Detecting the Upstream Extent of Fish in the Redwood Region of Northern California[1]

Aaron K. Bliesner[2] and E. George Robison[3]

Abstract

The point at which fish use ends represents a key ecological and regulatory demarcation on state and private forest land in the Redwood region. Currently, the end of fish use and other key demarcations with stream classification are measured or estimated based on judgments of Registered Professional Foresters and aquatic biologists with little guidance from empirical study of the issue in this region.

This study establishes a standard protocol for the detection of the end of fish use in streams, which reduces the effort required to produce quality data. During electrofishing the maximum distance traveled between fish presence in delineated habitat units was 289 m. This distance decreased as the slope of the channel increased. In 63 percent of the streams the distance was less than 20 m and in 96 percent the distance was less than 100 m. Fish were found in all habitat units the most abundant was pools at 56 percent of the time. This study has indicated that a pool based method will not give an accurate indication of the end of fish use in streams. A more accurate method should be based on distance were the all habitat units are shocked. In streams with low gradient a minimum of 300 m should be surveyed during the study. In streams were a gradient break of a minimum of eight to12 percent exist this study has indicated the 60 m is sufficient to survey to indicate the Class I, Class II break.

Key words: channel gradient, Class I, Class II, electrofishing protocol, headwater streams

Introduction

Current regulations in California dictate the degree of riparian buffer zone protection to be allocated based on the stream's classification. In California there are three categories, Class I (fish bearing), Class II (aquatic life), and Class III (without aquatic life) (CDF 2004). In recent years the distinction between where Class I ends and Class II begins as you move upstream has become increasingly more contentious. During the last five years the California Department of Fish and Game has refuted 85 percent of the watercourse classifications submitted in timber harvest plans during pre-harvest inspections (BOF 2003).

Extensive research has been conducted on the critical habitat requirements for salmonids in the Pacific Northwest Ecoregion (CDFG 1998, Spence 1996). However, little work has been conducted with trout near the maximum upstream range. Work

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[2] Graduate Student, Department of Forestry and Watershed Management, Humboldt State University, 1 Harpst Street, Arcata, CA 95521. email: akbliesner@yahoo.com

[3] Professor, Department of Forestry and Watershed Management, Humboldt State University, 1 Harpst Street, Arcata, CA 95521.

has been conducted on the upper limits of fish in Washington, Oregon, British Columbia and Alaska (Latterell and others 2003, MELP 2001, ODF and ODFE 1995, Sullivan 1997). The upper extent of fish distribution remains poorly understood in the redwood region of Northern California and a clear field tested methodology for testing the upper limits of fish in headwater streams has yet to be designed for this region.

The California Forest Practice Rules make no distinction of species of fish required to deem a stream a Class I. In this region resident cutthroat trout *(Oncorhynchus clarki clarki)* and rainbow trout *(Oncorhynchus mykiss)* are able to maintain viable populations in rugged headwater environments (McPhail 1967, Wydoski and Whitney 1979). The headwater environment can be affected by land management practices. Biological factors such as sources of food, water quality, biological interactions, flow regime, and habitat structure (Karr 1991), particularly in managed systems may influence the distribution of fish in headwater streams (Gordon and Forman 1983, Odum 1985, Rapport 1992, Steedman and Regier 1987).

Latterell and others (2003) found that timber harvest in the state of Washington had very little effect on the upstream extent of resident trout populations unless impassable culverts were present. Past management practices and current regulations may in fact lead to an extension of the upstream limit of fish. The practice of removing large woody debris obstructions and other barriers up until the late 1960s may have allowed fish easier access to headwater regions (Narver 1971). This coupled with hydraulic processes associated with timber harvest (for example, reductions in evapotransporation leading to increased summer runoff and an increase in the active channel up into the watershed) allow for increased opportunity for fish to colonize headwater portions of the stream (Ziemer and Lisle 1998).

