



Seasonal distribution and habitat use of westslope cutthroat trout in a sediment-rich basin in Montana
by Susan Comings Ireland

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management

Montana State University

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Abstract:

Several hierarchical scales were used to investigate critical habitat requirements for westslope cutthroat trout in the Taylor Fork drainage. Using a basin scale, high densities (18-33 cutthroat per 100 m²) were found in only 2 of the 10 surveyed reaches. Elevation, stream order, presence of exotic species, and proximity to spawning grounds were possible reasons for clumped distributions. On a reach scale, slow-water channel unit types (i.e. pools and glides) provided the most important habitat for cutthroat in both summer and winter. Channel unit measurements were analyzed to determine fish-habitat relationships. Using measurements from channel unit types throughout the drainage, significant correlations between cutthroat trout densities and stream-size related variables were found. Using measurements only from areas with high cutthroat densities resulted in significant correlations with habitat variables better describing fish habitat use, such as cover and mean depth. Because the drainage is naturally erosive, sedimentation and disturbance from land use practices did not appear to affect fish density or distribution. Cutthroat movement was generally limited after spawning, and during summer and winter. Upper Wapiti Creek and upper Cache Creek reaches appear to contain two distinct subpopulations of cutthroat. These reaches are important for the maintenance of viable cutthroat populations in the Taylor Fork drainage.

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TROUT IN A SEDIMENT-RICH BASIN IN MONTANA**

by

Susan Comings Ireland

**A thesis submitted in partial fulfillment
of the requirements for the degree**

of

Master of Science

in

Fish and Wildlife Management

**MONTANA STATE UNIVERSITY
Bozeman, Montana**

December 1993

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APPROVAL

of a thesis submitted by

Susan Comings Ireland

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGMENTS

I would like to extend my sincere appreciation to those who assisted me during this research effort. A special thanks to Dr. Thomas McMahon, who directed the study and offered support and encouragement from start to finish. Drs. Robert White, Robert Crabtree, and Lynn Irby reviewed the manuscript. Dr. Jack McIntyre and Russ Thurow of the Intermountain Forest Service Research Station gave funding and helpful advice throughout the study. Dr. Kathy Hansen of the Yellowstone Center for Mountain Environments provided funding for my school tuition. Trout Unlimited also helped fund my tuition by awarding me the 1992 Lee Wulff Memorial Scholarship. The staff of the Biology Department, especially Dee Topp, was helpful concerning the details of each 'hoop' necessary for the successful completion of graduate school. William Hughes gave selflessly of his time, providing assistance in many aspects of computer operation. Thanks to Mike Jones, my field technician, and to the many field volunteers, especially Jenn Staples, who was always 'ready to go'. And many thanks to my fellow graduate student Jim Magee, who was an excellent field partner, as well as a very good friend. Finally, I extend my love and gratitude to my friends and family, especially my parents and grandparents, for their continued support throughout my study.

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ABSTRACT

Several hierarchical scales were used to investigate critical habitat requirements for westslope cutthroat trout in the Taylor Fork drainage. Using a basin scale, high densities (18-33 cutthroat per 100 m²) were found in only 2 of the 10 surveyed reaches. Elevation, stream order, presence of exotic species, and proximity to spawning grounds were possible reasons for clumped distributions. On a reach scale, slow-water channel unit types (i.e. pools and glides) provided the most important habitat for cutthroat in both summer and winter. Channel unit measurements were analyzed to determine fish-habitat relationships. Using measurements from channel unit types throughout the drainage, significant correlations between cutthroat trout densities and stream-size related variables were found. Using measurements only from areas with high cutthroat densities resulted in significant correlations with habitat variables better describing fish habitat use, such as cover and mean depth. Because the drainage is naturally erosive, sedimentation and disturbance from land use practices did not appear to affect fish density or distribution. Cutthroat movement was generally limited after spawning, and during summer and winter. Upper Wapiti Creek and upper Cache Creek reaches appear to contain two distinct subpopulations of cutthroat. These reaches are important for the maintenance of viable cutthroat populations in the Taylor Fork drainage.

INTRODUCTION

Westslope cutthroat trout *Oncorhynchus clarki lewisi* have drastically declined in abundance and distribution during the last 100 years (Liknes and Graham 1988) and are listed by Montana Fish Wildlife and Parks (MFWP) as a species of special concern (Holton 1990). Protecting remaining populations of westslope cutthroat requires knowledge of their critical habitat requirements.

Critical habitats for westslope cutthroat are likely to differ over a drainage basin depending upon life stage and season. Small tributaries serve as spawning and rearing habitat for young juveniles, providing protection from high flows and bedload movement (Shepard et al. 1984; Rieman and Apperson 1989). Pools are important rearing habitat for juvenile cutthroat in summer (Shepard et al. 1984; Liknes and Graham 1988). Large, deep pools with complex cover, as well as cobble substrate are particularly important as winter habitat for juvenile and adult cutthroat. Peters (1988) found large aggregations of adult and subadult cutthroat in pools during winter. Small cutthroat (< 100 mm) have been found to move into interstitial spaces in the substrate as stream temperatures drop below 4–5° C (Bjornn et al. 1977; Liknes and Graham 1988). The availability of winter habitat may also have a strong influence on seasonal movements of westslope cutthroat. Extensive migrations of westslope cutthroat in the

fall have been observed where high quality pools were found downstream of spawning and rearing habitat (Bjornn and Liknes 1986; Liknes and Graham 1988). In contrast, Peters (1988) observed that westslope cutthroat resided the entire year in some streams where high quality pools provided both summer and winter habitat in the same stream section.

Because of their differing seasonal habitat requirements and potentially extensive seasonal movements, defining critical habitat requirements for westslope cutthroat likely requires the use of several different scales. Frissell et al. (1986) developed a hierarchical framework for stream habitat classification emphasizing a stream's relationship to its watershed across a wide range of scales in space and time, from the entire drainage basin, to reaches, channel units, and microhabitat. I investigated the hypothesis that three spatial scales (basin, reach, and channel unit) would be important for identifying critical habitats for westslope cutthroat during summer and winter. The drainage basin scale encompasses all surface waters in the watershed. Reaches are integrated geomorphic units within the basin that lie between breaks in channel slope and possess similar riparian vegetation, bank materials, and a characteristic range of substrate. The channel unit scale is a subsystem of a reach, having a characteristic pattern of flow velocities, depths, and sediment dynamics.

Westslope cutthroat populations appear to be sensitive to changes in habitat due to land use practices. Platts (1974) reported westslope cutthroat trout were common only in undisturbed reaches of streams in the Salmon River drainage of Idaho. In Idaho

and Montana, the distribution of remaining strong populations of westslope cutthroat is almost entirely within wilderness and National Parks (Liknes and Graham 1988). Natural and man-caused disturbances have resulted in substantial depositions of fine sediment and loss of bank stability in some stream channels. Bjornn et al. (1977) found carrying capacity of pools for cutthroat was negatively correlated to the degree of gravel embeddedness. Pool filling and reduction of interstitial space in the substrate that occurs with increased sedimentation may have a major impact on availability of winter habitat. The second hypothesis I tested was that fine sediment reduces habitat quality for westslope cutthroat by filling of interstitial spaces and decreasing pool depths.

The Taylor Fork basin was chosen for this study because the naturally erosive geology produces large amounts of silt-like sediment. Most previous investigations involving the effect of sediment deposition on freshwater resident trout have been conducted in the Idaho batholith region where granitic soils produce a sand-like sediment (Bjornn et al. 1977; Hillman et al. 1987). The geology of the region may influence the distribution of habitats, habitat characteristics, and susceptibility to disturbance (Benda et al. 1991).

Specific objectives for this study were to: (1) determine seasonal cutthroat distribution on a basin, reach, and channel unit scale in the Taylor Fork basin; (2) describe seasonal habitat characteristics of cutthroat trout; (3) examine effects of sedimentation on habitat use of cutthroat trout; and (4) determine seasonal movement patterns of cutthroat trout.

STUDY AREA

Located in the Gallatin National Forest, the Taylor Fork drainage in southwest Montana lies 24 km south of Big Sky near the western boundary of Yellowstone Park (Figure 1). The 160 km² basin contains approximately 100 stream kilometers and ranges in elevation from 3080 meters in the headwaters to 2032 meters at the confluence of the Taylor Fork and the Gallatin River. Major fish species in the Taylor Fork include westslope cutthroat trout, rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, mountain whitefish *Prosopium williamsoni*, and mottled sculpin *Cottus bairdi*. Hybridization has occurred between rainbow and cutthroat. Hybridization has also occurred between Yellowstone and westslope cutthroat in upper Wapiti Creek (48% Yellowstone, 52% westslope; Bruce May, Gallatin National Forest fishery biologist, personal communication). However, electrophoretic analysis indicates westslope cutthroat have remained more than 85% pure in Cache Creek, one of the highest purities remaining in the Gallatin River drainage (Liknes 1984).

Predominantly classed in the soft sedimentary rock category, the naturally unstable geologic composition in the Taylor Fork drainage is highly erosive and production of large amounts of suspended sediment is common during high flows (Snyder et al. 1978). Indeed, the Taylor Fork is widely known for its 'coloring' of the

Gallatin River many miles downstream during spring runoff and after heavy rainfall. Most of the stream channels throughout the basin were rated in "poor" condition by Snyder et al. (1978).

Channels of the lower, lower-mid, and mid Taylor Fork reaches are low gradient (1% or less) and meander or braid across an extensive floodplain (Figure 1). The upper Taylor Fork reach increases in gradient ($> 1.5\%$) and begins to enter a

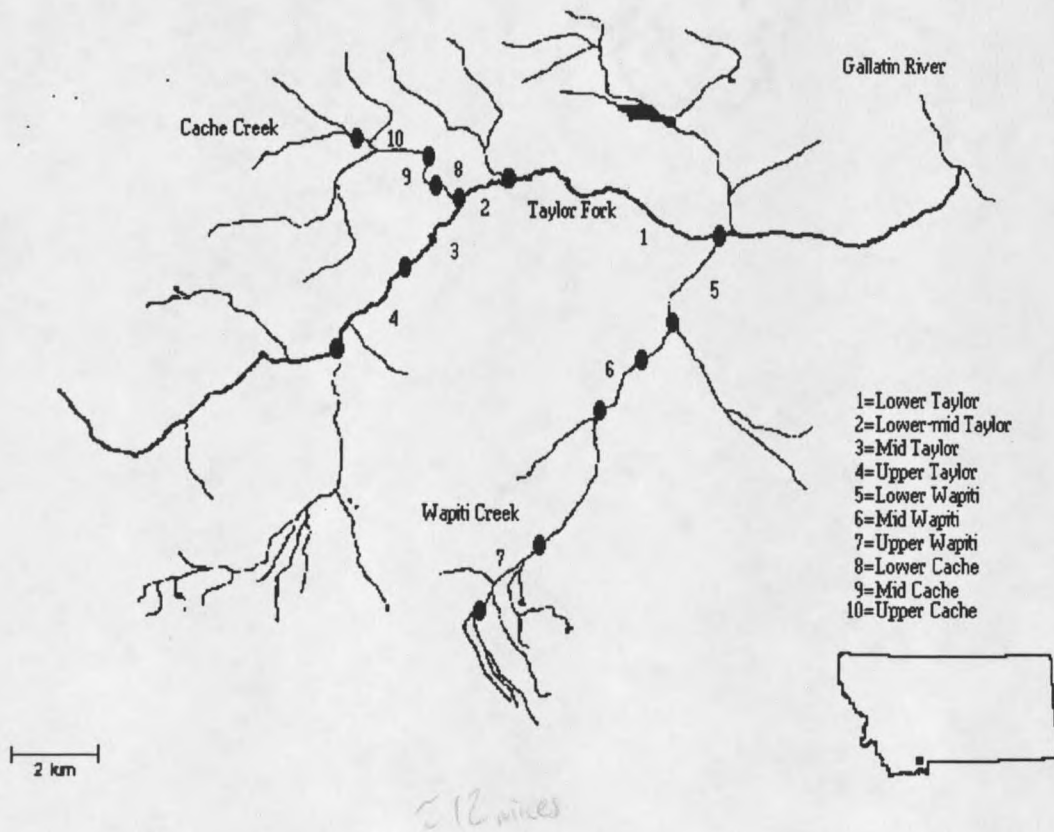


Figure 1. Map of Taylor Fork drainage and study reaches.

coniferous forest. Mid Wapiti and mid Cache Creek channels run through coniferous forest, are moderately steep ($> 2.5\%$) and are composed of coarse substrate. Their channel shape strongly reflects the presence of bedrock outcrops. The high elevation sections of the drainage, upper Wapiti and Cache Creek, meander through alpine meadows.

