Part 6: Fire-Induced Changes in Aquatic Ecosystems

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The aquatic ecosystems within the Hayman fire area represent a highly altered landscape that has been influenced by a variety of activities including mining, vegetation management, road building, urbanization, recreation and water development. Consequently, the expression of aquatic community structure has been significantly altered from the conditions found during European exploration and settlement in the late 1700s and early 1800s.

Introduction

The watersheds within the Hayman Fire area represent a mosaic of ephemeral, intermittent, and perennial streams of various sizes. Given the intensity of the fire, the effects on these streams will often vary from mild to severe. For example, the vegetation along streams in the upper Wigwam Creek drainage was almost completely removed by the intense fire that moved through the upper watershed, while vegetation along other streams was minimally affected (fig. 20; table 7). The severity of the fire in the surrounding watershed will generally dictate the initial response of the stream. Recovery of the stream/riparian interface generally parallels forest recovery (Minshall and others 1989).

The effects of wildfires on streams are generally viewed as "pulse" disturbances (Detenbeck and others 1992) that may be initially severe but are generally short lived. In some cases, sediment accumulations in downstream areas and incision in upstream areas may take decades or longer to recover to prefire conditions. Full recovery of aquatic communities is often dependent on the presence of intact communities that are adjacent to burned areas and the lack of additional disturbances that either retard recovery or pose additional stresses to the system. In the case of the Hayman Fire, human-caused chronic disturbances are present from roads, vegetation management, recreation, and urbanization. The full expression of recovery may be inhibited or truncated by these additional disturbances.

Aquatic Ecosystems Within the Hayman Fire: Prefire and Immediate Postfire Response

The response of aquatic ecosystems during and after a fire can be highly variable and depends on factors such as fire severity, magnitude of storm and snowmelt events relative to normal flow regimes, burned area relative to the watershed area, stream size, stream type, and the ecosystem of interest. The immediate effects of light to moderate fire severities were generally minimal. In these areas runoff and erosion rates may increase, but the increases will not be nearly as large as in severely burned areas, and rates rapidly return to prefire values. In the case of the Hayman Fire, the initial recovery of the riparian zones may have been slowed by the exceptionally dry conditions experienced after the fire. Many of the streams in the northern part of the fire are spring-fed, and the drought apparently caused a reduction or cessation of flow in many areas. Because of the dry conditions, the loss of the forest and riparian vegetation is unlikely to have affected stream flow in the first few months after the fire.

In areas that were severely burned there was almost a complete removal of the streamside vegetation as well as the loss of the duff and litter layer on the adjacent hill slopes. Other studies in the Colorado Front Range have shown that runoff and erosion rates can increase by several orders of magnitude in areas burned at high severity. We were fortunate that a

Table 7—Burn severity for upslope and riparian areas for seven subwatersheds in the Hayman Fire area.

Burn Class	Turkey Creek	Trout Creek	Tarryall Creek	Upper S. Platte R.	Goose Creek	Wigwam Creek	West Creek	Total
	Percent							
Upslope								
Unburned	14.90	17.78	4.84	23.74	14.62	19.31	21.08	17.77
Low	33.32	33.48	46.33	51.17	23.15	19.15	50.14	36.80
Moderate	20.14	36.55	17.18	14.09	5.92	3.73	3.78	12.42
High	31.64	12.18	31.65	11.01	56.32	57.82	25.00	33.01
								Riparian
Riparian								
Unburned	1.98	24.83	12.32	15.22	27.60	10.11	29.56	6.86
Low	2.00	37.82	55.60	53.15	26.89	28.21	28.13	12.24
Moderate	93.94	25.84	7.86	23.18	3.09	6.52	17.22	73.74
High	2.08	11.51	24.22	8.45	42.42	55.16	15.09	17.17

Figure 20—Riparian areas along streams within the fire area were differentially affected by the fire. Note presence of ash and fine sediment in picture on the left and minimal effects to riparian community on the right.

series of study sites had been established in the northern part of the Hayman Fire in summer 2001 to determine the effects of a proposed thinning project. These included the establishment of sediment fences on 12 pairs of swales ranging in size from 0.1 to 1 ha, the installation of 76-cm H-flumes on the 3.4km^2 Saloon Gulch and the 6.2km^2 Brush Creek watersheds, and the assessment of channel characteristics immediately upstream of each flume. Grab water samples were collected on eight occasions between August 2001 and April 2002, before the Hayman Fire.

Prior to the fire, most of the swales had no distinct channel, and there was no measurable erosion in any of the swales from mid-2001 to the time of the Hayman Fire. At the watershed scale, the estimated bankfull channels were less than 1 m wide and only a few centimeters deep (table 8). The channels were relatively stable and well vegetated. The grab water samples had total suspended sediment (TSS) concentrations of less than 10 mg/L, and low concentrations of nutrients and metals (table 9).

