IMPACTS OF RESTORATION ON A SOUTHWESTERN WISCONSIN RIVER

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Abstract

The immediate impacts of restoration activities on aquatic invertebrates, fish, and habitat structure were studied in the Blue River of southwestern Wisconsin during the summer and fall of 2004. Field surveys were conducted upstream, at, and downstream of the restoration site before and after restoration activities. The greatest changes in stream habitat occurred at the restoration site, while the downstream site changed the least. There was little change in the macroinvertebrate communities, although *Baetis* mayflies did significantly increase at the restoration site. Both diversity and abundance of fish increased at the restoration site with little change upstream or downstream following restoration. Restoration did not appear to influence the size and abundance of brown trout at the sites. While restoration activities potentially influence stream habitat and communities, such changes may not necessarily be as negative or extensive as expected.

Introduction

Restoration can be defined as returning an ecosystem into its previous, non-disturbed, state (Bradshaw 1996). However, altering streams does not only affect the physical stream characteristics (i.e. width, length, etc.), it also can affect fish (Gorman and Karr 1978, Schlosser 1982, Meffe and Sheldon 1998) and macroinvertebrate diversity and abundance (Allan 1975, Minshall 1984, Gore et al. 1998). Stream restorations are intended to be beneficial to the ecosystem, but may inadvertently result in unintended outcomes such as no change or lesser change then expected (Iversen et al. 1993, Kondolf 1995, Frissel 1997). Few studies have looked at the immediate impacts that river restoration has on stream characteristics, fish and macroinvertebrate abundance and diversity. Quantitative evaluations of stream restorations have been rare overall (NRC 1992, Kershner 1997), and assessed restorations indicated mixed responses (Frissell and Nawa 1992).

It is hard to understand the long-term impacts on aquatic biota because biotic recovery rates vary with trophic level and may be dependant on the type of disturbance (Niemi et al. 1990, Detenbeck et al. 1992). Stream restorations can be viewed as large-scale experiments to test basic ecological concepts for lotic systems (Moerke et al. 2004). Also, streams often are restored in an attempt to enhance biotic recovery and, thus, they may provide an opportunity to assess patterns of colonization and succession of aquatic biota (Moerke et al. 2004).

The Blue River, located in southwestern Wisconsin and flows north of the town of Montfort into the Wisconsin River, was restored during August 2004 for the recruitment of large brown trout. The objectives of this study were to observe if the river restoration affected the river habitat, fish and macroinvertebrate communities upstream, at, and downstream of a restoration site. Also, if restoration did have an effect on the habitat, fish and macroinvertebrate communities, to what magnitude were these communities altered. In addition, this study will provide base-line data for the upper Blue River.

It was hypothesized that the initial effects of restoration will alter riparian habitat characteristics in some of the sites, will alter the abundance and diversity of fish and macroinvertebrate populations in each site, and will alter the abundance and size of brown trout found within each site. It was predicted that sediment depth and channel erosion would increase in the downstream site (Site 1). At the restoration site (Site 2) it was hypothesized that channel width would decrease, channel depth would increase, channel erosion would not occur, and that there would be a decrease in riparian vegetation, and the upstream site (Site 3) would experience no significant changes. Hypotheses for macroinvertebrates included an increase in abundance and diversity at Site 1 and decreases in macroinvertebrate abundance and diversity at Site 2 and 3. It was predicted that the abundance and diversity of fish at Site 1 would increase, a decrease in abundance and an increase in diversity at Site 2, and a decrease in abundance and diversity of fish at Site 3. Abundance and size of brown trout at Site 1 was hypothesized to increase but decrease at Sites 2 and 3.

Methods

This study was conducted from June 2004 to November 2004, with sampling conducted from June to August. Habitat, fish, and macroinvertebrate surveys were conducted before and after restoration to compare the restoration's immediate effects.

Study Sites

The study sites stretch across three properties located where the Blue River crosses Hwy I in Montfort, each site having several hundred meters of stream running through it. Each study site consisted of 400 meters in length (divided into 12 transects); Microsoft EXCEL randomly selected the start of each site. These properties were located downstream (43°00.088N 90°25.968W), at (43°00.087N 90°25.583), and above the restoration site (43°00.220N 90°25.001W).

The three sampling sites varied in the type of habitat characteristics. The downstream site (Site 1) consisted of woody debris, an abundance of riparian vegetation that was surrounded by native prairie habitat. The sites at (Site 2) and above (Site 3) the restoration consisted of agricultural land, primarily used for cattle farming and cash crops. Site 2, pre-restoration, consisted of natural undercut banks, gravel substrate, few islands, and a variable amount of riparian vegetation. This area consisted of erosional areas were cattle crossed and areas where the width of the river was increasing, causing slow water flow. Site 3 contained silt and sand substrate with little to no cover. There was a higher abundance of macrophytes within this site compared to the other sites, and there was little to no tree coverage.

Transects for sampling macroinvertebrates and electroshocking fish were randomly chosen within each study site. Three transects, in each site, were electroshocked and sampled for macroinvertebrates. Electroshocking and Surber samples were conducted within the same transects at each site pre and post restoration.

Habitat Surveys

Habitat surveys on all sites were conducted using the Wisconsin Department of Natural Resources Habitat Survey Protocol. Habitat was measured at all 12 transects within each site.

The following are the characteristics that were measured: river width, river depth, bank erosion, coverage, substrate/embeddedness (including macrophytes), dissolved oxygen, pH, water temperature, and water conductivity. River depth, width, and bank erosion were measured using a yard stick and measuring tape. Coverage and substrate/embeddedness were estimated percentages, and water chemistry data was achieved by conductivity meter and water flow meter.