The protocol developed for Oregon requires a minimum of 45.7 m of stream to be electrofished without fish present and a minimum of six pools before the end of fish use can be determined (ODF and ODFE 1995), similar methods were used in Washington. In British Columbia the distance of 100m electrofished was sufficient without fish present to be classified as a Class II stream MELP 2001. More recently Latterell and others (2003) used 400 m minimum unless the gradient of the stream exceeded 30 percent. In the state of California methods for determining the presence/absence of coho salmon *(Oncorhynchus kisutch)* were developed by the Department of Fish and Game (Preston and others 2002). These methods describe the electrofishing of ten pools before absence determined.

Data are not yet available to ascertain whether or not these methods are accurate in determining the end of fish use in Northern California. For this reason this protocol has been designed to be the most detailed and comprehensive field investigation into the end of fish usage in headwater streams. In this paper, a field sampling method is developed and described that insures consistent comparable results and accurate determination of the end of fish use. The objective of this paper is to examine the end of fish use in streams under rigorous field examinations. Then develop a protocol that will define the class I, class II break in small headwater streams that is both accurate and cost effective. The development of this protocol is a portion of a larger study designed to correlate landscape features to the end of fish use for all tributaries within the redwood region of Northern California.

Methods

All data was collected within the 84,987 hectare land holdings of the Pacific Lumber Company near Scotia, California. The tributaries within the major watersheds sampled were Freshwater Creek, the Eel River, Elk River, Van Duzen River, and Mattole River. The maximum inland extent of the study range follows closely the inland extent of redwood in this region.

Electrofishing Protocol

The starting point for electrofishing was determined using maps and current class I, class II breaks. Moving upstream, habitat units were delineated as defined by McCain and others (1990). Visual inspections were conducted until fish were no longer visibly present. At this point electrofishing was started. During all field operations there was one person electrofishing and one person netting to help insure that fish were not missed. Each habitat unit was electrofished until the last fish was documented. At this point a 20 pool electrofishing survey was started. The survey consisted of shocking all habitat units but keeping only a tally of the number of pools to indicate the point to stop the survey. None of the previously stated methods for determining the last fish delineate the habitat units and few shock other units besides pools. If a fish was encountered during the 20 pool survey, the survey was started again. Pools were defined as per McCain and others (1990) and had a maximum depth greater than 0.25 m. No streams were encountered that did not meet this requirement (in other words, 20 pools with depths greater than 0.25 m).

Often in headwater streams portions of the active channel can become dry with the majority of the water going underground. Large wood can also obstruct the active channel completely making electrofishing impossible. In theses cases the unit codes were subsurface or complex in the case of large wood and not electrofished. These units were not used as part of the 20 pool count. Each unit was shocked for ample time to achieve an adequate depletion and shock time reflected the quality of the habitat. All shock times were recorded.

During the first year of this study additional units were shocked in streams were suitable habitat appeared to test the protocol. If suitable habitat was found and there were no blockages present above the 20 pool survey then a rapid 20 pool protocol was conducted to test for resident populations of fish. In this method 20 pools were electrofished and units in between were ignored.

Fish were identified to species and fork length was measured (mm). Amphibians were removed from the shock field and identified to species. Fish and amphibians were replaced in the units they were removed from during electrofishing.

Correlating Landscape Features

At each site three flow measurements were taken. In headwater streams it is difficult to use the velocity area approach to quantify discharge because headwater streams tend to be too shallow to obtain accurate readings. Instead, flow measurements can be taken accurately with a bucket of a known volume. In this method the bucket is placed at a drop where the water is funneled down to a width less than the diameter of the bucket. The time that it takes the bucket to fill was recorded. This procedure was repeated three times at each site and an average of the three was recorded as the discharge.

Temperature (ambient and water), conductivity, pH and a turbidity sample were taken at the start of each new reach to calibrate the electrofisher to water conditions.

Step and fall vertical heights (m) were recorded from the water surface at the bottom to the water surface at the top and the nature of the blockage was recorded (for example; rock, wood, or bedrock). Three depth and three wetted width measurements were taken when possible along with a max depth (m) and pool sill depth (m). The total length (m) of each was also recorded. Several bank full depths (m) were taken within the reach whenever possible. The substrate dominate and co-dominate of each unit was estimated in terms of composition and competency.

