Effects of Wildfire on In-Channel Woody Debris in the Eastern Sierra Nevada, California[1]

Neil H. Berg,[2] David Azuma,[3] and Ann Carlson[4]

Abstract

Management of in-channel woody debris after wildfire is controversial. Post-fire increases in stream discharges can cause more frequent downstream flooding. The resulting heightened transport and accumulation of debris can wash out bridges and cause other damage. In-channel debris is sometimes removed or cut into smaller pieces to expedite flushing through the system and to avoid debris jam formation. Biotic values of debris for fish cover, pool formation, sediment storage, and food sources for invertebrates and microorganisms are lost or reduced, however, when debris is removed or cut up. Information on debris dynamics after wildfire in the Sierra Nevada is scant. Changes in debris frequency, mobility, volume, aggregation, and carbon loading after a 1994 wildfire in the eastern Sierra Nevada were quantified by before and after comparative measurements at Badenaugh Creek in northern California, and by comparing selected attributes to a nearby "reference" stream. Fifty-seven percent of wood volume, and 25 percent of the pieces, were consumed by the fire. The fire reduced aquatic carbon loading from about 2½ to 1½ times terrestrial loading after the fire. Although more pieces moved 1 year after the fire at Badenaugh Creek than in the control stream, the size and number of debris jams both immediately and 1 year after the fire were appreciably reduced from pre-fire levels, probably because fewer pieces were available to form aggregates. Decisions on the disposition of post-fire debris must consider the interaction between fire intensity, channel width, and the size of the remaining wood. If few pieces of channel-spanning length remain after a fire, they may pose relatively little downstream danger.

Introduction

The role of in-channel woody debris in many lotic systems is well documented. Debris can help maintain channel stability in forested lands, decrease flow velocity, protect banks from erosion, trap sediment, and provide habitat for in-stream biota (Piegay and Gurnell 1997, Sedell and others 1988). Little is known, however, about the immediate or longer-term effects of wildfire on in-channel woody debris dynamics. A general premise is that woody debris movement is accelerated after fire (Minshall and others 1997) due to increased stream flow and decreased bank stability

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[2] Hydrologist, Pacific Southwest Research Station, USDA Forest Service, 800 Buchanan St., West Annex Bldg., Albany, CA 94710-0011 (e-mail: nberg@fs.fed.us)

[3] Research Forester, Pacific Northwest Research Station, 1221 SW Yamhill, Suite 200, Portland, OR 97205 (e-mail: dazuma@fs.fed.us)

[4] Fisheries Biologist, Tahoe National Forest, USDA Forest Service, P.O. Box 6003, Nevada City, CA 95959-6003 (e-mail: acarlson@fs.fed.us)

(Young 1994). Nevertheless, depending upon burn intensity and stream stage, debris pieces may be completely unaffected or could lose considerable mass from combustion.

Partly as a result of inadequate knowledge, management of in-channel debris after wildfire is controversial (DeBano and Neary 1996, Rinne and Neary 1996). Post-fire increases in stream discharges—resulting from reduced evapo-transpiration and development of hydrophobic soils—can cause downstream flooding. Post-fire increases in debris frequency (Minshall and others 1997) potentially elevate the amount of debris available for transport and downstream aggregation. The resulting heightened transport and accumulation of debris can wash out bridges and culvert crossings and exacerbate downstream flooding. From this purely engineering standpoint, in-channel debris is often removed or cut into smaller pieces to expedite flushing through the system and to avoid debris jam formation.

Indiscriminate removal or cutting may be inadvisable without understanding the critical interaction between channel width, debris size, and fire intensity on downstream effects. In headwater streams large, relatively stable logs decrease flow velocity, protect banks from erosion, and trap excess sediment. Intermediate-sized debris (approximately equivalent in length to the channel bankfull width) most effectively contributes to post-fire downstream aggregation at bridges, road crossings and culverts: these pieces are small enough to be moved easily by high flows, but are large enough to be trapped by bridge piers. The critical debris size for downstream aggregation depends strongly on channel size and flow. Sizes that are immobile in small, first-order streams may be routinely transported in higher-order channels (Piegay and Gurnell 1997, Reid and Smith 1992). High intensity fire can incinerate enough in-channel debris that the potential for debris to accumulate in "jams" is moot: intense wildfire may burn so much wood that insufficient debris exists for jam formation. From the biological perspective, retention of post-fire debris is typically beneficial, and DeBano and Neary (1996), for instance, recommend retention of post-fire debris on-site unless downstream risks are readily identified.

Information on the effects of fire on riparian and aquatic habitat elements is restricted largely to changes in water chemistry, water temperature, stream flow, sediment, and aquatic biota (e.g., Ewing 1996, Minshall and others 1989, Rinne and Neary 1996, Roby and Azuma 1995). Very little is known about direct or longer-term fire effects on in-channel wood debris dynamics (Young 1994), and the known published results are based on post-fire comparisons between burned and reference streams rather than before-after comparisons. After the Yellowstone fires in 1988, Minshall and others (1997) identified substantial increases in the number of debris pieces, and attributed those increases to fire-felled trees. The increases were greater in smaller stream systems (third order and below). These increases were somewhat balanced by significant losses of pre-fire debris (greater than 20 pieces/50 m channel distance) from burned sites. Young (1994) quantified increased post-fire movement of debris, and longer but smaller diameter debris pieces in a burned watershed versus an unburned system. Alexander and Rinne (1995) determined that length was not the only factor influencing the distance of debris movement in a burned watershed. None of the results from known studies address post-fire aggregation of debris.