Although there were few rainfall events after the fire, they caused dramatic changes in the swales, channels, and water quality, as nearly all of the swales and most of the watersheds above the flumes had been severely burned. By mid-July we had reestablished the sediment fences that had been burned by the Hayman Fire. On 21 July 2002 a rainstorm of only 19 mm resulted in an average sediment yield from the 20 swales of 0.6 kgm^{-2}. Each of the swales had developed an extensive rill network and a clearly incised channel as a result of this event (fig. 21). Permanent cross-sections established in six swales indicated that the newly formed channels were up to 45 cm wide and 15 cm deep.

At the watershed scale, the effects of a 19-mm storm on July 7 were remarkable. The flume in Upper Saloon Gulch, together with its 3-m approach section, was completely buried by the sediment eroded off of the hillsides and out of the headwater channels. A comparison of the prefire and postfire cross-sections shows that over 1 m of sediment was deposited (fig. 22). At the mouth of the Saloon Gulch watershed, a large alluvial fan has been deposited. This fan extends into the channel of the South Platte River, and the erosion of the distal edge of this fan is introducing substantial amounts of fine sediment into the South Platte River.

At Brush Creek the rebars marking the channel cross-section were destroyed by the July 7 storm, but figure 23 shows the relative change in channel dimen-

Table 8—Channel characteristics in Saloon Gulch and Brush Creek in summer 2001.

	Site	
Channel characteristics	**Saloon Gulch**	**Brush Creek**
Drainage area (km^2)	3.4	6.2
Date of survey (dd/mm/yr)	01/11/01	06/08/01
Active channel width (m)	0.64	0.4
Bankfull channel width (m)	0.76	0.67
Bankfull depth (m)	0.08	0.12
Discharge on survey date (l/s)	0.3	1.1
D50 (mm)	7	12
D84 (mm)	13	33
Percent fines <8 mm	62	35
Percent eroding banks	4	13

Table 9—Mean values for selected water quality parameters in Saloon Gulch and Brush Creek prior to and after the Hayman fire.

	Site			
	Saloon Gulch		Brush Creek	
Water quality parameters	**Prefire**	**Postfire**	**Prefire**	**Postfire**
Number of samples	8	1	8	6
Discharge (l s^{-1})	0.2	0.6	1.3	11.9
pH	8	8	8	8
Conductivity (uS)	180	400	170	290
K (mg l^{-1})	2.9	6.7	2.8	4.7
Mg (mg l^{-1})	4.3	11.6	4.3	7.9
Ca (mg l^{-1})	24.9	59.6	21.1	41.8
Cl (mg l^{-1})	1.8	2.5	2.2	2.3
NO_3 (mg l^{-1})	0.5	0.2	0.1	0.3
Total suspended sediment (mg l^{-1})	10	35	16	4600
Turbidity (ntu)	5	17	10	62
Sum of Anions (meq l^{-1})	1900	4500	1700	3100
Sum of Cations (meq l^{-1})	1900	4400	1700	3100

sions. The high water mark at Brush Creek was clearly distinguishable by the deposition of ash, and this indicated that the peak flow depth was close to 2 m. The flume itself was filled with fine sediment, woody debris, and boulders up to 50 cm in diameter. The particle-size distribution after this event showed a much greater preponderance of fine sediment, as the percent of the channel bed smaller than 8 mm in diameter increased from 35 to 70 percent (fig. 24a,b). The observed changes in the bed material at Brush Creek can be expected to sharply reduce macroinvertebrate density and diversity in the short term.

Results from a limited number of grab samples taken after the fire show a sharp increase in the mean TSS concentrations in Brush Creek from 16 to 4600 mg l^{-1}, and from 10 to 35 mg l^{-1} in Saloon Gulch (table 9). There also were substantial increases in the concentrations of potassium, magnesium, calcium, chloride, and nitrate. Overall, the sum of anions and cations approximately doubled as a result of the Hayman Fire. In contrast to the other parameters, there was no significant change in pH.

General observations indicate that each storm event after the fire caused extensive erosion, with large amounts of sediment being deposited on the roads. New alluvial fans developed at the mouth of many headwater channels. Large amounts of ash and sediment were deposited in other streams, and in some cases these deposits filled beaver ponds.

These data and observations show that even small convective storms can generate large amounts of runoff and erosion in severely burned areas. Incision will occur in headwater areas and deposition in downstream

Figure 21—Rills and incised channels in a study swale in Upper Saloon Gulch after the fire.

