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Eastern Washington Last Fish Variability Characterization Resurvey

Final Report

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SUBMITTED BY ABR, INC. ENVIRONMENTAL RESEARCH & SERVICES
PSC #02-197

EASTERN WASHINGTON LAST FISH VARIABILITY CHARACTERIZATION RESURVEY

FINAL REPORT

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EXECUTIVE SUMMARY

- The In-stream Scientific Advisory Group (ISAG) initiated a study in summer 2001 to develop an eastern Washington 'Last Fish Habitat' Water Typing Model. In 2002, ISAG contracted ABR, Inc., to resurvey ten watersheds surveyed in 2001 to begin to characterize annual variability in the upper limits of fish distribution in eastern Washington streams and to identify habitat attributes likely to influence distribution variability at the stream reach scale. In addition, multiple-pass surveys, termed Error Distance Surveys, were performed on a subset of sampled stream reaches to measure error associated with determining last fish locations.
- Resurveys of the ten watersheds sampled in 2001 were conducted between 2 July and 24 September 2002. In total, 172 terminal points and 136 lateral points, established in 2001, were resurveyed in 2002. Distances between 2001 terminal last fish points and 2002 last fish points ranged from -942 to 400 m and averaged -11.7 m. Excluding two relatively large downstream shifts, the mean distance between 2001 and 2002 last fish points was -2.5 m. Differences between 2001 and 2002 last fish points were evenly distributed among upstream shifts, no change, and downstream shifts from 2001 terminal points, with 59, 51, and 63 observations in each of the three categories, respectively. A one-sample *t*-test indicated that no net upstream or downstream movement occurred between the two years ($p = 0.195$).
- Terminal last fish locations most often occurred immediately below small impasses created by large woody debris (44.5% of all terminal locations). Gradient increased by an average of only 2.1% from below to above last fish points associated with woody debris jams; at 48 of 73 terminal last fish locations associated with woody debris, gradient increased by 3% or less, and at 16 of these locations, gradient was lower above the impasse than it was below. Fish use ended below permanent gradient-related features (waterfalls and cascades and other significant increases in stream gradient) at 49 of 164 (30%) terminal last fish points.
- Terminal last fish points associated with waterfalls, cascades, and other permanent gradient-related impasses most often coincided with 2001 last fish points, as 57% percent of last fish points associated with gradient-related features occurred at the same location as 2001 last fish points. Conversely, last fish points associated with woody debris jams, natural ends, and where last fish features were not immediately apparent were more variable in relation to 2001 last fish points. Only 20% of last fish points occurring below woody debris jams coincided with 2001 last fish points; fish had moved upstream or downstream at 42% and 37% of these locations, respectively.
- Almost all streams established as lateral points in 2001 again were found to support no fish, as 134 remained lateral points, only 2 were found to hold fish upstream, and 67 lacked any defined channel and, therefore, were excluded from the sample set.
- On 27 of 28 Error Distance (ED) surveys, no fish were encountered above 2002 last fish points. On one ED survey, fish were sampled 0.5 and 14 m above 2002 last fish. Error distance was zero on 27 of 28 streams and 14.5 m on the one stream where fish were detected during the ED survey. Mean error distance among all streams was 0.5 m, indicating that the survey effort employed was sufficient to accurately locate last fish.

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ACKNOWLEDGMENTS

This project was funded by the State of Washington, Department of Natural Resources, and was performed under contract number PSC 02-197. This project is one of a number of activities overseen by the In-Stream Scientific Advisory Group (ISAG) to the Cooperative Monitoring, Evaluation, and Research Committee (CMER) to develop water typing models for predicting fish use in Washington streams. We thank all ISAG members for their contribution to the 2002 eastern Washington last fish resurvey, and, in particular, the efforts of David Price (WDFW), Darin Cramer (DNR), Brian Fransen (Weyerhaeuser), Terry Jackson (WDFW), and Scott Craig (USFWS). We are also grateful to the numerous private land owners who allowed us access to survey sites on their properties. Last fish field surveys were led by ABR biologists Mike Cole, Jena Lemke, Ry Thompson, and Suzanne Cloutier, who were assisted by Julie Grobelny, Alden Miller, and Jeff Caudill. Todd Mabee provided additional logistic support in the field. A draft of this report was reviewed by Brian Cooper and Betty Anderson of ABR, Inc.

INTRODUCTION

The In-stream Scientific Advisory Group (ISAG) to the Cooperative Monitoring, Evaluation, and Research Committee (CMER) initiated a study in summer 2001 to develop an Eastern Washington 'Last Fish Habitat' Water Typing Model. The primary purpose of this study was to collect sufficient data to develop a multi-parameter, field-verified GIS logistic regression model that accurately predicts the locations of Type F (fish bearing) and Type N (non-fish bearing) boundaries in eastern Washington. Sampling in summer 2001 was conducted in ten watersheds across forested lands east of the Cascade Mountains crest.

In 2002, ISAG contracted ABR, Inc., to resurvey these ten watersheds to begin to characterize annual variability in the upper limits of fish distribution in eastern Washington streams and to identify habitat attributes likely to influence distribution variability at the stream reach scale. Prior to this year's study, no last fish resurvey data existed for eastern Washington streams, yet such information is necessary to adequately characterize variability associated with last fish points. In addition to resurveys, multiple-pass surveys were performed on a subset of resurvey streams to assess potential error in determining last fish locations.

METHODS

STUDY AREA AND SITE SELECTION

Resurveys were performed in all ten eastern Washington watersheds surveyed in 2001 (Table 1). Five watersheds are located in central Washington, four in northeast Washington, and one in southeast Washington. Surveyed areas within all of these watersheds occur on forested lands. Two of the survey areas occur within federally designated wilderness areas: the William O. Douglas Wilderness and the Alpine Lakes Wilderness.

Within each watershed, resurveys were performed on both "terminal" boundary points and "lateral" boundary points, as determined by 2001 surveys. Terminal boundary points are defined as those where last fish occurs within a fish-bearing channel or below the confluence of two non-fish-bearing channels. Lateral boundary points are defined as those that occur where a non fish-bearing stream laterally intersects a fish-bearing stream. Preliminary data collected on the west side of the Cascade Mountains and physical characteristics typically associated with each boundary type suggest that terminal boundary points likely will vary much more than will lateral boundary points. Terminal points are often associated with subtle and sometimes transient changes in channel conditions likely to influence distribution. In contrast, lateral boundaries are typically characterized by abrupt and sizable changes in stream size and/or gradient, usually offering little opportunity for changes in distribution to occur. Effort was allocated disproportionately, therefore, between terminal and lateral boundary points to increase survey efficiency and data utility in relation to the project objective of characterizing the variability in last fish locations. Within each watershed, all streams on which terminal points occurred were resurveyed, while only 20% of lateral points were resurveyed.

To begin to quantify the error associated with determining last fish locations, error distance (ED) surveys were performed on a randomly selected subset of streams where last fish occurred at a terminal location during 2002 resurveys.

TERMINAL POINT RESURVEYS

Last fish locations were determined using standard protocols following the Guidelines for Determining Fish Use for the Purposes of Typing Waters (WAC 222-16-030). These guidelines set forth procedures used to identify the upstream extent of fish use by electrofishing a minimum of 1/4 mile (~400 m) upstream of the last fish detected.

All resurveys were conducted by a two-person crew using a Smith-Root Model 11-A, 12-B, or LR-24 backpack electrofisher. To begin each survey, the crew first located the 2001 last fish location in the field from maps, notes, and field flagging. The crew would commence electrofishing immediately downstream (within 5–10 m) of this location, working in an upstream direction and sampling only the more suitable habitat (pools and other holding waters) to ascertain fish presence. If no fish were encountered after 150 m, the crew would reverse

Table 1. Watersheds in Eastern Washington used to characterize 2002 last fish variability.