Land uses in the Taylor Fork drainage have varied over the years. Throughout the drainage, Forest Service land is interspersed with private land belonging to Big Sky Lumber Company and individuals, including owners of a guest ranch on the lower Taylor Fork. Timber harvest and extensive tie cutting occurred between 1868 and 1906 (Snyder et al. 1978). Extreme channel instability below an old splash dam still remains on the middle Taylor Fork today, as evidenced by shallow, braided channels. Recent clearcuts are present in upper Taylor Fork and Cache Creek. Two cattle grazing allotments (220 cow-calf pairs each) exist along Cache Creek, middle Taylor Fork and middle Wapiti Creek. Cattle are brought in to graze during the first week in July and remain in the drainage until mid October. The Taylor Fork basin is an important wintering area for elk. Other land uses include hunting, outfitting, fishing, and backpacking. Overall, upper Wapiti Creek has remained relatively undisturbed, while other parts of the basin have been heavily impacted by past land use practices (Snyder et al. 1978).

METHODS

Reach Measurements

Ten distinct reaches were designated based on differences in gradient and geomorphology and the presence of tributary junctions in order to encompass the variety of stream habitat conditions present in the basin. To help determine reach boundaries, longitudinal stream profiles were constructed to identify breaks in stream gradient (Figure 2). A 1:24,000 scale U.S. Geologic Survey topographic map was used to determine study reach elevations and stream orders (Strahler 1957). UTM coordinates for each reach are listed in Appendix A. To categorize stream channels on the basis of measurable morphological features, stream reaches were classified according to the Rosgen stream classification system (Rosgen 1985). The morphological features used for Rosgen classification include: channel gradient; sinuosity (ratio of channel length to valley length); width/depth ratio; dominant particle size; and entrenchment and confinement of channel. To quantify differences in stream temperatures between study reaches, hourly water temperatures were recorded between October 1991 and November 1992 in four locations throughout the basin using Ryan thermographs. Weekly average temperatures were obtained by summing all readings for the week and dividing by the number of readings.

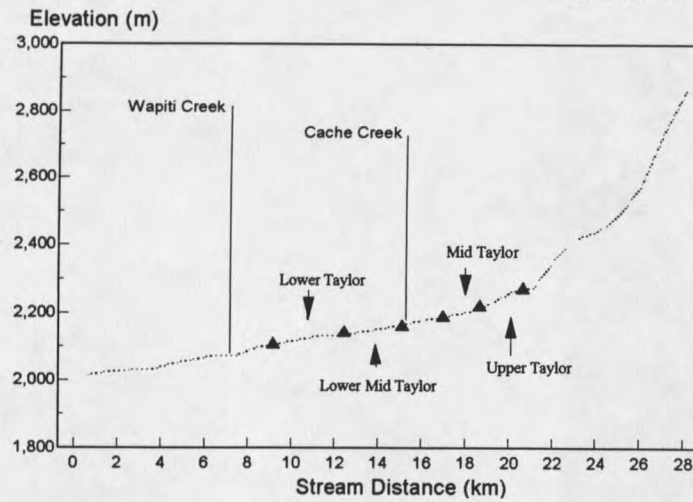
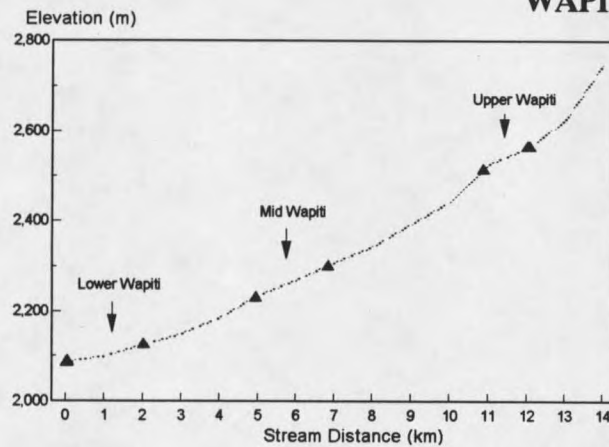
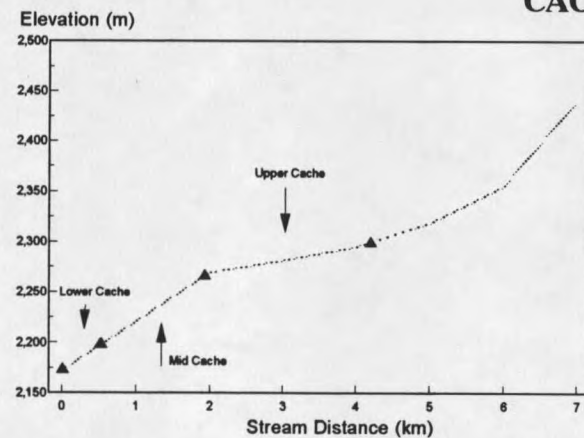
TAYLOR FORK**WAPITI CREEK****CACHE CREEK**

Figure 2. Longitudinal profiles of Taylor Fork, Wapiti Creek, and Cache Creek from mouth to headwaters (km).

Channel Unit Measurements

Nine stream reaches were surveyed during July and August 1992 using the systematic sampling approach outlined by Hankin and Reeves (1988) and following the stream habitat inventory methods developed by the U.S. Forest Service, Region 6 (Overton 1991). Channel units were classified according to Bisson et al. (1982) and modified to describe channel unit types most common in the Taylor Fork basin (Table 1). Habitat variables measured at every channel unit included: length, wetted width, and maximum depth for all pools. Length of each channel unit was measured by walking along the stream bank with a hipchain. Wetted width was measured with a meter tape perpendicular to the flow across the channel at a point representative of the average width of the unit. Maximum pool depth was measured with a meter stick at the deepest point in the pool.

Additional habitat measurements were performed at every 10th channel unit (with a random start). Measurements included channel width, mean depth, cover, pool quality, dominant substrate, embeddedness, substrate composition, percent surface fines, bank height and stability, riparian composition, and gradient. These units were marked with flagging for later fish sampling. Channel width was measured bank to bank from the point at which bankfull flow occurred. Depth was measured in three

Table 1. Classification of channel unit types used in the Taylor Fork stream habitat survey (modified from Bisson et al. 1982).

Fast-water channel unit types:

Riffle-Stream units with moderate current velocity (20-50 cm/sec) and moderate turbulence. Substrate was usually composed of gravel, pebble, and cobble-size particles (2-256 mm).

Step run - a sequence of runs separated by short riffle steps, generally found in high gradient, confined streams dominated by cobble and boulder. Distinguished from step pools by shallower depth (< 0.2 m) between riffle steps.

Step pool - a series of pools separated by short riffles, generally found in high gradient, confined streams dominated by cobble and boulder.

Slow-water channel unit types:

Glide - Stream unit possessing both attributes of riffles and pools, characterized by moderately shallow water with an even flow that lacked pronounced turbulence. Glides were most frequently located at the transition between a pool and the head of a riffle, but were also occasionally found in long, low gradient stream reaches with no major flow obstructions. Substrate was typically silt, peagravel, gravel, and cobble.

Corner pool - unit formed by flow impinging against one streambank because of sharp bend in channel, causing scouring of one bank. Corner pools are most common in low gradient meadows in streams with high sinuosity. Stream banks usually consist of alluvium and lack hard obstructions.

Mid-channel pool - large pool formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow and substrate is highly variable. Because of their low occurrence, channel confluence pools, plunge and dammed pools were also included in this category.

Lateral scour pool - pool formed by flow directed to one part of the stream by a partial channel obstruction, usually a large boulder or rootwad. Not common in the Taylor Fork drainage because of lack of large woody debris and boulders in stream.

places along a transect representing the average width of the unit. To compute mean depth, the three depth measurements were summed and divided by four to account for edge effects (Overton 1991).

For pools, cover was measured according to four categories: large substrate (> 30 cm), overhead cover (vegetation and large woody debris overhanging within 1 m of water surface), submerged cover (vegetation and large woody debris), and undercut bank (90° angle or less). Surface area measurements were recorded for each cover category. Pool quality was rated based on depth, cover, and size (Platts 1979; Table 2). Pool quality ratings ranged from 1 to 5, with a score of 5 representing highest quality.

Substrate composition was characterized using Wolman pebble counts (Wolman 1954) and percent surface fines measurements (Kramer and Swanson 1990) at riffles and pool tail-outs. Wolman pebble counts consisted of categorizing substrate particles by size via the Wentworth scale at 100 points across each site. Surface fines were measured with a 49-point grid by counting the number of intersections that had substrate < 2 mm. The grid was tossed 10 times to determine the average percent fines per site. Dominant substrate was visually estimated in all channel units using the substrate size classification modified from the Wentworth scale in Welch (1948) (Table 3). Embeddedness was visually estimated by rating the degree to which the larger particles were covered with fine sediment (Table 4). An embeddedness rating of 1 indicated the highest degree of embeddedness.

Table 2: Definition of pool quality ratings used in stream habitat survey methodology (adapted from Platts 1979).

SIZE		Rating
Pool longer or wider than mean width of stream.		3
Pool as wide or long as mean width of stream.		2
Pool shorter or narrower than mean width of stream.		1
COVER		
Abundant	> 30% of pool bottom obscured by depth, surface turbulence, or structures (LWD, boulders, vegetation).	3
Partial	10–30% of pool bottom obscured by depth, surface turbulence, or structures.	2
Exposed	< 10% of pool bottom obscured by depth, surface turbulence, or structures.	1
DEPTH		
Deepest part of pool	> 0.9 m	3
Deepest part of pool	0.6–0.9 m	2
Deepest part of pool	< 0.6 m	1

Numerical scores are summed and a rating value assigned:

Total Score	Pool Quality Rating
8 or 9	5
7	4
6	3
5	2
3 or 4	1

Table 3. Definition of substrate size classification used in stream habitat survey methodology (modified from the Wentworth Classification in Welch 1948).

Classification	Particle Diameter (mm)
Sand/silt	< 2
Peagravel	2-6
Gravel	6-7.5
Rubble	7.5-15
Cobble	15-30
Boulder	> 30
Bedrock	

Table 4. Definitions of embeddedness ratings used in stream habitat survey methodology (adapted from Platts et. al. 1983).

Rating	Description
5	Gravel, rubble, and boulder particles have < 5% of their surface covered by fine sediment.
4	Gravel, rubble, and boulder particles have 5-25% of their surfaces covered by fine sediment.
3	Gravel, rubble, and boulder particles have 25-50% of their surfaces covered by fine sediment.
2	Gravel, rubble, and boulder particles have 50-75% of their surfaces covered by fine sediment.
1	Gravel, rubble, and boulder particles have > 75% of their surfaces covered by fine sediment.

Bank height was measured from the wetted perimeter to the top of the bank. Bank stability ratings ranged from 1 to 4, with a score of 4 indicating the highest stability (Table 5). Riparian composition was classified as the percentage of bank comprised of soil/rock, grass, shrubs, sage, willow, or conifer. Gradient was measured with a hand-held clinometer.