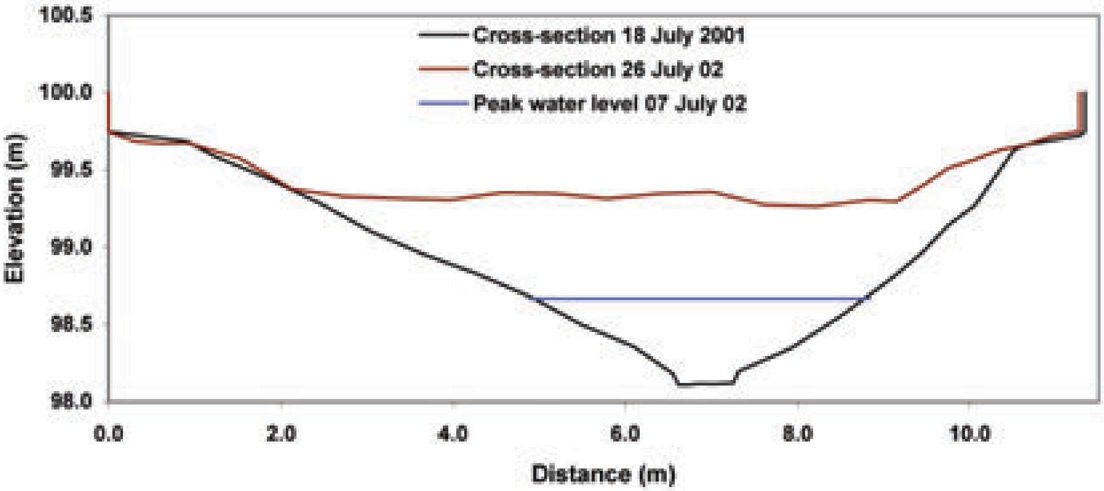

Figure 22—Cross–section of the channel in Saloon Gulch immediately upstream from the flume prior to the fire in summer 2001 and in July 2002 after the fire and a 19-mm storm event.

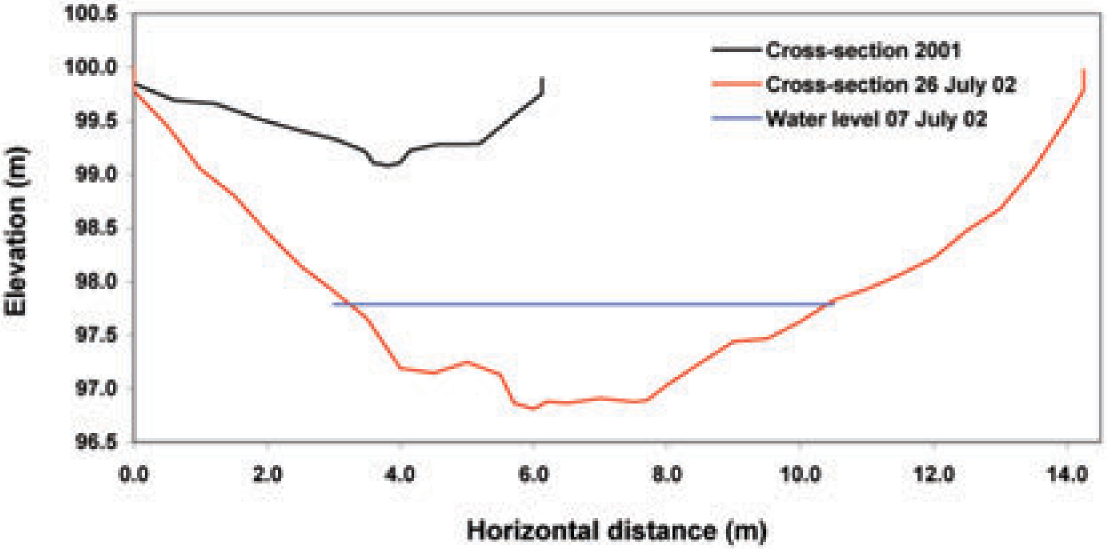

Figure 23—Channel cross-section in Brush Creek immediately upstream of the flume prior to the fire in summer 2001 and in July 2002 after the fire and a 14-mm storm event. The two cross-sections are each plotted relative to different benchmarks as the rebar established in 2001 were lost.

areas. Much larger effects can be expected from larger magnitude storm events, such as those that occurred after the 1996 Buffalo Creek Fire. Recovery in these aquatic ecosystems may be slow, as decades or longer may be needed to remove the sediment that is being deposited in lower gradient areas. Recovery of the incised rills and headwater channels should be relatively rapid once vegetation or organic debris protects the banks and slows the flow velocities. In contrast, the more deeply incised channels may require several decades before they fill in and recover to prefire conditions.

Small perennial streams that drained intensively burned watersheds most likely received inputs of nutrients from both ash and smoke during the fire (Spencer and Hauer 1991). We observed a coating of ash and burned needles over the stream bottom in many of the sections of stream during our field visit, as well as recent input of limbs and larger woody debris. Pulsed inputs of nutrients most likely resulted in elevated levels of phosphorus and nitrogen in the short-term, but these inputs may have returned to prefire levels within weeks after the fire. Pulsed inputs and elevated levels of nutrients will occur in the short-term during precipitation events and spring runoff.

Benthic macro-invertebrate communities were differentially affected in the fire area to a degree that depended on the severity within the immediate watershed and at the local site scale (authors' personal observation). Short-term effects during the fire may have included local extirpations or a catastrophic drift response where stream temperatures or water chemistry may have reached sublethal to lethal levels (Spencer and others 2003; Minshall and others 1989; Minshall 2003). Most likely, local populations may have been partially extirpated but maintained numbers of more tolerant organisms. We observed late instar mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), and other organisms patchily distributed where larger substrates were available in severe burn areas.

Immediate postfire response of the invertebrate community was also affected by the amount of sediment and debris transported into small streams from surface ravel and during initial runoff events. Stream channel sedimentation was occurring in many of the streams that we visited (fig. 25). Previous studies documented a decline in both diversity and biomass in some streams affected by fires where channel sedimentation has occurred (Minshall and others 1995, 2001; Rinne 1996). Local effects related to sedimentation appeared to be highly variable. Where large woody debris was present in sufficient quantity or there were beaver dams present to trap sediment, it appeared that stream substrate immediately downstream was much more heterogeneous.

