Population dynamics and demographics of westslope cutthroat trout *Oncorhynchus clarki lewisi* inhabiting isolated headwater tributaries of Montana

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Executive Summary

We sampled isolated headwater populations of westslope cutthroat trout Oncorhynchus clarki lewisi to provide estimates of fecundity, longevity, sex ratio, and age at sexual maturity. Fecundity was estimated from 31 fish collected from 2 of the 19 headwater study streams. Females less than 149 mm were generally immature and as a result, estimation of fecundity was not possible. Mean fecundities for 150-174 mm, 175-199 mm, and greater than or equal to 200 mm fork length (FL) groups were 227 (SD = 41.1), 346 (SD = 85.6), and 459 (SD = 150.8), respectively. A linear regression model to predict fecundity (E) from fork length (FL) was developed ($E = -494.9 + 4.4*FL$; $r^2 = 0.51$, $P < 0.001$) for westslope cutthroat trout in the upper Missouri River drainage. Regression slopes of fecundity against fish length differed significantly ($P < 0.01$) between stocks. Steeper slopes were associated with lacustrine-adfluvial stocks. The average sex ratio was 1.3 males per female across all sampled streams. Males began to mature sexually at age 2 and all were mature by age 4. Some females (27%) from study populations were sexually mature at age 3, with most (93%) mature by age 5. Length was a better predictor of sexual maturity than age. Males matured at 110 to 160 mm and females matured at 150 to 180 mm FL. The maximum estimated age was 8 years based otoliths from a total of 475 fish collected from our 19 study streams and 14 additional streams.

Westslope cutthroat trout Oncorhynchus clarki lewisi presently occupy less than 5% of their historical range within the upper Missouri River drainage in Montana. We assessed the risks of extinction for 144 known populations inhabiting streams within federally managed lands in the upper Missouri River basin using a Bayesian viability assessment procedure that estimates probability of persistence based on subjective evaluation of population survival and reproductive rates as influenced by environmental conditions. We first customized this model using estimates of demographic parameters from the literature and field data. Each population was classified into one of three risk groups based on their Bayesian probability of persistence over a 100 year period (p_{100}). Most (71%) of the 144 populations had a "Very High" predicted risk of extinction ($p_{100} <$ 50%), 19% exhibited a "High" risk ($50\% < p_{100} \leq 80\%$), and 10% had a "Moderate" risk ($80\% < p_{100} \leq 95\%$). Higher average predictions of p_{100} were consistently associated with those populations that inhabited watersheds with lower levels of management activities. ANOVA and a matrix of information divergence measures indicated that livestock grazing, mineral development, angling, and the presence of non-native fish had the greatest association with both estimated population parameters and persistence probabilities. Of 26 major sub-basins within the Upper Missouri, 16 presently support at least one known westslope cutthroat trout population on federal lands, and 14 of these 16 support at least one population with an estimated p_{100} value of 0.5 or greater. Results of our analysis has led to action by citizens of Montana, prompting state and federal managers to develop a conservation and restoration program for this subspecies in the upper Missouri River basin.

Evidence for the validity of otoliths as aging structures for westslope cutthroat trout was provided through comparison with a length frequency histogram. Ages interpreted from otoliths were significantly higher than ages interpreted from scales for 424 paired age structure samples (t-test; $P<0.001$). A missing first-year annulus was believed to cause some of this discrepancy. Ages assigned from otoliths were more precise than those assigned from scales and discrepancies between ages assigned from paired otolith and scale samples were smaller for younger fish. Eight-seven percent of recaptured Visible Implant (VI) tagged fish formed an interpretable annulus between the ages of 2 and 3, while only 10% formed an interpretable annulus between the ages of 4 and 5. It became very difficult to interpret annuli near the scale's margin after fish reached age 3, we suspect this is related to slower growth rates as fish matured. The combined problem of discerning annuli near scale margins of older fish and a missing first year annulus on some scales, raises serious concerns regarding the reliability of ages interpreted from scales. Empirical growth for fish 116 to 303 mm was assessed from 786 tag recapture events. Based on an assumed growth season extending from May 1 to October 15 the estimated daily growth averaged 0.11 mm per day. Expanding this daily growth to annual growth resulted in an average annual growth rate of about 19 mm. There was a slightly negative (slope of –0.003) and significant ($P < 0.001$) relationship between length at first capture and daily growth.

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Introduction

The USDA Forest Service's Rocky Mountain (formerly the Intermountain) Research Station contracted with the Montana Cooperative Fishery Research Unit to provide information for assessing the risk of extinction for stream salmonids. This study was designed to provide data on population demographics for stream salmonid populations presently existing as small populations. We selected westslope cutthroat trout Oncorhynchus clarki lewisi for study because they now occupy only small fragmented habitats within the upper Missouri River drainage, but occupy larger connected habitats in other portions of their range. The specific objectives were:

1. Establish protocols for use of visual implant (VI) tags to estimate amount of straying between adjacent populations and assess seasonal movement patterns within and between populations.

2. Estimate annual survival rates, population size, age composition, and fecundity for trout populations in headwater areas along the Continental Divide in Montana that have been reduced in size or fragmented by land use to provide for a basis for testing models designed to estimate probabilities of extinction for individual small populations.

3. Estimate annual survival rates, population size, age composition, and fecundity for trout populations in Tenderfoot Creek on the Tenderfoot Experimental Forest.

This report consists of three separate chapters. These chapters either have been published or will soon be submitted for publication in peer reviewed journals.

Objective 1 was addressed and reported in Shepard et al. (1998a) and was published in the North American Journal of Fisheries Management in 1996 (Volume 16: 913-920). A companion paper authored by Jim Robison-Cox of Montana State University (Robison-Cox 1998) appeared as Appendix A of Shepard et al. (1998a). The chapters in this report address Objective 2. Chapter 1 provides our estimates of demographic parameters for resident westslope cutthroat trout populations and was published by Downs et al. (1997; North American Journal of Fisheries Management, Volume 17: 85-93). Chapter 2 used our modification of Lee and Rieman's (1997) BayVAM model to assess the risk of extinction for westslope cutthroat trout within federal lands in the upper Missouri River basin and was published by Shepard et al. (1997a; North American Journal of Fisheries Management, Volume 17: 1158-1172). Chapter 3 contains estimates of age and growth. This chapter will be submitted to a journal sometime in 1999. The work presented in Chapters 2 and 3 were part of a Master's thesis by Christopher Downs (1996) which was provided to the Rocky Mountain Research station by Mr. Downs. The influence of habitat condition on population size was also assessed and reported in a separate report (Shepard et al. 1998b). Chapter 3 of Shepard et al. (1998b) provides length frequency summaries; however, no statistical analyses have yet been completed on these data. Age and survival estimates for westslope cutthroat trout in sample streams were to be estimated using length frequency data. Unfortunately, our ability to estimate ages and survival rates were dependent upon the results from another investigation conducted by another University group under contract to Rocky Mountain Station which was to develop a method for estimating age structure based on length structure. That investigation was unable to reliably convert length structure information to age structure information. In 1997 we submitted an administrative report that addressed Objective 3 by summarizing fish abundance and habitat data collected in Tenderfoot Creek within the Tenderfoot Experimental Forest (Shepard et al. 1997b).

Study Area

Streams

The study was designed to compare separate isolated headwater populations of westslope cutthroat trout (Oncorhynchus clarki lewisi) in Montana to investigate differences in population structure, demographics, and life-history strategies between populations. Sample populations were selected based on the following criteria (in relative order of importance):

1. relative size of population;
2. length of time the population has been isolated by either geologic factor (falls or intermittent segments) or anthropogenic factors (dams, culverts, etc.);
3. relative genetic purity of westslope cutthroat trout;
4. presence (absence) of sympatric species; and
5. relative condition of aquatic habitat.

Fisheries biologists from Montana Fish, Wildlife and Parks (FWP), USDA Forest Service (FS), and USDI Bureau of Land Management (BLM) were contacted and asked to provide listings of potential study streams and available information on the above criteria for each potential study stream. Sample streams were selected after developing a matrix of potential sites using the above criteria (Appendix A). Tenderfoot Creek, a tributary to the Smith River, was sampled in 1992 (Figure 1). Streams studied in 1993 were: Collar Gulch; Half Moon Creek; North Fork of Deadman Creek; Tenderfoot Creek; White's Gulch; West Fork, East Fork and main Cottonwood Creek; Halfway Creek; Muskrat Creek; North Fork, Middle Fork, South Fork, and main Douglas Creek; North Fork Gold Creek; Geyser Creek; Soap Creek; Delano Creek; and Jerry Creek (Tables 1 and 2; Figure 1). The Cabin and Stone Creek drainages were added in 1994 and Lick Creek was added in 1995.

Flows

Information from United State Geologic Survey gage sites near each sampled drainage were summarized to compare stream flow conditions during the study (1991-1995) to the period of record for each measurement site. We compared annual mean values and plotted monthly averages for the period of record in addition to the years 1991-1995 (Figure 2).

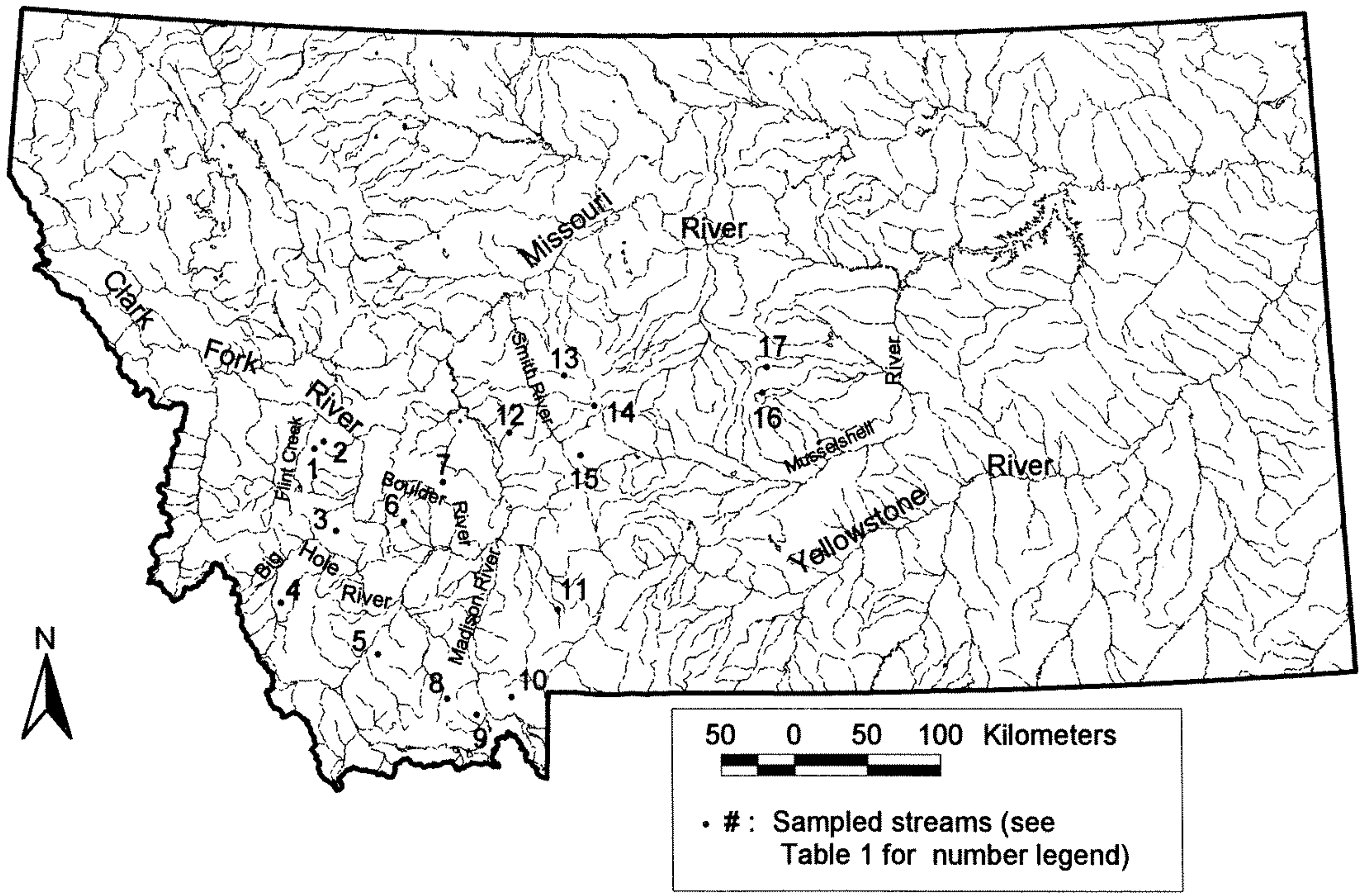

Figure 1. Map of Montana showing locations of streams where westslope cutthroat trout population and habitat sampling was conducted from 1992 to 1995. Numbers adjacent to points indicate sample streams and correspond to numbers in parentheses in Table 2.

Table 1. Streams selected for study showing major river drainage streams are tributary to, legal description, estimated length of stream (km) which supports cutthroat trout, and other species present (EBT=brook trout). Legal descriptions are given for the stream's mouth to help locate streams and do not necessarily indicate sample sites. "Y" indicates "YES", "N" indicates "NO", "?" indicates uncertain information.

DRAINAGE Stream	Legal description	Pure cutthroat present	Other species present	Length (km) with cutthroat	Barrier present	Type of barrier
BEAVERHEAD RIVER						
Stone Creek						
Left Fork Stone Creek	T07S;R06W;SEC21	Y	NONE	2.6	Y	Intermittent segment
M Fk Stone Creek	T07S;R06W;SEC21	Y	NONE	1.2	Y	Intermittent segment
BIG HOLE RIVER						
Jerry Creek	T01N;R11W;SEC36	Y	EBT	5.8	N	
Delano Creek	T02N;R10W:SEC20	Y	NONE	1.9	Y	Intermittent segment
McVey Creek	T02S;R14W:SEC17	Y	EBT	3.3	Y	Irrigation diversion
BOULDER RIVER						
Muskrat Creek	T06N;R03W:SEC06	Y	EBT	2.2	Y	Dam (pond)
CLARKS FORK						
Douglas Creek	T09N;R12W:SEC32	Y	EBT	1.1	Y	Culvert
M Fk Douglas Creek	T09N;R12W:SEC32	Y	EBT	3.7	N	
N Fk Douglas Creek	T09N;R12W:SEC32	Y	NONE	3.1	Y	Culvert
S Fk Douglas Creek	T09N;R12W:SEC32	?	NONE	3.5	N	
N Fk Gold Creek	T09N;R12W:SEC36	Y	NONE	4.2	Y	Waterfall
GALLATIN RIVER						
Lick Creek	T04S;R06E;SEC09	N	RB,EBT	2.0	Y	Culvert
JEFFERSON RIVER						
Halfway Creek	T03N;R06W:SEC13	Y	NONE	6.8[a]	Y	Waterfall

Table 1. (Continued).

DRAINAGE Stream	Legal description	Pure cutthroat present	Other species present	Length (km) with cutthroat	Barrier present	Type of barrier
MADISON RIVER						
Soap Creek	T11S:R01E;SEC27	Y	NONE	3.9	Y	Waterfall[b]
MUSSELSHELL RIVER						
Collar Gulch	T17N;R20E:SEC33	Y	NONE	2.7	Y	Intermittent segment
Half Moon Creek	T12N;R19E:SEC01	Y	NONE	7.3	Y	Intermittent segment
RUBY RIVER						
Cottonwood Creek	T10S;R07W:SEC23C	?	EBT,RB	5.8	N	
Geyser Creek	T10S;R02W:SEC29	Y	NONE	1.7	N	
SMITH RIVER						
Cottonwood Creek	T08N;R07E:SEC23	Y	NONE	0.6	Y	Intermittent segment
E Fk Cottonwood Creek	T08N;R07E:SEC23	Y	NONE	3.0	N	
W Fk Cottonwood Creek	T08N;R07E:SEC23	Y	NONE	2.8	N	
N Fk Deadman Creek	T12N;R08E:SEC14	Y	EBT,RB	3.6	N	
Tenderfoot Creek	T14N;R06E:SEC30	N	EBT,RB	8.1	N	Waterfall[c]
UPPER MISSOURI RIVER						
Whites Gulch	T10N;R02E:SEC16	Y	EBT	4.6	Y	Culvert[d]

[a] Allopatric population of westslope cutthroat trout extends about 1.0 km below waterfall barrier.
[b] Waterfall created by large boulders and logs across channel. Waterfall is about six feet tall and may have flows around falls during runoff events.
[c] Waterfall is bedrock, but exotic species (EBT and RB) were released above this waterfall.
[d] Culvert installed as fish barrier in 1993. Prior to that time an old mining settling pond acted as a barrier to upstream fish movement.

Table 2. Physical features of streams (numbers in parentheses are map locations shown in Figure 1) where densities of westslope cutthroat trout were estimated from 1992 to 1995. Mean temperatures, conductivities, and pH's are averages for several point estimates taken during field sampling.

Stream (map number)	Rosgen[a] type	Mean temperature (°C)	Mean conductivity (umho)	pH	Mean wetted width (m)	Length with cutthroat (km)	Lower elevation (m)	Upper elevation (m)	Mean channel gradient (%)	Latitude	Longitude
Cabin (10)	C3	14.0	329	8.8	6.6	2.9	2170	2304	4.6	44.54	111.18
M Fork Cabin	B3	11.7	203	8.7	3.3	7.0	2300	2600	4.2	44.54	111.16
Unnamed Trib	B3	8.1	268	8.7	1.6	1.0	2540	2560	2.4	44.53	111.15
Collar Gulch (17)	B2	7.9	174	8.3	2.0	2.7	1450	1550	3.6	47.12	109.10
Geyser (11)	A3	9.0	380	8.6	1.6	1.6	2460	2570	6.6	44.55	112.53
Cottonwood (Smith)(15)	B1	7.8	130	8.9	2.5	0.6	1830	1850	4.0	46.26	110.49
East Fork Cottonwood	A3	9.3	144	8.8	1.5	3.0	1850	2190	11.4	-[b]	-
West Fork Cottonwood	A3	8.8	126	8.1	2.5	2.8	1850	2110	9.1	-	-
Half Moon (16)	A2	9.9	344	8.7	3.0	7.3	1710	2010	4.2	46.49	109.16
Halfway (6)	B3	9.5	72	8.8	1.7	7.8	1830	2290	5.9	45.59	112.18
Jerry (3)	A3	6.5	156	8.7	5.8	2.8	2050	2220	3.0	45.52	112.52
Delano	A3	6.5	166	8.3	1.2	1.9	2120	2260	7.1	45.54	112.51
Lick (11)	A3	10.6	262	8.4	2.3	2.0	1950	2020	6.1	45.30	110.59

Table 2. (Continued).

Stream (map number)	Rosgen[a] type	Mean temperature (°C)	Mean conductivity (umho)	pH	Mean wetted width (m)	Length with cutthroat (km)	Lower elevation (m)	Upper elevation (m)	Mean channel gradient (%)	Latitude	Longitude
McVey (4)	B3	6.1	64	9.3	1.5	2.3	1860	1940	3.4	45.40	113.23
Muskrat (7)	A2	7.8	NA[c]	NA[c]	3.6	2.2	1570	1700	5.6	46.18	112.02
N. Fork Deadman (14)	A3	6.3	235	8.6	1.7	2.5	1960	2130	6.8	46.79	110.40
N. Fork Gold (2)	B3	6.8	166	8.5	1.9	4.2	1880	2010	3.2	46.29	113.01
N. Fork Douglas (1)	B2	8.4	252	8.5	1.5	3.1	1650	1790	4.7	46.29	113.09
Soap Creek(10)	A3	8.2	72	8.5	2.5	3.9	1910	2170	6.6	44.51	111.36
Stone Creek (5)											
Left Fork	A3	10.0	296	8.0	2.1	3.5	1920	2150	6.6	45.12	112.20
Middle Fork	B4	10.6	336	8.0	1.4	1.2	1920	1970	4.6	45.12	112.20
Tenderfoot (13)	A3	6.7	116	8.6		8.1	1730	3000	4.5	46.55	110.58
White's Gulch (12)	B3	8.6	661	8.2	1.5	4.6	1320	1470	3.3	46.37	111.29

[a] Rosgen channel types based on Rosgen (1994).
[b] Latitude and longitude for East and West Forks of Cottonwood Creek the same as main Cottonwood Creek.
[c] Data "Not Available".

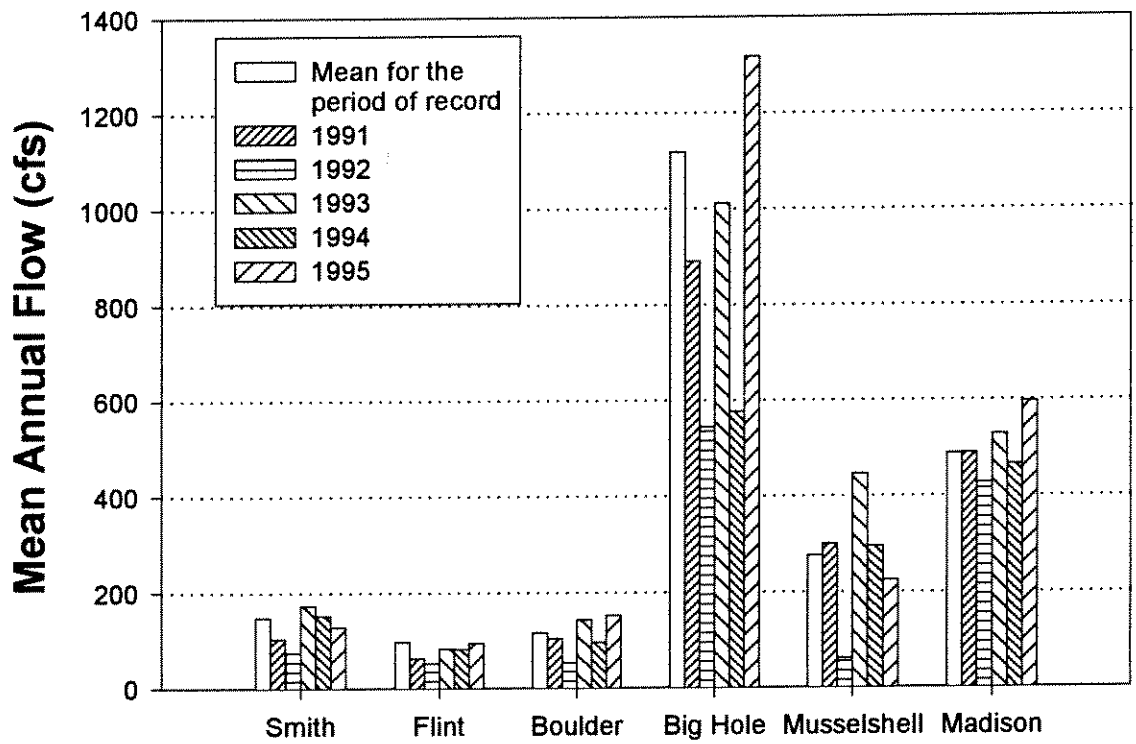

Figure 2. Annual mean stream flows for the period of record (open bars) and by year from 1991 through 1995 at selected measurement sites near sample streams.

Sample Sites

Streams in each of the 18 sample drainages were sampled at numerous sample sites at least once per year (Appendix B). Population estimates were made in 94 permanently referenced sample sections, but estimates were not always done in each section every year. Habitat availability and condition were estimated in 76 of the permanent sample sections (Appendix C).

Fish Species

Westslope cutthroat trout were found in all drainages. Horizontal starch gel electrophoresis was used to assess genetic purity of westslope cutthroat trout populations. Westslope cutthroat trout in all drainages except the Tenderfoot and Lick Creek drainages were determined to be at least 98% westslope cutthroat trout (Table 3). Other species of fish inhabiting sample streams included brook trout (Salvelinus fontinalis), rainbow trout (Oncorhynchus mykiss), and sculpins (Cottus spp.; Table 1). A fish stocking database maintained by FWP was queried to ascertain what species of fish, if any, had been released into study streams (Table 4).

Table 3. Genetic results from the Montana Salmon and Trout Genetics Laboratory, University of Montana for streams sampled from 1992-1995. WCT = westslope cutthroat trout and WCTxRB = hybrid between westslope cutthroat and rainbow trout.

DRAINAGE Stream	Legal description	Date	n	Species	Percent WCT
BEAVERHEAD					
M Fk Stone Creek	T07S;R06W;S27	03/17/92	16	WCT	100%
BIG HOLE					
Delano Creek	T02N;R10W;S20	07/23/87	8	WCT	100%
	T02N;R10W;S20	09/29/93	7	WCT	100%
Jerry Creek	T02N;R10W;S28	10/12/93	6	WCT	99%
Mcvey Creek	T02S;R14W;S18	10/02/89	10	WCT	100%
BOULDER					
Muskrat Creek	T06N;R03W;S06	10/18/90	10	WCT	100%
CLARK FORK					
Gold Creek	T08N;R12WS11	10/18/88	25	RBxWCT	
N Fk Gold Cr	T09N;R12W;S04	09/10/90	25	WCT	100%
N Fk Douglas Cr	T09N;R12W;S32	05/02/86	21	WCT	100%
GALLATIN					
Lick Creek	T04S;R06E;S10	07/01/94	1	WCT	100%
	T04S;R06E;S09 and S10	06/26/95 09/11/95	11	WCTxRB[a]	81%
JEFFERSON					
Halfway Creek	T03N;R06W;S12	08/--/85[b]	36	WCT	100%
	T03N;R06W;S13	10/07/91	15	WCT	100%
MADISON					
M Fk Cabin Creek	T11S;R04E;S11	06/01/93	10	WCT	100%
Soap Creek	T11S;R01E;S29	09/19/91	12	WCT	99%
	T11S;R01E;S29	09/01/92	16	WCT	99%
MUSSELSHELL					
Collar Gulch	T16N;R20E;S32	06/--/81[b]	16	WCT	100%
Halfmoon Creek	T12N;R19E;S14	08/10/94	18	WCT	100%

Table 3. (Continued).

DRAINAGE Stream	Legal description	Date	n	Species	Percent WCT
RUBY					
Cottonwood Creek	T10S;R02W;S32	09/20/94	16	WCT	100%
Geyser Creek	T10S;R02W;S29	06/--/90[b]	16	WCT	100%
SMITH					
N Fk Deadman Cr	T12N;R08E;S14	06/01/89	10	WCT	100%
Tenderfoot Creek	T14N;R06E;S30	08/01/88	5	WCTxRB	84%
	T14N;R06E;S36	08/21/92	10	WCTxRB	90%
W Fk Cottonwood C	T08N;R07E;S23	07/22/92	10	WCT	Pure
UPPER MISSOURI					
White's Gulch	T10N;R02E;S16	06/01/89	10	WCT	100%
	T10N;R02E;S15	04/29/92	7	WCT[c]	100%
	T10N;R02E;S16	04/29/92	2		

[a] Combined samples at several locations and over three dates in 1995.
[b] Exact day of sample not recorded.
[c] WCT based on 9 fish collected at both sites on 4/29/92.

Table 4. Fish previously stocked into streams selected for study. Species codes are: RB=rainbow trout; EBT=eastern brook charr; and CT=undesignated cutthroat trout. Locations are Township, Range, and Section (00 denotes unknown section).

STREAM Species Location	Date	Number	Length (in)
DEADMAN CREEK			
RB			
12N08E00	08/11/42	5000	2.0
12N08E00	08/17/43	5000	2.0
12N08E00	09/15/47	10000	0.0
12N08E00	07/28/48	5000	3.0
12N08E00	09/16/48	5000	0.0
12N08E00	08/18/50	10000	2.0
DOUGLAS CREEK			
CT			
09N13W10	08/17/31	13736	0.0
09N13W10	09/11/36	10500	0.0
09N13W10	10/12/43	17000	2.0
09N13W10	08/02/51	630	5.0
09N13W10	07/27/53	600	4.0
HALFWAY CREEK			
EBT			
02N06W00	07/27/51	840	3.0
JERRY CREEK			
RB			
01N11W36CDCB	08/11/42	6000	2.0
01N11W36CDCB	10/18/45	7000	2.0
01N11W36CDCB	07/21/48	3820	2.0
01N11W36CDCB	08/07/49	20000	1.0
CT			
01N11W36CDCB	08/30/36	9000	0.0
01N11W36CDCB	08/02/54	3000	4.0

Table 4. (Continued).

STREAM Species Location	Date	Number	Length (in)
MUSKRAT CREEK			
RB			
06N04W34	03/21/47	2000	4.0
06N04W34	03/21/47	2000	4.0
CT			
06N04W34	06/10/31	30000	4.0
06N04W34	06/10/31	30000	4.0
EBT			
06N04W34	05/27/33	25000	2.0
06N04W34	05/27/33	25000	2.0
06N04W34	04/25/41	12600	2.0
06N04W34	04/25/41	12600	2.0
06N04W34	04/30/46	3800	2.0
06N04W34	04/30/46	3800	2.0
06N04W34	09/12/47	4600	2.0
06N04W34	09/12/47	4600	2.0
06N04W34	07/27/50	2000	4.0
06N04W34	07/27/50	2000	4.0
06N04W34	07/01/51	2500	3.0
06N04W34	07/01/51	2500	3.0
06N04W00	06/16/53	6750	3.0
06N04W00	06/16/53	6750	3.0

Table 4. (Continued).

STREAM Species Location	Date	Number	Length (in)
TENDERFOOT CREEK			
RB			
14N04E00	09/15/48	1280	6.0
CT			
14N04E00	10/13/38	26200	0.0
14N04E00	09/22/39	34200	0.0
14N04E00	10/18/40	30000	0.0
14N04E00	09/18/41	25000	0.0
14N04E00	09/15/48	9600	2.0
14N04E00	09/17/48	25000	0.0
14N04E00	09/06/51	45000	1.0
14N04E00	08/25/54	54840	1.0
EBT			
14N04E00	08/28/34	8260	4.0

CHAPTER 1:
Age at Sexual Maturity, Sex Ratio, Fecundity, and Longevity of Isolated Headwater Populations of Westslope Cutthroat Trout Oncorhynchus clarki lewisi

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[a] The Unit is jointly sponsored by Montana State University, Montana Department of Fish, Wildlife, and Parks, and the U.S. National Biological Service.

Abstract

We sampled isolated headwater populations of westslope cutthroat trout Oncorhynchus clarki lewisi to provide estimates of fecundity, longevity, sex ratio, and age at sexual maturity. Fecundity was estimated from 31 fish collected from 2 of the 19 headwater study streams. Females less than 149 mm were generally immature and as a result, estimation of fecundity was not possible. Mean fecundities for 150-174 mm, 175-199 mm, and greater than or equal to 200 mm fork length (FL) groups were 227 (SD = 41.1), 346 (SD = 85.6), and 459 (SD = 150.8), respectively. A linear regression model to predict fecundity (E) from fork length (FL) was developed ($E = -494.9 + 4.4*FL$; $r^2 = 0.51$, $P < 0.001$) for westslope cutthroat trout in the upper Missouri River drainage. Regression slopes of fecundity against fish length differed significantly ($P < 0.01$) between stocks. Steeper slopes were associated with lacustrine-adfluvial stocks. The average sex ratio was 1.3 males per female across all sampled streams. Males began to mature sexually at age 2 and all were mature by age 4. Some females (27%) from study populations were sexually mature at age 3, with most (93%) mature by age 5. Length was a better predictor of sexual maturity than age. Males matured at 110 to 160 mm and females matured at 150 to 180 mm FL. The maximum estimated age was 8 years based otoliths from a total of 475 fish collected from our 19 study streams and 14 additional streams.

Introduction

Westslope cutthroat trout Oncorhynchus clarki lewisi have undergone a major reduction in distribution and abundance since the turn of the century because of land use practices, introduction of non-native fishes, and over-exploitation (Liknes and Graham 1988; Behnke 1992). Genetically pure populations of westslope cutthroat trout occupy about 2.5% of their historic range in Montana (Liknes and Graham 1988). Isolation of salmonid populations due to habitat fragmentation increases deterministic, stochastic, and genetic risks of extinction (Rieman et al. 1993). Westslope cutthroat trout populations have become highly fragmented throughout their range and are primarily relegated to headwater habitats. Fish managers need to assess extinction risk and develop conservation and recovery strategies for this native subspecies.

This study was initiated to examine headwater populations of westslope cutthroat trout to provide parameter estimates for an extinction risk model being developed by USDA Forest Service, Intermountain Research Station biologists. This model will be used to assess extinction risk associated with isolation and small population size. Our goal was to improve an existing fecundity-length relationship (Rieman and Apperson 1989) by examining small females (125 to 250 mm, FL), document length and age at sexual maturity, estimate sex ratio, and determine longevity of westslope cutthroat trout in headwater populations in Montana.

Methods

From May through October in 1993 and 1994, fish were collected using a backpack electrofishing unit (Smith-Root model 15-B). Nineteen study streams were selected supporting isolated genetically pure populations of westslope cutthroat trout (Figure 1). Fifteen of the streams drained into the upper Missouri River and four were tributaries to the Clark Fork River. The Wild Trout and Salmon Genetics Laboratory at the University of Montana, Missoula, provided fish from an additional 14 streams. We combined the samples from the Wild Trout and Salmon Genetics Laboratory with our own samples to estimate longevity for this study and in a related age structure study.

Fish were aged by viewing whole sagital otoliths submerged in distilled water under a binocular dissecting microscope using reflected light. Whole otoliths provide more accurate and precise age estimates than scales for westslope cutthroat trout from headwater habitats (Downs 1995). In addition, Fraley et al. (1981), Shepard et al. (1984), and Lentsch and Griffith (1987) all reported problems with interpreting ages from scale samples from cutthroat trout inhabiting cold, headwater streams. Otoliths have been used to age other salmonids such as chinook salmon Oncorhynchus tshawytscha (Neilson and Green 1983); sockeye salmon Oncorhynchus nerka (Marshall and Parker 1982); steelhead Oncorhynchus mykiss (Campana 1983); and brook trout Salvelinus fontinalis (Hall 1991).

Eggs were enumerated from mature females collected immediately prior to the onset of spawning in 1994 from 3 of the 19 study streams. These 3 streams were located in the upper Missouri

River drainage. We attempted to collect at least 10 females in each of four size groups: 125-149 mm, 150-174 mm, 175-199 mm, and greater than or equal to 200 mm fork length (FL), to be consistent with an earlier study (Magee 1993). Fecundity samples from one of the three streams were not used in our analysis because spawning had already begun and some captured fish released eggs in live-cars and during handling. As a result, we did not obtain 10 mature females in the two smallest length groups. Both ovaries were removed from each mature female and fixed in Davidson's solution (Kent 1992). Ova were enumerated using a binocular dissecting microscope.