Table 5. Definition of streambank stability ratings used in stream habitat survey methodology (adapted from Platts et. al. 1983).

Rating	Percent	Description
4 (Excellent)	75-100	> 75% of the streambank surfaces are covered by vigorous vegetation or by boulders and rubble. If not covered by vegetation the streambank is protected by materials that do not allow bank erosion.
3 (Good)	50-74	50-74% of the streambank surface are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2 (Fair)	25-49	25-49% of the streambank surfaces are covered by vegetation or gravel or larger material. Those areas not covered by vegetation are covered by materials that give limited protection.
1 (Poor)	0-24	< 25% of the streambank surfaces are covered by vegetation or gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

Habitat measurements for the tenth reach, the lower Taylor Fork (Figure 1), were based on 3–300 m long 'representative' reaches. The systematic survey approach could not be used since this reach was wide (> 10 m) and thus contained several distinct channel unit types across its width. Habitat measurements were thus conducted at every channel unit within each representative reach rather than at systematically sampled units as above.

Fish Distribution

To compare seasonal distribution and abundance of westslope cutthroat trout and other fishes across the entire basin, fish population estimates were conducted in 8 reaches in the summer (lower and lower-mid Taylor Fork; lower, mid, and upper Wapiti Creek; and lower, mid, and upper Cache Creek) and 7 reaches in the winter (lower, lower-mid, mid, and upper Taylor Fork; upper Wapiti; and lower and upper Cache Creek). Fish sampling during summer took place during low flow (31 July–07 October 1992). Winter fish sampling occurred after average daily stream temperatures had dropped below 4°C (10 October–08 November 1992; Figure 3). All streams iced over after November 8, precluding additional winter sampling.

Fish populations were sampled by electrofishing. In Wapiti Creek and Cache Creek reaches, a Coffelt-10 backpack shocker with CPS pulse was used. Because of the large size of mainstem Taylor Fork reaches, backpack shocking was ineffective.

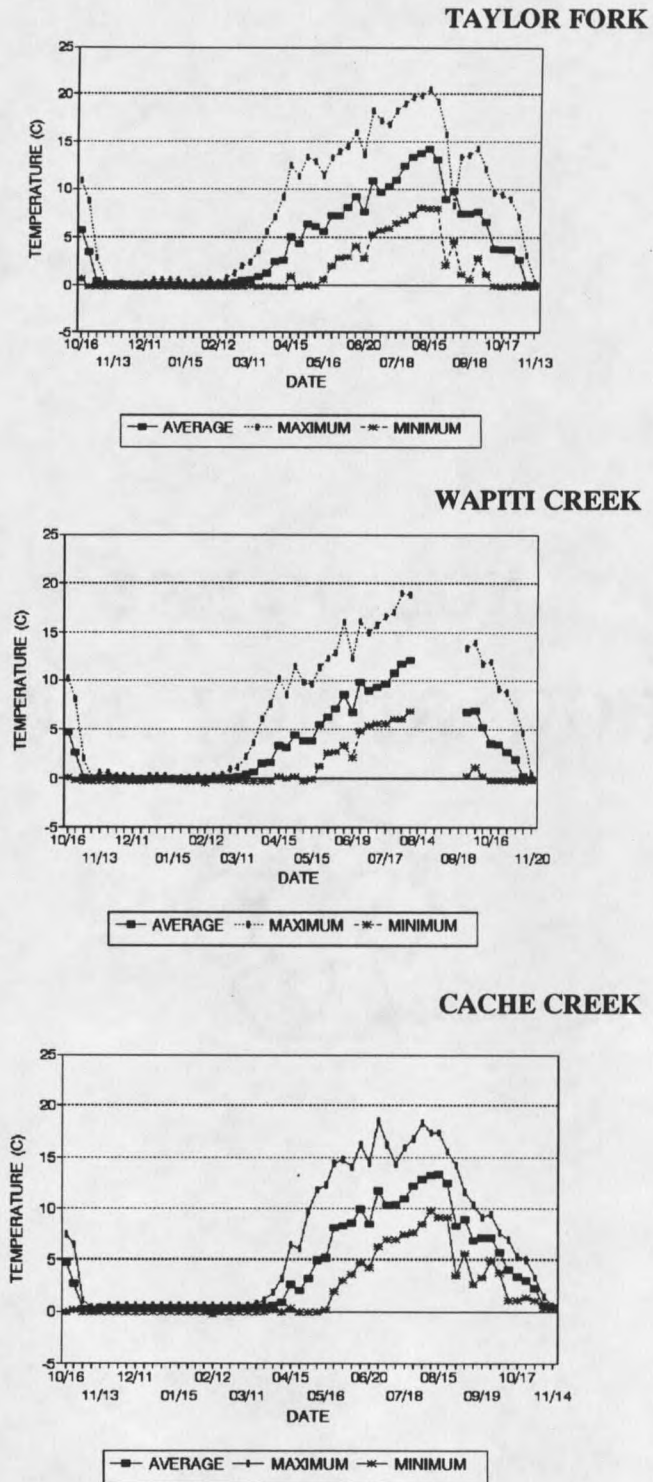


Figure 3. Mean, maximum, and minimum weekly temperatures for lower Taylor Fork, lower Wapiti Creek, and lower Cache Creek between October 1991–November 1992.

Therefore, a bank shocking unit with straight direct-current was used for fish sampling. Fish populations were sampled in channel units measured during the stream habitat inventory. Individual channel units were blocked at each end with nets, except in the lower Taylor Fork reach, where the entire 300 m representative reaches were sampled. Fish were weighed to the nearest gram and fork length was measured to the nearest millimeter. Fish > 130 mm were tagged with a visual implant tag in the adipose tissue behind the left eye. Only salmonids were netted and enumerated. Sculpins were present in all reaches except upper Wapiti and upper Cache, but were not included in fish abundance estimates.

Population estimates were obtained using a multiple depletion method (Zippin 1958) and estimates were computed using the program MICROFISH (Van Deventer and Platts 1986). Fish densities were calculated by dividing the population estimate for each channel unit or subreach by the surface area. Total number of cutthroat trout for each reach was computed by extrapolating the average density for each channel unit type to the total percentage of surface area of that channel unit type present in the reach.

Data Analysis

Differences in density by season for each channel unit type were analyzed by a Kruskal-Wallis nonparametric analysis of variance. In this analysis, I used data only from reaches containing greater than 30% of the total fish density (upper Wapiti and

upper Cache Creek). I did not include other reaches due to low occupancy of suitable habitat. Using only high density reaches for analysis enabled me to better understand cutthroat habitat use on a channel unit scale. A nonparametric multiple comparison test for unequal sample sizes was then used to determine differences in density by habitat type (Zar 1984). A Mann-Whitney test was used to compare mean density within each channel type between summer and winter. Lateral scour pools, step runs, and step pools were excluded from the analysis of seasonal habitat type preferences because lateral scour pools occurred in low frequency throughout the basin, while step runs and step pools occurred only in mid Wapiti and mid Cache Creek reaches where densities of cutthroat were low.

Habitat variables measured within channel units were tested for normality and equal variances. Because both assumptions were violated, multiple regression analysis was deemed inappropriate to identify relationships between fish abundance and specific habitat features. Associations between individual habitat variables and fish density and biomass were analyzed using Spearman's rank correlation (Zar 1984). In all statistical analyses, $P \leq 0.05$ was considered statistically significant. STATGRAPHICS statistical package (1989) was used to perform all statistical computations.

Habitat utilization by season was also determined by the equation (Bisson et al. 1982):

$$\text{Utilization} = \frac{\text{channel unit density} - \text{average total density}}{\text{average total density}}$$

where:

channel unit density = average density in the habitat type of interest;

average total density = average density over the entire stream reach, all channel units combined.

Potential values of the habitat utilization coefficient range from minus one, indicating avoidance of a particular habitat type, to positive infinity as a larger proportion of the population resides in the habitat type of interest (Bisson et al. 1982). Values of zero indicate fish are using the habitat type in proportion to its availability. To test for differences in habitat utilization by size, fish were divided into small and large size classes (< 150 mm and ≥ 150 mm) based on their bimodal length–frequency distribution (Figure 4). Analysis of scales from cutthroat trout from the Taylor Fork

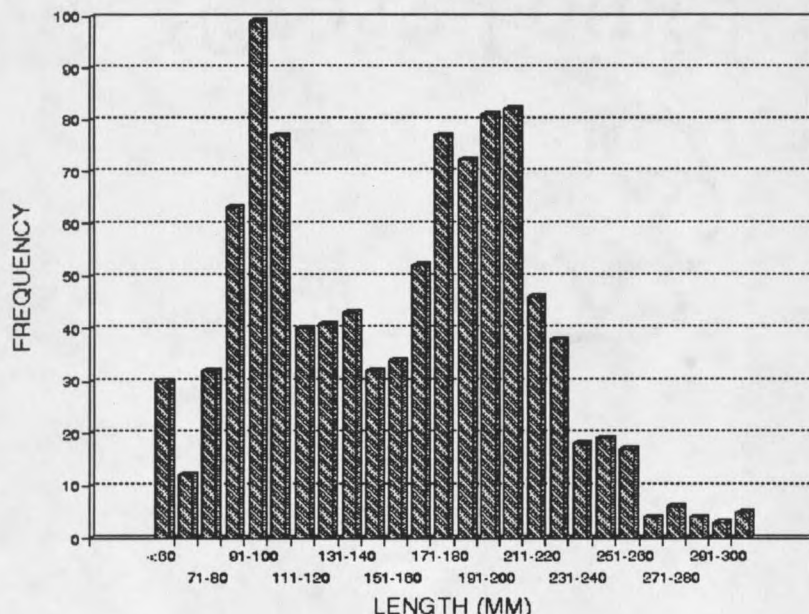


Figure 4. Length–frequency distribution of cutthroat trout caught in the Taylor Fork drainage during August–November 1992.

drainage indicate fish < 150 mm are likely to be age 1-2, while fish ≥ 150 mm are likely to be age 3+ (Nick Hetrick, Gallatin National Forest-Montana FWP fishery biologist, personal communication).

Effects of Sedimentation

To compare effects of sedimentation in reaches differing in degree of disturbance, the following representative measurements were chosen for comparison between reaches: percent surface fines, maximum pool depths, and bank stability. These variables were chosen as relative indicators of stream health and amount of sedimentation occurring within each reach. Reach differences in surface fines and maximum pool depths were analyzed using a one-way ANOVA and LSD multiple range test. Because bank stability was a rating rather than an actual value, a Kruskal-Wallis test and a nonparametric multiple comparison test for unequal sample sizes was used to compare differences among reaches. Cutthroat densities in pools in upper Wapiti (undisturbed) and upper Cache (disturbed) Creek reaches were compared using a nonparametric Mann-Whitney test.

Seasonal Movements

Degree of seasonal movement was assessed for two periods: cutthroat tagged with visual implant tags during spring spawning (May-June 1992) in upper Cache

Creek and recaptured during summer (August–September 1992) and winter sampling (October–November 1992), and cutthroat tagged throughout the basin during summer and recaptured in winter. Movement was measured as the distance between the point of original capture to the point of recapture .

RESULTS

Reach Characteristics

During the stream habitat survey, 17 km of stream were surveyed throughout the basin, representing a total of 663 channel units. Physical characteristics of the reaches in the Taylor Fork drainage helped identify similarities and differences between reaches (Table 6). Rosgen stream classifications showed the importance of classifying streams by particular reaches, as stream character changed in short distances due to shifts in channel gradient, substrate, entrenchment, and exposure to different land use practices. The lower reaches of the mainstem Taylor Fork and lower Wapiti Creek were characterized by low gradient ($< 1.5\%$), moderately confined channels, and a low number of deep pools. Substrate was predominantly cobble-rubble with a relatively low percentage of surface fines ($< 11\%$). The lower-mid Taylor Fork reach contained more pools, smaller dominant substrate, less willow in the riparian area, and a high degree of sedimentation (26.2% surface fines). Directly below the splash dam, the mid Taylor Fork reach was extensively braided, with an unconfined channel, and relatively small substrate. The upper Taylor Fork reach, located above the splash dam, increased in gradient ($> 1.5\%$) and had a moderately confined channel with stable alluvial terraces. Substrate was predominantly rubble with a low percentage of surface fines

Table 6. Physical characteristics for each reach in the Taylor Fork drainage.