Watershed	Region	Basin	Drainage Area (acres)	Elevation Range (ft)	Precipitation Range (in)
Big Sheep Creek**	NE	Columbia R.	42,000	1000–7000	10–30
Upper Rattlesnake Cr.*	C	Naches R.	35,570	3000–8000	40–80
Naneum**	C	Yakima R.	55,000	2600–4900	15–25
Upper Cle Elum - Cooper River WAU*	C	Yakima R.	38,462	2500–8000	45–140
Deer Creek	NE	Colville R.	31,484	1900–5000	15–20
NF Deep Creek**	NE	Columbia R.	30,419	2100–4700	25–40
LeClerc Creek*	NE	Pend Oreille R.	62,321	2300–5600	20–40
N.F. Touchet River*	SE	Touchet R.	28,644	2300–5500	20–40
Cabin Creek***	C	Yakima R.	23,546	2500–5500	50–100
Upper Taneum***	C	Yakima R.	28,417	3000–6500	35–70

* Bull trout present
* * In bull trout overlay—none known to be present
*** Last habitat data only and in bull trout overlay

direction and begin shocking downstream in the same manner until a fish was captured. If 2001 last fish field marks could not be located (occurred very infrequently), the crew would begin sampling where, in their estimation from examining maps, the 2001 last fish likely occurred.

When fish presence was confirmed through periodic sampling as described above, the crew began to sample continuously in an upstream direction, counting pools and measuring changes in stream gradient as they proceeded. The survey continued upstream for 400 m, unless the stream gradient exceeded and remained above the 20% gradient threshold and channel width decreased to 2 ft (0.6 m) or less. As additional fish were encountered, new temporary last fish points were established with flagging and survey efforts continued until the above effort criteria were met to establish the 2002 last fish location.

After locating the 2002 last fish, surveyors first permanently marked the location by nailing a plastic yellow tag labeled with the watershed name, stream identification number, date, and DNR contract number (02-197) to a live tree adjacent to the stream channel. Yellow and orange flagging was tied on or near the tag to aid location by future surveyors. Where 2001 and 2002 last fish occurred at the same location, tags and flagging were placed immediately adjacent to 2001 markings (Figure 1). Where 2001 and 2002 last fish locations differed, the distance between these two locations was measured to the nearest meter using a hip chain. Distance upstream from the 2001 location was recorded as a positive number; distance downstream was recorded as a negative number. On a few occasions, 2001 last fish location markings could not be found. When this occurred, the distance to another reference point (road crossing or tributary junction) was measured to allow accurate mapping of the new last fish location.

On a field form labeled "Last Fish Point Data", the last fish species and other species encountered during the survey were noted and the last fish feature was identified. When last fish occurred below a barrier (waterfall, chute, log-jam, etc.); length, height, and gradient of the impediment were measured. When the barrier was

Figure 1. Annual field marks from 2002 (yellow tag and flagging) and 2001 (red tag) surveys placed at terminal last fish boundaries established in eastern Washington, summers 2001 and 2002.

too steep to allow percent gradient to be measured using a clinometer, percent gradient was visually estimated or noted as vertical. Additional barrier characteristics were noted to provide further information regarding conditions preventing upstream movement by fish. Instantaneous water temperature and conductivity also were measured at the 2002 last fish location using a YSI Model 85 multiparameter water-quality meter.

Habitat characteristics were measured over a minimum distance of 100 m above and below the 2002 last fish location and recorded on “Last Fish Habitat” field data forms. When the distance between the 2001 and 2002 last fish point exceeded 100 m, physical habitat was measured over the entire distance between the two points, as well as over the 100-m distance in the opposite direction. Measurements included (a) mean channel gradient, (b) bankfull and wetted channel width, (c) pool count, and (d) dominant substrate.

Wetted and bankfull channel widths (BFW), as indicated by the margins of perennial vegetation or high-water scour marks on exposed sediment, were measured to the nearest 0.1 m at transects spaced 20 m apart using a fiberglass tape. All quiet water areas suitable for fish holding/resting were tallied and residual pool depths measured. Dominant substrate was visually characterized (according to Lanka et al. (1987); <0.25 cm = silt and sand; 0.26–7.5 cm = gravel; 7.6–30 cm = rubble; >30 cm = boulders/bedrock) at five evenly spaced points across each transect (10, 30, 50, 70, and 90% of the distance across the channel). Channel gradient was measured at least every 20 m (i.e. between each survey transect) and at significant changes in slope using a clinometer. To ensure an accurate gradient measurement, the surveyor would sight upstream to the other crew member standing at the gradient break or next upstream transect.

LATERAL POINT RESURVEYS

Lateral points were resurveyed only if a defined channel (as determined by the presence of exposed substrate) occurred at the location to be surveyed. When no defined channel occurred, the crew selected an alternate lateral site from a randomized list provided by ISAG. If a defined channel was present, but held insufficient water to sample, then no electrofishing was performed and only physical conditions were measured, as described above, in the first 100 m above the confluence with the fish-bearing stream. Resurveys of lateral points with defined channels and surface water commenced at the confluence of the Type-N stream with the Type-F stream (i.e., at the lateral point) following the same protocols and using the same survey effort criteria as described above, with the following modifications.

Because fish were known to occur in the Type-F stream adjacent to the lateral point, sampling was initiated as a continuous sampling effort, and remained as such until the survey was complete (i.e., no periodic sampling was performed to ascertain fish presence). If fish were located in the channel above the 2001 lateral point, the survey continued following protocols as described above and was unmodified. If no fish were encountered (i.e., the point remained a lateral point), the stream was flagged at the confluence with the fish-bearing stream with a single yellow flag labeled with the watershed name, the stream identification number, and date. Physical measurements then were taken in the 100-m reach of the Type-N channel above the confluence with the Type-F channel; no physical data were collected from the Type-F channel below.

ERROR DISTANCE SURVEYS

Error distance surveys were performed on a subset of 28 randomly selected streams in which 2001 last fish occurred at terminal boundary points. Streams that had significant barriers at or immediately above 2001 last fish locations were omitted from the pool of candidate ED survey streams to include only streams where upstream movement would not be precluded by significant barriers in the survey area. Last fish was first determined using standard protocols described earlier. Once 2002 last fish was established, a block net was placed immediately below (within 5 m) the 2002 last fish location. Three additional electrofishing passes were made through the 400 m survey reach to determine sampling error. Survey effort on each of the three subsequent passes equaled that of the first pass used to establish 2002 last fish, and a second block net was placed at the upstream end of the ED survey reach (400 m) to prevent fish from moving above the reach. The distance from the 2001 and 2002 last fish points to any fish encountered during the 2nd, 3rd, or 4th passes were measured with a hip chain and recorded; all fish sampled during the ED survey were measured and retained in separate buckets, separated by pass, until all three ED passes had been completed. Following the completion of the survey, fish were released at the approximate area of capture.

An ED survey continued until 400 m of stream were sampled four times without detecting a fish (i.e., last fish established with first pass and then ED survey performed on three subsequent passes). When fish were detected during the ED survey (passes two, three, or four), that distance from the 2002 last fish location was added to the remaining survey distance to ensure that 400 m were sampled above the uppermost fish encountered during the ED survey, and block nets were relocated in relation to the new uppermost fish point. This distance above the original 400 m survey reach was then sampled four times in the manner described above to standardize the effort through the entire survey reach. Locations of fish encountered during ED survey passes (2, 3, and 4) were marked with a single orange flag. These locations were not marked as new 2002 last fish locations to avoid biasing the data set with last fish points that were determined with more thorough sampling than the standard one-pass protocol. Following completion of the ED survey, physical and chemical data were recorded at the 2002 last fish location as described earlier. Physical characteristics and barriers associated with fish sampled during the ED survey also were noted.