We regressed our fecundity data and unpublished data from Cache Creek, Montana (A. Bowersox, Montana State University, personal communication) against fish length using transformed (log and nlog) and untransformed variables. We then combined this fecundity and length data with the data of Averett (1962) and Johnson (1963) and repeated the analysis.

We collected male (n = 50) and female (n = 79) westslope cutthroat trout from 11 of the 19 study streams to determine age and length at maturity. Status of sexual development was determined by laboratory examination of ovaries and testes. The difference between mature and immature ovaries was distinct. Immature ovaries were granular in appearance and located dorsally, rarely extending back beyond the dorsal fin. Mature ovaries were much larger, possessing eggs in an advanced stage of development, and extending from a dorsal origin to a ventral location, usually filling the abdominal cavity. Males were classified as immature if testes were located dorsally and appeared thread like. Because these populations all exhibit resident life histories in headwater habitats, we felt it was appropriate to pool samples across streams to increase sample sizes for statistical analyses.

We used logistic regression (Hosmer and Lemeshow 1989; SAS Institute 1994) to explore relationships between age and length and sexual maturity. Sexual maturity was entered into logistic regression models as a binomial variable, mature (1) or not mature (0). Age, length, and the interaction of length*age were entered as covariates. Akaike's Information Criterion (AIC; Akaike 1973, 1985) and Chi-square probability values for significance of individual variables within each model were examined for each sex. We used AIC values to select the best models, as recommended by Burnham and Anderson (1992). We tested for significant differences between models using differences in log likelihood values tested under a Chi-square distribution with one df using a P less than or equal to 0.05 significance level (Hosmer and Lemeshow 1989).

All fish captured during May and June, 1994 were externally examined to determine their gender and sexual condition. Sexual condition was rated as immature, mature, ripe, or spent. Immature fish could not be sexed. All males that extruded milt were rated as ripe. Females were considered ripe if eggs could be easily extruded or spent if their body cavity was hollowed in appearance and some residual eggs could be extruded. Gravid females were rated as mature. Sex ratios were calculated for sample streams using all fish rated as mature, ripe, and spent.

Longevity was estimated using otoliths taken from fish sacrificed for genetic analyses, fecundity and age at maturity determination, and incidental mortalities. Fish were not intentionally sacrificed to obtain longevity information because of concerns over potential long-term population effects of removing the largest mature individuals from small populations.

Results

Larger fish were more fecund; however, fecundity was highly variable within and between length groups (Table 5). We were unable to determine fecundity for our smallest length group (125-149 mm) because only two females in this group possessed mature eggs. Each of them had several mature, residual eggs in addition to ovaries developing for the next spawning period.

Table 5. Mean fish lengths (FL) and fecundity with associated standard deviations (SD), sample sizes (n), and ranges of observed fecundity from westslope cutthroat trout sampled from headwater streams during this study combined with unpublished data from Cache Creek, Montana (A. Bowersox, Montana State University, personal communication) by length group.

Length group (mm)	n	Mean length (mm)	SD	Mean fecundity	SD	Fecundity range
150-174	5	162	9.6	227	41.1	166-264
175-199	15	189	6.9	346	85.6	198-533
Over 200	11	218	11.8	459	150.8	224-644

We regressed fecundity against fish length, but the fit was poor. The best model, E = -494.9 + 4.4*FL ($r^2 = 0.51$, $P<0.001$), included untransformed fecundity (E) and fork lengths (FL). Including data from previous studies (Averett 1962; Johnson 1963), yielded a better fit (E = -790.7 + 6.2*FL, $r^2 = 0.88$, $P<0.001$) with untransformed fecundity and length data.

Sampled male westslope cutthroat trout first reached sexual maturity at age 2 (Figure 3). By age 4 all males sampled were mature. The youngest sexually mature females were age 3 with most age 5 females sampled being mature. All sampled females greater than age 5 were mature.

Length was a better predictor of maturity than age, especially for females. Logistic regression identified highly significant differences between the single variable models for both sexes using length versus age as predictors of maturity ($P<0.001$). For females, there was no significant difference between the full model (length, age, and the interaction of length and age) and the model which contained only length as a covariate ($0.50 < P < 0.75$). For males, even though there was not a significant difference between the full model and the model which contained only length as a covariate ($0.05 < P < 0.10$), results were less conclusive. Plots of predicted probabilities of maturity versus fish length showed that females matured at longer lengths, but over a narrower length range, than males (Figure 4). Probabilities of being mature (P_m) as predicted by fork length (FL) were:

$$P_m=(e^{(-8.09+0.06*FL)})/(1+e^{(-8.09+0.06*FL)})$$ for males; and
$$P_m=(e^{(-20.28+0.13*FL)})/(1+e^{(-20.28+0.13*FL)})$$ for females.

We used sexual maturity data we gathered from external examination of fish to evaluate the predictive capability of the logistic regression models. We compared the number of males and females we visually classified as mature during the spawning season to predicted probabilities of maturity generated by the logistic model, based on fish length, of greater than or equal to 0.5 and less than 0.5. The model for males predicted that 75% of those we visually classified as mature had a 50% or higher probability of being mature based on length. The predictive ability of the model for females was lower with only 56% of the females we visually classified as mature having a 50% or higher probability of being mature.

Sex ratios in our study streams varied from 0.8 to 2.2 males per female (Table 6), with an average sex ratio of 1.3:1. Sex ratios of more than 2 males per female were associated with small sample sizes.

The maximum age estimated for westslope cutthroat trout in our sample was 8 years (Table 7). Fish in 23 (70%) of the streams had maximum ages of 4 or more years. However, the length of the oldest fish aged using otoliths was often much less than the longest fish captured. Genetic collections not directly associated with this study account for 8 of the 10 streams which produced maximum age estimates of less than 4 years.

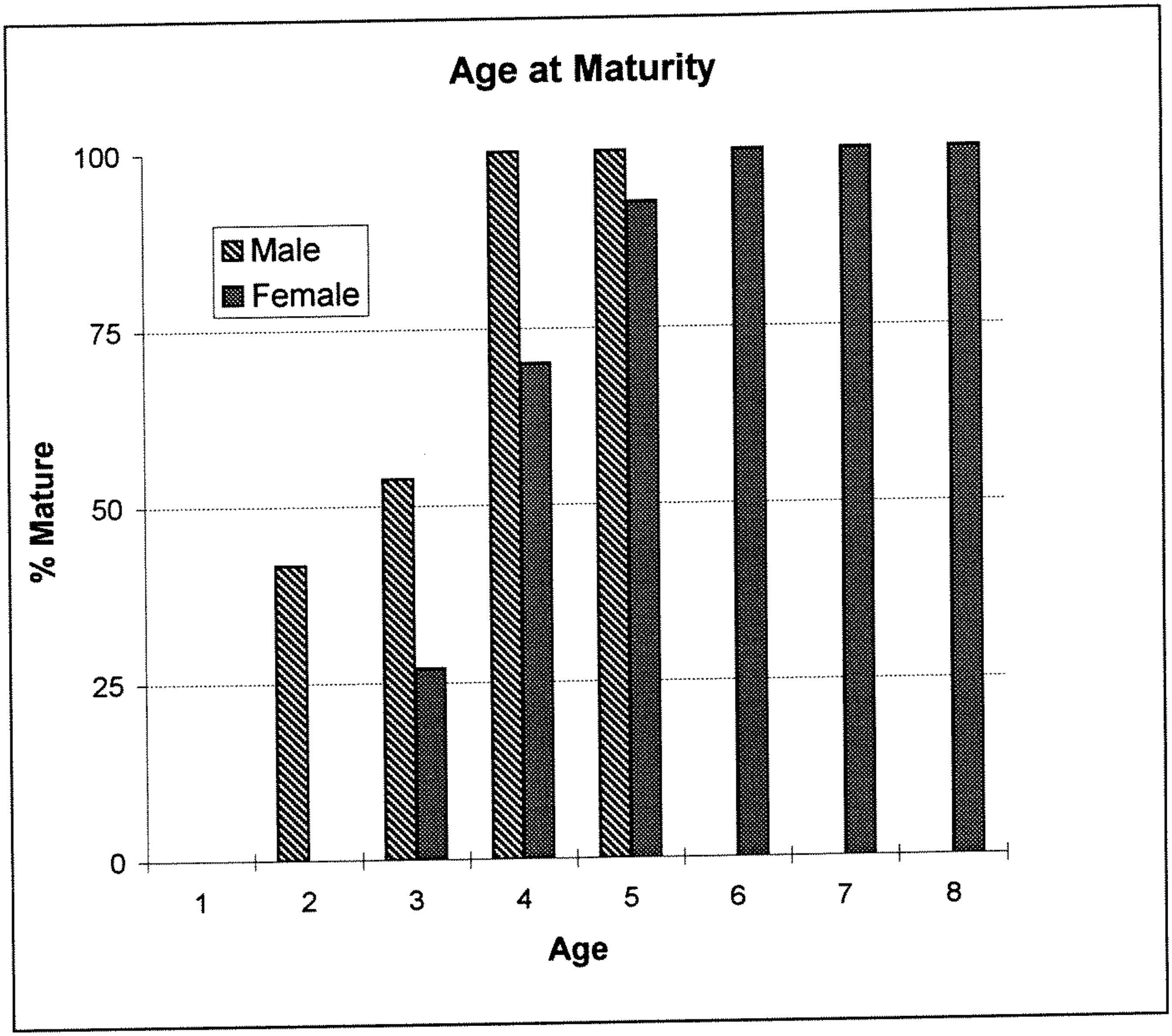

Figure 3. Proportion of male and female westslope cutthroat trout that were mature by age class based on a sample of 129 fish from 11 headwater streams in Montana.

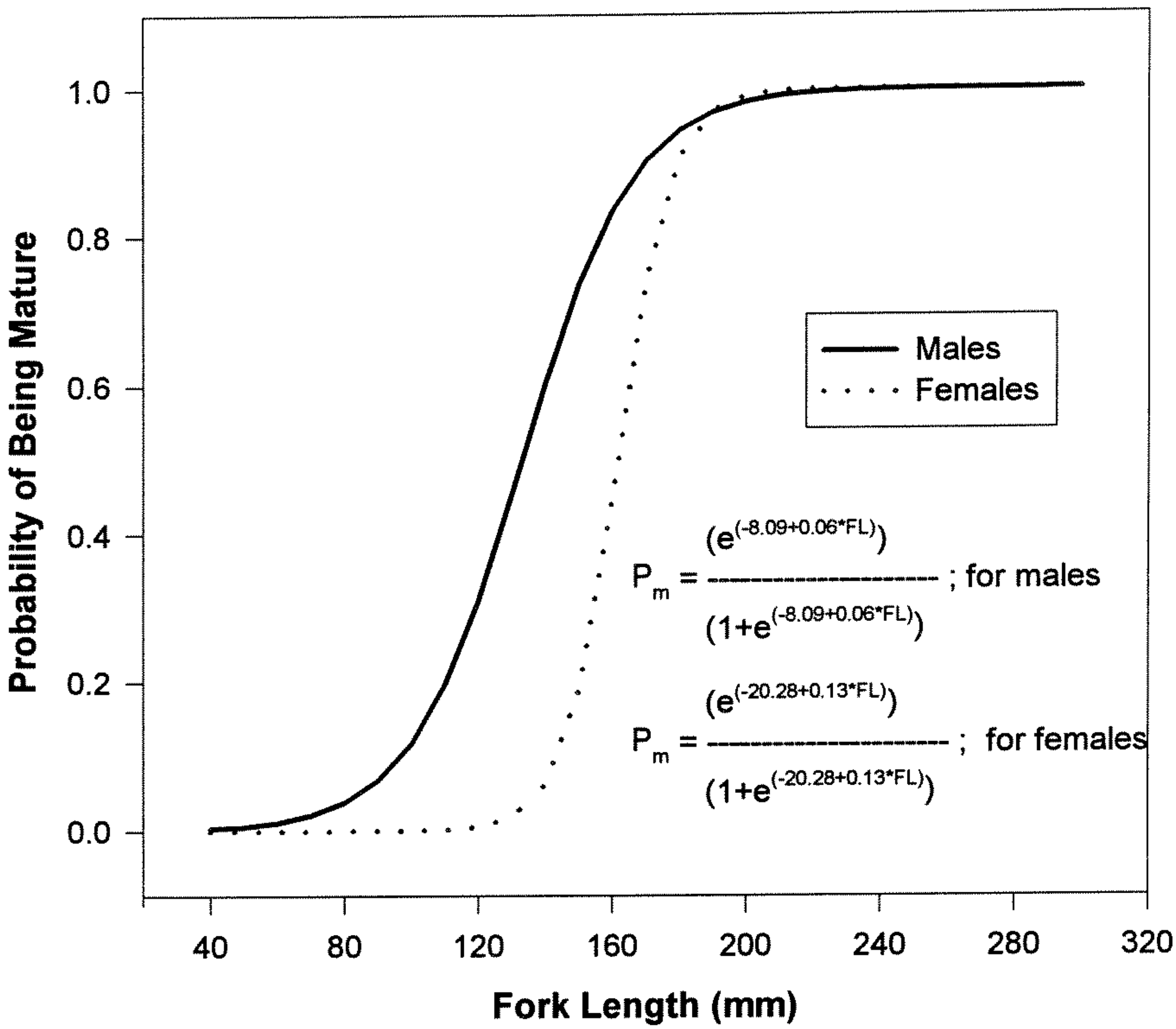

Figure 4. Predicted probability (P_m) of male and female westslope cutthroat trout in headwater streams of Montana being mature by fork length (FL) estimated using logistic regression analyses.

Table 6. Number of mature males and females (visually classified as mature, ripe or spent) and sex ratios (males: females) for headwater streams sampled during the spring of 1994.

Drainage	Dates Sampled	Males	Females	Sex ratio (M:F)
Collar Gulch	6/2 & 3	38	46	0.8:1
Cottonwood (Ruby)	6/15 & 16	59	52	1.1:1
Cottonwood (Smith)	5/6 & 24 6/28 & 29	87	50	1.7:1
Douglas Creek	6/13 & 14	22	26	0.8:1
Halfway Creek	5/25	45	31	1.5:1
Jerry Creek	6/6 & 7	70	47	1.5:1
North Fork Gold Creek	6/16	14	7	2.0:1
Soap Creek	6/16	13	6	2.2:1
TOTAL		348	265	1.3:1

Table 7. Maximum age, length at maximum age (FL, mm), and length range of all captured fish by stream for westslope cutthroat trout sampled from Montana headwater streams.

Stream	Collection year	Maximum age	Length at maximum age	Length range captured
Cache Creek	1994	8	226	113-230
Brushy Fork Creek[a]	1993	8	175	53-210
N Fk Deadman Creek	1993-94	7	164	40-216
Cabin Creek	1994	6	210	90-252
Cottonwood-Ruby	1993-94	6	246	41-324
W Fk Cottonwood	1993-94	6	212	46-268
Delano Creek	1993-94	6	159	37-209
Geyser Creek	1993-94	6	188	37-270
Halfway Creek	1993-94	5	185	27-278
Soap Creek	1993-94	5	230	38-239
E Fk Blue Creek[a]	1993	5	141	N/A[b]
Upper Cabin Creek[a]	1993	5	193	N/A[b]
Four Mile Creek[a]	1993	5	203	102-254
Collar Gulch	1993-94	4	178	45-230
E Fk Cottonwood	1994	4	178	62-256
Cottonwood-Smith	1993-94	4	222	64-258
N Fk Douglas Creek	1993-94	4	204	23-204
N Fk Gold Creek	1993-94	4	198	35-270
Jerry Creek	1993-94	4	154	33-235
Muskrat Creek	1993	4	262	73-262
Whites Gulch	1993-94	4	183	62-251
Hall Creek[a]	1993	4	169	102-178
Sauerkraut Creek[a]	1993	4	116	51-152
Douglas Creek	1993-94	3	207	45-227
Half Moon Creek	1994	3	202	56-270
Bear Creek[a]	1993	3	165	64-180
W Fk Blue Creek[a]	1993	3	160	75-173
W Fk Fishtrap Creek[a]	1993	3	188	N/A
Green Gulch[a]	1993	3	140	to 190
Prickly Pear Creek[a]	1993	3	158	76-178
Badger Cabin Creek[a]	1993	2	145	to 229
W Fk Dyce Creek[a]	1993	2	158	140-170
Wilson Creek[a]	1993	1	92	51-127

[a] Samples from University of Montana Wild Trout and Salmon Genetics Laboratory.
[b] N/A indicates data not available.

Discussion

While fecundity increased with increasing length, fecundity was highly variable, even within size groups, resulting in poor predictive capability. Rieman and Apperson (1989) developed a predictive model for westslope cutthroat trout fecundity using data from Averett (1962) and Johnson (1963). We hoped to improve the predictive ability of their model for smaller fish, but it appears that differences in length-fecundity relationships exist between stocks (Figure 5). We compared the slopes for regressions of length versus fecundity between stocks using Zar's (1984) methodology for multiple comparisons between slopes and found that the slopes were significantly different ($P < 0.01$). Although lacustrine-adfluvial (Liknes and Graham 1988) stocks had steeper slopes than resident stocks, a Tukey multiple comparison test (Zar 1984) showed no

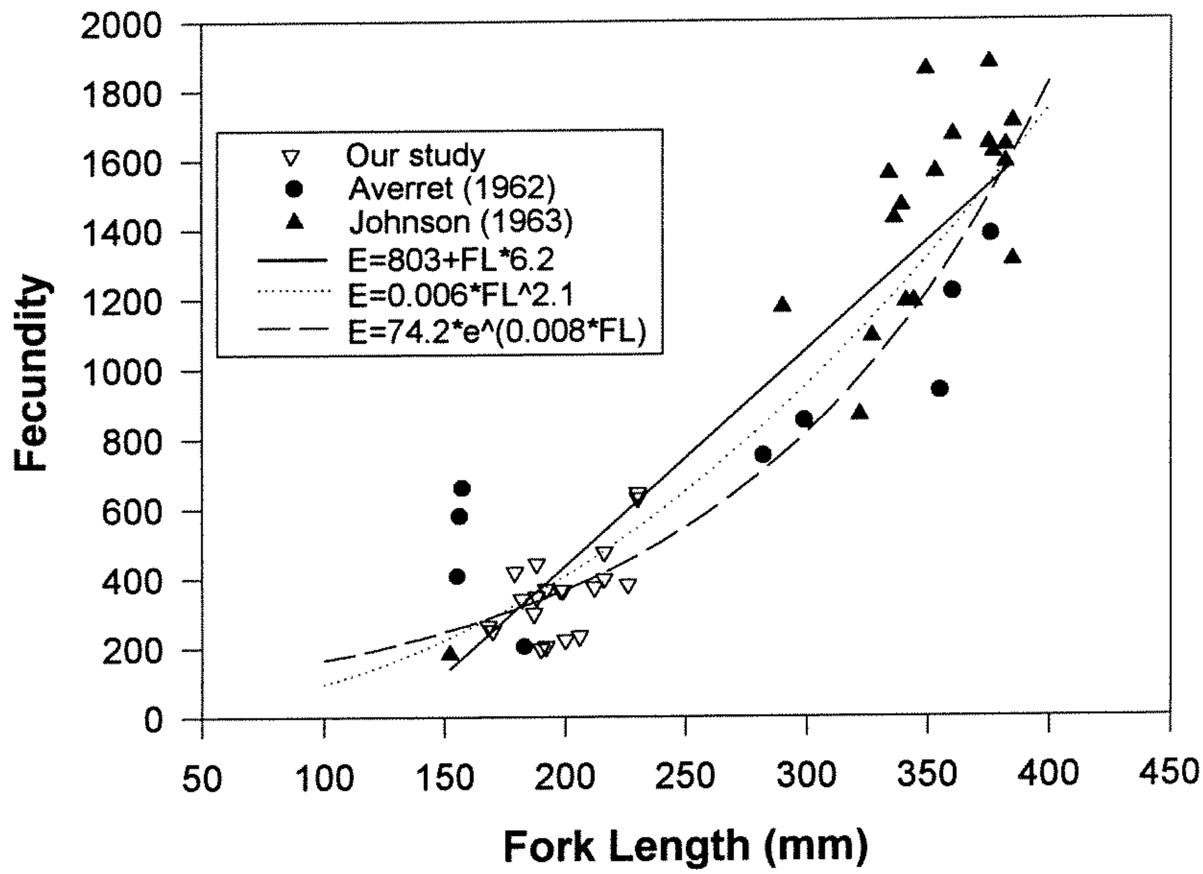

Figure 5. Scatter plot of fecundity to fork length from different stocks of westslope cutthroat trout. Data sources are as follows: resident, St. Joe River, Idaho (Averett 1962); adfluvial, Lake Couer d'Alene, Idaho (Averett 1962); adfluvial, Flathead Lake, Montana (Johnson 1963); resident, Flathead River, Montana (Johnson 1963); adfluvial, Hungry Horse Reservoir, Montana (J. Huston, Montana Fish, Wildlife and Parks, personal communication); Cottonwood and Cache creeks (this study).

consistent differences between slopes of the two life history types. The Flathead Lake lacustrine-adfluvial stock had a significantly steeper slope ($P < 0.001$) than any other stock examined. The slope of the resident Cottonwood Creek stock did not significantly differ from that of the adfluvial Hungry Horse Reservoir, the adfluvial Coeur d'Alene, or the resident Cache Creek stocks. The slope of the Cache Creek stock was significantly smaller ($P < 0.01$) than the adfluvial stocks. These comparisons suggest that length-fecundity relationships must be developed for each life-history type and, perhaps, for each stock. Dr. Michael Gilpin recently suggested that we should apply a cubic regression model to these data. We found a cubic model fit these data much better ($r^2 = 0.72$; $P < 0.05$).

While our fecundity model for resident westslope cutthroat trout was statistically significant ($P < 0.001$), a large proportion of the variance remained unexplained ($r^2 = 0.51$). We recommend applying this fecundity model ($E = -494.9 + 4.4*FL$) only to isolated, headwater populations occupying the upper Missouri River drainage in Montana. This recommendation reflects uncertainties in combining fecundity relations across different drainage basins and different stocks of westslope cutthroat trout.

While acknowledging the possibility of some genetic control of sexual maturation, our results indicate that length is more important than age in determining sexual maturity. Thus, westslope cutthroat trout populations that inhabit streams supporting faster growth should, on average, mature at younger ages. In river-lake systems, westslope cutthroat trout reach sexual maturity between ages 3 and 6 (Brown 1971; Lukens 1978; Liknes and Graham 1988; Behnke 1992). In our study streams males first reached sexual maturity at fork lengths from 110 to 160 mm (age 2), while females first reached sexual maturity between 150 and 180 mm (age 3). This probably reflects the different energy requirements for maturation of testes versus ovaries (Wootton 1985). Fish that grow faster may have different mortality rates within a given age (Busacker et al. 1990). Earlier maturation may compensate for higher mortality rates. In systems where predation by piscivorous fish species occurs, fast growth may be a means of avoiding predation. We do not believe this situation exists in our study streams because piscivorous fish species were not present. Because age and length at maturity may vary among streams, they should be evaluated for each stream.

When the predictive capability of the length-based logistic models was tested using field classifications of sexual maturity, results were better for males than for females. Because only males that extruded milt were classified as mature, they were easier to identify than females. The need to rely on visual appearance to assess female maturity may have biased our results. We recommend additional sampling of females to better document variation between streams. All ovaries examined from females older than age 5 contained mature ova and we interpret this as evidence for annual rather than alternate year spawning. Shepard et al. (1984) reported that some adfluvial westslope cutthroat trout in the Flathead Lake-River system appeared to be alternate year spawners, based on the presence of mature-sized fish remaining in Flathead Lake during the spawning season. Because resident westslope cutthroat trout do not perform extended migrations associated with spawning, more energy may be available for annual reproduction. This could maximize recruitment in a harsh environment.

Sex ratios were skewed to males in most study streams. This differs from ratios reported for fluvial and adfluvial westslope cutthroat trout populations. Values ranging between 0.2 to 0.9 males per female were reported by Bjornn (1957), Johnson (1963), Huston (1972), Lukens (1978), Thurow and Bjornn (1978), May and Huston (1983), by and Shepard et al. (1984). Irving (1954) also reported the ratio of males to females to decrease during the fishing season and suggested that mature male cutthroat trout were more susceptible to angling. We suspect that sex ratio differences between lacustrine - adfluvial and resident, headwater populations of westslope cutthroat trout may be explained by the greater susceptibility to angling of mature male trout. Headwater populations receive less angling pressure than lacustrine - adfluvial populations by virtue of their locations and slow growth environments (B. Shepard, Montana Fish, Wildlife, and Parks, personal communication) and subsequently, less harvest occurs on the more aggressive males.

Our results demonstrate that westslope cutthroat trout in headwater habitats live at least 8 years. Behnke (1992) reported that the life span of most western trout is 6 - 7 years. Johnson (1963) and Lukens (1978) estimated maximum ages of 6, and based on two tag returns, ages of 13 years have been documented for westslope cutthroat trout inhabiting Idaho waters (N. Horner, Idaho Department of Fish and Game, personal communication). Shepard et al. (1984) estimated maximum ages of 7 for westslope cutthroat trout inhabiting waters in the Flathead River-Lake basin in Montana. Large fish size does not necessarily translate into older ages. As described earlier, fish with different growth rates may have different mortality rates. We did not intentionally select for any size group to determine longevity. If incidental mortalities resulting from electrofishing or handling stress comprise a random sample of the population, our longevity estimates should be reasonable within the limits of sample size considerations. While electrofishing may cause higher voltage gradients (Ellis 1975) and injury rates in larger fish (Sharber and Carothers 1988), we do not believe this was a problem over the relatively narrow size range of fish we sampled (< 280 mm, FL). We recognized that the maximum ages we estimated from fish obtained for genetic analyses probably did not reflect maximum longevity because smaller individuals were often selected to minimize potential negative effects of removing the largest, or fastest growing, individuals from small populations.

These estimates of demographic parameters were incorporated into an extinction risk model for westslope cutthroat trout in the upper Missouri River basin developed by the USDA Forest Service, Intermountain Research Station. This parameterized model is presently being applied to known westslope cutthroat populations inhabiting streams within Federal lands of the upper Missouri River basin. Results from this assessment will allow land and fish managers to understand the relative risks of extinction for populations of westslope cutthroat trout over a broad geographic area and, hopefully, result in management actions to conserve this subspecies.

CHAPTER 2:
Status and Risk of Extinction for Westslope Cutthroat Trout in the Upper Missouri River Basin, Montana

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Abstract

Westslope cutthroat trout Oncorhynchus clarki lewisi presently occupy less than 5% of their historical range within the upper Missouri River drainage in Montana. We assessed the risks of extinction for 144 known populations inhabiting streams within federally managed lands in the upper Missouri River basin using a Bayesian viability assessment procedure that estimates probability of persistence based on subjective evaluation of population survival and reproductive rates as influenced by environmental conditions. We first customized this model using estimates of demographic parameters from the literature and field data. Each population was classified into one of three risk groups based on their Bayesian probability of persistence over a 100 year period (p_{100}). Most (71%) of the 144 populations had a "Very High" predicted risk of extinction (p_{100} < 50%), 19% exhibited a "High" risk (50% < p_{100} ≤ 80%), and 10% had a "Moderate" risk (80% < p_{100} ≤ 95%). Higher average predictions of p_{100} were consistently associated with those populations that inhabited watersheds with lower levels of management activities. ANOVA and a matrix of information divergence measures indicated that livestock grazing, mineral development, angling, and the presence of non-native fish had the greatest association with both estimated population parameters and persistence probabilities. Of 26 major sub-basins within the Upper Missouri, 16 presently support at least one known westslope cutthroat trout population on federal lands, and 14 of these 16 support at least one population with an estimated p_{100} value of 0.5 or greater. Results of our analysis has led to action by citizens of Montana, prompting state and federal managers to develop a conservation and restoration program for this subspecies in the upper Missouri River basin.

Introduction

The abundance and distribution of westslope cutthroat trout (Oncorhynchus clarki lewisi) have declined dramatically throughout the subspecies' historical range, which included the upper Columbia, Missouri, and South Saskatchewan river basins, as well as disjunct, isolated populations in the John Day drainage of Oregon and Lake Chelan, Methow, Entiat, Yakima, and Wenatchee river drainages of Washington (Liknes and Graham 1988; Behnke 1992; McIntyre and Rieman 1995). Behnke (1992) stated that the original distribution of westslope cutthroat trout within the upper Missouri River basin (Upper Missouri) is not known with certainty and suggested that their native range included "...the upper Missouri basin (main river and all tributaries) downstream to about Fort Benton, Montana, about 60 km below Great Falls, as well as headwaters of the Judith, Milk, and Marias rivers, which join the Missouri downstream from Fort Benton" (Figure 6). Hanzel (1959) suggested that their original range extended down to the Musselshell River.

Factors which have been identified as leading to declines of westslope cutthroat trout include introductions of non-native fishes, habitat alterations caused by land and water use practices, and over-harvest (Hanzel 1959; Liknes and Graham 1988; McIntyre and Rieman 1995). Allendorf and Leary (1988) suggested that genetic introgression is the most important factor responsible for the loss of native cutthroat trout populations. Montana's Department of Fish, Wildlife and Parks (FWP) recently (1996) changed angling regulations for westslope cutthroat trout in streams and rivers in the Upper Missouri to "catch and release" to lessen potential population losses caused by angling.

Remaining populations within the Upper Missouri are now restricted to isolated headwater habitats. Many of these habitats have been impacted by land/water management activities, invaded by non-native salmonids, or both. These factors could lead to an increase in the deterministic risk of extinction, as well as increasing the risk from stochastic (random catastrophic) environmental effects (Rieman and McIntyre 1993; Shaffer 1987, 1991). Fish survey data collected by the Montana Fish, Wildlife and Parks (FWP), the USDA Forest Service (Forest Service), and the USDI Bureau of Land Management (BLM) revealed the following. At least three populations have been extirpated within the past ten years. Many existing populations have been recently (within the past 50 years) invaded by non-native salmonids and have declined. Most remaining populations presently occupy isolated habitat fragments that are less than 10 km long.

Concern for the status of westslope cutthroat trout led FWP to form an interagency (members are scientists from FWP, Forest Service, BLM, and university) Upper Missouri Westslope Cutthroat Trout Technical Committee (Technical Committee) in early 1995 to make recommendations for

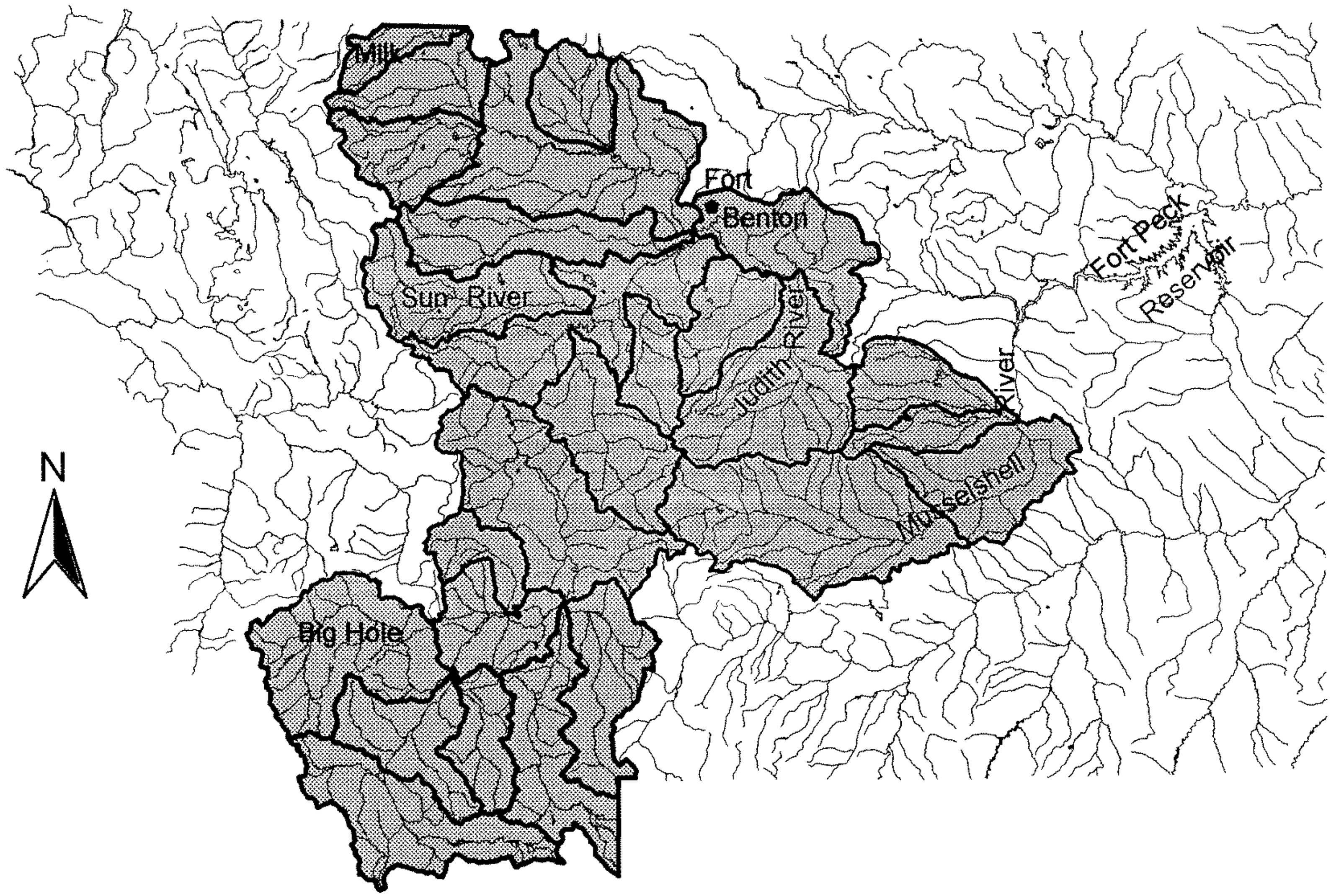

Figure 6. Map of Montana showing the sub-basins believed to have been historically occupied by westslope cutthroat trout (<u>Oncorhynchus clarki lewisi</u>) within the upper Missouri River basin (dark outlined sub-basins) at the time of European expansion into the upper Missouri basin. Features referenced in the text are shown.

conserving and restoring westslope cutthroat trout in the Upper Missouri. To justify and prioritize conservation and restoration efforts, federal land and state fish managers needed to know the overall status of the subspecies within the Upper Missouri and the relative extinction risk to each remaining population. Effective conservation of native fishes, such as the westslope cutthroat trout, requires understanding their current distribution and status, and threats to their existence. To support the efforts of the Technical Committee we described the current status and distribution of westslope cutthroat trout in the Upper Missouri and provided a comprehensive evaluation of the relative risks of extinction for 144 populations presently inhabiting streams within federally administered lands within the basin. We used a Bayesian Viability Assessment Module (BayVAM) developed at the USDA Forest Service's Rocky Mountain Research Station (Lee and Rieman 1997).