Gradient measurements were taken 100 m below and 100 m above the last fish documented. A water level was created and consisted of a 15 m hose filled with water, with both open ends placed between two stadia-rods and held with a temporary tie. The water level was calculated simultaneously at each rod and the distance between the two rods was recorded to determine the overall gradient. Orange flagging was left at the upstream location of measurement, enabling the downstream surveyor to locate the upstream spot and maintain a continuous survey. This was repeated throughout the entire reach until the survey was completed. To calculate gradient the following equation was used $g = (h-h^2*d-1) *100$ (Walkotten and Bryant 1980) where g is the gradient, h is the downstream measurement, h^2 is the upstream measurement, and d is the distance between measurements. For streams where instream complexity or location prevented surveys, gradient was calculated using Terrain Navigator Pro®[4] (version 3.0 2004).

For each stream surveyed the total watershed area was calculated. The end of fish use points collected were located with GPS equipment when possible and then located on a map. The majority of the sites selected for this study were in steep valleys and heavily wooded. At times these two factors made it impossible to receive accurate GPS readings. At sites where GPS coordinates were not possible to obtain, stream lengths were used to identify end of fish. This data was then entered into mapping software (Terrain Navigator Pro®[4] version 3.0, 2004) and watershed areas and slopes were delineated.

Results

A total of 37 tributaries in Freshwater Creek, the Eel River, Elk River, Van Duzen River, and Mattole River watersheds were sampled during the early portion of summer 2003 (May 16 to July 10) and 2004 (April 7 to July 16). Of these 37 tributaries, eight streams that were sampled contained no fish. The 29 remaining steams with fish present were used for the development of the final end of fish this protocol described earlier. Results from this extensive electrofishing survey show that pools should be at least 0.25 m in depth to be counted as a pool for this protocol. The minimum distance traveled during the 20 pool protocol was 104 m.

Every creek received at least the extended protocol detailed above, of electro-fishing twenty pools and all habitat types in between. A total of 60 pools were electroshocked on Cummings Creek West, the stream with the largest watershed area above the end of fish use. In three streams, 40 pools were electroshocked. During these extended efforts no fish were detected. This indicated that the 20 pool protocol

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[4] The use of trade of firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any project or service.

was sufficient and after the first year the rapid protocol in addition to on top of the original method was abandoned. In all cases the initial standard protocol was sufficient in defining the end of fish presence.

At or near the end of fish in streams the only fish captured were either cutthroat or rainbow trout. The average fork length of all trout collected at the upstream limit of their distribution was 154 m with a (range of 102 to 254 m) (standard deviation = 53 mm). Only one trout demonstrated signs of being anadromous, displaying standard signs of smoltification (change in body shape, silver color, and loss of parr marks). This particular fish was captured in came from Graham Gulch, which has the most direct rout to the ocean of any tributaries sampled in this study Young-of-the-year fish were not present within a maximum of 57 m of the end of fish presence, with the exceptions of two creeks, Dunlap Gulch and an unnamed tributary to Lawrence Creek. At these two creeks the last fish present was a young-of-the-year fish.

Stream gradient appeared to play a major role in excluding fish from reaches. Stream gradient was obtained using the water level for all but eight streams, where in-stream complexity and location made use of the water level impossible. Overall, average gradient for all streams surveyed was 10 percent with a range of two percent to 17 percent (standard deviation = 13 percent) *(table 1)*. The average gradient where fish were present was 53 percent (standard deviation = 4 percent) and the average gradient where fish were not present was 11 percent (standard deviation = 16 percent) *(table 1)*. The maximum average stream gradient where fish were present was in Devil's Elbow Creek at 19 percent (standard deviation = 13 percent) *(table 1)*.