DATA ARCHIVING AND ANALYSIS

Last fish resurvey data were entered into an MS Access database (filename: 02-197 Last Fish Database). Raw physical data that included multiple measurements on the same variable first were entered into an MS Excel spreadsheet (filename: 02-197 Last Fish Raw Physical Data), in which means or frequencies were calculated, and then included in the Access database. ED survey data were entered into a separate Excel spreadsheet and maintained as a separate data file from the resurvey data (filename: 02-197 Error Survey Data). Summary statistics (means, frequencies, ranges, and standard deviations) were produced to characterize relationships between 2001 and 2002 last fish points and to relate last fish feature types to 2002 last fish points. A one-sample *t*-test was preformed on 2001 and 2002 last fish locations to test whether the mean difference between the two years did not equal zero.

RESULTS

VARIABILITY BETWEEN 2001 AND 2002 LAST FISH LOCATIONS

Resurveys of the ten watersheds sampled in 2001 were conducted between 2 July and 24 September 2002. In total, 172 terminal points and 136 lateral points, established in 2001, were resurveyed in 2002 (Table 2). Of the 173 streams with terminal points to be resurveyed, 162 were found to be fish bearing in 2002, 10 no longer held fish (i.e., were found to be lateral points in 2002), and one was not sampled because conditions prevented effective sampling with electrofishing equipment. Distances between 2001 terminal last fish points and 2002 last fish points ranged from -942 to 400 m and averaged -11.7 m (SD ± 118). Excluding the two largest downstream movements of 664 and 943 m, the average distance moved from 2001 terminal last fish points was -2.5 m (SD ± 80). Differences between 2001 and 2002 last fish locations were evenly distributed among upstream shifts, no change, and downstream shifts (Table 3 and Figure 2) from 2001 terminal points; with 59, 51, and 63 observations in each of the three categories, respectively.

A *t*-test of the hypothesis that the mean distance between 2001 and 2002 last fish was other than zero was non-significant ($p = 0.195$, with the two large distances retained in the dataset), indicating that no net upstream or downstream movement occurred between 2001 and 2002 from terminal points established in 2001. Last fish points did not change from 2001 to 2002 at 51 of 172 locations and, when movement occurred (in either direction), the last fish point had shifted by 25 m or less at an additional 61 of the 172 terminal points. Last fish shifted by more than 100 m in either direction at only 17 of 172 locations, and moved more than 200 m at only 8 locations. Last fish shifted by more than 500 m at only three locations; all of these were downstream movements.

Ten 2001 terminal points shifted downstream to lateral points in 2002, as no fish were present in these ten tributaries (Deer 177; Naneum 12, 69, 97, 190, and 301; Touchet 329; LeClerc 241; Rattlesnake 30; and Big Sheep 6). The distance between 2002 and 2001 last fish points in these streams ranged from -5 to –450 m with a mean distance of -75.2 m. Excluding the –450 m distance, the distance between these 2001 terminal points and 2002 lateral points averaged -28.4 m.

One stream where last fish was established at a terminal point in 2001, stream number 162 in the Cooper River watershed, had a conductivity too low (<5 µs/cm) to allow effective sampling with electrofishing gear. An extensive effort, with electrofishing gear using various unit settings, was made to sample the stream at and below the area thought to be close to the 2001 last fish point (neither the 2001 last fish, nor the 2001 last habitat flags could be located), but no fish were detected. To verify that the gear was properly functioning, the crew tested the unit in a nearby tributary with a higher conductivity and immediately captured fish.

Almost all lateral points established in 2001 again supported no fish, as 134 remained lateral points, only 2 were found to hold fish upstream (Figure 3), and 67 lacked any defined channel and, therefore, were excluded from the sample set (Table 2). Non-defined channels commonly were encountered at 2001 lateral points in the Deer, Naneum, Deep, and NF Touchet watersheds. In 2002, fish were sampled upstream of three lateral points established in 2001. Two of these locations were lateral points established in 2001, while the other occurred in an unmapped tributary upstream of a 2001 terminal last fish point. Fish were detected 60 and 107 m upstream of 2001 lateral points Naneum 51 and Le Clerc 178, respectively. The unmapped stream (referred to as LeClerc 905), a tributary above 2001 terminal point 105 in the Le Clerc basin, held fish 103 m upstream of its mouth.

Across all 2002 last fish points (terminal and lateral, combined), 94% of last fish locations shifted by 50 m or less (Figure 4). Of 309 terminal and lateral sites resurveyd in 2002, last fish points did not change at 150 sites. Weighing terminal sites in proportion to their occurrence in relation to lateral sites to produce estimates of fish movement across the study area, no movement occurred from 2001 to 2002 at 78% of last fish locations (Figure 4)

Interannual variability in streamflow has been hypothesized to produce shifts in fish distribution from one year to the next. Examination of streamflows at the time of sampling during each year in relation to changes in last fish locations

Table 2. Summary of 2002 eastern Washington last fish resurvey effort and resulting last fish point types on streams where last fish points were established in 2001. The upper table summarizes the survey effort on terminal last fish points first established in 2001; the lower table summarizes effort on lateral last fish points first established in 2001. Streams appearing on the original resurvey site lists and rejected from the sample set in the field because of non-defined channels (NDC) also are listed in the second table; no data were collected on these systems.

	Results of 2002 Resurveys at 2001 **Terminal** Points			
Watershed	2002 Terminal LF	2002 Lateral LF	Did not survey	Total
Big Sheep	5	1	0	6
Cabin	11	0	0	11
Cooper	14	0	1*	15
Deep	8	0	0	8
Deer	14	1	0	15
Le Clerc	38	1	0	39
Naneum	27	5	0	32
Rattlesnake	20	1	0	21
Taneum	17	0	0	17
Touchet	8	1	0	9
Total	162	10	1	173

* Stream conductivity was below the limits of the effective operating range of electrofishing unit.

	Results of 2002 Resurveys at 2001 **Lateral** Points			
Watershed	2002 Lateral LF	2002 Terminal LF	NDC	Total
Big Sheep	8	0	0	8
Cabin	11	0	2	13
Cooper	15	0	0	15
Deep	14	0	13	27
Deer	5	0	21	26
Le Clerc	22	1	4	27
Naneum	26	1	16	43
Rattlesnake	8	0	3	11
Taneum	15	0	7	22
Touchet	10	0	1	11
Total	134	2	67	203

Table 3. Distribution of changes in last fish location from last fish terminal points established in eastern Washington in 2001 and resurveyed in 2002 (n = 172). A positive value indicates an upstream shift in position; a negative value indicates a downstream shift.

Watershed	2002 LF Below 2001 LF	2002 LF Coincides with 2001 LF	2002 LF Above 2001 LF	Mean Distance (m)	Range (m)
Big Sheep	4	2	0	-85.2	-450 to 0
Cabin	2	7	2	4.5	-12 to 47
Cooper	9	4	1	-57.1	-664 to 49
Deer	9	2	4	-34.8	-195 to 61
Le Clerc	14	10	16	-32.8	-943 to 400
Naneum	9	9	14	13.8	-80 to 142
NF Deep	2	3	3	1.4	-40 to 39
NF Touchet	5	0	4	15.8	-33 to 215
Rattlesnake	5	10	6	11.1	-16 to 149
Taneum	4	4	9	14.2	-137 to 310
Total	63	51	59	-11.7	-943 to 400
Percent	36.4	29.5	34.1		

may help elucidate whether changes in streamflow do affect fish distribution. Although USGS gage data could not be located for any of the surveyed watersheds, data from neighboring watersheds indicate that 2002 streamflows were not consistently higher or lower than 2001 streamflows in the larger geographic areas encompassing the study watersheds. For example, using data from the Kettle River (USGS gage 12404500), located to the west of Big Sheep Creek, discharge on 10 September 2001 was 204 cfs, while on 5 September 2002 it was 226 cfs, indicating that streamflows in the area likely were similar during the 2001 and 2002 sampling periods in Big Sheep Creek. Gage data from the American River (USGS 12488500), located north of the Rattlesnake Creek drainage, indicate that streamflows were potentially higher in Rattlesnake Creek during the 2002 sampling period than they were during sampling in 2001, as American River discharge was 103 cfs on 10 August 2002 versus only 59 cfs on 3 August 2001. Conversely, the Priest River gage (USGS 12395000), located to the south of the Le Clerc River watershed, recorded a discharge of 365 cfs on 21 July 2001 versus 225 cfs on 14 August 2002, indicating that, at the times that sampling occurred in the LeClerc, flows likely were lower in 2002 than they were during sampling in 2001.