Although woody debris functions as an important long term carbon store for aquatic systems and is probably more important in this role in small headwater streams (Malanson and Kupfer 1993), little is known about the cycling of carbon in in-channel woody debris or about the losses of carbon from wildfire in riparian zones. Because riparian areas—relative to other terrestrial zones—appear to be a focus of terrestrial woody debris accumulation (Harmon and others 1987), in-channel loading of woody debris per unit area may be greater than hillslope loading, and impacts of fire may be greater on in-channel debris carbon loading.

This paper reports the results of a study on the effects of wildfire on woody debris by comparing debris found at two creeks—Badenaugh and Sagehen—in the Sierra Nevada of California.

Fire History

In August 1994, the Cottonwood wildfire burned 46,800 forested acres on the Tahoe National Forest, including 99 percent of the Badenaugh Creek watershed. Burn intensity, which provides a measure of the fire's effect on ecosystem processes, was high on 71 percent of the Badenaugh Creek watershed and moderate on most of the rest of the watershed. Only a few of the trees in the lower portion of the watershed had green growth by 1997. Many riparian areas were burned, and fish mortality was noted in all major drainages after the fire. Before the fire, this area supported dense riparian vegetation with approximately 95 percent canopy closure and October water temperatures 6-13^{o}C (USDA Forest Service 1995).

Before the arrival of settlers in the 1800s, fire return intervals were relatively short in the Cottonwood area and averaged between 8 and 15 years (Hermit 1994). Fire suppression during the last century has lengthened wildfire frequency to 40 to 140 years and increased wildfire energy (USDA Forest Service 1995). Terrestrial ecosystem consequences of these changes include extensive tree mortality from insect and disease epidemics; loss of tree, shrub, and herbaceous species important for wildlife habitat and species diversity; and heavy fuel build-ups leading to potentially larger, more severe wildland fires. Effects of the 1954 “stand-replacing” Smithneck Fire—which covered the study area—on riparian trees bordering the study streams is unknown, although mature Jeffrey pine *(Pinus jeffreyi)* lining Badenaugh Creek and nearby Smithneck Creek before the 1994 wildfire were large enough to have survived the 1954 burn.

Objectives

This study was designed to address immediate and short-term (1-year) changes in woody debris attributes by comparing debris frequency, size, volume and aggregation, and in-channel carbon loading before and immediately after a wildfire. These attributes, along with recruitment of new debris and debris movement, were further assessed 1 year after the wildfire.

Because post-fire mobility and aggregation of debris relate to potential downstream hazards and are central to the management controversy over the disposition of post-fire debris, and because of a dearth of information on post-fire debris jam formation, we focused specifically on changes in aggregate accumulation by evaluating three related hypotheses: the number of aggregates increases post-fire, the volume of aggregates increases post-fire, and total debris volume increases post-fire as potential inputs to aggregations.

To our knowledge published data based on “before and after” wildfire comparisons does not exist for these characteristics of woody debris.

Methods

The experimental approach combined before-and-after and control-impacted comparisons. Measurements were made on one creek located 40 km north of Lake Tahoe on the eastern slope of the central Sierra Nevada of California in 1993 and 1994 before a wildfire and after the fire in 1994 and 1995. We made similar measurements during the summers of 1993, 1994, and 1995 at a second creek that was unaffected by the wildfire and located 22 km from the burned watershed. At both creeks we monitored debris location, size, abundance, and aggregation.

Study Sites

Observations were made at Badenaugh Creek (39°37'30" N, 120°10'10" W) and Sagehen Creek (39 °26'20" N, 120°14'35" W), an unburned "control" stream located on the eastern slope of the central Sierra Nevada in California. The climate of this area is influenced by the general maritime climate of California. Summer and winter air temperatures are mild, and summers are dry with no precipitation except occasional thunderstorms. The hydrologic regime is dominated by snowmelt flows, with the highest flow volumes occurring between May and July. Flows likely to move woody debris can occur, however, in winter floods caused by rain-on-snow events. Baseflow dominates late summer stream conditions, and there is the potential for dewatering of channels (except for major rivers) after sustained drought periods. Mass wasting, as a source of in-channel debris, is not regarded as a major erosive agent in most of the Sierra Nevada, and relatively little interaction occurs between high flows and initiation of landslides within the inner gorges of Sierra Nevada streams (Seidelman and others 1986). Analysis of orthophotographs of the basins upstream from the study reaches revealed no evidence of mass wasting that could have caused catastrophic inputs of debris into the stream channels, and no evidence of mass wasting was observed during the field surveys.

Major portions of both watersheds were railroad-logged between 1900 and 1918. Since 1975, about 375 hectares of the Sagehen Creek watershed and at least 250 hectares of the Badenaugh Creek watershed were harvested. About 250 hectares of the Sagehen Creek watershed experienced wildfire between 1920 and 1929, and much of the northeast section of the watershed burned in 1960. Current land uses in both watersheds include logging, grazing, and recreation (hiking, off-road vehicle use and camping). Both streams had unimpeded stream flows and trout populations before the Cottonwood fire. During surveys of these waterways, we found no evidence of tree removal close to the channel, and mature conifers typically lined the stream banks in 1993. Nor did we find evidence of removal of debris from the channel. Substrates on both streams consist primarily of a mix of cobbles and small boulders with finer sediment or bedrock in some places. The streams are characteristically high-gradient, step-pool systems. They are bordered by the east-side pine forest type (Burns and Honkala 1990) with Jeffrey pine *(Pinus jeffreyi)* and aspen *(Populus tremuloides)* common. Trees in these forest types often grow to be more than 1 m in diameter at breast height and 45-65 m in height.