	ELEV (m)	ORDER	ROSGEN CLASS	MEAN GRADIENT	W/D RATIO	MEAN WIDTH (m)	POOL/ RIFF RATIO	MAX POOL DEPTH (m)
L. Taylor	2121	4	C1	1	32.4	10.9	0.4	1.2
L. M. Taylor	2188	4	C1	0.5	20.2	8.2	1.1	1
M. Taylor	2195	4	D2	0.5	23.7	6.7	0.7	0.8
U. Taylor	2213	4	B2	1.6	23.4	7.2	0.5	0.8
L. Wapiti	2109	3	C2	0.9	21.1	6.3	0.5	0.8
M. Wapiti	2268	3	B2	2.5	21.5	5.3	0.6	0.6
U. Wapiti	2560	2	C5	1	12.4	2.7	1.1	0.6
L. Cache	2170	3	C5	0.5	13	3.1	1.3	0.6
M. Cache	2225	3	A2	4.1	10.2	3.2	0.8	0.6
U. Cache	2274	3	C5	0.5	12	2.9	1.4	0.7

Table 6. Continued.

	DOMINANT SUBST	%SURFACE FINES	POOL RATING	RIPARIAN COMPOSITION (%)				
				SOIL/ROCK	GRASS	SAGE	WILLOW	CONIFER
L. Taylor	RUBBLE	10.9	5	50	29	0	21	0
L. M. Taylor	GRAVEL	26.2	5	60	37	0	3	0
M. Taylor	GRAVEL	11.4	3	60	20	3	17	0
U. Taylor	RUBBLE	3.8	4	56	31	0	12	1
L. Wapiti	COBBLE	4.8	4	34	33	0	30	3
M. Wapiti	COBBLE	12.8	3	42	27	0	9	22
U. Wapiti	PEAGRAVEL	10	3	49	43	0	8	0
L. Cache	PEAGRAVEL	21.2	3	19	56	5	20	0
M. Cache	BOULDER	21.2	4	21	14	0	24	41
U. Cache	PEAGRAVEL	14.4	4	17	34	0	49	0

(3.8%). Both mid Cache and mid Wapiti Creek reaches entered coniferous forests and were characterized by an increase in gradient ($> 2.5\%$), well confined channels, and cobble-boulder substrate. A recent clearcut in 1992 next to the mid Cache Creek reach may account for the high percentage of surface fines (21.2%) occurring in that reach. The low gradient meadow reaches of lower Cache, upper Cache, and upper Wapiti were characterized by sinuous, slightly confined channels, high pool to riffle ratios, small substrate, and varying amounts of surface fines (10–21.2%). Although upper Cache Creek has been grazed heavily, riparian composition was still predominantly willow (49%).

Percentages of channel unit types by reach varied widely. Lower Wapiti and all mainstem Taylor Fork reaches had high percentages of riffle habitat ($> 68\%$) and few pools ($< 6\%$; Table 7). Mid Wapiti and mid Cache Creek had a high occurrence of step runs and step pools, due to steeper gradients. Upper Wapiti, upper Cache, and lower Cache Creek reaches had the highest percentages of pools (21–46%).

Seasonal temperatures varied little between stream reaches in the basin (Table 8). All reaches averaged between 10–12° C during July and August. Elevation did not appear to strongly affect stream temperatures. Relatively large temperature fluctuations were observed at all four locations in July and August. By October, stream temperatures averaged $< 4^{\circ}$ C in all four sites, and fish were assumed to have shifted to winter habitat at this time.

Table 7. Percentage of channel unit types by reach in the Taylor fork basin.

CHANNEL UNIT REACH	n	Corner Pools	Mid Channel Pools	Lateral Scour Pools	Glides	Riffles	Step Pools	Step Runs
L. Taylor	27	2	4	0	16	78	0	0
L. M. Taylor	57	5	5	6	4	80	0	0
M. Taylor	52	3	5	2	22	68	0	0
U. Taylor	29	0	4	1	11	84	0	0
L. Wapiti	63	1	2	1	16	80	0	0
M. Wapiti	68	0	3.5	1.5	0	35	28	32
U. Wapiti	105	36	10	0	23	31	0	0
L. Cache	41	10	30	1	24	35	0	0
M. Cache	17	0	2	0	0	4	24	70
U. Cache	<u>204</u>	12	8	1	34	45	0	0
N=	663							

Table 8. Mean, maximum, and minimum monthly temperatures (C) for lower Taylor Fork, lower Wapiti Creek, and lower and upper Cache Creek reaches during July to November 1992.

MONTH	ELEV (m)	JUL avg/max/min	AUG avg/max/min	SEPT avg/max/min	OCT avg/max/min	NOV avg/max/min
L. Taylor	2121	11.4/19.7/6.7	12.7/20.6/2.1	7.6/16.6/0.6	3.7/12.1/-0.2	0.1/3.2/-0.2
L. Wapiti	2109	10.1/19.0/6.4	-	6.3/13.9/0.3	2.9/11.9/-0.2	-0.2/2.4/-0.0
L. Cache	2170	11.4/18.3/6.9	12.1/17.4/3.6	7.0/11.6/2.6	3.3/7.6/0.7	0.6/0.9/0.3
U. Cache	2274	11.1/23.1/6.2	12.1/23.9/0.3	6.9/18.6/-0.1	2.7/13.9/-0.3	0.1/0.6/-0.3

Habitat Use by Reach

Cutthroat trout density varied considerably (20-fold) by reach within the Taylor Fork basin (Figure 5). Cutthroat densities were highest in upper Wapiti and upper Cache Creek reaches in both summer (18–23 cutthroat/100 m²) and winter (29–33 cutthroat/100 m²). Lower Cache Creek reach was intermediate in density (5 cutthroat/100 m² in summer, 8 cutthroat/100 m² in winter), while lower Wapiti and all the Taylor Fork reaches contained low cutthroat densities (0.3–2 cutthroat/100 m² in summer, 0.4–4 cutthroat/100 m² in winter). Cutthroat densities appeared to increase in most reaches from summer to winter, although reaches with low cutthroat densities in summer still had relatively low densities in winter.

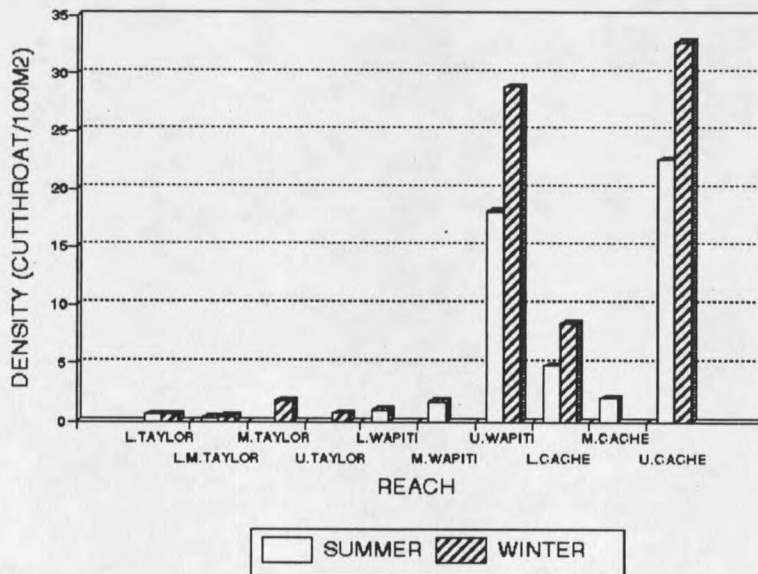


Figure 5. Cutthroat trout density (number of fish per 100 m²) in summer and winter by reach in the Taylor Fork drainage.

Comparisons of percent of cutthroat density and total area sampled show the importance of upper Wapiti and Cache Creek reaches (Figure 6). Although only a small percentage of the total basin area sampled (< 13%), upper Wapiti and Cache Creek reaches contained the highest percentage of cutthroat densities in both seasons (> 35% each; total = 79% in summer, 82% in winter).

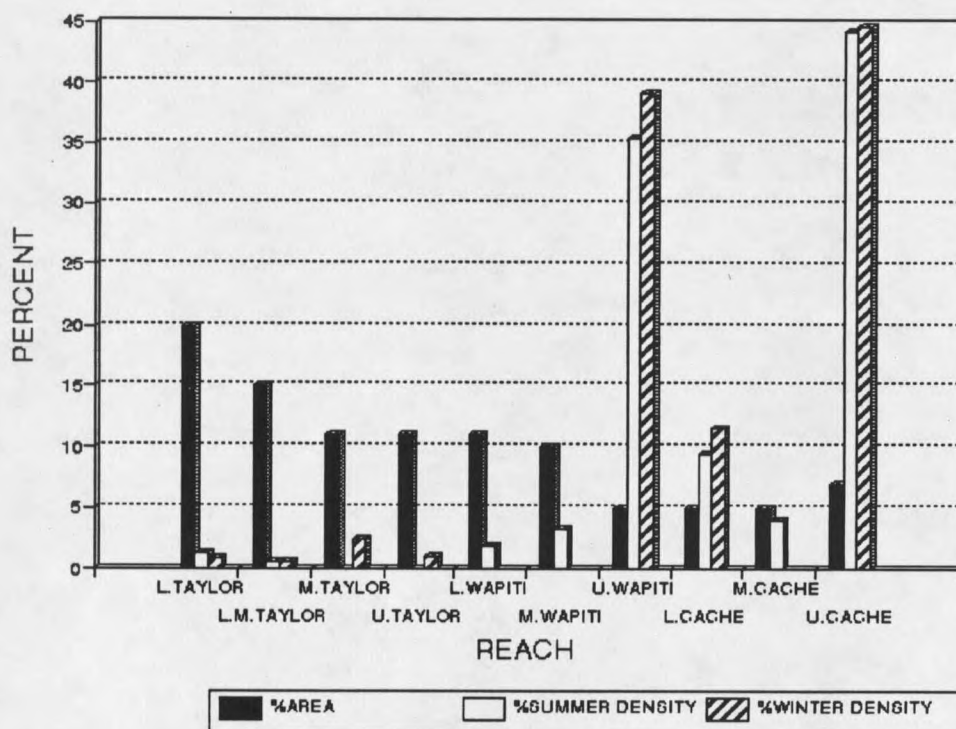


Figure 6. Comparison of percent of cutthroat trout distribution in summer and winter to percent of total area for each reach in the Taylor Fork drainage.

Stream order and elevation appeared to influence cutthroat trout density. Most cutthroats were found in 2nd and 3rd order streams, with declining densities as order increased, a relationship found in previous studies of westslope cutthroat distribution (Table 9). Density of westslope cutthroat trout was positively associated with elevation, with most cutthroats occurring at elevations > 2200 m in both summer and winter (Figure 7).

Table 9. Comparison of mean densities of cutthroat trout (number of fish per 100 m²) and stream order in the Taylor Fork drainage in summer and winter and the Flathead drainage in summer.

