$) but large woody debris was not significant within the model ($p = 0.312$). This model was

$$\hat{y} = 0.59 - 4.64 \times width + 18.84 \times lwd$$

and is consistent with other models suggesting a negative relationship between biomass and wetted width and a positive relationship between biomass and large woody debris.

The best two variable model for biomass included large woody debris and cumulative equivalent clearcut acreage. The model was significant overall ($p = 0.023$) and both large woody debris ($p = 0.01$) and cumulative equivalent clearcut acreage ($p = 0.021$) were individually significant. This model was

$$\hat{y} = 0.51 + 23.75 \times lwd - 45.78 \times cumeca$$

and continues to show increased biomass with increased large woody debris and decreased biomass for increased cumulative equivalent clearcut acreage.

Cumulative equivalent clearcut acreage was significant alone in predicting biomass ($p = 0.034$) but was only able to account for 9.58% of the variability in biomass. Neither wetted width ($p = 0.077$) nor large woody debris ($p = 0.64$) were individually significant in predicting biomass.

Using multiple regression, I did not find any significant relationships between capture efficiency and any of the independent variables measured for this research ($p > 0.25$). Densities estimated for all streams sampled during 1996 ranged from 0.001 to 0.219 fish/m^2 ($\bar{x} = 0.057$, $s = 0.043$). Estimated biomass ranged from 0.008 to 2.105 g/m^2 ($\bar{x} = 0.037$, $s = 0.464$).

Discussion

Trout abundance in streams has been related to many physical habitat features including pool habitat (Irving 1987; Pratt 1984), geomorphologic and reach habitat (Lanka et al. 1987; Kruse et al. 1997), and large woody debris (Harvey 1998). Stream size and reach gradient have been suggested (Kozel and Hubert 1989) as two dominant geomorphic factors that strongly influence both stream habitat and trout standing crop in streams with little alteration by man. Possibly due to the long history of land use in the Coeur d'Alene basin (Maclay 1940) and the associated impacts at the watershed level, most variables measured at the site scale were not significant in predicting density or biomass of cutthroat trout. Wetted width, large woody debris count per 1000m channel, watershed area, cumulative equivalent clearcut area, and road density were the independent variables most related to cutthroat trout density and biomass. Wetted width is the only one of these variables measured at the site scale. Large woody debris counts were measured at the stream scale, and the others were measured at the watershed scale. Some watersheds sampled in the Coeur d'Alene River basin had more than 60% of the area clearcut in the last 30 years. From the best-fitting models for both cutthroat trout density and biomass, wetted width and a measure of disturbance due to timber harvest appear to be affecting abundance in the Coeur d'Alene River basin for the streams included in this analysis. Other researchers (Swanstrom 1991; Behnke 1992) also have found significant relationships between timber harvest activities and trout abundance. It is possible that other variables included in this research also have significant relationships with cutthroat trout density and biomass, but were excluded from analysis as a result of missing values.

Timber harvest activities have been reported to affect components of the hydrological cycle including precipitation, infiltration, evaporation, transpiration, storage and runoff (Swanston 1991). Clear-cutting causes increased snow deposition in the openings, and speeds the timing and rate of snowmelt. These effects can last for several decades. Snowmelt can be accelerated by the large wind-borne energy of warm rain falling on snow. Harvested areas contain wetter soils than unlogged areas during periods of evapotranspiration, hence higher groundwater levels and more potential late-summer runoff. Effects of harvest on erosion and sedimentation include effects due to road-related sediment productions (Furniss et al. 1991). Reid and Dunne (1984) report increased sediment productions by 40% when gravel-surfaced logging roads were heavily used by logging trucks. Increased mass movements have been associated with clearcuts and the associated roads (Rood 1984; O'Loughlin 1972). Channel forms can be affected by harvesting practices by weakening channel banks, removing the source of large woody debris, altering the frequency of channel-modifying flows, and changing sediment supply. Although road densities in some watersheds in the Coeur d'Alene River basin exceed 19 km/km^2 (U.S. Forest Service, unpublished data), road density was not significantly related to either cutthroat trout density or biomass.

Other impacts to the Coeur d'Alene River system from timber harvest activities include those from the water transportation of logs in the early part of this century. Before water transportation could occur, streams were cleared of obstructions and accumulations of debris. Small, low gradient streams were often substantially widened during log drives by the frequent flushings of the streams from splash dams and by the impacts of logs along the streambanks (Brown 1936). Many of the splash dams formed barriers to fish migration (Wendler and Deschamps 1955), but the long-term damage was probably caused by stream alterations made before drives including scouring, channel widening, and displacement of main-channel gravels that occurred before the drive.

Most of these effects occur at the stream, watershed, or sub-basin level, and could explain why densities observed in 1996 were more related to variables measured on these larger scales than at the site or habitat scale. These effects (water transportation of logs) are also probably occurring at scales larger than the site scale and probably contribute to the relationship between cutthroat density and the larger scale variables of large woody debris counts per 1000 m of channel and cumulative equivalent clearcut acreage. My results support the work of other authors (Hankin and Reeves, 1988; Rieman and McIntyre, 1995; Herger et al., 1996) that suggest that individual stream reaches are not sufficient sampling units because spatial variability in habitats at the basin scale influences the distribution of fish and are not accounted for simply by measuring reach-level variables.

Wildfires destroy the covering vegetation on slopes and along stream channels and may locally alter the physical properties of the surface layers of soil (Swanston 1991). Both total water yield and storm-flow discharges from the watershed are included in the immediate effects of forest burning. Fire also exposes the bare mineral soil to increased surface runoff and surface erosion. The potential for landslides is increased for up to 5 years due to the decay of anchoring and reinforcing root systems (Swanston 1974; Ziemer and Swanston 1977). The intense heat associated with the 1910 fire has still left much of the Upper Coeur d'Alene drainage altered. It is possible that although timber harvest has generally not occurred in that area, effects of the fire have had similar influences on cutthroat trout abundance as the extensive harvests in the other three drainages.

The combination of effects of extensive timber harvest, water transportation, road construction and the 1910 forest fire are likely more important reasons that a large amount of the variability in westslope cutthroat density in the Coeur d'Alene River basin is unaccounted for in this research. Although the Upper Coeur d'Alene drainage has generally not been logged and roads are at a minimum, it does not adequately serve as a "control" to compare results to drainages heavily impacted by timber harvest and road construction. Additional variability, possibly introduced from using the average capture efficiency to estimate fish numbers and densities, could be the portion unexplained by the physical variables.

I believe that an interaction of effects of land management practices including the 1910 fire, and physical habitat properties, explains the overall cutthroat trout abundance the Coeur d'Alene basin. The results of my research also suggest that densities are more impacted by effects at larger scales than the stream level, so any processes including land management practices that have effects on the larger scales are likely influencing the abundance of cutthroat trout. Most variables measured at the site scale (with the exception of wetted width) did not have significant relationships with cutthroat trout densities, suggesting that management at that small level may have little impact on fish populations.

Although Dunnigan (1997) found that capture efficiency for cutthroat trout in the Coeur d'Alene system was significantly related to wetted stream width, my results indicated that none of the habitat and physical variables measured could accurately predict sampling efficiency in 1996.

SUMMARY

1. I estimated cutthroat trout densities using single pass electrofishing for 62 second and third order tributaries in the Coeur d'Alene River Basin during 1996. Densities were used to quantify the effects of the winter, 1996 flood on cutthroat trout populations.

2. Cutthroat trout were present in every stream sampled in the Coeur d'Alene River Basin in 1996, indicating that no local extinctions occurred after a 100 year flood event.

3. Mean cutthroat density for the basin was significantly lower in 1996 than 1995, although mean densities for streams tributary to the Main Coeur d'Alene or North Fork Coeur d'Alene were not significantly different. Differences in density in streams tributary to the Upper Coeur d'Alene and Shoshone Creek were highly significant between the 2 years.

4. The range of densities observed in 1996 was substantially smaller than the previous year. Among the four large drainages, streams tributary to the North Fork Coeur d'Alene were nearly significantly different ($0.05 < p < 0.10$) from those tributary to the Main Coeur d'Alene River and Shoshone Creek in 1996. No other pairwise comparisons among the four drainages were significant.

5. Length frequency distributions of cutthroat trout were significantly different among 1994, 1995 and 1996. During both 1995 and 1996, few age-1 cutthroat trout were collected.

6. Significant differences were found in the distance from the stream mouth, wetted width, water temperature and gradient when age-0 cutthroat trout were present or absent, however, the probability of observing age-0 cutthroat trout was most significantly related to gradient ($p < 0.05$).

7. Cutthroat trout densities were modeled from physical habitat and land management variables. A significant model ($p = 0.001$) using wetted width, large woody debris counts per 1000 m of channel, and cumulative equivalent clearcut acreage ($R^2 = 0.638$) was found to predict cutthroat trout density.

8. Cutthroat trout biomass was also significantly related to wetted width, large woody debris counts per 1000 m channel, and equivalent cumulative clearcut acreage ($R^2 = 0.47$).

APPENDIX A

MEAN DENSITIES ESTIMATED IN 1995 AND 1996

Appendix Table A. Mean densities estimated in 1995 and 1996.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Alden	1	95	0.0584	0.0460	0.0293	0.1115
		96	0.0146	0.0153	0.0000	0.0304
	2	95	0.0665	0.0051	0.0611	0.0712
		96	0.0777	0.0923	0.0000	0.1797
	3	95	0.0688	0.1013	0.0000	0.1852
		96	0.1468	0.1036	0.0706	0.2647
Avery	1	95	0.1881	0.0895	0.0882	0.2609
		96	0.0969	0.0855	0.0201	0.1891
	2	95	0.2378	0.0518	0.1984	0.2965
		96	0.1631	0.0361	0.1343	0.2036
	3	95	0.1580	0.1477	0.0493	0.3262
		96	0.0913	0.0501	0.0334	0.1203
Barney	1	96	0.0350	0.0061	0.0304	0.0420
	2	96	0.0523	0.0747	0.0000	0.1379
	3	96	0.0539	0.0490	0.0221	0.1103
Bear	1	95	0.0227	0.0083	0.0168	0.0286
		96	0.2539	0.1891	0.0630	0.4412
	2	95	0.0585	.	0.0585	0.0585
		96	0.0951	0.0814	0.0473	0.1891
	3	95	0.0516	0.0168	0.0397	0.0635
		96	0.1858	0.1095	0.1103	0.3114
Big Elk	1	96	0.0266	0.0126	0.0123	0.0359
	2	96	0.0281	0.0289	0.0000	0.0577
	3	96	0.0547	0.0145	0.0460	0.0714
Big Hank	1	95	0.0738	0.0034	0.0714	0.0762
		96	.	.	.	.
	2	95	0.0462	0.0067	0.0414	0.0539
		96	0.0557	0.0552	0.0000	0.1103
	3	95	0.1459	0.1398	0.0488	0.3061
		96	0.0947	0.0213	0.0735	0.1161
Blacktail	1	95	0.0628	0.0016	0.0616	0.0646
		96	0.0138	0.0128	0.0000	0.0252
	2	95	0.0681	0.0488	0.0149	0.1107
		96	0.0746	0.0489	0.0410	0.1307
	3	95	0.0454	0.0245	0.0175	0.0635
		96	0.1400	0.0526	0.0817	0.1838
Bootjack	1	95	0.0164	.	0.0164	0.0164