Stream flow has been measured on Sagehen Creek approximately ½ km below the lower boundary of the Sagehen study area since 1954. During the 1993-1995 study period, daily maximum and instantaneous peak flows spanned the bulk of the historical extremes of recorded flows on Sagehen Creek. The April 19, 1994 maximum daily flow of 0.45 m^3/sec for that year was lower than 93 percent of the recorded daily maxima. In contrast, the May 1, 1995 maximum daily flow of 5.0 m^3/sec for that year was greater than 85 percent of the recorded daily maxima for all years of record.

In 1993 as part of a broader study of woody debris in the central Sierra Nevada (Berg and others 1998), we identified ten headwater reaches, each 100 m long, five in a lower and five in an upper section of each channel, in anticipation that the narrower channels in the upper sections would accumulate and move wood of a smaller size than wider reaches below. Location of the lowest 100-m study reach in each section (upper and lower) was determined by upstream basin drainage area. The lowest of the lower five reaches began where the basin drained about 2,500 ha. The lower end of the upper five reaches began where the upstream drainage area was about 830 ha. The study reaches ranged in elevation from 1,920 to 2,292 m at Sagehen Creek and from 1,792 to 2,027 m at Badenaugh Creek. In Badenaugh and Sagehen Creeks the upper study sections were first-order channels (defined on the basis of U.S. Geological Survey topographic quad blue lines), and the lower sections for both streams were second-order channels. To reduce geomorphological sources of variation and to determine whether channel type affected woody debris dynamics, each 100-m study reach was limited to one channel type as described by Rosgen (1994). Study reaches could be adjacent if sequential 100-m channel segments were a single channel type. Otherwise there were gaps of varying lengths between study reaches. The study reaches of both streams are Rosgen types B3 or B4 on the lower sections and types A3 or A4 on the upper sections. Berg and others (1998) determined that pre-fire volume did not vary by Rosgen channel type between study reaches on the two streams.

Measurement Variables and Procedures

Hydrologic variables quantified for each 100-m reach included bankfull width and depth, Rosgen channel type, and surface-water gradient. The mean values of these variables, except channel type, based on two or three measurements per reach are:

Variables	Badenaugh[1]	Sagehen[1]
Bankfull width (m)	2.5[2]	2.1
	4.0	5.0
Bankfull depth (m)	0.48[2]	0.47
	0.65	0.61
Gradient (pct)	6.6[2]	6.6[2]
	2.6	2.1
Channel length (km)	9.0	16.1

[1] First line in each entry (e.g., 2.5 and 2.1 for bankfull width) refers to the five 100-m reaches in the upper section of each study stream encompassing an upstream watershed area of about 830 hectares. The second line refers to the lower set of five reaches further downstream whose lowest point encompasses an upstream watershed area of about 2,500 hectares.

[2] Significant differences between the upper and lower sections at $\alpha = 0.05$ (e.g., Badenaugh upper section bankfull width [2.5 m] differs significantly from the lower section width [4.0 m]).

Wood-related variables quantified for each 100-m reach included longitudinal distance of all debris pieces from a benchmark located at the downstream end of each reach, and length and representative diameter of each piece. Piece volume was calculated as the volume of a cylinder. All pieces (including rootwads) within the bankfull channel greater than or equal to 0.08 m in diameter and 1 m in length were tagged in three places with numbered metal disks that uniquely identified each piece. In July 1994 before the fire, we quantified the addition of new debris in all 10 study reaches of both creeks by tagging, locating, and measuring new pieces meeting the size criteria. We also measured downstream movement (defined as a change of debris position of at least 5 m) of each previously tagged piece. Immediately after the fire, in September 1994, we re-surveyed Badenaugh Creek. In the summer of 1995 we quantified recruitment and movement of tagged pieces in all 20 reaches of Sagehen and Badenaugh Creeks. In the post-1993 surveys, we searched downstream of the study reaches several hundred meters to locate pieces that had been transported out of the study reaches.

Because post-fire accumulation of woody debris is often blamed for downstream damages, we were particularly interested in the dynamics of debris accumulation through time after the fire in the Badenaugh watershed. We operationally defined debris aggregates as comprising at least four pieces all located within 1.5 m longitudinal distance, with at least one piece being equivalent in length to bankfull width. This length criteria is based on observations by Reid and Smith (1992, p. 10) that “jams are usually triggered by pieces that span the [channel] constriction” and by Piegay and Gurnell (1997, p. 112) that “the size of pieces of wood may exceed the channel width... encouraging debris jams to develop.” We anticipated that aggregations would be both larger (in both the number of debris pieces per aggregate and in debris volume per aggregate) and more prevalent after the fire. As a corollary to this presumption, we also anticipated that the total volume of woody debris would be greater after the fire as a source of elevated amounts of wood for the aggregates.