Macroinvertebrate Surveys

Macroinvertebrates were collected from 6 random locations within each site before and immediately after restoration occurred. Samples from different channel locations were taken using a Surber sampler. After individual samples were collected, from each site, they were placed in whirl-paks with 75% ethanol and taken back to the lab to be processed. In the lab, all aquatic macroinvertebrates were identified down to either family or genera (Table 1).

Fish Biotic Index

Fish surveys were conducted before and immediately after restoration occurred. The fish were collected using an electro-shocker at 3 randomly selected locations in each sampling site. Each location represented a single pass spanning 30m upstream. In the field, all fish that were collected were counted and identified down to species (Table 2). All brown trout and their sizes (TL) were recorded. After all fish were identified, and measurements of all brown trout were taken, all fish were released.

Statistics

Paired-t tests were performed on habitat and macroinvertebrate data from each site to compare pre and post data, and to find significant changes that my have been due to the restoration. Multiple one-way ANOVA tests were used to determine significant community shifts pre and post restoration within the three study sites, specifically significant differences between habitat, macroinvertebrate community, and the fish community. Also, ANOVA tests were used to compare changes among and between each site pre and post restoration.

Results

Habitat

There were significant changes to all sampling sites immediately following restoration. Following restoration, channel substrate composition was found to have changed at all sampling sites (Fig.1), while individual sites also had significant changes in channel depth and width (Fig. 2), erosion, and sediment embededness (Fig. 3).

After restoration, Site 1 had a significant increase in the amount of sediment present and the amount of sediment embededness (P= 0.000). Also, gravel significantly decreased (P= 0.059), but the abundance of silt significantly increased (P= 0.000). At restoration Site 2 channel width and depth, the amount and type of substrate, and erosion significantly changed after restoration. The channel width significantly decreased (P= 0.000), and the channel depth significantly increased (P= 0.001). The abundance of gravel substrate significantly decreased (P= 0.043) as the level of silt and cobble increased (P= 0.007, P= 0.007). Also, there was a significant decrease in erosion at Site 2 (P= 0.000). Site 3 had significant changes in width, substrate composition, and erosion. Channel width decreased (P= 0.011), as did erosion (P= 0.014). Site 3 exhibited the most abundant changes in sediment composition; the amount of substrate embededness significantly increased (P= 0.001), cobble (P= 0.035) and clay (P= 0.045) substrate both increased, but boulder (P= 0.016) and sand (P= 0.032) substrate decreased.

Macroinvertebrates

Restoration did influence the macroinvertebrate community. The abundance of macroinvertebrates in Site 1 and 3 stayed relatively the same pre and post restoration, however, the abundance at Site 2 did increase (Fig. 4). This increase at Site 2 was driven largely by a significant increase in the mobile Baetidae mayfly population (P= 0.038). The chronomidae abundance at Site 2 did not change significantly (P= 0.078), but it was the second most abundant macroinvertbrate following the Baetidae family.

A total of fourteen macroinvertebrate families were identified (Table 1). The most abundant macroinvertebrates throughout the entire study area included amphipods, Brachycentridae *Brachycenttrus*, Ephemeroptera Baetidae *Baetis* and *Labobaetis*, Chronomidae, and Oligochetes. The Oligochetes had a significantly higher abundance (P=0.00) than any other in the macroinvertebrate community. Macroinvertebrate diversity did not significantly change at any of the sampling sites (Fig. 4).

Fish Analysis

A total of ten fish species were identified throughout the samplings sites (Table 2). Brown trout, white sucker, mottled sculpin and slimy sculpin were the most abundant fish in all three sites. After restoration occurred, the overall fish abundance increased at Site 1 and 2, but decreased at Site 3 (Fig. 5). The increase at Site 2 may be due to the increase in abundance of sculpin after restoration. Fish diversity at Site 1 and 3 did not change, however the fish diversity increased at Site 2 (Fig. 5).

Brown trout abundance increased at all three sites (Fig. 6); however, brown trout lengths at Site 1 significantly increased (P= 0.018), while brown trout size at Site 3 significantly decreased (P= 0.045) (Fig. 6). Brown trout size at Site 2 decreased, but not significantly. The size of brown trout found in Site 1, after restoration, stayed constant with brown trout found before restoration (Fig. 7). Before restoration, brown trout in Site 2 were variable sizes (100-450 mm), but after restoration there is an increase in brown trout measuring 150-300 mm (Fig. 7). Site 3 exhibited an entire brown trout size shift. Before restoration, the brown trout sizes ranged from 250-400 mm, but after restoration brown trout sizes ranged from 100-350, with a peak in size at 200mm (Fig. 7).

Discussion

The results show immediate impacts of restoration on channel characteristics and aquatic biota. The data collected from this study indicates that channel characteristics, fish, and macroinvertebrate communities have been initially impacted by the Blue River restoration. The results do not indicate lasting changes, only immediate changes in channel characteristics and organism populations. Recovery after a natural disturbance is relatively rapid in streams because communities generally are adapted to these disturbances (Yount and Niemi 1990). However, recovery by stream communities after severe anthropogenic alteration, such as restoration varies and, in many instances, recovery is incomplete (Niemi et al. 1990, Detenbeck et al. 1992).