We acknowledge the limitations in using these streamflow data from neighboring watersheds and caution the use of these data for any purpose other than making general statements about the likely differences or similarities in streamflows in the study watersheds between the two years. Further, we recognize that precipitation patterns may vary within a geographic region enough to produce dissimilar streamflow patterns in neighboring watersheds. Nonetheless, review of these gage data from the various watersheds that are adjacent to the study watersheds indicate that 2001 and 2002 streamflows generally were similar, and may help explain the large number of last fish locations that did not change or shifted only short distances from 2001 to 2002.

In the absence of data supporting or refuting the hypothesis that changes in streamflow will produce larger and more frequent shifts in last fish locations, other factors potentially affecting fish movements at the upper limits their distribution should be considered. These potential factors could be broadly classified as physical or biological. Physical factors that may be driving fish movement (other than physical barriers to movement, as discussed elsewhere) include

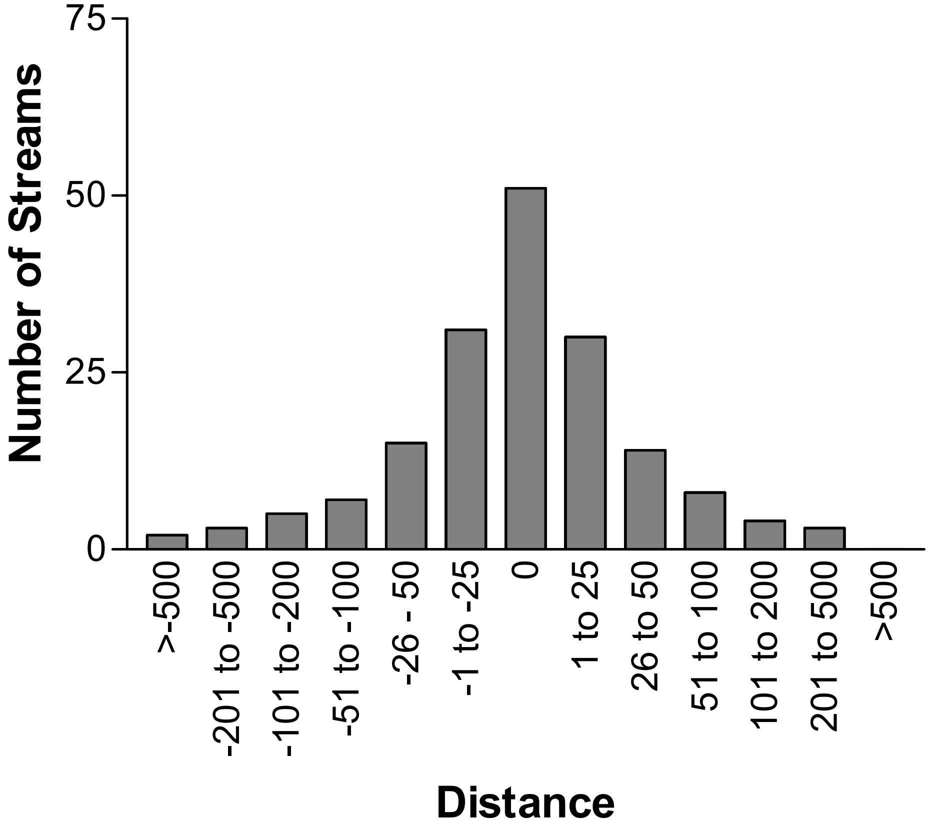

Figure 2. Distribution of distances (m) between terminal last fish locations established in eastern Washington in 2001 and resurveyed in 2002 (n = 172).

disturbance and recovery cycles, perhaps in response to periodic high or low flows or rarer events such as severe droughts or floods. Biological factors potentially affecting fish movements include food availability, biological interactions, and selective pressures towards remaining in the same location over time. Clearly, factors other than streamflow may affect the upper limits of fish distribution in streams, all of which require consideration when attempting to explain fish movements in these areas, particularly if future surveys performed under a wider range of flows fail to show larger shifts in last fish locations.

2002 LAST FISH POINT FEATURES ACROSS ALL SITES

Across all sites (terminal and lateral sites, combined), an abrupt change in stream size was most frequently recorded as the last fish feature, occurring at 159 of 309 sites (Figure 5). Such abrupt changes in stream size most often occurred at tributary junctions, where a non-fish-bearing channel intersected a fish-bearing channel; the last fish feature at 143 of 146 lateral last fish locations was classified as this feature type. Transient barriers were cited as the last fish feature at 26% of all sites (2 lateral points and 78 terminal points), while gradient increases, including waterfalls and barriers occurred at 16% of all last fish points (Figure 5).

FEATURES ASSOCIATED WITH 2002 TERMINAL LAST FISH POINTS

Terminal last fish points most often occurred immediately below small impasses created by large woody debris (Table 4), as such conditions occurred immediately above 78 of 164 (47.6%) terminal last fish points established in 2002. These woody debris jams ranged from 0.2 m to 3.0 m in height, averaged 0.9 m high, and most often produced a close-to-vertical barrier to upstream fish movement. Fish were often located above

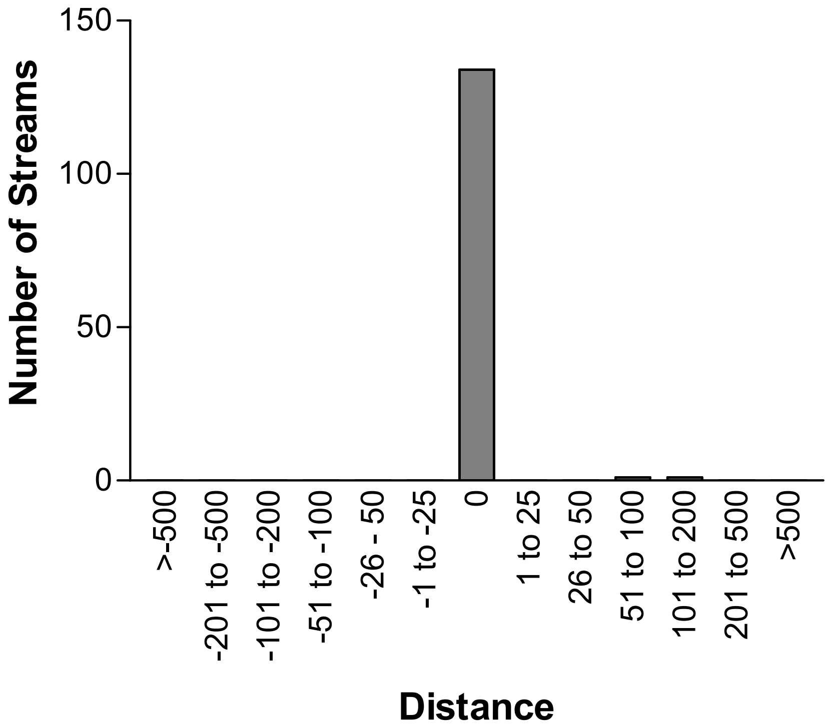

Figure 3. Distribution of distances (m) between lateral last fish locations established in eastern Washington in 2001 and resurveyed in 2002 (n = 136).