Size measurements, and therefore volume determinations, of stable debris pieces varied from year to year for several reasons, including sediment movement and bank cutting that could cover or uncover portions of pieces, and observer-induced measurement variability. Because we assumed the size of immobile pieces at Sagehen Creek would not change through time, we averaged the diameter and length of immobile pieces and used this standardized value across all years that a piece was immobile. Because the fire in Badenaugh Creek clearly reduced the size of some pieces, we averaged the size of immobile pieces at Badenaugh separately for the pre- and post-fire periods.

Carbon was estimated as a percentage of the weight of the woody debris and is dependent on species, wood density, and decay class. Because we do not know the decay status of our debris pieces, we used a conservatively low estimate of wood density, 0.34 gm cm^{-3} wood volume, coinciding with a moderate decay class (Harmon and others 1987). We used a carbon concentration of 50 percent, which is within the range of Harmon and others’ (1987) estimates for Jeffrey pines. The weight of woody debris was calculated by multiplying the volume by the specific gravity, and the amount of carbon was calculated as a percentage of that weight.

We used paired, two-sample t-tests (Steel and Torrie 1960) to assess the differences between pre- and post-fire debris volume per aggregate, number of aggregates, and percent of pieces in aggregates per 100-m at the Badenaugh Creek study reaches. The total volumes measured were compared without a statistical test between pre- and post-fire time periods.

Results and Discussion

Debris Size, Volume, and Frequency

More than 500 debris pieces were tagged, measured, and tracked on the study reaches between 1993 and 1995. Significantly more pieces in the "medium" size range (less than 0.3 m diameter or less than 3 m length) were identified in 1993 at the Badenaugh Creek study reaches than on the Sagehen reaches (two-tailed t-test with unequal variances, $\alpha = 0.05$; Berg and others 1998). At both study streams, changes in debris size, volume, and frequency between 1993 and July 1994 were minimal. All pieces tagged in 1993 were found in the July 1994 surveys, and none of the pieces had moved. One new piece on the Badenaugh study reaches and five new pieces on the Sagehen study reaches were found in 1994. We believe the lack of change was due to the near-record low stream flows of winter 1993-1994, which were incapable of moving pieces either within or into the study reaches. Because debris at Badenaugh Creek did not move over the 1993-1994 winter, we believe no flow-induced movement occurred between the July and September 1994 surveys and that consequently any changes in debris size, frequency, and location identified in September were due to the August 1994 wildfire.

Twenty-five percent of the pieces (78) tagged on Badenaugh Creek disappeared between the July and September surveys (a reduction from 31.9 pieces/100 m to 24.0 pieces/100 m). We believe these pieces, comprising 56.7 percent (26.7 m^{-3}) of the pre-fire volume, were completely incinerated. Observer recordings included "one tag is melted" and "completely burned (found tags)." We attribute the 52 new pieces (5.2 pieces/100 m channel distance with a mean volume of 0.6 m^{-3}/100 m), identified in the September 1994 survey to fire effects (e.g., snags burning through at base).

Many of the debris pieces that were not completely incinerated were reduced in size by the fire. The range in lengths was reduced appreciably *(fig. 1)* with few post-fire pieces measuring more than 6 m in length. Mean length decreased from 5.1 m to 2.5 m after the fire. The percentage of pieces longer than the mean bankfull width (2.5 m) decreased from more than 65 before the fire to 33 after the fire. This reduction in length implies that fewer aggregates would form after the fire because fewer channel-spanning pieces were available to act as anchors for the aggregates. The change in the size distribution of debris also potentially affects the stability of wood for habitat and geomorphic functions; fewer bank-spanning pieces imply less bank armoring by debris and a reduced role by wood as a cover element for fish or in pool formation.

After the high stream flows during winter 1994-1995, the total number of debris pieces and the total volume of debris in both sets of study reaches increased, although the increases at the Badenaugh study reaches were confined largely to reaches 2 and 5, and the five upstream reaches draining a smaller watershed area experienced a net loss of eight pieces *(table 1)*. In comparison, most of the study reaches at Sagehen Creek gained debris *(table 2)*. The absolute magnitude of increases in both debris frequency and volume were five and three times greater, respectively, at the Sagehen reaches than at the Badenaugh study reaches *(tables 1, 2)*.

Changes in frequency and volume totals for each study stream mask potential fire-induced differences in the annual losses of older pieces or gains of newly recruited pieces. Losses result from movement of pieces out of the study area or from complete disintegration; gains result both from pieces transported into the study reaches from upstream and recruitment of wood from the riparian zone within the study reaches. Although fire-induced gains in the number of pieces at Badenaugh between July and September 1994 were appreciable (mean = 5.2/100 m), the losses were greater in both number and volume so that a sizeable net loss of debris occurred as a result of the fire. Gains between September 1994 and 1995 were slightly greater than losses at Badenaugh both in the number and volume of pieces *(table 1)*.

