Preliminary Response of Fish Habitat to Post-Fire Salvage Logging in Riparian Areas in a Northwestern Montana Stream

Elizabeth Gardner
Flathead National Forest
Tally Lake Ranger District
1335 Hwy 93 West
Whitefish, MT 59937 bgardner@fs.fed.us

Abstract

Fish habitat in a northwestern Montana stream was monitored following riparian timber salvage. The Hand Creek watershed was burned in a 1994 wildfire and then experienced a spruce beetle (*Dendroctonus rufipennis*) outbreak in 1996. To reduce the spread of spruce beetles, land managers selectively harvested infested riparian stands and left other riparian areas unharvested. Fish habitat was monitored immediately following the fire in 1994, prior to salvage activities in 1996, and again in 2000. The stream did experience a gradual shift in channel characteristics, presumably due to the fire, but little distinction is noticed between harvested and unharvested study sites. Hand Creek became slightly wider and shallower and stream banks were less stable in all study sites. Low gradient reaches increased in habitat complexity while moderate gradient reaches did not. Large woody debris frequency increased. The percentage of pool habitat did not change but wood increasingly became important as the formative feature for pools. The average size of streambed substrate increased from fine sediment to gravel. The rate of change appears consistent between harvested and unharvested study sites and suggests riparian timber salvage activity has not impacted the stream to date. No major floods have taken place since the project was initiated and when one takes place in the future, channel changes may be more prominent. Due to study limitations, a rigorous statistical analysis is not possible. Further monitoring of Hand Creek is recommended to ascertain if riparian timber salvage had any long-term ramifications to fish habitat.

Introduction

The aftermath of a wildfire can create difficult decisions for land managers in western North America. Fire-killed and fire-weakened trees topple across streams, and sometimes the dead trees pile up to impressive densities. Managers are faced with the challenge of providing for sustained large woody debris (LWD) recruitment into the stream so that it provides fish habitat and cover. At the same time, there can be concern about undesirable build up of fuel, potential insect outbreaks, reduced natural forest regeneration and lost economic opportunity of salvaged wood.

Fisheries managers have recognized the importance of unharvested riparian areas in living forests. Riparian trees help regulate water temperature, provide nutrients, stabilize stream banks, and create cover and pools as the trees die and collapse into the stream channel (Gregory et al. 1991; Ralph et al. 1994; Sugden et al. 1998; Hauer et al. 1999). National Forests in the Columbia River basin have adopted a standardized riparian delineation as a minimum of 91.4 meters from either side of the stream channel in fish-bearing streams. Timber harvest in riparian areas is prohibited except when certain catastrophic events result in vaguely defined "degraded conditions" (USDA Forest Service 1995). The state of Montana has also enacted a Streamside Management Zone Act requiring that a minimum of 10 trees per 30.5 lineal meters in a 15.2 to 30.5 meter wide buffer be left on either side of the channel.

Wildfires are a natural process that periodically kill trees and provide new recruitment of LWD into streams. Fires are part of disturbance regime that maintains ecosystems in the western North America (Beschta et al. 1995). However, the magnitude and intensity of recent wildfires have sparked new debates regarding the role wildfires have on aquatic resources (Rieman et al. 1995). After a fire takes place, fisheries biologists and land managers face tough questions on what to do next. There is urgency associated with harvesting burned timber to recover the greatest economic value. Is it possible salvage trees in riparian areas without impairing fish habitat? The objective of this study was to determine if harvesting fire-killed trees significantly altered fish habitat. This study does not interpret habitat quality and does not monitor fish population response to habitat changes.