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Bootjack	1	96	0.0000	0.0000	0.0000	0.0000
	2	95	0.0216	.	0.0216	0.0216
		96	0.0036	0.0062	0.0000	0.0108
	3	95	.	.	.	.
		96	0.0000	0.0000	0.0000	0.0000
Bottom	1	95	0.0503	0.0353	0.0253	0.0752
		96	0.0258	0.0226	0.0000	0.0420
	2	95	0.0743	0.0274	0.0549	0.0937
		96	0.0082	0.0142	0.0000	0.0245
	3	95	0.0771	0.0804	0.0157	0.1681
		96	0.0511	0.0322	0.0323	0.0882
Brett	1	95	0.0460	0.0340	0.0209	0.0847
		96	0.0041	0.0071	0.0000	0.0123
	2	95	0.0500	0.0337	0.0227	0.0876
		96	0.0000	0.0000	0.0000	0.0000
	3	95	0.0247	0.0040	0.0220	0.0293
		96	0.0000	0.0000	0.0000	0.0000
Browns	1	95	0.0424	0.0135	0.0328	0.0519
		96	0.0310	0.0242	0.0147	0.0588
	2	95	0.0517	0.0034	0.0493	0.0541
		96	0.0580	0.0282	0.0294	0.0858
	3	95	0.0251	.	0.0251	0.0251
		96	0.0350	0.0321	0.0000	0.0630
Buckskin	1	95	0.2683	0.1373	0.1671	0.4246
		96	0.0049	0.0085	0.0000	0.0147
	2	95	0.1698	0.1135	0.0835	0.2983
		96	0.0700	0.1036	0.0000	0.1891
	3	95	0.2318	0.1632	0.1323	0.4202
		96	0.0350	0.0061	0.0304	0.0420
Bumblebee	1	95	.	.	.	.
		96	0.0035	0.0061	0.0000	0.0105
	2	95	.	.	.	.
		96	0.0049	0.0085	0.0000	0.0147
	3	95	0.0612	0.0631	0.0138	0.1329
		96	0.0247	0.0216	0.0000	0.0401
Burnt Cabin	1	95	0.0284	0.0109	0.0207	0.0361
		96	0.0278	0.0072	0.0196	0.0333

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Burnt Cabin	2	95	.	.	.	.
		96	0.0267	0.0343	0.0000	0.0654
	3	95	0.0301	.	0.0301	0.0301
		96	0.0694	0.0270	0.0392	0.0913
Cabin	1	95	0.0679	0.0586	0.0265	0.1093
		96	0.0437	0.0140	0.0324	0.0594
	2	95	0.3074	0.1073	0.1917	0.4037
		96	0.1057	0.0722	0.0619	0.1891
	3	95	0.3502	0.0448	0.3045	0.3941
		96	0.1722	0.0387	0.1285	0.2022
Cascade	1	95	0.0614	0.0275	0.0420	0.0809
		96	0.0042	0.0073	0.0000	0.0126
	2	95	0.0528	0.0345	0.0284	0.0772
		96	0.0177	0.0102	0.0113	0.0294
	3	95	0.1242	0.0461	0.0916	0.1568
		96	0.0670	0.0212	0.0427	0.0817
Cateract	1	95	0.0964	.	0.0964	0.0964
Clinton	1	95	.	.	.	.
		96	0.0833	0.0557	0.0441	0.1471
	2	95	0.0677	0.0135	0.0582	0.0772
		96	0.0152	0.0133	0.0000	0.0245
	3	95	0.1795	0.1188	0.0807	0.3114
		96	0.1019	0.0296	0.0679	0.1218
Coal	1	95	0.0194	0.0055	0.0155	0.0232
		96	0.0428	0.0129	0.0350	0.0577
	2	96	0.0000	.	0.0000	0.0000
Dahlman	1	95	0.1203	0.0429	0.0752	0.1605
		96	0.0241	0.0210	0.0000	0.0384
	2	95	0.1240	0.0645	0.0552	0.1832
		96	0.0245	0.0425	0.0000	0.0735
	3	95	0.2484	.	0.2484	0.2484
		96	0.0243	0.0072	0.0192	0.0294
Deception	1	95	.	.	.	.
		96	0.0455	0.0398	0.0000	0.0735
	2	95	0.0251	.	0.0251	0.0251
		96	0.0000	0.0000	0.0000	0.0000
	3	95	0.0214	0.0040	0.0185	0.0242

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Deception	3	96	0.0290	0.0181	0.0090	0.0441
Deer	1	95	0.0459	0.0491	0.0143	0.1024
		96	0.0179	0.0079	0.0088	0.0228
	2	95	0.0467	0.0243	0.0237	0.0721
		96	0.0000	0.0000	0.0000	0.0000
	3	95	0.0337	0.0143	0.0237	0.0438
		96	0.0284	0.0320	0.0000	0.0630
Downey	1	95	0.0241	0.0219	0.0086	0.0395
		96	0.0452	0.0300	0.0169	0.0766
	2	95	0.0267	0.0232	0.0089	0.0529
		96	0.0073	0.0066	0.0000	0.0128
	3	95	0.0403	0.0162	0.0256	0.0577
		96	0.0882	0.0353	0.0490	0.1176
East Alden	1	95	0.0527	0.0210	0.0284	0.0655
		96	0.0338	0.0318	0.0000	0.0630
	2	95	0.0591	0.0485	0.0247	0.0934
		96	0.0067	0.0116	0.0000	0.0201
	3	95	0.0937	0.0637	0.0298	0.1571
		96	0.0437	0.0075	0.0384	0.0490
East Fork Steamboat	1	95	0.0745	0.0358	0.0533	0.1158
		96	0.0249	0.0077	0.0200	0.0338
	2	95	0.0585	0.0386	0.0290	0.1022
		96	0.1328	0.1282	0.0189	0.2717
	3	95	0.1671	0.1106	0.0744	0.2896
		96	0.1401	0.1074	0.0265	0.2399
Falls	2	95	0.1283	0.0108	0.1159	0.1361
	3	95	0.1224	0.0297	0.1036	0.1567
Grizzly	1	95	0.0648	0.0307	0.0431	0.0866
		96	0.0906	0.0148	0.0774	0.1066
	2	95	0.1722	0.1183	0.0774	0.3048
		96	0.1106	0.0596	0.0460	0.1634
	3	95	0.2440	0.0325	0.2070	0.2679
		96	0.4541	0.2992	0.1532	0.7516
Halsey	1	96	0.0748	0.0414	0.0501	0.1225
	2	96	0.0556	0.0227	0.0408	0.0817
	3	96	0.0440	0.0207	0.0315	0.0679
Haystack	1	95	0.0393	0.0256	0.0229	0.0688

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Haystack	2	95	0.0663	0.0283	0.0340	0.0866
	3	95	0.0355	0.0070	0.0275	0.0405
Hemlock	1	95	0.0236	0.0113	0.0164	0.0366
		96	0.0138	0.0239	0.0000	0.0414
	2	95	0.0337	0.0261	0.0152	0.0521
		96	0.0434	0.0620	0.0000	0.1144
	3	95	0.1108	0.0794	0.0194	0.1633
		96	0.0806	0.0587	0.0358	0.1471
Hemlock (Shoshone)	1	95	0.0348	0.0210	0.0154	0.0571
		96	0.0278	0.0104	0.0184	0.0389
	2	95	0.0807	0.0247	0.0585	0.1073
		96	0.0716	0.0290	0.0456	0.1029
	3	95	0.1479	0.0304	0.1166	0.1772
		96	0.0907	0.0185	0.0735	0.1103
Honey	1	96	0.0000	0.0000	0.0000	0.0000
	2	96	0.0207	0.0012	0.0201	0.0221
	3	96	0.0067	0.0116	0.0000	0.0201
Iron	1	96	0.0883	0.0512	0.0535	0.1471
	2	96	0.0694	0.0636	0.0288	0.1427
	3	96	0.0465	0.0646	0.0000	0.1203
Jordan	1	95	0.5335	0.1601	0.4329	0.7181
		96	0.0222	0.0238	0.0000	0.0473
	2	95	0.4303	0.0537	0.3759	0.4833
		96	0.0621	0.0220	0.0384	0.0817
	3	95	0.1240	0.0798	0.0508	0.2091
		96	0.0686	0.0731	0.0170	0.1203
Laverne	1	95	0.0120	0.0011	0.0112	0.0128
		96	0.0216	0.0034	0.0176	0.0238
	2	95	0.0310	.	0.0310	0.0310
		96	0.0067	0.0058	0.0000	0.0103
	3	95	0.0208	0.0095	0.0144	0.0317
		96	0.0173	0.0206	0.0000	0.0401
Lavin	1	95	0.0181	.	0.0181	0.0181
		96	0.0229	0.0065	0.0158	0.0285
	2	95	0.0455	0.0118	0.0331	0.0566
		96	0.0593	0.0934	0.0000	0.1669
	3	95	0.0672	0.0682	0.0190	0.1154

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Lavin	3	96	0.2594	0.0788	0.2076	0.3501
Leiburg	1	96	0.0022	0.0037	0.0000	0.0065
	2	96	0.0028	0.0049	0.0000	0.0085
	3	96	0.0061	0.0106	0.0000	0.0184
Lewelling	1	95	0.0234	.	0.0234	0.0234
		96	0.0415	0.0600	0.0000	0.1103
	2	95	0.0728	0.0600	0.0304	0.1152
		96	0.0918	0.0738	0.0260	0.1716
	3	95	0.0577	0.0266	0.0389	0.0765
		96	0.0000	.	0.0000	0.0000
Little Lost Fork	1	95	0.0492	0.0231	0.0232	0.0674
		96	0.0239	0.0063	0.0184	0.0308
	2	95	0.0628	0.0229	0.0435	0.0882
		96	0.0334	0.0298	0.0000	0.0572
	3	95	0.2081	.	0.2081	0.2081
		96	0.0308	0.0190	0.0092	0.0452
Little Tepee	1	95	0.0196	.	0.0196	0.0196
		96	0.0061	0.0106	0.0000	0.0184
	2	95	0.0130	.	0.0130	0.0130
		96	0.0296	0.0267	0.0000	0.0519
	3	95	0.1769	0.2102	0.0283	0.3256
		96	0.1054	0.0200	0.0835	0.1225
Lone Cabin	1	95	0.0224	0.0031	0.0203	0.0260
		96	0.0221	0.0095	0.0126	0.0315
	2	95	0.0227	0.0054	0.0164	0.0261
		96	0.0801	0.0252	0.0519	0.1003
	3	95	0.0369	0.0195	0.0230	0.0507
		96	0.0134	0.0232	0.0000	0.0401
Lost Fork	1	95	0.2287	0.0493	0.1725	0.2646
		96	0.0069	0.0119	0.0000	0.0206
	2	95	0.7099	0.2524	0.5252	0.9974
		96	0.0274	0.0041	0.0232	0.0315
	3	95	0.2460	0.0371	0.2070	0.2810
		96	0.0337	0.0188	0.0201	0.0551
Marten	1	95	0.0677	0.0567	0.0276	0.1078
		96	0.0850	0.0083	0.0802	0.0945
	2	95	0.1274	0.0282	0.0969	0.1524