The BayVAM procedure was designed to provide a rigorous method of incorporating subjective judgments about habitat quality in a quantitative risk assessment that explicitly acknowledges uncertainty in parameter estimates, and uncertainty due to random environmental fluctuations. The BayVAM procedure utilizes three main components. First, users judge the relative condition of the habitat and estimate survival and reproductive rates for the population in question by completing an assessment survey. Second, a stochastic simulation model provides a mathematical representation of important demographic and environmental processes. Finally, a probabilistic network uses the results of the assessment survey to define likely parameter ranges, mimic the stochastic behavior of the simulation model, and produce probability histograms for average population size, minimum population size, and time to extinction. The structure of the probabilistic networks allows partitioning of uncertainty due to ignorance of population parameters from that due to unavoidable environmental variation. Although probability histograms are based on frequency distributions of a formal stochastic model, they can also be interpreted as Bayesian probabilities (i.e., the degree of belief about a future event). By using the estimates of demographic parameters for stream-resident westslope cutthroat trout from Downs et al. (1997), the parameters used in the BayVAM model component were customized for this analysis.

Methods

Distribution and Status

To assess the present status and distribution of westslope cutthroat trout in the Upper Missouri we examined evidence from the historical record to estimate the length of streams and rivers once occupied by westslope cutthroat trout. Anecdotal evidence suggests that the upper Sun River drainage (above a natural barrier, presently occupied by an irrigation diversion dam, about 155 km above its mouth) was barren of fish (B. Hill, Montana Department of Fish, Wildlife and Parks, personal communication). Two tributaries in the lower Musselshell drainage (one in the Box Elder drainage and one in the Flatwillow drainage) contain populations of genetically pure westslope cutthroat trout (Dr. R. Leary, Salmon and Trout Genetics Laboratory, University of Montana, personal communication). This evidence could support inclusion of the Musselshell drainage in the historical distribution. However, numerous releases of "fine spotted, native trout", a description used for both westslope and Yellowstone cutthroat trout (O. clarki bouvieri), were made by residents of Lewistown, Montana in unnamed local waters during the early 1900's (Montana Game and Fish Commission 1914). A report in the Meagher County *Castle News* (April 26, 1888) suggested that no trout inhabited the Musselshell or its branches. This evidence makes it impossible to discern whether westslope cutthroat trout populations in the Musselshell drainage originated from releases of hatchery stocks. Headwater capture of streams from the Judith drainage by streams in the Musselshell drainage may have allowed for the inter-basin transfer of westslope cutthroat trout. For this analysis, we assumed that westslope cutthroat trout originally occupied the entire Missouri River drainage down to, and including, the Musselshell River and the upper Milk River basin, but not the upper Sun River basin.

Present status and distribution of westslope cutthroat trout in the Upper Missouri were estimated using the Montana River Information System (MRIS) and a 1:100,000 geographic information system hydrography layer. We estimated total kilometers of historically occupied habitats and presently occupied habitats by genetic status. The MRIS is a relational database linked to the hydrography layer by stream reach. Reaches have been segregated based on physical attributes (gradient, valley shape, flow volume, and landform) and land ownership. The MRIS contains fish information for each reach of stream that has been surveyed. This information includes relative abundance and genetic status determined by allozyme electrophoresis (Leary et al. 1987). We summed the length and number of reaches (by major subbasins) that supported either westslope cutthroat trout that were electrophoretically tested to be at least 90% genetically pure, or fish classified as westslope cutthroat trout in the field, but not genetically tested. Westslope cutthroat trout electrophoretically determined to be less than 90% pure were classified as hybrids and not tallied. We recognize the problem of relying on field examination to determine levels of introgression, as reported by Leary et al. (1984; 1996), and acknowledge that an unknown number of reaches listed in the database as supporting untested westslope cutthroat trout may contain hybrid fish.

Extinction Risk Assessment

Populations of westslope cutthroat trout were relatively easy to define because each discrete population was isolated, either physically by a barrier to fish movement or biologically by the presence of a nonnative salmonid population. Each population occupied relatively small habitat patches (< 35 km of continuous stream length). We assessed extinction risk for 144 westslope cutthroat trout populations inhabiting federally administered lands of the Upper Missouri basin. Nine populations were believed to be genetically pure based on field morphometric examinations, and 135 populations had been genetically tested (by allozyme electrophoresis on a sample of individuals from the population) as being at least 90% pure.

For each population, a two-part assessment questionnaire was completed. The first part was completed by local fisheries biologists familiar with the individual fish populations, usually via field surveys or by reviewing survey data. The second part was completed by those same fisheries biologists along with a team of resource specialists familiar with watersheds that contained each population. Watersheds were delineated based on sixth-level hydrologic boundaries, consistent with the methods of Maxwell et al. (1995), and ranged from about 8,000 to 16,000 hectares in size. These watersheds were used to assess possible effects of present land management activities on the predicted persistence of westslope cutthroat trout populations. The sixth-level watershed was the smallest scale for which federal land-use information existed throughout the Upper Missouri. Eight fisheries biologists and six teams of resource specialists completed assessment questionnaires for 144 populations in 117 watersheds.

Part 1: Population survey - Local biologists completed questionnaires for each population; the questionnaire called for estimates of population demographic parameters and stream habitat capability. Responses to questionnaires were based on biologists' field surveys of fish populations and stream habitat, which are integral parts of the BayVAM approach (Lee and Rieman 1997). For each population, biologists were asked to assign likelihood values by using established range criteria for each of 11 life history (demographic) and population parameters (Table 8). The ranges were set to correspond with reasonable values that might be expected for westslope cutthroat trout within the upper Missouri basin based on field research (Downs et al. 1997). Guidelines were prepared to provide a common set of assumptions (standards) for assigning likelihood values (Appendix D). The guidelines directed the biologists to evaluate instream conditions directly, not to infer conditions based on land-use activities within the watershed. Biologists also estimated the length of stream habitat occupied by each population, although length of occupied habitat was not explicitly used in the BayVAM model.

Part 2: Land-use Assessment - Management activities within each watershed occupied by a westslope cutthroat trout population were assessed by rating the effects of each activity on the portion of stream channel occupied by westslope cutthroat trout. Local FS, BLM, and FWP resource scientists rated these management impacts. Four FS and two BLM interdisciplinary (ID) teams ranked nine land, water, or angling impacts: (1) roads, (2) livestock grazing, (3) mineral and/or oil and gas development, (4) timber harvest, (5) water withdrawals and impoundments, (6) angling pressure, (7) the distribution and abundance of non-native fishes, (8) catastrophic risk associated with wildfire, and (9) land-use designations which could potentially impact stream habitats within the land management plans for each watershed (i.e., the area of the watershed allocated to commercial resource extraction by a local planning document). Each management risk factor was subjectively ranked on an ordinal scale as having no, low, moderate, or high effect based on a combination of empirical data and professional judgment.

Table 8. Criteria ranges for eight life history and three population level parameters used within the BayVAM model to assess the relative risk of extinction for each of 144 westslope cutthroat trout populations in the upper Missouri River basin of Montana. Low values are the first range reported, followed by moderate, and high ranges (see Appendix D for details).

Parameter	Ranges	Parameter	Ranges
<u>Life History Parameters</u>			
Spawning Habitat Availability	60-80% 85-95% 100%	Adult Survival 30 - 50% 50 - 70%	10 - 30%
Fecundity (eggs/female)	200-500 500-800 800-1100 1100-1500	Age at First Maturity (% of population)	age 3 (30%) age 4 (40%) age 5 (20%) age 6 (10%)
Incubation Success	5 - 20% 20 - 35% 35 - 50%	<u>Population Parameters</u>	
		Initial Population (Adults)	< 450 450 - 850 > 850
Maximum Fry Survival	10 - 20% 20 - 30% 30 - 40%	CV of Juvenile Survival	< 40% 40 - 65% > 65%
Fry Capacity	1000 - 4000 4000 - 7000 7000 - 20000	Risk of Catastrophe (Year interval)	120 - 170 70 - 120 20 - 70
Juvenile Survival	14 - 26% 26 - 38% 38 - 50%		

General guidelines were provided to ID teams to promote consistency. These guidelines specified that land management risk factors (factors 1-5, 8, and 9) be ranked based on the proportion of the stream network within the watershed that potentially could be affected by each risk factor. Angling (factor 6) was rated from none to high using fishing regulations and access. Effects of introduced fish species (factor 7) were ranked by the presence and relative abundance of introduced fishes within each watershed. A tenth category (cumulative effects) was intended to capture the ID teams' views on the magnitude of the cumulative effects of all watershed activities on aquatic resources. The original watershed assessment was directed at the entire watershed and stream system, not just that portion supporting westslope cutthroat populations; however, ID teams were contacted and asked to specifically rank impacts to occupied habitats for the final analysis.

Part 3: Data Analysis - Survey responses for each population parameter were summarized for each population and across all populations. Data were summarized by tabulating the frequency of likelihood scores biologists assigned to each of three classifications (low, moderate, and high) for each population parameter used in the BayVAM model. For each population, the associated set of likelihood values for the population parameters were used in the probabilistic network provided within the BayVAM procedure to calculate probabilities associated with minimum population size, average population size, and time to extinction (if applicable) based on a 100 year simulation period. We then ran the BayVAM model for each population and compared the probabilities of persisting for 100 years (p_{100} values) to provide a perspective on the perceived condition of the populations.

We used p_{100} values as a standard for comparisons among populations. Populations were classified into three risk groups based on their estimated probabilities of persistence: very high-risk ($p_{100} \leq 50\%$), high risk ($50\% < p_{100} \leq 80\%$), or moderate risk ($80\% < p_{100} \leq 95\%$). None of the assessed populations had a p_{100} value greater than 95%, a criterion proposed by Shaffer and Sampson (1985) for low risk. Populations were also classified genetically: one class contained populations at least 90% pure as measured by allozyme electrophoresis; another class contained populations suspected of being pure, but untested by genetic techniques.

The BayVAM procedure uses a 100-year simulation period, which is roughly 20 times the generation time of westslope cutthroat trout (Downs et al. 1997). Although longer time frames may be appropriate for some species (Marcot and Murphy 1996), 100 years is sufficient to characterize the dynamics of model populations and provide useful indices of risk. We recognized that changes in environmental conditions and management are certain to occur within the next 100 years. The 100-year time frame was used as a standard of reference for the assessment based solely on conditions assessed at the time of analysis.

We had two concerns about observer bias. We relied on local expert opinion to describe the status of populations in their management areas. Thus, each expert was responsible for assessing multiple populations concentrated in roughly adjacent geographical areas that might share similar land management histories. We were unable to assign populations randomly to observers (because we used local expert opinion), or to replicate population assessments (i.e., have more than one biologist assess each population). We explored potential observer bias by testing for differences in predicted probabilities of persistence across observers using the Kruskal-Wallis test (Daniel 1978). We attempted to minimize the effect of observer bias on our assessment of land-use effects by the use of ID teams, which should mitigate some of the bias associated with individuals.

We examined the relationship between management risk factors, identified by the ID teams, and populations in two ways. First, we looked for differences in likelihood assignments for each population parameter that could be associated with different management risk factors. We calculated an information divergence measure (Kullback and Leibler 1951). This divergence measure compares the conditional probability distributions (i.e., the likelihood function for a population parameter conditional on a given ranking of a risk factor) to the marginal probability function (i.e., the likelihood function for a population parameters generated by summing over all rankings) for each parameter-risk factor combination. This information divergence can be interpreted as an average measure of the information difference between two sets of probabilities (Whittaker 1990). It provides a convenient means of illustrating which risk factors might have a causal association with the habitat conditions that led to the likelihood values assigned to a given population parameter.

Second, we compared risk factors with the probability of persistence directly using a multi-factor analysis of variance (ANOVA) in a general linear model approach (SAS 1988). We used ANOVA as an exploratory tool to identify coarse patterns in the data, not to rigorously test specific hypotheses. We conducted two analyses. The first included roads, livestock grazing, mining (including oil and gas development), timber harvest, water diversion, angling, and presence of non-native fishes because ratings of these activities were provided for all 144 populations. We excluded cumulative effects since this variable incorporated effects from the individual activity classes above. The second analysis included cumulative effects, forest plan allocation, and risk of a catastrophic event for 134 populations where ratings were provided for these variables. Ratings of all the above effects, except cumulative effects, were classed as none, low, moderate, or high. The "none" rating was omitted for cumulative effects.

Results

Distribution and Status

Based on 1:100,000 scale digital hydrography, we estimated that a total of just over 93,000 km of lotic habitats were historically occupied by westslope cutthroat trout in the Upper Missouri at the time of European expansion into the basin. Westslope cutthroat trout at least 90% genetically pure based on genetic tests using allozyme electrophoresis presently inhabit less than 3% of their historical range within the Upper Missouri basin. An additional 3% of historical range still contained westslope cutthroat trout that were classified using examination of external morphometric characters, but had not been confirmed by genetic testing. If only reaches which had been surveyed were assessed, about 5% of the basin contained westslope cutthroat trout at least 90% pure, while another 8% contained genetically untested fish which appeared to be westslope cutthroat trout based on external morphologic features. Westslope cutthroat trout of at least 90% genetic purity occupied a total of 199 reaches.

Extinction Risk Assessment

Biologists did not always enter values for all population parameters, therefore sample sizes varied by parameter. All biologists used the default values for age at maturity and fecundity parameters, which were based on field observations (Downs et al. 1997). Biologists had relatively high confidence that spawning habitat availability was high for a majority of populations and those initial population sizes were low. They were fairly confident that most of the populations did not fall into the high category for fry capacity and juvenile survival, but they were less certain whether ratings should be low or moderate. For all other parameters, biologists were less confident in their assessments or believed parameters fell into the moderate range for a majority of populations.

The BayVAM model predicted that most (103 or 71%) of the populations had a less than 50% probability of persisting for 100 years (Figure 7). The cumulative distribution plot showed a relatively clear change in slope above this 50% probability of persistence (Figure 7). Thus, 71% of the 144 populations had a very high risk of extinction ($p_{100} \leq 50\%$), 27 populations (19%) had a high risk of extinction ($50\% < p_{100} \leq 80\%$), and 14 populations (10%) had a moderate risk of extinction ($80 < p_{100} \leq 95\%$). Slightly more than half of the populations in all extinction risk categories had been genetically tested as 100% pure.

Average predicted probabilities of persistence differed significantly ($p<0.001$) among observers (Figure 8). It is unclear whether these differences were due to observer bias or to regional effects. Observer 7 had higher than average probability values, but the populations he assessed - the subjects of his ongoing research - were mostly healthy. Observer 2's assessment resulted in lower-than-average probabilities, but most populations this observer assessed inhabited streams affected by improper livestock grazing. Although observer bias cannot be dismissed, the assessments seemed to be fairly consistent across observers.

The matrix of information divergence measures indicated that grazing, mineral development, angling, and the presence of non-native fish had the greatest association with assigned likelihood values across all parameters. These are the activities that produced the 13 highest observed

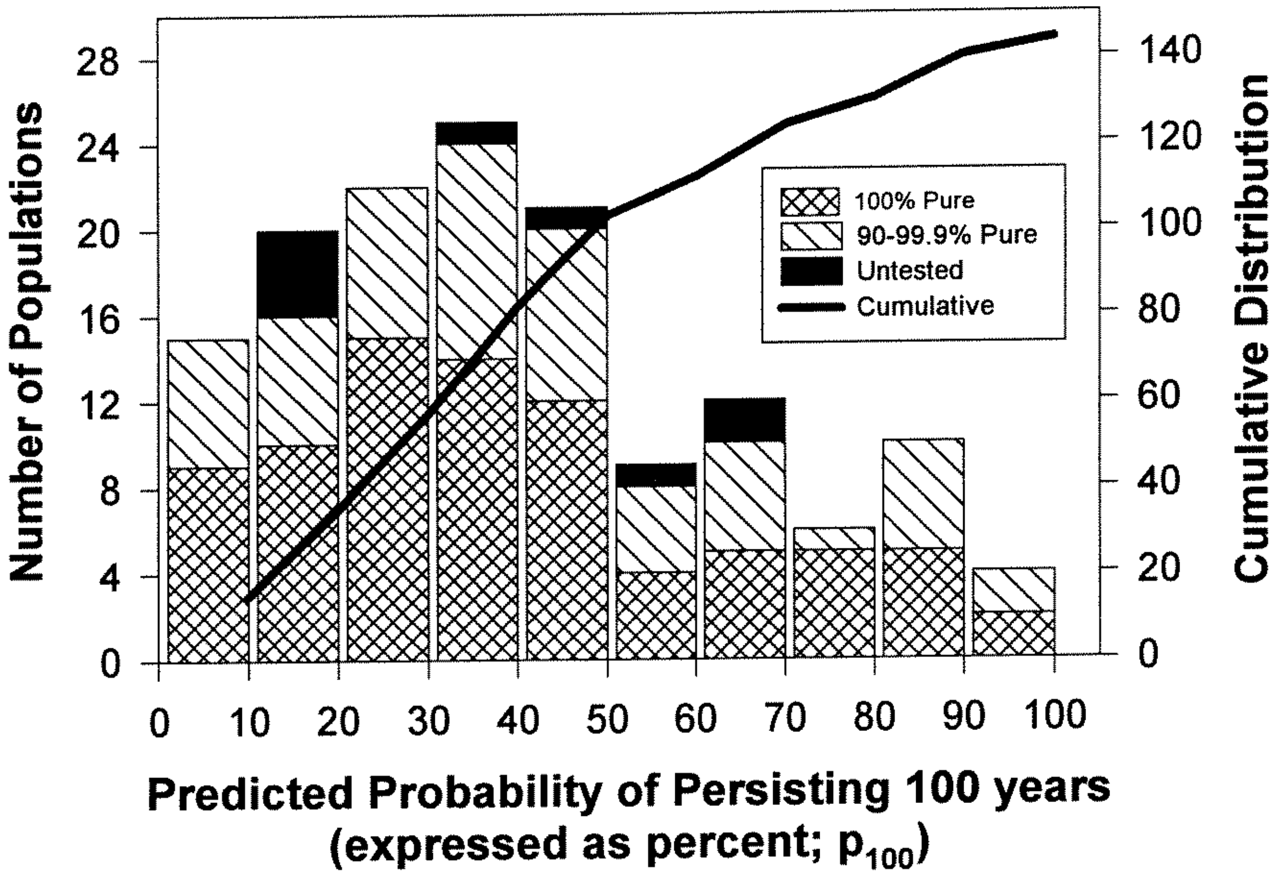

Figure 7. Number of populations within each 10% predicted probability of persistence bin by genetic status (bars) and cumulative number of populations by predicted probability of persistence (line) for 144 westslope cutthroat trout populations in tributaries located in the upper Missouri River basin.

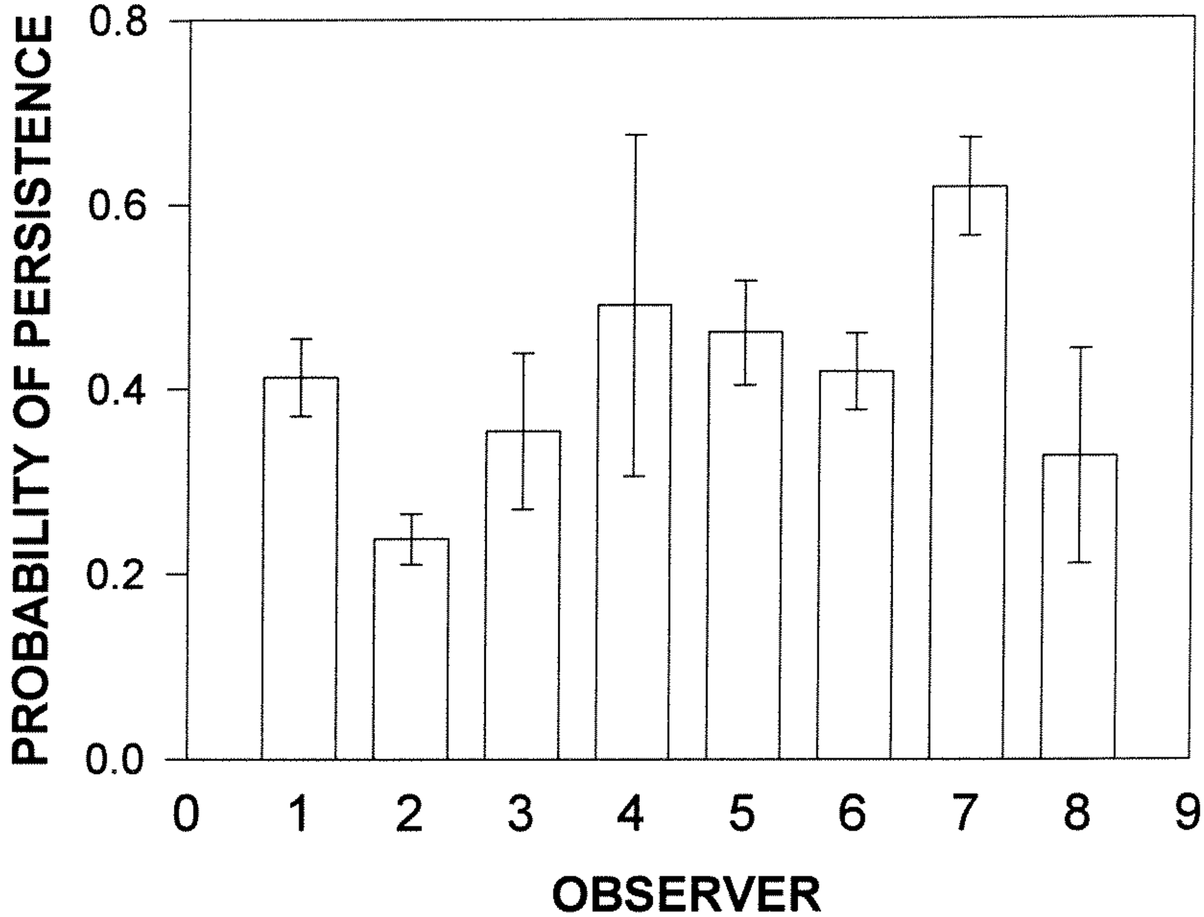

Figure 8. Means (bars) and SE's (vertical lines) of predicted probabilities of persistence by observer for westslope cutthroat trout populations inhabiting federal lands in the upper Missouri River basin.

values in the information matrix (Table 9). We did not attempt to estimate significance of these values; to do so would require a more intensive analysis based on the sampling properties of the information divergence measure. Rather, we identified noteworthy high values as those greater than 0.668, which is the overall mean of the observed values plus one standard deviation. Fourteen (14%) of the elements within the information matrix exceeded this threshold. The highest values span all of the population parameters except spawning habitat availability, fecundity, initial population, and age at maturity. Because age at maturity was constant for all populations, its information divergence was zero and it was omitted from Table 9.

Higher average estimates of the probability of persistence were consistently associated with those populations inhabiting watersheds with lower management risk factors (Table 10). The association of each risk factor with probability of persistence was examined both in terms of the sequential sum of squares, where each activity was entered into the ANOVA model first, and in terms of the partial sum of squares where each risk factor was entered in the ANOVA model last. These ANOVA's suggested potential interaction effects or confounding among the management activities, evidenced by substantively different significance values for partial and sequential sums of squares for many parameters (Table 10). However, sample sizes were insufficient to test comprehensively for interaction effects. The presence of interaction effects, combined with the heavily unbalanced design and potential confounding, makes the significance levels highly suspect for hypothesis testing. Nevertheless, the significance values are useful guides to potentially important main effects.

All risk factors except mineral development and timber harvest showed meaningful effects (ie., low P values) when entered first in the ANOVA model, suggesting they would be important if examined in isolation. Only livestock grazing and nonnative fish explained significant variation in p_{100} values when entered last in the model containing all individual risk factors. This result suggests that these factors remain important after all other factors are accounted for. Catastrophic risk and cumulative effects were consistently important in the more reduced analysis of integrated risk factors.

The historical range of westslope cutthroat trout within the upper Missouri River basin encompasses 26 subbasins, aggregations of watersheds classified as fourth-code hydrologic units by the U.S. Geological Survey. Sixteen of these subbasins still support at least one westslope cutthroat trout population on federal land. Of these 16 sub-basins, 14 contain populations with a moderate or high risk of extinction. These subbasins are spread throughout the Upper Missouri (Figure 9); however, almost all of the remaining populations occupy high elevation, mountainous stream fragments.

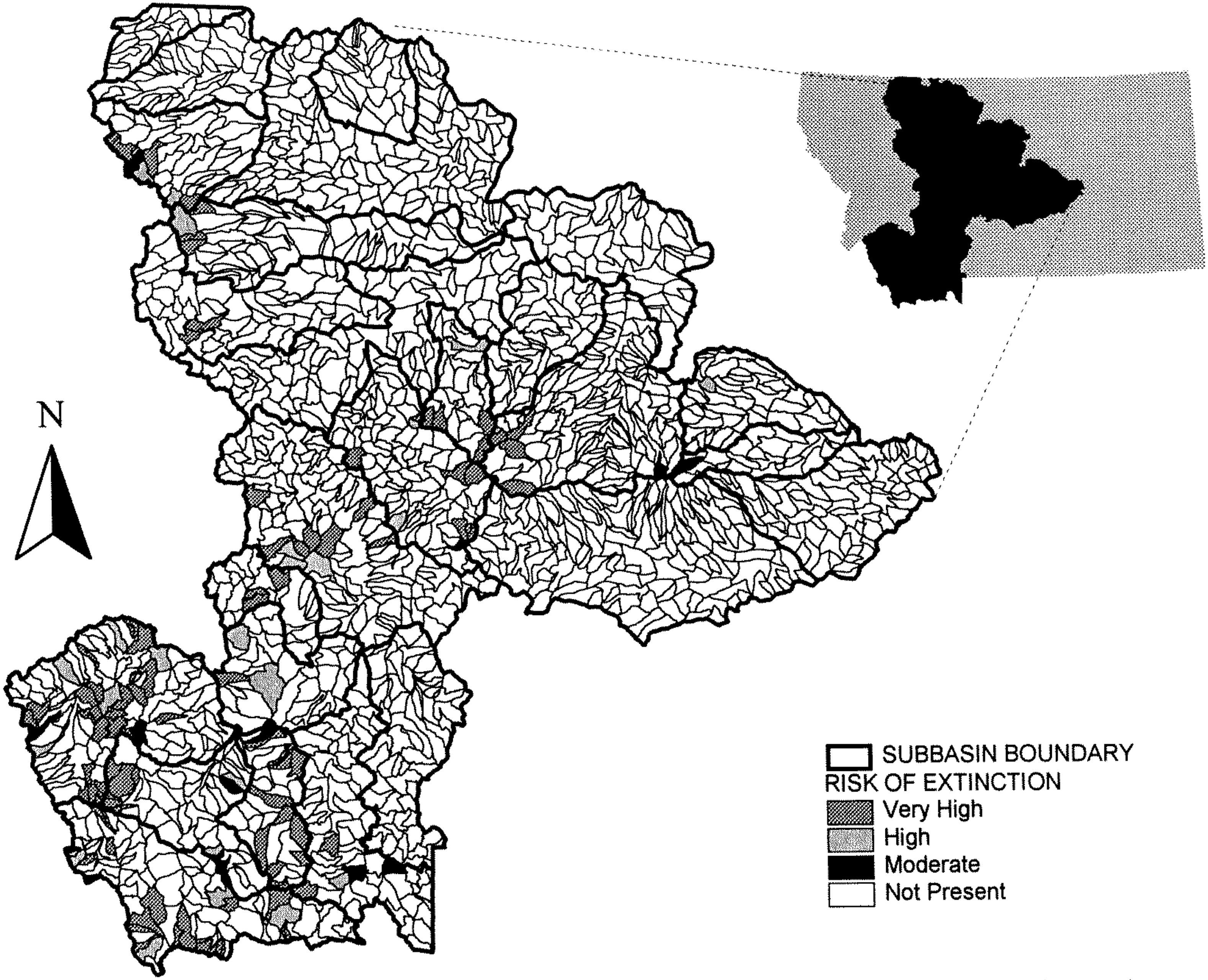

Figure 9. Watersheds within sub-basins of the upper Missouri River basin that presently support populations of westslope cutthroat trout by extinction risk class.

Table 9. Kulback-Leibler (1951) information divergence calculated for each combination of population characteristics (node) and landuse activity. This divergence can be interpreted as an average measure of the information difference between the marginal probability distribution for each node, and a nodal probability distribution conditioned on the level of each activity. Highlighted values represent the highest observed values in the matrix.

	Land Use Activity									
Population characteristic	Roads	Grazing	Minerals	Timber harvest	Water withdrawal	Angling	Non-native fishes	Forest Plan Allocation	Major Risk	Cumulative Effect
Spawning Habitat	0.21	0.26	0.36	0.36	0.43	0.08	0.09	0.42	0.16	0.17
Incubation Success	0.57	**0.70**	0.46	0.18	0.11	0.60	0.11	0.12	0.17	0.22
Max Fry Survival	0.06	0.34	0.52	0.09	0.17	**0.83**	**1.22**	0.05	0.23	0.40
Fry Capacity	0.19	0.24	**0.84**	0.43	0.36	0.43	0.57	0.18	0.15	0.06
Juvenile Survival	0.19	0.32	**0.97**	0.43	0.27	**0.78**	**1.19**	0.07	0.19	0.44
Adult Survival	0.45	0.19	**1.05**	0.38	0.17	**1.92**	**0.77**	0.22	0.22	0.42
Fecundity	0.09	0.16	0.22	0.10	0.23	0.18	0.19	0.06	0.31	0.12
Initial Population	0.33	0.20	0.34	0.20	0.36	0.38	0.23	0.07	0.17	0.26
CV Juvenile Surv	0.15	**0.69**	0.48	**0.67**	0.22	0.50	0.17	0.05	0.17	0.17
Risk of Catastrophe	0.30	**0.75**	**0.76**	0.31	0.32	0.34	0.57	0.06	0.66	0.10

Table10. Means (sample size) of probabilities of 144 westslope cutthroat trout populations within the upper Missouri River basin persisting from the BayVAM model by "None", "Low", "Moderate", and "High" rating categories assigned by biologists for effects of management related disturbances on those populations along with results from ANOVA tests. "Major Event" = Catastrophic risk from major event; "Cumul Effects" = rated impacts from cumulative effects of individual management classes; and "Forest Plan" = Forest Plan Allocation.

	Individual Management Classes									
Rated impact	Grazing	Non-native Fish	Roads	Minerals	Timber	Water Withdrawal	Angling	Major Event	Cummul Effects	Forest Plan
None	0.701 (7)	0.592 (27)	0.481 (18)	0.402 (84)	0.407 (68)	0.454 (61)	0.378 (21)	0.255 (12)	N/A[a]	0.414 (2)
Low	0.456 (42)	0.357 (14)	0.407 (73)	0.412 (39)	0.393 (55)	0.366 (47)	0.420 (104)	0.339 (86)	0.573 (26)	0.491 (49)
Moderate	0.412 (40)	0.400 (30)	0.374 (32)	0.328 (12)	0.345 (13)	0.314 (15)	0.343 (11)	0.519 (32)	0.405 (58)	0.321 (30)
High	0.297 (55)	0.328 (73)	0.313 (21)	0.341 (9)	0.390 (8)	0.348 (21)	0.192 (8)	0.481 (6)	0.309 (60)	0.308 (53)
ANOVA test results for individual management classes (N=144): Model F value = 4.33; P < 0.001.										
ANOVA test results for Forest Plan, Cumulative Impacts, and Catastrophic (Major) Events (N=134): Model F value = 8.09; P<0.001.										
Sequential (Type I) Sum of Squares for each treatment when entered first in the model										
F value	11.53	11.83	2.55	0.83	0.37	3.40	3.64	8.65	16.89	8.27
P	0.0001	0.0001	0.0591	0.4795	0.7738	0.0199	0.0147	0.0001	0.0001	0.0001
Partial (Type III) Sum of Squares for each treatment when entered last in the model										
F value	9.63	12.30	1.61	0.03	1.17	1.36	0.98	7.15	11.85	1.09
P	0.0001	0.0001	0.1913	0.9927	0.3225	0.2598	0.4047	0.0002	0.0001	0.3545

[a] N/A indicates no data.

Discussion

Liknes (1984) and Liknes and Graham (1988) conservatively estimated that westslope cutthroat trout historically occupied about 25,500 km of stream habitats in Montana with an estimated 11,400 km located within the Upper Missouri. We estimated that westslope cutthroat trout historically occupied about 93,000 kilometers of stream habitats within the upper Missouri basin. Liknes (1984) and Liknes and Graham (1988) worked with 1:250,000 scale maps; our estimates are based on 1:100,000 scale maps. In addition, Liknes and Graham only considered the Missouri River above Fort Benton and the headwaters of the Marias, Judith, Musselshell, and Milk river basins in their analysis. An analysis of Liknes's (1984) data indicated that about 1,300 km (11%) of the historical 11,400 km remain occupied by westslope cutthroat trout; however, genetic data was very limited. We estimate that about 4,300 km (5%) of 93,000 km of historically occupied streams now support this subspecies. This estimate includes both genetically tested and untested populations.

We believe we have analyzed extinction risk for most known westslope cutthroat trout populations ($\geq$ 90% genetically pure) in the Upper Missouri because (1) only 199 total reaches in the Upper Missouri were known to support 90% (or more) pure westslope cutthroat trout, (2) several populations analyzed in this risk assessment inhabited more than one reach, and (3) the only populations which were not assessed were restricted to streams totally within private ownership. Our analysis indicates that westslope cutthroat trout populations inhabiting federal lands within the Upper Missouri are at serious risk of extinction under existing conditions (i.e., without additional stresses placed on them by new land or water management activities, or a concerted management effort to preserve and restore them). This conclusion is based on the trends over time which show a major reduction in range of genetically pure populations and the alarmingly low estimated probabilities of persistence for nearly all populations examined.

These low estimates arise from a combination of two factors. First, there are unmistakable impacts of land-use activities, though the full nature of these impacts is not clear. Among the management risk factors, grazing and the presence of nonnative fishes have the most obvious and consistent impacts on population parameters, and subsequently, on probability of persistence. Mineral development and angling have noticeable associations with population parameters, but these associations do not translate clearly into measurably different probabilities of persistence. Confounding or interactions of mineral development and angling with other, more dominant factors might explain these observed associations, but we do not know. The impacts of roads, timber harvesting, and water withdrawal within the present context are even more obscure.