Habitat

The habitat data suggests that most significant changes occurred at Site 2, and that restoration of this site increased habitat characteristics that are favorable for brown trout. These characteristics include a good food source, cover (for protection from predation), deep pools, undercut banks, clear and oxygenated water, cool water (15-19°C) and gravel substrate (Hunter 1991). The results supported the hypothesis that the most changes and the greatest magnitude of change would occur within this site. One reason why the most changes occurred at Site 2 may be because the most physical alterations happened within this site; steam channels became narrower and deeper with the construction of more pools. Rip-rap was added to the stream banks to decrease erosion caused by overgrazing, and bridges for cattle crossings were constructed. Site 2 had lower water temperature after restoration, as did the other two sites. This may be due to the increased riffle-pool sequences and narrowing of channel to provide fast moving water.

Unlike Site 2, Site 1 had the fewest significant changes after restoration. This did not support our hypothesis that this site would have significant changes following Site 2 due to its downstream location. The minimal changes in habitat characteristics at Site 1 may be due to Site 1's overall habitat complexity. Site 2 is a natural meandering channel, and the channel's meanders and in-stream structures provided a buffering system, allowing particles that were picked up during the restoration process to be filtered out and deposited before it reached the Site 1 sampling area 400 m. downstream. White (1973) supports this idea that diversity in ecosystems promotes stability in the sense that incoming energy is thoroughly used and the community is buffered against severe environmental damage.

Results from Site 3 did not support the hypothesis that there would be no changes in habitat characteristics at this site after restoration. There were decreases in channel width and erosion, with increases in channel substrate composition. The changes that occurred at Site 3 were unexpected because this site was upstream from the restoration site and would not be physically altered by the restoration processes. Decreases in river width may be due to the pre-restoration surveys being taken in early summer, when the water levels were high, and post restoration surveys being taken after the rainy season in August, allowing for the river level to subside. Channel substrate composition may have changed due to the flooding events throughout the summer; coarse and fine sediments were picked up upstream, transported downstream, and deposited in Site 3.

Macroinvertebrates

The results from the macroinvertebrate surveys did not support the hypothesis that abundance and diversity would increase at Site 1, decrease at Site 2, and not change at Site 3. The data supports the hypothesis that the greatest changes in abundance and diversity would occur at Site 2 due to the restoration processes. The data suggests that after restoration occurred, macroinvertebrates moved downstream, from Site 3 into Site 2, increasing the abundance at Site 2. The increase in abundance may be due to the increased amount of Baetidae found in this site after restoration. Site 3 also had the greatest change in abundance. One explanation for these changes could be that Site 3 is not an ideal habitat for many aquatic organisms. The site contains silt substrate and an abundance of macrophytes. Although macrophytes produce oxygen, they also consume it through respiration; thus, macrophytes deplete oxygen that cannot be used by other organisms. Most invertebrates we found are well adapted to such conditions. Willers (1981) points out that dissolved carbon dioxide levels derive primarily from the atmosphere and from the respiration of aquatic organisms, and at extremely high levels the gas becomes toxic. Unlike Sites 2 and 3, Site 1 experienced little change which may be due to its habitat complexity and the natural buffering system previously explained.

Substrate is one of the most important environmental factors affecting the abundance of benthic macroinvertebrates (Tarzwell 1937, Smith and Moyle 1994, Pennak and Van Gerpen 1947). The increase of substrate complexity at Site 2 could explain the increase in macroinvertebrate population and the decrease of macroinvertebrates at Site 3. This idea is supported by various studies indicating that general increases in benthic populations have been found to occur with increasing sediment particle size, which can provide shelter (Smith and Moyle 1994, Pennak and Van Gerpen 1947, Sprules 1947). After restoration occurred, Site 2 had an increase in substrate composition. Investigations showing rapid recovery of benthos following river channelization occurred in streams with stable gravel, and rubble substrates (Rees 1959, Warner and Porter 1960, Burkhard 1967, and Winger 1972). The increase in macroinvertebrate abundance at Site 2 may be due to the characteristics at the site following restoration. Site 3 primarily consisted primarily of silt substrate. Schmal and Sanders (1978) explain that any activity that increases the amount of sand substrate will tend to decrease the amount of benthos. This supports the idea that Site 3 was not an ideal habitat for many aquatic organisms.

The macroinvertebrate survey indicates that the Blue River still needs improvement. The macroinvertebrates with the highest abundance include the Chronomids, Oligochetes, Ephemeroptera, Amphipods, and Trichopterans. These organisms are semi-sensitive or semi-tolerant to pollutants (Norris et al 1982, Noris 1986, Rosenberg and Vincent 1993). The data collected indicated few Plecopteran which are sensitive to pollutants, indicating that the Blue River system still needs adjustments to incorporate more pollutant-sensitive macroinvertebrates into its system. The macroinvertebrate collection from this study indicates that this stream contains pollutants which are limiting the macroinvertebrate population, therefore limiting the food supply for fish populations.

Fish

It was hypothesized that the abundance of fish would increase at Site 1, decrease at Site 2, and not change at Site 3. The idea was that the restoration process would inflict stress on the fish community at Site 2, and the fish would move downstream (into Site 1) away from the stress. It was also expected that the diversity would increase at Site 1 and Site 2, but would not change at Site 3. It was also hypothesized that the greatest changes in abundance and diversity would occur at Site 2 because it was being physically altered by restoration processes. The results support some of these hypotheses.

The greatest changes in abundance and diversity occurred at Site 2 because of the restoration. Site 2 provides undercut banks, ripple pool sequences, deep pools, and fast moving water. These characteristics provide habitat for more fish (Hunter 1991) that were not previously found within the site. Fish abundance may have increased at Site 2 and decreased at Site 3 due to the fish moving downstream from Site 3 into Site 2. The abundance of sculpin in the area after restoration increased the overall abundance of fish in Site 2. An explanation could be that after restoration, Site 2 may have provided better sculpin habitat, more rubble and rock riffles than Site 3 (Page and Burr 1991). The slight change in abundance indicated at Site 1 could be explained by the habitat complexity and the distance between site 1 and 2. Fish diversity increased at Site 2, with no change at Site 1 or Site 3. After restoration occurred at Site 2, the site provided ideal habitat for more fish species other than those fish found in that site.

