

# SHORT-TERM EFFECTS OF THE PICTURE FIRE ON FISHES AND AQUATIC HABITAT

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## Abstract

The Picture Fire burned approximately 5,000 hectares on the Tonto National Forest in June of 2003. Seven monitoring sites were established to determine the effects of post-wildfire ash and sediment inputs on fishes and their habitats. Sites were sampled prior to runoff events and following the post-fire, summer monsoon season. Native fishes sampled at these sites were headwater chub *Gila nigra*, desert sucker *Catostomus clarki*, and speckled dace *Rhinichthys osculus*. Percent decrease in total fish numbers varied with position on the watershed. Numbers of all species decreased after the summer, post-fire runoff events at five of the six sampling sites and ranged from 52% to 94% reductions. The most upstream and downstream sites on the watershed sustained the greatest reductions in fish numbers with a complete loss of all fish species occurring at the lowest site in the watershed.

Spikes in turbidity of over 1000 NTU were recorded and initial spikes of high turbidities were correlated with a pronounced drop in dissolved oxygen. High turbidity also was negatively correlated with a dampening of the diurnal pattern of dissolved oxygen rise and fall. Little change in pH was observed. Suspended solids and pebble counts suggested periodic, immediate, and dramatic changes in water quality and stream channel substrates.

Short-term results of this study corroborate previous studies documenting the short-term, dramatic and negative impact on native fishes in fire-impacted streams.

## **Introduction**

The purpose of this paper is to document the short-term effects of the Picture Fire on fishes and their habitat. It is one of several ongoing case studies that are being undertaken by the Rocky Mountain Research Station in the Southwestern United States (Rinne and Carter in press, Rinne 2004a). Multiple case studies of fire effects on fishes and aquatic habitats are important because of the characteristic high variability in fire size and intensity, vegetation type, geomorphology, species assemblage, and other factors. Rinne (1996) first studied fire effects on fishes and aquatic habitats in the Southwest. This pioneering research documented the extirpation of three trout populations from three streams along the Mogollon rim in central Arizona following the Dude Fire of 1990. An entire assemblage of native cypriniform fishes was extirpated over 40 km of the one fire-impacted stream (Ponil Creek) following the Ponil Fire in northeastern New Mexico (Rinne and Carter in press; Rinne 2004a). Other case studies have demonstrated dramatic results. For example, post-fire runoff from the Borrego Fire (Rinne and Carter, in press, Rinne 2004a, 2004 b) that burned in north-central New Mexico in 2002 reduced a brown trout population by 70%. Fish population reduction was nearly equal to the percent reduction of pool habitat in study reaches. This trout population has remained fairly stable over subsequent (2003-2004) years (unpublished data).

The Picture Fire burned approximately 5,000 hectares on the Tonto National Forest between 6/17/2003 and 6/26/2003. Study began on 7/15/2003 before the summer rains fell on

the fire-impacted watershed. The fire burned primarily through pinyon/juniper-mixed chaparral-scrub, pinyon/juniper-mixed grass-shrub, chaparral-shrub live oak-manzanita, ponderosa pine/pinyon-juniper, and ponderosa pine vegetation types. Burn severity data indicated a two percent high burn severity and a ten percent medium to high burn severity. The topography of the watershed is steep and rugged and riparian areas are mostly canyon-bound. During the drought year of 2003, continuous surface flow was sustained at all study sites.

### **Methods and Study Sites**

Seven monitoring sites were established on Spring Creek and two tributaries (Rock and Turkey creeks) that were impacted by the Picture Fire (Figure 1). One site on Spring Creek was positioned outside of the fire's influence and served as a control. All of the sites were sampled before and after the summer runoff events occurred. The sites were approximately 150-200 meters long, consisting of two pools and one to two riffle sections each. Fish were sampled with pulsed DC backpack electrofishing units. Numbers and total lengths of each fish species were recorded and all fishes were returned alive at the stream site in which they were collected. One additional site outside of the fire's influence (Spring Creek Meadow Site) was established after the monsoon season ended, but there was no pre-monsoon data taken.

Hydrolab units (datasonde 4a) were deployed throughout the study period at two sites: Site 3 (Rock Creek) and Site 6 (lower Spring Creek). Multiple water quality parameters (temperature (degrees C), turbidity (NTU), conductivity (mS/cm), dissolved oxygen, and pH) were measured. A third Hydrolab instrument was deployed at the upper end of the study reach,

Site 1 (Turkey Creek), but it failed to log data and was removed. In addition, automated water samplers (Isco model 1680) were deployed near the Hydrolab instruments at the three above-mentioned sites, and were programmed to collect water samples at twelve-hour intervals throughout the study period. These samples were filtered with Fisherbrand quantitative Q5 filter paper, dried in the laboratory at 85 degrees C for 72 hours and weighed to determine suspended solids (mg/l).

Stream cross sections were installed at each site and re-measured several times throughout the study period. Stream bank and channel profile, water's edge, and high water ash/debris lines were measured at cross sections. Cross sectional data was entered into a watershed hydrology computer package (WinXspro) to calculate base and flood flows. Pebble counts (Bevenger and King 1995) were taken during each field visit to determine stream channel substrate changes. Macroinvertebrate samples were collected with Surber samplers at each site several times throughout the study period but are not discussed herein. The volume of each habitat unit (pool/riffle) was measured at each site to determine habitat changes over time and to enable calculation of fish densities.