Stream order	Cutthroat This study Summer	Cutthroat This study Winter	Cutthroat Shepard 1984 Flathead
2	18.1	28.8	8.3
3	9.5	20.1	5
4	0.6	0.9	1.4
5	—	—	0.7

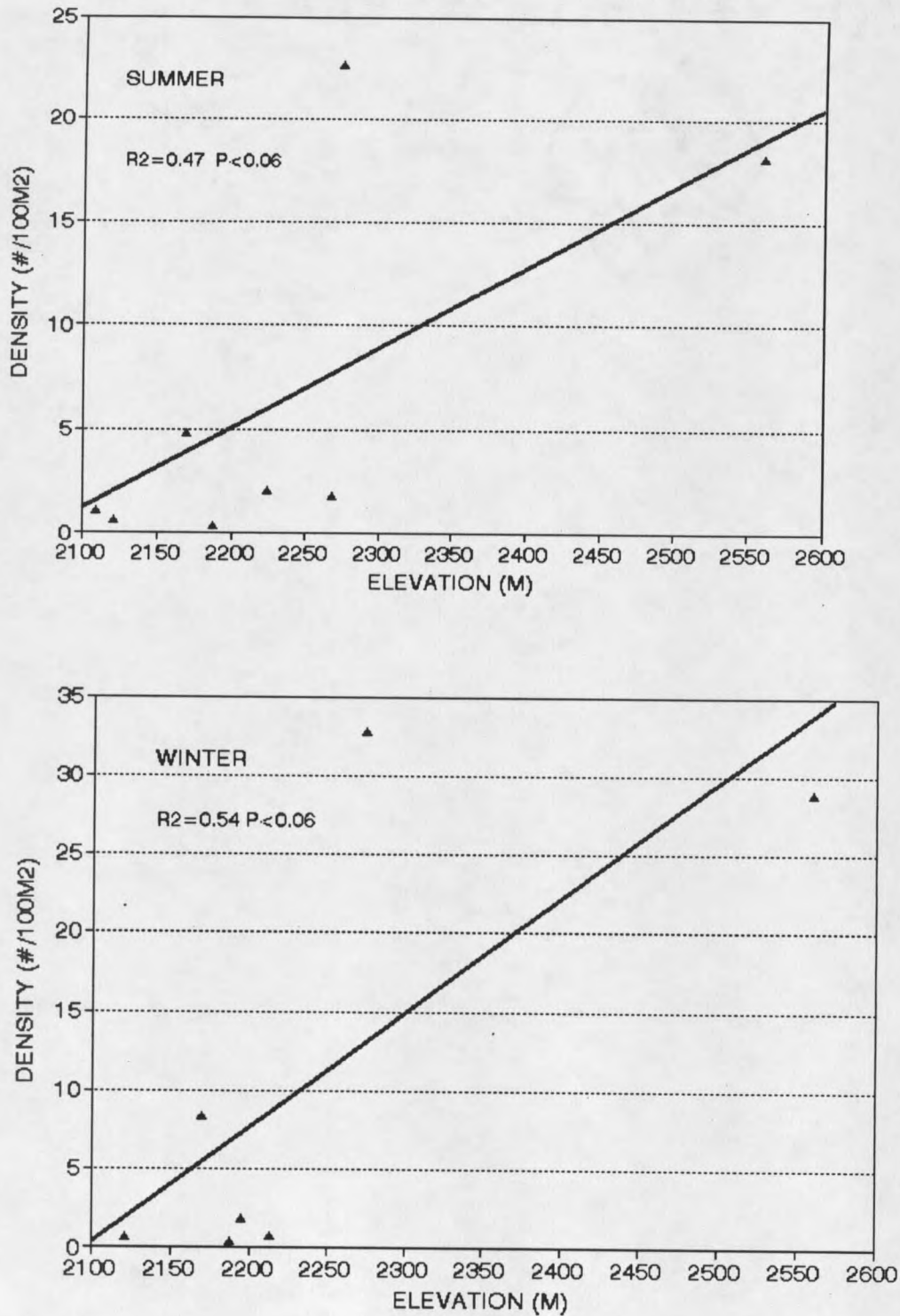
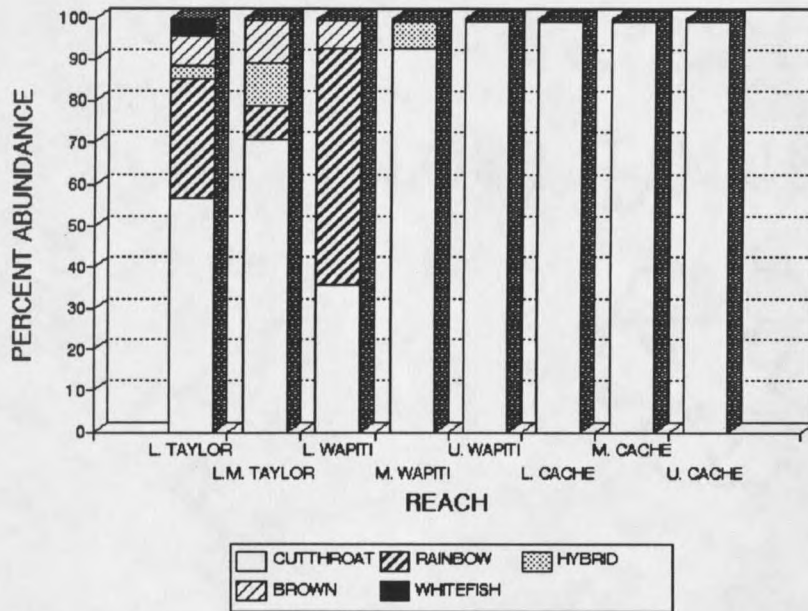


Figure 7. Relationship between elevation and density (number of fish per 100 m²) of cutthroat trout in summer and winter in the Taylor Fork drainage.

Species interactions may also have influenced cutthroat distribution. Mainstem Taylor Fork reaches contained cutthroat, rainbow trout, hybrid rainbow x cutthroat, brown trout, and whitefish (Figure 8). Cutthroat trout abundance declined in reaches where other species were present. In the summer, lower Wapiti was dominated by rainbow trout, while cutthroat were the only salmonid present in upper Wapiti and all Cache Creek reaches. In the winter, brown trout increased in the lower-mid Taylor Fork reach, possibly moving upstream from the Gallatin River to spawn. Sculpins were found in abundance throughout the basin except in upper Wapiti and upper Cache, where highest cutthroat densities occurred.

Despite an increase in total number of fish species present as elevation declined, there was an overall sharp decline in total fish densities (Figure 9). Densities of all species in the mainstem Taylor Fork reaches were very low (< 5 fish per 100 m^2) for both summer and winter. Cutthroat densities were highest in high elevation reaches and were the only species present above 2268 m in both summer and winter.

SUMMER



WINTER

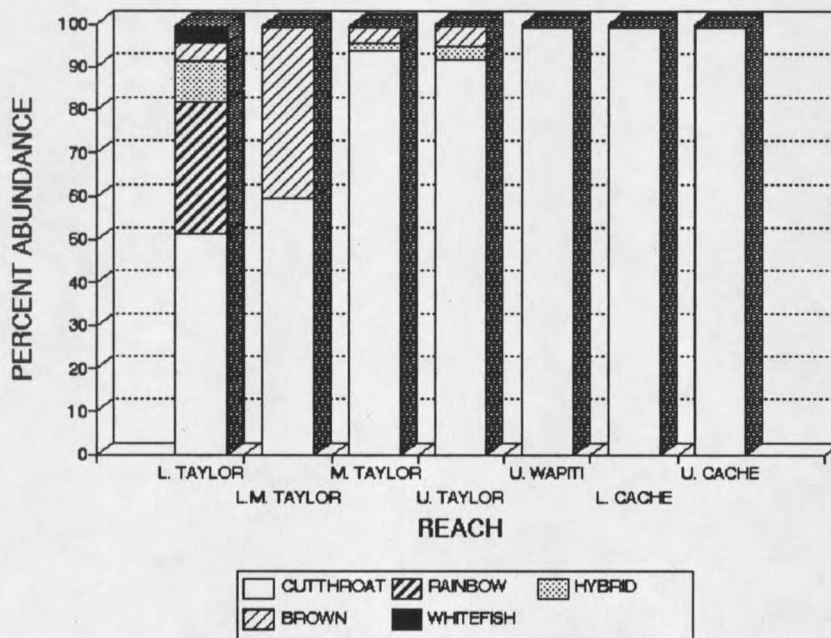


Figure 8. Relative abundance of all species by reach in summer and winter in the Taylor Fork drainage.

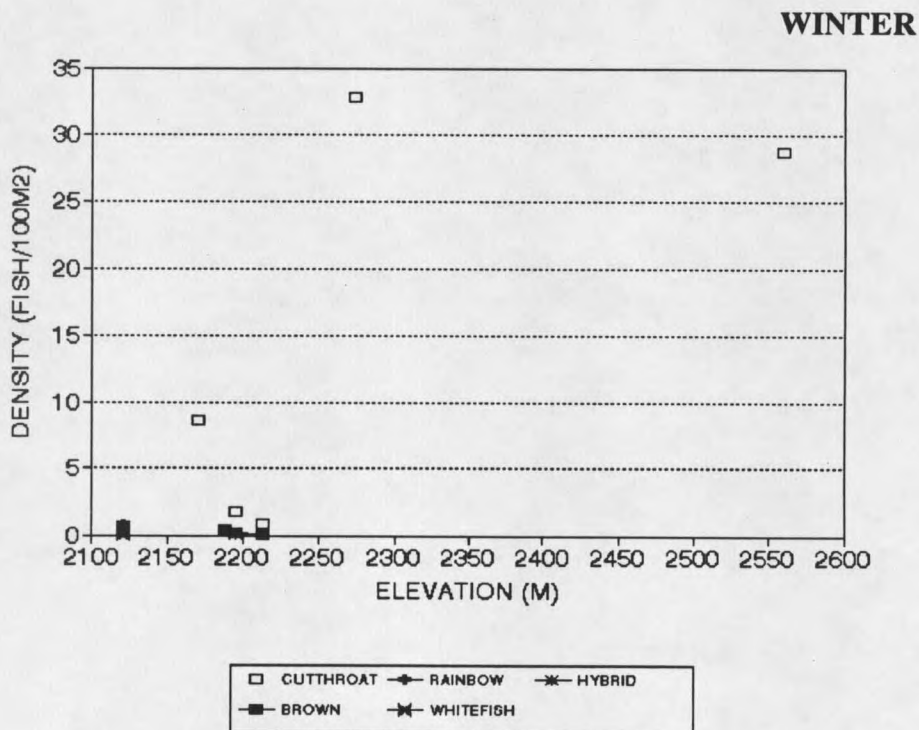
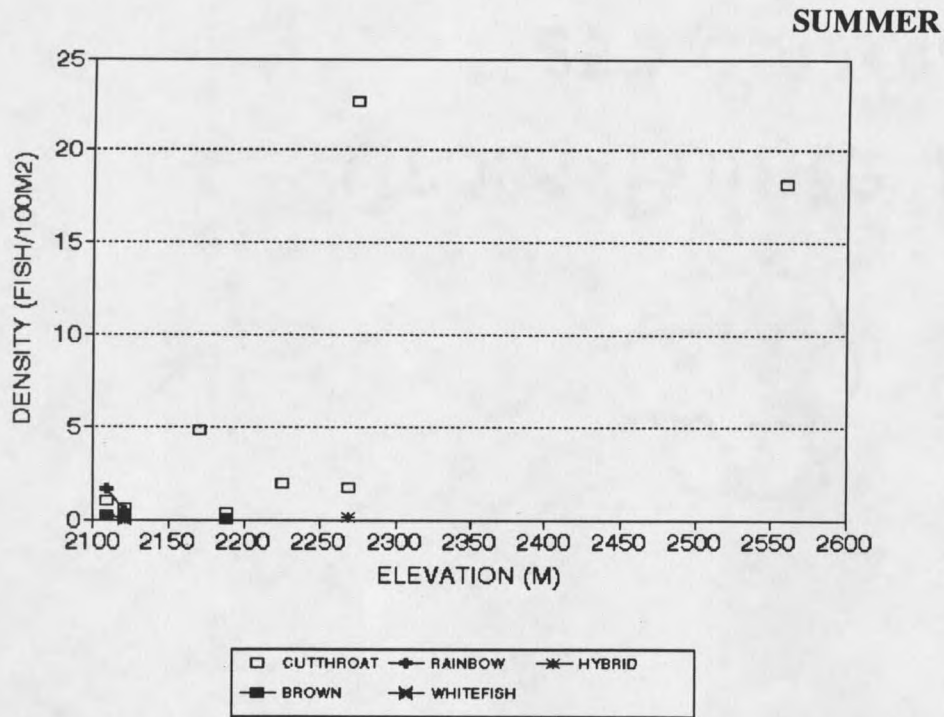


Figure 9. Relationship between elevation and density of each species (number of fish per 100 m²) in summer and winter in the Taylor Fork drainage.