The second principal reason for low estimated persistence is poor information on demographic parameters for each population. This ignorance complicates our understanding of causal relationships and confuses relationships between risks and management effects. It also increases the Bayesian probability of extinction, because high uncertainty in demographic parameters, as expressed in the survey responses, connotes high uncertainty regarding the future status of a population. Uncertainty, whether originating from a model, data used in the model, or random events connotes higher risk. We contend that by incorporating the uncertainty arising from lack of knowledge into our assessment, we will estimate extinction risks better, not overestimate them. In reality, a population will persist or not (i.e., in a classical sense its probability of persistence is either one or zero), but we do not know the future outcome. We can only estimate the chance of persistence given what we know. In outlining the BayVAM approach, Lee and Rieman (1997) take the position that ignorance of population parameters and processes is a genuine component of risk that must be addressed in viability assessments designed to aid management. We share this view.

The collective evidence suggests that even if reducing uncertainty about population parameters could reduce estimates of risk, it would not significantly change the overall picture that westslope cutthroat trout are in trouble in the upper Missouri basin. The p_{100} values estimated for most of these populations are so low that it would require both major reductions in uncertainty regarding population parameters and substantive shifts in the modal values of many known parameters to reduce the risks of extinction to moderate or low for most populations. The small habitat fragments these populations now occupy (Figure 10) and lack of connectivity between these populations further contributes to their tenuous status (Rieman and McIntyre 1993). Some optimism over the conservation of this subspecies in the basin may be warranted because 14 of the 16 subbasins within the upper Missouri basin that still contain westslope cutthroat trout have at least one population with a p_{100} value of greater than 50%. In addition, these 14 subbasins are well distributed throughout the upper basin.

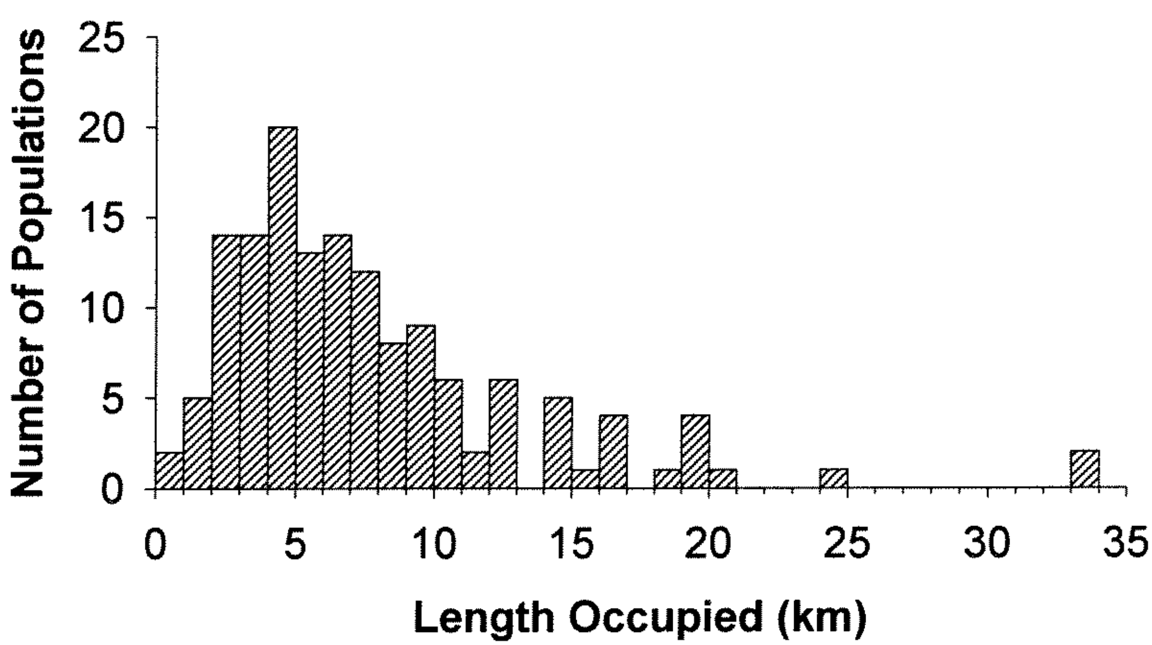

Figure 10. Frequencies of estimated stream length (km) occupied by each of 144 westslope cutthroat trout populations in the upper Missouri River basin of Montana.

Management Implications

How should resource managers respond to a risk assessment showing that a combination of ignorance and random environmental processes leads to a poor outlook for survival of an important subspecies? They have three options. Ignore the assessment and proceed with business as usual, postpone action until further information can be gathered that might change the tone of the assessment, or act quickly to initiate steps to protect the subspecies while continuing to gather information that could promote effective management. Option 1 is generally accompanied by an attack on the methods used and claims of a fatal flaw in the assessment. Option 2 has merit if the risks of not acting quickly are low, new information can be obtained efficiently, and new information will likely change the conclusions of the assessment. Option 3 is the logical choice when actions taken in the short term are not excessively costly and do not preclude future options that might seem more appropriate in light of new information.

The response of the State of Montana, the FS, and the BLM to our assessment has been in line with option 3. In September 1996, the Governor of Montana convened a Westslope Cutthroat Trout Conservation Workshop to initiate a statewide conservation effort. This conservation and restoration effort is being led by FWP and already has begun in the Upper Missouri. A steering group, consisting of agency and private representatives, has been formed to recommend conservation and restoration efforts to FWP. A technical committee, chartered in 1995, interacts with both the steering committee and FWP to recommend technically sound conservation and restoration strategies. Local citizen watershed groups have been formed in some watersheds of the upper Missouri basin to implement conservation and restoration efforts. An ambitious restoration program was recently initiated in the upper Madison River drainage. All of these conservation and restoration efforts were stimulated, in part, by our extinction risk assessment of westslope cutthroat trout in the upper Missouri basin.

The FS and the BLM also asked the technical committee for interim recommendations, based on preliminary results from this analysis, to conserve westslope cutthroat trout inhabiting federal lands within the upper Missouri basin until FWP's conservation and restoration plan was adopted. The technical committee made the following two recommendations:

(1) Aquatic habitats in all streams that now support populations at least 90% genetically pure (144 populations at present) should be protected from existing and future land management impacts. The level of protection should be specified further and related to genetic purity of individual populations. It was recognized that the 144 streams presently supporting populations likely will change; some populations may become extinct and additional populations may be found. However, the BLM and the FS have defined all 144 streams as suitable habitats that will be protected, regardless of future extinctions. The intent of this recommendation is that any habitats now supporting populations of westslope cutthroat trout (> 90% pure) should be protected or restored to allow for recovery of this subspecies in known suitable habitats.

(2) Until the basinwide conservation strategy being developed by FWP is adopted,

management emphasis must be placed on westslope cutthroat trout in tributaries that support genetically pure populations with a moderate or high probability of extinction. Populations that are 100% pure should be secured first, followed by populations less than 100% pure. Twenty-one populations presently have been genetically tested as pure and meet the moderate or high risk criteria. Again, it was recognized that these numbers are probably dynamic. Local opportunities and information for securing these populations also will be considered in setting priorities

The rationale for recommending that healthier populations be secured first is that, generally, the level of effort needed to secure a relatively healthy population will be less than that needed to secure populations more at risk. We believe that this extinction risk assessment provides a valuable tool for illustrating the relative risk of extinction between populations and puts regional basin-wide extinction risks in perspective for land and fishery managers.

CHAPTER 3:
Age Determination and Growth of Headwater Populations of Westslope Cutthroat Trout *Oncorhynchus clarki lewisi*

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[a] The Unit is jointly sponsored by Montana State University, Montana Department of Fish, Wildlife, and Parks, and the U.S. National Biological Service.

Abstract

Evidence for the validity of otoliths as aging structures for westslope cutthroat trout was provided through comparison with a length frequency histogram. Ages interpreted from otoliths were significantly higher than ages interpreted from scales for 424 paired age structure samples (t-test; $P<0.001$). A missing first-year annulus was believed to cause some of this discrepancy. Ages assigned from otoliths were more precise than those assigned from scales and discrepancies between ages assigned from paired otolith and scale samples were smaller for younger fish. Eight-seven percent of recaptured Visible Implant (VI) tagged fish formed an interpretable annulus between the ages of 2 and 3, while only 10% formed an interpretable annulus between the ages of 4 and 5. It became very difficult to interpret annuli near the scale's margin after fish reached age 3, we suspect this is related to slower growth rates as fish matured. The combined problem of discerning annuli near scale margins of older fish and a missing first year annulus on some scales, raises serious concerns regarding the reliability of ages interpreted from scales. Empirical growth for fish 116 to 303 mm (fork length) was assessed from 786 tag recapture events. Based on an assumed growth season extending from May 1 to October 15 the estimated daily growth averaged 0.11 mm per day. Expanding this daily growth to annual growth resulted in an average annual growth rate of about 18.5 mm. There was a slightly negative (slope of –0.003) and significant ($P < 0.001$) relationship between length at first capture and daily growth.

Introduction

Scales are commonly used to age many species of fish and are often preferred because their removal and examination does not require sacrificing fish. Several studies have demonstrated that some cutthroat trout Oncorhynchus clarki subspp. do not form a first year annulus (Fraley et al. 1981; Shepard et al. 1984; Lentsch and Griffith 1987). This lack of first year annulus formation has been attributed to the low number of degree-days these fish are exposed to during their first year of life (Laakso and Cope 1956; Jensen and Johnsen 1982; Lentsch and Griffith 1987). In addition, annuli may become crowded or indistinguishable as fish growth slows with increasing age (Johnson 1976). Scales may also be partially resorbed as individuals age and mature, as was documented in chinook salmon Oncorhynchus tshawytscha (Chilton and Bilton 1986). Further, scales may become damaged or lost, and regenerated scales will not accurately reflect an individual fish's age or growth. Estimating fish growth rates is an important component of understanding fish demographics.

Using scales to age westslope cutthroat trout Oncorhynchus clarki lewisi from headwater populations without first validating the accuracy and precision of this method could result in inaccurate estimates of age. Inaccurate age estimates could lead to errors in the calculation of growth, recruitment, and mortality rates, important parameters in guiding management actions.

Otoliths have been used to age various salmonid species including chinook salmon (Neilson and Green 1983), sockeye salmon Oncorhynchus nerka (Marshall and Parker 1982), steelhead trout Oncorhynchus mykiss (Campana 1983), and brook trout Salvelinus fontinalis (Hall 1991). Simkiss (1974) demonstrated that bones and otoliths in many fishes have priority over scales in calcium deposition and, in some instances, calcium may be resorbed from scales. However, the need to sacrifice fish to obtain otoliths is a major concern, especially for a subspecies that is being considered for protection under the Endangered Species Act. We evaluated the use of scales for aging resident westslope cutthroat trout from headwater tributary streams of Montana.

Rieman and Apperson (1989) found no documentation of growth for resident westslope cutthroat trout. Subsequently, Mullan et al. (1992) reported relatively slow growth for cutthroat trout in tributaries to the Methow River. We estimated empirical growth rates for resident westslope cutthroat trout from tag-recapture data.

Study Area

Nineteen headwater streams were selected for this study. Fifteen of the selected study streams were in the upper Missouri River drainage and four were part of the Clark Fork River drainage (Figure 1). Streams selected for study represented typical headwater habitats in Montana. Study stream elevations ranged from 1320 m at Collar Gulch to 2570 m at Geyser Creek (Table 2). Mean channel gradients ranged from 3.0% for Jerry Creek to 7.1% for Delano Creek. Productivity in most streams was low, with water conductivities ranging from 69 umhos in McVey Creek to 661 umhos in White's Gulch.

Most study streams consisted of allopatric populations of genetically pure westslope cutthroat trout. Seven study streams also supported populations of brook trout Salvelinus fontinalis (Table 1). Two study streams supported populations of westslope cutthroat trout that were introgressed with rainbow trout.

Methods

We collected paired otolith and scale aging structures from westslope cutthroat trout that inhabited headwater streams in Montana. Westslope cutthroat trout were not intentionally sacrificed to obtain otoliths. Instead, otoliths were removed only from fish that died incidentally during sampling and handling, or that were sacrificed for genetic analysis. Both sagittal otoliths were removed from fish after they had been measured to the nearest mm (fork length; FL) and weighed to the nearest gram on an electronic scale (accuracy of 0.2 g). A sample of scales was also obtained from these incidental mortalities. Scale samples were removed from the left side of the body just above the lateral line at the anterior end of the caudal peduncle, the location of the earliest scale formation on westslope cutthroat trout (Averett 1962). A total of 148 paired age structure samples from 15 additional headwater streams were obtained from fish sacrificed for genetic analysis.

The Montana Fish, Wildlife and Parks' Scale Laboratory impressed scale samples in acetate. Scales were sorted under a 7 to 10 power dissecting microscope, laid out on cellulose acetate sheets, and covered with a stainless steel plate. Samples were then placed in a Carver laboratory press at 450°F and 15000 psi for 1 minute. The scales were then discarded. Scale impressions were interpreted on a microfiche reader at 72 power and ages were assigned according to the methods described by Jearld (1983).

Sagittal otoliths were removed by making an incision perpendicular to the horizontal axis of the fish's body immediately posterior to the eyes and extending downward to the base of the orbit. The anterior portion of the head was depressed, exposing the brain. The sagittal otoliths were usually visible just behind and beneath the brain and could be easily removed with a pocketknife in the field. Otoliths were stored dry in 4-ml vials to protect them from damage. All otoliths collected under field conditions were initially stored together with scales in a scale envelope and later transferred into dry vials. The paired structures from each fish were labeled identically using an alphanumeric code to facilitate comparisons.

Otoliths were viewed whole. They were immersed in distilled water in a small Pyrex dish, placed on a dark background, then viewed through a compound microscope at 40 power with reflected light. The criteria for assigning ages was similar to that used by Mackay et al. (1990).
Random subsamples of otoliths and scales were selected and read by another experienced reader. Each reader, without any *a priori* knowledge about the individual fish (i.e., length or sample location), determined ages. The "Index of Average Percent Error" (Beamish and Fournier 1981) was calculated to determine which aging technique was more precise. Beamish and Fournier suggest this method is superior to simply calculating the percent agreement between readers

because it accounts for the age of the fish. For example, an aging discrepancy of 2 years for a 5-year old fish is more serious than the same discrepancy for a fish that lives to age 25. Percent agreement does not take this into account.

We compared ages assigned from a length-frequency histogram with ages interpreted from otoliths for a population inhabiting the West Fork Cottonwood Creek to assess the validity of otoliths as aging structures for westslope cutthroat trout. West Fork Cottonwood Creek was used because it provided a more easily interpretable length-frequency histogram than other study streams.

We used visible implant (VI) tags to individually identify all westslope cutthroat trout 120 mm and longer during this study (Haw et al. 1990). Scale samples were removed from the left side of fish that were VI tagged in 1993. Scale samples were removed from the right side of recaptured VI tagged fish in 1994 to validate annulus formation on these fish. We adjusted scale ages assigned to VI tagged fish using methods described by Downs (1995) in an attempt to account for potential missing first year annuli. Scale ages were compared for VI tagged and subsequently recaptured fish from four of the study streams. The streams were Collar Gulch, the West Fork and main Cottonwood creeks in the Smith River drainage, and Geyser Creek. These four streams were the only streams where enough tagged fish were recaptured (> 10 each).

We also assessed empirical growth of westslope cutthroat trout using VI tags. Lengths of all tagged and subsequently recaptured fish were recorded. Daily growth was estimated by assuming that growth occurred from May 1 through October 15 of each year. This assumption was based primarily on water temperature data collected from July 1995 through May of 1996 (Figures 11 and 12). We assumed fish grew little at water temperatures under 4 C. These assumptions resulted in a 167-day growing period. Daily and annual growth were estimated for each recapture event. Annual growth was calculated by multiplying estimated daily growth by 167. Recapture events that occurred less than 10 days apart were omitted from the analysis. Recapture events where lengths at recapture were at least 5 mm less than the previous length were also omitted. When a recapture length was from 0 to 5 mm shorter than the previous recorded length, we assigned a growth increment of 0. A few fish were recaptured more than once and each recapture event was recorded separately.

The relationship between length at initial capture and estimated daily growth was evaluated for all recapture events, and separately for each tributary drainage where more than 20 recapture events occurred, using simple linear regression. We transformed estimated daily growth using a $\log_{10}$ transformation.

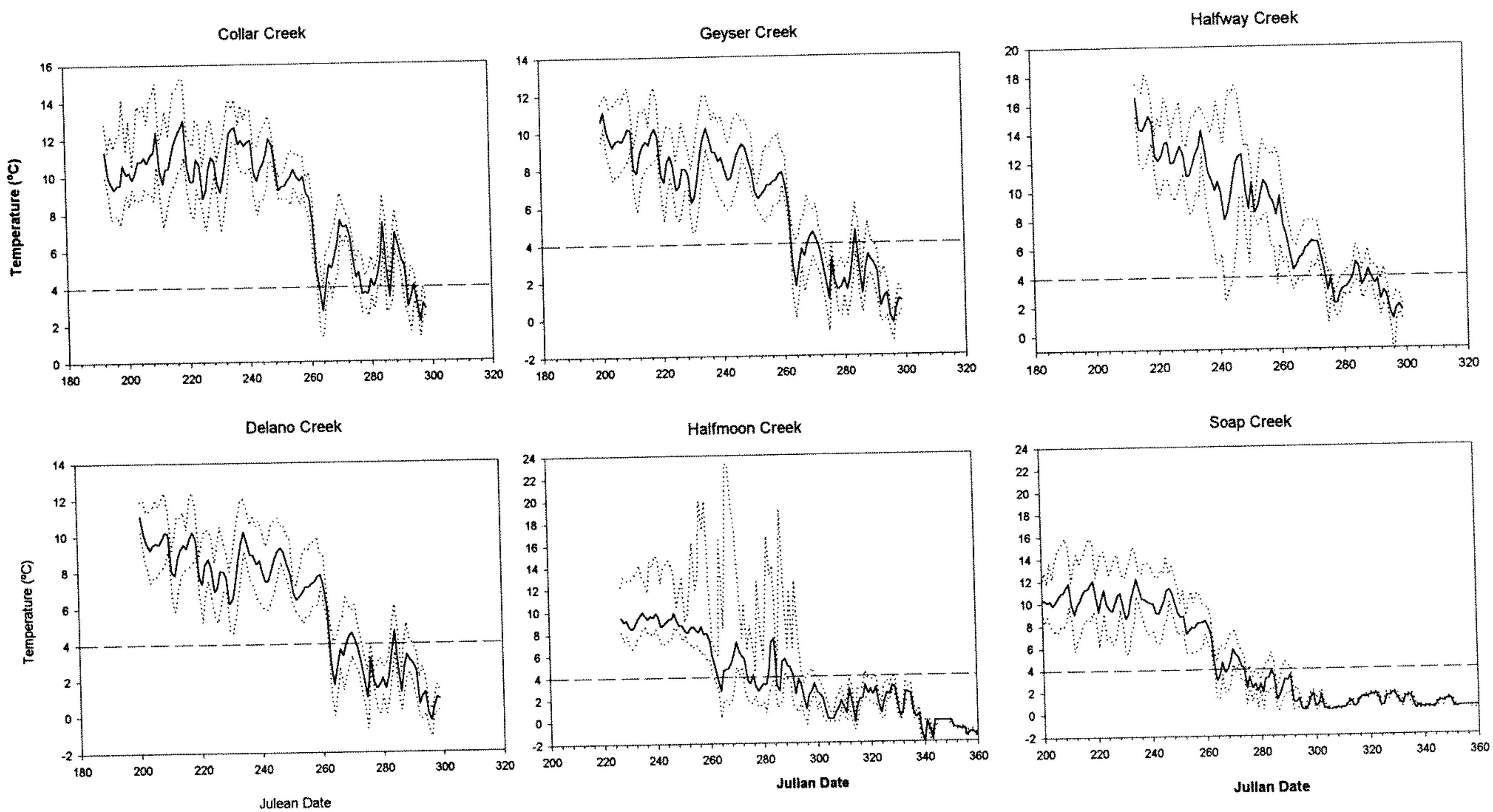

Figure 11. Mean, minimum, and maximum daily water temperatures recorded during the summer of 1995 in selected streams inhabited by westslope cutthroat trout. A reference temperature of 4° C is shown as a horizontal line on all graphs. The fall cut-off date assumed for cessation of growth was a Julian date of 288.

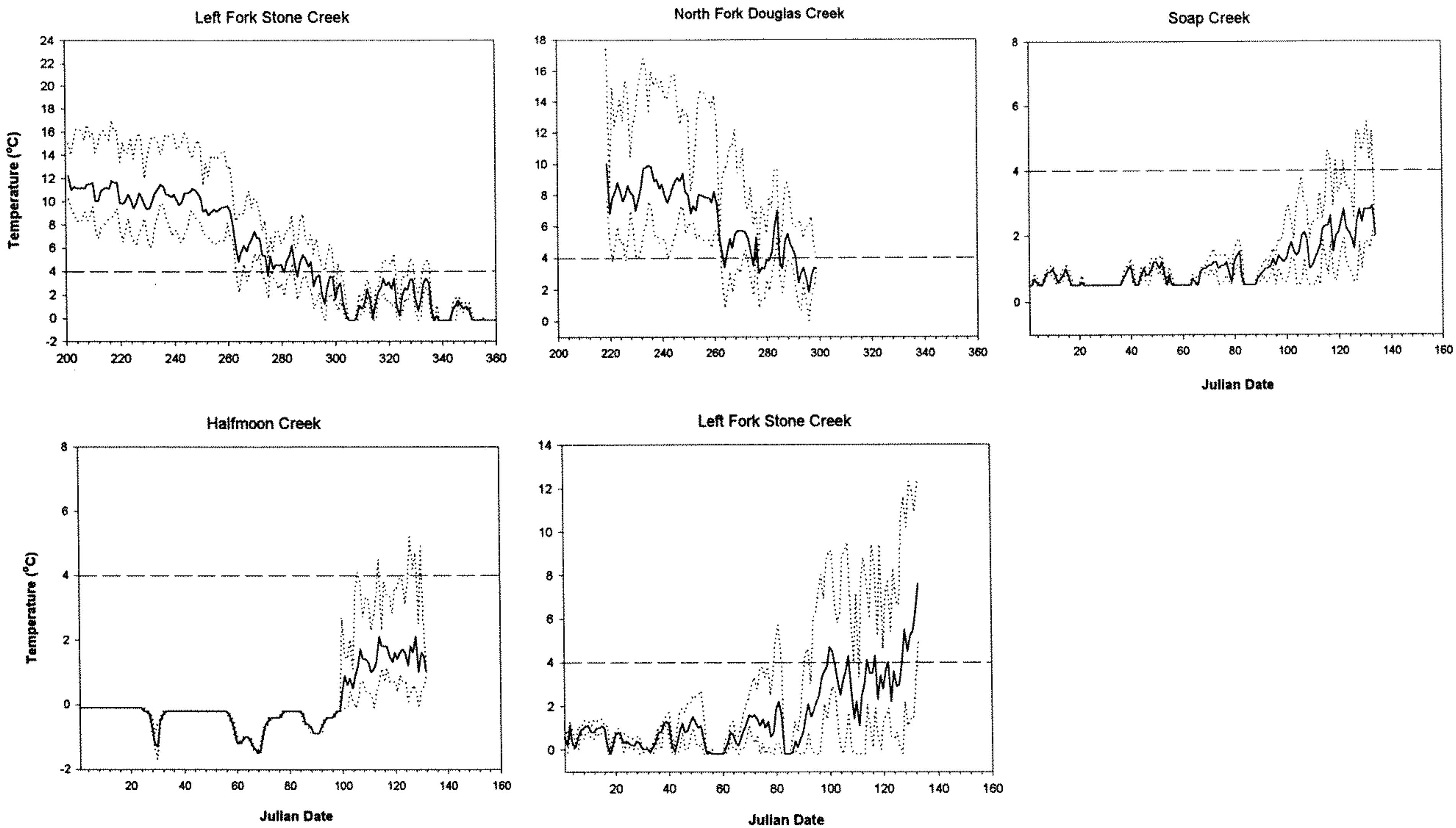

Figure 12. Mean, minimum, and maximum daily water temperatures recorded during the winter and spring of 1995/96 in selected streams inhabited by westslope cutthroat trout. A reference temperature of 4° C is shown as a horizontal line on all graphs. The spring cut-off date assumed for initiation of growth was a Julian date of 121.

Results

Ages interpreted from otoliths were consistently older than ages interpreted from scales for the 424 paired age structure samples (Figure 13). These discrepancies increased with increasing age. Agreement between paired otolith and scale samples was 25%, prior to correcting for a potential missing first year annulus according to Downs (1995). Otoliths resulted in older age estimates for 74% of the pairs, while scale interpreted ages were older for only 1% of the pairs. A paired sample t-test indicated that the ages interpreted from otoliths were significantly higher than ages interpreted from scales (t-test; $P<0.001$). From 50 to 85% of the westslope cutthroat trout from these streams were missing their first year annulus.

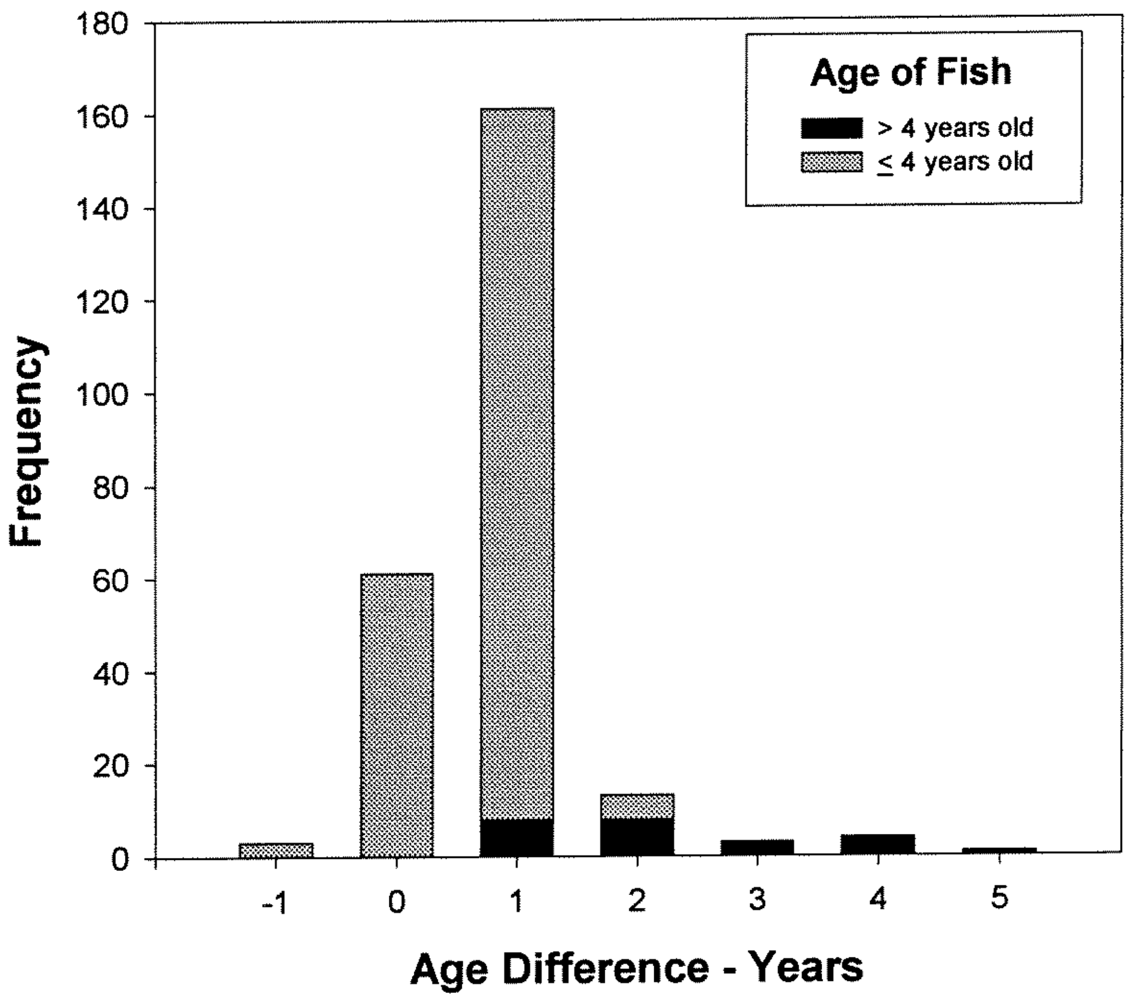

Figure 13. Age discrepancies in years between paired otolith and scale samples from westslope cutthroat trout stratified by fish 4 years old or less and those over 4 years of age.

The "Index of Average Percent Error" (AEI%) was 3.2% for otoliths and 11% for scales (Table 11). We found better precision for ages estimated from otoliths than for ages estimated from scales. Age estimates for replicate readings of otoliths were not significantly different (t-test; $P>0.10$) while age estimates between replicate readings of scales samples were significantly different (t-test; $P<0.001$).

Table 11. "Index of Average Percent Error" (AEI%) and p-values based on t-tests for differences between independent, experienced readers for ages of westslope cutthroat trout interpreted from otoliths and scales.

Structure	N	AEI%	p-value
Otolith	89	3.2	> 0.10
Scale	72	11	< 0.01

Ages interpreted from otoliths agreed well with ages assigned by length-frequency analysis for westslope cutthroat trout from the West Fork Cottonwood Creek for ages 1 (n=5), 2 (n=22), and 3 (n=3). However, beyond age 3, ages could no longer be clearly interpreted from the length-frequency histogram (Figure 14).

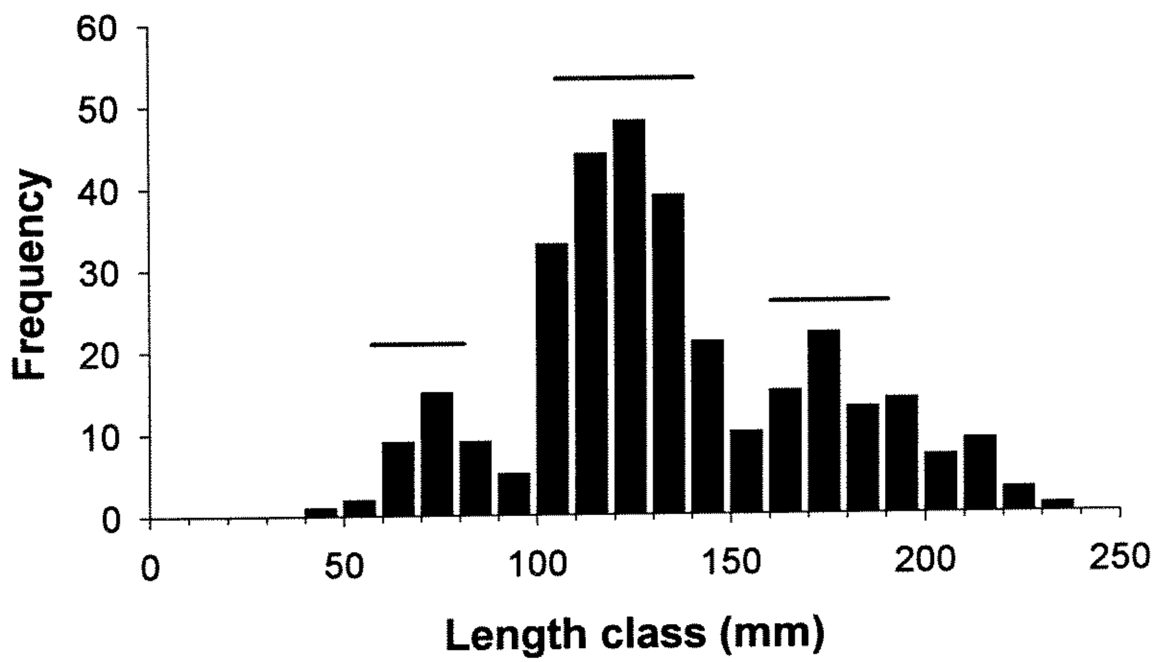

Figure 14. Histogram showing length-frequency for westslope cutthroat trout from the West Fork of Cottonwood Creek. Horizontal bars represent length ranges for fish of age 1, 2, and 3 interpreted from otoliths.

Discerning annuli near a scale's margin became increasing difficult with increasing age (Figure 15). Eighty-seven percent of the individuals tagged at age 2 had formed an additional annulus by the time of recapture at age 3 (n = 30), while only 45% of fish tagged at age 3 formed an interpretable annulus by age 4 (n = 38). Only ten percent of the fish formed an interpretable annulus between the ages of 4 and 5 (n = 10).

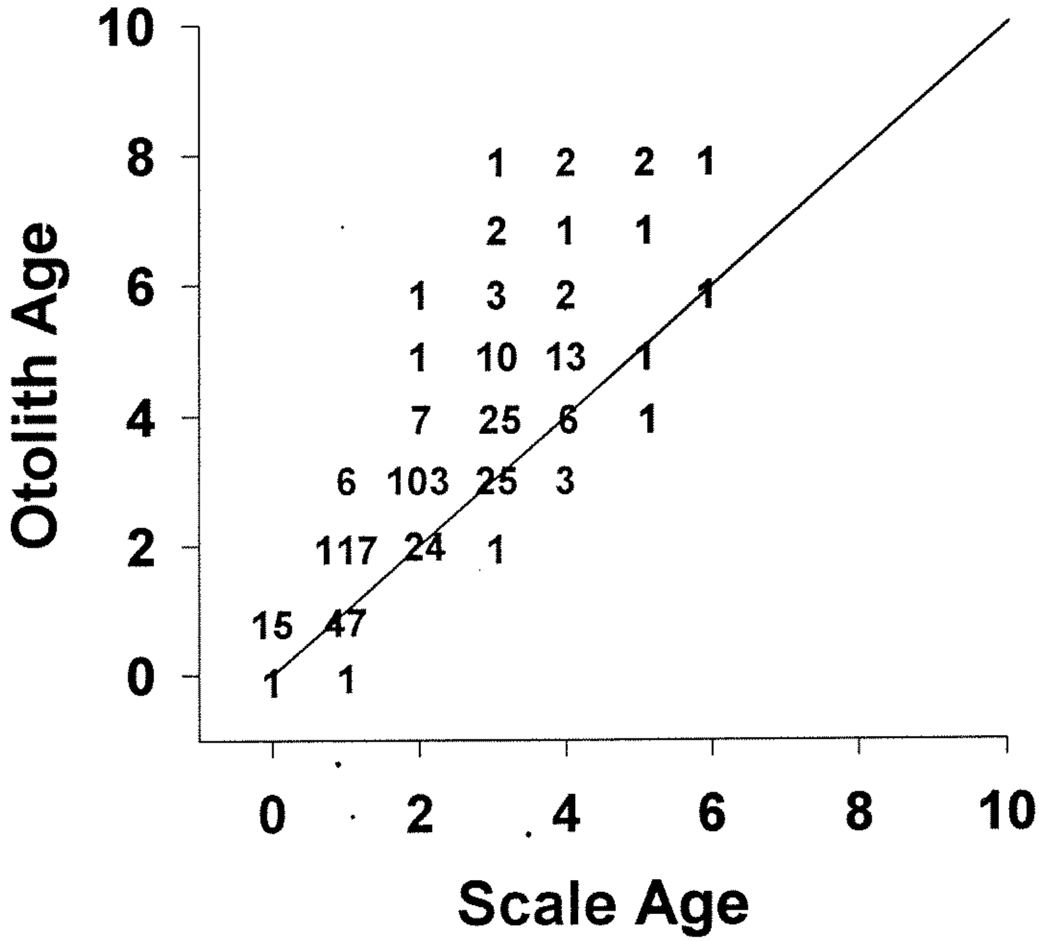

Figure 15. Scatter plot of frequencies of paired otolith-scale samples of westslope cutthroat trout. Solid line shows a 1:1 agreement between otoliths and scales.