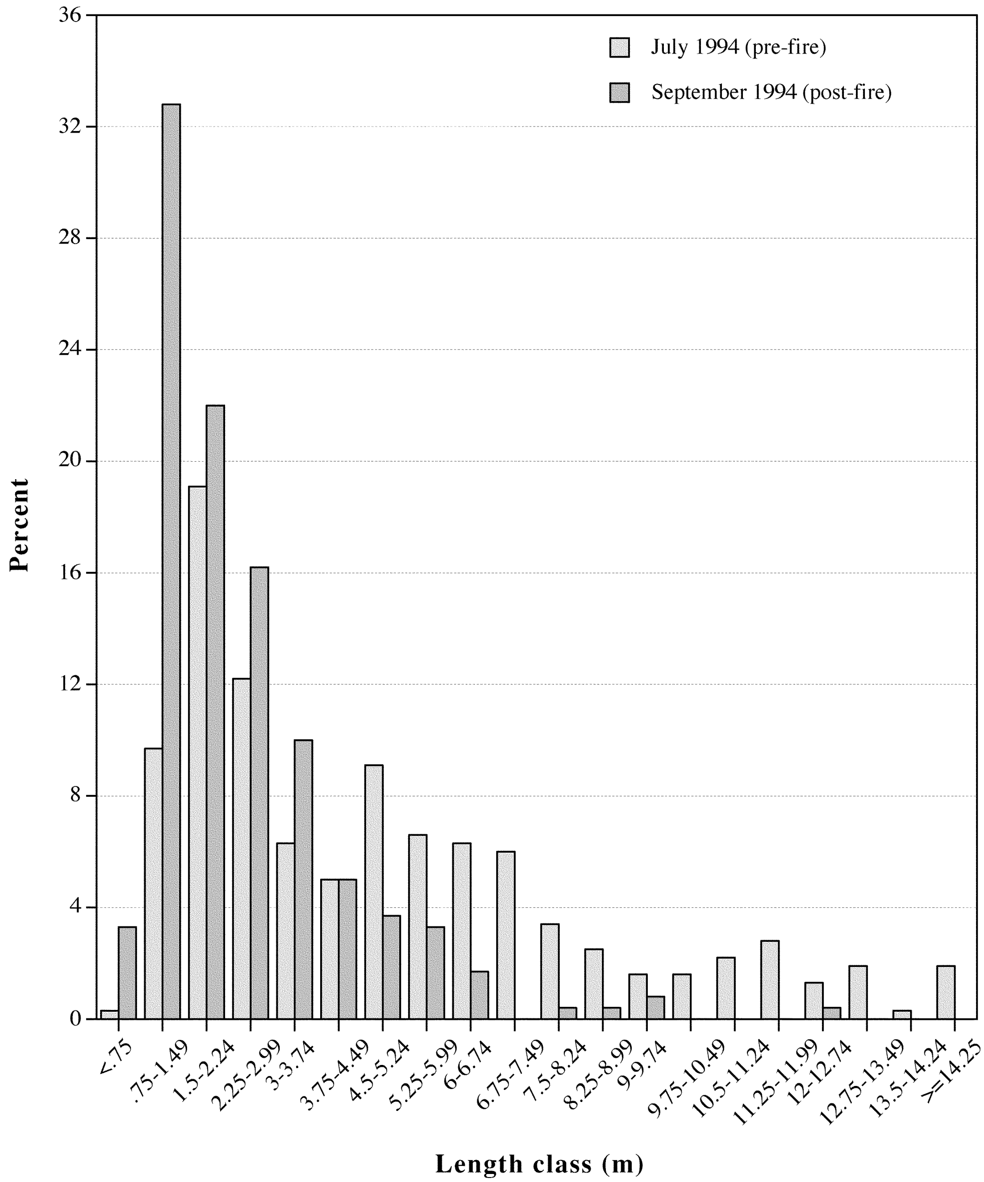

Figure 1—Distribution of debris pieces, before and after August 1994 wildfire, Badenaugh Creek, by lengths.

Table 1—*Changes in debris frequency and volume, and pieces gained and lost between surveys in July 1994 and July 1995 on 10 study reaches at Badenaugh Creek.*

	July 1994		September 1994				July 1995			
Reach number	Total number pieces	Volume (m^{-3})	Total number pieces	Volume (m^{-3})	Number pieces lost	Number pieces gained	Total number pieces	Volume (m^{-3})	Number pieces lost	Number pieces gained
1	31	2.4	24	1.7	9	2	24	1.8	7	7
2	37	3.4	31	1.7	8	2	37	2.5	9	15
3	33	12.0	31	8.6	6	4	30	8.2	8	7
4	8	.2	6	.5	2	0	6	.3	1	1
5	24	1.8	16	.9	10	2	26	1.2	1	11
6	46	4.5	41	1.4	9	4	41	1.4	1	1
7	38	6.0	43	3.3	10	15	38	3.0	6	1
8	44	11.8	41	3.8	13	10	41	5.5	9	9
9	33	2.6	32	2.3	9	8	33	2.3	2	3
10	25	2.5	28	2.1	3	5	24	3.5	5	1
Total	319	47.1	292	26.3	79	52	300	29.6	49	56

At Sagehen Creek, gains compared to losses between the 1994 and 1995 surveys were appreciable *(table 2).* The gains approximated those at the Badenaugh study reaches (6.3 pieces/100 m at Sagehen vs. 5.6 pieces/100 m at Badenaugh), but the losses were appreciably less at Sagehen. The greater losses at Badenaugh, equating to greater transport of debris, may be fire-induced as a result of increased stream flow and increased mobility of the smaller, burned pieces. The complete lack of losses at the upper five study reaches on Sagehen is notable and suggests that flow magnitude is insufficient in this narrow channel to transport debris even during high flows. The larger gains at Sagehen observed in 1995 (6.3 pieces/100 m) compared to winter 1993-1994 (0.5 pieces/100 m) suggest that recruitment or transport, or both, are episodic as a function of stream flow or other controlling factors.