Habitat Use by Channel Unit Type

Within upper Cache and upper Wapiti Creek reaches, where most of the cutthroat trout were located, slow-water channel unit types (pools and glides) contained the highest cutthroat densities. Densities of cutthroat trout were significantly lower in riffles compared to corner pools, mid-channel pools, and glides in both summer and winter (Table 10). Although corner pools appeared to be the most important channel unit type, there were large variations in cutthroat densities among channel unit types. Between summer and winter, cutthroat densities in channel unit types did not differ significantly except in riffles (Mann-Whitney, $P < 0.01$).

Table 10. Mean density (number of fish per 100 m²) of cutthroat trout for channel unit types in Upper Wapiti and Cache Creek for summer and winter. Standard deviation in parentheses. Values with letters in common are not significantly different.

TYPE	SUMMER DENSITY	WINTER DENSITY
Corner Pool	50.5 (73.8)z	75.2 (132.1)z
Mid-channel Pool	25.5 (13.2)z	38.4 (17.5)z
Glide	34.6 (39.4)z	50.6 (40.8)z
Riffle	7.7 (6.1)y	0.7 (1.4)x

Both small (< 150 mm) and large (≥ 150 mm) cutthroat preferred slow-water channel unit types, although habitat selection differed slightly between the two size classes. Habitat utilization coefficients indicated preference for corner pools and midchannel pools by small cutthroat during both summer and winter, while large cutthroat preferred corner pools and glides in both seasons (Figure 10). Both size classes avoided riffles in summer and winter.

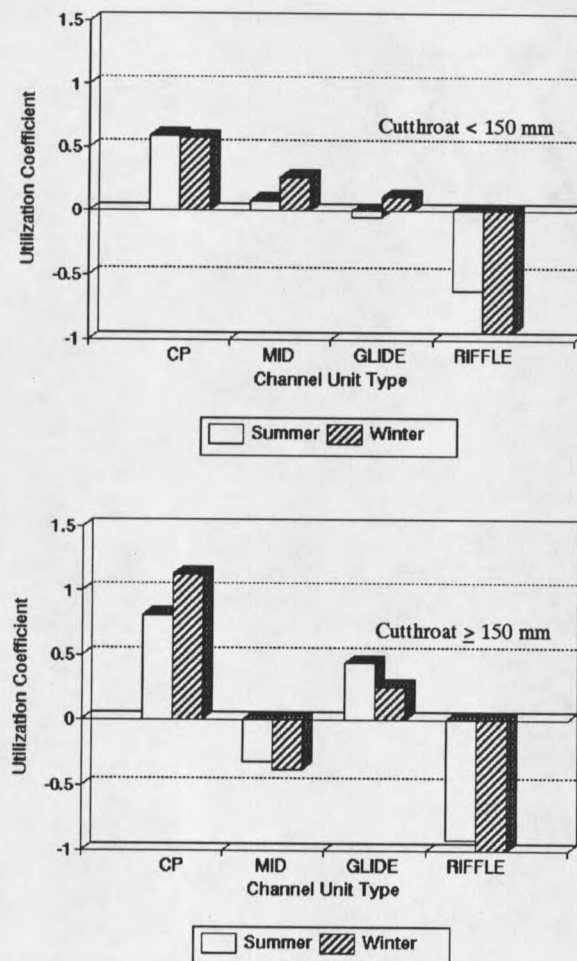


Figure 10. Habitat utilization coefficients for each channel unit type for small (< 150 mm) and large (≥ 150 mm) cutthroat trout in combined analysis of upper Wapiti and Cache Creek reaches.

Variation in cutthroat densities within channel unit types at the reach scale were also observed throughout the basin. While mean cutthroat densities in corner pools were high (42–103 cutthroat/100 m²) for summer and winter in upper Wapiti and Cache Creek reaches, mean densities were low in corner pools (2–9 cutthroat/100 m²) in other reaches, except in the mid Taylor Fork reach in winter, where only one corner pool was sampled and a density of 37 cutthroat/100 m² was found (Table 11). Similarly, mean cutthroat densities in mid-channel pools and glides for both seasons in upper Wapiti and Cache Creek reaches were higher (23–52 cutthroat/100 m²) than in other reaches in the basin (0–4 cutthroat/100 m²).

Table 11. Mean densities of cutthroat trout (number of fish per 100 m²) in specific channel unit types in each reach of the Taylor Fork drainage.

Reach	Channel unit type codes *						
	1	2	3	4	5	6	7
SUMMER							
Lower-mid Taylor	2	0	3	1	0	--	--
Lower Wapiti	2	1	15	0	1	--	--
Mid Wapiti	--	3	3	--	1	2	1
Upper Wapiti	42	23	--	43	7	--	--
Lower Cache	9	13	0	0	0	--	--
Mid Cache	--	2	0	--	0	2	1
Upper Cache	60	27	--	27	9	--	--
WINTER							
Lower-mid Taylor	0	1	2	3	0	--	--
Mid Taylor	37	--	--	0	1	--	--
Upper Taylor	--	6	7	4	0	--	--
Upper Wapiti	47	46	--	52	0	--	--
Lower Cache	9	25	5	0	0	--	--
Upper Cache	103	35	--	50	1	--	--

* 1 = corner pool; 2 = mid-channel pool; 3 = lateral scour pool; 4 = glide; 5 = riffle; 6 = step run; 7 = step pool

Fish-Habitat Relationships

When habitat measurements from all channel unit types throughout the basin were pooled, stream size-related variables were most important in accounting for variation in cutthroat density. Density was negatively correlated with several stream size-related features such as surface area, channel unit length, wetted width, channel width, and dominant substrate (Table 12), which characterize the small headwater

Table 12. Habitat variables correlated ($P \leq 0.05$) with density of cutthroat trout in all channel unit types in the Taylor Fork drainage using Spearman's rank correlation for two sampling stratifications. + = positive correlation; - = negative correlation.

Variable	All Units (n=92)	U. Cache and U. Wapiti only (n=34)
Surface Area	-	
Length	-	
Wetted Width	-	-
Channel Width	-	
Mean Depth	+	+
Dominant Substrate	-	-
Embeddedness	+	
Cover	+	+
Bank Stability	+	
Bank Height		
Gradient		

reaches of upper Wapiti and upper Cache Creeks where most cutthroats occurred. Embeddedness and bank stability were ^{1. not w/ embeddedness} positively correlated with density. Higher densities were found in less embedded channel unit types with more stable banks. When analysis included only habitat variables from channel unit types in upper Cache and upper Wapiti Creek reaches, many of the stream size-related variables, such as surface area, channel length, and channel width, became nonsignificant. Cover and mean depth were positively correlated with density in both analyses.

When data from pools alone were analyzed, differences in correlation of significant habitat variables were more pronounced between the two analyses (Table 13). With all pool channel units throughout the basin combined for analysis, many stream size-related variables (surface area, wetted width, channel width, and dominant substrate) were again significantly correlated with density. When pools from upper Cache and Wapiti Creek reaches were analyzed, only one variable (large substrate cover) was positively correlated with cutthroat density.

Table 13. Habitat variables correlated ($P \leq 0.05$) with density of cutthroat trout in pools in the Taylor Fork drainage using Spearman's rank correlation for two sampling stratifications. + = positive correlation; - = negative correlation.

Variable	All Pools (n=51)	Pools within U. Cache and U. Wapiti (n=17)
Surface Area	-	
Length		
Wetted Width	-	
Channel Width	-	
Mean Depth		
Max Pool Depth		
Dominant Substrate	-	
Embeddedness	+	
Large Substrate Cover		+
Overhead Cover		
Pool Rating		
Bank Stability		
Bank Height		
Gradient		

Effects of Sediment on Habitat

Measures of surface fines, maximum pool depths, and bank stability ratings were used to quantify differences in sedimentation and disturbance between reaches. Differences in percent surface fines between reaches varied over five-fold (Table 14). The highest degree of channel instability and percent surface fines occurred in reaches on the Taylor Fork below the splash dam and in Cache Creek reaches. Mean maximum pool depths ranged from 0.97 m in the lower Taylor Fork reach to 0.56 m in the mid

Table 14. Comparison of mean values of disturbance characteristics for reaches in Taylor Fork drainage. Standard deviations in parentheses. Values with a letter in common are not significantly different.

REACH	% SURFACE FINES	MAX POOL DEPTH	BANK STABILITY	LAND USE *
L. M. Taylor Fork	26.2 (18.9) z	0.97 (0.57) z	1.7 (0.5) z	SD,G,R
M. Taylor Fork	10.9 (6.3) z	0.77 (0.56) z	2.1 (0.5)zyx	SD,G,R
U. Taylor Fork	3.8 (2.2)y	0.77 (0.50)z	2.0 (0.5)zy	OCC,R
L. Wapiti	4.8 (1.3)zy	0.75 (0.41)z	2.6 (0.5)yxw	R
M. Wapiti	12.8 (8.5)zy	0.57 (0.34)z	3.1 (0.6)ywu	RCC,G
U. Wapiti	10 (7.3)zy	0.59 (0.30)z	1.8 (0.9)z	NONE
L. Cache	21.2 (19.3)zy	0.54 (0.40)z	2.7 (0.8)yxwu	G,R
M. Cache	21.2 (7.8)zy	0.56 (0.34)z	3.3 (1.0)wu	RCC,R
U. Cache	14.4 (9.4)zy	0.65 (0.38)z	3.4 (0.5)u	RCC,G,R

* Land use codes; SD = splash dam; RCC = recent clear-cut; OCC = old clear-cut; G = grazing; R = road

Cache Creek reach. Mean maximum pool depths were not significantly different among reaches, even though deeper pools would be expected in the Taylor Fork reaches because of the larger size of the river compared to its tributaries. Bank stability ratings varied among reaches. Banks were most stable in the high gradient forested reaches of mid Wapiti and mid Cache Creeks, as well as the upper Cache Creek reach. Low bank stabilities occurred in all the Taylor Fork reaches, possibly due to the effects of the splash dam, as well as upper Wapiti Creek. Although upper Wapiti Creek has not been exposed to land use practices, the presence of sedimentation and channel instability reflected the natural erosiveness of the Taylor Fork drainage. A Mann-Whitney

comparison of cutthroat densities in pools in the undisturbed reach of upper Wapiti and the upper Cache Creek reach, which has been exposed to logging, roading, and grazing, indicated no significant differences in cutthroat densities between the two reaches in summer ($P < 0.13$) or winter ($P < 0.41$).

Seasonal Movement

Although movement was not the main focus of this study, a small number of recaptured tagged cutthroat allowed a preliminary evaluation of seasonal movement patterns of cutthroat in the Taylor Fork drainage. Movement was assessed in two distinct time periods: cutthroat tagged during spring spawning (May–June) and recaptured during summer (August–September) and winter sampling (October–November), and cutthroat tagged during summer and recaptured in winter. During the study period, 1200 fish > 130 mm in length were tagged with visual implant tags. In all, only 120 salmonids were recaptured (111 cutthroat); 45 were cutthroat recaptured from the spring spawning traps; 19 were cutthroat tagged in summer and recaptured in the winter. Seven cutthroat recaptured within the same sampling period as they were tagged (summer) were not included in the evaluation of movement. Of the cutthroat recaptured, 40 did not retain tags for a tag loss rate of 36%.