Watershed areas ranged in size from 15 ha to 680 ha for all creeks *(table 2)*. Excluding the eight streams without fish present; the smallest watershed area was Fox Creek at 26 ha *(table 2)*. Graham Gulch covers the largest watershed area at 568 ha. The average watershed area for the streams with fish present was 177 ha (standard deviation = 115 ha) *(table 2)*.

A critical component in scrutinizing the electrofishing protocol was the number of habitat units between fish present and the distance between these units. The average number of units between fish was six (standard deviation = seven) *(table 2)*. The average distance between units with fish present was 33 m (standard deviation = 58 m) *(table 2)*. Two creeks, Graham Gulch and Clapp Creek East, proved to have inconsistent numbers of units between fish and subsequently large distances between units with fish present, when compared to the other 35 creeks surveyed in this study. In Graham Gulch, there were 36 units between fish, covering a total distance of 289 m *(table 2; fig. 1)*, which is four times greater than the same distance measurement for any other creek. Clapp Creek East had a maximum of seven units between fish, which was not abnormal, but a distance of 68 m was covered between fish. As a result of the anomalous natures of Graham Gulch and Clapp Creek East, data from these creeks were excluded, and an additional analysis was performed.

When Graham Gulch is excluded, the highest number of units between fish was 12 units and the average was four units (standard deviation = three) *(table 2; fig. 2).* Clapp Gulch East was very complex and most of the units that made up the distance between fish were not electrofished. The average distance between fish present without Graham Gulch and Clapp Gulch East, was 20 m (standard deviation = 19m) *(fig. 2).*

Table 1—*Average gradient (percent) taken for 36 creeks in Northern California using a water level, unless otherwise stated. Values are geometric means (values in parentheses are standard deviations).*

Creek	Gradient with fish present	Gradient without fish present	Total stream gradient
Allen Creek	--a	56.7 (120.7)	56.6 (120.7)
Balcom Creek	--a	6.4 (5.3)	6.5 (5.3)
Bell Creek	7.4 (3.6)	4.3 (3.24)	5.3 (3.5)
Blanton Creek	3.3 (--b)	4.3 (--b)	3.8 (--b)
Browns Gulch	2.4 (2.5)	4.0 (4.5)	3.1 (3.6)
Byron Creek	--a (--b)	4.3 (--b)	4.2 (--b)
Clapp Creek East	8.8 (--b)	29.3 (--b)	19.0 (--b)
Clapp Creek West	5.1 (--b)	27.6 (--b)	16.4 (--b)
Corner Creek	11.2 (7.0)	27.0 (17.4)	20.9 (16.0)
Corrigan Creek	6.1 (11.6)	16.7 (12.1)	11.7 (12.7)
Cummings Creek East	5.4 (1.3)	40.5 (107.0)	21.3 (80.6)
Cummings Creek West	13.0 (4.8)	20.9 (28.4)	13.7 (16.6)
Dauphiny Creek	4.7 (3.0)	9.3 (2.7)	7.0 (3.6)
Devil's Elbow Creek	18.5 (13.0)	23.4 (11.5)	20.6 (12.4)
Dunlap Gulch	4.0 (2.7)	4.2 (4.3)	4.1 (3.3)
Fish Creek	5.1 (2.8)	5.9 (5.0)	5.5 (3.9)
Fox Creek	3.5 (3.1)	3.5 (2.6)	3.5 (2.7)
Graham Gulch	5.9 (2.0)	12.8 (7.0)	9.5 (6.2)
Mardell Creek	5.4 (3.8)	6.1 (3.2)	5.8 (3.4)
McCann Creek	19.4 (29.1)	--c	19.4 (29.1)
Poison Oak Creek East	6.1 (4.5)	15.3 (6.7)	16.2 (6.8)
Poison Oak Creek West	6.1 (4.5)	14.1 (6.6)	10.4 (6.8)
Root Creek East	6.9 (4.2)	76.3 (144.0)	56.8 (125.4)
Root Creek West	--a (--b)	11.9 (--a)	11.9 (--a)
Shively Creek East	3.0 (2.1)	5.5 (4.6)	4.2 (3.7)
Shively Creek West	3.5 (2.4)	8.0 (16.9)	6.2 (13.0)
Strawberry Creek	3.9 (3.3)	8.2 (7.1)	6.3 (6.0)
Strongs Creek Main	5.2 (--b)	19.5 (--b)	12.4 (--b)
Strongs Creek East	1.0 (--d)	5.7 (27.5)	2.4 (27.3)
Strongs Creek West	--a	44.6 (73.5)	44.4 (73.5)
Unnamed Paired Creek to Van Duzen River East, Confluence	2.6 (2.5)	11.5 (10.9)	6.4 (8.4)
Unnamed Paired Creek to Van Duzen River West	--a	3.8 (4.2)	3.8 (4.2)
Unnamed Tributary to Van Duzen River East	9.6 (3.0)	5.8 (4.2)	6.5 (4.2)
Unnamed Tributary to Van Duzen River West	--a	18.4 (15.6)	18.4 (15.6)
Unnamed Tributary to Lawrenece Creek (Road 8)	10.0 (6.3)	17.2 (23.5)	13.4 (16.7)
Unnamed Tributary to Yager Creek	3.6 (18.8)	36.0 (12.1)	33.6 (22.8)
West Fork Elk River	0.7 (--b)	18.1 (--b)	9.4 (--b)
Total	4.8 (4.5)	17.7 (16.2)	14.1 (13.4)