A variety of short-term responses have been noted for fish communities affected by wildfire. Local extirpation of fishes has been noted where fire severity was high, potentially caused by lethal increases in water temperature and short-term changes in water quality that may have created unfavorable conditions for fish (Spencer and others 2003). Fish mortality may also be the result of poorly placed fire retardant that enters

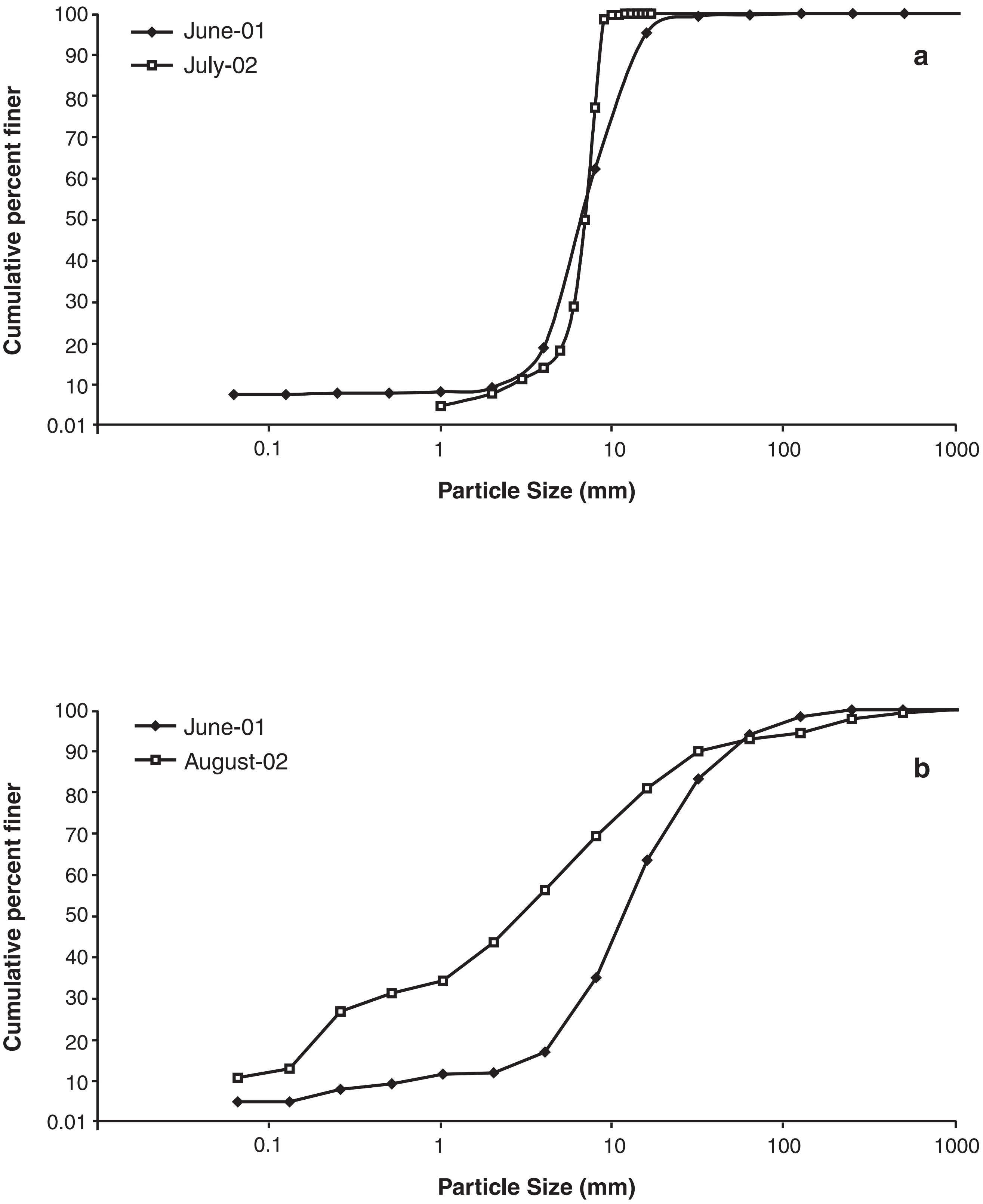

Figure 24—Size distribution of the bed material before and after the Hayman Fire in (a) Saloon Gulch and (b) Brush Creek.

the water during suppression (Minshall and others 1989).

The impact of these effects is often dependent on the availability of refugia in proximity to the affected area (Gresswell 1999). Short-term refugia may exist at small scales. For example, cool ground water sources may provide refugia at the scale of individual pools. In other cases, fish may be dependent on neighboring stream reaches or streams outside of the most impacted affected streams for temporary habitat. This presupposes that fish will be able to freely move within and among watershed.