Empirical growth was based on a total of 786 tag recapture events. Tagged fish ranged in length from 116 to 303 mm. Estimated daily growth averaged 0.11 mm per day resulting in an average annual growth of about 18.5 mm. The shortest duration between capture events was 10 days and the longest was 354 growth days. Average estimated daily growths had relatively wide ranges among both sampled streams (0.053-0.223 mm/day; or 9 to 37 mm/year) and tributary drainages (Table 12). Estimated daily growth was zero for 84 recapture events. The $\log_{10}$ transformation resulted in these observations being excluded from regression analyses. There was a slightly negative (slope of – 0.003), but significant ($r^2 = 0.04$; $P < 0.001$), relationship between length at first capture and daily growth (Figure 16). A single observation was removed because it had a large leverage due to its large size at tagging (303 mm). This westslope cutthroat trout was probably introgressed with rainbow trout based on field observations. The negative relationship between length at first capture and daily growth was also seen within all sampled drainages, but the magnitude of the negative slope varied among drainages (Table 12 and Figure 17).

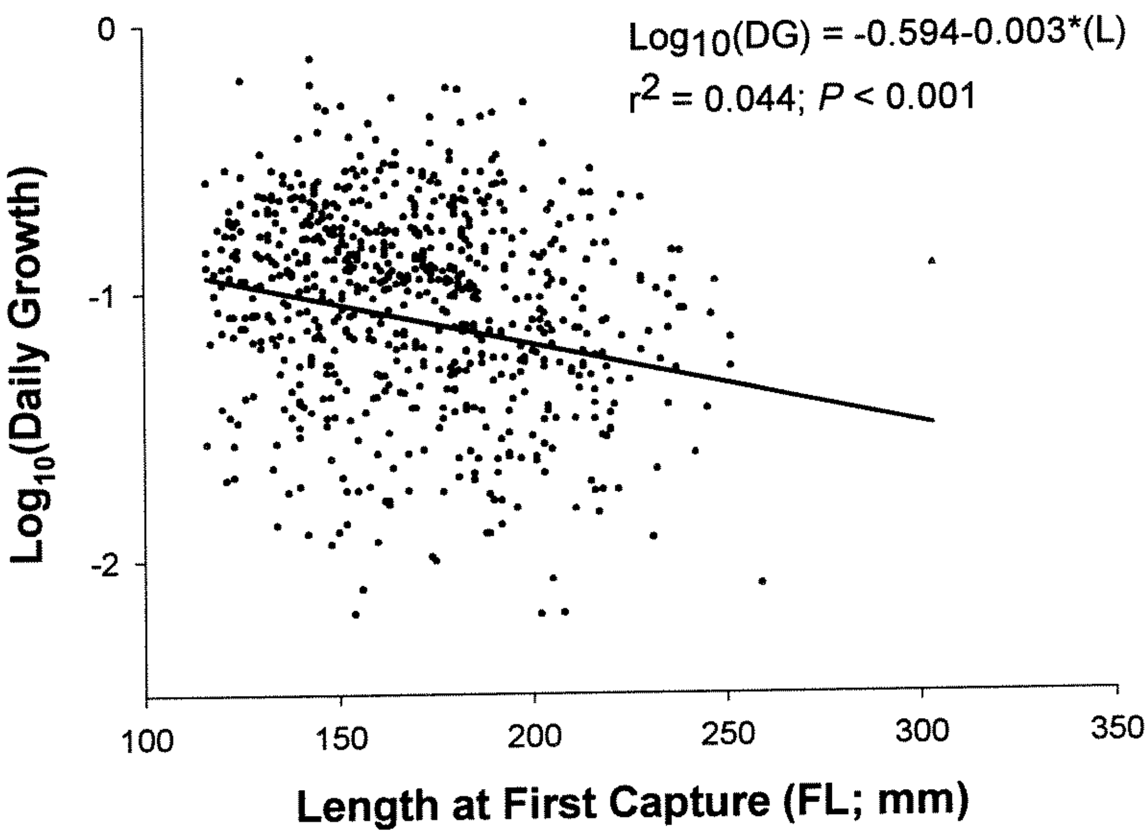

Figure 16. Relationship between estimated daily growth and fork length at initial capture for 786 westslope cutthroat trout.

Table 12. Number of VI tagged fish recaptured, minimum and maximum length (mm) at tagging, estimated average daily and annual growth, conductivity of waters inhabited, and elevation near lower boundary of sample area.

Drainage	Stream	n	Length range (mm) at tagging Min -Max	Average growth (mm) Daily	Annual	Conductivity (umhos)	Elevation (m)
Cabin	M Fk Cabin Creek	5	137 -220	0.070	11.7	175	2400
Collar	Collar Gulch	115	116 -219	0.142	23.7	206	1450
Cottonwood - Smith							
	Cottonwood Creek	47	136 -235	0.121	20.2	131	1830
	West Fork	142	116 -251	0.100	16.7	126	1850
	East Fork	26	132 -251	0.129	21.5	57	1850
	Unnamed tribs	4	138 -192	0.088	14.7		
	TOTAL	219	116 -251	0.108	18.0		
Cottonwood - Ruby							
	Cottonwood Creek	28	130 -303	0.090	15.0		2260
	Geyser Creek	111	121 -242	0.072	12.0	447	2460
	TOTAL	139	121 -303	0.076	12.7		
Douglas							
	Douglas Creek	3	145 -223	0.205	34.2	245	1570
	N Fk Douglas Creek	33	117 -190	0.082	13.7	253	1650
	TOTAL	36	117 -223	0.092	15.4		
Gold	N Fk Gold Creek	21	120 -220	0.094	15.7	174	1880
Half Moon	Half Moon Creek	36	141 -246	0.108	18.0	333	1710
Halfway	Halfway Creek	46	116 -223	0.079	13.2	78	1830
Jerry							
	Delano Creek	40	116 -177	0.053	8.9	180	2120
	Jerry Creek	31	120 -195	0.069	11.5	160	2100
	TOTAL	71	116 -195	0.060	10.0		
McVey	McVey Creek	11	120 -236	0.179	29.9	78	1860
Soap	Soap Creek	22	119 -203	0.200	33.4	81	1910
Tenderfoot	Tenderfoot Creek	11	147 -222	0.134	22.4	119	1730
White's	White's Gulch	47	130 -238	0.223	37.2	649	1320
	OVERALL	786	116 -303	0.111	18.5		

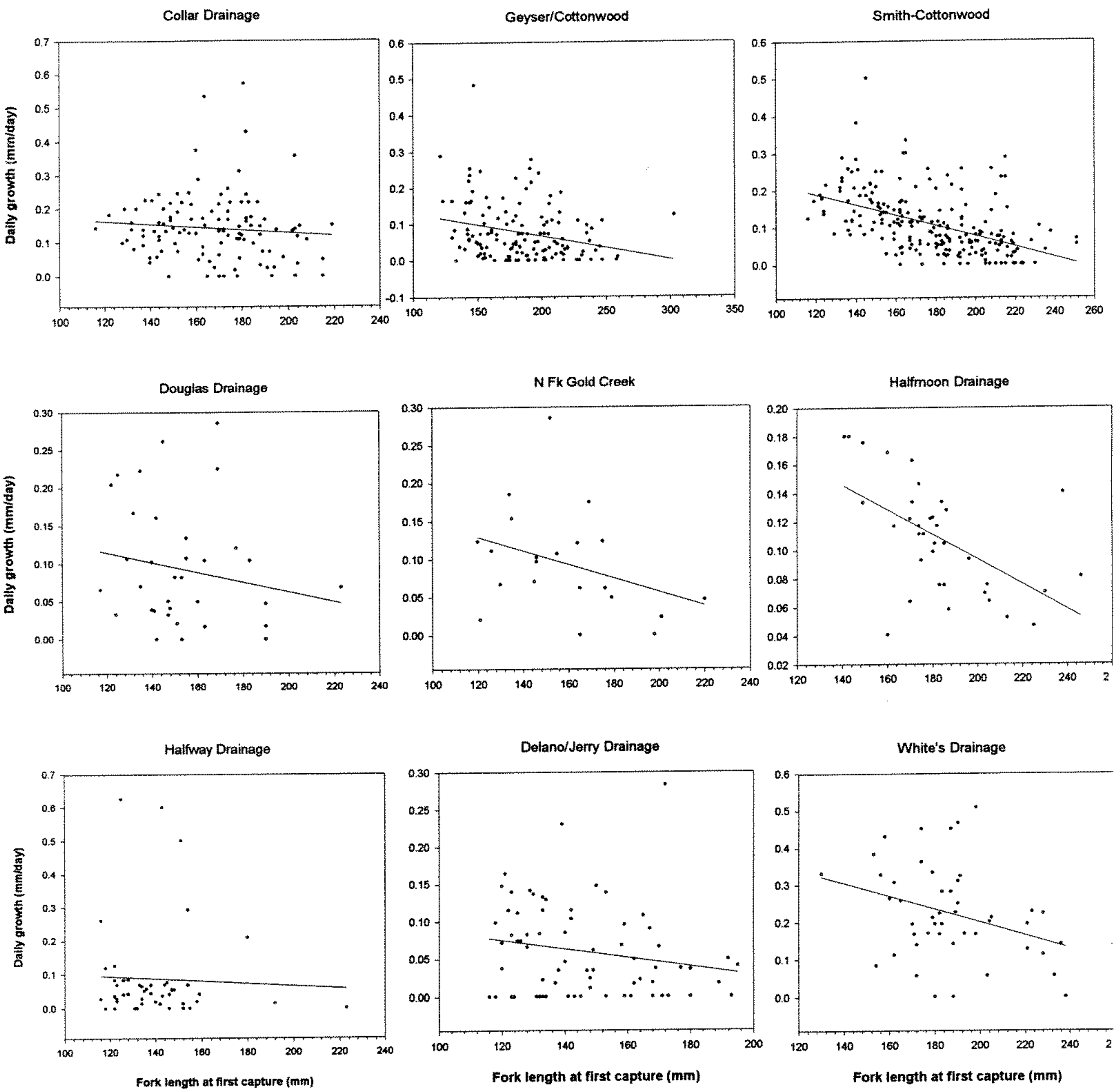

Figure 17. Relationship between estimated daily growth and fork length at initial capture for westslope cutthroat trout by drainage.

Discussion

A major assumption of the scale aging technique is that annual scale growth maintains a constant ratio with annual body growth throughout the life of the fish (Van Oosten 1929). Therefore, when body growth slows, there should be an associated reduction in scale growth. Another important assumption is that a distinguishable annulus is deposited each year of life. However, if body growth is very slow, discerning annuli, especially near the scale's margin, becomes extremely difficult. Headwater portions of streams are often not conducive to rapid growth due to colder temperatures and low productivity. Westslope cutthroat trout living in headwater habitats generally grow very slowly. We found that westslope cutthroat trout grew an average of less than 20 mm per year after they reached age 2, and annual growth was less than 10 mm in a few streams. This slow growth made it hard to interpret annuli formation on scales and led to inaccurate aging. Fish also may grow slower once they reach sexual maturity due to the shifting of energy resources from growth into gamete production, spawning migration, and spawning behaviors.

Our data indicated that scales underestimated true ages of westslope cutthroat trout from headwater streams. This conclusion is based on ages interpreted from both scales and whole otoliths. Otoliths are present at hatching and have been shown to provide older age estimates than scales for slow growing or mature salmonids (Craig and Poulin 1974; Erickson 1979; Barnes and Power 1984; Sharp and Bernard 1988). We typically did not encounter age 0 fish until mid-August, and in some cases as late as mid-September. We observed newly emerged westslope cutthroat trout fry as late as the first week of September in a few of the study sites. Scarnecchia and Bergersen (1986) reported that emergence of young-of-the-year greenback cutthroat trout (O. c. stomias) and Colorado River cutthroat trout (O. c. pleuriticus) from headwater systems in Colorado peaked near mid-August and few individuals exceeded 30-35 mm before they entered their first winter. Cooper (1970) found that cutthroat trout (O. c. clarki) from Chef Creek, located on Vancouver Island, did not form scales until they reached 37 mm. Averett and MacPhee (1971) reported that westslope cutthroat trout from three Idaho streams first formed scales at lengths of 42 to 46 mm. Shepard et al. (1984) reported that in the Flathead River basin, Montana, scales first formed on westslope cutthroat trout at lengths of 38 to 44 mm and documented that a first year annulus did not form on some scales. Brown and Bailey (1952) reported that scales did not cover the entire body of cutthroat trout until they were 63 to 68 mm in length. Lentsch and Griffith (1987) reported that a first year annulus did not always form for Yellowstone cutthroat trout (O. c. bouveri). When westslope cutthroat trout fry emerge late in the growing season, as they often do in mountain headwater populations, they may not grow large enough during their first year of life to either form scales or, if scales form, to lay down a discernible first year annulus. If not accounted for, this missing first year annulus results in an underestimate of age throughout the life of the fish.

Large underestimates of ages from scales are even more likely for older fish, particularly if a first year annuli is missing and annual growth is slow, especially following maturation. For fish under age 4, which are mostly immature based on maturation ages previously reported by Downs et al. (this report and 1997), ages determined from scales were usually 1 year less than those determined from otoliths (Figure 12). Fish beyond age 4 exhibited larger discrepancies. Scales may be a suitable aging structure for immature westslope cutthroat living in headwater streams if one accounts for missing first year annuli. This is supported by Sharp and Bernard (1988) who concluded that scales could be used to age immature lake trout Salvelinus namaycush from interior Alaska, but ages interpreted from scales of mature fish were lower and less precise that ages interpreted from otoliths. Casselman (1987) reported no significant correlation between ages interpreted from scales and actual ages for lake trout ranging in age from 9 to 36 years.

The level of exploitation a population receives may influence the reliability of scales as an aging structure. Headwater populations of westslope cutthroat trout typically experience low levels of exploitation by virtue of their physical isolation, slow growth rates, and small population sizes. Fish from unexploited populations achieve older ages than fish from exploited populations leading to greater discrepancies between ages assigned from otoliths and scales (Erickson 1979; O'Gorman et al. 1987). We recommend that caution be exercised when scales are used as an aging structure. If ages interpreted from scales are accepted without validation, estimates for production, growth, and mortality may be erroneous (Beamish and McFarlane 1983). In addition, longevity and the age at sexual maturity may be underestimated. In relatively unexploited populations, these types of errors may not be a major concern. However, for fish populations where relatively heavy harvest is occurring, errors in population parameter estimates could lead to improper management.

We found a 3.2% "Index of Average Percent Error" (AEI) for otoliths and 11% for scales, demonstrating that ages interpreted from otoliths were more precise than those interpreted from scales for headwater populations of westslope cutthroat trout. Studies of arctic grayling Thymallus arcticus (Craig and Poulin 1974), and lake trout Salvelinus namaycush (Sharp and Bernard 1988) support these results. Knapp and Dudley (1990) examined headwater populations of golden trout Oncorhynchus aguabonita and found no interpretable annuli on scales, while annuli on otoliths were easily interpreted. However, Hubert et al. (1987) concluded that scales were appropriate for aging Yellowstone Lake cutthroat trout Oncorhynchus clarki bouvieri, while otoliths were less precise. These authors reported an AEI of 33% for otoliths and 15% for scales, indicating a lower precision within ages interpreted from otoliths. It should be noted, however, that otoliths generally provided older age estimates than scales in this study. The high AEI% associated with ages interpreted from otoliths of Yellowstone Lake cutthroat population may identify problems associated with precision. Low precision indicates problems associated with annulus recognition. The ability to recognize annuli using a particular structure can be affected by how that structure is prepared. We viewed otoliths whole without using a clearing technique. Annuli were easily recognizable without clearing the otoliths, indicated by our low AEI% (3.2%). Hubert et al. (1987) employed the otolith clearing technique described by Reimers (1979). It is possible that the high AEI% (33%) they reported for otoliths was a result of preparation techniques.

The agreement between ages interpreted from otoliths and a length-frequency histogram for West Fork Cottonwood Creek indicated that otoliths provided reasonable age estimates for westslope cutthroat trout (Figure 13). Unfortunately, using otoliths for age determination requires sacrificing the fish. Examining a sub-sample of otoliths to validate ages interpreted from scales may be a way to minimize the number of fish sacrificed from a population. A decision could then be made whether aging from scales was appropriate for a given population. Otoliths from small trout are easily extracted, prepared, and viewed. Given the relative consistency in physical parameters of headwater streams between years, annual examination of otoliths would not be required. A one-time collection of fish from various age classes in a given stream would provide guidance on the validity of scale ages up to at least age 3, when most fish begin maturing. Ages assigned using scales should be viewed as conservative estimates of age instead of absolute estimates and the potential for errors associated with age estimation must be acknowledged.

Our empirical estimates of annual growth from tag returns indicated that westslope cutthroat trout over 120 mm grew very slowly, averaging about 19 mm per year. This estimate is lower than published estimates of annual growth that we found, however, almost all these published estimates of growth were based on back-calculated lengths at each annulus and most were also based on stream-residency of either fluvial or adfluvial stocks. One study that assessed growth of resident westslope cutthroat in the Taylor's Fork drainage of the Gallatin River, Montana found that annual growth was about 25 mm per year (McMahon et al. 1994). Mullan et al. (1992) presented a figure showing average length and ranges at each age for westslope cutthroat trout in the Methow River drainage. This figure indicates nearly linear growth of about 35 mm per year up to age 5 (at a length of about 180 mm), after which growth slows to less than 10 mm per year. The review of westslope cutthroat trout life histories by Rieman and Apperson (1989) and McIntyre and Rieman (1995) cited no studies that documented the growth of resident westslope cutthroat trout. Growth of two-year old and older fluvial westslope cutthroat trout in headwaters of the West Gallatin River was about 80 mm between age 2 and 3, and about 18 mm between age 3 and 4 (Purkett 1950). Fleener (1951) reported an annual growth increment for cutthroat trout from the Logan River, Utah between age 2 and 3 to be 53 mm. Irving (1954) reported annual growth increments for cutthroat trout from Henry's Lake, Idaho to be from 15 to 100 mm from age 3 to age 6. Bjornn (1961) found that stream growth of two-year old and older adfluvial westslope cutthroat trout from Priest and Upper Priest lakes in Idaho was about 40-50 mm per year. Johnson (1963) reported that growth for westslope cutthroat trout in Flathead River, Montana tributaries was about 60 mm per year up to age 3, after which growth slowed to about 35 mm per year. Cooper (1970) found that coastal cutthroat trout grew about 30 mm per year in Chef Creek, located on Vancouver Island. Averett and MacPhee (1971) reported that westslope cutthroat trout from six Idaho streams grew about 45 mm between age 2 and 3. Lukens (1978) reported that juvenile adfluvial westslope cutthroat trout from Wolf Lodge Creek, Idaho grew an average of 38 mm between their second and third year of life and about 25 mm between their third and fourth year.

Our results emphasize that using scales for aging resident westslope cutthroat trout may result in underestimates of age. These underestimates are a result of the fact that scales from some fish will be missing a first year annulus combined with the difficulty in recognizing annuli near the scale's margin of fish age 3 and older. We support Beamish and McFarlane's (1983) recommendation that aging techniques must be validated and demonstrated a method for using otoliths and tag-recapture studies to augment and validate scale aging for westslope cutthroat trout. We documented relatively slow annual growth rates for resident westslope cutthroat trout inhabiting headwater streams of Montana, especially for fish older than age 3, and suspect these slow growth rates are the norm for resident westslope cutthroat trout occupying these high elevation headwater streams. We showed that growth rates slow slightly with increased body length, a relationship we speculate was related to a re-direction of energy resources from growth to gamete production following maturation and the phenomenon of "indeterminate growth".

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Appendix A

Criteria for selection of sample streams

Table A-1. Criteria for selection of sample streams for estimating westslope cutthroat trout population dynamics.

Criterion	Ranking
Supports population of westslope cutthroat trout	1
Westslope cutthroat trout tested genetically pure	2
Westslope cutthroat trout isolated by some type of barrier	3
Westslope cutthroat trout allopatric	4
Location of population near Continental Divide	5

Appendix B

Characteristics of sections sampled by electrofishing

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
DRAINAGE CABIN								
CABIN CREEK								
2.0	7/21/94	101.9	6.6	1	334.0	8.8	14.0	0.0
3.0	7/20/94	160.0	1.5	1	324.0	8.8	9.3	0.0
1.0	7/21/94	20.0	7.0	1	0.0	0.0	0.0	0.0
4.0	8/ 1/95	140.0	2.5	1	0.0	0.0	0.0	0.0
GULLY CREEK								
1.0	7/20/94	87.0	2.5	1	366.0	8.8	13.2	0.0
1.0	8/ 1/95	125.0	1.5	1	0.0	0.0	0.0	0.0
M FK CABIN CREEK								
1.0	7/20/94	90.5	3.3	2	250.0	8.8	13.1	0.0
3.0	7/19/94	87.3	2.6	2	0.0	0.0	0.0	21.1
2.0	7/19/94	76.8	3.1	2	0.0	0.0	0.0	0.0
4.0	7/19/94	126.2	2.0	2	438.0	8.5	14.7	0.0
6.0	7/18/94	48.0	0.3	1	48.0	8.3	13.3	0.0
5.0	7/18/94	146.3	1.4	2	48.0	8.3	13.3	0.0
2.0	8/ 1/95	76.8	4.0	2	173.0	8.6	16.9	29.4
1.0	8/ 1/95	91.0	4.0	3	189.0	8.6	12.2	23.9
3.0	8/ 1/95	87.2	3.8	2	164.0	9.0	8.3	18.3
4.0	7/31/95	126.0	2.0	2	272.0	9.0	16.7	26.1
5.0	7/31/95	146.3	1.0	3	380.0	8.9	14.2	0.0
6.0	7/31/95	60.0	0.8	2	65.4	8.9	16.4	25.6
N TRIB M FK CABIN - PO								
1.0	7/20/94	58.0	1.0	1	0.0	0.0	0.0	0.0
2.0	7/20/94	50.0	1.0	1	0.0	0.0	0.0	0.0
S FK CABIN CREEK								
1.0	7/20/94	100.0	1.0	1	355.0	8.6	11.2	0.0
S TRIB M FK CABIN CK								
1.0	7/31/95	160.0	1.3	2	130.0	8.8	10.4	25.0
S TRIB M FK CABIN CK (								
1.0	7/19/94	59.7	0.8	1	146.0	8.6	10.7	0.0
S TRIB TO M FK CABIN C								
1.0	7/19/94	160.3	1.6	2	25.4	8.8	9.9	0.0
2.0	7/19/94	42.6	1.8	1	0.0	0.0	10.7	0.0
SP AT KM 6.1 M FK CABI								
1.0	7/19/94	20.0	0.2	1	0.0	0.0	0.0	0.0
SPRING BY S FK CABIN C								
2.0	7/19/94	200.0	0.5	1	401.0	8.2	5.2	0.0
1.0	7/19/94	87.0	0.5	1	401.0	8.2	5.2	0.0
TRIB (FORKED) TO M FK								
1.0	7/19/94	25.0	0.3	1	268.0	8.7	8.1	0.0
2.0	7/19/94	15.0	0.3	1	268.0	8.7	8.1	0.0
TRIB TO M FK CABIN (N								
1.0	7/19/94	140.2	0.9	1	604.0	8.6	6.3	0.0
UNNAMED TRIB TO CABIN								
1.0	8/ 1/95	55.0	1.0	1	0.0	0.0	0.0	0.0
DRAINAGE CHICA								
CHICAGO GULCH								
1.0	6/13/95	55.0	2.0	1	168.0	9.3	15.9	23.9
2.0	6/14/95	80.0	2.0	1	172.0	9.1	10.7	20.0
E FK CHICAGO GULCH								
1.0	6/14/95	70.0	1.5	1	172.0	9.1	10.7	20.0
2.0	6/14/95	53.0	1.0	1	145.0	8.6	16.3	27.4
W FK CHICAGO GULCH								
1.0	6/14/95	50.0	1.0	1	160.0	8.7	12.6	27.4
DRAINAGE COLL								
COLLAR GULCH								
1.0	7/12/93	88.0	3.0	1	0.0	0.0	7.8	11.1
2.0	7/12/93	137.0	3.8	1	0.0	0.0	7.8	11.1

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
3.0	7/12/93	173.0	3.0	1	0.0	0.0	7.8	11.1
4.0	7/12/93	202.0	3.6	1	0.0	0.0	7.8	11.1
5.0	7/12/93	187.0	3.6	1	0.0	0.0	7.8	11.1
6.0	7/12/93	71.3	3.6	2	0.0	0.0	7.8	11.1
7.0	7/12/93	112.0	3.6	1	0.0	0.0	7.8	11.1
15.0	7/14/93	129.4	3.5	2	0.0	0.0	7.2	14.4
14.0	7/14/93	110.0	3.5	1	0.0	0.0	7.2	14.4
8.0	7/13/93	50.0	3.5	1	0.0	0.0	7.2	8.3
9.0	7/13/93	105.0	3.8	1	0.0	0.0	7.2	8.3
10.0	7/13/93	75.0	3.8	1	0.0	0.0	7.2	8.3
11.0	7/13/93	89.4	3.8	2	0.0	0.0	7.2	8.3
12.0	7/13/93	107.0	3.8	1	0.0	0.0	7.2	8.3
13.0	7/13/93	92.0	3.6	1	0.0	0.0	7.2	8.3
17.0	7/13/93	75.0	3.0	1	0.0	0.0	7.2	8.3
16.0	7/13/93	93.0	3.5	1	0.0	0.0	7.2	8.3
18.0	7/14/93	105.0	2.5	1	0.0	0.0	7.2	14.4
19.0	7/14/93	85.0	2.0	1	0.0	0.0	7.2	14.4
11.0	6/28/93	136.0	3.8	1	0.0	0.0	13.3	21.1
3.0	6/28/93	100.0	3.0	1	0.0	0.0	12.2	16.7
15.0	11/ 4/9	129.4	2.0	1	0.0	0.0	0.0	-6.1
6.0	11/ 4/9	71.3	1.5	1	0.0	0.0	0.0	-6.1
7.0	11/ 4/9	70.0	1.5	1	0.0	0.0	0.0	-6.1
3.0	11/ 4/9	173.0	1.5	1	0.0	0.0	0.0	-6.1
11.0	11/ 4/9	90.0	2.0	1	0.0	0.0	0.0	-6.1
15.0	6/ 3/94	134.0	2.0	1	0.0	0.0	6.7	11.7
3.0	6/ 2/94	190.0	2.0	1	0.0	0.0	8.9	20.0
6.0	6/ 2/94	71.0	2.0	1	0.0	0.0	8.9	20.0
11.0	6/ 2/94	90.0	2.0	1	0.0	0.0	8.9	20.0
16.0	6/ 3/94	55.0	2.0	1	0.0	0.0	6.7	16.1
3.0	7/12/94	173.0	2.5	2	206.0	8.2	10.7	0.0
6.0	7/14/94	71.0	3.0	2	0.0	0.0	8.9	12.2
7.0	7/13/94	74.0	3.0	2	0.0	0.0	10.6	0.0
11.0	7/13/94	90.0	2.5	2	206.0	8.4	10.7	0.0
15.0	7/13/94	134.0	2.5	2	0.0	0.0	10.6	0.0
17.5	7/13/94	100.0	2.0	1	0.0	0.0	13.9	0.0
15.0	7/12/95	134.0	2.0	2	143.0	8.6	13.9	0.0
11.0	7/12/95	90.0	2.5	2	158.0	8.1	13.2	0.0
6.0	7/13/95	71.3	2.5	2	158.0	8.1	13.2	0.0
3.0	7/13/95	173.0	3.0	3	174.0	8.6	11.1	20.0
DRAINAGE ©OTTR								
COTTONWOOD CREEK (RUBY								
1.0	7/27/93	120.0	5.7	1	0.0	0.0	0.0	0.0
1.0	10/ 5/9	50.0	2.0	1	0.0	0.0	3.3	12.2
3.0	10/ 5/9	35.0	2.5	1	0.0	0.0	3.3	12.2
2.0	10/ 5/9	25.0	2.0	1	0.0	0.0	3.3	12.2
1.0	6/15/94	50.0	0.0	1	0.0	0.0	5.0	10.0
2.0	6/15/94	25.0	0.0	1	0.0	0.0	5.0	10.0
3.0	6/15/94	35.0	0.0	1	0.0	0.0	5.0	10.0
2.0	7/28/94	20.0	0.0	1	0.0	0.0	0.0	0.0
0.5	9/ 6/94	15.0	3.0	1	0.0	0.0	11.1	20.0
0.1	9/ 6/94	20.0	3.0	1	0.0	0.0	11.1	20.0
0.7	9/ 6/94	75.0	3.0	1	0.0	0.0	11.1	20.0
1.0	9/ 6/94	90.0	3.0	1	0.0	0.0	11.1	20.0
3.0	9/ 6/94	70.0	3.5	1	0.0	0.0	10.6	21.1
4.0	9/ 7/94	5.0	4.0	1	0.0	0.0	5.6	15.6
5.0	9/ 7/94	5.0	3.0	1	0.0	0.0	7.8	15.6
6.0	9/ 7/94	50.0	2.5	1	0.0	0.0	7.8	15.6
8.0	9/ 7/94	100.0	1.5	1	0.0	0.0	7.8	15.6
7.0	9/20/94	50.0	2.5	1	0.0	0.0	0.0	0.0
GEYSER CREEK								

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	7.0	6/24/93	100.0	3.0	1	0.0	0.0	0.0	0.0
	7.0	7/26/93	127.0	3.0	2	0.0	0.0	0.0	0.0
	9.0	7/27/93	118.3	1.4	2	0.0	0.0	5.0	10.0
	3.0	7/27/93	51.0	3.1	1	0.0	0.0	5.0	10.0
	2.0	7/27/93	88.7	2.5	2	0.0	0.0	5.0	10.0
	11.0	7/27/93	63.7	1.6	2	0.0	0.0	5.0	10.0
	6.0	7/28/93	99.0	2.5	1	0.0	0.0	7.2	15.6
	5.0	7/28/93	110.0	2.0	1	0.0	0.0	7.2	15.6
	8.0	7/28/93	51.0	2.0	1	0.0	0.0	10.6	26.1
	1.0	10/ 4/9	42.0	1.0	1	0.0	0.0	5.6	15.6
	2.0	10/ 4/9	90.0	1.0	1	0.0	0.0	5.6	15.6
	3.0	10/ 4/9	50.0	1.0	1	0.0	0.0	5.6	15.6
	4.0	10/ 5/9	61.0	1.2	1	0.0	0.0	3.3	12.8
	5.0	10/ 5/9	91.0	1.0	1	0.0	0.0	9.4	13.3
	6.0	10/ 5/9	58.0	1.5	1	0.0	0.0	9.4	13.3
	7.0	10/ 5/9	127.0	1.5	1	0.0	0.0	9.4	13.3
	8.0	10/ 5/9	68.0	1.5	1	0.0	0.0	7.8	15.6
	9.0	10/ 5/9	127.0	1.0	1	0.0	0.0	7.8	15.6
	11.0	10/ 4/9	64.0	0.5	1	0.0	0.0	6.1	19.4
	10.0	10/ 4/9	47.0	0.5	1	0.0	0.0	6.1	19.4
	12.0	10/ 4/9	60.0	0.5	1	0.0	0.0	6.1	19.4
	2.0	6/15/94	130.0	2.0	1	0.0	0.0	5.6	8.9
	5.0	6/15/94	60.0	2.0	1	0.0	0.0	5.6	8.9
	7.0	6/15/94	127.0	2.0	1	0.0	0.0	5.6	8.9
	9.0	6/16/94	120.0	1.0	1	0.0	0.0	3.3	12.2
	11.0	6/16/94	64.0	1.0	1	0.0	0.0	3.3	12.2
	2.0	7/27/94	90.0	2.0	2	453.0	8.6	11.1	23.9
	7.0	7/27/94	127.0	2.5	3	435.0	8.6	11.1	23.9
	9.0	7/27/94	118.0	1.0	2	425.0	8.5	15.0	0.0
	11.0	7/27/94	64.0	1.0	2	473.0	8.5	18.2	21.1
	2.0	7/17/95	90.0	2.5	2	337.0	8.5	15.7	0.0
	3.0	7/19/95	74.0	3.0	1	340.0	8.6	12.2	16.7
	4.0	7/19/95	88.0	3.0	1	340.0	8.6	12.2	16.7
	4.1	7/19/95	40.0	3.0	1	340.0	8.6	12.2	16.7
	4.2	7/19/95	110.0	3.0	1	340.0	8.6	12.2	16.7
	4.3	7/19/95	89.0	3.0	1	340.0	8.6	12.2	16.7
	4.4	7/19/95	108.0	3.0	1	340.0	8.6	12.2	16.7
	5.0	7/19/95	152.0	3.0	1	340.0	8.6	12.2	16.7
	6.0	7/19/95	102.0	3.0	1	340.0	8.6	12.2	16.7
	7.0	7/19/95	127.0	2.0	2	384.0	8.7	17.4	11.3
	9.0	7/21/95	118.0	1.0	2	403.0	8.6	12.8	6.7
	11.0	7/21/95	64.0	1.0	1	467.0	8.5	12.8	7.8
	2.0	7/27/95	0.0	2.5	1	373.0	8.3	11.7	22.8
TRIB TO GEYSER CREEK									
	1.0	7/27/93	54.0	1.0	1	0.0	0.0	0.0	0.0
DRAINAGE COTTS									
COTTONWOOD CREEK (SMIT									
	1.0	7/ 8/93	70.0	3.0	1	0.0	0.0	6.7	11.1
	2.0	9/ 7/93	136.8	3.6	2	0.0	0.0	5.0	18.3
	2.0	5/ 6/94	130.0	2.5	2	0.0	0.0	5.0	15.0
	3.0	6/30/94	27.0	2.5	1	160.8	8.4	7.6	0.0
	2.0	6/28/94	137.0	2.5	3	100.6	8.3	13.0	0.0
	2.0	6/28/95	137.0	4.0	3	106.0	9.8	6.2	13.0
	2.0	9/ 6/95	137.0	3.5	2	153.0	9.0	10.9	18.3
E FK COTTONWOOD CREEK									
	1.0	9/ 7/93	122.5	2.8	2	0.0	0.0	8.9	23.3
	2.0	9/ 8/93	58.0	2.5	1	0.0	0.0	8.3	18.3
	1.0	5/ 6/94	122.0	1.5	2	0.0	0.0	7.8	14.4
	2.0	5/24/94	32.0	3.0	1	0.0	0.0	0.0	0.0
	1.0	6/28/94	122.5	1.5	2	58.0	8.0	13.0	0.0