Brown Trout

Brown trout abundance increased at all three sites after restoration, at relatively the same magnitude. This may be due to one of two reasons or a combination of the two 1) pre restoration survey methods were new and unfamiliar to the individuals conducting the surveys, but post restoration surveys were more accurate because of the familiarity with the equipment and study sites, and/or 2) at the end of the summer, the river was lower and thus concentrated the trout, making them easier to collect.

Site 1 had the highest abundance of brown trout, followed closely by Site 2. One explanation could be that Site 1 was dominated by a lot small brown trout, and while restoration was occurring, more brown trout moved downstream (out of Site 2), away from the stresses of the restoration processes.

Before restoration, Site 3 had the largest brown trout (250-300mm), but after restoration, Site 2 had the largest sized brown trout (200-250mm). Site 3 had the smallest sized brown trout pre and post restoration. Site 1 had prime rearing habitat for smaller brown trout, which is why Site 1 was dominated by small trout. Primary brown trout rearing habitat consist of cold, well-oxygenated, gravel-bottomed streams, in locations near cover (Hunter 1991). Site 2, unlike Site 1, has habitat that is preferred by larger brown trout (Hunter 1991).

It is difficult to explain why brown trout size decreased at Site 3, with little change in size at the other two sites. One explanation could be that the larger brown trout in Site 3 moved upstream or downstream out of the sampling sites. Another explanation may be that the smaller trout in Site 3 moved into Site 2 to utilize the new habitat.

Conclusion

Immediate impacts of river restoration presented in this study may be indefinite. For example, macroinvertebrate recolonization studies of enhanced stream reaches have found that macroinvertebrates require 70-150 days to reach maximum densities (Cairns et al. 1971,Williams and Hynes 1977, Gore 1979), and 250 days for the development of stable communities (Gore 1982). In addition, Jungwirth et al (1995) found that total fish density and abundance exceeded unrestored levels 1 year after restoration of a stream. The current study was conducted within a 100 day period, not allowing total biotic recovery from the restoration processes.

The Blue River has been immediately affected by restoration efforts. Brown trout abundances have increased; the restoration site is more suited for large brown trout, and food sources (i.e. mayflies) for all fishes have increased. A continued study of this restoration effort must be done in order to study the long term effects restoration will have on the Blue River's ecosystems.

Table 1. List of macroinvertebrates sampled from the Blue River in summer 2004.

ORDER	FAMILY	GENUS
Trichoptera	Brachycentridae	*Brachycentrus*
	Hydrosychidae	*Hydropsyche*
Ephemeroptera	Baetidae	*Baetis*
		Labobaetis
Hemiptera	Corixidae	*Trichocororixa*
Coleoptera	Elmidae	*Optioservus*
	Dytiscidae	
Diptera	Tipulidae	*Dicronota*
		Antocha
	Tabanidae	*Tabanus*
	Simulidae	*Sinulium*
	Chronomidae	
Gastropoda	Planorbidae	
	Physidae	
	Sphaeriidae	
Corbiculauas		
Amphipods		
Oligochetes		
Lepidopteras		
Earth Worms		
Water Mites		
Leeches		
Planarians		

Table 2. List of fish species sampled from the Blue River in summer 2004.

COMMON NAME	SCIENTIFIC NAME
Brown Trout	*Salmo trutta*
Common Shinner	*Luxilus cornutus*
White Sucker	*Catostomus commersonii*
Horneyhead Creek Chub	*Nocomis biguttatus*
Creek Chub	*Semotilus atromaculatus*
Mottled Sculpin	*Cottis bairdi*
Slimy Sculpin	*Cottus cognatus*
Johnny Darter	*Etheostoma nigrum*
Longnose Dase	*Rhinichthys cataractae*
Lamprey (ammocoete)	*Petromyzon sp.*