Study Area

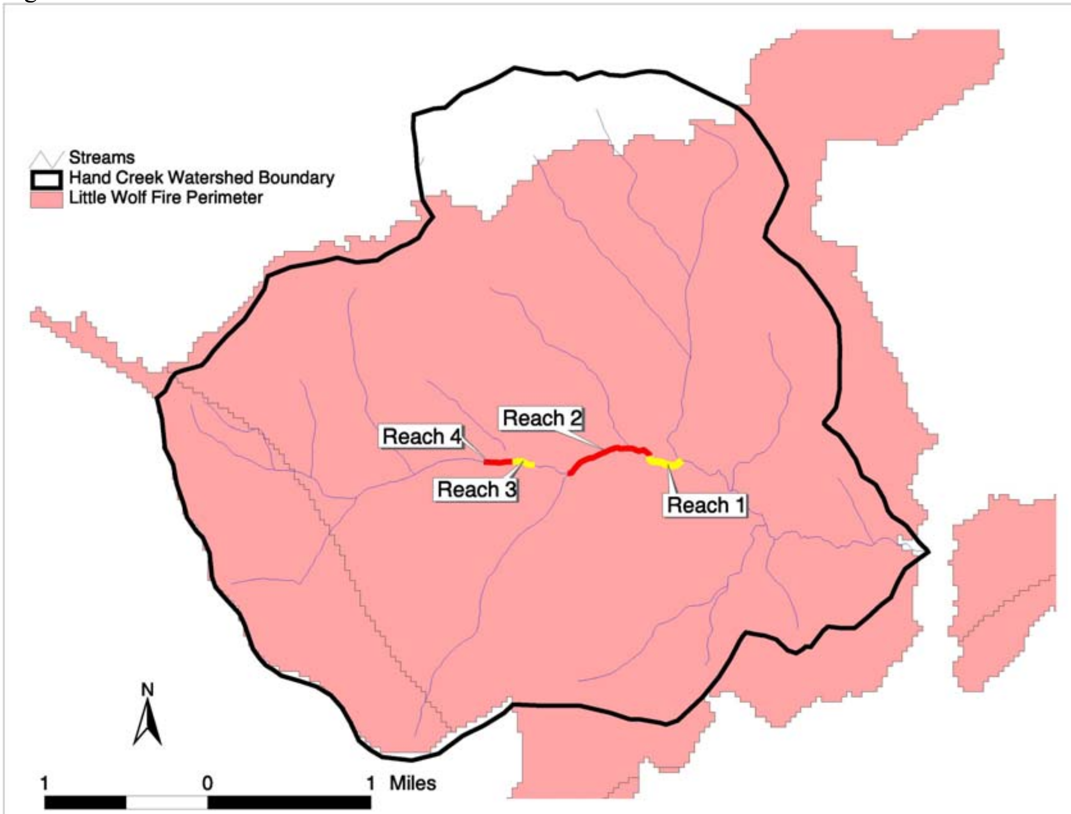
This study was conducted on Hand Creek, a third-order stream located on Flathead National Forest in northwestern Montana. Hand Creek has a 33.4 square kilometer watershed and elevation varies from 1,311-1,676 meters. The stream averages 2 to 5 m bankfull width and has a summer mean flow of about 0.28 cubic meters per second (10 cfs) at the mouth of the stream. Approximately 47% of Hand Creek's watershed had received some type of timber harvest by 1994. The predominate timber type is Subalpine fir (*Abies lasiocarpa*) and spruce (*Picea* spp.). At one time Hand Creek contained westslope cutthroat trout (*Oncorhynchus clarki lewisi*) but this species was extirpated in the 1970s and Hand Creek now contains non-native brook trout (*Salvelinus fontanalis*). No other fish species is present.

In August and September 1994, a 4,742 hectare wildfire named "Little Wolf" burned 89% of the Hand Creek watershed (Figure 1). The fire burned in a mosaic of severity. It killed all trees in some areas but in others it only initially weakened and stressed trees, especially along Hand Creek. From 12-26 October 1994, a two-person crew surveyed 6 km of fish habitat on Hand Creek. This survey took place as soon as the burned area was considered safe for entry and before any significant precipitation. The 1994 survey should represent pre-fire conditions. No other historic fish habitat information is available.

In 1995 the Flathead National Forest authorized salvage harvest for much of the upland burn areas on Hand Creek but retained all the trees in the riparian areas. For this study, riparian areas are defined as 91.4 m from either side of the stream channel. Many of these streamside trees were spruce that gradually succumbed to fire-related stress. Trees began to "jackstraw" on top of each other and in some places the downed wood was more than 3 m thick over the stream.