Cutthroat recaptured downstream from the Cache Creek spawning trap exhibited relatively short movement distances (Figure 11). Over half of the recaptured cutthroat

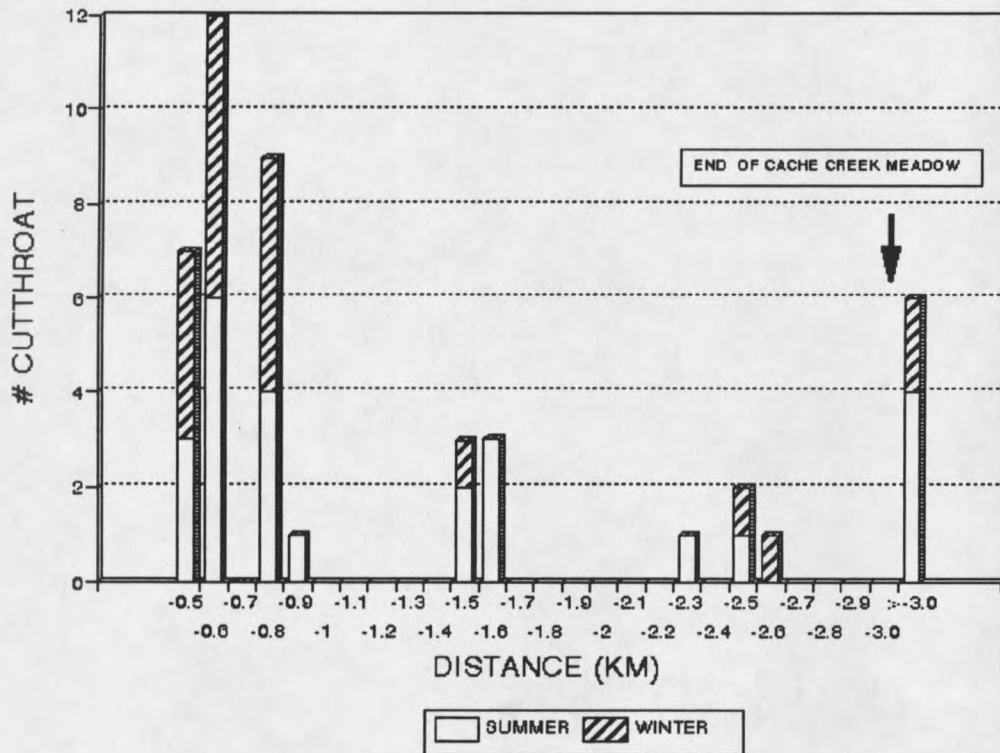


Figure 11. Movement distance (km) for cutthroat trout recaptured downstream from Cache Creek spawning trap in summer and winter. - = downstream movement

tagged at the spawning trap (65%) had moved less than 1 km downstream from the spawning trap during the summer and winter sampling period. Eighty-seven percent of the recaptured spawners remained in the upper Cache Creek reach (0.5–3.0 km downstream from the spawning trap), suggesting upper Cache Creek may be an important rearing area during both summer and winter. Movement of the remainder of recaptured spawning cutthroat ranged downstream from 3.8–7.7 km, to lower reaches of the Taylor Fork.

Movement of cutthroat tagged in the summer and recaptured during winter sampling was generally limited (Figure 12). Over 65% of the recaptured cutthroat were caught in the same channel unit in which they had been marked. Only 20% had moved distances greater than 2 km upstream or downstream. No cutthroat tagged in upper Cache Creek during the summer–winter sampling period were recaptured in any other reach except upper Cache. All cutthroat recaptured from upper Wapiti Creek had remained in that reach except one that moved downstream 13.7 km to the lower Taylor Fork reach during winter.

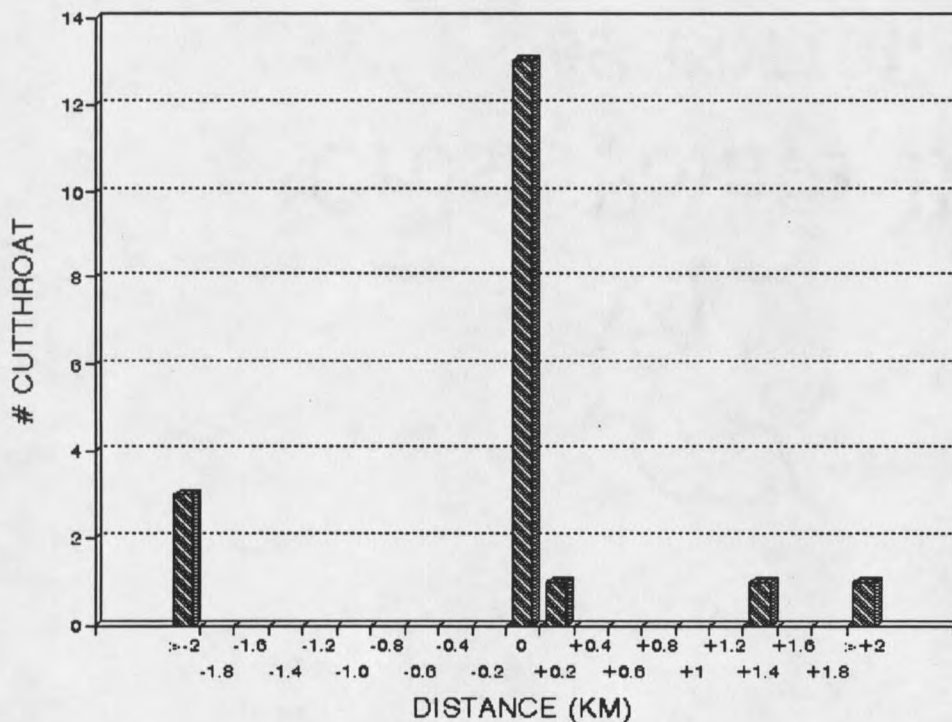


Figure 12. Movement distance (km) for cutthroat trout tagged during summer sampling and recaptured during winter sampling in the Taylor Fork drainage. + = upstream movement; - = downstream movement.

DISCUSSION

Several different scales (basin, reach, and channel unit) were important for identifying critical summer and winter rearing habitat of westslope cutthroat trout in the Taylor Fork drainage. Many investigators have emphasized the need to use a basin scale approach to identify variability in fish densities between stream reaches (Bisson undated; Frissell 1986; Everest et al. 1987; Sullivan et al. 1987; Dolloff et al. 1993). Fish population and habitat data from representative reaches is often extrapolated in fisheries research and management studies to derive estimates of total population size. Estimates based on extrapolation from representative reaches, especially in small streams, can be highly variable and risks considerable error in calculating the total number of fish within a drainage (Bisson undated; Shepard 1983). In the Taylor Fork drainage, over 70% of cutthroat densities were clumped in 2 of the 10 surveyed reaches. These reaches (upper Wapiti and upper Cache Creek) comprised only 12% of the total area surveyed, revealing the importance of a basin perspective to identify areas of highest habitat use.

There may be many reasons for the clumped distribution of cutthroat in the Taylor Fork basin: geomorphic variables such as order and elevation, species interactions, and proximity to spawning areas. Geomorphic variables have been used by several investigators to describe fish distribution throughout a basin. For example,

Platts (1979) established a relationship between stream order and fish populations in the Idaho Batholith and found cutthroat trout occurred in higher densities in low order streams. Lanka et al. (1987) demonstrated that measures of drainage basin geomorphology are related to both stream habitat variables and trout standing stock in Wyoming streams. In a study of streams in the central Rocky Mountains, Bozek and Hubert (1992) used elevation as one of three habitat dimensions to predict distribution of four trout species. They found cutthroat occurrence more common at high elevations (> 2500 m). Cutthroat distributions in the Taylor Fork drainage generally reflected findings by these investigators. Areas containing high cutthroat densities were high-elevation, low-order stream reaches located in alpine meadows.

Competition with exotic species such as brown trout and rainbow trout seems to negatively influence the presence of cutthroat trout (Griffith 1988). Cutthroat trout are now described as a headwater species, but prior to introductions of exotic salmonids, they were known to occur in more downstream reaches (Varley and Gresswell 1988). Today, cutthroat trout persist in many high-elevation, headwater reaches, where they appear to have a competitive advantage over introduced salmonids (Fausch 1989). Cutthroat in the Taylor Fork drainage follow this pattern, with low densities occurring in the mainstem Taylor Fork and lower Wapiti reaches where introduced salmonids are present, and high densities occurring in the high-elevation, headwater reaches such as upper Wapiti and upper Cache Creek, where introduced salmonids are absent.

Rainbow trout densities are low in the mainstem of the Taylor Fork, although initial stocking of rainbows could have pushed cutthroat to higher elevation headwater reaches in the drainage. Also, brown trout may be using the Taylor Fork drainage during spawning, as brown trout densities increased in several reaches during fall sampling. In a review of competition between cutthroat and other salmonids, Griffith (1988) mentions that replacement of cutthroat by another species may be an irreversible process and it is unlikely that space would ever be regained by cutthroat in the presence of exotic species.

Poor habitat quality in downstream reaches due to the effects of the splash dam, grazing, and logging may also have influenced distribution of all fish species in the Taylor Fork drainage. In a study conducted in an Idaho river drainage, Platts (1979) found that as stream order increased, the number of fish species and total number of fish increased. This pattern was not observed in the Taylor Fork drainage. Although total number of fish species increased with increasing stream order, there was a drop in the total number of fish present in the downstream reaches.

Although geomorphic variables, quality of habitat, and competition from other species may account for the spatial distribution of cutthroat, location of spawning habitat may also be an important influence on the current cutthroat distribution in the Taylor Fork drainage. Beard and Carline (1991) found brown trout in a small stream in Pennsylvania did not disperse widely from natal areas, and that local population densities were largely a function of the availability of spawning habitat. Bozek and

Rahel (1991) found an absence of young cutthroat from some stream reaches that had suitable microhabitat but lacked suitable spawning habitat. Cutthroat in the Taylor Fork drainage spawn in headwater tributaries of upper Wapiti and Cache Creeks (Magee 1993). These small tributaries are in close proximity to the reaches containing high densities of cutthroat.

Some reaches (lower Cache and meadow sections on the Taylor Fork), contained seemingly good habitat, i.e. large, deep pools, but supported very low densities of cutthroat. Temperature did not seem to play an important role in cutthroat distribution, as there appeared to be no strong elevational differences in stream temperatures throughout the basin. Reasons for such low densities of cutthroat trout in pools of the lower reaches could include 1) influence of elevation and stream order, 2) competition with introduced species, 3) proximity to spawning grounds, and 4) high angling mortality. Angling mortality was not investigated in this study, but cutthroat are known to be vulnerable to fishing pressure (Rieman and Apperson 1989). The reaches on the Taylor Fork and lower Cache Creek are quite accessible by road and anglers were often observed in these areas during the study period.

The second hierarchical scale important for describing critical habitat for westslope cutthroat was the reach scale. Bisson et al. (1982) developed a classification system of channel unit types to study habitat utilization by salmonids within reaches in four Washington streams. Relating channel unit types to cutthroat densities within a reach allows the investigator to estimate the habitat potential of that reach. Although

cutthroat densities were not found to be significantly different between channel unit types (except riffles) because of high variability within the channel units, highest mean cutthroat densities were found within slow-water habitats (i.e. pools and glides). Reasons for the variability within channel unit types may include food availability (dependent upon the extent of a riffle above a pool), cover availability, and angling mortality.