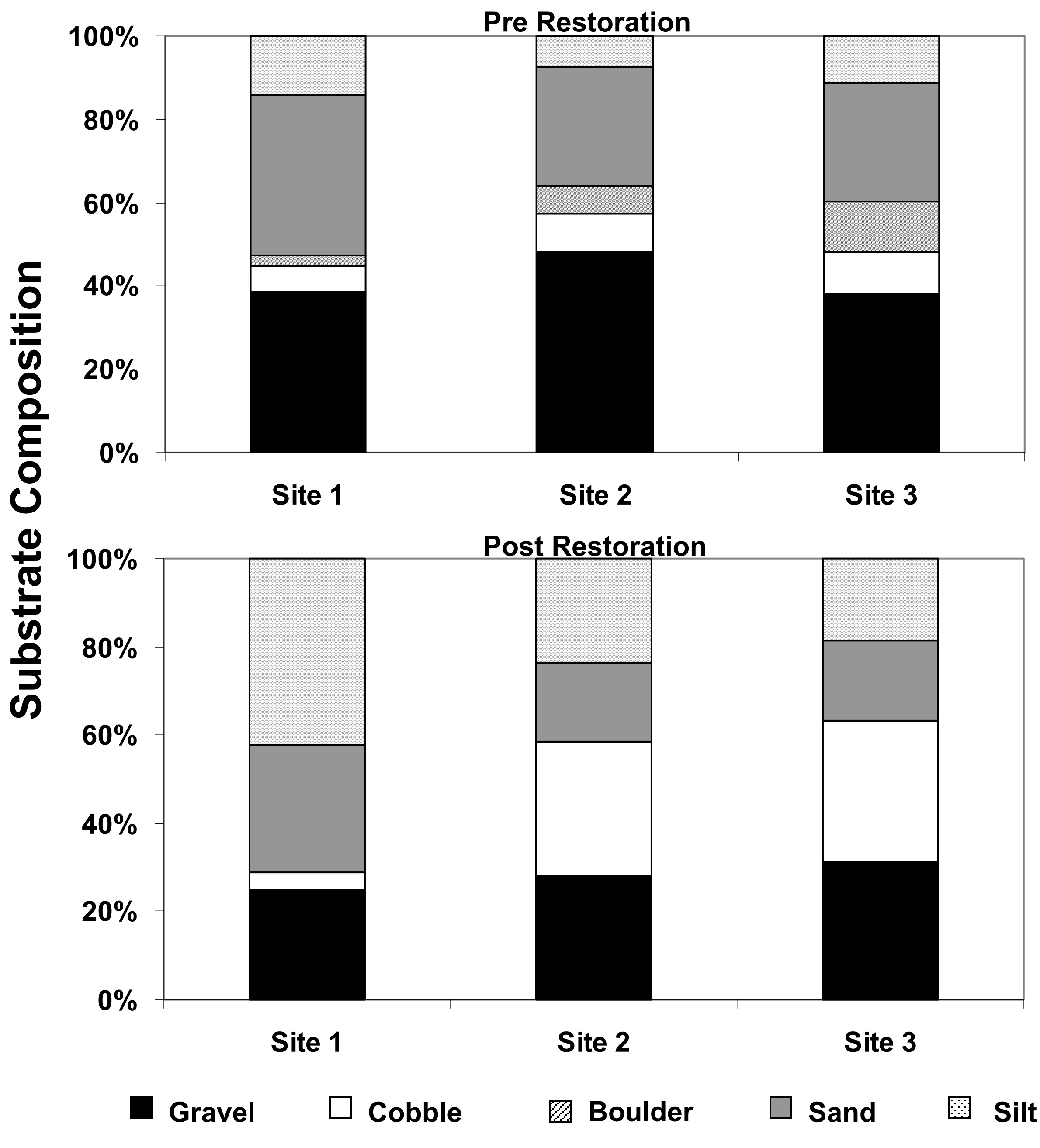

Figure 1. Comparison of substrate composition among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

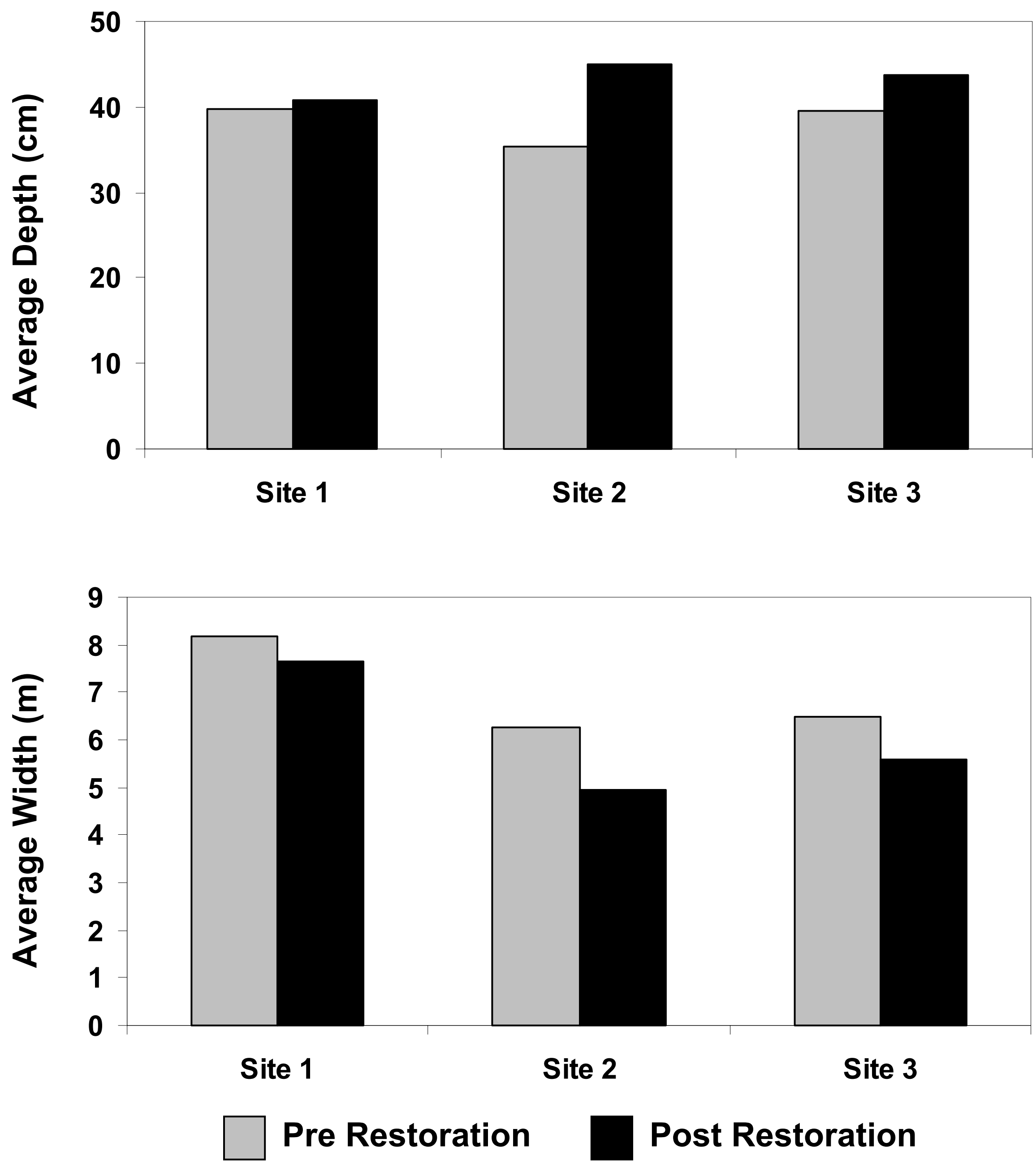

Figure 2. Comparisons of average depth and width among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