In early 1996 entomologists reported an epidemic of spruce beetle *(Dendroctonus rufipennis)* infestation in the Hand Creek riparian area and were concerned that this outbreak could threaten nearby old-growth spruce forests. The spruce beetle outbreak was in intermittent patches along the riparian area. The beetles only used the spruce trees that were weakened by the fire and avoided the severely burned trees. The Flathead National Forest elected to salvage much of the infested riparian spruce to halt this epidemic.

Figure 1. Location of monitored reaches in Hand Creek.



From 1-9 July 1996 crews monitored four discrete subsamples collected from within the larger 1994 baseline survey. The lower two study sites are located on lacustrine deposits of silts, fine sands, and clays which are poorly drained and saturated to the surface much of the year (Sirucek and Bachurski 1995). The channel type is low gradient (<1%), meandering within a unconfined valley bottom and is classified as a C4 type (Rosgen 1994). The upper two study sites are on a moderately sloped glacial outwash terrace composed of sandy loams and boulders that are also poorly drained and saturated (Sirucek and Bachurski 1995). The channel type is a B4 with moderate entrenchment, 1-3% gradient, and dominated by riffles (Rosgen 1994). For each pair of study sites, one was treated with riparian harvest and one was not. The unharvested areas either little spruce or were too severely burned in the 1994 fire to attract beetles.

In November 1997 riparian salvage took place along approximately 29% of the total length of fish habitat in Hand Creek. All spruce trees greater than 20.3 cm diameter breast height were removed unless they were already waterlogged and incorporated by the stream. Salvage logging within the study area was done by helicopter. Non-spruce species, primarily subalpine fir, were retained as much as feasible. The effort was successful in preventing the spread of spruce beetle to nearby old-growth.

These four study sites were monitored again from 27 September to 16 October 2000. There were no floods from 1994 to 2000. Hand Creek experienced larger than usual spring runoffs each year following the fire but no unusual precipitation events had taken place since this study began.

Methods

The four study sites are clustered into two reaches that are separated by a gap of 290 m of unburned riparian vegetation (Table 1). The study sites are immediately adjacent to each other with the downstream one of each pair being the unharvested site. Reaches were marked with flagging. Although the beginning and ending points for the reaches did not change, the surveyed lengths varied over the years. The variation in length was caused by habitat complexity changes (increased sinuosity) and observer error.

Table 1. Study site characteristics and lengths.

	Gradient	Characterization	Total length
Reach 1	0-1%	Control	538-587 m
Reach 2	0-1%	Harvested in 1997	923-1275 m
Reach 3	1-3%	Control	295-309 m
Reach 4	1-3%	Harvested in 1997	261-285 m

Fish habitat was surveyed using methodology that was commonly used by US Forest Service fisheries biologist in the Rocky Mountains at that time. The methodology was very similar to that described by Overton et al (1997). The methodology is repeatable but it has limitations due to the subjective nature of determining unit boundaries and the influence of discharge on observing unit complexity (Peterson and Wollrab 1999). To overcome these weaknesses, the same observers who made the 1994 survey conducted the subsequent surveys. The 1994 and 2000 monitoring surveys were done in the same low flow conditions, as recorded at a gauged site in the extreme headwaters of Hand Creek (both years at 0.001 cubic meters per second). Unfortunately, the 1996 survey was completed during a higher discharge period (0.02 cubic meters per second) due to scheduling problems. This change in discharge plus the variable reach lengths prevented meaningful statistical analyses of the data.

Surveyors walked upstream and recorded measurements at successive habitat units. The surveyors categorized each habitat unit as either a fast water unit or slow water unit. No measurements were taken in side channels. Fast water units were further defined as either a riffle, run, or glide. Slow water units (pools) were further classified by their type (dammed or scoured), their location in the thalweg (main, lateral, plunge, or underscoured) and their formative feature (LWD, boulders, or stream meander). Protocol used to delineate these habitat types are found in Hankin and Reeves (1988) and Overton et al. (1997).