Observations within the Hayman Fire area indicated that localized fish kills did occur in some of the more severely affected burn areas. Direct fire-related mortality was observed in Wigwam Creek (Denny Bohon, South Platte District Biologist, personal observation). We are unsure of the extent and the severity of the mortality. Certainly in cases where high fire intensity has severely affected water temperature, large-scale mortality can occur and cause significant population losses (Rinne 1996).

Fish mortality occurred within the fire area after the first rains carried debris flows into some of the larger streams and reservoirs. Fish mortality was observed in Cheesman Reservoir by employees of the Denver Water Board after rains carried ash and sediment into the reservoir. Fish mortality also occurred in off-channel rearing ponds located at the confluence of Wigwam Creek and the South Platte River (Pete Gallagher, Fisheries Technician, Pike National Forest, personal communication). These events are generally localized because large amounts of water from multiple watersheds provide some buffering capacity in these larger systems (Gresswell 1999; Minshall 2003).

Figure 25—Sedimentation of stream bed as a result of surface ravel and coarse-grained sediment inputs from ephemeral tributaries. Woody debris has trapped sediment in the area directly upstream.

Aquatic Ecosystems Within the Hayman Fire: Immediate Postfire Response to 5-Year Period

The speed and trajectory of aquatic ecosystem recovery within the Hayman Fire area will be affected by a variety of factors. The recovery of the hill slope and riparian vegetation will influence how quickly the aquatic environments recover. Clearly, the areas that were less severely burned will most likely recover to prefire conditions most rapidly. Recovery of the severely burned watersheds will be most dependent on riparian recovery, the juxtaposition to high quality habitats that can provide sources for recolonization, and the mitigation of additional chronic disturbances.

In general, the 5-year period after a major wildfire is one of transition in aquatic ecosystems. Stream nutrient levels and suspended sediment increase within the first year postfire and gradually decline within the first 5 years (Spencer and others 2003; Minshall and others 1989) (fig. 26). The trajectory and the speed of this response are often dependent on the presence of major debris flows and/or catastrophic floods. For example, Buffalo Creek experienced a major flood and debris flow following the 1996 Buffalo Fire. Debris terraces are still present in much of lower Buffalo Creek, but the stream has continued to cut through those terraces and establish a new channel in the floodplain. The initial pulse of sediment appears to be moving through the system, and a much more heterogeneous particle size distribution is apparent (fig. 27). The aggrading channels will take much longer to recover, as there has to be sufficient flow to scour out the channels without any substantial inputs of sediment. Depending on the sequence of future storm events, this could take anywhere from decades to centuries.

Increased solar inputs from the opened canopy, combined with increased nutrient levels, often result in an increase in primary production and a shift in the aquatic invertebrate community from organisms that process leaf litter and debris to organisms that can scrape and graze attached algae from the substrate (Minshall 2003; Gresswell 1999). The extent of this phenomenon will be dependent on the recovery of riparian vegetation and the extent that the canopy closes over the stream. For example, small streams within the Buffalo Fire area have developed an almost closed canopy of early successional vegetation in some areas. In areas where little vegetation is present, temperature increases will be dependent on water

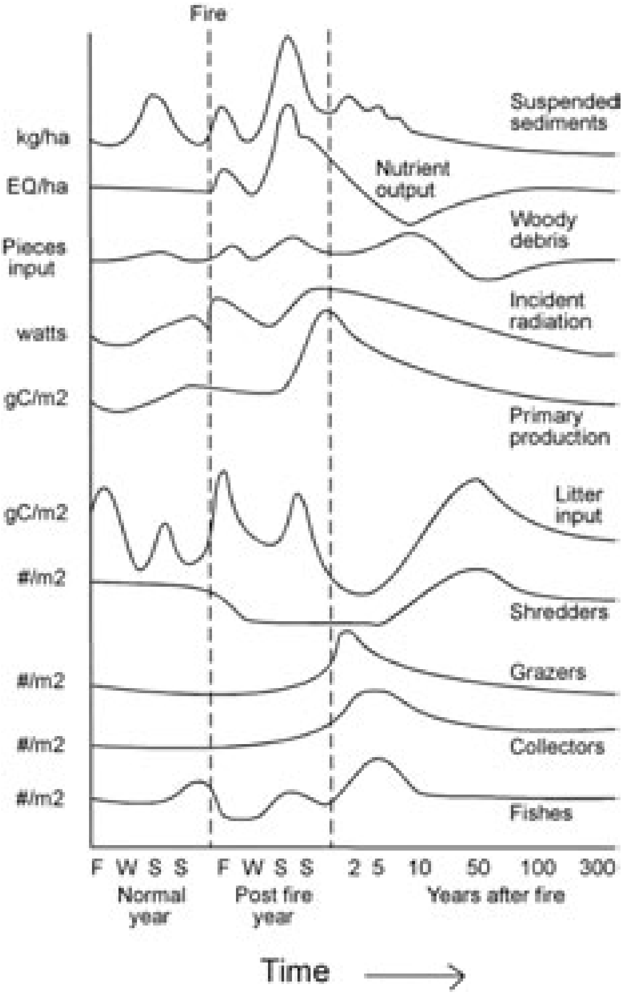

Figure 26—A generalized temporal sequence of selected events in response of aquatic ecosystems to fire (from Minshall and others 1989; Gresswell 1999). Note the short-term inputs of sediment and nutrients that may occur in the first few years after a fire. Most other major fire-related disturbances to streams, such as debris flows or flooding, typically occur within the first few years after a fire.

quantity available and the recovery of riparian vegetation. Short-term increases in temperature are more likely to occur in smaller, perennial streams.