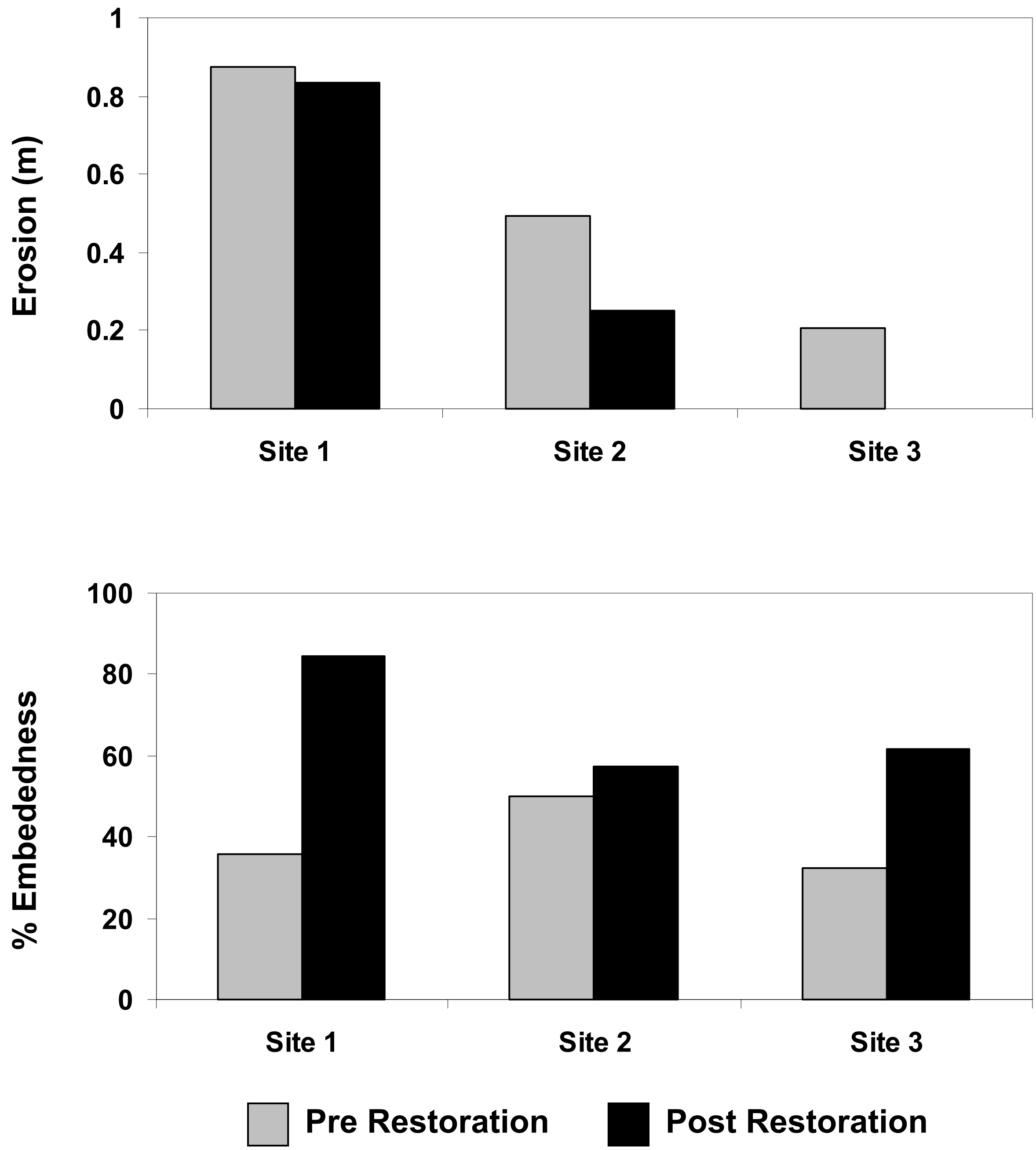

Figure 3. Comparisons of average erosion and embededness among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