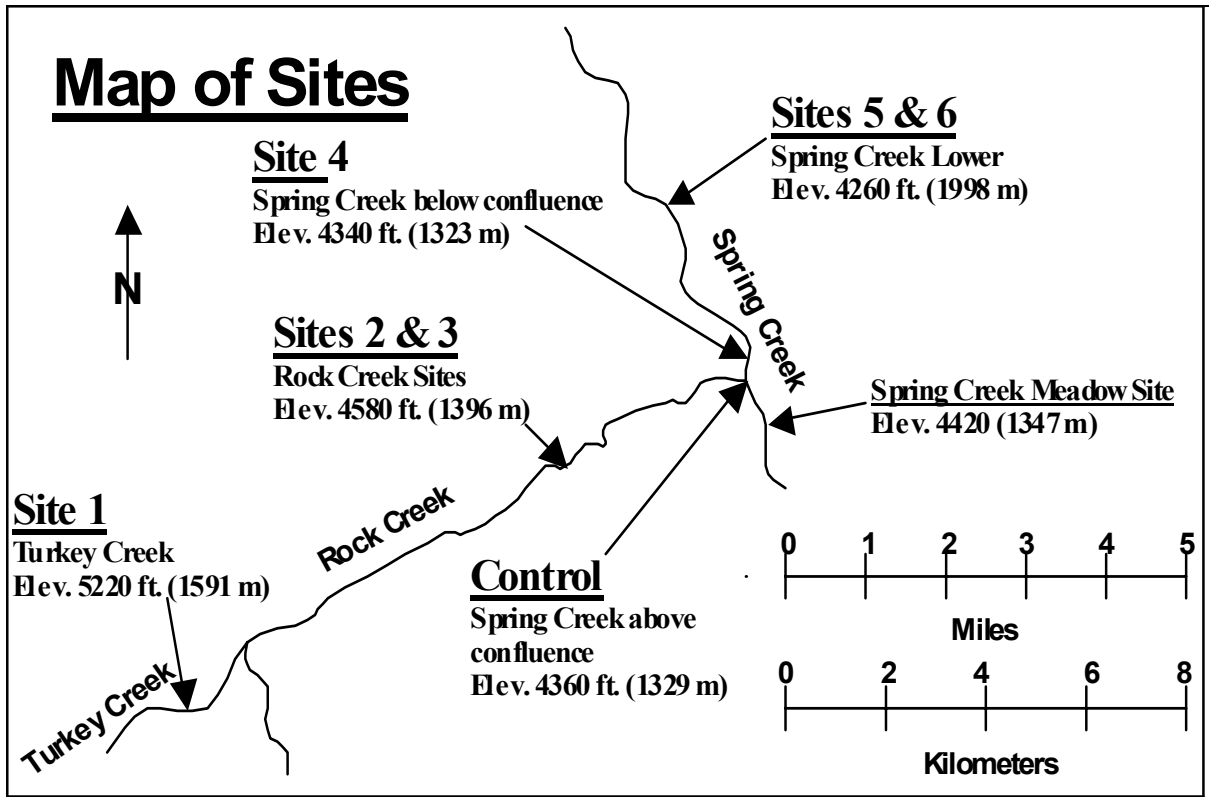


Figure 1. Map of study sites. The Picture Fire impacted the watershed upstream of Turkey Creek and along Rock Creek but did not impact the Spring Creek watershed above the confluence with Rock Creek (Control Site and Spring Creek Meadow Site). All sites were sampled before and after the summer monsoon season, except for the Spring Creek Meadow Site which was sampled only after the summer monsoon season.

FREQUENCY	SEVERITY	ACRES (HECTARES)
2	High	271 (110)
3	Low	8,328 (3370)
3	Low-Medium	619 (251)
11	Medium	2,064 (835)
4	Medium-High	1,247 (505)
	Total acres	12,528 (5070)

Table 1. Area and frequency of occurrence of each burn severity level.

## Results

### *Fishes*

Percent reduction in fish numbers before and after the summer monsoon runoff events varied according to position in the watershed. Reduction in fish numbers following post-fire, summer monsoon runoff events varied from a low of 31.7% at Site 3, to a complete loss of all fish species at Site 6 (Table 2; Figures 1 and 2). The sites in the uppermost and lowermost position in the watershed had the greatest reduction relative to sites located in the middle of the watershed (Figure 1). Total fish population at Site 1, the uppermost site in the watershed, was reduced by 97%. A partial resample (approximately ½ the habitat) was done at Site 1 immediately after the first ash flow, and indicated a 19% reduction in fish numbers (Table 3). Percent loss of fishes at the lowest sites was 97.2% at Site 5 and 100% for Site 6. By comparison, variable reductions in fish populations occurred at the sites in the middle of the watershed (Figure 1). Although Sites 2 and 3 are contiguous with each other, Site 2 sustained a much greater reduction (92.5%) in fish numbers than did Site 1 (31.7%). Combined, the two Rock Creek sites averaged a 77.1% reduction in fish numbers (Table 2). Site 4, at the confluence with Rock and Spring Creeks, had a 64% reduction. The combined total, across all fire-impacted sites, was an 87% reduction in fish numbers.

Native fish species at all sites were reduced by 84%, and nonnatives by 96.7%. (Table 2; Figure 2). The nonnative brown *Salmo trutta* was absent from the samples taken in fire-impacted reaches after the post fire flow events. Based on our sampling, the headwater chub was not only the most common and abundant species ( n = 608) at sample sites but also

sustained the greatest reduction in numbers (608 to 113 individuals; 89%). Post wildfire runoff appeared to have a greater impact on juvenile chub (Figure 9). Another native southwestern cyprinid, speckled dace, was locally abundant at the uppermost site in the watershed. This species sustained the highest percent loss of all the natives (94.8%) as a result of post-fire runoff. The only other native fish, desert sucker, was not as abundant as the two other native species, and was present only at the middle and upper sites. This species sustained a 75% reduction over the course of this study. The control site above the confluence of Spring Creek and Rock creeks remained nearly constant in total fish numbers over the study period although there was a distinct change in composition (Table 2; Figure 2) The decrease in headwater chub was nearly equal to the increase in the nonnative green sunfish *Lepomis cyanellus*. It should be noted that brown trout were yet present at this site follow the summer runoff events (Table 2; Figure 2).

### *Water Quality*

Water quality parameters were measured with Hydrolab DataSonde 4a instruments continuously logging data from 7/20/03 to 10/15/03 (Figures 4, 5, and 6). Multiple ash/sediment flow events occurred during the study period as indicated by spikes in turbidity to 1000+ NTU. Turbidity data for Site 3 at Rock Creek and Site 6 at lower Spring Creek are shown in Figure 6. Six distinct runoff events occurred at Site 3 that resulted in turbidity values of 1000 NTU or greater. By comparison Site 6 registered seven ash flow events. Further, Site 6 maintained high levels of turbidity for a longer period of time. There also were two high turbidity spikes recorded at Site 6 that were not recorded at Site 3.

A distinct drop in dissolved oxygen is associated with the first spike of high turbidity at sites 3 and 5 (Figures 4 and 5). Subsequent high turbidity events however were not associated with drops in dissolved oxygen. Conversely, several subsequent high turbidity events were paralleled by increased dissolved oxygen. A diel pattern in DO can be seen before the first high turbidity spikes (Figures 4 and 5). The first turbidity spike disrupted this pattern, flattening out the diel of rise and fall of dissolved oxygen. The prolonged drop in dissolved oxygen recorded at Site 6 near the middle of the deployment period was due to the loss of calibration. On 8/22/03 the Site 6 Hydrolab was re-calibrated and re-deployed. Figure 4 shows the relationship between turbidity and pH at Site 3. The pH levels remained between 8.6 and 7.7 throughout the study period. Only slight perturbations (reductions) were observed with each turbidity spike. A similar pattern was observed at Site 6.

Suspended solids data are illustrated in Figures 7 and 8. Multiple samples were missed at each site due to equipment failure or damage from high flow events, rendering direct comparisons between the sites difficult. Spikes in suspended solids persisted above 100 mg/l for 3-5 days (mean of 4 std dev 1.41, SE 1) at Site 3, and for 3.5-7days (mean of 5.25 std dev 1.44, SE .72) at Site 6. The Site 1 water sampler at Turkey Creek only collected 6 samples above 100 mg/l. Spikes in turbidity at Site 1 persisted an average of 24 hours.

Major anions and cations in water grab samples were measured in a water analyzer (Tables 5 and 6). The only discernable difference in water chemistry before and after the post-fire runoff events was an apparent increase in phosphate, sulfate, potassium, and calcium at Site 3 and Site 6. Pre-monsoon water samples were not available from Site 1.

### *Physical Habitat*

The pebble count data showed an increase in % fines (substrate material <2mm diameter) from an average over all sites of 3.8% before the summer rains to an average of 10% after the summer rains, a 2.6 fold increase (ANOVA,  $p = .06$ ). A mid-monsoon season pebble count was conducted at Site 3 in Rock Creek. The change in % fines increased from 0.75% to 6.5%, an 8.6 fold increase (ANOVA,  $p = .07$ ). The percent fines in the pool habitats changed significantly before and after the summer runoff events across all sites from an average across all pools of 3.2% fines to 15.2% fines (ANOVA,  $p = .003$ ).