Other inputs from the riparian area show a variety of responses. Inputs of leaf and needle litter may decline within the first 5 years if the canopy and surrounding riparian vegetation has been completely burned or removed. Large wood inputs often increase in the short-term as a result of windthrow but generally remain stable during the first decade or more (fig. 26). Long-term replacement of large wood is affected by the rate of forest succession. Recruitment from the dead standing wood in the riparian areas within the fire will be critical to maintain instream large wood in the near future.

Fish populations have generally shown a positive response during the initial 5-year period postwildfire where populations exhibit good connectivity with key refugia throughout the watershed (Minshall and others 1989; Gresswell 1999). Fish will generally reinvade fire-affected areas rapidly where movement is not limited by barriers created by poorly designed road crossings/culverts, diversions, or dams. These new colonists generally come from areas upstream of the affected area, from surrounding watersheds and from mainstem rivers where migration is not limited. Fish population recovery generally tracks the increase in primary and secondary production that occurs in the early postfire period. Where sediment is continually delivered into the mainstem and reservoirs of the South Platte, there could be short-term negative effects on fish and macroinvertebrate communities.

Postfire fish population surveys in the South Platte River indicate that the short-term consequences to populations varied in severity, depending on the location (Steve Puttman, Fisheries Biologist, Colorado Division of Wildlife Resources, unpublished data). For example, fall population estimates in the lower Cheesman Canyon indicated that the numbers of rainbow and brown trout were consistent with estimates from surveys conducted from 1998 to 2001 (table 10). Population estimates conducted at a site above Decker's Bridge show no clear trend, although the number of rainbow trout in this section declined from the 2001 survey (table 11). However, these numbers are still higher than numbers reported from 1996

Figure 27—Buffalo Creek 6 years after a severe wildfire and catastrophic debris flow. The initial inputs of wood and debris have been transported downstream. Debris accumulations may still be observed at the mouth of Buffalo Creek. Substrate within this stream reach represents a heterogeneous mix of particle sizes. Road location was returned to the floodplain where potential for stream interaction is high. Note that debris accumulations and scour lines are still present in the trees to the right of the stream.

to 2000. Brown trout numbers and density increased slightly while biomass declined to the lowest level during the survey period. Numbers of brown trout equal to or less than 35 cm/ha declined from 2001(highest reported during the survey period) but were higher than all but 2 other years during the 23-year survey history.

Brown trout and rainbow trout populations were also surveyed below Decker's Bridge, approximately 0.5 km downstream of the confluence with Horse Creek. This station was affected by flash flood inputs from both Wigwam Creek and Horse Creek after the Hayman Fire. Brown trout population numbers, density, and biomass declined dramatically in the fall of 2002 compared to 2001 and are at or near all-time lows for the period of study (table 12). Rainbow trout population parameters were also near all-time record low levels in the fall of 2002; however, those statistics have been hovering at that level since the mid-1990s, due in large part to the effects of whirling disease. It will be important to document the duration and magnitude of this response to predict the long-term effects on the blue ribbon trout fishery.

The postfire response of aquatic ecosystems during the first 5 years will be a resorting and renewal of the stream environment. The disturbance resulting from the fire will be followed by an initial response period that can be highly variable but generally moving in a predictable path (fig. 26). Recovery can be hindered by other pulsed or more chronic disturbances. For example, chronic fine sediment inputs from roads, ditches, and fill slopes can retard the ability of streams to sort this sediment and restore habitat. Poorly designed culverts that impede passage of all life stages of fish may slow or even prevent the recolonization of some stream sections. Native fishes such as longnose dace and suckers may require different passage requirements than do salmonids.

It is somewhat misleading to put the short-term condition and recovery of the aquatic environments of the Hayman Fire in the context of historic range of variability. Certainly, the aquatic ecosystems within the fire area can be characterized as a distribution of conditions that probably represented a broad array of habitat conditions from poor to excellent. These conditions were historically present in a mosaic across the

Table 10—South Platte River trout population (N), density (N/Ha), biomass (Kg/Ha), and abundance of trout ≥35 cm (N/Ha) at the lower Cheesman Canyon monitoring site (1979 to 2002).