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Marten	2	96	0.0560	0.0642	0.0000	0.1261
	3	95	0.1044	0.0351	0.0657	0.1341
		96	0.0884	0.0239	0.0630	0.1103
Middle Fork Hudlow	1	96	0.0466	0.0405	0.0000	0.0735
	2	96	0.0694	0.0212	0.0464	0.0882
	3	96	0.0761	.	0.0761	0.0761
Mosquito	1	95	0.0757	0.0259	0.0541	0.1044
		96	0.0582	0.0348	0.0201	0.0882
	2	95	0.0741	0.0355	0.0471	0.1143
		96	0.0972	0.0706	0.0210	0.1604
	3	95	0.1907	0.1734	0.0680	0.3133
		96	0.0000	.	0.0000	0.0000
Nicholas	1	95	0.0180	0.0014	0.0170	0.0190
		96	0.0158	0.0273	0.0000	0.0473
	2	95	0.0384	0.0189	0.0172	0.0537
		96	0.0878	0.0517	0.0519	0.1471
	3	95	0.0528	0.0335	0.0292	0.0765
		96	0.1020	0.0523	0.0420	0.1379
North Grizzly	1	95	0.0735	0.0217	0.0484	0.0864
		96	0.0996	0.1048	0.0368	0.2206
	2	95	0.1886	0.0803	0.1058	0.2661
		96	0.0746	0.0787	0.0267	0.1654
	3	95	0.1457	0.0477	0.0907	0.1764
		96	0.1680	0.1226	0.0848	0.3088
Picnic	1	95	0.0550	0.0250	0.0261	0.0700
		96	0.0311	0.0233	0.0170	0.0580
	2	95	0.0535	0.0270	0.0246	0.0781
		96	0.0201	0.0193	0.0000	0.0384
	3	95	0.1993	.	0.1993	0.1993
		96	0.0170	.	0.0170	0.0170
Pine Flat	1	95	0.0334	0.0139	0.0192	0.0470
		96	0.0390	0.0267	0.0094	0.0613
	2	95	0.1012	0.0139	0.0907	0.1170
		96	0.0563	0.0555	0.0226	0.1203
	3	95	0.1345	.	0.1345	0.1345
		96	0.0704	0.0253	0.0525	0.0882
Rampike	1	95	0.1723	0.0897	0.0687	0.2241

Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Rampike	1	96	0.0331	0.0468	0.0000	0.0662
	2	95	0.1047	0.0278	0.0788	0.1341
		96	0.2034	0.2208	0.0473	0.3595
	3	95	0.1768	0.0517	0.1405	0.2360
		96	0.0828	0.0493	0.0480	0.1176
Scott	1	95	0.1108	0.0018	0.1095	0.1120
		96	0.0568	0.0283	0.0251	0.0795
	2	95	0.0527	0.0308	0.0224	0.0840
		96	0.0775	0.0230	0.0600	0.1036
	3	95	0.1416	0.0594	0.0929	0.2078
		96	0.0420	0.0417	0.0000	0.0834
Sentinel	1	95	0.0501	0.0254	0.0335	0.0794
		96	0.0404	0.0120	0.0301	0.0535
	2	95	0.0729	0.0744	0.0286	0.1587
		96	0.0483	0.0289	0.0212	0.0788
	3	95	0.0920	0.0061	0.0877	0.0963
Sob	1	96	0.0100	0.0174	0.0000	0.0301
Solitaire	1	96	0.0648	0.0233	0.0401	0.0863
	2	96	0.0290	0.0268	0.0000	0.0529
	3	96	0.0359	0.0315	0.0000	0.0588
Spruce	2	95	0.2317	0.0426	0.1843	0.2670
		96	0.0241	0.0139	0.0083	0.0346
	3	95	0.3725	0.0469	0.3206	0.4118
		96	0.0813	0.0401	0.0389	0.1188
Svee	1	95	0.0506	0.0356	0.0128	0.0835
		96	0.0586	0.0401	0.0126	0.0858
	2	95	0.0248	0.0031	0.0227	0.0270
		96	0.0676	0.0223	0.0530	0.0932
Teddy	1	95	0.0483	0.0246	0.0224	0.0714
		96	0.0911	0.0599	0.0537	0.1602
	2	95	0.0779	0.0605	0.0414	0.1478
		96	0.1219	0.0446	0.0934	0.1733
	3	95	0.0518	0.0136	0.0417	0.0672
		96	0.0619	0.0171	0.0516	0.0817
Tie	1	95	0.0682	0.0205	0.0446	0.0821
		96	0.0440	0.0303	0.0170	0.0767
	2	95	0.0973	0.0892	0.0220	0.1958

Appendix Table A. Continued.

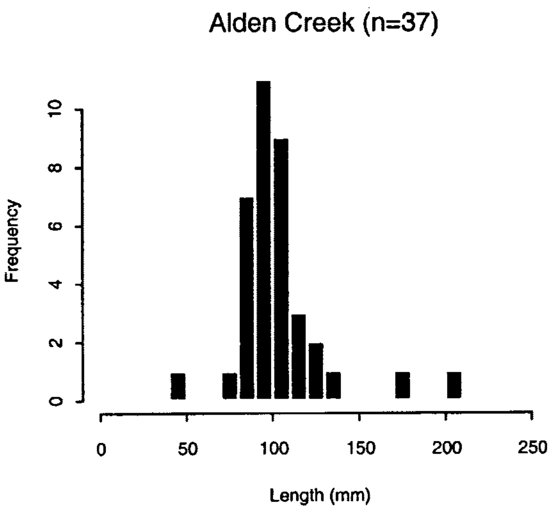
Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Tie	2	96	0.0543	0.0489	0.0201	0.1103
	3	95	0.0626	0.0558	0.0231	0.1020
		96	0.1413	0.1356	0.0000	0.2704
Tom Lavin	1	96	0.0105	0.0182	0.0000	0.0315
	2	96	0.0389	0.0286	0.0184	0.0715
	3	96	0.1094	0.0663	0.0410	0.1733
Ulm	1	95	0.0537	0.0486	0.0225	0.1096
		96	0.0531	0.0537	0.0142	0.1144
	2	95	0.0971	0.0357	0.0719	0.1223
		96	0.0708	0.0493	0.0260	0.1235
	3	95	.	.	.	.
		96	0.0593	0.0392	0.0142	0.0858
Upper Coeur d'Alene	1	95	0.0781	0.0406	0.0323	0.1095
		96	0.0089	0.0154	0.0000	0.0267
	2	95	0.2399	0.1080	0.1488	0.3591
		96	0.0227	0.0215	0.0000	0.0427
Upper Coeur d'Alene	3	95	0.1299	0.0935	0.0581	0.2356
		96	0.0265	0.0063	0.0192	0.0308
West Elk	1	95	0.0513	0.0416	0.0115	0.0945
	2	95	0.0868	0.0633	0.0397	0.1587
	3	95	0.0640	.	0.0640	0.0640
West Fork Hudlow	1	96	0.0303	0.0179	0.0100	0.0441
	2	96	0.0233	0.0239	0.0000	0.0477
	3	96	0.0000	0.0000	0.0000	0.0000
West Fork Steamboat	1	95	0.0599	0.0142	0.0435	0.0685
		96	0.0228	0.0070	0.0163	0.0302
	2	95	0.1283	0.0654	0.0675	0.1975
		96	0.0859	0.0672	0.0452	0.1634
	3	95	0.2240	0.0942	0.1366	0.3238
		96	0.3782	0.2683	0.1961	0.6863
Whitetail	1	95	0.1818	0.1878	0.0705	0.3987
		96	0.0394	0.0518	0.0000	0.0980
	2	95	0.1294	0.0538	0.0740	0.1814
		96	0.0490	0.0281	0.0184	0.0735
	3	95	0.1109	0.0544	0.0529	0.1609
		96	0.1722	0.0540	0.1103	0.2101
Yellowdog	1	95	0.0398	0.0082	0.0340	0.0491

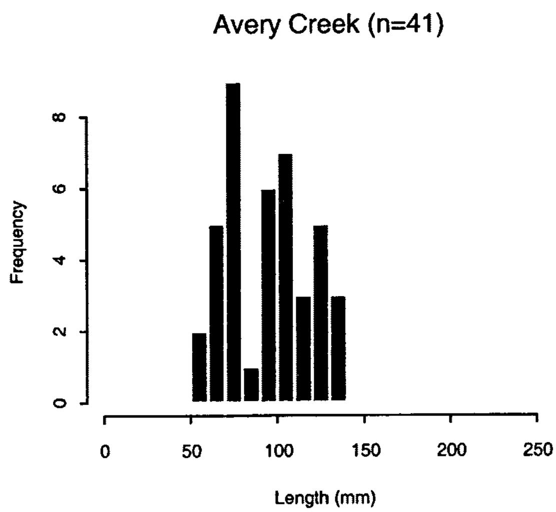
Appendix Table A. Continued.

Stream	Reach	Year	Mean	Std Dev	Minimum	Maximum
Yellowdog	1	96	0.0053	0.0093	0.0000	0.0160
	2	95	0.0452	0.0124	0.0340	0.0586
		96	0.0338	0.0121	0.0198	0.0410
	3	95	0.0366	0.0110	0.0298	0.0493
		96	0.0228	0.0122	0.0095	0.0334

APPENDIX B

1996 LENGTH FREQUENCY DISTRIBUTIONS


Alden Creek (n=37)
Frequency
0 2 4 6 8 10
0 50 100 150 200 250
Length (mm)


Avery Creek (n=41)
Frequency
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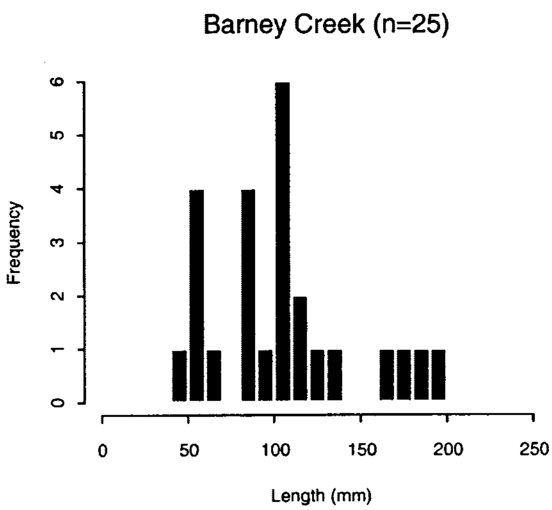
Length (mm)


Barney Creek (n=25)
Frequency
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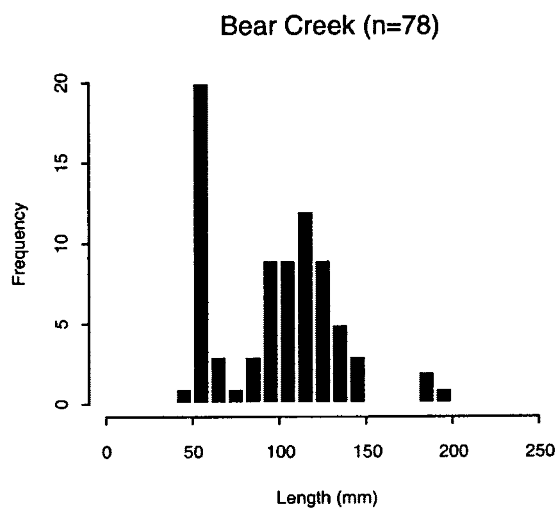
0 50 100 150 200 250
Length (mm)