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	3.0	6/30/94	40.0	1.5	1	0.0	0.0	7.8	0.0
	4.0	6/30/94	70.0	1.2	1	0.0	0.0	7.8	0.0
	5.0	6/30/94	50.0	1.2	1	55.8	8.3	10.6	0.0
	1.0	6/28/95	122.5	2.5	2	370.0	0.3	6.6	13.0
	1.0	9/ 6/95	122.5	2.0	2	91.0	8.7	13.3	25.0
TRIB TO E FK COTTONWOO									
	1.0	6/30/94	25.0	0.8	1	0.0	0.0	7.8	0.0
	2.0	6/30/94	40.0	0.5	1	0.0	0.0	7.8	0.0
TRIB TO W FK COTTONWOO									
	1.0	8/18/93	38.0	1.0	1	0.0	0.0	9.4	18.3
	1.0	6/27/94	50.0	1.0	1	0.0	0.0	11.1	25.6
	2.0	6/27/94	55.0	1.0	1	0.0	0.0	11.1	25.6
	3.0	6/27/94	75.0	1.0	1	0.0	0.0	11.1	25.6
UPPER TRIB TO W FK COT									
	1.0	5/24/94	60.0	1.0	1	0.0	0.0	10.0	17.2
	2.0	6/27/94	90.0	1.0	1	0.0	0.0	11.1	21.1
W FK COTTONWOOD CREEK									
	1.0	7/ 8/93	38.0	2.0	1	0.0	0.0	6.7	11.1
	7.0	7/ 8/93	101.0	2.0	1	0.0	0.0	6.7	11.1
	2.0	9/ 8/93	21.0	4.3	1	0.0	0.0	9.4	16.1
	3.0	9/ 8/93	38.5	2.8	1	0.0	0.0	9.4	16.1
	1.0	8/19/93	55.7	2.6	2	0.0	0.0	6.1	16.1
	2.0	8/19/93	37.0	0.0	1	0.0	0.0	6.1	16.1
	5.0	8/19/93	73.0	2.7	2	0.0	0.0	5.6	13.3
	8.0	8/18/93	35.0	1.0	1	0.0	0.0	10.6	18.3
	6.0	8/18/93	49.0	2.0	1	0.0	0.0	10.6	18.3
	7.0	8/18/93	57.2	2.3	2	0.0	0.0	10.0	20.0
	9.0	8/18/93	46.6	1.2	2	0.0	0.0	6.7	15.0
	10.0	8/18/93	39.0	1.0	1	0.0	0.0	10.0	18.3
	4.0	9/ 8/93	34.6	2.5	1	0.0	0.0	8.9	17.8
	1.0	5/ 6/94	55.0	3.0	2	0.0	0.0	6.7	13.3
	2.0	5/24/94	64.0	2.0	1	0.0	0.0	5.0	11.1
	5.0	5/24/94	73.0	2.0	1	0.0	0.0	7.8	11.1
	8.0	5/24/94	55.0	1.5	1	0.0	0.0	10.0	17.2
	10.0	5/24/94	55.0	1.0	1	0.0	0.0	10.0	17.2
	9.0	5/24/94	15.0	1.0	1	0.0	0.0	10.0	17.2
	6.5	6/28/94	58.0	2.0	1	0.0	0.0	7.8	15.6
	5.5	6/28/94	82.0	2.5	1	95.1	8.1	10.0	15.6
	11.0	6/27/94	44.0	1.0	1	0.0	0.0	10.0	21.1
	12.0	6/27/94	55.0	1.0	1	0.0	0.0	10.0	21.1
	13.0	6/27/94	75.0	1.0	1	0.0	0.0	10.0	21.1
	5.0	6/29/94	73.0	2.0	2	182.3	7.8	9.4	25.6
	6.0	6/29/94	49.0	2.0	2	87.8	8.2	13.7	0.0
	7.0	6/29/94	57.0	2.4	2	83.3	8.2	14.2	0.0
	9.0	6/29/94	47.0	0.8	2	134.4	8.2	12.6	0.0
	1.0	6/29/94	93.0	2.8	2	173.8	8.5	9.9	0.0
	14.0	6/27/94	80.0	1.0	1	0.0	0.0	10.0	21.1
	1.0	6/28/95	55.0	3.0	2	119.0	8.3	7.1	0.0
	2.0	6/28/95	15.0	3.0	1	119.0	8.3	7.1	0.0
	6.0	6/29/95	49.0	2.5	2	64.0	7.0	4.9	7.2
	7.0	6/29/95	57.0	2.0	2	64.0	7.0	4.9	7.2
	9.0	6/29/95	47.0	1.5	2	64.0	7.0	4.9	7.2
	1.0	9/ 6/95	55.0	2.0	2	206.0	8.9	12.5	25.4
	5.0	9/ 7/95	73.0	2.0	2	192.0	8.7	6.9	8.8
	6.0	9/ 7/95	49.0	2.0	2	137.0	8.8	9.3	11.9
	7.0	9/ 7/95	57.0	2.0	2	122.0	8.7	9.4	12.8
	9.0	9/ 7/95	47.0	1.0	2	166.0	8.6	11.4	13.9
DRAINAGE DEAD									
DEADMAN CREEK									
	1.0	9/21/94	115.0	4.5	1	0.0	0.0	6.1	20.0

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
2.0	9/21/94	60.0	3.0	1	0.0	0.0	6.1	20.0
3.0	9/21/94	112.0	3.0	1	0.0	0.0	4.4	14.4
4.0	9/21/94	60.0	3.0	1	0.0	0.0	4.4	12.2
5.0	9/21/94	40.0	3.0	1	0.0	0.0	4.4	12.2
N FK DEADMAN CREEK								
7.0	7/ 7/93	124.0	2.0	1	0.0	0.0	5.6	10.6
4.0	7/ 7/93	137.0	2.0	1	0.0	0.0	5.6	10.6
3.0	6/29/93	50.0	2.0	1	0.0	0.0	9.4	16.1
1.0	8/17/93	65.0	2.5	1	0.0	0.0	6.1	12.2
6.0	8/17/93	41.0	1.0	1	0.0	0.0	5.0	8.3
2.0	8/16/93	89.6	2.4	2	0.0	0.0	6.1	12.2
3.0	8/16/93	70.3	2.0	2	0.0	0.0	6.1	12.2
4.0	8/16/93	87.2	1.9	2	0.0	0.0	7.8	19.4
5.0	8/17/93	75.7	1.4	2	0.0	0.0	5.0	6.7
1.0	8/24/94	66.0	1.5	1	285.0	8.6	10.1	21.2
2.0	8/24/94	89.0	2.0	2	289.0	8.5	9.6	0.0
4.0	8/25/94	87.0	1.5	2	219.0	8.8	9.7	25.7
3.0	8/25/94	71.0	1.5	2	200.0	8.7	6.4	25.7
0.5	8/25/94	76.0	2.0	1	277.0	8.4	10.3	24.6
0.5	9/14/94	250.0	0.0	1	0.0	0.0	6.1	0.0
0.6	9/14/94	250.0	0.0	1	0.0	0.0	6.1	0.0
0.7	9/14/94	250.0	0.0	1	0.0	0.0	6.1	0.0
2.5	9/22/94	300.0	0.0	1	0.0	0.0	0.0	0.0
3.5	9/22/94	300.0	0.0	1	0.0	0.0	3.3	16.7
4.5	9/22/94	300.0	0.0	1	0.0	0.0	0.0	0.0
1.0	9/ 8/95	66.0	2.5	2	281.0	8.4	6.7	8.3
2.0	9/ 8/95	89.0	2.5	2	247.0	8.6	7.2	8.9
3.0	9/ 8/95	71.0	1.5	2	198.0	8.6	9.4	14.4
4.0	9/ 8/95	87.0	1.5	2	179.0	8.7	7.8	12.1
5.0	9/ 8/95	75.0	1.5	2	175.0	8.3	7.6	10.4
TRIB TO N FK DEADMAN C								
1.0	7/ 7/93	83.0	1.5	1	0.0	0.0	5.6	9.4
2.0	7/ 7/93	80.0	1.5	1	0.0	0.0	5.6	9.4
5.0	6/29/93	100.0	1.0	1	0.0	0.0	6.1	12.2
1.0	8/17/93	78.0	1.1	1	0.0	0.0	4.4	5.6
3.0	8/17/93	61.0	1.0	1	0.0	0.0	4.4	5.6
4.0	8/17/93	48.0	1.0	1	0.0	0.0	4.4	5.6
DRAINAGE DOUG								
DOUGLAS CREEK								
6.0	8/11/93	33.0	3.0	1	0.0	0.0	5.6	18.9
5.0	8/11/93	88.0	3.0	1	0.0	0.0	5.6	17.8
4.0	8/11/93	84.0	3.0	1	0.0	0.0	5.6	17.8
7.0	8/11/93	67.0	3.0	1	0.0	0.0	5.6	13.9
1.0	9/29/93	34.0	4.0	1	0.0	0.0	5.6	16.7
2.0	9/29/93	43.0	3.0	1	0.0	0.0	5.6	16.7
5.0	9/29/93	113.0	3.0	1	0.0	0.0	5.0	14.4
7.0	9/29/93	71.0	3.0	1	0.0	0.0	5.0	14.4
4.0	9/29/93	126.0	3.0	1	0.0	0.0	3.9	9.4
3.0	9/29/93	70.0	3.0	1	0.0	0.0	5.6	16.7
1.0	6/13/94	45.0	3.0	1	0.0	0.0	5.6	13.3
3.0	6/13/94	70.0	3.0	1	0.0	0.0	5.6	13.3
6.0	6/13/94	60.0	2.5	1	0.0	0.0	5.6	13.3
6.0	8/17/94	80.0	3.0	1	245.0	8.9	9.4	0.0
M FK DOUGLAS CREEK								
1.0	6/23/93	45.0	3.5	1	0.0	0.0	0.0	0.0
4.0	6/23/93	60.0	2.5	1	0.0	0.0	0.0	0.0
3.0	6/23/93	40.0	3.0	1	0.0	0.0	0.0	0.0
2.0	8/11/93	19.0	3.0	1	0.0	0.0	5.6	13.9
N FK DOUGLAS CREEK								
25.0	6/23/93	250.0	2.0	1	0.0	0.0	6.7	5.0

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	21.0	6/23/93	66.0	2.0	1	0.0	0.0	6.7	5.0
	20.0	6/23/93	83.0	2.0	1	0.0	0.0	6.7	5.0
	3.0	6/23/93	98.0	2.0	1	0.0	0.0	6.7	5.0
	3.0	8/ 9/93	93.0	1.0	2	0.0	0.0	13.3	27.8
	10.0	8/ 9/93	58.0	1.0	2	0.0	0.0	11.1	26.7
	7.0	8/10/93	69.0	1.2	2	0.0	0.0	5.6	8.9
	20.0	8/10/93	74.0	1.5	3	0.0	0.0	7.2	21.1
	21.0	8/10/93	69.0	1.5	1	0.0	0.0	7.2	21.1
	17.0	8/10/93	86.0	1.0	2	0.0	0.0	7.2	21.1
	18.0	8/10/93	34.0	1.0	2	0.0	0.0	7.2	21.1
	23.0	8/10/93	71.0	1.0	1	0.0	0.0	7.2	23.3
	24.0	8/10/93	70.0	1.0	1	0.0	0.0	7.2	23.3
	15.0	8/10/93	72.0	1.5	1	0.0	0.0	7.2	23.3
	13.0	8/10/93	83.0	2.0	1	0.0	0.0	7.2	23.3
	1.0	8/11/93	52.0	2.0	1	0.0	0.0	5.6	18.9
	4.0	8/12/93	78.0	2.0	1	0.0	0.0	6.1	10.0
	5.0	8/12/93	95.0	2.0	1	0.0	0.0	6.1	10.0
	2.0	9/27/93	18.0	1.0	1	0.0	0.0	8.3	21.7
	3.0	9/27/93	93.0	1.0	1	0.0	0.0	8.3	21.7
	4.0	9/27/93	74.0	1.0	1	0.0	0.0	8.3	21.7
	5.0	9/27/93	90.0	1.0	1	0.0	0.0	8.3	21.7
	6.0	9/27/93	106.0	1.5	1	0.0	0.0	8.9	16.1
	7.0	9/28/93	85.0	1.5	1	0.0	0.0	3.9	1.7
	9.0	9/28/93	60.0	1.5	1	0.0	0.0	3.9	1.7
	10.0	9/28/93	58.0	1.5	1	0.0	0.0	3.9	1.7
	11.0	9/28/93	52.0	1.5	1	0.0	0.0	3.9	1.7
	12.0	9/28/93	70.0	2.2	1	0.0	0.0	6.7	17.8
	13.0	9/28/93	94.0	2.2	1	0.0	0.0	6.7	17.8
	14.0	9/28/93	100.0	2.2	1	0.0	0.0	6.7	17.8
	16.0	9/28/93	112.0	1.5	1	0.0	0.0	7.2	13.9
	17.0	9/28/93	86.0	1.5	1	0.0	0.0	7.2	13.9
	18.0	9/28/93	59.0	1.5	1	0.0	0.0	7.2	13.9
	19.0	9/28/93	100.0	1.5	1	0.0	0.0	6.7	5.0
	20.0	9/28/93	74.0	1.5	1	0.0	0.0	6.7	5.0
	21.0	9/28/93	70.0	1.5	1	0.0	0.0	6.7	5.0
	22.0	9/28/93	80.0	1.5	1	0.0	0.0	6.7	5.0
	8.0	9/27/93	50.0	1.5	1	0.0	0.0	8.9	16.1
	3.0	6/13/94	98.0	0.0	1	0.0	0.0	5.0	9.4
	8.0	6/13/94	50.0	1.0	1	0.0	0.0	5.0	9.4
	13.0	6/13/94	70.0	1.0	1	0.0	0.0	5.0	9.4
	17.0	6/13/94	80.0	1.0	1	0.0	0.0	5.0	9.4
	20.0	6/14/94	74.0	1.0	1	0.0	0.0	3.9	8.3
	7.0	6/14/94	100.0	1.0	1	0.0	0.0	3.9	8.3
	3.0	8/17/94	93.0	0.7	2	256.0	8.7	5.8	0.0
	7.0	8/17/94	85.0	1.5	2	261.0	8.7	5.8	0.0
	10.0	8/17/94	58.0	1.5	2	261.0	8.7	5.8	0.0
	17.0	8/17/94	86.0	2.0	1	261.0	8.7	5.8	0.0
	20.0	8/17/94	74.0	2.0	2	228.0	8.9	7.4	0.0
	5.0	8/17/94	80.0	1.5	1	0.0	0.0	0.0	0.0
	3.0	8/ 7/95	93.0	1.0	2	236.0	8.8	14.4	0.0
	4.0	8/ 7/95	100.0	0.0	1	236.0	8.8	14.4	0.0
	5.0	8/ 7/95	142.0	0.0	1	236.0	8.8	14.4	0.0
	7.0	8/ 7/95	85.0	1.5	2	249.0	7.8	13.1	19.5
	10.0	8/ 9/95	58.0	1.5	3	254.0	8.4	4.9	7.1
	17.0	8/ 8/95	86.0	1.0	1	259.0	8.2	5.7	10.8
	20.0	8/ 8/95	74.0	1.0	1	259.0	8.2	5.7	10.8
	3.0	8/ 9/95	0.0	0.0	1	274.0	8.4	5.4	7.8
DRAINAGE ELKH									
ELKHORN CREEK									
	4.0	10/ 4/9	360.0	2.0	1	0.0	0.0	7.8	13.3

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Temperature (C) Air
2.0	10/ 4/9	170.0	2.0	1	0.0	0.0	0.0	0.0
1.0	10/ 4/9	400.0	4.0	1	0.0	0.0	0.0	0.0
3.0	10/ 3/9	230.0	2.0	1	0.0	0.0	0.0	0.0
5.0	10/ 4/9	190.0	2.0	1	0.0	0.0	0.0	0.0
N FK ELKHORN CREEK								
1.0	10/ 4/9	120.0	1.0	1	0.0	0.0	0.0	0.0
2.0	10/ 4/9	240.0	1.0	1	0.0	0.0	0.0	0.0
S FK ELKHORN CREEK								
2.0	10/ 3/9	280.0	1.0	1	0.0	0.0	0.0	0.0
3.0	10/ 3/9	170.0	1.0	1	0.0	0.0	0.0	0.0
1.0	10/ 4/9	400.0	1.0	1	0.0	0.0	0.0	0.0
DRAINAGE FREEZ								
FREEZEOUT CREEK								
1.0	7/29/93	60.0	1.0	1	0.0	0.0	6.7	15.6
DRAINAGE GOLD								
N FK GOLD CREEK								
10.0	8/11/93	69.0	1.5	2	0.0	0.0	6.7	22.2
7.0	8/11/93	83.0	3.0	2	0.0	0.0	12.2	16.7
6.0	8/12/93	63.0	3.0	1	0.0	0.0	10.0	12.2
3.0	8/12/93	107.0	2.0	2	0.0	0.0	10.0	12.2
1.0	9/30/93	83.0	2.0	1	0.0	0.0	7.8	14.4
2.0	9/30/93	90.0	2.5	1	0.0	0.0	6.1	13.3
3.0	9/30/93	107.0	2.5	1	0.0	0.0	6.1	13.3
4.0	9/30/93	73.0	2.5	1	0.0	0.0	6.1	13.3
5.0	9/30/93	87.0	2.0	1	0.0	0.0	6.7	7.8
7.0	9/29/93	83.0	2.0	1	0.0	0.0	6.1	12.8
8.0	9/29/93	55.0	2.0	1	0.0	0.0	6.1	12.8
9.0	9/30/93	61.0	1.0	1	0.0	0.0	4.4	12.2
10.0	9/30/93	69.0	1.0	1	0.0	0.0	4.4	12.2
11.0	9/30/93	60.0	1.0	1	0.0	0.0	4.4	12.2
7.0	6/14/94	83.0	3.0	1	0.0	0.0	5.0	6.1
6.0	6/14/94	60.0	2.0	1	0.0	0.0	5.0	6.1
10.0	6/14/94	69.0	3.0	1	0.0	0.0	5.0	6.1
3.0	6/14/94	107.0	2.0	1	0.0	0.0	5.0	6.1
3.0	8/16/94	107.0	1.5	2	0.0	0.0	0.0	0.0
4.5	8/18/94	77.0	2.0	2	209.0	8.6	7.7	26.7
7.0	8/18/94	83.0	3.0	2	152.0	8.8	9.4	0.0
10.0	8/18/94	69.0	2.0	1	161.0	8.9	5.1	0.0
3.0	8/ 8/95	107.0	1.5	2	179.0	8.5	8.2	11.4
4.5	8/ 8/95	77.0	2.0	3	145.0	8.3	9.4	12.8
7.0	8/ 8/95	83.0	3.0	2	170.0	8.1	8.7	4.4
10.0	8/ 8/95	69.0	3.0	1	145.0	8.3	5.4	9.8
DRAINAGE HALFM								
HALF MOON CREEK								
16.0	7/15/93	100.0	2.5	1	0.0	0.0	6.7	14.4
15.0	7/15/93	24.0	2.5	1	0.0	0.0	6.7	14.4
14.0	7/15/93	85.0	2.5	1	0.0	0.0	6.7	14.4
11.0	7/15/93	35.0	2.5	1	0.0	0.0	6.7	14.4
12.0	7/15/93	16.0	2.5	1	0.0	0.0	6.7	14.4
13.0	7/15/93	25.0	2.5	1	0.0	0.0	6.7	14.4
10.0	7/15/93	10.0	3.0	1	0.0	0.0	6.7	14.4
9.0	7/15/93	70.0	3.0	1	0.0	0.0	6.7	14.4
8.0	7/15/93	31.0	3.0	1	0.0	0.0	6.7	14.4
7.0	7/15/93	28.0	3.0	1	0.0	0.0	6.7	14.4
6.0	7/15/93	15.0	3.0	1	0.0	0.0	6.7	14.4
5.0	7/15/93	38.0	3.0	1	0.0	0.0	6.7	14.4
1.0	6/28/93	100.0	4.0	1	0.0	0.0	9.4	15.6
2.0	6/28/93	50.0	4.0	1	0.0	0.0	9.4	15.6

ppendix B. Characteristics of sample sections.

RAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Temperature (C) Air
	4.0	6/29/93	30.0	4.0	1	0.0	0.0	9.4	15.6
	3.0	6/29/93	100.0	4.0	1	0.0	0.0	9.4	15.6
	4.9	8/10/94	81.7	3.4	2	365.0	8.7	8.9	11.1
	5.0	8/10/94	31.0	2.8	1	365.0	8.7	9.4	15.0
	5.6	8/10/94	84.6	3.4	2	329.0	8.7	13.3	18.9
	5.8	8/10/94	47.6	3.4	2	316.0	8.7	17.8	23.9
	1.5	8/12/94	98.0	3.0	2	294.0	9.0	9.2	0.0
	2.5	8/11/94	80.0	3.0	3	322.0	8.2	11.1	23.9
	4.5	8/11/94	84.0	2.5	2	296.0	8.8	13.7	23.9
	7.5	8/10/94	70.0	2.5	2	336.0	8.7	15.6	23.9
	9.0	8/11/94	90.0	3.0	2	354.0	8.7	12.2	23.9
	10.0	8/11/94	35.0	3.0	2	354.0	8.7	12.2	23.9
	1.5	8/16/95	98.0	3.5	2	332.0	8.6	8.3	8.6
	4.5	8/14/95	84.0	3.0	2	342.0	8.8	13.1	25.6
	4.9	8/14/95	81.7	2.5	2	343.0	8.9	13.6	22.2
	5.6	8/15/95	85.0	3.5	2	371.0	8.9	10.0	13.1
	5.8	8/15/95	47.6	2.5	3	393.0	8.7	12.8	17.8
	7.5	8/15/95	70.0	2.5	2	350.0	8.6	15.3	24.1
	9.0	8/15/95	90.0	2.0	2	392.0	8.5	12.8	28.3
	10.0	8/15/95	35.0	2.0	2	354.0	8.7	13.6	28.7
	2.5	8/16/95	80.0	2.5	2	321.0	8.6	6.7	7.2
DRAINAGE HALFW									
HALFWAY CREEK									
	11.0	6/22/93	50.0	2.0	1	0.0	0.0	11.1	10.0
	12.0	8/ 3/93	0.0	0.0	1	0.0	0.0	0.0	0.0
	14.0	8/ 4/93	77.0	1.0	2	0.0	0.0	7.2	11.1
	7.0	8/ 2/93	83.0	1.5	1	0.0	0.0	4.4	3.9
	13.0	8/ 4/93	65.0	1.5	2	0.0	0.0	12.2	25.0
	10.0	8/ 3/93	73.0	1.5	1	0.0	0.0	14.4	12.8
	3.0	8/ 3/93	68.0	2.0	2	0.0	0.0	9.4	21.1
	1.0	8/ 3/93	85.0	2.2	2	0.0	0.0	9.4	21.1
	11.0	8/ 2/93	88.0	1.4	3	0.0	0.0	13.9	16.7
	1.0	10/19/9	85.0	2.0	1	0.0	0.0	1.1	2.2
	2.0	10/19/9	38.0	1.5	1	0.0	0.0	1.1	2.2
	3.0	10/19/9	68.0	1.5	1	0.0	0.0	1.1	2.2
	4.0	10/19/9	56.0	1.5	1	0.0	0.0	1.1	2.2
	5.0	10/20/9	90.0	1.5	1	0.0	0.0	1.1	5.6
	6.0	10/18/9	83.0	1.5	1	0.0	0.0	2.8	4.4
	7.0	10/18/9	52.0	1.5	1	0.0	0.0	2.8	3.9
	8.0	10/18/9	90.0	1.5	1	0.0	0.0	2.8	3.9
	9.0	10/18/9	83.0	1.5	1	0.0	0.0	2.8	1.1
	10.0	10/19/9	54.0	1.0	1	0.0	0.0	2.2	0.0
	11.0	10/19/9	88.0	1.5	1	0.0	0.0	2.2	0.0
	13.0	10/20/9	65.0	1.0	1	0.0	0.0	0.6	3.3
	13.0	5/25/94	65.0	0.0	1	0.0	0.0	8.3	20.6
	1.0	5/25/94	85.0	0.0	1	0.0	0.0	10.0	20.6
	3.0	5/25/94	68.0	0.0	1	0.0	0.0	11.7	17.8
	1.0	8/ 2/94	85.0	2.0	2	82.2	8.7	13.1	0.0
	3.0	8/ 2/94	65.0	2.0	2	0.0	0.0	0.0	0.0
	11.0	8/ 3/94	88.0	1.0	2	82.4	8.4	16.0	0.0
	13.0	8/ 3/94	65.0	1.0	3	70.5	8.4	17.8	0.0
	14.0	8/ 2/94	77.0	1.0	2	0.0	0.0	0.0	0.0
	0.5	9/ 8/94	59.9	2.5	2	0.0	0.0	7.8	15.6
	0.8	9/ 8/94	67.0	2.5	2	0.0	0.0	7.8	15.6
	11.0	5/25/94	88.0	0.0	1	0.0	0.0	16.1	15.6
	15.0	8/ 1/94	73.0	0.5	1	76.5	7.9	15.6	0.0
	12.0	8/ 2/94	0.0	0.0	N	0.0	0.0	0.0	0.0
	0.1	8/ 3/94	25.0	2.0	1	0.0	0.0	0.0	0.0
	0.2	8/ 3/94	35.0	2.0	1	0.0	0.0	0.0	0.0
	0.3	8/ 3/94	35.0	2.0	1	0.0	0.0	0.0	0.0

ppendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	0.4	8/ 3/94	20.0	2.0	1	0.0	0.0	0.0	0.0
	1.0	7/25/95	85.0	2.0	2	68.4	9.2	18.4	28.1
	3.0	7/24/95	68.0	2.0	2	69.0	9.3	17.8	28.3
	4.0	7/24/95	93.0	2.0	1	69.0	9.3	17.8	28.3
	5.0	7/25/95	85.0	2.0	1	69.0	9.3	18.7	24.2
	6.0	7/25/95	265.0	2.0	1	69.0	9.3	18.7	24.2
	11.0	7/26/95	88.0	1.0	2	63.5	9.1	13.0	21.1
	3.0	8/ 3/95	0.0	0.0	1	73.0	8.3	14.7	26.1
	13.0	7/26/95	65.0	1.0	2	65.0	8.8	13.9	26.7
	14.0	7/26/95	77.0	1.0	2	76.3	8.6	11.7	21.4
TRIB TO HALFWAY CREEK									
	1.0	8/ 3/93	72.0	1.0	1	0.0	0.0	12.8	13.3
	1.0	10/20/9	103.0	1.0	1	0.0	0.0	0.6	0.0
UNNAMED TRIB TO HALFWA									
	1.0	5/25/94	110.0	11.0	1	0.0	0.0	8.3	20.6
	2.0	5/25/94	152.0	11.0	1	0.0	0.0	8.3	20.6
UPPER TRIB TO HALFWAY									
	1.0	8/ 1/94	85.0	0.5	1	83.5	8.4	17.1	0.0
	2.0	8/ 1/94	400.0	0.3	I	83.5	8.4	17.1	0.0
DRAINAGE JERRY									
DELANO CREEK									
	2.0	8/24/93	68.1	1.9	2	0.0	0.0	7.2	9.4
	5.0	8/24/93	117.0	2.3	2	0.0	0.0	6.7	10.0
	8.0	8/24/93	43.0	2.0	2	0.0	0.0	6.7	7.8
	1.0	9/20/93	92.0	1.0	1	0.0	0.0	5.0	8.9
	2.0	9/20/93	68.0	1.0	1	0.0	0.0	5.0	8.9
	3.0	9/20/93	72.0	0.9	1	0.0	0.0	5.0	8.9
	4.0	9/20/93	108.0	1.2	1	0.0	0.0	5.6	11.1
	5.0	9/20/93	112.5	1.5	1	0.0	0.0	5.6	11.1
	6.0	9/20/93	80.0	1.5	1	0.0	0.0	5.0	12.2
	10.0	9/21/93	48.0	0.8	1	0.0	0.0	2.2	0.6
	11.0	9/21/93	67.0	0.6	1	0.0	0.0	2.2	0.6
	7.0	9/21/93	90.0	1.0	1	0.0	0.0	2.2	-1.1
	8.0	9/21/93	43.0	1.0	1	0.0	0.0	2.2	-1.1
	9.0	9/21/93	59.0	1.0	1	0.0	0.0	2.2	-1.1
	2.0	6/ 6/94	70.0	2.0	1	0.0	0.0	8.3	16.7
	5.0	6/ 6/94	150.0	2.0	1	0.0	0.0	8.9	16.7
	7.0	6/ 6/94	84.0	2.0	1	0.0	0.0	8.9	11.7
	8.0	6/ 6/94	40.0	2.0	1	0.0	0.0	8.9	11.7
	5.0	8/30/94	112.0	1.0	3	178.0	8.8	10.2	15.6
	8.0	8/31/94	43.0	1.0	2	179.0	8.5	6.9	8.3
	2.0	8/31/94	68.0	1.5	2	182.0	8.7	8.6	12.8
	2.0	8/29/95	68.0	1.0	2	158.0	7.6	9.2	22.4
	4.0	8/29/95	60.0	1.0	1	158.0	7.6	9.2	22.4
	5.0	8/29/95	112.0	1.5	2	162.0	8.3	10.0	16.1
	8.0	8/29/95	43.0	1.5	2	148.0	8.4	10.3	19.4
FLUME CREEK									
	1.0	6/24/93	25.0	2.0	1	0.0	0.0	0.0	0.0
	1.0	6/ 7/94	47.0	0.5	1	0.0	0.0	6.1	12.2
JERRY CREEK									
	5.0	6/24/93	133.0	3.0	1	0.0	0.0	0.0	0.0
	6.0	6/24/93	108.0	2.5	1	0.0	0.0	0.0	0.0
	3.0	6/24/93	57.0	2.5	1	0.0	0.0	0.0	0.0
	2.0	6/24/93	60.0	3.5	1	0.0	0.0	0.0	0.0
	3.0	8/23/93	101.2	3.3	2	0.0	0.0	10.0	17.8
	5.0	8/23/93	101.5	2.7	2	0.0	0.0	9.4	11.7
	1.0	9/21/93	83.0	2.5	1	0.0	0.0	2.2	3.9
	2.0	9/21/93	75.0	2.5	1	0.0	0.0	2.2	3.9
	3.0	9/21/93	101.0	2.5	1	0.0	0.0	3.9	1.1
	4.0	9/21/93	77.0	2.0	1	0.0	0.0	3.3	1.1

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
3.0	6/ 7/94	100.0	3.0	1	0.0	0.0	4.4	7.8
5.0	6/ 7/94	100.0	3.0	1	0.0	0.0	5.6	7.8
2.0	6/ 7/94	72.0	3.0	1	0.0	0.0	6.1	12.2
5.0	8/30/94	101.0	1.5	2	178.0	9.2	11.3	18.8
3.0	8/31/94	101.0	1.5	2	169.0	8.7	6.9	9.4
0.5	8/31/94	50.0	2.0	1	132.0	8.7	12.1	18.9
3.0	8/30/95	101.0	2.0	2	125.0	8.4	4.9	5.6
5.0	8/30/95	101.0	1.5	3	177.0	8.4	8.6	11.1
UNNAMED TRIB TO DELANO								
1.0	9/21/93	25.0	0.5	1	0.0	0.0	0.0	0.0
DRAINAGE LICK								
LICK CREEK								
1.0	6/26/95	316.0	3.0	2	210.0	9.3	14.2	22.2
2.0	6/29/95	40.0	3.0	1	0.0	0.0	0.0	0.0
3.0	6/29/95	300.0	3.0	1	0.0	0.0	0.0	0.0
4.0	6/29/95	86.0	2.0	1	0.0	0.0	0.0	0.0
5.0	7/11/95	98.0	1.5	1	154.0	8.3	17.9	0.0
6.0	7/11/95	82.0	1.5	1	154.0	8.3	17.9	0.0
7.0	7/11/95	112.0	1.5	1	154.0	8.3	17.9	0.0
1.0	9/12/95	150.0	2.0	1	0.0	0.0	0.0	0.0
1.5	9/12/95	166.0	2.0	1	0.0	0.0	0.0	0.0
2.0	9/12/95	40.0	0.8	1	302.0	8.8	5.6	9.4
2.5	9/12/95	112.0	0.8	1	302.0	8.8	5.6	9.4
3.0	9/12/95	190.0	0.8	1	302.0	8.8	5.6	9.4
4.0	9/11/95	167.0	2.0	1	275.0	7.9	8.6	15.1
4.1	9/11/95	46.0	2.0	1	275.0	7.9	8.6	15.1
4.2	9/11/95	92.0	2.0	1	275.0	7.9	8.6	15.1
4.3	9/11/95	172.0	2.0	1	275.0	7.9	8.6	15.1
4.4	9/11/95	180.0	2.0	1	275.0	7.9	8.6	15.1
0.0	9/18/95	0.0	0.0	1	0.0	0.0	7.6	14.3
1.0	9/19/95	0.0	0.0	1	0.0	0.0	5.0	7.2
2.0	9/19/95	0.0	0.0	1	0.0	0.0	3.9	5.0
DRAINAGE MCVEY								
MCVEY CREEK								
15.0	7/ 1/93	157.0	2.5	2	0.0	0.0	8.3	17.8
16.0	7/ 1/93	50.0	2.5	1	0.0	0.0	8.3	17.8
2.0	8/31/93	211.0	2.0	3	0.0	0.0	0.0	0.0
1.0	8/31/93	25.0	0.0	1	0.0	0.0	0.0	0.0
3.0	8/25/93	152.0	2.0	2	0.0	0.0	7.2	14.4
4.0	8/25/93	153.0	2.0	2	0.0	0.0	7.2	14.4
5.0	8/25/93	162.7	1.6	2	0.0	0.0	7.2	14.4
6.0	8/25/93	152.0	1.6	2	0.0	0.0	7.2	10.0
7.0	8/25/93	162.0	1.6	2	0.0	0.0	7.2	10.0
8.0	8/26/93	151.0	1.6	2	0.0	0.0	5.6	6.7
9.0	8/25/93	153.0	1.6	2	0.0	0.0	7.2	14.4
10.0	8/25/93	150.0	1.6	2	0.0	0.0	7.2	15.6
11.0	8/26/93	162.0	1.6	2	0.0	0.0	5.6	6.7
12.0	8/26/93	152.0	1.6	2	0.0	0.0	5.6	6.7
13.0	8/26/93	152.0	1.6	2	0.0	0.0	5.6	6.7
14.0	8/26/93	152.0	1.6	2	0.0	0.0	5.6	6.7
15.0	8/26/93	164.0	1.6	2	0.0	0.0	5.6	6.7
16.0	8/26/93	148.0	1.6	3	0.0	0.0	5.6	6.7
17.0	8/26/93	152.0	1.6	2	0.0	0.0	5.6	6.7
18.0	8/26/93	43.0	1.6	2	0.0	0.0	5.6	6.7
1.0	9/22/93	39.0	0.5	1	0.0	0.0	0.0	2.2
2.0	9/22/93	193.0	1.5	1	0.0	0.0	0.0	2.2
3.0	9/22/93	153.0	1.5	1	0.0	0.0	3.3	21.1
4.0	9/22/93	67.0	1.5	1	0.0	0.0	3.3	21.1
5.0	9/22/93	135.0	1.5	1	0.0	0.0	3.3	21.1