	Brown trout				Rainbow trout			
Year[a]	N	N/Ha[b]	Kg/Ha	N/Ha ≥35 cm	N	N/Ha[b]	Kg/Ha	N/Ha ≥35 cm
F1979	327	791 (±29)	192	84	512	1238 (±60)	401	342
S1980	329	795 (±130)	176	79	514	1243 (±72)	422	404
F1980	333	805 (±22)	165	44	384	929 (±27)	336	355
S1981	259	766 (±27)	170	52	496	1467 (±33)	566	673
F1981	221	534 (±53)	135	62	264	638 (±85)	259	394
S1982	305	738 (±48)	164	34	344	832 (±46)	344	526
F1982	231	559 (±58)	121	33	232	561 (±77)	234	384
F1983	427	1032 (±41)	244	99	570	1378 (±31)	359	476
F1984	261	631 (±82)	168	61	373	802 (±85)	322	381
F1985	186	449 (±29)	120	83	247	597 (±12)	262	474
F1986	251	607 (±75)	143	69	262	634 (±80)	315	463
F1987	258	822 (±76)	186	47	230	735 (±108)	320	436
F1989	463	896 (±23)	204	108	384	743 (±15)	280	362
F1990	716	1435 (±36)	292	120	538	1078 (±18)	376	391
F1991	445	860 (±27)	216	83	238	461 (±17)	191	194
F1993	396	766 (±29)	200	110	199	385 (±14)	184	248
F1994	323	735 (±34)	210	121	176	400 (±14)	240	358
F1995	286	802 (±36)	219	192	121	339 (±20)	201	283
F1996	276	583(±45)	201	245	101	212(±18)	137	183
F1997	335	639 (±17)	218	285	182	348 (±15)	150	181
F1998	249	476 (±41)	169	253	103	198 (±23)	108	126
F1999	374	724 (±29)	254	336	104	202 (±6)	125	158
F2000	331	633(±19)	221	281	85	162(±8)	102	55
F2001	290	554(±13)	174	236	101	193(±10)	119	153
F2002	340	650(± 16)	209	262	117	224 (± 15)	105	123

[a] F prefex preceding the year denotes fall sample; S denotes a spring sample.

Table 11—South Platte River trout population (N), density (N/Ha), biomass (Kg/Ha), and abundance of trout ≥35 cm (N/Ha) at the above Deckers Bridge monitoring site (1979 -2002).[a]

	Brown trout				Rainbow trout			
Year	**N**	**N/Ha[c]**	**Kg/Ha**	**N/Ha ≥35 cm**	**N**	**N/Ha[c]**	**Kg/Ha**	**N/Ha ≥35 cm**
F1979[b]	416	1097 (±179)	141	14	140	369 (±53)	61	0
S1980	409	1079 (±34)	137	0	58	152 (±18)	28	7
F1980	545	1318 (±293)	164	5	130	314 (±203)	44	11
S1981	303	733 (±41)	103	7	37	89 (±10)	15	13
F1981	396	957 (±421)	185	46	88	213 (±324)	40	7
S1982	205	496 (±48)	77	4	17	41 (±5)	6	0
F1982	696	1683 (±210)	190	8	117	285 (±36)	32	8
F1983	973	2352 (±48)	270	20	313	757 (±19)	106	23
F1984	393	951 (±82)	145	3	132	319 (±15)	77	34
F1985	405	979 (±29)	158	3	244	590 (±10)	173	81
F1986	487	1179 (±34)	202	8	199	482 (±10)	165	156
F1987	641	2049 (±42)	306	14	224	716 (±80)	188	128
F1989	959	2140 (±16)	328	36	379	847 (±2)	238	193
F1990	1092	2643 (±58)	460	56	310	751 (±15)	247	199
F1991	1204	2686 (±49)	407	63	242	539 (±7)	171	145
F1993	806	1798 (±31)	398	37	162	361 (±9)	156	184
F1994	520	1325 (±23)	266	55	66	167 (±3)	89	126
F1995	419	934 (±85)	199	99	52	117 (±7)	58	80
F1996	334	745(±66)	130	82	23	50(± 3)	20	30
F1997	274	605 (±19)	179	169	35	76 (±22)	19	20
F1998	285	631 (±11)	167	48	21	46 (±3)	7	6
F1999	391	873 (±105)	208	129	22	49(±12)	29	33
F2000	239	533(± 31)	176	59	22	50(±2)	28	14
F2001	204	456(±6)	161	185	67	149(±22)	59	83
F2002	224	500 (± 3)	122	112	36	79 (± 3)	28	23

[a] An 8 trout/day bag limit was in effect on this section up through December 1982. Catch and release on all rainbow trout and a 2 trout ≥16 inches bag limit on brown trout with fly and lure only terminal tackle in effect in 1983.

[b] F prefix preceding the year denotes fall sample; S denotes a spring sample.

[c] 95% confidence limits in parentheses

Table 12—South Platte River trout population (N), density (N/Ha), biomass (Kg/Ha), and abundance of trout ≥35 cm (N/Ha) at the below Deckers Bridge monitoring site (1982 -2002).[a]