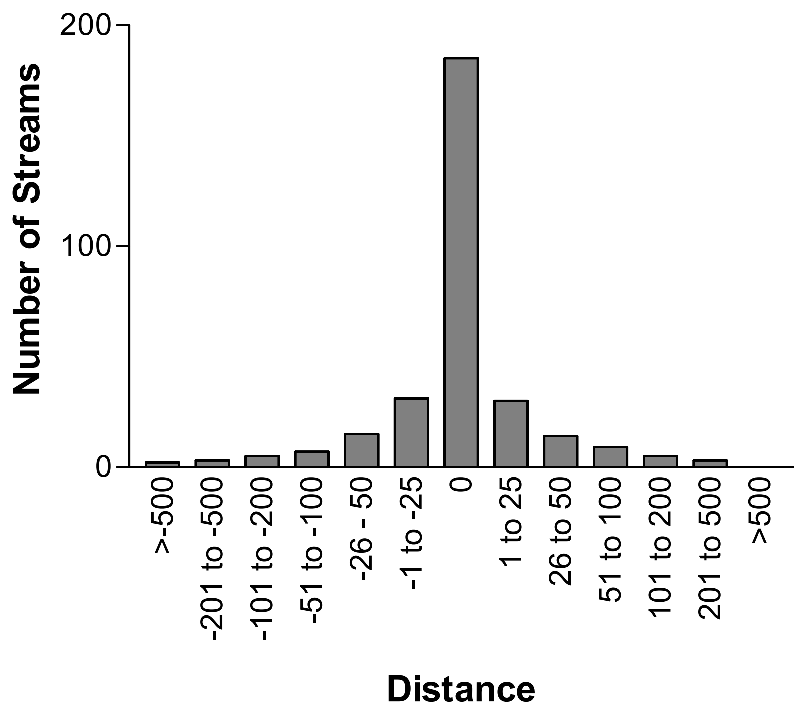

Figure 4. Distribution of movement (m) across all last fish locations established in eastern Washington in 2001 and resurveyed in 2002 (n = 309). Proportions are weighted by the relative occurrence of lateral and terminal points across the study area.

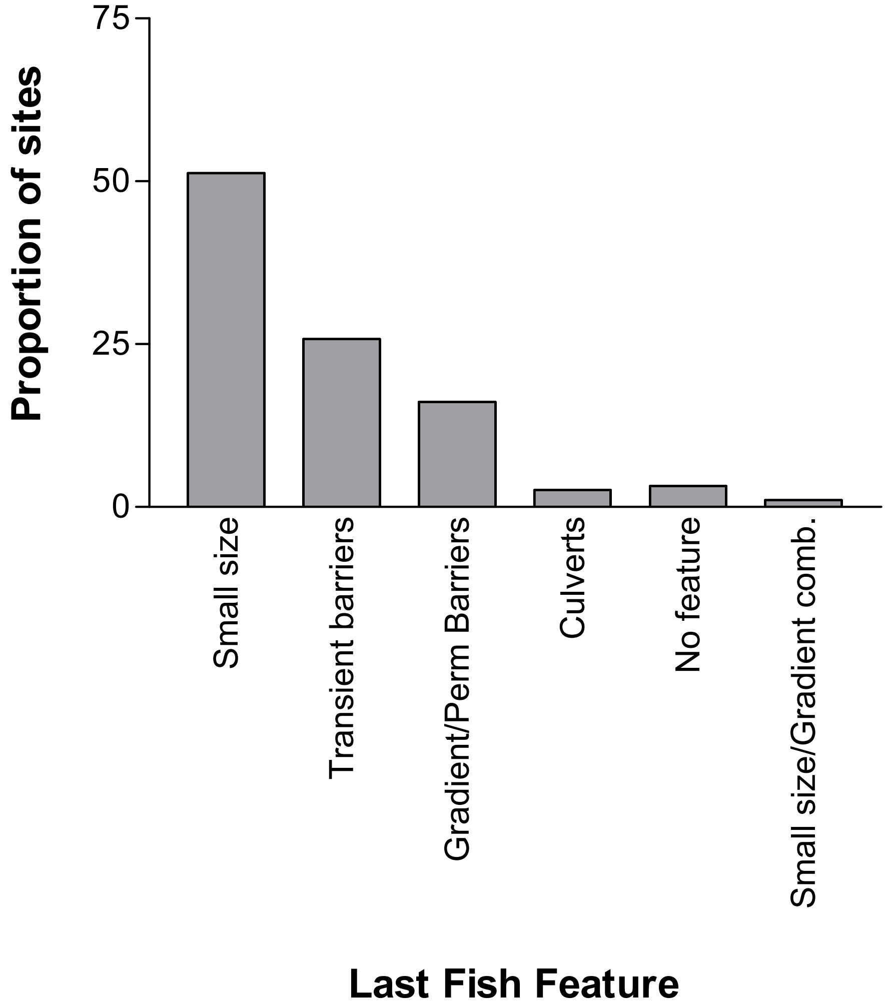

Figure 5. Frequency of occurrence of last fish feature types across all 2002 eastern Washington last fish resurvey sites (terminal and lateral sites, combined; n = 309).

debris jams in the range of the dimensions described above, suggesting, in part, that these small and transient barriers only temporarily impede upstream fish movements, especially if usable habitat occurs upstream, as was frequently encountered above these debris jams. The location and size of such barriers can shift from year to year, and fish may be able to negotiate some debris jams under certain flow conditions, depending on the particular structure and size of, and the resulting flow through and around, the barrier. Additionally, as long as fish occur above debris jams at the time they are formed, fish may remain above even those that appear to be completely impassable.

Gradient increased by an average of only 2.1% from below to above last fish points associated with woody debris jams. At 48 of 73 terminal last fish locations associated with woody debris, gradient increased by 3% or less. At 16 of these locations, gradient was lower above the impasse than it was below (Figure 6), indicating that, at most of these locations, upstream habitat is usable, and only temporarily being blocked by debris jams.

Last fish coincided with permanent gradient-related features at 49 of 164 (30%) terminal points. Most of these features were bedrock or boulder waterfalls or cascades; however, at eight of these 49 points, upstream fish use was prevented by an increase in stream

Table 4. Frequency of last fish features associated with 2002 terminal last fish locations (n = 164) established in eastern Washington during summer 2002.

Watershed	Large Woody Debris	Gradient (waterfall)	Natural End	Reason Not Apparent	Road Culvert	Size and Gradient
Big Sheep	3	0	2	0	0	0
Cabin	3	6	0	1	2	0
Cooper	6	6	2	0	0	0
Deer	5	1	2	3	2	0
Le Clerc	12	12	9	3	2	2
Naneum	14	9	1	3	0	0
NF Deep	6	2	0	0	0	0
NF Touchet	5	1	0	1	0	1
Rattlesnake	11	9	0	0	0	0
Taneum	13	3	0	0	1	0
Total	78	49	16	11	7	3
Percent	47.6	29.9	9.8	6.7	4.3	1.8

gradient without the presence of any particular obstruction. Vertical height of these waterfall and cascade obstructions ranged from 0.4 m to 30.0 m, averaged 5.4 m, and varied widely in length and gradient characteristics. As in 2001, fish were occasionally encountered above prominent waterfalls and cascades that clearly were barriers to fish passage.

Terminal last fish points coincided with a "natural end" on 16 of 164 occasions. Last fish was considered to occur at a natural end if the point coincided with a noticeable reduction or end in streamflow or channel dimensions. Some last fish points classified as natural ends occurred close to the stream origin, while most others occurred where flow was absent or became intermittent in association with increasingly smaller channel dimensions. On 11 occasions, the last fish point could not be related to any particular changes in channel or flow characteristics. Under such circumstances, stream characteristics appeared not to differ immediately above and below the last fish, yet no fish occurred above this point. At several of these locations, woody debris jams or other obstructions occurring some distance upstream were noted as potentially limiting distribution, but were not inventoried as were features more closely associated with last fish locations. Last fish points were associated with road crossings on only 7 of 164 occasions, while on only 3 streams was the last fish location related to changes in both stream size and gradient.