Bear Creek (n=78)
Frequency
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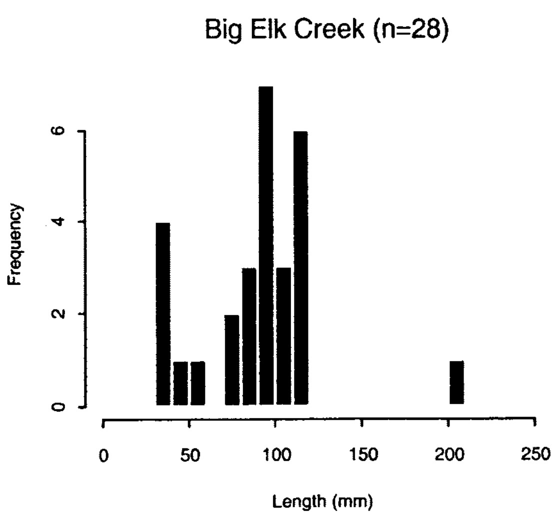
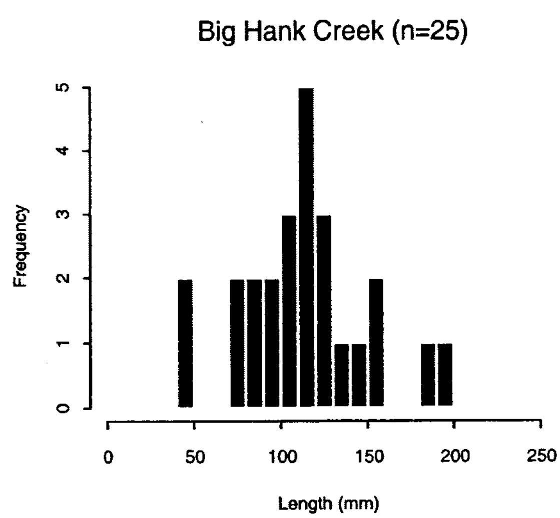
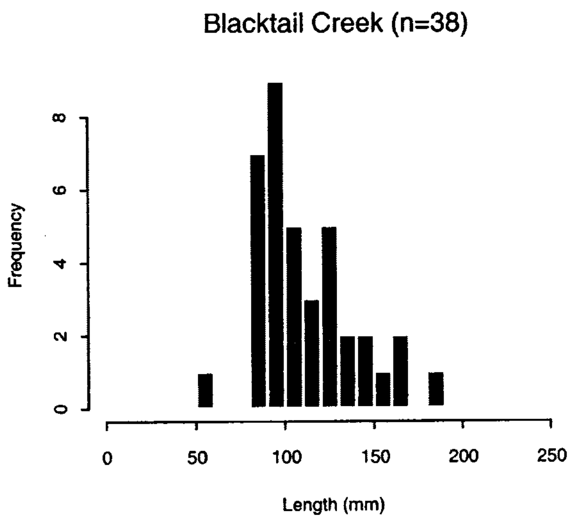
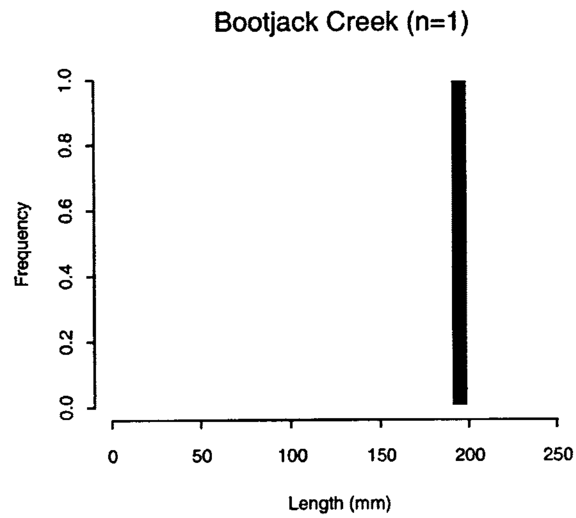
0 50 100 150 200 250
Length (mm)


Big Elk Creek (n=28)
Frequency
0 2 4 6
0 50 100 150 200 250
Length (mm)


Big Hank Creek (n=25)
Frequency
0 1 2 3 4 5
0 50 100 150 200 250
Length (mm)


Blacktail Creek (n=38)
Frequency
0
2
4
6
8
0
50
100
150
200
250
Length (mm)


Bootjack Creek (n=1)
Frequency
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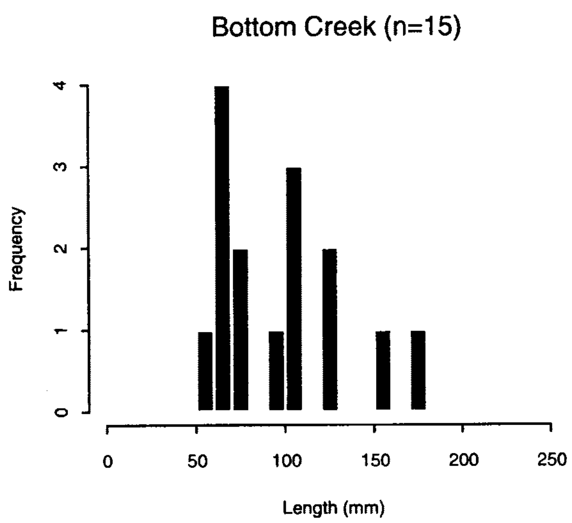
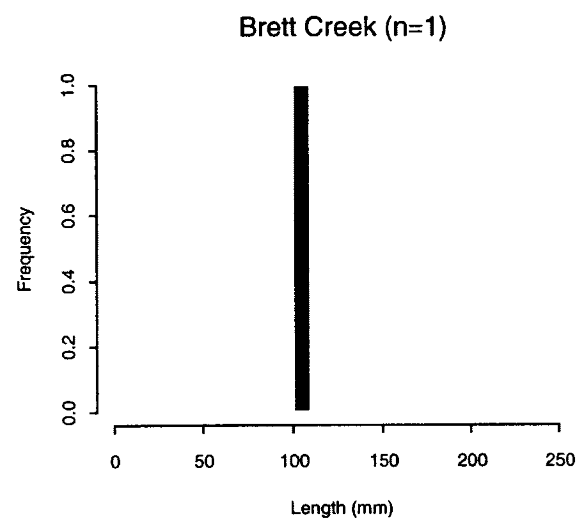
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
Length (mm)


Bottom Creek (n=15)
Frequency
0
1
2
3
4
0
50
100
150
200
250
Length (mm)


Brett Creek (n=1)
Frequency
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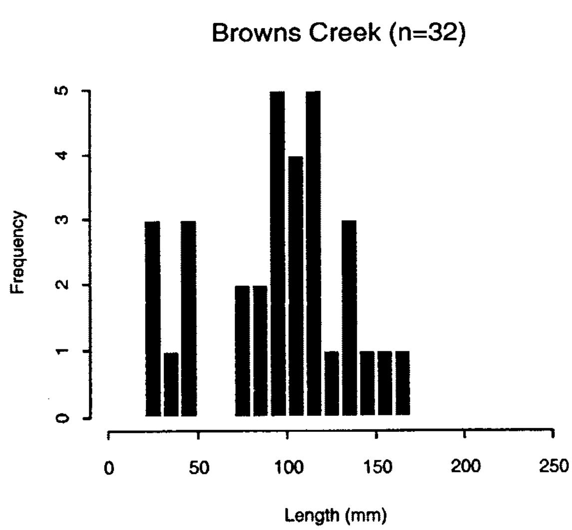
0.4
0.6
0.8
1.0
0
50
100
150
200
250
Length (mm)


Browns Creek (n=32)
Frequency
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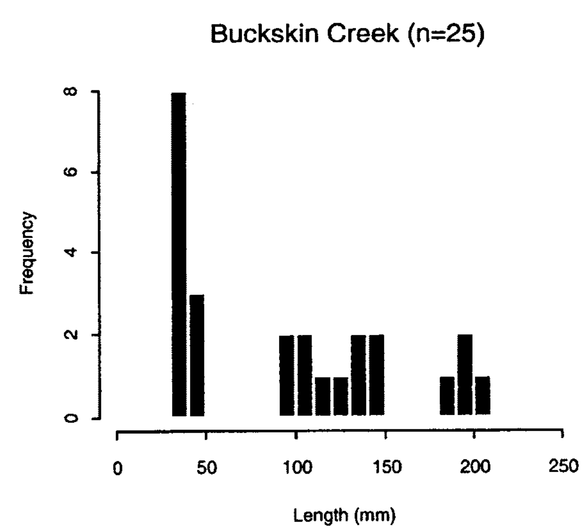
1
2
3
4
5
0
50
100
150
200
250
Length (mm)


Buckskin Creek (n=25)
Frequency
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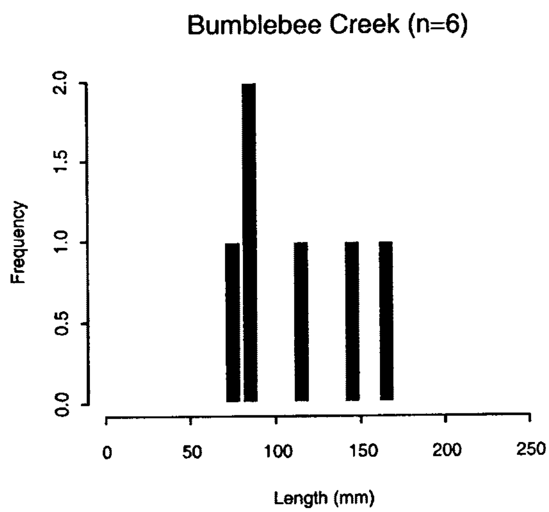
2
4
6
8
0
50
100
150
200
250
Length (mm)


Bumblebee Creek (n=6)
Frequency
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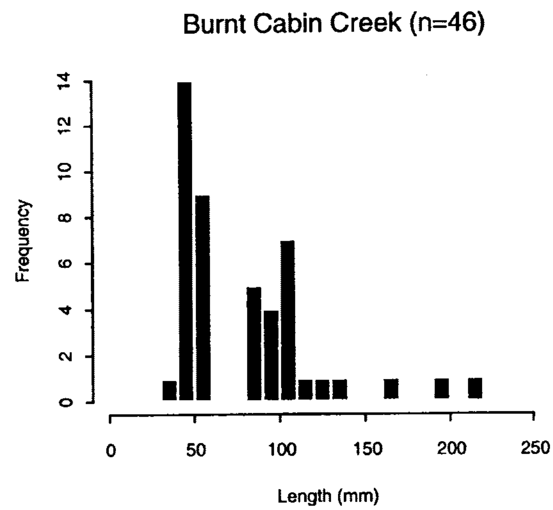
0.5
1.0
1.5
2.0
0
50
100
150
200
250
Length (mm)