	Headwater chub ( <i>Gila nigra</i> )		Speckled dace ( <i>Rhinichthys osculus</i> )		Desert sucker ( <i>Catostomus clarki</i> )		Brown trout ( <i>Salmo trutta</i> )		Green sunfish ( <i>Lepomis cyanellus</i> )		Yellow bullhead ( <i>Ameiurus natalis</i> )	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
<b>Ash Flow</b>												
<b>Site 1</b> Turkey Creek	14	4	161	3	28	3						
<b>Site 2</b> Rock Creek	34	22	6	6	3	0	18	0	3	0		
<b>Site 3</b> Rock Creek	97	82	5	0	1	4	23	0				
<b>Site 4</b> Spring Creek Below Confl.	7	5			0	1	9	0	6	3	6	1
<b>Site 5</b> Lower Spring Creek	9	0							26	0	25	0
<b>Site 6</b> Lower Spring Creek	13	0							57	3	73	1
<b>Control</b>	24	5			1	2	5	2	8	27		
<b>Spring Cr. Meadow Site</b>		16				3		18		52		

Table 2. Numbers of fish sampled at each site before and after the summer runoff events.

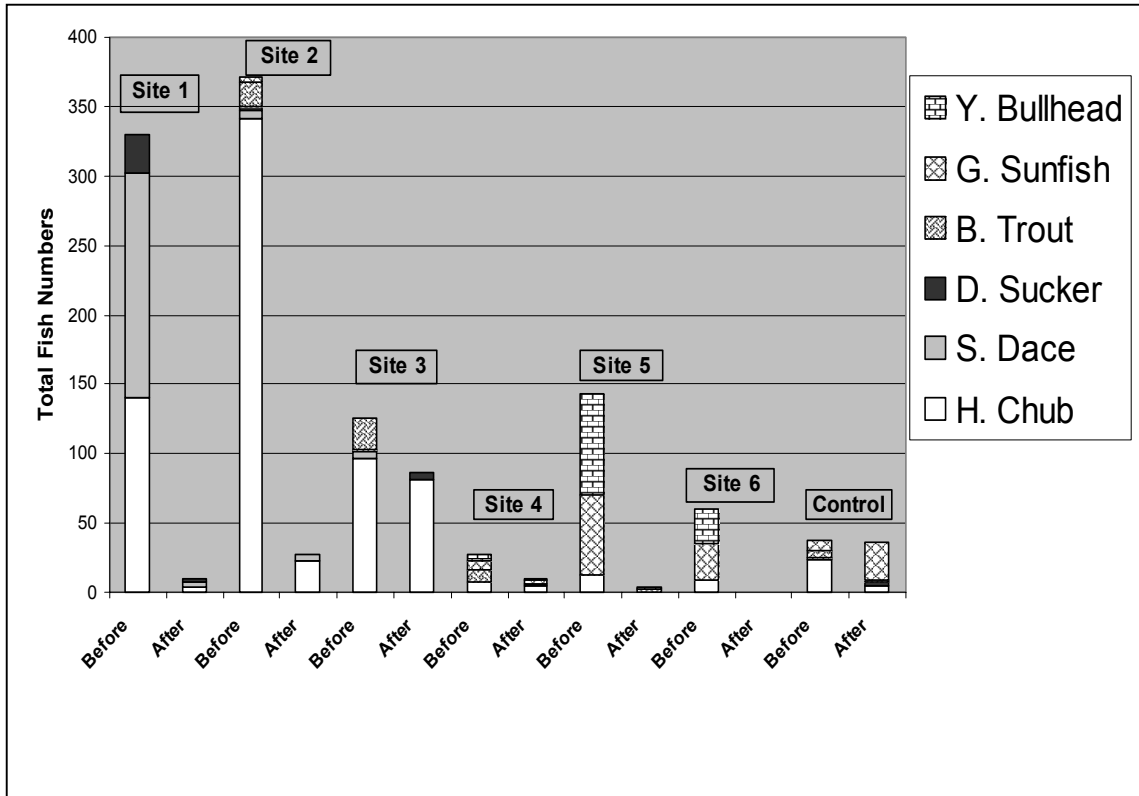


Figure 2. Numbers of fish sampled at each site before and after the summer runoff events.

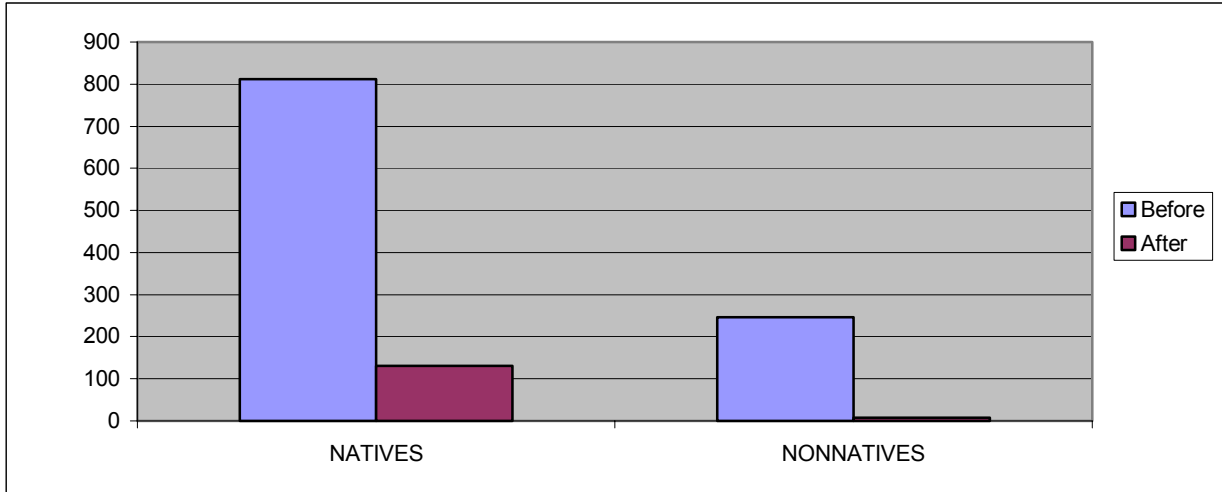


Figure 3. Total number of native and nonnative fishes sampled across all sites before and after the summer rains.