Terminal last fish points associated with waterfalls, cascades, and other permanent gradient-related impasses most often coincided with 2001 last fish points, as 57% percent of last fish points associated with gradient-related features occurred at the same location as 2001 last fish points (Table 5). Only 7 of 49 (14%) last fish points associated with gradient-related features occurred below 2001 last fish points; 4 of these occurred within 10 m of 2001 last fish. Only one of these 7 points was a prominent waterfall, located on stream number 299 in the Cooper River watershed. In 2002, last fish was located on this stream 664 m below the mapped 2001 last fish location. A second waterfall of about 7 m in height is located another 300 m above 2002 last fish, or approximately 364 m below the mapped 2001 last fish location. The stream was electrofished well beyond the suspected location of 2001 last fish (>700 m above 2002 last fish), but no 2001 tags were located in the field, despite thorough searches well up beyond the limits of usable habitat.

Last fish points associated with woody debris jams, natural ends, and where last fish features

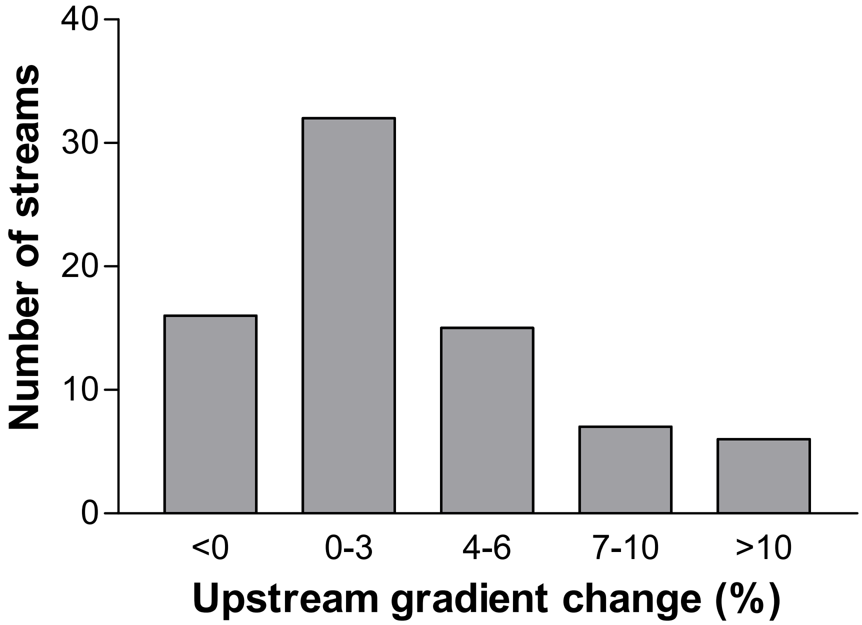

Figure 6. Distribution of change in gradient from below to above terminal last fish locations associated with woody debris jams (n = 78). Positive gradient change categories represent an increase in gradient above the barrier.

were not immediately apparent were more variable in relation to 2001 last fish points. Only 20% of 2002 last fish points occurring below woody debris jams coincided with 2001 last fish points; fish had moved upstream or downstream at 43% and 37% of these locations, respectively. Few (6%) terminal last fish points associated with natural ends in 2002 coincided with 2001 last fish points. Upstream and downstream movement occurred at 50% and 44%, respectively, of these points associated with natural ends. Likewise, 2002 last fish coincided with 2001 last fish at only 20% of locations where last fish features were not readily identifiable. These data suggest that, as would be expected, streams with upstream fish use being impeded by permanent barriers such as waterfalls and cascades show the lowest variability in year-to-year changes in last fish locations. Last fish points occurring at small transient barriers and where habitat may expand or contract with changes in streamflow appear to exhibit more variability than those in association with larger and more permanent barriers. Data for 2001 last fish features could be used to further examine these relationships between last fish point variability and last fish feature types.

HABITAT CHARACTERISTICS AT TERMINAL LAST FISH LOCATIONS

Habitat characteristics varied widely among 2002 terminal last fish locations; stream bankfull and wetted widths above last fish ranged from 0.6 to 11.0 and 0.2 to 10.4 m, respectively. Wetted width above terminal last fish locations averaged 1.7 m; bankfull width above averaged 2.5 m. Stream gradient above and below terminal points ranged from 1.0 to 49.0% and 0.8 to 23%, respectively. Average stream gradient increased from 10.7% below terminal last fish points to 14.6% above terminal last fish points. Terminal last fish points most frequently occurred at bankfull and wetted widths ranging from less-than-one to two meters, and at gradients ranging from 10 to 20 percent (Figure 7). Pool counts above and below terminal last fish points varied widely, as well, with pool frequencies (pools > 15 cm deep per 100 m) of 5-10 and 10-15 per 100 m occurring most often both above and below terminal points (Figure 7).

Channel dimensions at terminal last fish points in wilderness watersheds were significantly larger than in managed watersheds, as indicated by

Table 5. Distribution of distances between 2001 and 2002 terminal last fish (LF) locations in relation to last fish feature type (n = 164).

Distance between 2001 & 2002 LF (m)	Last Fish Feature (%)* Large Woody Debris	Gradient**	Natural End	Reason Not Apparent
>-100	3.8	2.0	0.0	20.0
-11 to -100	19.2	6.1	37.5	30.0
-1 to 10	14.1	6.1	6.3	0.0
0	20.5	57.1	6.3	20
1 to 10	5.1	6.1	6.3	0.0
11 to 100	32.1	20.4	25.0	30.0
>100	5.1	2.0	18.8	0.0

* Does not include road culverts and size/gradient combination (fewer than 10 observations in each category.
** Gradient includes waterfalls, cascades, and significant increases in stream gradient.

Mann Whitney U tests of bankfull ($p < 0.001$) and wetted ($p < 0.001$) widths. Bankfull widths above terminal last fish points in wilderness areas averaged 3.9 m (SD = 1.5), while bankfull widths above last fish locations in managed watersheds averaged only 2.1 m (SD = 1.7). Similarly, wetted widths above terminal last fish points in wilderness areas averaged 2.4 m (SD = 1.9), while bankfull widths above last fish locations in managed watersheds averaged only 1.5 m (SD = 1.2). Gradients were somewhat higher above terminal last fish locations in wilderness watersheds than in managed watersheds, averaging 18.1% and 13.7% in the two types of watersheds, respectively. These results suggest that last fish locations tend to occur in larger, higher order streams (i.e. lower in the drainage network) in wilderness watersheds than in managed watersheds. Almost half (44%) of all terminal last fish locations in wilderness watersheds occurred at permanent gradient-related features, such as waterfalls or cascades, while only 26% of terminal last fish points in managed watersheds were associated with such features. Several plausible explanations may account for this apparent pattern, including differing historic fish stocking patterns between managed and wilderness areas, or differences in topography and resulting stream morphology between managed and wilderness areas. Wilderness areas may occur in more "rugged" mountainous terrain, where waterfalls and other prominent physical features may restrict fish movement, and channel gradient may begin to limit fish movements in higher order streams.

HABITAT CHARACTERISTICS AT LATERAL LAST FISH LOCATIONS

Lateral last fish points occurred almost exclusively at abrupt changes in stream size and/or gradient. Stream habitat above lateral points was generally characterized by very limiting channel dimensions, particularly wetted channel widths (Figure 8), by steep channel gradients, or by a combination of these two features. Wetted width above lateral last fish points averaged 0.5 m (range 0.0–2.3 m); bankfull width averaged 1.4 m (range 0.2–5 m). No surface water (wetted width = 0.0 m) occurred in 49 channels (34%) above lateral last fish points. Channel gradient above lateral last fish points averaged 16.7% and ranged from 1.6% to 90%. Gradient above lateral last fish points exceeded 20% at 40 of 146 lateral sites. Pools > 15 cm deep above lateral last fish points occurred infrequently, and were often absent, as frequency averaged 2.3 pools per 100 m of channel (range 0–19/100 channel m). Pool habitat (pools > 15 cm deep) above lateral last fish locations was absent in 86 (59%) channels.