Burnt Cabin Creek (n=46)
Frequency
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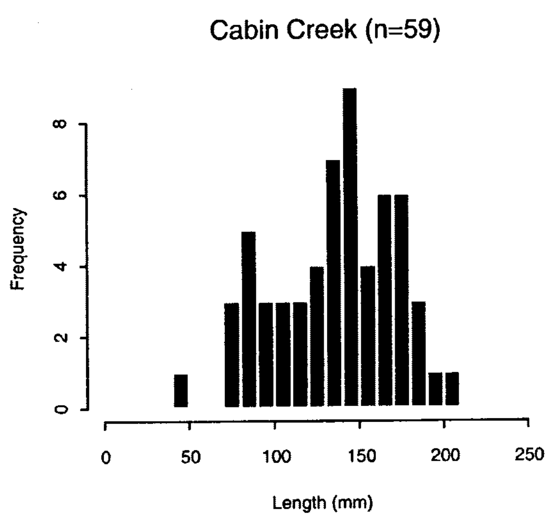
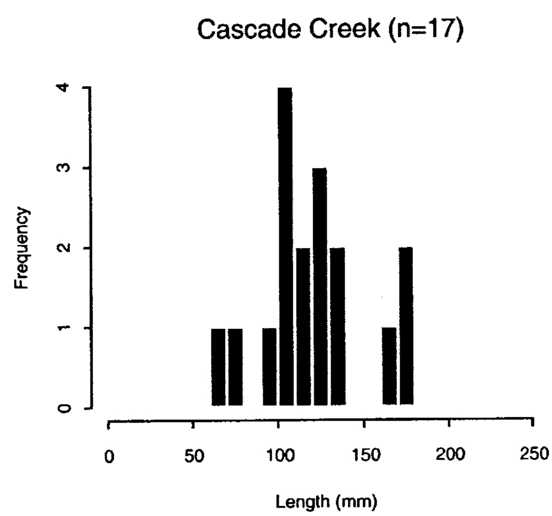
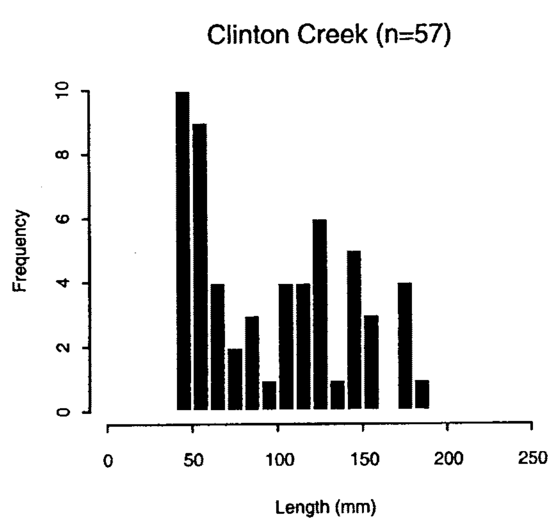
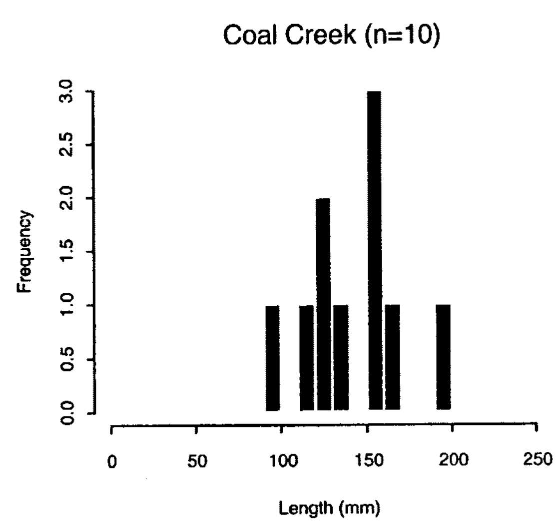
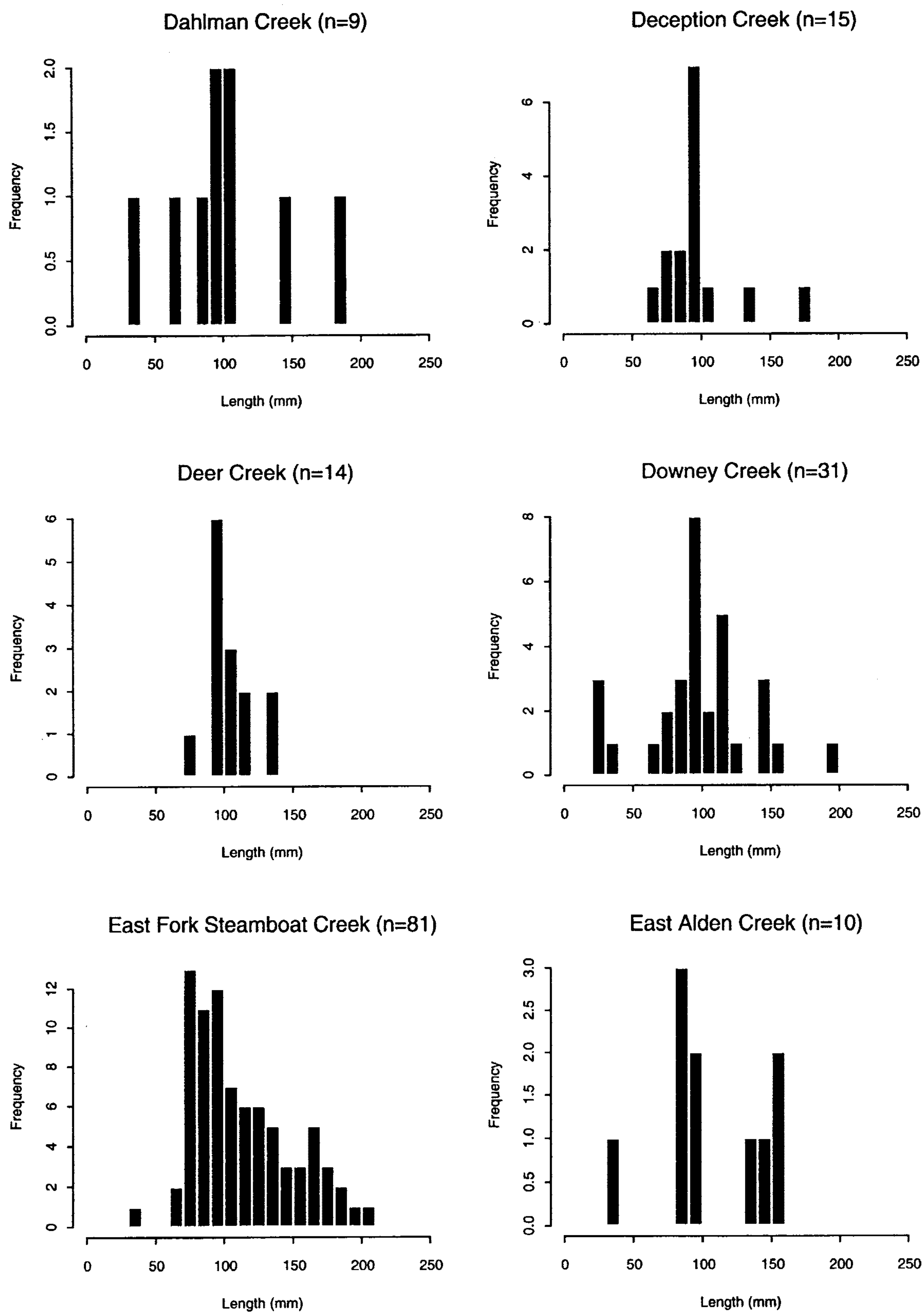
2
4
6
8
10
12
14
0
50
100
150
200
250
Length (mm)

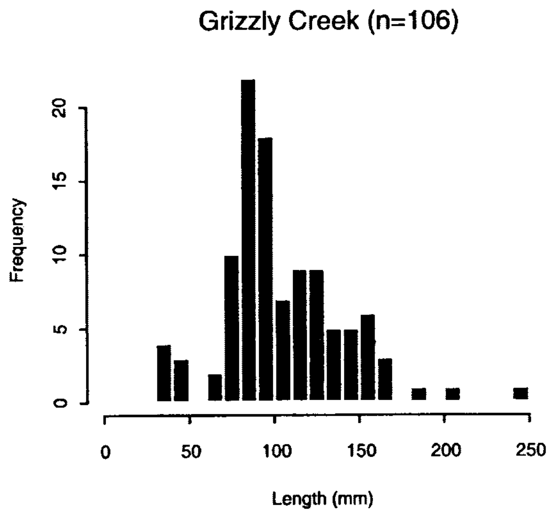

Cabin Creek (n=59)
Frequency
0
2
4
6
8
0
50
100
150
200
250
Length (mm)

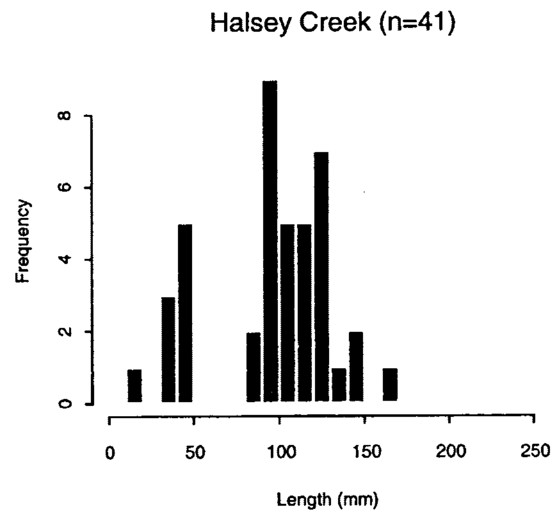

Cascade Creek (n=17)
Frequency
0
1
2
3
4
0
50
100
150
200
250
Length (mm)

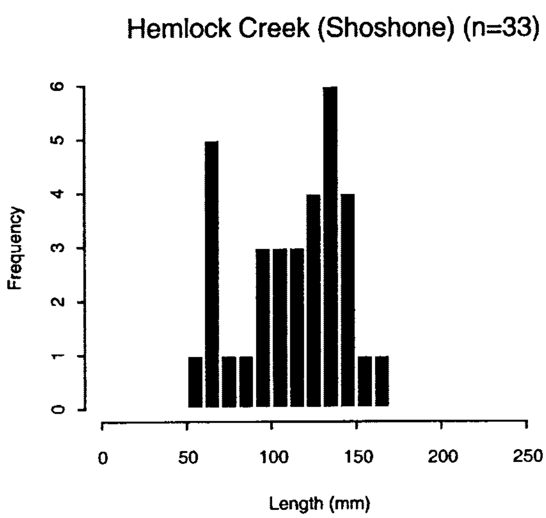

Clinton Creek (n=57)
Frequency
0
2
4
6
8
10
0
50
100
150
200
250
Length (mm)