Aggregation

Rather than increasing after the wildfire, the frequency of debris aggregations on the 10 study reaches at Badenaugh Creek decreased significantly (at $\alpha = 0.05$) from 2.0 per 100 m (channel length) in July 1994 to 1.2 per 100 m in September 1994 immediately after the fire and remained at that frequency after high stream flows recorded at Sagehen Creek during the winter of 1994-1995 *(fig. 2).* High flows were conceivably elevated further at Badenaugh Creek in response to reduced evapo-transpiration due to the wildfire. Although high flows over the 1994-1995 winter may have caused the increase in aggregate frequency on Sagehen Creek *(fig. 2),* this is speculative because cause-effect linkages between flow magnitude and aggregate formation are not known. Because aggregate frequency increased on the control stream in 1995, without the fire aggregate frequency on Badenaugh Creek presumably would have increased in 1995, further contrasting the post-fire decrease in aggregate frequency on Badenaugh.

Table 2—*Changes in debris frequency and volume, and pieces gained and loss between surveys in July 1994 and July 1995 on 10 study reaches at Sagehen Creek.*

Reach number	July 1994 Total number pieces	July 1994 Volume (m^{-3})	July 1995 Total number pieces	July 1995 Volume (m^{-3})	July 1995 Number pieces lost	July 1995 Number pieces gained
1	17	7.0	15	8.4	5	3
2	30	19.0	33	19.1	7	10
3	8	2.4	8	2.5	2	2
4	24	10.6	29	13.5	1	6
5	44	9.3	53	12.3	4	13
6	23	1.9	30	2.2	0	7
7	16	5.7	27	7.6	0	11
8	16	5.8	19	5.9	0	3
9	22	6.1	26	6.5	0	4
10	8	2.0	12	2.2	0	4
Total	208	69.7	252	80.3	19	63

The number of pieces per aggregate in the study reaches at both Badenaugh and Sagehen Creeks remained essentially constant over time *(fig. 3),* and the minor differences in the mean number of debris pieces per aggregate between 1993 and 1995 on both creeks are not statistically significant. We did not find evidence that the fire caused more pieces to aggregate.

Mean aggregate volume did not increase after the fire on the study reaches in Badenaugh Creek and instead decreased significantly (α = 0.05) from 0.8 m^3/aggregate pre-fire to 0.25 m^3/aggregate immediately after the fire, with only a slight increase the following year to 0.35 m^3/aggregate *(fig. 4)*. These changes approximated the magnitude of change at the reference stream reaches, implying that the changes in aggregate volume at the Badenaugh study reaches may be within the range of natural, non-fire variability. The threefold to fourfold difference in mean aggregate volume between the reference and burned streams *(fig. 4),* however, precludes rigorous comparison of aggregate volumes between the two creeks.