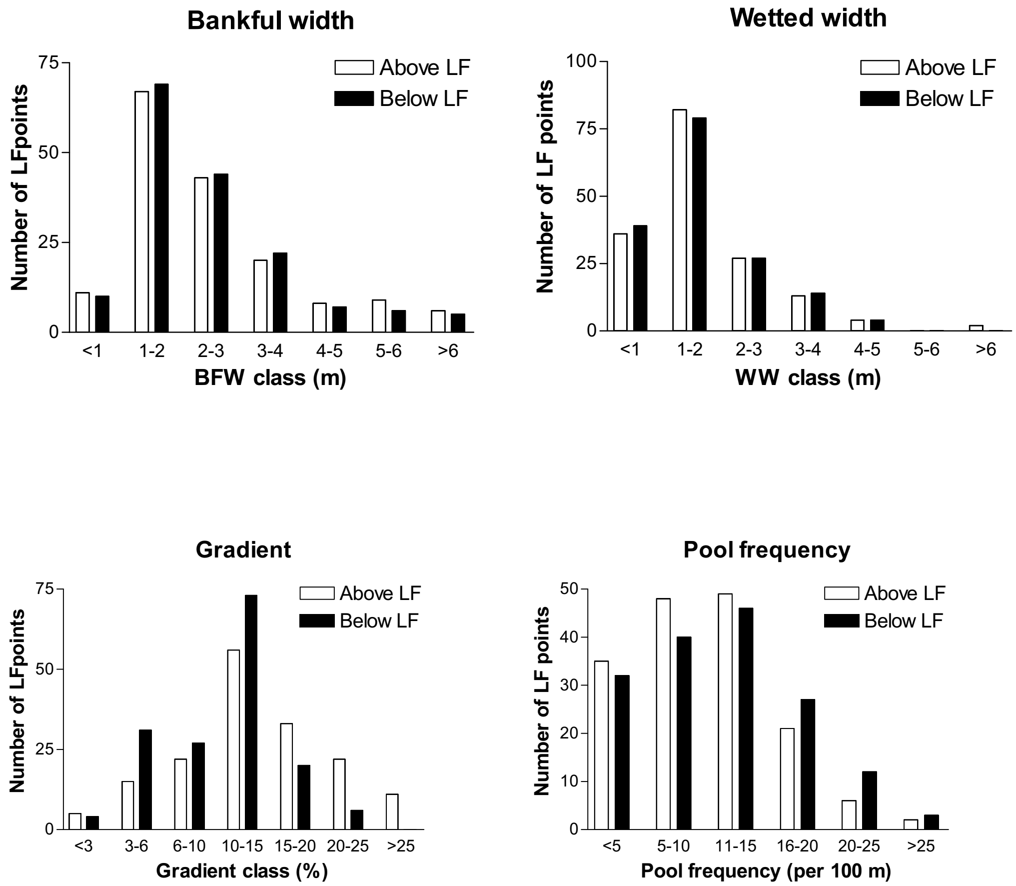

Figure 7. Frequency of occurrence of habitat characteristics at terminal last fish points surveyed in eastern Washington in 2002 (n = 164).

SPECIES ENCOUNTERED

Five species of fish were observed during 2002 resurveys, including cutthroat trout (*Oncorhynchus clarki*), brook trout (*Salvelinus fontinalis*), bull trout (*Salvelinus confluentus*), redband trout (*Oncorhynchus mykiss*), and sculpin (*Cottus* spp.) (Table 6). Surveyors were unable to identify one last fish that eluded capture (noted as an unknown salmonid in the database). Across all watersheds, cutthroat trout were the most commonly encountered fish, occurring in eight out of ten watersheds. Brook trout occurred in five watersheds, and were the most frequently encountered last fish in the Big Sheep and Deer Creek drainages.

Redband and bull trout were observed only in the NF Touchet watershed, where they were the only two species encountered. Bull trout were reported from five tributaries to the NF Touchet, and were last fish in four of these tributaries. Redband trout were last fish observed in three streams in the NF Touchet drainage; one last fish in the NF Touchet system (stream 330) eluded capture. Because this fish could have been a bull trout, further efforts to capture and identify the fish were avoided to prevent injuring or killing the individual.

Bull trout were reported from three streams in the Rattlesnake Creek watershed in 2001, but never as the last fish observed (Cupp 2002). Bull trout were not sampled from the Rattlesnake drainage in 2002, likely because 2002 sampling efforts in the Rattlesnake Creek system were directed towards the upper reaches of stream systems where 2001 last fish points had previously been established.

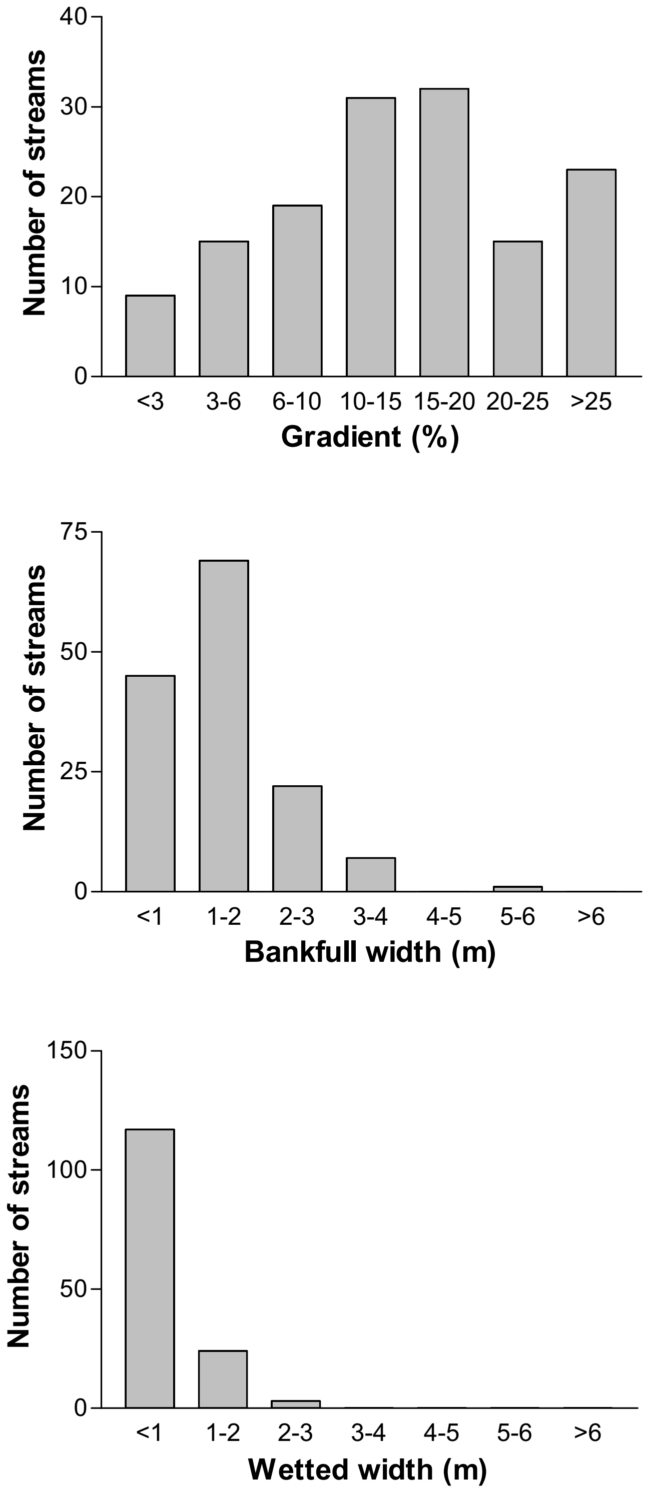

Figure 8. Frequency of occurrence of habitat characteristics occurring above lateral last fish points established in eastern Washington in 2002 (n = 136).