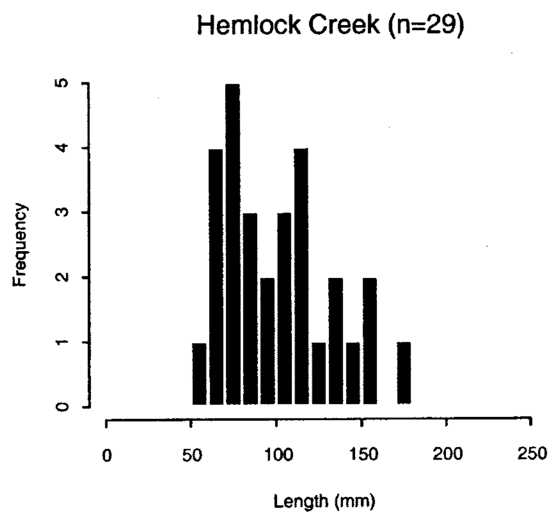

Coal Creek (n=10)
Frequency
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
50
100
150
200
250
Length (mm)

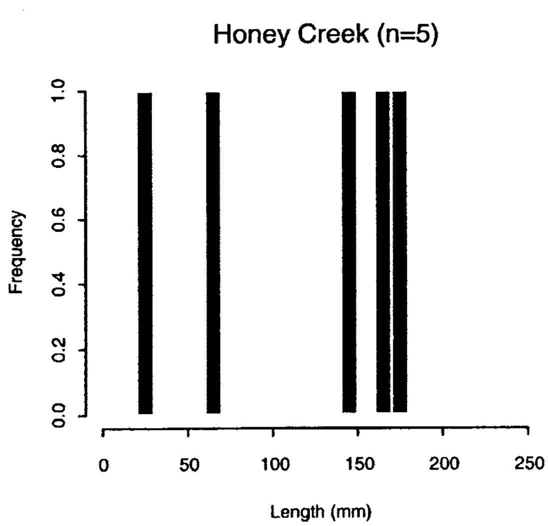

Dahlman Creek (n=9)
Frequency
Length (mm)
Deception Creek (n=15)
Frequency
Length (mm)
Deer Creek (n=14)
Frequency
Length (mm)
Downey Creek (n=31)
Frequency
Length (mm)
East Fork Steamboat Creek (n=81)
Frequency
Length (mm)
East Alden Creek (n=10)
Frequency
Length (mm)

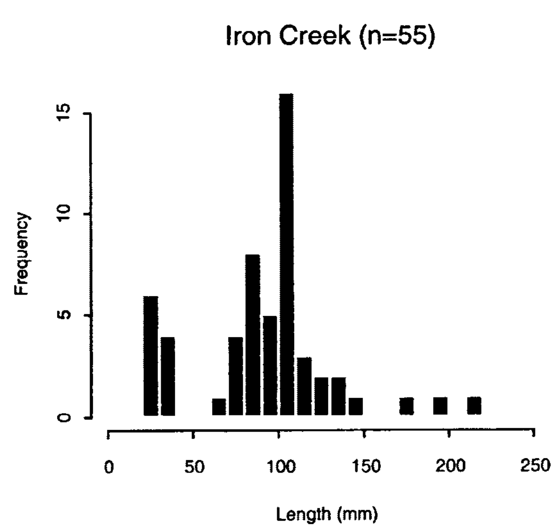

Grizzly Creek (n=106)
Frequency
0 5 10 15 20
0 50 100 150 200 250
Length (mm)

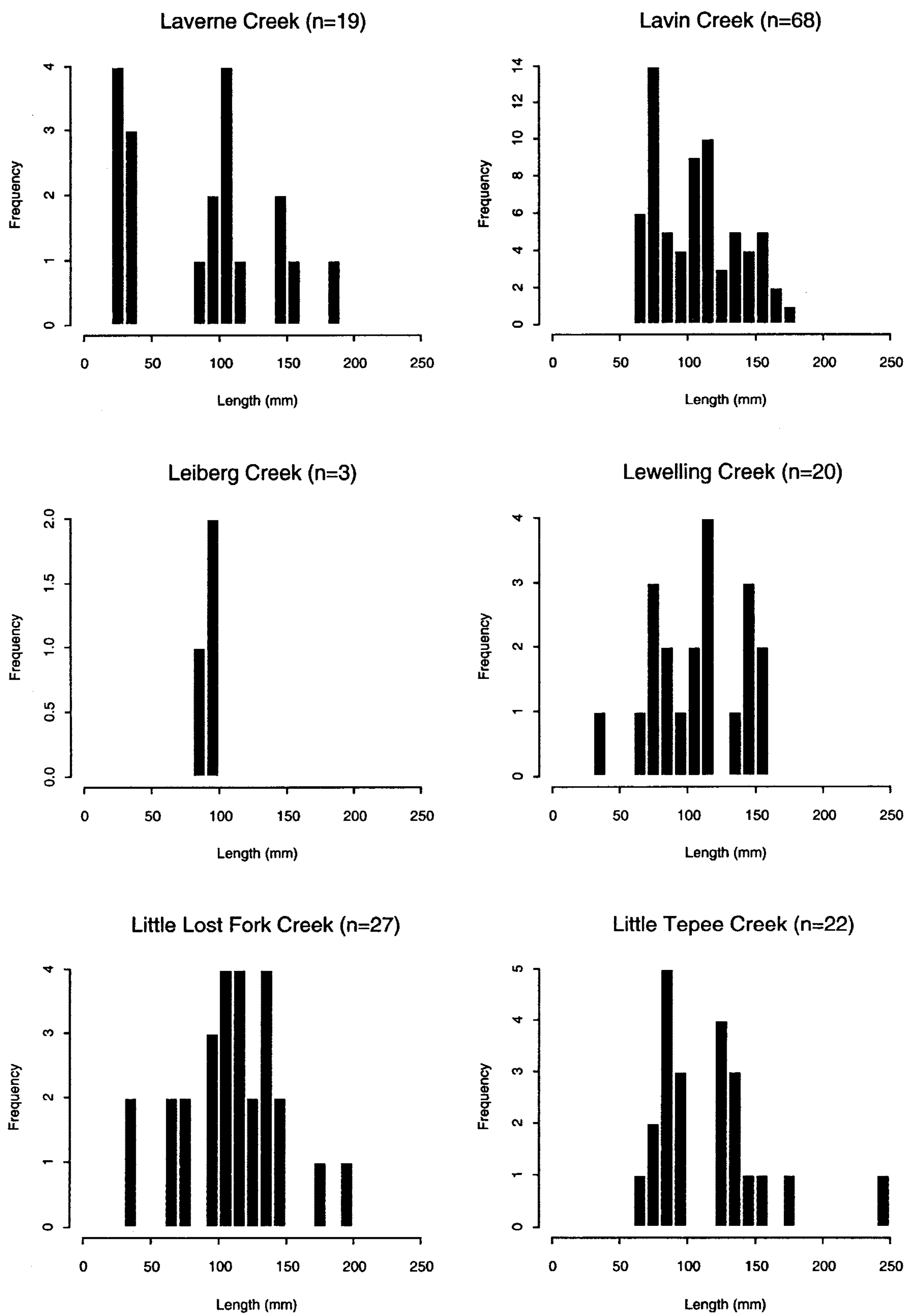

Halsey Creek (n=41)
Frequency
0 2 4 6 8
0 50 100 150 200 250
Length (mm)


Hemlock Creek (Shoshone) (n=33)
Frequency
0 1 2 3 4 5 6
0 50 100 150 200 250
Length (mm)

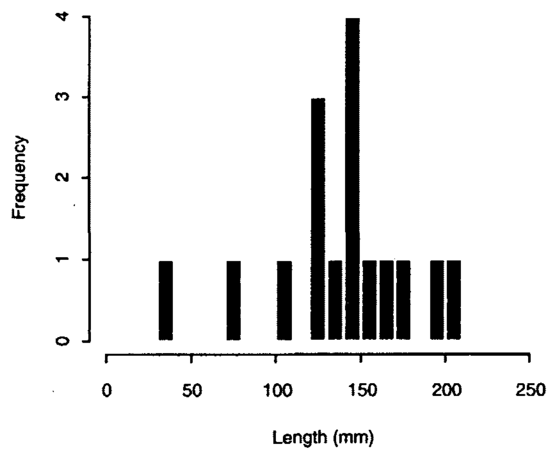

Hemlock Creek (n=29)
Frequency
0 1 2 3 4 5
0 50 100 150 200 250
Length (mm)


Honey Creek (n=5)
Frequency
0.0 0.2 0.4 0.6 0.8 1.0
0 50 100 150 200 250
Length (mm)

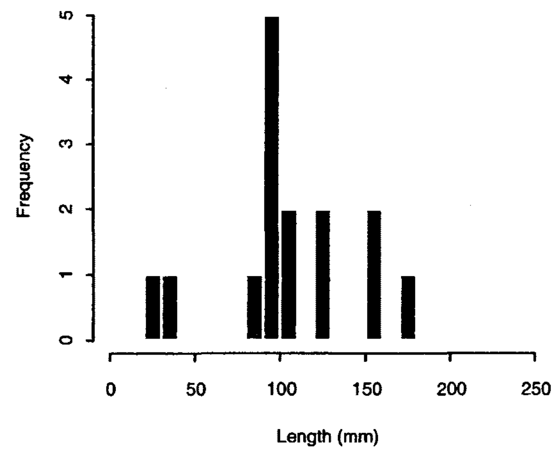

Iron Creek (n=55)
Frequency
0 5 10 15
0 50 100 150 200 250
Length (mm)


Laverne Creek (n=19)
Frequency
0 1 2 3 4
0 50 100 150 200 250
Length (mm)
Lavin Creek (n=68)
Frequency
0 2 4 6 8 10 12 14
0 50 100 150 200 250
Length (mm)
Leiberg Creek (n=3)
Frequency
0.0 0.5 1.0 1.5 2.0
0 50 100 150 200 250
Length (mm)
Lewelling Creek (n=20)
Frequency
0 1 2 3 4
0 50 100 150 200 250
Length (mm)
Little Lost Fork Creek (n=27)
Frequency
0 1 2 3 4
0 50 100 150 200 250
Length (mm)
Little Tepee Creek (n=22)
Frequency
0 1 2 3 4 5
0 50 100 150 200 250
Length (mm)

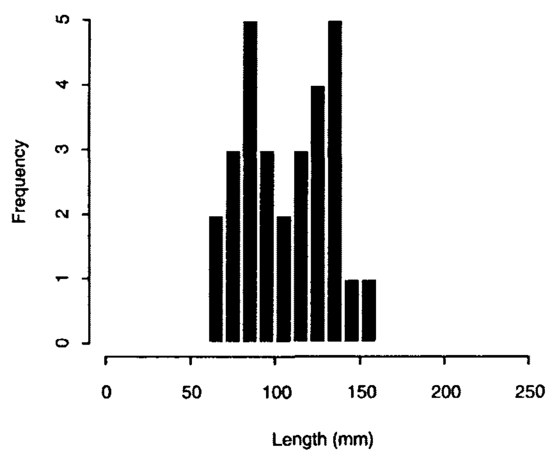
Lone Cabin Creek (n=16)