The total surface area and wetted width/depth ratio was derived differently in the fast water and slow water units. For both types, the length of each unit was measured to the nearest 0.1 m in the thalweg. In fast water units, the surveyors then selected a transect that best typified the average width of the unit and measured the wetted width to the nearest 0.1 m. In the same transect, the wetted depth was measured with a stadia rod to the nearest centimeter at three equally spaced locations between the wetted edges. These three measurements were then summed and divided by four to estimate mean depth.

In slow water (pool) units, the maximum depth and the thalweg depth at the tail crest was measured to the nearest 0.1 m with a stadia rod. In pools formed by dams, the tail crest was the upstream lip of the pool. The mean value between the maximum and tail crest depth was calculated and then sought out by probing with the stadia rod along the thalweg. At this location, a transect was established to measure the wetted width to the nearest 0.1 m. The average depth of the pool was calculated as described above.

In the 1994 survey, large woody debris (LWD) was tallied for each unit but in subsequent years LWD was only counted at every 5th slow water unit and 10th fast water unit (subsampled units) to get a weighed average for the reach. LWD was counted only if it was greater than 3 m long, at least 0.1 m in diameter (measured at 1/3 of the length) and was at least partially within the bankfull channel. All wood that was outside the bankfull channel area, even if it was lying across the channel, was ignored. Occasionally the surveyors recorded a " LWD aggregate" when multiple pieces of wood clustered together and substantially impacted the channel. Wood was not counted in these aggregates but by definition all aggregates had at least two pieces of LWD. While aggregates were uncommon in Hand Creek, not counting the individual pieces in aggregates resulted in an underestimate of LWD.

During the 1994 survey, length and width measurement were recorded for every 10th piece of wood. The entire length of the wood (even portions outside of the bankfull channel) was measured to the nearest centimeter. The diameter was measured to the nearest centimeter at a location 1/3 from the base. The 1996 and 2000 surveys recorded the same LWD measurements but, because of human error, differed in sampling intensity from 1994. The later surveys tallied and measured all of the wood in subsampled units only and LWD in other units was ignored.

Both left and right stream banks at bankfull height were subjectively assigned a percentage of "stable banks" for overall bank length per unit. Survey crews judged the stream banks stable if there was no evidence of slumping, vertical erosion, or tension failure.

No information about substrate composition was collected in 1994. In subsequent surveys, surveyors conducted pebble counts (Wolman 1959) at stratified, subsampled units (the same units where large woody debris was inventoried). The substrate inventory was located at transects perpendicular to the stream that intersected potential brook trout spawning habitat. Thus, the pebble counts were collected at every 5th slow water unit at the tail crests and at every 10^{th} fast water unit at evenly spaced transects throughout the unit. At least 100 substrate measurements were taken at every sampled unit. Substrate was assigned to categories of either fines (<2 mm) or small gravels (2-8 mm) or gravels (8-64 mm) or small cobbles (64-128 mm) or cobbles (128-256 mm) or small boulders (256-512 mm). There is no substrate on Hand Creek that is larger than a small boulder.

Although not directly a part of this study, two permanent cross-sections were established on Hand Creek in 1993, one year before the wildfire. The cross-sections are a means of precisely measuring the channel width and depths at two particular transects. The transects were marked with steel posts and the channel dimensions between measured with a surveyor's level. The cross-sections are about 25 meters apart from each other and located about 1 km downstream of this study. The cross-sections were monitored five times from 1993 to 2000.

Results

A total of 2,415 m of fish habitat was monitored each year in 1994, 1996, and 2000. The 1994 and 1996 inventories took place prior to riparian salvage harvest and the 2000 took place three years after the salvage was completed.

The surveyed reach lengths and number of habitat units (pools, riffles, etc) varied among the years (Table 2). Reaches 1 and 2 (low gradient reaches) became longer after each survey although the beginning and end points remained constant. Also the number of habitat units in the reaches increased. It is possible that the low gradient areas increased in habitat complexity and sinuosity after the wildfire. There is the possibility of surveyor error. Reaches 3 and 4 (moderate gradient reaches) had less variation between years in reach length and total habitat units. These reaches ultimately declined in length and complexity. The estimated length of Reach 2 (a harvested reach) demonstrated the greatest increase but since Reach 4 did not increase, it is uncertain if riparian harvest caused this change.