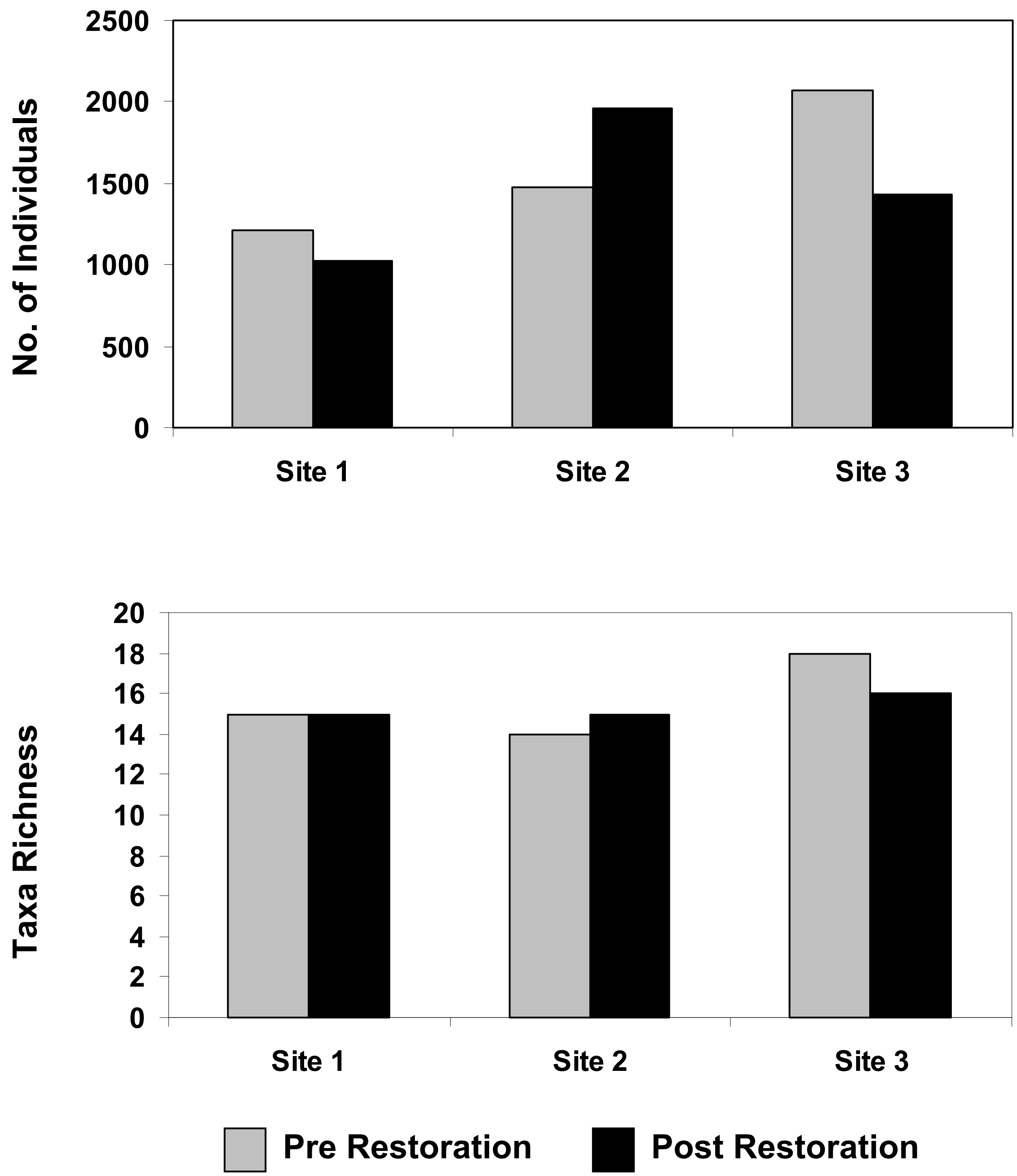

Figure 4. Comparisons of average abundance and diversity of macroinvertebrates among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