	HEADWATER CHUB	SPECKLED DACE	DESERT SUCKER
Number	54	71	9

Table 3. Fish numbers from a partial re-sample (approximately ½ of the habitat) of the Turkey Creek site during the monsoon season 8/20/2003

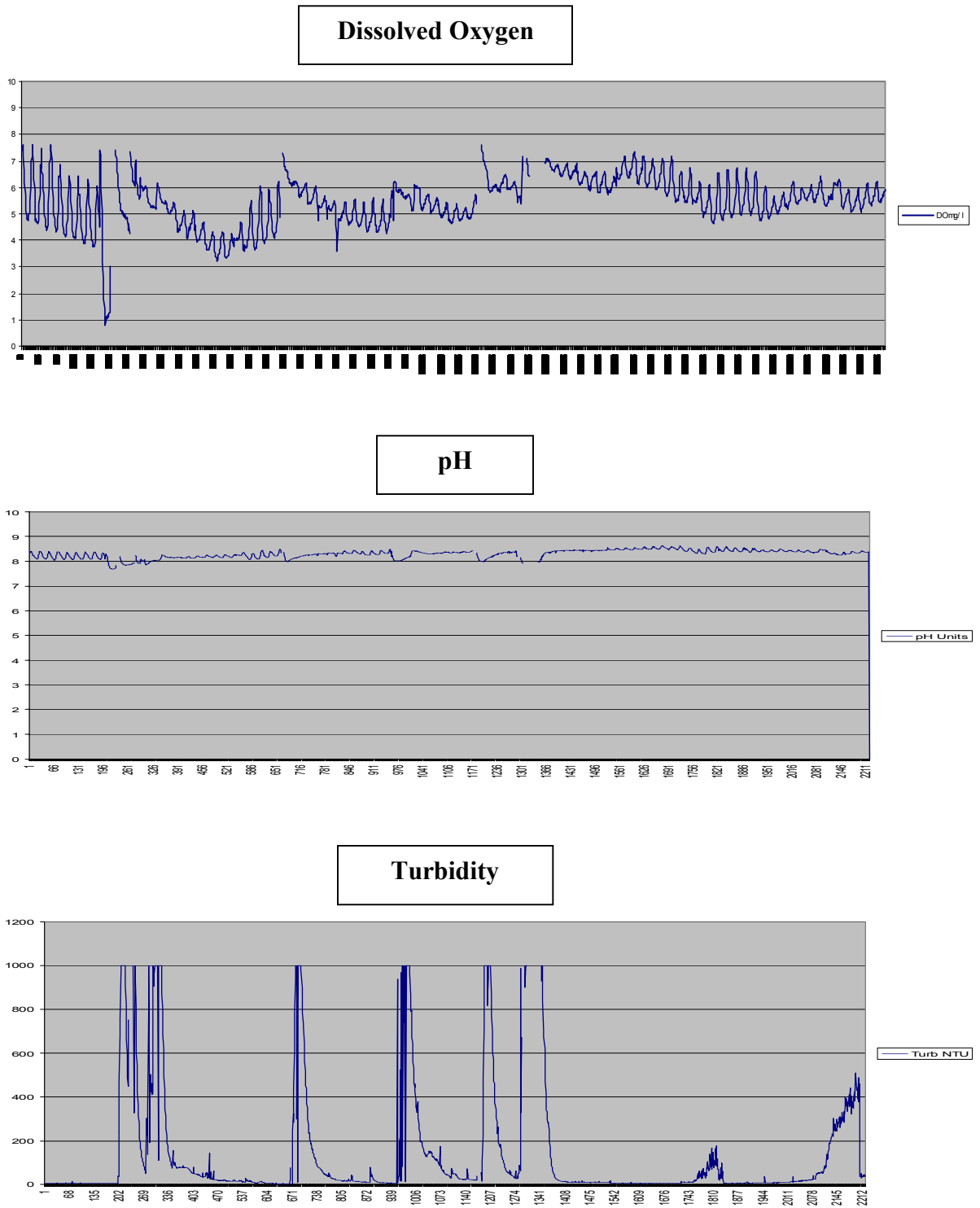


Figure 4. Dissolved Oxygen, pH, and Turbidity at Rock Creek 7/20/03 – 10/15/03.

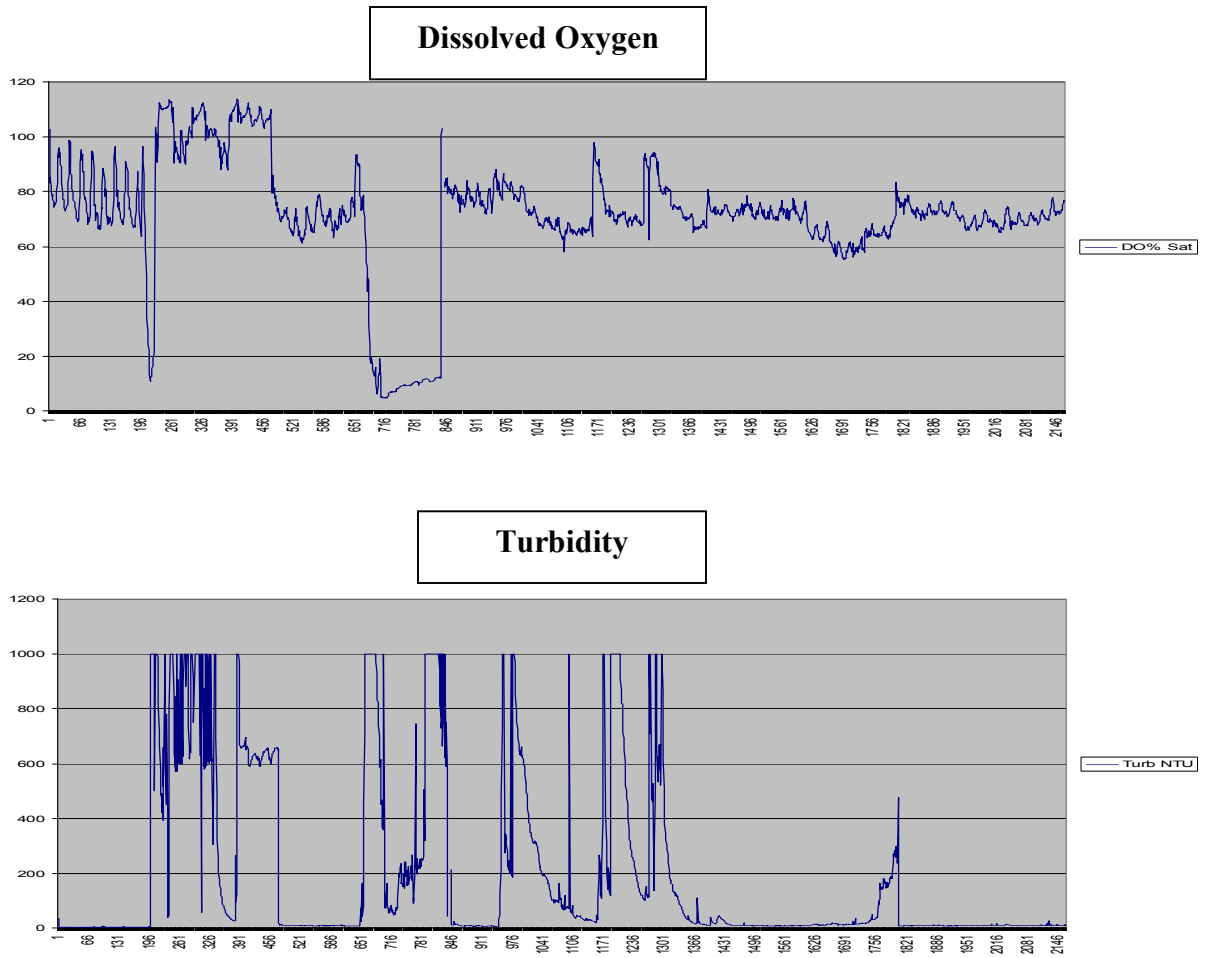
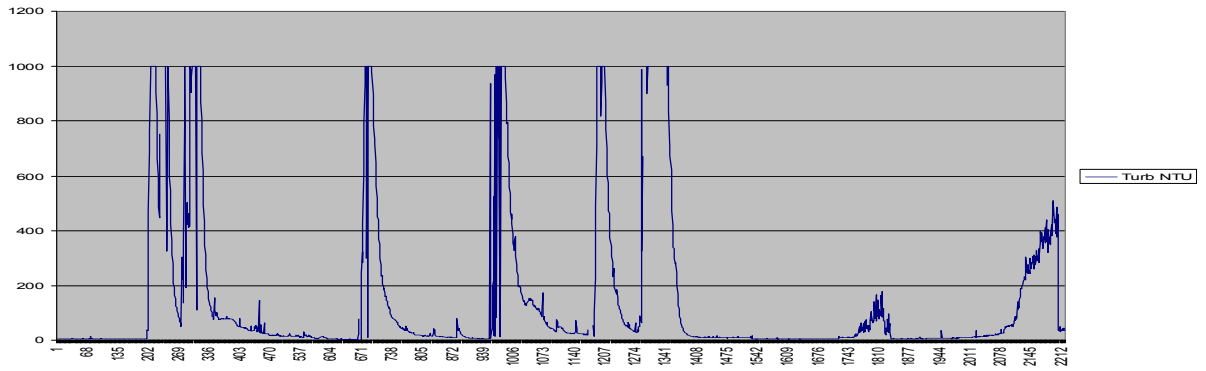