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	13.0	9/22/93	160.0	1.5	1	0.0	0.0	3.3	10.0
	3.0	6/ 8/94	200.0	2.0	1	0.0	0.0	4.4	5.6
	5.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	5.6
	7.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	5.6
	9.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	5.6
	11.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	5.6
	13.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	5.6
	17.0	6/ 9/94	80.0	0.0	1	0.0	0.0	0.0	0.0
	16.0	6/ 9/94	90.0	0.0	1	0.0	0.0	0.0	0.0
	15.0	6/ 9/94	70.0	0.0	1	0.0	0.0	0.0	0.0
	14.0	6/ 9/94	160.0	0.0	1	0.0	0.0	0.0	0.0
	6.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	0.0
	8.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	0.0
	10.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	0.0
	12.0	6/ 8/94	152.0	2.0	1	0.0	0.0	4.4	0.0
	3.0	9/ 1/94	180.0	1.5	1	87.0	8.7	11.7	19.4
	12.0	9/ 1/94	208.0	1.2	1	68.0	8.8	12.9	24.9
	3.0	7/22/94	180.0	1.5	1	0.0	0.0	0.0	0.0
	5.0	7/22/94	152.0	2.0	1	0.0	0.0	0.0	0.0
	9.0	7/22/94	152.0	0.0	1	0.0	0.0	0.0	0.0
	3.0	8/17/94	180.0	1.5	1	0.0	0.0	0.0	0.0
	7.0	8/17/94	152.0	2.0	1	0.0	0.0	0.0	0.0
	9.0	8/17/94	152.0	0.0	1	0.0	0.0	0.0	0.0
	3.0	6/21/95	150.0	3.0	1	51.0	9.9	5.4	0.0
	17.0	6/21/95	100.0	1.5	1	44.0	0.4	4.0	0.0
	3.0	8/28/95	152.0	1.5	2	78.0	9.4	14.6	27.3
	4.0	8/28/95	153.0	1.5	2	62.0	9.3	13.2	20.4
	10.0	8/28/95	150.0	1.5	2	54.7	8.7	11.4	20.0
	15.0	10/17/9	100.0	2.0	1	0.0	0.0	0.0	0.0
	5.0	10/17/9	100.0	2.0	1	0.0	0.0	0.0	0.0
	3.0	10/17/9	100.0	2.5	2	0.0	0.0	0.0	0.0
	4.0	7/ 8/96	128.2	2.0		0.0	0.0	0.0	0.0
	7.0	7/ 8/96	144.1	2.3		0.0	0.0	0.0	0.0
N FK MCVEY CREEK									
	1.0	9/22/93	50.0	0.5	1	0.0	0.0	5.6	19.4
	1.0	6/ 9/94	50.0	1.0	1	0.0	0.0	0.0	0.0
TRIB TO MCVEY CREEK									
	3.0	7/ 1/93	95.0	1.5	1	0.0	0.0	0.0	0.0
	2.0	7/ 1/93	80.0	1.5	1	0.0	0.0	0.0	0.0
	1.0	7/ 1/93	110.0	1.5	1	0.0	0.0	0.0	0.0
UNNAMED TRIB OF MCVEY									
	1.0	6/ 9/94	80.0	1.0	1	0.0	0.0	3.9	11.1
	2.0	6/ 9/94	100.0	1.0	1	0.0	0.0	3.9	11.1
DRAINAGE MISC									
E FK FORDS CREEK									
	1.0	6/13/95	50.0	0.5	1	670.0	8.6	12.7	27.4
NEBEL COULEE									
	1.0	6/15/95	70.0	5.0	1	90.0	8.9	5.8	0.0
	2.0	6/15/95	100.0	5.0	1	90.0	8.9	5.8	0.0
DRAINAGE MUSKR									
MUSKRAT CREEK									
	10.0	8/ 4/93	70.0	3.0	1	0.0	0.0	7.2	14.4
	7.0	8/ 5/93	79.5	3.3	2	0.0	0.0	8.9	19.4
	8.0	8/ 5/93	68.9	3.8	2	0.0	0.0	6.7	12.2
	9.0	8/ 5/93	35.0	3.5	1	0.0	0.0	6.7	12.2
	1.0	10/21/9	31.0	2.5	1	0.0	0.0	3.3	8.9
	2.0	10/21/9	10.0	2.5	1	0.0	0.0	3.3	8.9
	3.0	10/21/9	61.0	2.0	1	0.0	0.0	3.3	10.0
	5.0	10/21/9	20.0	3.5	1	0.0	0.0	1.1	1.1

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
4.0	10/21/9	31.0	2.0	1	0.0	0.0	2.2	4.4
6.0	10/21/9	20.0	2.0	1	0.0	0.0	2.2	4.4
7.0	10/20/9	79.5	2.5	1	0.0	0.0	2.2	2.8
DRAINAGE SOAP								
SOAP CREEK								
4.0	7/29/93	83.5	3.0	2	0.0	0.0	10.0	15.0
13.0	7/29/93	0.0	0.0	0	0.0	0.0	0.0	0.0
10.0	7/29/93	127.0	2.0	3	0.0	0.0	10.0	21.1
12.0	7/29/93	55.0	1.0	1	0.0	0.0	7.8	20.6
7.0	7/28/93	135.5	2.5	2	0.0	0.0	7.8	16.7
1.0	10/ 7/9	65.0	1.5	1	0.0	0.0	5.0	3.9
2.0	10/ 7/9	64.0	2.0	1	0.0	0.0	5.0	3.9
3.0	10/ 7/9	90.0	2.5	1	0.0	0.0	5.6	8.3
4.0	10/ 7/9	83.5	2.5	1	0.0	0.0	5.6	8.3
5.0	10/ 7/9	70.0	2.5	1	0.0	0.0	5.6	8.3
8.0	10/ 6/9	69.0	2.0	1	0.0	0.0	5.6	11.1
6.0	10/ 6/9	84.0	2.0	1	0.0	0.0	5.6	11.1
7.0	10/ 6/9	135.5	2.0	1	0.0	0.0	5.6	11.1
9.0	10/ 6/9	83.0	2.0	1	0.0	0.0	4.4	9.4
10.0	10/ 6/9	127.0	2.0	1	0.0	0.0	4.4	9.4
11.0	10/ 6/9	83.0	2.0	1	0.0	0.0	5.6	10.6
6.0	5/11/94	84.0	3.0	1	0.0	0.0	5.6	20.6
10.0	5/11/94	135.0	3.0	1	0.0	0.0	5.6	20.6
12.0	5/11/94	50.0	3.0	1	0.0	0.0	5.6	20.6
6.0	6/16/94	84.0	2.0	1	0.0	0.0	7.2	20.0
7.0	6/16/94	120.0	2.0	1	0.0	0.0	7.2	20.0
7.0	7/26/94	135.0	2.5	2	79.6	8.4	13.4	0.0
4.0	7/26/94	70.0	2.5	2	91.0	8.1	13.6	0.0
10.0	7/26/94	127.0	2.5	2	63.0	7.8	13.9	0.0
2.5	7/28/94	70.0	2.5	2	91.5	8.8	12.5	0.0
2.5	7/20/95	70.0	3.5	2	74.5	8.8	10.4	21.7
4.0	7/20/95	83.0	3.0	2	69.0	8.7	10.6	21.7
7.0	7/20/95	135.0	2.5	2	64.0	8.9	13.1	28.3
10.0	7/20/95	127.0	2.5	3	46.0	8.8	8.5	21.4
DRAINAGE STONE								
L FK STONE CREEK								
2.0	7/ 6/94	300.0	0.5	1	0.0	0.0	0.0	0.0
1.0	7/ 5/94	575.0	1.5	P	0.0	0.0	10.0	0.0
1.0	7/ 7/95	680.0	1.5	2	296.0	8.0	10.0	0.0
M FK STONE CREEK								
1.0	7/ 5/94	203.0	0.6	2	364.0	7.2	13.9	26.7
3.0	7/ 5/94	223.9	1.4	2	369.0	8.0	14.6	0.0
2.0	7/ 5/94	82.0	0.6	2	369.0	8.0	14.6	0.0
4.0	7/ 6/94	100.0	0.9	1	331.0	8.2	8.1	0.0
5.0	7/ 6/94	140.0	0.9	1	331.0	8.2	8.1	0.0
6.0	7/ 6/94	77.0	0.9	2	331.0	8.2	8.1	0.0
7.0	7/ 6/94	210.0	0.9	1	331.0	8.2	8.1	0.0
8.0	7/ 6/94	95.0	0.9	1	331.0	8.2	8.1	0.0
9.0	7/ 6/94	80.0	0.0	1	0.0	0.0	0.0	0.0
10.0	7/ 6/94	50.0	0.0	1	0.0	0.0	0.0	0.0
1.0	7/ 6/95	203.0	0.0	2	306.0	8.2	12.3	0.0
3.0	7/ 7/95	223.0	3.0	2	295.0	7.8	9.7	0.0
STONE CREEK								
3.0	7/ 6/94	200.0	2.0	1	0.0	0.0	0.0	0.0
2.0	7/ 6/94	200.0	2.0	1	0.0	0.0	0.0	0.0
1.0	7/ 6/94	150.0	2.0	1	0.0	0.0	0.0	0.0
DRAINAGE TEND								
BUBBLING SPRING								

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	1.0	8/24/94	120.0	0.8	1	66.0	8.8	12.6	27.2
	1.0	8/20/92	100.0	0.8	V	0.0	0.0	0.0	0.0
SPRING PARK CREEK									
	1.0	8/31/93	48.0	1.0	1	0.0	0.0	0.0	0.0
	1.0	8/20/92	50.0	1.0	1	109.0	8.8	11.7	0.0
STRINGER CREEK									
	2.0	9/ 1/93	67.0	1.0	1	0.0	0.0	3.9	9.4
	1.0	8/19/92	78.0	2.6	1	103.0	8.3	7.6	0.0
SUN CREEK									
	1.0	8/31/93	98.0	1.4	2	0.0	0.0	5.0	7.8
	1.0	8/22/94	102.0	1.0	4	76.0	8.6	10.4	15.6
	1.0	8/21/95	102.0	1.0	2	62.2	8.8	13.1	24.1
	1.0	8/19/92	91.5	1.1	3	82.3	7.8	13.7	0.0
TENDERFOOT CREEK									
	14.0	9/ 1/93	100.0	3.0	1	0.0	0.0	0.0	0.0
	15.0	8/30/93	174.0	3.4	2	0.0	0.0	3.9	5.6
	16.0	9/ 1/93	115.0	3.0	1	0.0	0.0	4.4	6.7
	17.0	9/ 1/93	70.0	3.0	1	0.0	0.0	4.4	6.7
	18.0	8/31/93	87.0	1.6	4	0.0	0.0	3.3	7.8
	2.0	10/13/9	24.0	3.0	1	0.0	0.0	2.8	10.0
	1.0	10/13/9	7.0	3.0	1	0.0	0.0	2.8	10.0
	4.0	10/13/9	15.0	3.0	1	0.0	0.0	2.8	10.0
	5.0	10/13/9	15.0	3.0	1	0.0	0.0	2.8	10.0
	6.0	10/13/9	12.0	3.0	1	0.0	0.0	2.8	10.0
	7.0	10/13/9	12.0	3.0	1	0.0	0.0	2.8	10.0
	8.0	10/13/9	15.0	3.0	1	0.0	0.0	2.8	10.0
	9.0	10/13/9	20.0	3.0	1	0.0	0.0	2.8	10.0
	10.0	10/13/9	5.0	3.0	1	0.0	0.0	2.8	10.0
	11.0	10/13/9	14.0	3.0	1	0.0	0.0	2.8	10.0
	3.0	10/13/9	175.0	5.0	1	0.0	0.0	2.8	10.0
	13.0	10/12/9	140.0	5.0	1	0.0	0.0	2.8	10.0
	14.0	10/12/9	177.0	3.0	1	0.0	0.0	2.8	5.0
	12.0	10/12/9	133.0	5.0	1	0.0	0.0	2.8	5.0
	18.0	8/22/94	87.0	1.5	2	192.0	8.5	11.8	15.6
	15.0	8/23/94	174.0	3.0	2	108.0	8.8	7.5	12.7
	14.0	8/23/94	177.0	2.5	2	98.0	8.5	10.8	0.0
	12.0	8/23/94	133.0	5.0	2	102.0	8.8	11.5	0.0
	3.0	8/24/94	175.0	4.0	2	96.0	8.6	11.3	25.7
	0.1	9/16/94	132.2	4.8	2	0.0	0.0	11.1	25.6
	0.2	9/16/94	103.0	5.5	1	0.0	0.0	8.3	17.8
	3.0	8/22/95	175.0	4.0	2	78.2	8.6	10.3	21.7
	12.0	8/22/95	133.0	5.0	3	80.0	8.7	11.2	25.1
	14.0	8/22/95	177.0	2.5	2	84.0	8.3	13.1	29.3
	15.0	8/21/95	174.0	3.0	2	114.0	8.9	10.7	28.9
	18.0	8/22/95	87.0	1.5	2	152.0	8.6	12.8	21.1
	3.0	8/18/92	175.0	4.2	2	113.0	8.5	8.8	0.0
	12.0	8/18/92	133.0	5.0	2	113.0	8.5	8.8	0.0
	14.0	8/19/92	177.0	2.7	2	109.0	8.6	8.4	0.0
	15.0	8/20/92	174.0	3.2	2	115.0	8.8	11.6	0.0
	18.0	8/20/92	80.0	1.4	2	191.0	9.0	9.7	0.0
DRAINAGE WHITE									
LEFT FK WHITE'S GULCH									
	1.0	9/14/94	100.0	0.8	1	0.0	0.0	0.0	0.0
	2.0	9/14/94	265.0	0.8	1	0.0	0.0	8.9	15.6
SPRING GULCH									
	1.0	10/28/9	120.0	1.0	1	0.0	0.0	0.0	0.0
WHITE' S GULCH									
	0.9	10/22/9	800.0	3.0	1	708.0	0.0	6.4	6.7
WHITE'S GULCH									
	8.0	7/ 6/93	193.0	1.0	1	0.0	0.0	8.9	13.9

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	2.0	7/ 6/93	173.0	1.5	3	0.0	0.0	8.9	17.8
	31.0	7/ 6/93	295.0	1.0	1	0.0	0.0	8.9	17.8
	30.0	7/ 6/93	500.0	1.0	1	0.0	0.0	8.9	17.8
	1.0	7/ 6/93	134.0	1.5	1	0.0	0.0	8.9	19.4
	1.0	9/ 9/93	100.0	2.0	1	0.0	0.0	10.0	17.2
	2.0	9/ 9/93	100.0	2.5	2	0.0	0.0	8.9	21.1
	3.0	9/ 9/93	100.0	2.5	2	0.0	0.0	8.9	21.1
	4.0	9/ 9/93	100.0	2.5	2	0.0	0.0	8.9	21.1
	5.0	9/ 9/93	100.0	2.4	2	0.0	0.0	8.9	19.4
	6.0	9/ 9/93	100.0	2.4	2	0.0	0.0	10.6	20.0
	7.0	9/ 9/93	117.0	2.4	3	0.0	0.0	10.6	20.0
	8.0	9/ 9/93	100.0	1.8	2	0.0	0.0	8.9	17.8
	9.0	9/ 9/93	100.0	1.8	1	0.0	0.0	8.9	17.8
	10.0	9/ 9/93	100.0	1.5	2	0.0	0.0	8.9	16.1
	11.0	9/10/93	128.0	1.7	2	0.0	0.0	8.3	10.0
	12.0	9/10/93	107.0	1.7	2	0.0	0.0	8.3	10.0
	13.0	9/10/93	98.0	1.7	1	0.0	0.0	8.3	10.0
	14.0	9/10/93	102.0	1.7	1	0.0	0.0	8.3	10.0
	15.0	9/10/93	113.0	1.7	1	0.0	0.0	8.3	10.0
	16.0	9/10/93	113.0	1.7	1	0.0	0.0	8.3	10.0
	17.0	9/10/93	97.0	1.6	1	0.0	0.0	10.6	19.4
	18.0	9/10/93	113.0	1.6	1	0.0	0.0	10.6	19.4
	19.0	9/10/93	106.0	1.6	1	0.0	0.0	10.6	19.4
	20.0	9/10/93	124.0	1.6	1	0.0	0.0	10.6	19.4
	21.0	9/10/93	108.0	1.6	1	0.0	0.0	10.6	19.4
	22.0	9/10/93	100.0	1.6	1	0.0	0.0	10.6	19.4
	23.0	9/10/93	106.0	1.6	1	0.0	0.0	10.6	19.4
	24.0	9/10/93	102.0	1.6	1	0.0	0.0	10.6	19.4
	25.0	9/10/93	100.0	1.6	1	0.0	0.0	10.6	19.4
	26.0	9/10/93	100.0	1.6	1	0.0	0.0	10.6	19.4
	27.0	9/10/93	100.0	1.6	1	0.0	0.0	10.6	19.4
	28.0	9/10/93	100.0	1.6	1	0.0	0.0	10.6	19.4
	29.0	9/10/93	20.0	1.6	1	0.0	0.0	10.6	19.4
	1.0	10/28/9	130.0	2.0	1	0.0	0.0	5.0	-0.6
	18.0	10/28/9	8.0	2.0	1	0.0	0.0	5.0	-0.6
	2.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	3.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	4.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	5.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	6.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	7.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	8.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	9.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	10.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	1.7
	11.0	10/28/9	100.0	2.0	1	0.0	0.0	5.0	0.0
	1.0	6/20/94	134.0	0.0	1	0.0	0.0	11.1	23.9
	1.0	7/11/94	130.0	0.0	1	0.0	0.0	0.0	0.0
	2.0	7/11/94	249.0	0.0	2	0.0	0.0	12.2	0.0
	4.0	7/11/94	210.0	0.0	2	0.0	0.0	12.2	26.7
	6.0	7/11/94	175.0	0.0	2	0.0	0.0	12.2	26.7
	8.0	7/11/94	200.0	0.0	2	649.0	8.2	10.2	26.7
	0.5	7/11/94	100.0	0.0	1	0.0	0.0	0.0	0.0
	0.1	9/13/94	85.0	1.5	1	0.0	0.0	11.1	21.1
	0.2	9/13/94	58.0	1.5	1	0.0	0.0	11.1	23.9
	0.3	9/13/94	43.0	1.5	1	0.0	0.0	11.1	23.9
	0.4	9/13/94	65.0	1.5	1	0.0	0.0	11.1	23.9
	0.5	9/13/94	115.0	1.0	1	0.0	0.0	13.3	22.2
	1.0	9/20/95	175.0	1.5	1	0.0	0.0	0.0	0.0
	2.0	9/20/95	100.0	1.5	2	0.0	0.0	0.0	0.0
	3.0	9/20/95	100.0	1.5	2	0.0	0.0	0.0	0.0
	4.0	9/20/95	100.0	1.5	2	0.0	0.0	0.0	0.0

Appendix B. Characteristics of sample sections.

DRAINAGE STREAM	Section	Sample date	Section length (m)	Width (m)	Estimator	Conductivity (umhos)	pH	Temperature (C) Water	Air
	5.0	9/20/95	100.0	1.5	3	0.0	0.0	0.0	0.0
	6.0	9/20/95	100.0	1.5	2	0.0	0.0	0.0	0.0
	7.0	9/20/95	117.0	1.5	3	0.0	0.0	0.0	0.0
	8.0	9/21/95	100.0	1.5	2	0.0	0.0	4.4	0.0
	9.0	9/21/95	100.0	1.5	1	0.0	0.0	4.4	0.0
	10.0	9/21/95	100.0	1.5	1	0.0	0.0	4.4	0.0
	11.0	9/21/95	100.0	1.5	1	0.0	0.0	4.4	0.0
	12.0	9/21/95	100.0	1.5	1	0.0	0.0	4.4	0.0
	0.9	10/27/9	800.0	2.0		0.0	0.0	0.0	0.0
	0.7	10/ 9/9	382.0	2.0	2	0.0	0.0	0.0	0.0
	0.7	10/13/9	60.0	2.0	1	0.0	0.0	0.0	0.0
	0.8	9/21/95	330.0	2.0	1	0.0	0.0	0.0	0.0
	0.7	9/21/95	60.0	2.0	1	0.0	0.0	0.0	0.0
	0.9	9/21/95	800.0	2.0	1	0.0	0.0	0.0	0.0
	8.0	9/12/96	100.0	3.3	2	638.0	0.0	9.5	0.0
	6.0	9/12/96	146.5	3.3	2	638.0	0.0	9.8	0.0
	2.0	9/12/96	105.0	2.4	2	670.0	0.0	8.8	15.1
	0.7	10/22/9	500.0	3.0	1	0.0	0.0	0.0	0.0
	0.8	10/22/9	200.0	3.0	1	0.0	0.0	0.0	0.0

Appendix C

Estimated populations of westslope cutthroat trout and brook trout in 76 permanent sample sections from 1992 to 1995

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
DRAINAGE:CABIN											
M FK CABIN CREEK											
	1.00	7/20/94	2	0	0	22 (1)	7 (1)	130.1	0 (0)	0 (0)	0.0
	3.00	7/19/94	2	0	0	16 (1)	24 (1)	163.5	0 (0)	0 (0)	0.0
	2.00	7/19/94	2	0	0	26 (1)	17 (1)	154.8	0 (0)	0 (0)	0.0
	4.00	7/19/94	2	0	0	13 (0)	9 (1)	145.0	0 (0)	0 (0)	0.0
	5.00	7/18/94	2	1	0	6 (0)	15 (1)	162.8	0 (0)	0 (0)	0.0
	5.00	7/31/95	3	0	0	4 (0)	18 (1)	172.4	0 (0)	0 (0)	0.0
	6.00	7/31/95	2	2	0	1 (0)	3 (0)	121.9	0 (0)	0 (0)	0.0
	2.00	8/ 1/95	2	1	0	7 (0)	11 (0)	152.1	0 (0)	0 (0)	0.0
	1.00	8/ 1/95	3	4	0	7 (0)	14 (1)	147.3	0 (0)	0 (0)	0.0
	3.00	8/ 1/95	2	3	0	10 (0)	24 (0)	152.3	0 (0)	0 (0)	0.0
	4.00	7/31/95	2	0	0	15 (0)	12 (1)	144.8	0 (0)	0 (0)	0.0
S TRIB TO M FK CABIN C											
	1.00	7/19/94	2	0	0	10 (1)	10 (0)	139.6	0 (0)	0 (0)	0.0
	1.00	7/31/95	2	0	0	1 (0)	3 (1)	162.3	0 (0)	0 (0)	0.0
DRAINAGE:COLL											
COLLAR GULCH											
	3.00	6/28/93	P	0	0	1 (0)	10 (1)	174.1	0 (0)	0 (0)	0.0
	6.00	7/12/93	2	0	0	2 (0)	11 (1)	171.8	0 (0)	0 (0)	0.0
	11.00	7/13/93	2	0	0	8 (1)	8 (0)	154.9	0 (0)	0 (0)	0.0
	15.00	7/14/93	2	0	0	30 (3)	7 (1)	129.2	0 (0)	0 (0)	0.0
	3.00	7/12/94	2	28	0	49	6	85.7	0	0	0.0

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(3)	(1)		(0)	(0)	
	6.00	7/14/94	2	2	0	5 (1)	10 (0)	145.8	0 (0)	0 (0)	0.0
	7.00	7/13/94	2	2	0	3 (1)	11 (1)	154.5	0 (0)	0 (0)	0.0
	11.00	7/13/94	2	6	0	5 (1)	26 (1)	153.8	0 (0)	0 (0)	0.0
	15.00	7/13/94	2	6	0	34 (2)	17 (1)	126.1	0 (0)	0 (0)	0.0
	15.00	7/12/95	2	11	0	24 (0)	4 (0)	95.3	0 (0)	0 (0)	0.0
	11.00	7/12/95	2	7	0	30 (5)	2 (0)	94.5	0 (0)	0 (0)	0.0
	6.00	7/13/95	2	0	0	30 (3)	3 (0)	98.8	0 (0)	0 (0)	0.0
	3.00	7/13/95	3	6	0	50 (2)	0 (0)	93.7	0 (0)	0 (0)	0.0
DRAINAGE:COTTR GEYSER CREEK											
	2.00	7/27/93	2	5	0	28 (5)	5 (0)	111.4	0 (0)	0 (0)	0.0
	7.00	7/26/93	2	1	0	15 (1)	17 (1)	149.4	0 (0)	0 (0)	0.0
	9.00	7/27/93	2	0	0	8 (11)	10 (1)	160.4	0 (0)	0 (0)	0.0
	11.00	7/27/93	2	3	0	1 (0)	8 (0)	150.0	0 (0)	0 (0)	0.0
	2.00	7/27/94	2	7	0	19 (7)	6 (0)	107.4	0 (0)	0 (0)	0.0
	7.00	7/27/94	3	2	0	37 (6)	41 (5)	147.8	0 (0)	0 (0)	0.0
	9.00	7/27/94	2	0	0	17 (1)	16 (1)	151.1	0 (0)	0 (0)	0.0
	11.00	7/27/94	2	0	0	4 (1)	1 (0)	121.2	0 (0)	0 (0)	0.0
	2.00	7/17/95	2	3	0	28 (2)	9 (0)	121.7	0 (0)	0 (0)	0.0
	7.00	7/19/95	2	2	0	21 (1)	14 (0)	139.2	0 (0)	0 (0)	0.0
	9.00	7/21/95	2	1	0	10 (0)	17 (0)	170.5	0 (0)	0 (0)	0.0

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
DRAINAGE:COTTS											
COTTONWOOD CREEK (SMIT											
	2.00	9/ 7/93	2	3	0	66 (4)	44 (3)	148.0	0 (0)	0 (0)	0.0
	2.00	5/ 6/94	2	0	0	21 (1)	32 (14)	153.4	0 (0)	0 (0)	0.0
	2.00	6/28/94	3	0	0	32 (3)	57 (2)	161.1	0 (0)	0 (0)	0.0
	2.00	6/28/95	3	0	0	19 (6)	19 (1)	160.4	0 (0)	0 (0)	0.0
	2.00	9/ 6/95	2	0	0	24 (2)	58 (0)	167.6	0 (0)	0 (0)	0.0
E FK COTTONWOOD CREEK											
	1.00	9/ 7/93	2	0	0	8 (0)	13 (0)	173.3	0 (0)	0 (0)	0.0
	1.00	5/ 6/94	2	0	0	4 (0)	18 (1)	187.0	0 (0)	0 (0)	0.0
	1.00	6/28/94	2	0	0	7 (1)	26 (1)	175.4	0 (0)	0 (0)	0.0
	1.00	6/28/95	2	0	0	1 (0)	11 (1)	176.5	0 (0)	0 (0)	0.0
	1.00	9/ 6/95	2	0	0	1 (0)	23 (1)	193.3	0 (0)	0 (0)	0.0
W FK COTTONWOOD CREEK											
	1.00	8/19/93	2	0	0	50 (3)	19 (1)	142.2	0 (0)	0 (0)	0.0
	5.00	8/19/93	2	4	0	48 (1)	39 (1)	145.8	0 (0)	0 (0)	0.0
	7.00	8/18/93	2	3	0	34 (5)	9 (0)	120.7	0 (0)	0 (0)	0.0
	9.00	8/18/93	2	5	0	20 (0)	2 (0)	101.3	0 (0)	0 (0)	0.0
	1.00	5/ 6/94	2	0	0	14 (1)	15 (1)	152.8	0 (0)	0 (0)	0.0
	5.00	6/29/94	2	0	0	35 (2)	35 (1)	153.2	0 (0)	0 (0)	0.0
	6.00	6/29/94	2	1	0	15 (0)	17 (1)	142.4	0 (0)	0 (0)	0.0
	7.00	6/29/94	2	2	0	22 (1)	2 (0)	130.9	0 (0)	0 (0)	0.0
	9.00	6/29/94	2	3	0	10	4	107.1	0	0	0.0

Appendix . Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	EBT	Estimated number (SD) of WCT by length class 75-149 mm	150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	150 + mm	Average length EBT (mm)
						(1)	(1)		(0)	(0)	
	1.00	6/29/94	2	0	0	33	61	162.6	0	0	0.0
						(2)	(1)		(0)	(0)	
	6.00	9/ 7/95	2	2	0	44	19	123.0	0	0	0.0
						(3)	(0)		(0)	(0)	
	1.00	6/28/95	2	0	0	6	22	174.8	0	0	0.0
						(1)	(1)		(0)	(0)	
	6.00	6/29/95	2	0	0	17	19	152.9	0	0	0.0
						(1)	(1)		(0)	(0)	
	7.00	6/29/95	2	0	0	17	29	159.5	0	0	0.0
						(0)	(1)		(0)	(0)	
	9.00	6/29/95	2	2	0	19	11	117.6	0	0	0.0
						(1)	(0)		(0)	(0)	
	1.00	9/ 6/95	2	2	0	12	58	172.1	0	0	0.0
						(0)	(0)		(0)	(0)	
	5.00	9/ 7/95	2	3	0	43	61	145.4	0	0	0.0
						(1)	(0)		(0)	(0)	
	7.00	9/ 7/95	2	2	0	44	10	118.8	0	0	0.0
						(2)	(0)		(0)	(0)	
	9.00	9/ 7/95	2	0	0	24	3	105.1	0	0	0.0
						(1)	(0)		(0)	(0)	
DRAINAGE:DEAD											
N FK DEADMAN CREEK											
	2.00	8/16/93	2	0	7	2	0	115.3	20	21	123.1
						(1)	(0)		(2)	(5)	
	3.00	8/16/93	2	1	8	2	0	75.0	28	7	100.9
						(1)	(0)		(2)	(0)	
	4.00	8/16/93	2	1	8	2	1	99.5	56	8	110.3
						(0)	(0)		(18)	(0)	
	5.00	8/17/93	2	0	2	1	1	129.3	17	8	104.8
						(1)	(0)		(4)	(1)	
	2.00	8/24/94	2	0	10	3	0	120.3	27	25	127.0
						(0)	(0)		(1)	(0)	
	4.00	8/25/94	2	0	10	5	0	118.0	38	16	116.1
						(1)	(0)		(3)	(0)	
	3.00	8/25/94	2	0	17	0	0	0.0	29	7	92.9
						(0)	(0)		(5)	(0)	
	1.00	9/ 8/95	2	0	4	1	2	169.7	13	7	120.9
						(0)	(0)		(1)	(1)	
	2.00	9/ 8/95	2	0	5	2	1	144.3	12	14	128.6
						(0)	(0)		(1)	(1)	
	3.00	9/ 8/95	2	0	6	0	0	0.0	11	5	101.1

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(0)	(0)		(0)	(0)	
	4.00	9/ 8/95	2	0	28	2 (0)	1 (0)	116.3	28 (3)	6 (1)	82.2
	5.00	9/ 8/95	2	0	5	1 (0)	0 (0)	102.0	20 (1)	3 (0)	104.7
DRAINAGE:DOUG											
N FK DOUGLAS CREEK											
	3.00	8/ 9/93	2	3	0	20 (1)	0 (0)	92.1	0 (0)	0 (0)	0.0
	7.00	8/10/93	2	0	0	20 (1)	0 (0)	93.6	0 (0)	0 (0)	0.0
	10.00	8/ 9/93	2	7	0	24 (1)	1 (0)	98.8	0 (0)	0 (0)	0.0
	17.00	8/10/93	2	0	0	5 (0)	3 (0)	136.8	0 (0)	0 (0)	0.0
	20.00	8/10/93	3	0	0	5 (0)	3 (0)	139.7	0 (0)	0 (0)	0.0
	3.00	8/17/94	2	9	0	39 (3)	1 (0)	99.2	0 (0)	0 (0)	0.0
	7.00	8/17/94	2	4	0	15 (1)	4 (1)	113.2	0 (0)	0 (0)	0.0
	10.00	8/17/94	2	3	0	22 (2)	7 (1)	120.0	0 (0)	0 (0)	0.0
	20.00	8/17/94	2	0	0	16 (1)	1 (0)	127.0	0 (0)	0 (0)	0.0
	3.00	8/ 7/95	2	11	0	24 (1)	0 (0)	90.9	0 (0)	0 (0)	0.0
	7.00	8/ 7/95	2	3	0	14 (1)	4 (0)	111.3	0 (0)	0 (0)	0.0
	10.00	8/ 9/95	3	1	0	15 (1)	8 (1)	131.6	0 (0)	0 (0)	0.0
DRAINAGE:GOLD											
N FK GOLD CREEK											
	3.00	8/12/93	2	3	0	37 (6)	4 (0)	109.8	0 (0)	0 (0)	0.0
	7.00	8/11/93	2	11	0	15 (1)	3 (0)	95.2	0 (0)	0 (0)	0.0
	10.00	8/11/93	2	0	0	3 (0)	1 (0)	123.0	0 (0)	0 (0)	0.0
	3.00	8/16/94	2	6	0	31	9	123.0	0	0	0.0