[a] No fish present in creek
[b] Gradient calculated using Terrain Navigator Pro®
[c] Culvert blocking fish passage
[d] One gradient measurement taken

Table 2—*Summary of habitat units sampled below the Class I, Class II break for 36 creeks in Northern California.*

Creek	Total units	Units with fish	Units without fish	Pools	Low gradient riffles	Vertical units [b]	High gradient riffles	Runs	Farthest between [c]	Farthest between distance (m) [d]	Area (ha)
Allen Creek [a]	0	0	0	0	0	0	0	0	0	0	250
Balcom Creek [a]	0	0	0	0	0	0	0	0	0	0	110
Bell Creek	4	3	1	2	2	0	0	0	1	2.7	129
Blanton Creek	9	9	4	5	4	0	0	0	0	2	680
Browns Gulch	4	1	3	1	0	0	0	0	3	13.7	212
Byron Creek [a]	0	0	0	0	0	0	0	0	0	0	528
Clapp Gulch East	36	14	22	11	2	0	0	1	7	68	117
Clapp Gulch West [a]	0	0	0	0	0	0	0	0	0	0	33
Corner Creek	1	1	1	0	0	0	0	0	0	--	454
Corrigan Creek	1	1	1	0	1	0	0	0	0	--	35
Cummings Creek East	14	8	6	1	3	1	1	0	3	14.6	135
Cummings Creek West	9	1	8	0	0	0	1	0	8	7.6	243
Dauphiny Creek	10	4	6	4	0	0	0	0	2	5.8	153
Devil's Elbow Creek	27	13	14	6	2	0	5	0	7	59.7	138
Dunlap Gulch	81	15	66	10	3	0	0	2	12	47.6	121
Fish Creek	1	1	1	0	0	0	0	0	0	--	111
Fox Creek [e]	23	10	13	13	0	0	0	0	--e	--	26
Graham Gulch	64	6	58	6	0	0	0	0	36	283.9	568
Mardell Creek	8	2	6	2	0	0	0	0	6	39	228
McCann Creek	1	1	0	1	0	0	0	0	0	--	165
Poison Oak Creek East	29	12	17	10	1	0	0	1	3	7.4	247
Poison Oak Creek West	29	12	17	10	1	0	0	1	3	7.4	94
Root Creek East	20	5	15	3	3	3	6	0	4	6.7	174
Root Creek West a	0	0	0	0	0	0	0	0	0	0	61
Shively Creek East	127	88	39	0	13	26	0	0	0	--	75
Shively Creek West	101	83	18	0	10	8	0	0	1	5.1	208
Strawberry Creek	1	1	0	1	0	0	0	0	0	--	375
Strongs Creek Main	22	6	16	6	0	0	0	0	3	38.1	70
Strongs Creek East	2	1	1	0	1	0	0	0	1	1.7	233