Figure 5. Dissolved Oxygen and Turbidity at Spring Creek 7/20/03 – 10/15/03.

**Site 3  
Turbidity**



**Site 6  
Turbidity**

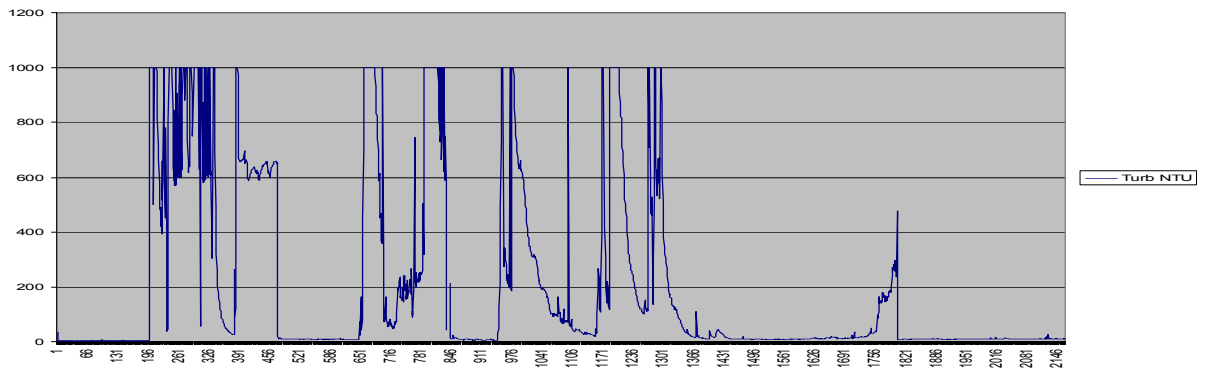


Figure 6. Turbidity at Site 3 (Rock Creek) and Site 6 (Spring Creek) 7/20/03 – 10/15/03.

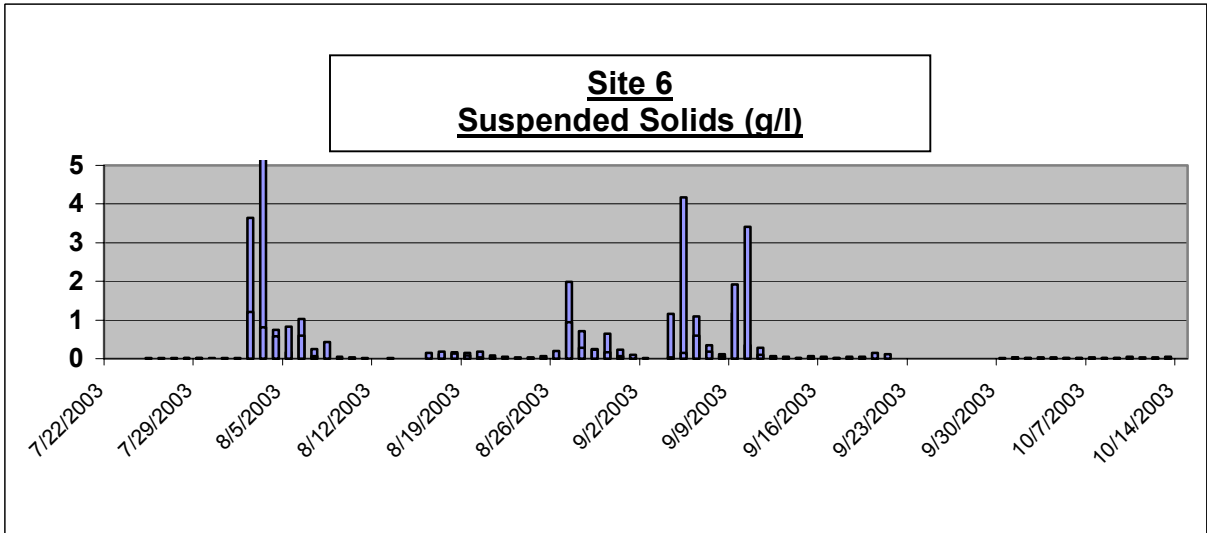
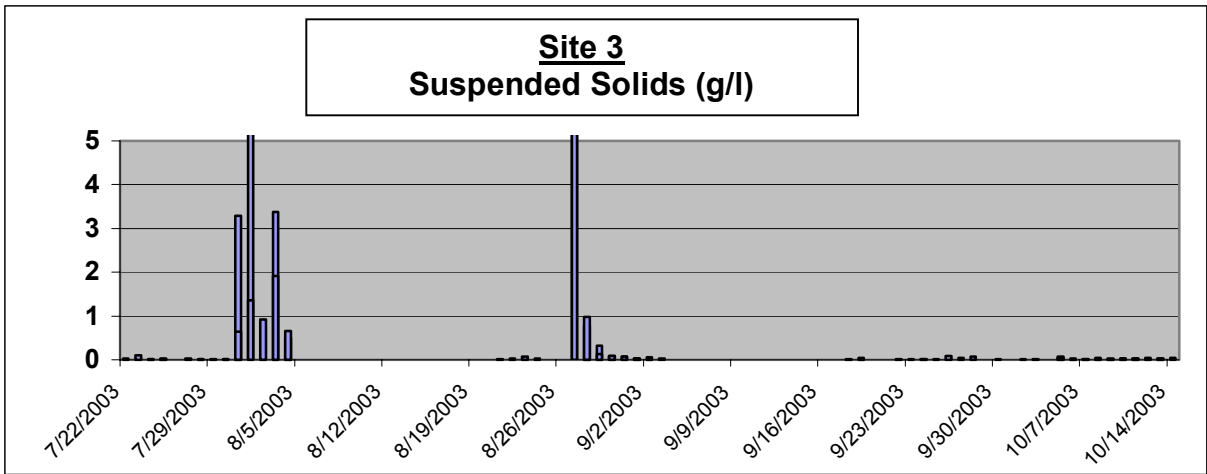
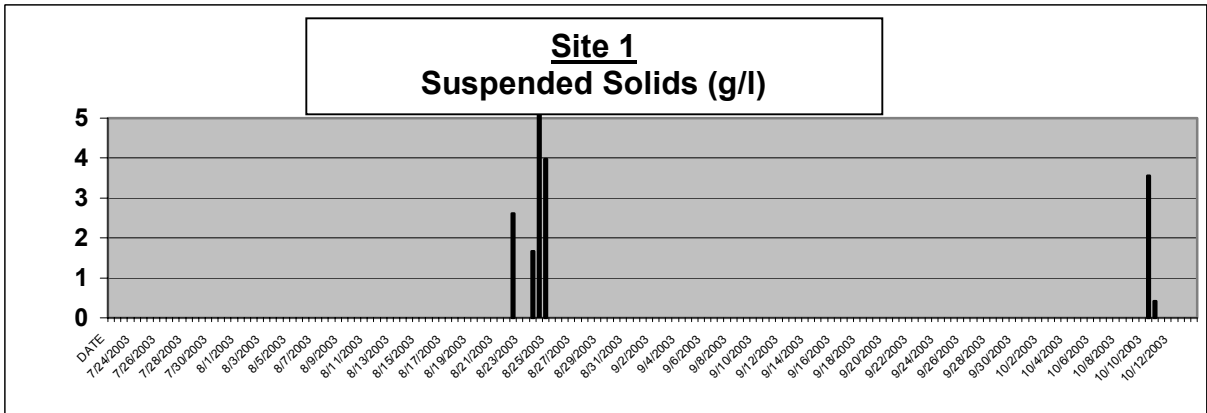