[illegible] the first electrofishing pass, estimate
westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio
parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(1)	(0)		(0)	(0)	
	4.50	8/18/94	2	13	0	37	5	104.6	0	0	0.0
						(1)	(0)		(0)	(0)	
	7.00	8/18/94	2	13	0	24	5	98.5	0	0	0.0
						(2)	(1)		(0)	(0)	
	3.00	8/ 8/95	2	5	0	22	2	107.7	0	0	0.0
						(1)	(1)		(0)	(0)	
	4.50	8/ 8/95	3	6	0	35	3	99.6	0	0	0.0
						(2)	(0)		(0)	(0)	
	7.00	8/ 8/95	2	5	0	21	1	100.3	0	0	0.0
						(1)	(0)		(0)	(0)	
DRAINAGE HALFM											
HALF MOON CREEK											
	4.90	8/10/94	2	0	0	16	19	154.9	0	0	0.0
						(1)	(0)		(0)	(0)	
	5.60	8/10/94	2	0	0	30	14	139.8	0	0	0.0
						(3)	(0)		(0)	(0)	
	5.80	8/10/94	2	0	0	13	58	170.4	0	0	0.0
						(3)	(2)		(0)	(0)	
	1.50	8/12/94	2	0	0	12	9	155.0	0	0	0.0
						(0)	(0)		(0)	(0)	
	2.50	8/11/94	3	0	0	17	11	140.9	0	0	0.0
						(1)	(1)		(0)	(0)	
	4.50	8/11/94	2	0	0	5	14	167.1	0	0	0.0
						(1)	(2)		(0)	(0)	
	7.50	8/10/94	2	4	0	18	7	130.8	0	0	0.0
						(1)	(0)		(0)	(0)	
	9.00	8/11/94	2	0	0	16	17	154.1	0	0	0.0
						(0)	(0)		(0)	(0)	
	10.00	8/11/94	2	0	0	12	22	167.0	0	0	0.0
						(0)	(2)		(0)	(0)	
	2.50	8/16/95	2	0	0	16	16	149.7	0	0	0.0
						(1)	(0)		(0)	(0)	
	1.50	8/16/95	2	0	0	9	15	156.3	0	0	0.0
						(0)	(0)		(0)	(0)	
	4.50	8/14/95	2	0	0	2	12	185.5	0	0	0.0
						(1)	(0)		(0)	(0)	
	4.90	8/14/95	2	3	0	14	22	138.7	0	0	0.0
						(0)	(1)		(0)	(0)	
	5.60	8/15/95	2	1	0	17	28	152.1	0	0	0.0
						(1)	(1)		(0)	(0)	
	5.80	8/15/95	3	0	0	6	45	178.0	0	0	0.0

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
					(1)	(2)		(0)	(0)	
7.50	8/15/95	2	1	0	11	17	158.6	0	0	0.0
					(0)	(1)		(0)	(0)	
9.00	8/15/95	2	1	0	6	22	171.3	0	0	0.0
					(1)	(0)		(0)	(0)	
10.00	8/15/95	2	1	0	5	18	167.0	0	0	0.0
					(1)	(0)		(0)	(0)	
DRAINAGE:HALFW										
HALFWAY CREEK										
1.00	8/ 3/93	2	16	0	56	4	99.3	0	0	0.0
					(3)	(0)		(0)	(0)	
3.00	8/ 3/93	2	6	0	43	2	102.1	0	0	0.0
					(2)	(0)		(0)	(0)	
11.00	8/ 2/93	3	4	0	16	9	98.6	0	0	0.0
					(3)	(1)		(0)	(0)	
13.00	8/ 4/93	2	0	0	13	3	131.3	0	0	0.0
					(0)	(1)		(0)	(0)	
14.00	8/ 4/93	2	16	0	28	0	75.9	0	0	0.0
					(14)	(0)		(0)	(0)	
1.00	8/ 2/94	2	12	0	38	0	87.7	0	0	0.0
					(4)	(0)		(0)	(0)	
3.00	8/ 2/94	2	12	0	34	1	87.7	0	0	0.0
					(0)	(0)		(0)	(0)	
11.00	8/ 3/94	2	2	0	91	9	104.3	0	0	0.0
					(6)	(0)		(0)	(0)	
13.00	8/ 3/94	3	0	0	14	8	126.2	0	0	0.0
					(2)	(6)		(0)	(0)	
14.00	8/ 2/94	2	9	0	6	0	72.1	0	0	0.0
					(1)	(0)		(0)	(0)	
0.50	9/ 8/94	2	15	0	37	1	85.8	0	0	0.0
					(2)	(0)		(0)	(0)	
0.80	9/ 8/94	2	9	0	54	1	98.0	0	0	0.0
					(3)	(0)		(0)	(0)	
1.00	7/25/95	2	9	0	40	0	88.2	0	0	0.0
					(2)	(0)		(0)	(0)	
3.00	7/24/95	2	8	0	15	0	86.5	0	0	0.0
					(2)	(0)		(0)	(0)	
11.00	7/26/95	2	13	0	81	8	99.2	0	0	0.0
					(3)	(0)		(0)	(0)	
13.00	7/26/95	2	0	0	10	3	135.3	0	0	0.0
					(1)	(0)		(0)	(0)	
14.00	7/26/95	2	6	0	10	1	90.9	0	0	0.0

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, e... westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with ...dard de... (in parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(0)	(0)		(0)	(0)	
DRAINAGE:JERR											
DELANO CREEK											
	2.00	8/24/93	2	0	0	20 (1)	3 (1)	106.4	0 (0)	0 (0)	0.0
	5.00	8/24/93	2	1	0	81 (7)	8 (1)	117.0	0 (0)	0 (0)	0.0
	8.00	8/24/93	2	0	0	20 (0)	0 (0)	108.4	0 (0)	0 (0)	0.0
	5.00	8/30/94	3	1	0	90 (3)	9 (0)	118.0	0 (0)	1 (0)	170.0
	2.00	8/29/95	2	12	0	32 (1)	3 (0)	90.4	3 (0)	0 (0)	119.0
	5.00	8/29/95	2	1	0	72 (2)	4 (0)	118.5	4 (0)	5 (0)	153.4
	8.00	8/29/95	2	0	0	7 (0)	4 (0)	140.0	0 (0)	0 (0)	0.0
JERRY CREEK											
	3.00	8/23/93	2	5	4	61 (5)	10 (0)	114.3	14 (1)	2 (0)	106.2
	5.00	8/23/93	2	15	1	80 (3)	8 (1)	100.1	24 (6)	1 (0)	97.7
	3.00	8/30/95	2	30	0	83 (2)	10 (0)	94.9	8 (0)	7 (0)	142.7
	5.00	8/30/95	3	20	0	95 (2)	12 (1)	107.0	13 (0)	1 (0)	129.4
DRAINAGE:JERRY											
DELANO CREEK											
	8.00	8/31/94	2	0	0	9 (0)	0 (0)	124.3	0 (0)	0 (0)	0.0
	2.00	8/31/94	2	16	0	30 (0)	1 (0)	89.0	0 (0)	1 (0)	167.0
JERRY CREEK											
	5.00	8/30/94	2	5	0	12 (5)	19 (1)	112.6	16 (1)	1 (0)	130.9
	3.00	8/31/94	2	13	0	45 (3)	2 (0)	87.1	9 (0)	1 (0)	125.3

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
DRAINAGE:LICK										
LICK CREEK										
1.00	6/26/95	2	6	0	7 (0)	5 (0)	103.2	1 (0)	0 (0)	143.0
DRAINAGE:MCVEY										
MCVEY CREEK										
2.00	8/31/93	3	0	93	0 (0)	0 (0)	0.0	69 (3)	19 (0)	104.0
3.00	8/25/93	2	1	20	2 (1)	4 (0)	155.7	73 (2)	21 (0)	103.0
4.00	8/25/93	2	0	17	4 (1)	1 (0)	136.0	59 (4)	13 (1)	95.0
5.00	8/25/93	2	0	11	0 (0)	0 (0)	143.0	63 (5)	13 (0)	100.7
6.00	8/25/93	2	0	17	3 (1)	0 (0)	90.5	50 (5)	8 (0)	87.5
7.00	8/25/93	2	2	17	0 (0)	0 (0)	110.8	0 (0)	8 (1)	87.9
8.00	8/26/93	2	4	8	6 (1)	0 (0)	87.6	40 (3)	8 (0)	100.2
9.00	8/26/93	2	3	0	9 (1)	0 (0)	81.9	33 (32)	4 (1)	110.0
10.00	8/25/93	2	13	0	9 (1)	2 (1)	89.8	62 (5)	5 (0)	102.8
11.00	8/26/93	2	5	0	8 (3)	0 (0)	89.8	40 (2)	9 (0)	109.8
12.00	8/26/93	2	3	9	6 (0)	0 (0)	86.3	84 (15)	8 (1)	97.1
13.00	8/26/93	2	10	13	6 (1)	3 (1)	98.3	67 (3)	3 (0)	86.4
14.00	8/26/93	2	7	0	11 (5)	3 (1)	96.4	49 (3)	9 (1)	107.5
15.00	7/ 1/93	2	0	1	6 (1)	1 (0)	113.9	4 (1)	0 (0)	87.2
15.00	8/26/93	2	5	0	8 (1)	2 (0)	94.2	12 (1)	5 (1)	125.2
16.00	8/26/93	3	2	0	13 (2)	1 (0)	86.1	13 (13)	5 (0)	130.5
17.00	8/26/93	2	12	0	11 (0)	0 (0)	79.1	6 (1)	4 (0)	127.5
18.00	8/26/93	2	1	0	3	0	85.8	1	0	94.0

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(0)	(0)		(0)	(0)	
	3.00	8/28/95	2	0	1	8	4	144.3	14	40	123.0
						(0)	(1)		(6)	(0)	
	4.00	8/28/95	2	0	2	0	2	160.0	52	11	118.2
						(0)	(0)		(1)	(1)	
	10.00	8/28/95	2	0	0	7	1	127.5	9	8	154.6
						(0)	(0)		(0)	(0)	
DRAINAGE:MUSKR											
MUSKRAT CREEK	7.00	8/ 5/93	2	0	10	4	2	135.7	10	13	107.5
						(1)	(0)		(24)	(3)	
	8.00	8/ 5/93	2	0	0	0	0	0.0	21	3	107.5
						(0)	(0)		(2)	(1)	
DRAINAGE:SOAP											
SOAP CREEK	4.00	7/29/93	2	3	0	23	6	124.4	0	0	0.0
						(1)	(0)		(0)	(0)	
	7.00	7/28/93	2	8	0	53	7	110.2	0	0	0.0
						(7)	(1)		(0)	(0)	
	10.00	7/29/93	3	0	0	26	10	127.6	0	0	0.0
						(2)	(0)		(0)	(0)	
	7.00	7/26/94	2	7	0	26	8	104.7	0	0	0.0
						(1)	(0)		(0)	(0)	
	4.00	7/26/94	2	3	0	11	4	107.6	0	0	0.0
						(0)	(1)		(0)	(0)	
	10.00	7/26/94	2	0	0	10	2	128.9	0	0	0.0
						(1)	(0)		(0)	(0)	
	2.50	7/28/94	2	1	0	10	3	101.2	0	0	0.0
						(1)	(1)		(0)	(0)	
	2.50	7/20/95	2	1	0	21	7	133.0	0	0	0.0
						(1)	(4)		(0)	(0)	
	4.00	7/20/95	2	6	0	20	0	104.4	0	0	0.0
						(1)	(0)		(0)	(0)	
	7.00	7/20/95	2	11	0	11	3	100.0	0	0	0.0
						(0)	(1)		(0)	(0)	
	10.00	7/20/95	3	0	0	5	6	143.3	0	0	0.0
						(1)	(1)		(0)	(0)	

DRAINAGE:STONE

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DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
LEFT FK STONE CREEK											
	1.00	7/ 7/95	2	0	0	3 (1)	4 (0)	163.6	0 (0)	0 (0)	0.0
	1.00	7/ 5/94	P	1	0	31 (6)	54 (1)	167.9	0 (0)	0 (0)	0.0
M FK STONE CREEK											
	1.00	7/ 5/94	2	1	0	2 (0)	15 (1)	214.7	0 (0)	0 (0)	0.0
	3.00	7/ 5/94	2	0	0	12 (10)	5 (1)	148.2	0 (0)	0 (0)	0.0
	2.00	7/ 5/94	2	0	0	2 (0)	4 (0)	182.0	0 (0)	0 (0)	0.0
	6.00	7/ 6/94	2	0	0	0 (0)	4 (0)	230.8	0 (0)	0 (0)	0.0
	1.00	7/ 6/95	2	0	0	2 (0)	6 (1)	214.5	0 (0)	0 (0)	0.0
	3.00	7/ 7/95	2	0	0	9 (1)	12 (0)	155.1	0 (0)	0 (0)	0.0
DRAINAGE:TEND											
SUN CREEK											
	1.00	8/31/93	2	0	7	0 (0)	0 (0)	0.0	40 (8)	5 (1)	106.9
	1.00	8/19/92	3	0	2	0 (0)	0 (0)	0.0	30 (3)	3 (0)	106.4
	1.00	8/22/94	4	0	1	0 (0)	0 (0)	0.0	55 (4)	1 (0)	104.6
	1.00	8/21/95	2	0	7	0 (0)	0 (0)	0.0	29 (1)	5 (1)	110.3
TENDERFOOT CREEK											
	15.00	8/30/93	2	0	0	0 (0)	2 (1)	151.3	0 (0)	6 (1)	155.6
	18.00	8/31/93	4	0	1	0 (0)	0 (0)	0.0	42 (3)	13 (0)	123.3
	3.00	8/18/92	2	1	2	12 (3)	15 (0)	155.1	13 (1)	23 (1)	156.5
	12.00	8/18/92	2	0	0	4 (1)	5 (0)	173.1	2 (0)	19 (1)	184.1
	14.00	8/19/92	2	0	0	0 (0)	5 (1)	198.0	5 (0)	28 (0)	179.4
	15.00	8/20/92	2	0	0	2	5	172.2	5	2	136.0

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DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1 WCT	Number < 75 mm captured pass 1 EBT	Estimated number (SD) of WCT by length class 75-149 mm	Estimated number (SD) of WCT by length class 150 + mm	Average length WCT (mm)	Estimated number (SD) of EBT by length class 75-149 mm	Estimated number (SD) of EBT by length class 150 + mm	Average length EBT (mm)
						(1)	(0)		(1)	(0)	
	18.00	8/20/92	2	0	2	0	0	0.0	53	3	101.8
						(0)	(0)		(3)	(0)	
	18.00	8/22/94	2	0	4	0	0	0.0	40	6	110.8
						(0)	(0)		(3)	(0)	
	15.00	8/23/94	2	0	3	0	3	173.7	4	9	147.4
						(0)	(0)		(0)	(0)	
	14.00	8/23/94	2	0	4	1	4	186.4	6	17	154.0
						(0)	(0)		(0)	(0)	
	12.00	8/23/94	2	0	0	1	6	184.6	13	14	154.4
						(0)	(1)		(3)	(0)	
	3.00	8/24/94	2	0	6	9	15	161.7	23	22	146.1
						(1)	(1)		(3)	(1)	
	0.10	9/16/94	2	2	8	28	34	153.2	10	11	136.2
						(2)	(0)		(0)	(0)	
	3.00	8/22/95	2	1	8	2	9	181.5	13	27	141.4
						(0)	(0)		(1)	(1)	
	12.00	8/22/95	3	0	6	0	3	190.3	11	18	126.4
						(0)	(0)		(2)	(1)	
	14.00	8/22/95	2	0	0	1	3	187.8	21	9	127.5
						(0)	(0)		(1)	(0)	
	18.00	8/22/95	2	0	9	0	0	0.0	37	8	101.1
						(0)	(0)		(1)	(1)	
	15.00	8/21/95	2	0	0	0	1	180.0	4	9	169.3
						(0)	(0)		(1)	(0)	
DRAINAGE WHITE											
WHITE'S GULCH											
	2.00	7/ 6/93	3	0	0	2	2	85.2	8	1	139.6
						(0)	(0)		(18)	(0)	
	2.00	9/ 9/93	2	1	0	5	0	87.7	0	8	191.1
						(1)	(0)		(0)	(0)	
	3.00	9/ 9/93	2	0	0	8	0	96.4	3	5	180.5
						(0)	(0)		(0)	(0)	
	4.00	9/ 9/93	2	0	0	3	5	149.4	2	8	177.2
						(1)	(0)		(0)	(0)	
	5.00	9/ 9/93	2	0	0	1	1	123.0	2	4	164.5
						(0)	(0)		(0)	(0)	
	6.00	9/ 9/93	2	0	0	0	8	191.8	2	9	171.0
						(0)	(0)		(0)	(1)	
	7.00	9/ 9/93	3	0	0	0	6	184.1	3	15	168.6
						(0)	(1)		(1)	(1)	
	8.00	9/ 9/93	2	0	0	0	8	182.1	2	23	180.5

Appendix C. Number of westslope cutthroat trout (WCT and brook trout (EBT) captured on the first electrofishing pass, estimate westslope (WCT) and brook trout (EBT) by 75-149 mm and 150 mm and longer size classes along with standard deviatio parentheses), and average length of captured WCT and EBT by section and date.

DRAINAGE STREAM	Section	Date	Estimator	Number < 75 mm captured pass 1		Estimated number (SD) of WCT by length class		Average length WCT (mm)	Estimated number (SD) of EBT by length class		Average length EBT (mm)
				WCT	EBT	75-149 mm	150 + mm		75-149 mm	150 + mm	
						(0)	(1)		(0)	(1)	
	10.00	9/ 9/93	2	0	0	0	2	178.5	0	0	0.0
						(0)	(0)		(0)	(0)	
	11.00	9/10/93	2	0	0	3	0	111.3	0	9	187.8
						(1)	(0)		(0)	(1)	
	12.00	9/10/93	2	0	0	0	0	0.0	0	5	199.6
						(0)	(0)		(0)	(0)	
	12.00	9/10/93	2	0	0	0	0	0.0	0	5	199.6
						(0)	(0)		(0)	(0)	
	2.00	7/11/94	2	0	0	9	7	157.6	1	12	162.4
						(0)	(0)		(0)	(1)	
	4.00	7/11/94	2	0	0	1	11	202.7	0	3	194.3
						(0)	(0)		(0)	(0)	
	6.00	7/11/94	2	0	3	0	13	217.8	0	1	79.7
						(0)	(1)		(0)	(0)	
	8.00	7/11/94	2	0	0	1	10	201.4	0	4	154.3
						(0)	(1)		(0)	(1)	
	2.00	9/20/95	2	2	0	6	0	83.9	0	2	158.5
						(1)	(0)		(0)	(0)	
	3.00	9/20/95	2	5	0	14	1	88.7	1	6	173.6
						(1)	(0)		(0)	(0)	
	4.00	9/20/95	2	1	0	20	5	128.0	0	4	184.0
						(1)	(0)		(0)	(1)	
	5.00	9/20/95	3	0	0	8	1	116.0	0	3	176.7
						(1)	(0)		(0)	(0)	
	6.00	9/20/95	2	0	0	8	3	133.1	0	0	0.0
						(0)	(0)		(0)	(0)	
	7.00	9/20/95	3	0	0	19	2	116.7	0	2	183.5
						(5)	(0)		(0)	(0)	
	8.00	9/21/95	2	0	0	12	2	120.7	0	4	168.3
						(0)	(0)		(0)	(1)	

Appendix D

Explanations of survey forms used to collect information for conducting BayVAM extinction risk assessments for westslope cutthroat trout in the Upper Missouri River drainage

APPENDIX D

In general, local populations are defined by watersheds or stream systems that support self-sustaining, reproductively isolated populations. In most cases, local populations will be recognized on the basis of isolation or fragmentation of suitable habitats. A score or rating was generated by the local fisheries biologist(s) at each model "node" using directions provided in this Appendix. In addition, a narrative was required to be completed at each node identifying citations of available data and other rationale used to support the score or rating given.

The following information was used to also provided at each "node":

LIFE HISTORY CHARACTERISTICS

Quantity and Distribution of Spawning Habitat

Availability of spawning habitat (quantity and distribution) may determine whether available rearing habitat is fully seeded. Three classes of availability of spawning habitat (gravels) were defined: Low (60-80%); Moderate (85-95%); and High (100%). When spawning gravels are readily available throughout the watershed, spawning habitat would not be considered limiting to the local population. In these cases the rating would be High (100%). Unless there is clear evidence that spawning habitat is likely limiting the population, the High rating should be used. Where the quantity or distribution of spawning gravels severely limits the potential for egg deposition, resulting in underseeding of rearing habitat, the user should classify spawning habitat as severely limited. For these populations spawning success would rate between 60-80% (Low). The intermediate class would include situations where spawning habitat is limited in either quantity or distribution, corresponding to spawning success of 85-95%. The user should note that resident westslope cutthroat trout populations where females mature at relatively small sizes (lengths of 150 to 200 mm) suitable spawning habitat may consist of small isolated patches (0.2 m^2) of pea-sized gravel behind water velocity breaks.

Fecundity

Higher fecundity increases reproductive potential, resulting in higher resilience to exploitation or disturbance. Low fecundity is expected for most resident westslope cutthroat trout populations where mean body size of mature females is less than 200 mm (200-500 eggs per adult female). In resident populations where mature female size consistently exceeds 200 mm, fecundity of 500-800 eggs per female would be expected. Since resident westslope cutthroat rarely exceed 300 mm in length, moderate or high fecundity rates would not be expected. Fecundity in the 800-1,100 eggs per female range, although not expected, may occur in migratory populations were mature fish exceed 300 mm in length. It is not expected that any westslope cutthroat trout within the upper Missouri system would have fecundities over 1,100. Fecundities were rated as: Low (200-500); Moderate (500-800); High (800-1,100); and Very High (1100-1500). "Very High" **should not** be used in the upper Missouri River basin analysis.

Incubation Success

Survival at this critical life stage may strongly influence the population growth rate and resilience or the ability of the population to absorb or recover from disturbance. Where incubation and survival to emergence are not reduced due to natural or human caused habitat disruption, incubation survival would be expected to be similar to survivals documented in the field within the best spawning habitats for cutthroat trout (35% to 50%). For this level to be selected: fine sediments or sediment loading should not differ from natural conditions; channel and watershed conditions should be well within sediment/discharge equilibrium; and high water quality and favorable stream flows are maintained throughout the incubation period. The ranges were: Low (5-20%); Moderate (20-35%); and High (35-50%).

"Maximum Fry Survival" (i.e. Density Independent, Early Rearing and Overwinter Survival)

The quality of initial rearing and overwinter habitats for young-of-the-year salmonids is an important determinant of population resiliency, thus influencing temporal variability in population size. High mortality (survivals rates under 20%) during this period may restrict the capability of the population to recover from disturbance. Relative survival ranges were inferred from habitat condition. Superior habitat conditions produce high survival rates (> 30%). Extensive off channel and stream margin habitats and high levels of instream cover are important for cutthroat fry. Instream cover should create low water velocity microhabitats and visually isolate fry occupying these microhabitat sites from other instream terrestrial, and avian habitats (i.e. woody debris and substrate). Unembedded, cobble substrates should be widely available for age 0 cutthroat to use during winter. Non-native fish species, especially brook trout, are believed to have an important influence on cutthroat trout and might be particularly important in disrupted habitats. Non-native fish species should not be present, or have limited potential of introduction through natural dispersal, for an estimated survival rate of >30% to be assigned.

Where early rearing habitats are not widely distributed, where wood debris or other cover is very low, and where off channel habitats are either lacking because of channel geomorphology, or seriously degraded because of channel instability, maximum fry survival should be rated under 20%. Moderately to highly embedded substrates where alternative cover is lacking also suggest a low survival. In addition, low survival would be consistent where one or more species of non-native occur within the watershed and either are, or could be, widely distributed throughout. The influence of non-native fish species could be considered moderate only if it can be shown that the influence of that non-native species has little impact on cutthroat trout. The ranges for the classes are: 10-20% (Low); 20-30% (Moderate); and 30-40% (High).

"Fry Capacity"- Habitat Capacity for Early Rearing

The availability of habitat critical to early rearing and overwinter survival can limit the ultimate size of a population. Habitats capable of supporting more than 7,000 age 1 cutthroat trout would indicate that juvenile rearing habitat is widely distributed throughout the watershed, particularly in relation to spawning sites. For this habitat capacity to be selected, no non-native trout species would occupy, or have easy access to, the portion of habitat where this level of age 1 fish could be supported, and the length of stream occupied by cutthroat trout should be at least 4 km. Low habitat capacity would indicate watersheds where juvenile rearing habitat is in short supply, and is not widely distributed in relation to spawning sites. A low habitat capacity would indicate the habitat is capable of supporting fewer than 4,000 age 1 fish. The presence of non-native fish species, particularly brook trout, should indicate a low fry habitat capacity. Habitats described above may be restricted in availability or in distribution such that habitat for juvenile rearing becomes limiting to the population. Fry capacity classes were: Low (1,000-4,000), Moderate (4,000-7,000); and High (7,000-20,000).

Sub-adult Survival

Sub-adult survival has an important influence on the structure of salmonid populations, influencing year-class strength and resilience. Survival from age 1 to adult may vary substantially between resident and migratory life history forms and be strongly influenced by human caused disturbance and environmental conditions. Interactions with non-native salmonids, especially brook trout, may influence sub-adult survival. Competitive for space and food, or direct mortality from predation may reduce survival of sub-adults. Sub-adult survival rates in the high range (38-50%) would generally be expected for resident populations that do not migrate out of the local watershed, and where high quality pools, complex cover, or other habitats important for rearing and overwinter are widely available. The population would be allopatric (the only fish species present) or exist within native species assemblages. Moderate sub-adult survival rates (26-38%) may occur in allopatric populations occupying degraded habitats; or in populations occupying high quality habitats if they are exposed to competition or predation influences from non-native fishes. Low survival rates (<26%) during this stage would be expected for populations in degraded habitats with limited rearing and over-wintering habitats and where non-native species are present. Low sub-adult survival would also be expected for migratory populations that must use migratory corridors and associated rearing environments (larger rivers, lakes, ocean) where human caused or natural changes (dams and diversions, introduced and or enhanced predator populations, water quality) have significantly reduced survival. The ranges for sub-adult survival are: Low (14-26%); Moderate (26-38%); and High (38-50%).

Adult Survival

A number of factors may influence adult survival (annual survival during and following the year of first maturity), but exploitation is particularly common for westslope cutthroat. For moderate or slow growing populations in unproductive waters, unrestricted fishing effort of 100 to 200 angler hours per km can result in serious over exploitation of mature fish (Rieman and Apperson 1989). The three equal classes are: Low (10-30%); Moderate (30-50%); and High (50-70%).

Age of First Maturity (age 3 to age 6)

Age of maturity, longevity, and fecundity will influence reproductive potential and the potential growth rate of a population. Recent information on westslope cutthroat populations in the Upper Missouri Basin (Downs and Shepard, in prep.) give the following proportions for age at first maturity in females:

age 3: 30%
age 4: 40%
age 5: 20%
age 6: 10%.

Unless specific data exists for the population being evaluated, it is suggested these proportions be used.

POPULATION LEVEL CHARACTERISTICS

The model provides two ways to derive local population characteristics. These characteristics can be derived using information output from the individual life stage portion of the model, or can be input by the user based on their knowledge of an individual population. The local population characteristics which the BayVAM model use are population size and resilience, temporal variability, and catastrophic risk.

Since it is possible for the equilibrium population size and population resiliency to come from two levels, the life stage or population levels, some weighting of the evidence is required. Thus, module users must state whether they wish the population-level information to be given less, equal, more, or much more weight than the life-stage information. In general, life stage information should be weighted more than population information unless time trend population data has been collected.

Initial Population Size

The size of a population influences risk of extinction through environmental variability. Although small watersheds are likely to support smaller populations than large watersheds, population size is best inferred with some basic information on fish density and distribution. Recent estimates of several isolated populations demonstrate that watersheds with only a few kilometers of available habitat can support tens to thousands of individuals. If the data necessary to extrapolate an approximation are available they should be used. Total populations that exceed 850 adults and are not expected to drop below these numbers are considered "high". Adult populations that are consistently below 450 individuals should be considered "low". When estimating adult numbers, consider all mature fish alive in a given year, not just those spawning. It should be noted that initial population size has relatively little effect on model outputs other than setting initial conditions.

Expected Population Size (high, moderate, low, zero)

The information collected at the individual life stage level collectively will predict an expected equilibrium population size. If independent data or information are available that would lead to an independent estimate of the expected number of adults to be found within the basin, this can be included in the analysis. A "high" score would correspond to an estimated adult population size of greater than 850 adults; "moderate" = 450-850 adults; "low" = less than 450. If population monitoring data exists which shows a consistent downward trend, the population is likely headed to extinction, so an equilibrium size of "zero" is appropriate.

Population Resilience (high, moderate, low, none)

Populations with negative growth rates face a "deterministic" extinction unless stabilized by compensation in survival or reproductive rates. A population may have no clear trend in abundance but its inherent resilience will still determine its ability to resist or recover from future disturbance. Both the trend and resilience of a population will be the integration of survival, age at maturity and reproductive potential. The characteristics defined under Individual Life Stages should provide the necessary evidence of resilience but often information will be limited or conflicting. Trends in populations and inferences about resilience may also be possible from information on the population as a whole that will either support or outweigh information available for individual life stages.

A "high" population resilience should show no negative trend in abundance with at least 10 years of good density or population estimates. If the population has been reduced by a short term disturbance, it is clearly recovering. Alternatively densities should be consistent with those reported for strong populations in good habitat. Local habitat quality should be high, and human disturbance or recent natural events should not have altered watershed condition or channel equilibrium. Available estimates of growth and survival should be consistent with other strong populations. If a migratory form is present, the complementary environments (e.g. larger river, lake, ocean, and migratory corridors) do not impose any unusual or increased mortality (e.g. fishing, predation, overwinter survival, smolt survival).

"Low" resilience could be evident from a slow decline in population trend information although inter-annual variability may make the trend statistically insignificant. Low resilience might be expected if habitat has been disrupted to some degree such that a significant reduction in abundance, growth, or survival of any life stage is anticipated in relation to the best habitats and likely will not recover to pre-disturbance conditions within one to two generations. Alternatively a low resilience should be characteristic of a population that appears stable at densities well below those expected for the system; or a population that has been depressed by a short term or recently eliminated disturbance (e.g. exploitation) but shows no evidence of recovery.

A "None" resilience should be concluded from any significant negative trend in number that has extended for several generations. A decline might be inferred from a substantial reduction in population size that can be associated with a continuing, irreversible (in the short term) loss of critical habitat quality or quantity.

Temporal Variability in First Year Survival or Adult Numbers (Juvenile CV and Adult CV in Model)

The most influential determinant of temporal variability in population number is believed to result from environmental variation affecting spawning success and early rearing. Variation in population size may be strongly influenced by the natural disturbance regime but also by the condition of the local habitat and distribution of the population through space. In our underlying model, temporal variability in the population results from fluctuations in juvenile survival. It is mitigated by the degree of population resilience, i.e., more resilient populations exhibit lower levels of variability in population numbers. If information is available on variation in first year survival, it can be incorporated into the analysis in the "Juvenile CV" node. In addition, we can use information on the coefficient of variation in adult numbers to infer both environmental variability and population resilience. Estimates of the coefficient of variation in either juvenile survival/abundance or in total/adult population number are best made from extended time series of population size or density. If this type of information is available, it should provide a more realistic of value the variability experienced by that population, especially if the time series of data is relatively long (ie. ten years or longer). If this data is unavailable, inferences can be made from habitat and population age structure information, however, the confidence in classes assigned from these type of data should be lower.

"Low" variability in juvenile survival could be inferred from low variability in channel events such as extreme flows, or other environmental conditions that likely influence spawning and incubation, and in systems with highly diverse, widely distributed and complex habitats available all life stages. In general, habitat complexity and spatial diversity should strongly influence temporal variability even in noisy environments. The availability of refuges and distribution of the population and critical life stages over a broader area makes the whole population less vulnerable to localized disturbance. Such complexity is characteristic of large watersheds where all resident life stages or necessary habitats (spawning, early rearing) are widely distributed throughout. Ideally multiple tributary streams would exist, each being capable of supporting all life stages should others be lost. There should be no evidence or expectation of year class failures and all age classes would be fully represented in population samples (Coefficient of Variation [CV] in fry survival less than 40%).

"High" temporal variability is expected in systems where survival and recruitment clearly respond to frequent (1 or more per generation) events. Year-class failures would be common and population samples would often show uneven distribution of age classes. High variability might be anticipated in simplified or spatially restricted habitats critical for individual life stages, and in watersheds with only a single tributary stream available for any life stage, especially where extreme flow events (rain on snow, drought) or bedload scour is common. (CV in fry survival is between 65% and 90%).

Evidence temporal variability based on time series of adult numbers can be divided into four categories based on the CV in the adult index: low = $CV < 25\%$, moderate = $25\% < CV < 50\%$, high = $50\% < CV < 100\%$, and very high = $CV > 100\%$.

Catastrophic Risk (high, moderate, low)

Catastrophic events are low frequency events that substantially affect all members of a population. Catastrophic impacts on habitat may take years to recover. Thus, populations are at risk through the event itself, but also are likely to be less resilient and thus at greater risk to some future disturbance following the event.

Massive debris flow and scour, droughts, volcanic eruptions, earthquakes, glaciers, fire storms, toxic spills, and dam failures are all examples of catastrophic events for salmonid populations. Catastrophic events are by nature unpredictable and have been rarely considered in viability assessments. Such events, however, may strongly influence the risks of extinction for many populations. The potential for a catastrophic event will be influenced by physiographic characteristics of the watershed, and by the distribution of fish, critical habitats or refuge . In some cases human disturbance or development may significantly increase the potential for catastrophe from natural extreme events. Some poorly managed watersheds, for example, may suffer catastrophic changes to stream habitats as a result of an extreme hydrologic event within a stream channel impacted by management or by debris or sediment torrents triggered by a combination of natural (climatic) and management (logging and roading) conditions.

A "high" catastrophic potential would be appropriate where a half or more of the population (50% or more) could be lost in a single event expected within 20 to 70 years. Watersheds with high risk also are prone to major channel events such as debris torrents, massive bedload scour or extensive channel dewatering, perhaps because of the combination of intensive watershed disruption and high frequency of extreme hydrologic events (rain on snow, drought). Major fires might result in catastrophic loss in portions of a watershed. Fire likely would not have a high catastrophic potential unless the population were restricted to a relatively small area (single stream), or if the fire occurred in concert with other disturbance of the watershed substantially increasing the risk of a hydrologic event.

"Moderate" catastrophic potential is likely for most watersheds exposed to some human disturbance. This level corresponds to an event expected on a frequency of 70-120 years.

"Low" catastrophic potential could be appropriate for large watersheds that essentially are not exposed to human disturbance or development, are stable geologically and hydrologically, and have populations with all life stages, range of elevations, and multiple tributary streams. Probability of a catastrophic event less than 1 in 120 years.