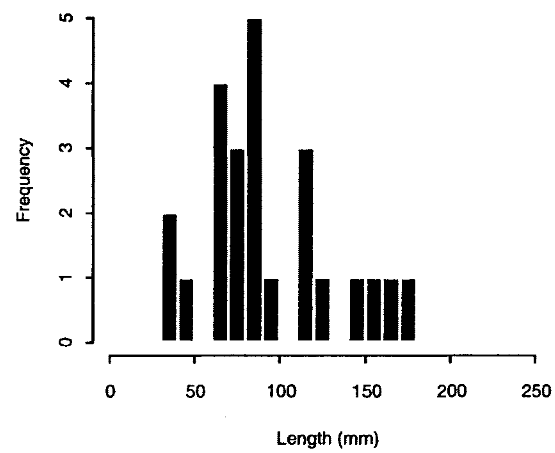
Lost Fork Creek (n=15)



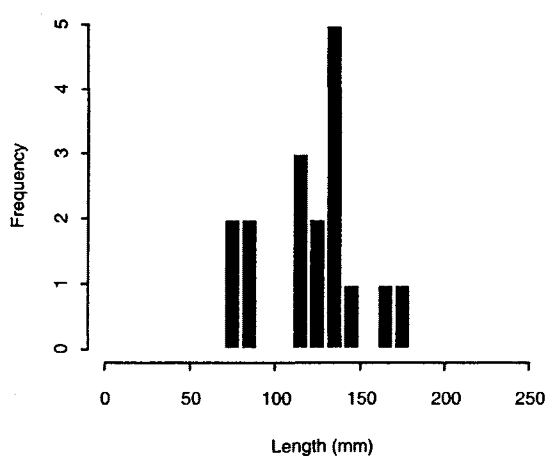
Marten Creek (n=29)



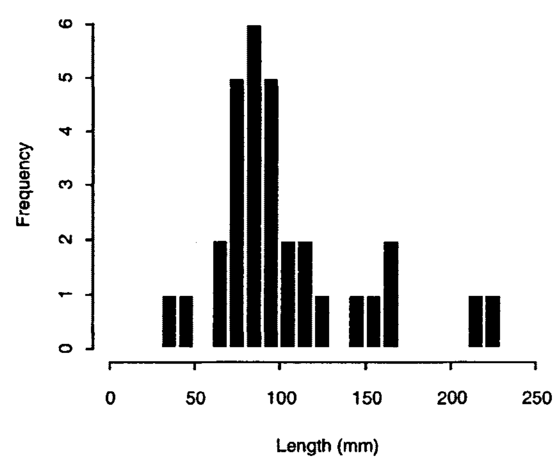
Middle Fork Hudlow Creek (n=24)

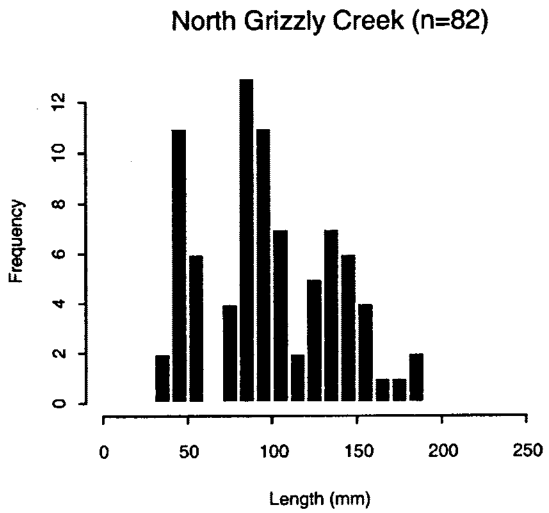


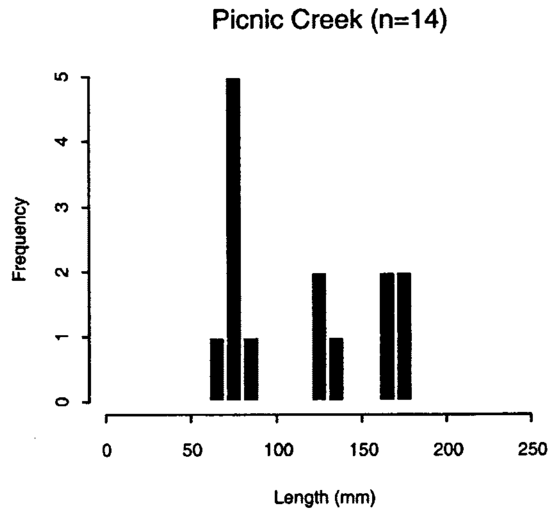
Mosquito Creek (n=17)

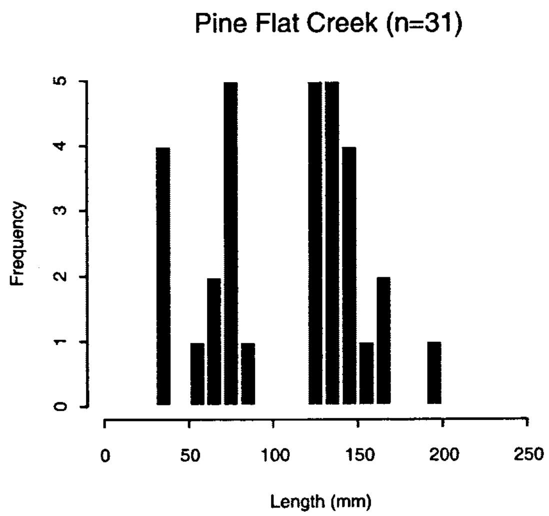


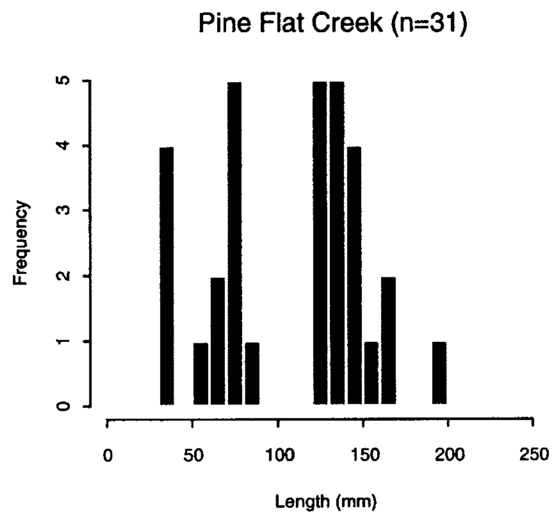
Nicholas Creek (n=31)

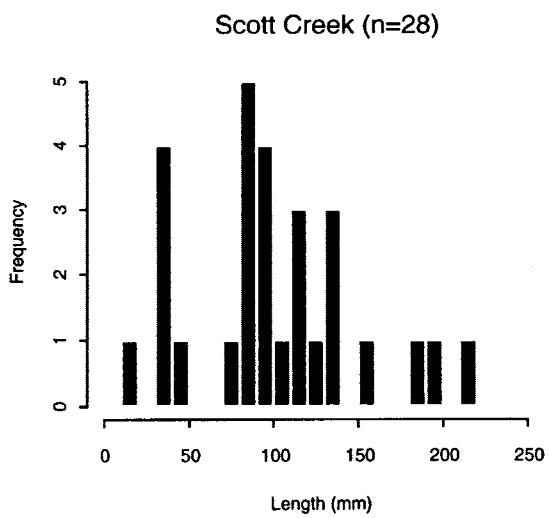


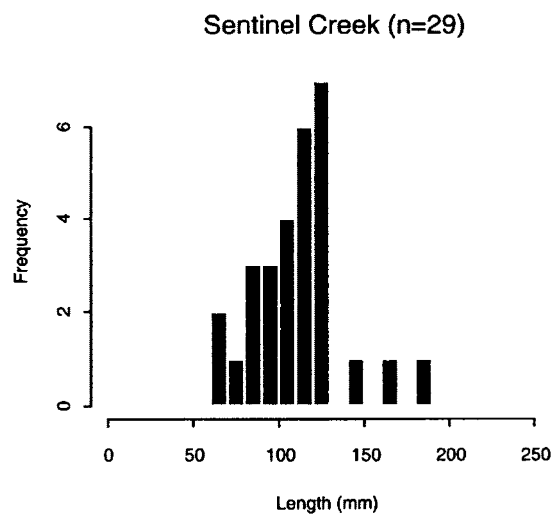

North Grizzly Creek (n=82)
Frequency
0
2
4
6
8
10
12
0
50
100
150
200
250
Length (mm)

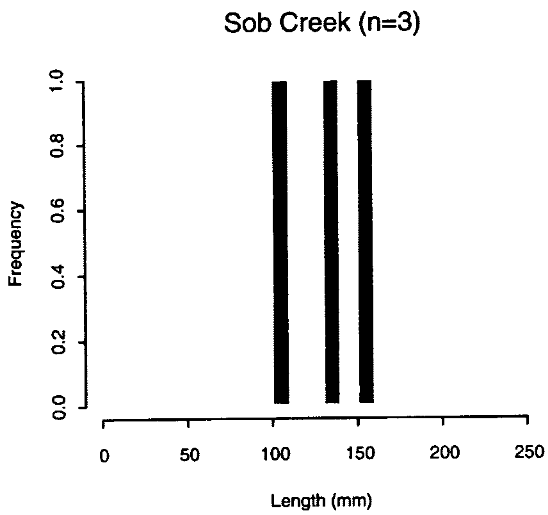

Picnic Creek (n=14)
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
Length (mm)

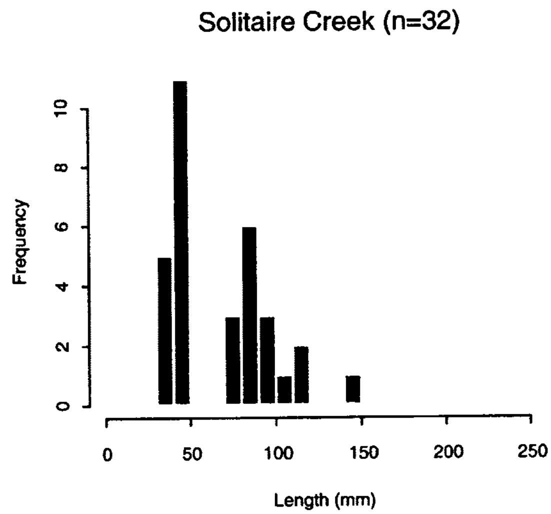

Pine Flat Creek (n=31)
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
Length (mm)

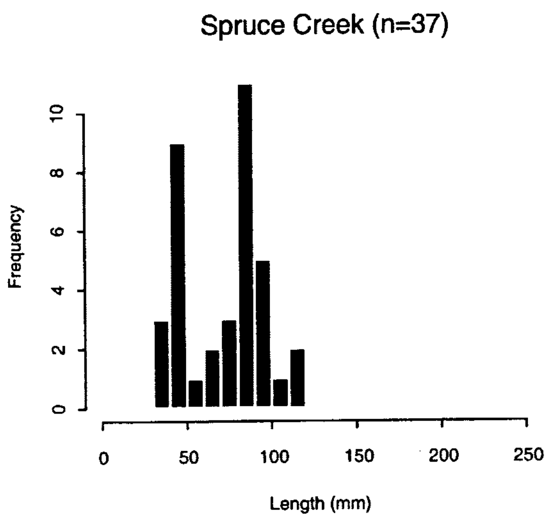

Pine Flat Creek (n=31)
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
Length (mm)