Creek	Total units	Units with fish	Units without fish	Pools	Low gradient riffles	Vertical units [b]	High gradient riffles	Runs	Farthest between [c]	Farthest between distance (m) [d]	Area (ha)
Strongs Creek West a	0	0	0	0	0	0	0	0	0	0	245
Unnamed Paired Creek to Van Duzen River East, Confluence	20	5	15	5	0	0	0	0	6	44.4	15
Unnamed Paired Creek to Van Duzen River West	13	4	9	4	0	0	0	0	3	32	145
Unnamed Tributary to Van Duzen River East	5	3	2	2	1	0	0	0	1	2.9	297
Unnamed Tributary to Van Duzen River West a	0	0	0	0	0	0	0	0	0	0	330
Unnamed Tributary to Lawrence Creek (Road 8)	39	25	14	14	7	0	3	1	2	7.6	104
Unnamed Tributary to Yager Creek	2	1	1	1	0	0	0	0	1	13.2	45
West Fork Elk River	73	25	48	22	3	0	0	0	9	56.3	55
Totals	776	356	420	140	52	38	16	6		--	7208
Average (standard deviation)									3 (6)	33.9 (58.3)	195 (157)

[a] No fish present in creek – entire creek classified as Class II.
[b] Vertical units include cascades, steps, and falls.
[c] Farthest between refers to the total units where fish were not present.
[d] Farthest between distance refers to the total distance between units where fish were not present.
[e] Rapid 20 pool protocol used – only pools were electro-shocked.

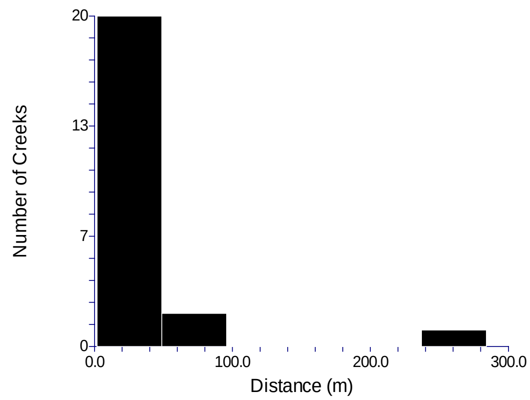

Figure 1—Histogram showing the maximum distance between units with fish present during electrofishing surveys of 24 headwater streams in Humboldt County.

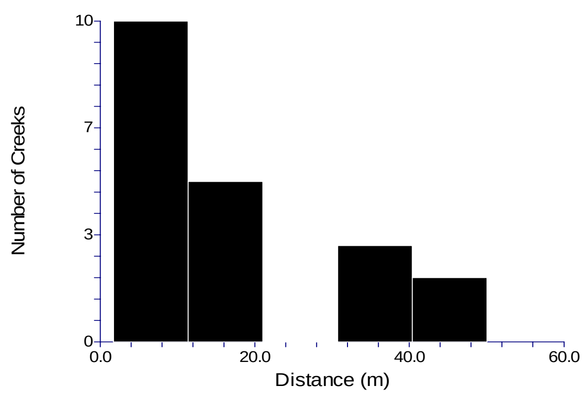

Figure 2—Histogram showing the maximum distance between units with fish present during electrofishing surveys of 24 headwater streams in Humboldt County, excluding two inconsistent creeks, Graham Gulch and Clapp Gulch East.

Fish at or near the upstream limit of their distribution were found in each kind of habitat unit encountered *(fig. 3)*. Fifty-six percent of the trout captured were found in pools, followed by 21 percent in riffles. Only two percent of the trout were captured in runs, which were also the least encountered habitat unit in these headwater streams.