Figure 7. Suspended Solids at Rock Creek, Spring Creek, and Turkey Creek (0 – 5 g/l).



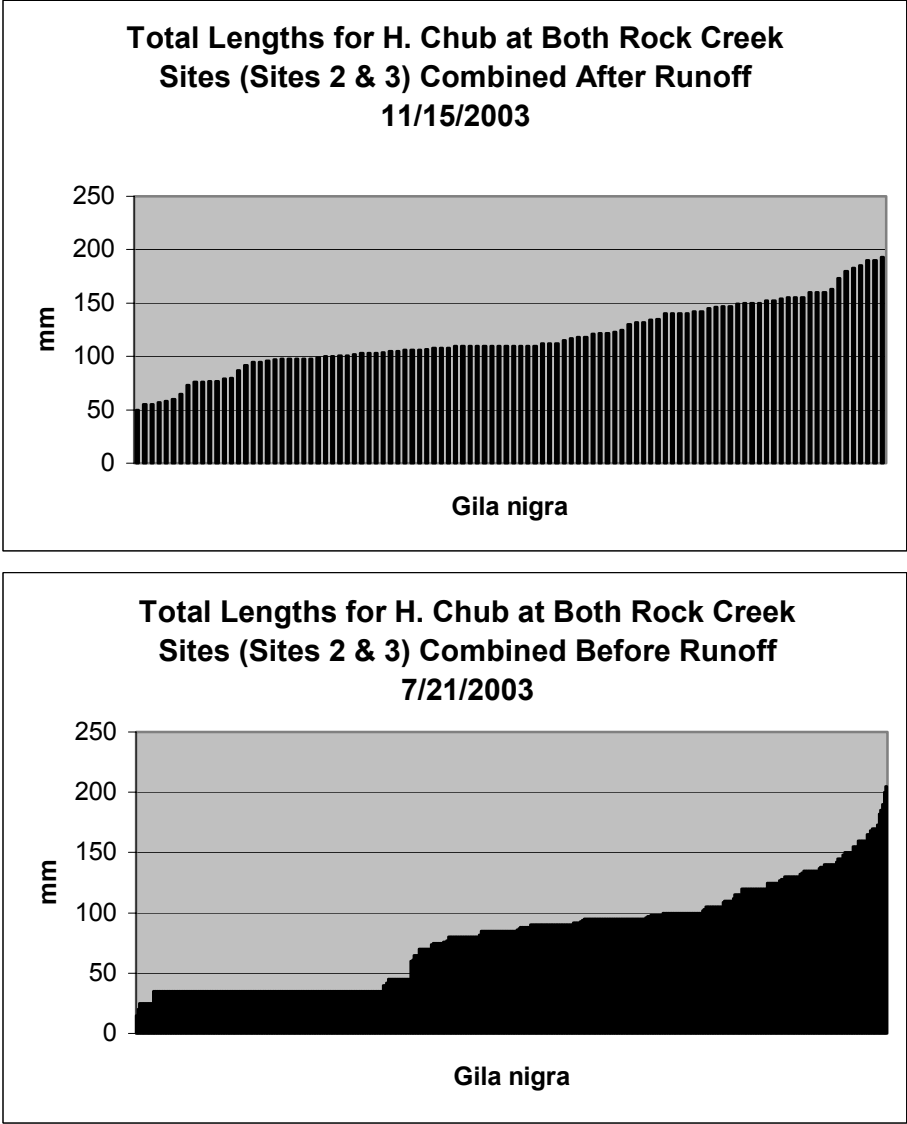


Figure 9. Total lengths of *Gila nigra* sampled at Rock Creek sites 1 and 2 combined. The upper chart is before the ash/sediment flows, and the bottom chart is after.

<b>X-Section Date</b>	<b>Site 1</b>	<b>Site 3</b>	<b>Rock Cr. Confl.</b>	<b>Site 4</b>	<b>Site 6</b>	<b>Control</b>
Base Flow	0.1	0.18	0.14	0.26	0.15	0.2
8/5-8/6	1.65	34.58				
8/20-8/22		2.43	93.61	109.43	85.48	156.45
		3.73			39.35	
		9.74			57.01	
		13.93				
9/17-9/18	93.17	132.7			52.89	
11/22-11/23				15.47	72.36	209.82
				49.16		

Table 4. Calculated base flows and flood flows at each site ( $\text{m}^3 \text{s}^{-1}$ ).

DATE	SITE	CHLORIDE (MG/L)	NITRATE (MG/L)	PHOSPHATE (MG/L)	SULFATE (MG/L)
8/6/2003	Site 1	7.35	1.07	1.53	8.90
8/21/2003	Site 1	7.15	1.07	1.46	9.25
10/1/2003	Site 1	5.82	1.07	1.37	8.93
11/11/2003	Site 1	5.21	1.04	1.14	8.98
7/18/2003	Site 3	6.63	1.08	0.58	4.63
8/5/2003	Site 3	7.93	1.08	1.53	9.23
8/21/2003	Site 3	5.84	1.08	1.50	5.69
10/1/2003	Site 3	6.74	1.07	1.40	5.03
11/11/2003	Site 3	5.17	0.97	1.16	7.79
7/24/2003	Site 6	7.76	1.07	0.58	4.68
8/7/2003	Site 6	7.72	1.08	1.41	8.34
8/22/2003	Site 6	7.68	1.08	1.52	6.68
10/1/2003	Site 6	6.98	1.07	1.40	6.45
11/11/2003	Site 6	7.88	0.97	1.14	10.41

Table 5. Major anions in water samples at three sites. All sample dates after 8/1/2003 are post ash flow. Values averaged over 3 replicate samples. SE not included.