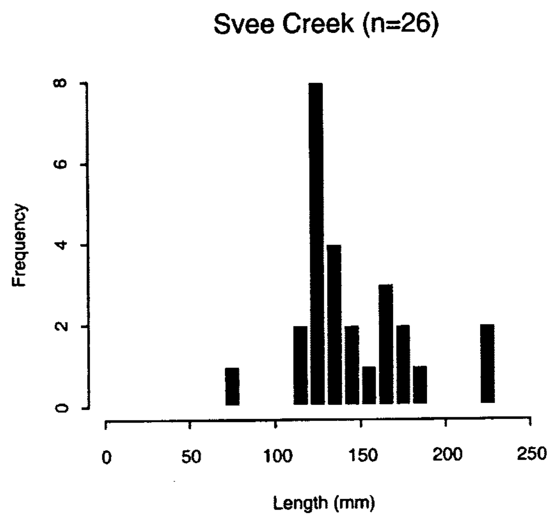

Scott Creek (n=28)
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
Length (mm)

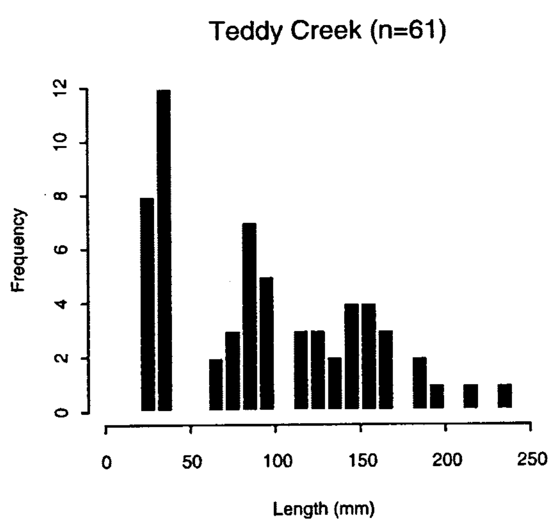

Sentinel Creek (n=29)
Frequency
0
2
4
6
0
50
100
150
200
250
Length (mm)

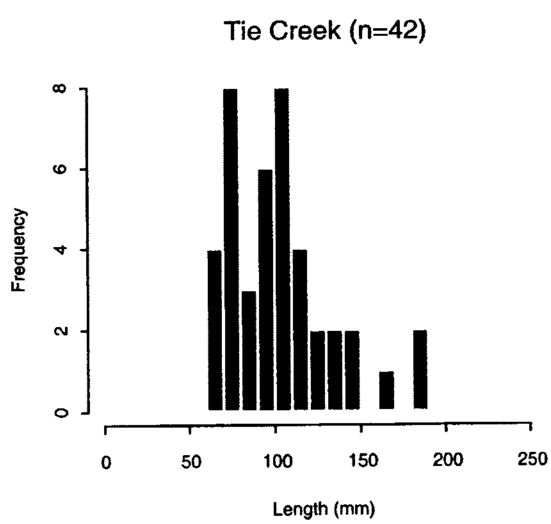

Sob Creek (n=3)
Frequency
0.0 0.2 0.4 0.6 0.8 1.0
0 50 100 150 200 250
Length (mm)


Solitaire Creek (n=32)
Frequency
0 2 4 6 8 10
0 50 100 150 200 250
Length (mm)

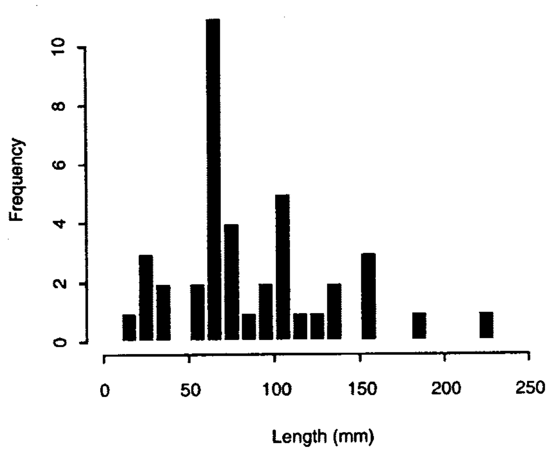

Spruce Creek (n=37)
Frequency
0 2 4 6 8 10
0 50 100 150 200 250
Length (mm)


Svee Creek (n=26)
Frequency
0 2 4 6 8
0 50 100 150 200 250
Length (mm)

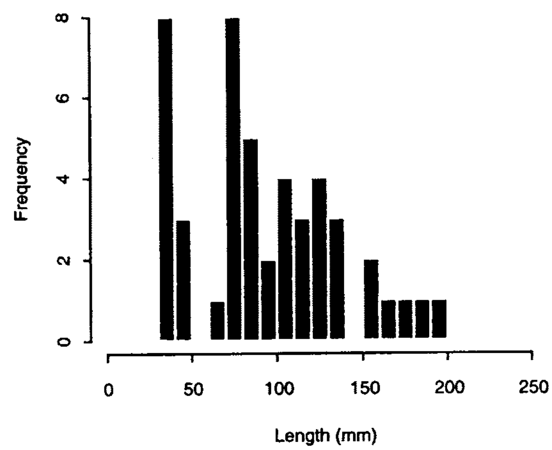

Teddy Creek (n=61)
Frequency
0 2 4 6 8 10 12
0 50 100 150 200 250
Length (mm)


Tie Creek (n=42)
Frequency
0 2 4 6 8
0 50 100 150 200 250
Length (mm)

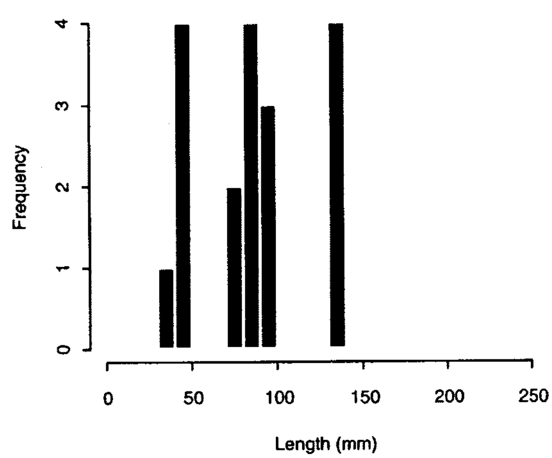
Tom Lavin Creek (n=40)



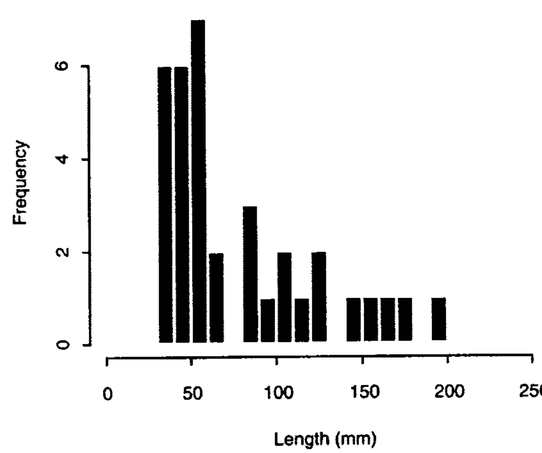
Ulm Creek (n=47)



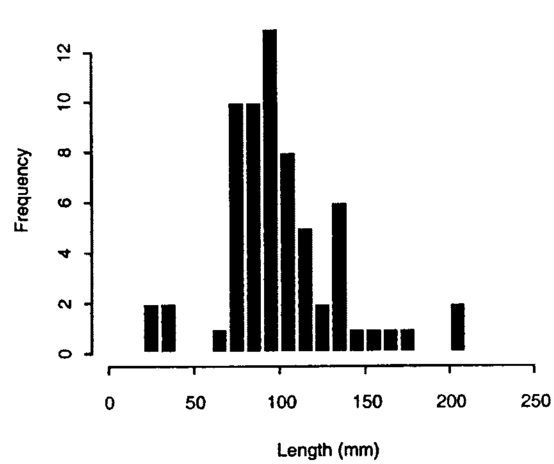
Upper Coeur d'Alene River (n=18)



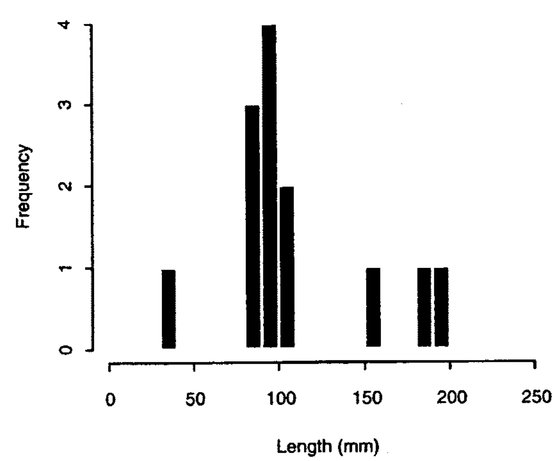
Upper Jordan Creek (n=35)

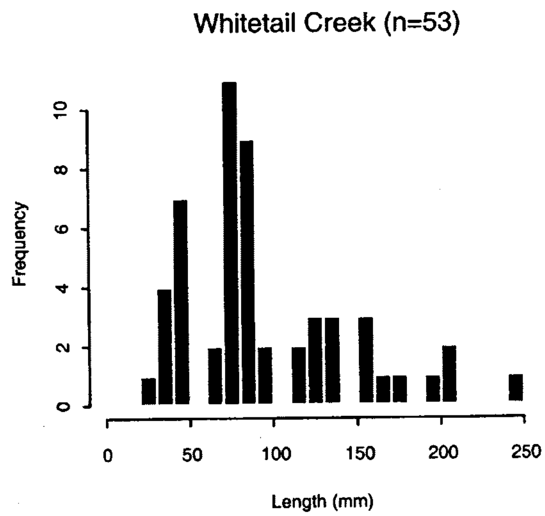


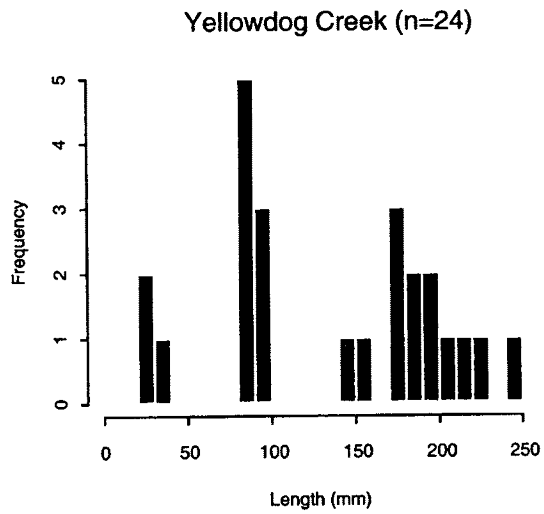
West Fork Steamboat Creek (n=65)



West Fork Hudlow Creek (n=13)




Whitetail Creek (n=53)
Frequency
0
2
4
6
8
10
0
50
100
150
200
250
Length (mm)


Yellowdog Creek (n=24)
Frequency
0
1
2
3
4
5
0
50
100
150
200
250
Length (mm)

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