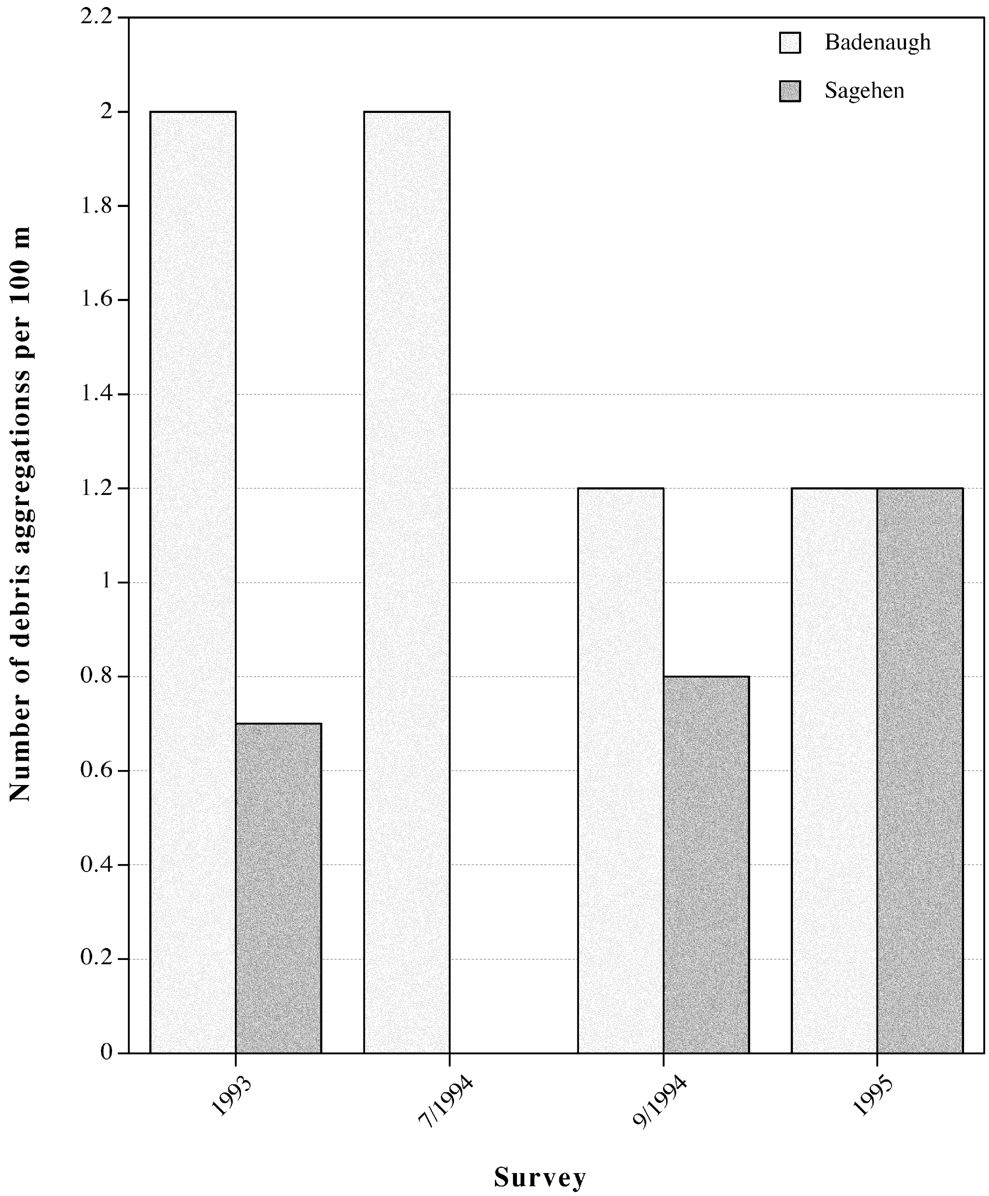

Figure 2—Frequency of debris aggregations, Badenaugh Creek (burned August 1994) and Sagehen Creek (unburned).

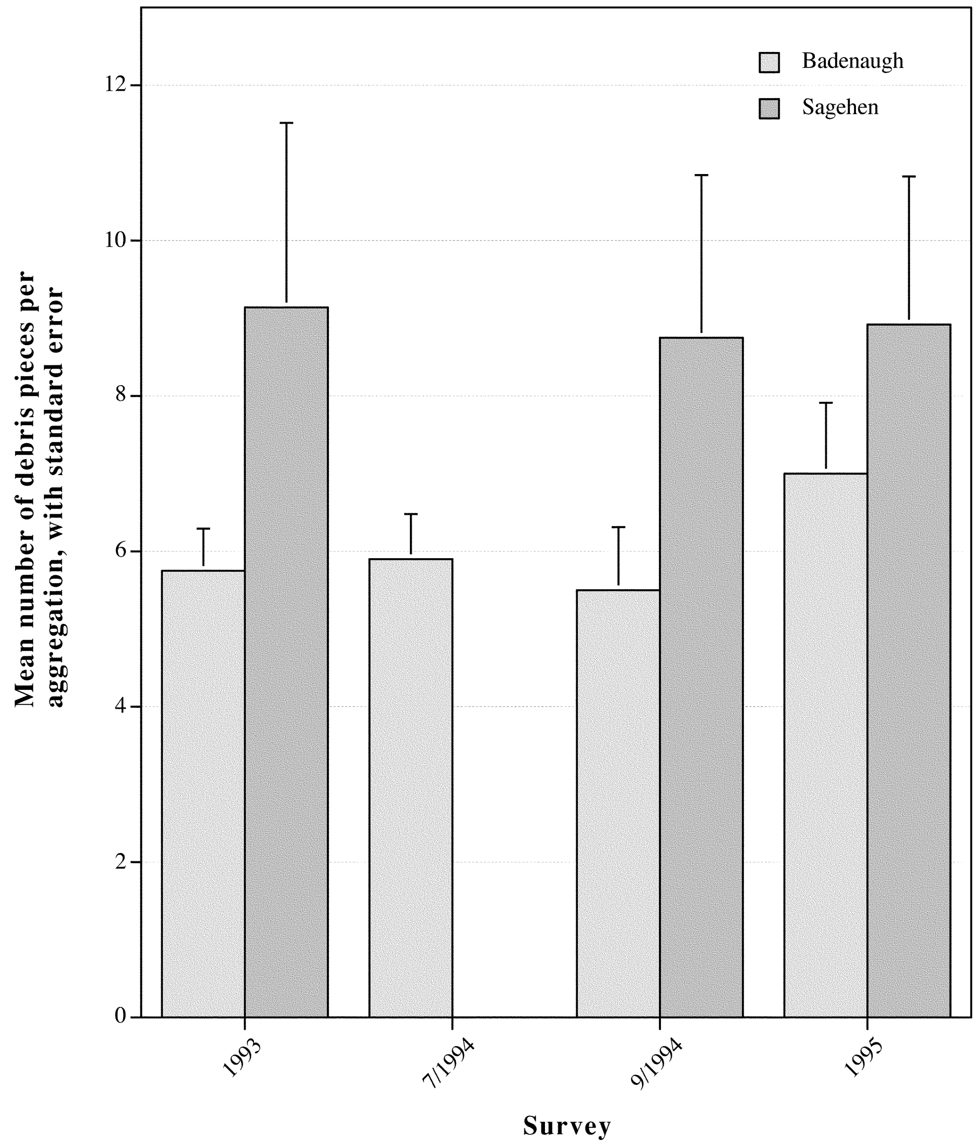

Figure 3—Number of debris pieces per aggregation, Badenaugh Creek (burned August 1994) and Sagehen Creek (unburned).