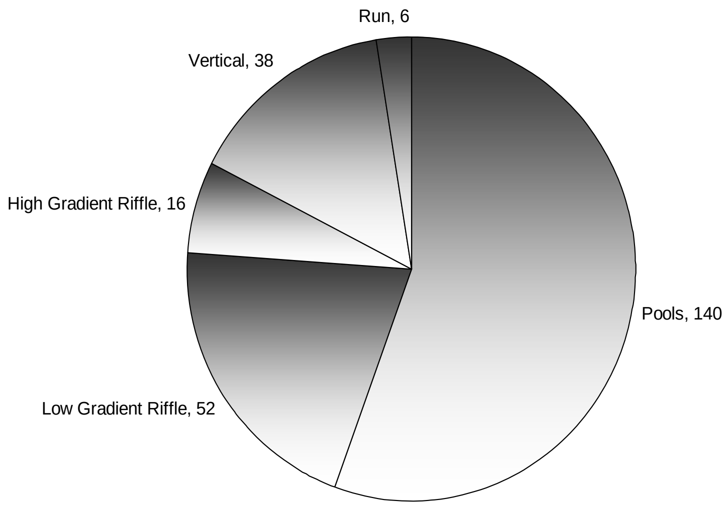

Figure 3—The distribution of fish in habitat units at or near the upstream limit of their distribution in 24 creeks in Northern California.

Discussion

In the absence of a clear barrier to upstream migration (for example, waterfall or impassible chute) a method is required for determining the end of fish use in streams. Methods in the past (Latterell and others 2003, MELP 2001, ODF and ODFE 1995, Sullivan 1997) have not provided a thorough explanation for choosing the set protocols for defining the end of fish use points in streams. This is critical to accurately define the end of fish presence in headwater streams. This does not include vertical units (for example, cascades and steps). Current protocols in Oregon, Washington and British Columbia stipulate the electroshocking of only pools during an end of fish survey. Data collected for this study has indicated that methods based solely on pools is inadequate for documenting the last fish present almost 50 percent of the time. For this reason all habitat units should be eletrofished for accurate placement of the Class I Class II break. Therefore, methods should not be based on pools but on the distance covered in the survey. Graham Gulch had the largest span of units surveyed between the last two fish detections (36) covering a total distance of 289 m. For this creek, 300m would be an acceptable distance to survey to define the Class I, Class II break. Graham Gulch happened to be a lower gradient reach. However the majority of streams with steeper gradients surveyed during this study required far less distances to be covered to define the point were fish end (with 63 percent of the streams being under 20 m and 96 percent being less than 100m).

This study has indicated that the presence/absence of rainbow and cutthroat trout in head water streams is dependent on gradient and the presence of large vertical steps in headwater streams; which is similar to results found in Washington by Latterell and others (2003). Unlike Latterell and others (2003), data from this study indicates that fish due inhabit other habitat units at or near the end of fish presence, other than pools. For this reason we suggest that all stream units should be electroshocked at or near the end of fish presence. As the survey moves closer to the last fish, more electrofishing was required to find fish present in each unit. This is an indication that reaches close to the Class I, Class II break are less populated with fish. Abrupt changes in average channel gradient (for example, 13 percent) can be attributed to the end of fish presence for the majority of streams used in this study. Using this information in concert with the distance covered, survey protocol effort can be greatly reduced. The maximum distance between the last two fish detections covered in streams where a change in gradient occurred was 60 m.

Because of the diversity of watershed sizes encountered (15 ha to 680 ha), methods based on map based criteria, such as watershed area, are problematic. For this reason the watershed area dataset is not useful in determining the Class I, Class II breaks.

The existing 20 pool protocol presented above has proven to be more than sufficient at defining the last fish present within the stream. A streamlined protocol, of 300 m should be electrofished in stream systems were there is not an apparent change in stream gradient greater than a minimum eight to 12 percent and 60 m should be electrofished when this threshold is exceeded. These two methods in combination should be precise enough to define fish absence in headwater streams and robust enough to capture end of fish points in streams where fish populations are low and where distances between habitat units containing fish are high, while decreasing the work load.

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