Table 2. Survey reach length and total number of habitat units by year.

	Survey length			**Total number of habitat units**		
	1994	**1996**	**2000**	**1994**	**1996**	**2000**
Reach 1 control	538m	540m	587m	17	30	39
Reach 2 harvested in 1997	923m	1081m	1275m	57	73	73
Reach 3 control	307m	309m	295m	15	17	13
Reach 4 harvested in 1997	285m	261m	261m	24	26	15

Average wetted channel widths increased in all four study reaches with each consecutive survey (Table 3). Hand Creek increased from an average wetted width of 2.2 m to 3.0 m in 1994 to 3.4 m to 4.2 m in 2000. The rate of width increase was generally consistent between all four reaches. This suggests that the stream experienced increased springtime runoffs and adjusted to the new flows by widening the channel.

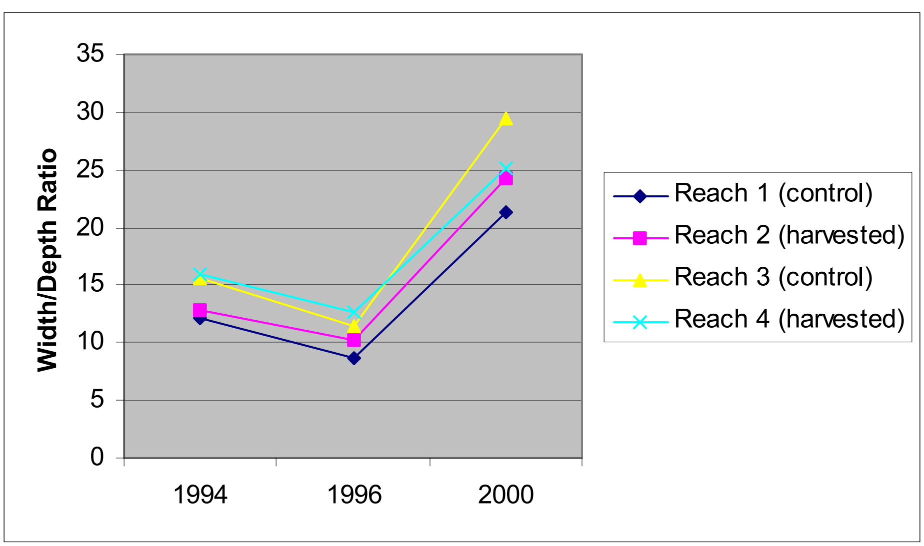
The average wetted depth increased in all four study reaches from 1994 to 1996 (Table 3). However all four wetted depths became shallower in 2000, falling below average depths recorded in 1994. The increased average depth in 1996 is presumably caused by higher flows during the survey period. The 1994 and 2000 discharges are comparable and thus it appears Hand Creek had decreasing average depth over time.

Table 3. Average channel dimensions of wetted width (meters), depth (meters), and width/depth ratio.

	Wetted Width			**Wetted Depth**			**Width/Depth Ratio**		
	1994	**1996**	**2000**	**1994**	**1996**	**2000**	**1994**	**1996**	**2000**
Reach 1 control	3.03	3.71	4.25	0.25	0.43	0.20	12.12	8.63	21.25
Reach 2 harvested in 1997	2.69	3.36	3.89	0.21	0.33	0.16	12.81	10.18	24.31
Reach 3 control	2.34	2.98	3.25	0.15	0.26	0.11	15.6	11.46	29.24
Reach 4 harvested in 1997	2.24	3.02	3.38	0.14	0.24	0.12	16.0	12.58	25.17

The width/depth ratio increased from 1994 to 1996, presumably due to greater discharge (Figure 2). However, in 2000 the width/depth ratio declined beyond the 1994 baseline level. Hand Creek became wider and shallower in all reaches over time. No difference was detected between control and harvested sites. This observation is supported by the two cross-section transects located downstream of the monitoring study. The cross-section transects revealed that Hand Creek became wider and shallower by about 3% of the bankfull area.

Figure 2. Width/depth ratio for each reach. Illustrates channel has become wider and shallower since 1994.