	Brown trout				Rainbow trout			
Year	**N**	**N/Ha[c]**	**Kg/Ha**	**N/Ha ≥35 cm**	**N**	**N/Ha[c]**	**Kg/Ha**	**N/Ha ≥35 cm**
F1982[b]	810	2,588 (±208)	295	?	189	604 (±214)	72.4	?
F1983	942	3,010 (±60)	380	?	302	963 (±49)	120	?
F1984	407	1,300 (±35)	199	10	196	626 (±32)	111	11
F1985	339	1,083 (±32)	209	7	160	511 (±16)	122	20
F1986	406	958 (±30)	189	10	174	410 (±23)	116	67
F1987	621	1,984 (±48)	248	11	278	889 (±32)	146	33
F1989	650	1,533 (±10)	272	29	488	1,150 (±13)	268	122
F1990	884	1,789 (±18)	326	72	477	966 (±6)	252	146
F1991	1,071	2,167 (±37)	332	42	391	791 (±24)	193	110
F1993	776	1,570 (±26)	343	28	182	368 (±11)	143	45
F1994	No sampling conducted at this station in the fall of 1994							
F1995	182	708 (±14)	185	58	112	435 (±10)	250	149
F1996	456	1,262 (±57)	274	36	56	154 (±4)	73	36
F1997	386	1,070 (±34)	306	107	74	206 (±25)	70	32
F1998	249	476 (±41)	169	102	104	198 (±21)	108	51
F1999	641	1,297 (± 20)	266	49	77	155 (±10)	52.2	16
F2000	482	976 (±16)	303	67	80	163 (±2)	69.7	28
F2001	404	817 (±18)	276	106	88	178 (±25)	60.6	29
F2002	244	494 (±8)	138	52	85	171 (±5)	56.5	23

[a] An 8 trout/day bag limit was in effect on this section up through December 1982. Catch and release on all rainbow trout and a 2 brown trout ≥16 inches bag limit with fly and lure only terminal tackle went into effect beginning in 1983.

[b] F prefix preceding the year denotes fall sample.

[c] 95% confidence limits in parentheses

landscape where some watersheds were intact while others may have been recovering as a result of a variety of natural disturbances (Reeves and others 1995). High quality habitat most likely was available throughout other areas of the watershed while streams and watersheds recovered from disturbance.

The current situation is somewhat different. The full expression of habitat capability has been compromised in many areas as a result of disturbances that do not allow for the full range of recovery. Management emphasis areas that include water withdrawals and urbanization are unlikely to ever reach historic levels of habitat capability. Roads that are within the historic floodplain of streams or limit the ability of streams to interact with the floodplain also limit the full expression of habitat conditions. The removal of beaver and beaver dams in streams may also inhibit full habitat recovery. In these areas, aquatic ecosystems are unlikely to ever recover to historic conditions unless there is a change in management emphasis. There are curious exceptions. Stream habitat capability within the North Fork and mainstem of the South Platte River is sustained at artificially high levels by the interbasin transfer of water and resulting increase in base flows.

Recovery of the riparian and aquatic ecosystems within the Hayman Fire area has already begun. The recovery of aquatic ecosystems may be influenced by large storm events. Large storms can generate high flows that cause channel incision in headwaters and the deposition of large quantities of fine sediment in lower gradient reaches. Where additional anthropogenic disturbance has not inhibited or truncated ecosystem processes, recovery should proceed along the trajectory we have outlined. In areas that have been influenced by chronic, human-caused disturbances, aquatic ecosystems will not fully recover to their historic potential. Postfire studies are urgently needed to identify the rate and direction of recovery of a range of ecological conditions within the Hayman Fire watersheds. In addition, few studies have documented the rate and extent of channel incision and deposition within streams affected by wildfires. We were fortunate in having some prefire data, and these have provided a relatively unique opportunity to track changes over time, relate these changes to specific storm events, develop a process-based understanding and then use this understanding to predict the physical rate of recovery.

Rehabilitation is often suggested as a means to accelerate the recovery of streams and riparian systems. Rehabilitation efforts could potentially accelerate the recovery of the headwater channels. The basic approach would be to slow the flow of water and facilitate sediment deposition by structural (for example, small check dams) or bio-engineering techniques (planting vegetation). The latter will only be successful in those streams with perennial flow or shallow groundwater, but the problem is that many of the incising streams are much farther up in the watersheds where flow is typically ephemeral.

In contrast, rehabilitation of the aggrading perennial streams downstream from the fire is impractical or difficult at best. The large volume of sediment in the system, poor access in many areas, and the logistical difficulty of removing spoil material would make this operation extremely difficult and costly. Efforts to accelerate the recovery of the hillslopes may help by reducing the future inputs of sediment, but so much sediment has already been mobilized, or is poised to move into the downstream areas, that relatively little can be done to stop the problem.

Given the limited number of postfire studies, this opportunity to understand the response of streams and riparian areas to wildfire should not be wasted. It is important to understand the range of responses of the postfire aquatic ecosystem in a variety of disturbance regimes (Bisson and others 2003). Well designed monitoring studies that track the biological, chemical, and physical aspects will provide useful information on the rate and trajectory of recovery.

The speed and trajectory of postfire recovery will be influenced by the amount and location of anthropogenic disturbances. While it is unrealistic to completely eliminate all of these disturbances within the fire area, there may be opportunities to restore a full range of processes in some watersheds. A watershed or landscape analysis that links fire-related disturbance with existing disturbances should be completed as quickly as possible. By linking this analysis to current restoration efforts, it should be possible to identify restoration opportunities through additional postfire rehabilitation efforts, as well as removing or modifying roads, campgrounds, and other stressors that will hinder or preclude the recovery of riparian and aquatic ecosystems.

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