Carbon Loading

Loss in woody debris volume translates directly to loss in carbon loading within the channel. By reducing the volume of debris appreciably, the fire volatilized a large portion of the long-term carbon stores in the woody debris. We estimated average carbon loading at over 34,000 kg/ha for the Badenaugh study reaches before the fire and over 19,000 kg/ha after the fire—a loss of almost 45 percent. Based on a 82.5 m^3/ha volume for Jeffrey pine logs in Sequoia National Park (Harmon and others 1987), the equivalent carbon content for Jeffrey pine is about 14,000 kg/ha. The fire reduced aquatic carbon loading from about 2½ to 1½ times terrestrial Jeffrey pine loading.

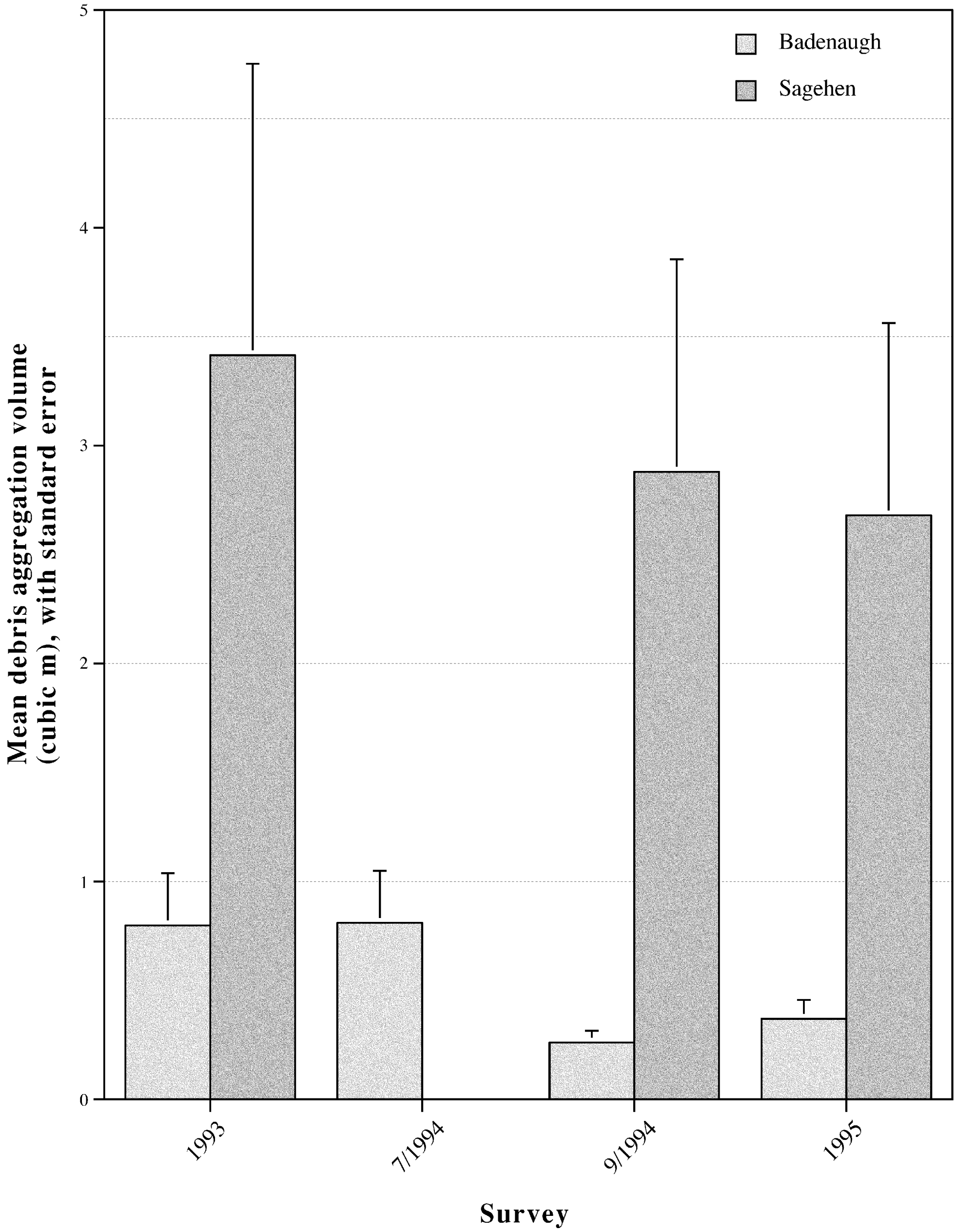

Figure 4—Volume of aggregations, Badenaugh Creek (burned August 1994) and Sagehen Creek (unburned).

Conclusions

Decisions on management of post-fire in-channel woody debris should consider fire intensity, channel width, and the size of the remaining wood. Fire can incinerate debris and shorten non-incinerated pieces. If few post-fire pieces remain that are longer than the bankfull width of the channel, the potential for downstream accumulation of wood at bridge abutments or other structures is relatively low, and retention of wood for aquatic habitat values is probably a better course of action. We found a reduction—rather than an increase—in debris aggregations 1 year after the wildfire, further suggesting that for the stream reaches we studied, increased frequency and magnitude of post-fire debris jams is not a problem in the short term. Longer term results are needed to compare against these short term findings, and potentially in-channel debris quantities will increase in the future as fire-killed trees in the riparian zone fall over and enter the channel. We recommend post-fire surveys of debris size and channel bankfull width as part of the decision process on post-fire debris removal or cutting.

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