Stream bank stability for all units were averaged and displayed on Table 4. All four reaches initially had 97.6% -100% stream bank stability in 1994. All four reaches declined in bank stability and ranged from 81.4% to 93.2% in 2000. The loss of bank stability is intuitive with the phenomena of the stream handling increased springtime runoffs. The decline of bank stability appears to be faster in harvested study sites than the control study site, but it is uncertain if this is statistically significant.

Table 4. Average percentage of stream bank that is classified as stable

		1994	1996	2000
Reach 1	Control	99.94%	96.9%	93.7%
Reach 2	Harvested in 1997	97.63%	98.6%	88.94%
Reach 3	Control	100%	98.4%	91.13%
Reach 4	Harvested in 1997	100%	99.4%	81.44%

Large woody debris (LWD) was calculated for all units in 1994 and extrapolated from random sampling units in subsequent years. The total count was then converted into the average number of LWD per kilometer (Table 5). All four reaches experienced substantial increases in LWD per kilometer when compared to 1994. The rate of LWD recruitment into the stream appears highly variable between reaches, suggesting that wood does not topple into the stream at an even, constant rate. Very limited sampling was conducted on reaches 3 and 4 following 1994 due to the reaches' short lengths. This confounds the ability of the data to actually show change. No explanation is readily available to describe the apparent decline of LWD abundance in Reach 3 in the final year, other than it is likely the sampling strategy selected poor representative units.

The mean diameter and mean total length of the LWD measured is displayed on Table 5. No clear trend emerged in any reach. While there appears to be more wood in the stream, there is no obvious indication that the size of the wood is either increasing or decreasing. There is no apparent difference between harvested and control reaches. It was anticipated that control reaches would have experienced an increase in mean size and diameter of wood as the large, burned spruce trees fell into the stream, while the harvested units would not have a similar influx. The results do not support this hypothesis so far. Apparently the large spruce trees have not yet influenced the channel. It may just take more time for limbs to breakdown and allow the large trees to sink into the stream. Results can also be interpreted to mean that riparian harvesting did not result in excessive "slash" in the stream (at least for woody pieces large enough to be counted).

Table 5. Large woody debris frequency and size. LWD numbers per stream kilometer. Mean diameter and mean total length of LWD (m).

	LWD pieces per kilometer			**LWD mean diameter**			**LWD mean total length**		
	1994	**1996**	**2000**	**1994**	**1996**	**2000**	**1994**	**1996**	**2000**
Reach 1 control	350.7	353.7	502.7	0.29	0.24	0.24	6.91	8.69	8.18
Reach 2 harvested in 1997	118.1	176.7	512.2	0.28	0.32	0.28	8.30	8.52	7.61
Reach 3 control	286.6	715.2	491.5	0.23	0.24	0.26	8.62	10.19	6.68
Reach 4 harvested in 1997	298.3	334.0	1,197.7	0.25	0.43	0.27	12.14	15.5	12.3