Corner pools appeared to be the most important slow-water channel unit type and were used in higher proportion than their availability in both summer and winter, while fast-water habitats such as riffles were avoided. The preference exhibited by cutthroat trout for slow-water habitats has been reported by other researchers (Shepard 1983; Peters 1988; Rieman and Apperson 1989). High frequency of occurrence of pool habitat may be an important reason why cutthroat are found in the two meadow sections of upper Cache and Wapiti Creeks. These reaches meander through alpine meadows and have a relatively high percentage of pool habitat compared to other reaches (except lower Cache Creek).

Densities of cutthroat trout in pools are high in upper Wapiti and upper Cache Creeks compared to other studies (Table 15). Cutthroat trout form dominance hierarchies in the absence of cover and will "stack" vertically in the water column in pools, enabling the fish to utilize more available space (Shepard et al. 1984). Because of the high frequency of occurrence of pools, these meadow sections of stream may be

Table 15. Comparison of age 1 and older cutthroat trout (number of fish per 100 m²) observed in pools of tributaries to river drainages in Montana and Idaho. Original citations in Shepard et al. 1984.

DRAINAGE	CUTTHROAT/100 m ²	SOURCE
Upper Wapiti Creek	32.5	This study (summer)
Upper Cache Creek	43.5	This study (summer)
Flathead River	17.7	Shepard 1984
S.F. Clearwater	14.3	Shepard 1983
Lemhi River	3.0	Horner 1978
St. Joe River	1.4	Thurrow & Bjornn 1977
Lochsa River	0.8	Graham 1977
Selway River	1.1	Graham 1977
Wolf Lodge Creek	26.1	Lukens 1978

able to support higher densities of cutthroat than a higher gradient stream reach with fewer, shallower pools.

Investigators have used habitat variables measured at the channel unit scale to identify habitat requirements of stream fish. Scarnecchia and Bergerson (1987) related cutthroat productivity to habitat variables such as substrate diversity, width-to-depth ratios, and area of zero velocity water in Rocky Mountain streams. At the channel unit scale, site variables important for describing fish density in the Taylor Fork drainage appeared to reflect dominant reach characteristics. In the analysis that included all channel unit types in the drainage, significant negative correlations for surface area,

length, wetted width, and channel width, and dominant substrate reflected the fact that highest fish densities were found in small, low order, high elevation streams. These streams have smaller surface areas, stream widths, and shorter lengths per channel unit than larger, low elevation streams. When channel units from reaches other than upper Cache and Wapiti were dropped from the analysis, surface area and length became nonsignificant.

A more striking difference in scale for variables important for describing fish-habitat relationships was observed in the two analyses performed on pools only. Cutthroat density was correlated with six habitat variables in the first analysis and only one habitat variable when pools from only high cutthroat density reaches were analyzed. Again reflecting reach characteristics, surface area, channel width, and dominant substrate were only significant when all pools throughout the drainage were analyzed. Interestingly, large substrate cover (boulders) was not significant when all the pools were analyzed together but became positively correlated with fish density when only pools from upper Cache and Wapiti were analyzed. A possible explanation for this could be that, throughout the drainage, many pools with large substrate cover were uninhabited by cutthroat, while in upper Cache and Wapiti Creeks, cutthroat may have been selecting pools containing large substrate cover. In many studies, large substrate is positively correlated with fish density (Bjornn 1971, Bjornn et al. 1977, Hillman et al. 1987).

Cover was positively correlated with cutthroat density in the analyses that included all channel unit types throughout the basin and in upper Cache and Wapiti Creeks, but was not significant in the analyses that included pools only. Griffith (1970) found cover and complex habitat to be important for westslope cutthroat trout, particularly juvenile fish. Large woody debris and overhanging vegetation that could be used for cover were limited in pools throughout the Taylor Fork basin and may account for the insignificance of cover (except large substrate) in the pool analyses.

In upper Cache and upper Wapiti Creek, the two reaches with highest cutthroat densities, cover was restricted. Food abundance may have some influence on cutthroat distribution throughout the basin. Wilzbach (1985) found that at summer temperatures, food abundance overrode cover in determining abundance distribution of adult cutthroat within streams in the Oregon Cascades. Upper Wapiti and upper Cache reaches lack cover, but primary productivity seems to be high. Visual observation indicated plecopterans, ephemeropterans, and trichopterans were present in riffles, and terrestrial insects such as grasshoppers were present during late summer.

Effects of sedimentation on cutthroat habitat did not appear to influence cutthroat distribution in the Taylor Fork drainage. Cutthroat densities in pools did not differ significantly between upper Wapiti and upper Cache Creek reaches, although upper Cache Creek has been exposed to numerous land use practices, while upper Wapiti Creek remains relatively pristine. Sedimentation and channel instability due to poor land use practices has been shown to be a limiting factor for many salmonid

populations (Bjornn et al. 1977; Everest et al. 1987; Hillman et al. 1987). Conversely, a study of cutthroat distribution in northeastern Nevada showed that native cutthroat had the ability to occupy degraded sites, giving them a competitive edge over introduced species (Nelson et al. 1992). The Taylor Fork drainage is composed mainly of soft sediments and is naturally unstable. Cutthroat in this drainage have evolved in these conditions and may have adapted mechanisms to deal with large amounts of sediment. For example, small cutthroat generally use interstitial spaces for overwintering (Bjornn et al. 1977), but because cobble-rubble substrate was limited and embedded with sediment in the reaches with high densities, small cutthroat appeared to inhabit slow-water habitats such as corner pools and mid-channel pools in winter.

In some basins, westslope cutthroat move extensively, using different reaches during spawning, summer rearing, and overwintering (Rieman and Apperson 1989). Very small tributaries serve as spawning and initial rearing habitat and then cutthroat may migrate downstream to a larger stream (Shepard et al. 1984). This behavior was demonstrated in the Taylor Fork drainage as fish moved into very small tributaries in upper Cache and Wapiti Creek reaches to spawn, and then downstream after spawning (Magee 1993). Over 85% of the recaptured cutthroat tagged at the spawning trap in Cache Creek were found to reside in Cache Creek during summer and winter. Some of the larger cutthroat may have moved downstream to the Taylor Fork or Gallatin River after spawning.

Availability of winter habitat can have a strong influence on seasonal movements. When winter habitat is not available, downstream migrations of over 100 km have been documented (Peters 1988). Conversely, Peters (1988) observed that cutthroat reside the entire year in some streams reaches where both summer and winter habitat are found together. In the Taylor Fork drainage, over 65% of the recaptured cutthroat from the summer–winter sampling period had not moved from the specific channel unit in which they were tagged, while a small fraction of the cutthroat was more mobile. Heggenes et al. (1991) studied seasonal habitat selection and preferences by cutthroat in a small stream in British Columbia and found little variation in seasonal habitat selection by cutthroat. Pools and glides in the upper Cache and Wapiti Creek reaches contained high numbers of cutthroat in the summer and winter. Heggenes et al. (1991) also studied spatial stability of cutthroat and found the majority of the population to be static. Different migratory strategies may be adaptations to different environments. In the Taylor Fork basin, most cutthroat were found to reside close to the spawning grounds after spawning was complete. Also, little movement occurred during the temperature drop that can trigger a shift from summer to overwinter habitat, indicating both summer and winter habitat may be abundant enough to prevent downstream migration from the upper Cache and Wapiti Creek reaches.

By using three hierarchical scales to examine fish–habitat relationships, areas containing both suitable habitat and high cutthroat densities were identified within the Taylor Fork drainage. Each scale was important and provided different information

concerning critical habitat for cutthroat. Densities were highest in reaches containing the greatest amount of pool habitat, but the presence of suitable habitat (i.e. corner pools) did not guarantee that fish would be present. Elevation, stream order, presence of other species, and proximity to spawning sites may also be important variables to consider when determining why fish may not occupy otherwise suitable habitat. Although sedimentation did not appear to affect cutthroat distribution throughout the drainage, there may be a threshold to sediment tolerance, making it important to protect those reaches containing high cutthroat densities. Incorporating several hierarchical scales to assess habitat requirements for fish will enable us to better understand the relationship of habitat abundance and fish densities. In the Taylor Fork drainage, upper Wapiti and upper Cache Creek and their tributaries appear very important to the maintenance of viable cutthroat populations in the Taylor Fork basin.

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APPENDICES

APPENDIX A
UTM COORDINATES

Table 16. UTM coordinates for stream reaches in the Taylor Fork drainage.

REACH	DOWNSTREAM POINT		UPSTREAM POINT		U.S.G.S. MAP
L.Taylor					
Reach A	477200	4990000	476900	4990200	LINCOLN MTN
Reach B	475900	4990700	475600	4990600	LINCOLN MTN
Reach C	475200	4991000	474900	4991200	LINCOLN MTN
L.M.Taylor	471800	4991100	472600	4990500	LINCOLN MTN
M. Taylor	471800	4982300	470800	4988200	LINCOLN MTN
U. Taylor	470800	4988200	469800	4987000	LINCOLN MTN
					KOCH PEAK
L.Wapiti	478700	4989700	477600	4987500	LINCOLN MTN
M.Wapiti	476600	4986500	475800	4984700	LINCOLN MTN
U.Wapiti	473500	4981500	472800	4980600	PIKA POINT
L.Cache	472600	4990500	472300	4990700	LINCOLN MTN
M.Cache	472300	4990700	472000	4990400	LINCOLN MTN
U.Cache	472000	4990400	470500	4991800	LINCOLN MTN

APPENDIX B

SPEARMAN RANK CORRELATION COEFFICIENTS AND P-VALUES

Table 17. Spearman's rank correlation coefficients (r_s) and significance ($*P \leq 0.05$) for habitat variables associated with cutthroat trout density in all channel unit types in the Taylor Fork drainage using two stratifications.

VARIABLE	All Units			U.Cache and U.Wapiti	
	R_s	P		R_s	P
Surface Area	-0.40	0.0001	*	-0.19	0.2687
Length	-0.26	0.0117	*	-0.10	0.5540
Wetted Width	-0.43	0.0001	*	-0.36	0.0372 *
Channel Width	-0.52	0.0001	*	-0.34	0.0514
Mean Depth	0.34	0.0013	*	0.44	0.0122 *
Dominant Substrat	-0.46	0.0001	*	-0.57	0.0011 *
Embeddedness	0.36	0.0006	*	0.26	0.1284
Cover	0.24	0.0226	*	0.51	0.0037 *
Bank Stability	0.32	0.0021	*	0.20	0.2490
Bank Height	-0.13	0.2281		-0.14	0.4000
Gradient	-0.02	0.8245		-0.27	0.1196

Table 18. Spearman's rank correlation coefficients (r_s) and significance ($*P \leq 0.05$) for habitat variables associated with cutthroat trout density in pools in the Taylor Fork drainage using two sampling stratifications.

VARIABLE	All Units			U.Cache and U.Wapiti	
	R_s	P		R_s	P
Surface Area	-0.31	0.0277	*	-0.11	0.6733
Length	-0.22	0.1119		-0.05	0.8522
Wetted Width	-0.32	0.0221	*	-0.41	0.0965
Channel Width	-0.46	0.0011	*	-0.41	0.0991
Mean Depth	0.10	0.4635		0.05	0.8392
Max Pool Depth	-0.17	0.2286		-0.05	0.8289
Dominant Substrate	-0.53	0.0002	*	-0.40	0.1123
Embeddedness	0.36	0.0092	*	0.04	0.8710
Cover					
Large substrate	-0.20	0.1591		0.50	0.0467 *
Overhanging veg.	0.12	0.3772		0.15	0.5451
Submerged	0.16	0.2428		0.43	0.0883
Undercut bank	0.25	0.0715		0.19	0.4439
Pool Rating	0.05	0.7137		0.12	0.6178
Bank Stability	0.15	0.2799		0.22	0.3764
Bank Height	-0.08	0.5624		0.02	0.9450
Gradient	-0.10	0.4973		-0.23	0.3657

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