Table 6. Fish species observed in each watershed during 2002 last fish resurveys in eastern Washington.

Watershed	Cutthroat trout	Brook trout	Bull trout	Redband trout	Sculpin spp.
Big Sheep		X			
Cabin	X				
Cooper	X	X			
Deer	X	X			
Le Clerc	X	X			
Naneum	X				X
NF Deep	X				
NF Touchet			X	X	
Rattlesnake	X				
Taneum	X	X			

LAST FISH ERROR DISTANCE

Last fish error distance (ED) surveys were performed on 28 streams on which terminal last fish points were established in 2002 (ABR was initially provided with a list of 29 ED sites). Twenty seven of these streams were selected from randomized lists of terminal last fish points. One site (Taneum 300) was selected in the field during the last few days of sampling, when it was determined that 400 m of this stream could be sampled without encountering any significant barriers above the established last fish point. Four passes on reach lengths varying from 150 to 400 m were performed on each of these 28 stream reaches. Distance covered was less than 400 m only when the stream channel became and remained dry through the remaining length of the reach; 7 of 28 EDS streams were surveyed for fewer than 400 m for these reasons.

On 27 of 28 ED surveys, no fish were encountered above last fish established by the first pass. On one ED survey, one fish was observed during the second pass 0.5 m upstream of last fish established during the first pass, and one fish was captured 14 m above 2002 last fish during the third pass. It is worth noting that the only ED survey that produced fish was the first ED survey performed by the crews, when ED survey methods and effort were being taught, tested, and refined. Error distance was 0 m on 27 of 28 streams and 14 m on one stream; mean error distance among all streams was 0.5 m.

Our data indicate that the survey effort employed was sufficient to accurately locate last fish points. Concern that last fish locations may not reliably be determined with electrofishing gear has arisen because it is known that electrofishing can produce low fish detection rates. ED surveys for this study were performed almost entirely above relatively distinct habitat breaks (primarily woody debris jams), below which sampling efficiently revealed fish presence, and above which (where the ED survey was performed) no fish occurred. Even with detection rates well lower than 100%, fish would have been detected, had they been present above these last fish points. Additionally, almost all of our sampling was performed under ideal sampling conditions, including low streamflows and clear water, sampling from small habitats, where fish cannot easily escape above or below the crew, and using two-person crews. Each of these factors contributed to the ability of crews to reliably locate last fish points. Additionally, we intentionally selected sites that were most likely to provide an opportunity to miss fish (by omitting those sites with obvious barriers from EDS sampling); these data are therefore a conservative estimate of survey error across the study area.

PROBLEMS ENCOUNTERED

Problems encountered were often immediately communicated to ISAG members and solutions to the problems were offered in a timely manner. A brief summary of the problems that ABR encountered during the field work period follows.

FIELD WORK SCHEDULE

Field work for this project began in early July, almost a month later than the proposed start date. Delays in bull trout permit processing further postponed sampling in watersheds with bull trout until the last week of July, while the permit required the completion of sampling in known bull trout spawning watersheds by August 12th in the Yakima basin (Rattlesnake Creek) and August 15th elsewhere in eastern Washington (LeClerc Creek and NF Touchet River). These time constraints imposed by the bull trout permit precluded completion of all lateral last fish points in the Touchet and LeClerc watersheds. In the Touchet watershed, two lateral sites were not surveyed because the effort required to reach the sites would have required an extra day of sampling in the watershed, and it was clear that the crew needed to begin work in the LeClerc if sampling was to be complete by August 15. In the LeClerc, only 23 of 34 lateral last fish points were sampled before the August 15th deadline arrived. Four additional lateral sites in the LeClerc were checked, but not surveyed by the crews because they lacked a defined channel (see below).

ABSENCE OF DEFINED CHANNELS

Lateral point resurvey lists sometimes included sites without defined channels. In Deer Creek, the first watershed sampled in 2002, this problem was most frequently encountered, as 21 of 26 lateral last fish points had no channel. We again encountered multiple draws without channels in the Naneum system, the second watershed surveyed. New lateral site lists were generated after an effort was made to remove draws without defined channels from the list of candidate sites. The new site lists generally included fewer draws without defined channels, but several lists still included a number of such locations that were identified in the field and omitted from sampling.

ED SURVEY SITE SELECTION

Error distance surveys were performed on a randomly-selected subset of 2001 terminal last fish points. The subset was first selected from the pool of all 2001 terminal last fish points, and therefore included sites where last fish would occur in close proximity to last habitat, above which fish were very unlikely to occur. ED surveys were performed on only 4 of 8 initially-selected sites in the Naneum watershed because 4 of the candidate last fish points were closely associated with impassable features. Subsequently, ABR received a final list of ED survey sites to be completed (dated 8-20-02) and completed surveys on 10 of the 11 sites listed. One site was not surveyed because conditions did not allow effective sampling with electrofishing gear at this location (stream 162 in the Cooper River system, as described earlier). A suitable replacement stream (#300) was selected in the Taneum watershed based on the distance between 2001 last fish and last habitat. In total, ED surveys were performed on 28 streams; the initial site list provided to ABR listed 29 streams.

RECOMMENDATIONS

LATERAL SITE SELECTION

Many lateral sites, even some that had defined channels and surface flow, clearly would never support fish. Efforts to quantify variability in last fish locations could be better spent by focusing on a subset of lateral last fish locations where drainage size and reach-scale characteristics would not be certain to preclude fish use. This year's data could be used to relate stream characteristics (channel dimensions, gradient, presence of a defined channel, etc.) to drainage area. Then, drainage area could be used to remove from the sample set lateral points above which fish will likely never occur. Excluding sites from the sample set that will not support fish under any circumstances would allow field efforts to focus on collecting data that are most useful to quantifying variation in last fish locations and avoid having crews making repeated visits to locations that would not support fish under any circumstances.

ADDITIONAL FIELD DATA

Changes in the upper limits of fish distribution likely will be most influenced by two factors: the destruction and creation of transient barriers (i.e., debris jams) and changes in streamflow, which expand or contract the amount of suitable habitat. Currently, no methods exist to accurately quantify changes in streamflow in these watersheds, which would likely contribute valuable information to efforts to relate changes in fish distribution to environmental conditions. Streamflow data could be collected at several predetermined locations within each watershed to allow precise and accurate collection of discharge data at the time that last fish resurveys are performed. We suggest collecting streamflow data using standard methods and an electromagnetic flowmeter.

Because last fish locations are frequently associated with temporary debris jams, we suggest recording the location and dimensions of all small drops and jumps created by boulders and woody debris, for 100 m both above and below last fish locations. Gradient measurements could be measured in degrees with a clinometer to allow measurement of all barriers at all angles, and these measurements could be included in channel gradient measurements to allow production of a detailed stream channel profile that includes all breaks that potentially could restrict upstream fish movements.

ADDITIONAL SAMPLING

Discharge data from eastern Washington watersheds indicate that both 2001 and 2002 surveys occurred during low-water years. Because variation in streamflow is likely to produce the most pronounced shifts in fish distribution, resurveys of these watersheds should occur when streamflows are higher to reexamine last fish locations. Efforts could be focused on streams where increased streamflow may allow upstream movements (i.e., streams other than those where last fish occurs at a prominent waterfall). Seasonal variation in last fish locations also could be examined in relation to seasonal changes in discharge. Specifically, highest flows tend to occur in the study watersheds in late spring, perhaps allowing fish movements considerably farther upstream than late summer sampling indicates. Sampling during these high-water periods would be difficult and dangerous for field crews, but sampling could be performed earlier or later in the year, when streamflows are higher than late summer low flows, yet not too high to preclude effective sampling.

LITERATURE CITED

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