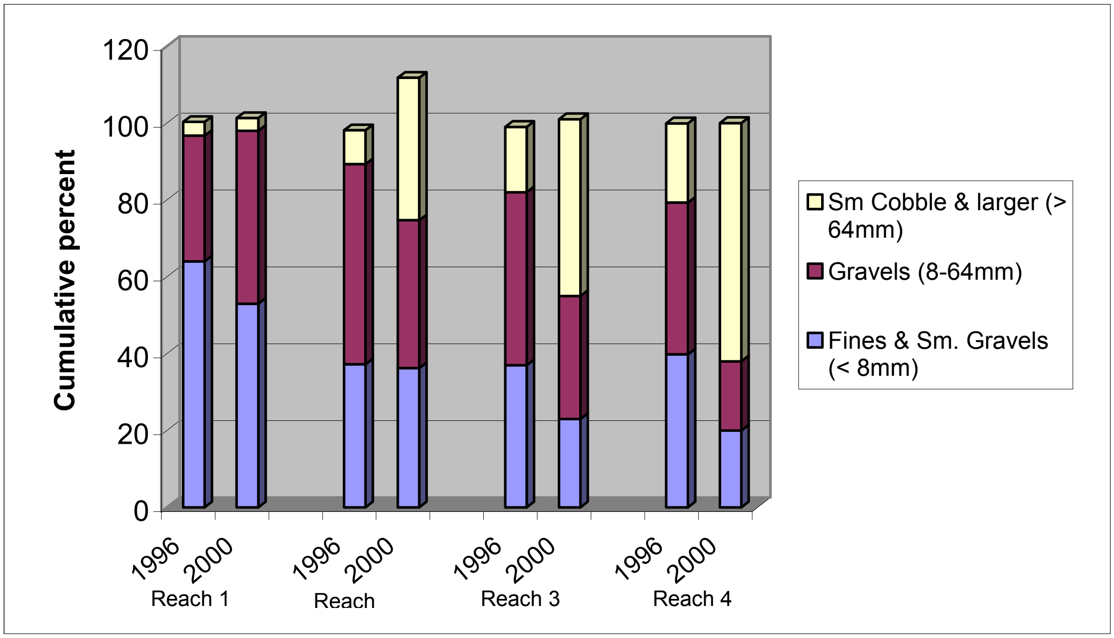
The percentage of pool habitat in relation to total surface area fluctuated unevenly between reaches and study years (Table 6). All reaches had more pool surface area in 1996 than any other year. This may be due to higher flows during the 1996 sampling rather than actual change in habitat. In 2000, pool habitat declined below that in 1994 in all reaches except Reach 1. The decline of pool habitat in most reaches is likely related to increased width/depth ratio. The types of pool habitat changed for most reaches over time (Table 6). Reaches 2-4 eventually had more pools formed by woody debris than other factors (such as stream meanders or scouring from small boulders). This corresponds to the increase of LWD throughout Hand Creek. The pools in Reach 1 are not as dependant on LWD and this reach has retained a high percentage of pool habitat.

Table 6. Percentage of pool habitat surface area and percentage of pools formed by wood.

	Percentage of surface area in pool habitat			**Percentage of pools formed by wood**		
	1994	**1996**	**2000**	**1994**	**1996**	**2000**
Reach 1 control	17.4%	58%	57.6%	40.7%	56%	43.7%
Reach 2 harvested in 1997	40.5%	49.4%	27.9%	39.7%	53%	88.4%
Reach 3 control	12.2%	22.3%	9.5%	91.8%	100%	100%
Reach 4 harvested in 1997	30.8%	41.7%	18.1%	69.4%	67.7%	79.9%

No baseline data on substrate composition in Hand Creek was collected in 1994. A total of 17 pebble count transects were collected in 1996 and 19 in 2000. Because of the methodology, the pebble counts were not necessarily in the same locations. Results are displayed on Figure 3. The figures do not total up to exactly 100% due to minor variances in some individual pebble counts. All four reaches had fewer fine materials and increased amounts of larger sized materials. This is likely caused by increased springtime runoffs that scour out fine materials. No obvious difference was found between the control and harvested reaches. More sampling over time is needed to determine if this is an actual trend.

Figure 3. Cumulative percentages of substrate sizes by categories in 1996 and 2000.



Conclusion

The project did not detect any differences between treated and control reaches in channel shape, large woody debris size and frequency, pool habitat abundance, and substrate size. A slight difference was noted in bank stability between the reaches. This can be interpreted that, other than bank stability, riparian harvest has not yet impacted Hand Creek's channel condition. Therefore a tentative conclusion is that riparian salvage has not yet harmed fish habitat. It may be possible for land managers to selectively salvage riparian trees following a wildfire without short-term harm. Mitigation measures used in Hand Creek, namely helicopter logging and leaving all uninfected riparian trees, appear effective. Due to limitations that block statistical analysis, this finding should not be utilized as a rigorous scientific study.

No conclusion is possible on the long-term impacts of riparian salvage harvesting to fish habitat. Only one sample has taken place since the 1997 harvest. All four reaches have exhibited gradual change and it is still uncertain if there is any pattern between harvested and control reaches. Fish habitat has not had much time to respond to the timber harvest. It may take years before unharvested reaches can incorporate the big spruce trees. It is recommended that monitoring on Hand Creek should continue.

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