DATE	SITE	SODIUM (MG/L)	AMMONIUM (MG/L)	POTASSIUM (MG/L)	MAGNESIUM (MG/L)	CALCIUM (MG/L)
8/6/2003	Site 1	5.75	7.28	3.17	20.57	52.47
8/21/2003	Site 1	6.02	3.27	4.19	23.18	65.23
10/1/2003	Site 1	5.33	1.26	3.23	21.00	54.38
11/11/2003	Site 1	4.89	0.08	2.32	20.64	57.98
7/18/2003	Site 3	6.48	0.76	2.23	16.73	53.04
8/5/2003	Site 3	5.92	2.80	5.19	20.43	67.71
8/21/2003	Site 3	5.79	0.5	4.31	21.95	71.96
10/1/2003	Site 3	5.91	3.19	2.75	18.84	63.73
11/11/2003	Site 3	5.19	0.01	2.13	18.70	62.49
7/24/2003	Site 6	10.63		2.45	20.34	40.44
8/7/2003	Site 6	8.76	2.51	4.71	18.52	46.43
8/22/2003	Site 6	8.77		5.75	23.83	61.67
10/1/2003	Site 6	9.40	1.44	3.56	24.75	63.59
11/11/2003	Site 6	9.22	0.03	2.92	23.34	59.13

Table 6. Major cations in water samples at 3 sites. All sample dates after 8/1/2003 are post ash flow. Values averaged over 3 replicate samples. SE not included.

## Discussion

Overall, after the summer monsoon runoff events there was an 87% reduction in total fish numbers within all fire-impacted sites in the Spring Creek drainage. As a group, native fishes, sustained a slightly lower percent reduction (84%) than did nonnatives (96.7%). The speckled dace population, largely confined to the upper reaches of the watershed, sustained the greatest percent reduction (95%) in numbers among the native species. Pre-fire, nonnative fishes displayed the highest abundance in the lowest reaches, which also sustained greatest reduction in fish numbers. The headwater chub, the most numerous species sampled ( $n = 608$ ), sustained an overall 81% reduction in numbers. The least abundant ( $n = 28$ ), and least impacted, native species was the desert sucker, which was reduced by 75%. The reduction of native fishes varied according to position in the watershed. The uppermost and lowermost sites sustained the greatest reduction in native fish numbers.

At the uppermost site, Site 1 at Turkey Creek, scouring flood flows occurred during the monsoon season of 2003. Estimated flows of  $93 \text{ m}^3 \text{ s}^{-1}$  occurred in the narrow channel that had a base flow of approximately  $0.1 \text{ m}^3 \text{ s}^{-1}$  (Table 4). Localized down-cutting, rearrangement and transport of cobble sized substrate, and the erosion of pool tail crests caused a reduction in pool habitat at this most upstream site in the study area. Flood flows occurred at the other sites, however, the channels were broader in these downstream sites and scouring effects were not observed to be as dramatic. Water samples from the automated samplers in Site 1 indicated spikes in suspended solids from 0.42 g/l to 5.16 g/l (Figure 7). The average persistence of these high sediment load events was approximately 24 hours – a much shorter duration than at the middle and lower sites. Two field visits to Site 1 during the early monsoon season found

ash deposits on the bank and substrate, but the turbidity was low (around 1 NTU) and there were no measurable suspended solids at that time. Fish were observed from the bank on both of the early monsoon site visits to Site 1 (8/5/2003 and 8/20/2003). A portion of this site was sub-sampled for fish on 8/5/03 indicating only a moderate (approx. 20%) reduction in fish numbers for all species (Table 3). During the 9/17/2003 site visit extreme scouring and channel rearrangement was observed. No fish were observed from the bank during this visit. When Site 1 was re-sampled 11/3/03 the numbers had dropped from 141 headwater chub to 4 (-97%), from 161 speckled dace to 3 (-99%), and from 28 desert sucker to 3 (-90%). Unlike Site 1, all other sites remained too turbid to sample throughout the summer monsoon season.

The lowest sites on the watershed, Sites 5 and 6 in lower Spring Creek, also sustained extreme reductions in fish numbers (Table 2; Figure 2). Reductions ranged from 95% to 100%. Headwater chub, the only native fish present at these two sites before the ash flow events, was not found after the summer rains. There was a much greater loss of fish at lower Spring Creek than at the sites in the middle of watershed. Flood flows were recorded at the lowest sites (Table 4), but the scouring observed in the upper watershed was not evident. One explanation for the greater loss of fish at this site relative to the middle sites might be seen in the water quality data (Figures 4 thru 8). Pulses of high turbidity/suspended solids occurred at both Site 6 and Site 3. Multiple spikes in turbidity at or above 1000 NTU and multiple spikes in suspended solids of greater than 1 g/l was recorded at both sites. However, a greater number of turbidity/suspended solids spikes were recorded at the Site 6. The Hydrolab recorded eight spikes of turbidity at or above the 1000 NTU level at Site 6 versus six spikes at Site 3 the (Figure 6). The first spike of high turbidity at Site 6 persisted for a longer duration than the first spike at Site 3 (Figure 6). From the suspended solids data available, the persistence of

high ash/sediment loads was calculated. During runoff events, spikes in suspended solids persisted above 100 mg/l for 3-5 days (mean of 4, std dev 1.41, SE 1) at Site 3 and for 3.5-7 days (mean of 5.25 std dev 1.44, SE .72) at Site 6.

The sites in the middle of the study area, Sites 2 and 3 at Rock Creek, and Site 4 at the confluence of Rock and Spring Creeks, were variously impacted by post-fire runoff, and the impact was less severe than at the upper and lower watershed. Site 4 had the lowest reduction in fish numbers of all the sites (64.3% overall). This may be due to the close proximity of the un-impacted reach of Spring Creek. Spring Creek above the confluence had an estimated base flow of  $0.2 \text{ m}^3\text{s}^{-1}$  and may have served to dilute or flush ash and sediment from the site.

Further, the un-impacted waters of Spring Creek also may have served as a temporary refugia for downstream fishes subjected to post-fire impacts. Post-monsoon, downstream emigration of fishes from the upper portion of Spring Creek may also have been a factor.

Notwithstanding, Site 4 below the confluence had much smaller fish numbers (total  $n = 28$ ) pre-fire than the other fire-impacted sites, which could make Site 4 a less reliable estimator of impact.

The two Rock Creek sites (Sites 2 and 3) sustained a combined 77% reduction in total fish numbers. There were large numbers of fish ( $n = 497$ ) present at the two sites prior to the summer rains, which was reduced down to 114 following post-fire runoff. The most abundant species in the assemblage was the headwater chub (Table 2). Brown trout, the second most abundant fish species, was reduced to zero following the summer monsoon and runoff events from the wildfire—which was the case at all of the fire-impacted sites where brown trout were present. Desert sucker and speckled dace were present in small numbers both before and after the ash flow events. As mentioned previously, reduction in fish numbers was less dramatic at

the Rock Creek sites relative to the uppermost and lowermost sites in the Spring Creek drainage system. The occurrence of fewer high turbidity events and shorter duration of high sediment loads may have been factors. The reason for the difference in the number and persistence of high turbidity events may have been due to localized hydrologic conditions, availability of source material, and/or the specific location of convectonal rain events, which are often isolated, yet intense in this region.

The two Rock Creek sites (Sites 2 and 3) were contiguous, separated only by a short riffle section. Site 2 sustained a 94% reduction in total fish numbers compared to only a 15% reduction at Site 3 (Table 2). Even though the two sites are contiguous, the habitat is markedly different. The pool habitats at Site 3 have a large component of undercut banks and associated woody cover, preferred habitat of *Gila* species (Bestgen 1985). The pool habitat at Site 2 lacked undercut banks. Prior to the post-wildfire monsoon flood flows, however, there was a large accumulation of woody debris at Site 2, where a large number of chubs were collected during sampling. After the flood flows little woody debris remained. We suggest that because of loss of this woody, “cover” material, there was a generalized population reduction of chubs at this site with remaining individuals seeking out remaining preferred habitat.

The length/frequency structure of the headwater chub sampled at the Rock Creek sites is noteworthy (Figure 9). A dramatic change occurred in length/frequency structure of this species between pre- and post-fire runoff. The 0-100 mm size range was disproportionately reduced. The 0-100mm size class comprised 75% of the size class composition before the ash flows--only 27% after. No individuals under 50 mm total length were sampled after the summer runoff events. Prior to the summer rains and post-fire runoff, the Rock Creek Site 2 had a large percent composition (42%) of chubs less than 50 mm.

The Control Site for this study displayed little reduction (5.3%) in fish numbers (Table 2 Figure 2). However, there was a distinct shift in species composition. The number of green sunfish increased by the almost identical amount that headwater chub decreased. This site was in a very narrow, steep-sided canyon characterized by abundant bedrock substrate. Flows from normal monsoon runoff occurred at this site exceeding  $200 \text{ m}^3 \text{ s}^{-1}$  (Table 4). Such high flow events and localized hydrology may have influenced change in fish species composition. In addition, the lower 17 meters of the Control Site also received ash/sediment input from ash-laden waters that backed up during flood flows issuing from Rock Creek. Also, as discussed above, post ash flow immigration and emigration may have occurred. It should be noted that brown trout, not present at any of the impacted sites, were still present at the control site.

In November an additional site was set up in upper Spring Creek (Spring Creek Meadow Site) above the confluence with Rock Creek (Figure 1, Table 2). This site was out of the fire's influence and was in an open, low gradient meadow reach. Evidence of high water levels was found, but no evidence of extreme current velocity was observed. Headwater chub were present at this site, as were desert sucker, brown trout, and green sunfish. No pre-monsoon season data was collected however.

Differences in the pebble count data before and after the ash flows may or may not be significant depending on the alpha level chosen (.05 or .10). The pebble count data showed an increase in % fines (substrate material <2mm diameter) from an average over all sites and all habitat types (pool/riffle) of 3.8% before the summer rains to an average of 10% after the summer rains, a 2.6 fold increase ( $p = .06$ ). A mid-monsoon season pebble count conducted at Sites 2 and 3 in Rock Creek revealed an increase in fines from 0.75% to 6.5%--an 8.6 fold increase ( $p = .07$ ). The percent fines in the pool habitats across all sites changed significantly

before and after the summer runoff events from an average of 3.2% fines to 15.2% fines ( $p = .003$ ). At Site 1, immediately after the initial pulse of sediment and ash, the stream substrate was completely buried in fines in all the pool and eddy habitats. However, subsequent spates quickly flushed out most of the fine sediments during the monsoon season.

### **Management Implications**

There are future management concerns about continuing impacts of the Picture Fire. A principal issue as discussed generally for the West by Rieman et al (2003) and for other species in the Southwest (Brown et al. 2001, Rinne 2004a) is the real and potential impacts of wildfire on native threatened, endangered, and sensitive fishes. Populations of native fish in the Spring Creek drainage have been reduced to very low numbers at the upper and lower sites. Population numbers may be too low to be reproductively viable. Turkey Creek, on the uppermost portion of the watershed is of special concern. Reaches above and below the Turkey Creek site were intermittent at the time of this study, and it is unknown if populations of native fish exist upstream from the site, or in contiguous reaches downstream. Speckled dace is likely to be the native species of greatest concern. The only site where this species was found to be numerous was in the uppermost watershed. Headwater chub remained fairly abundant at the sites in the middle of the watershed. Desert suckers was present in low numbers before the summer rains.

There may also be problems with spawning substrate since the wildfire. Speckled dace spawn in gravels in swift water (Sublette et al 1990). Although most of the fines have been flushed out of the system and larger size bed load remains, it is possible that ash and fine

sediments have filled interstitial spaces in the substrate, reducing oxygen flow through potential spawning substrate and macroinvertebrate habitat. Ash and fine sediment in the interstitial spaces in the substrate potentially inhibit water and oxygen exchange to the hyporheic zone – an important habitat for certain life stages of many aquatic invertebrates that may serve as food sources for native stream fishes. Continued scouring of the substrate at Turkey Creek has resulted in bed load being comprised of mostly greater cobble- and pebble-sized material thereby reducing available smaller (sand/gravel) spawning substrate. The lack of adequate spawning-sized bed materials for trout in streams also has been observed in streams impacted by the Dude Fire (Rinne 2004a) over a decade following initial fire impacts. As mentioned previously, the substrate in much of the stream habitat in the study was buried initially in ash and fine sediments. There yet remain large deposits of ash and fine sediments on stream banks that likely will be transported through the stream during high flow events in out years. Such events could again increase fine substrate material and reducing water quality.

From a larger perspective, an ongoing concern is the potential effects of the increasing number of large, high intensity fires on native fishes. Native fishes in the Southwest have been extirpated from much of their historical range (Rinne and Minckley 1991, Rinne 2003). Many populations of native fish exist in isolated populations, high within watersheds (Rinne 1995). Reductions and extirpations of native fishes in many southwestern streams have reduced the connectivity of native populations (Minckley and Deacon 1991). When a population is lost there may likely be no source populations of natives to re-colonize the habitat.

These sites should continue to be monitored for several years to come to assess re-colonization and recruitment of fishes. Pebble counts and cross-sections should be re-

measured to assess changes in substrate, changes in channel morphology, and to estimate discharge from flood events. Invertebrate response also should be monitored

The Picture Fire case study and other case studies that have been done before, along with geo-spatial data from the specific fires, conceivably will aid us in shaping a model that will help to predict how a given wildfire will be expected to impact the associated aquatic biota and habitat. Some of the parameters that will be used are size of the fire, burn severity, slope, aspect, vegetation type for each level of burn severity, stream gradient, channel type, bed composition, sinuosity, fish species, other colonization sources (refugia) in upstream areas or tributaries, colonization sources in far down stream reaches (basin wide connectivity), the presence or absence of flushing flows (springs, tributaries), geology (sediment type that will be generated by the post-fire runoff), geomorphology, elevation, microclimate, and past hydrographs. A model of this nature will not only aid in predicting when to intervene to protect key aquatic habitat, or to remove threatened and endangered fishes, but may also be used in fire management plans to prescribe burns that will have a low probability of impacting aquatic resources.

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