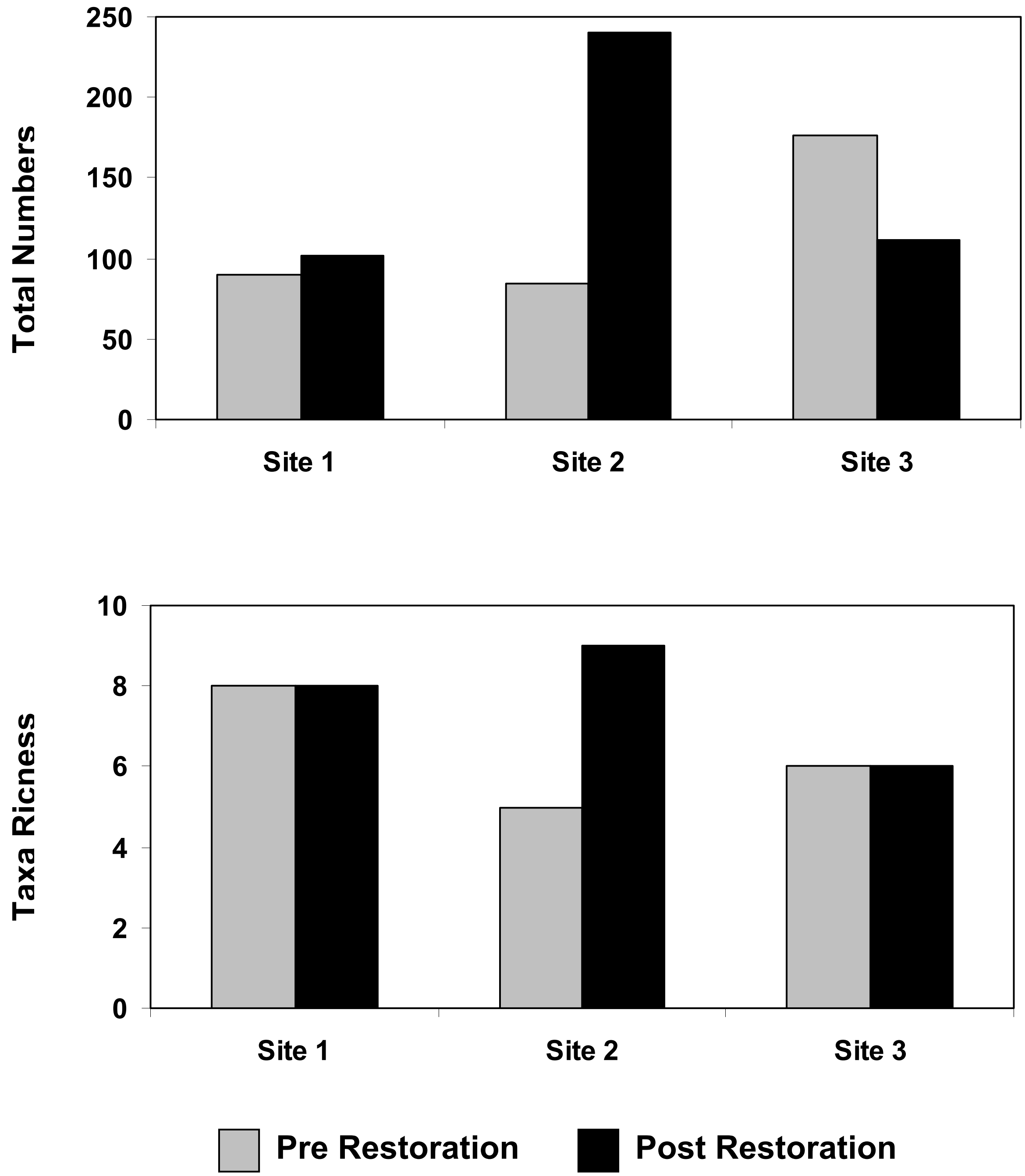

Figure 5. Comparisons of abundance and diversity of fish among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

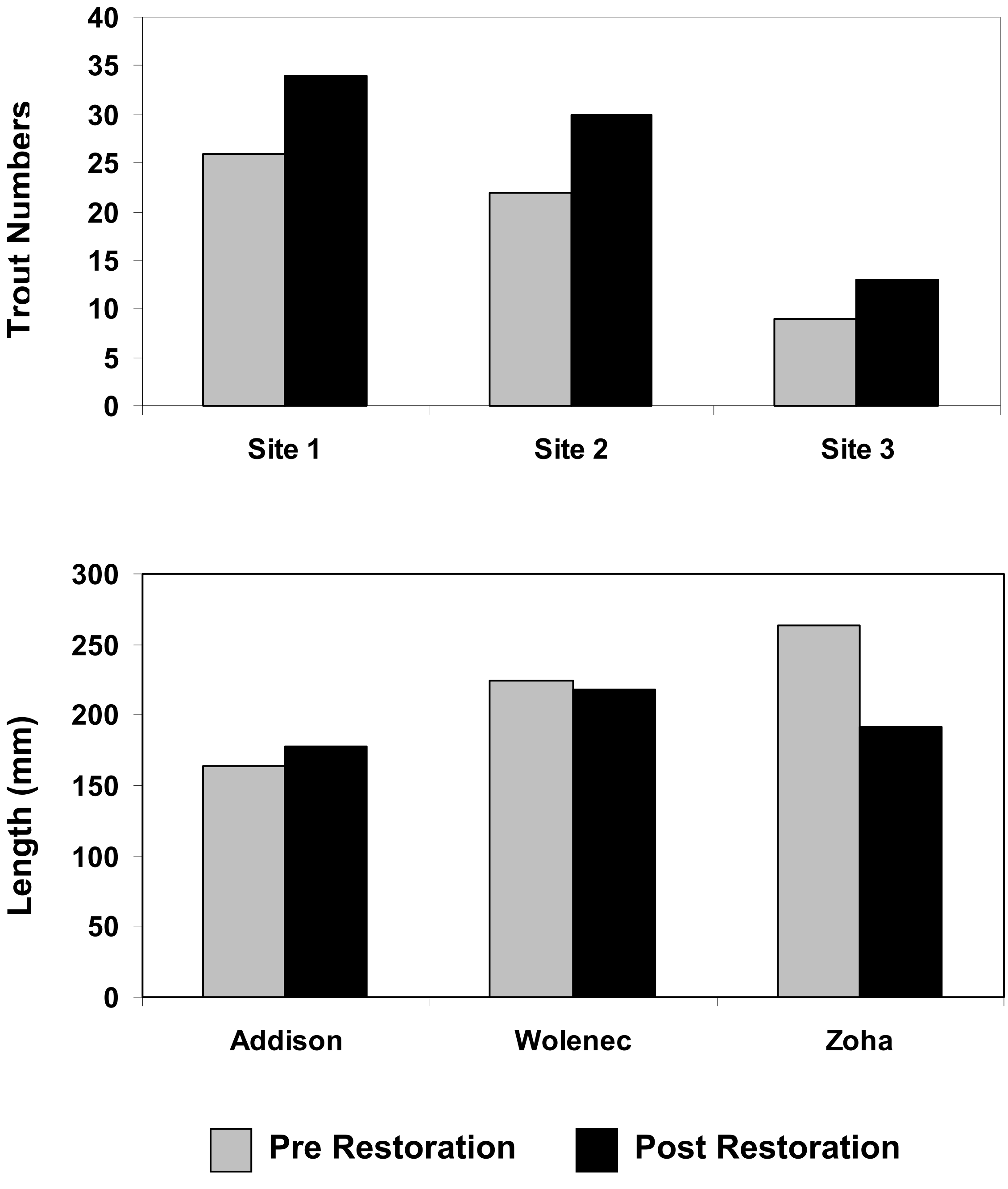

Figure 6. Comparisons of abundance and average size of brown trout among the three Blue River sites before and after restoration activities in summer 2004. Site 2 is where restoration occurred, Site 1 is downstream and Site 3 is upstream.

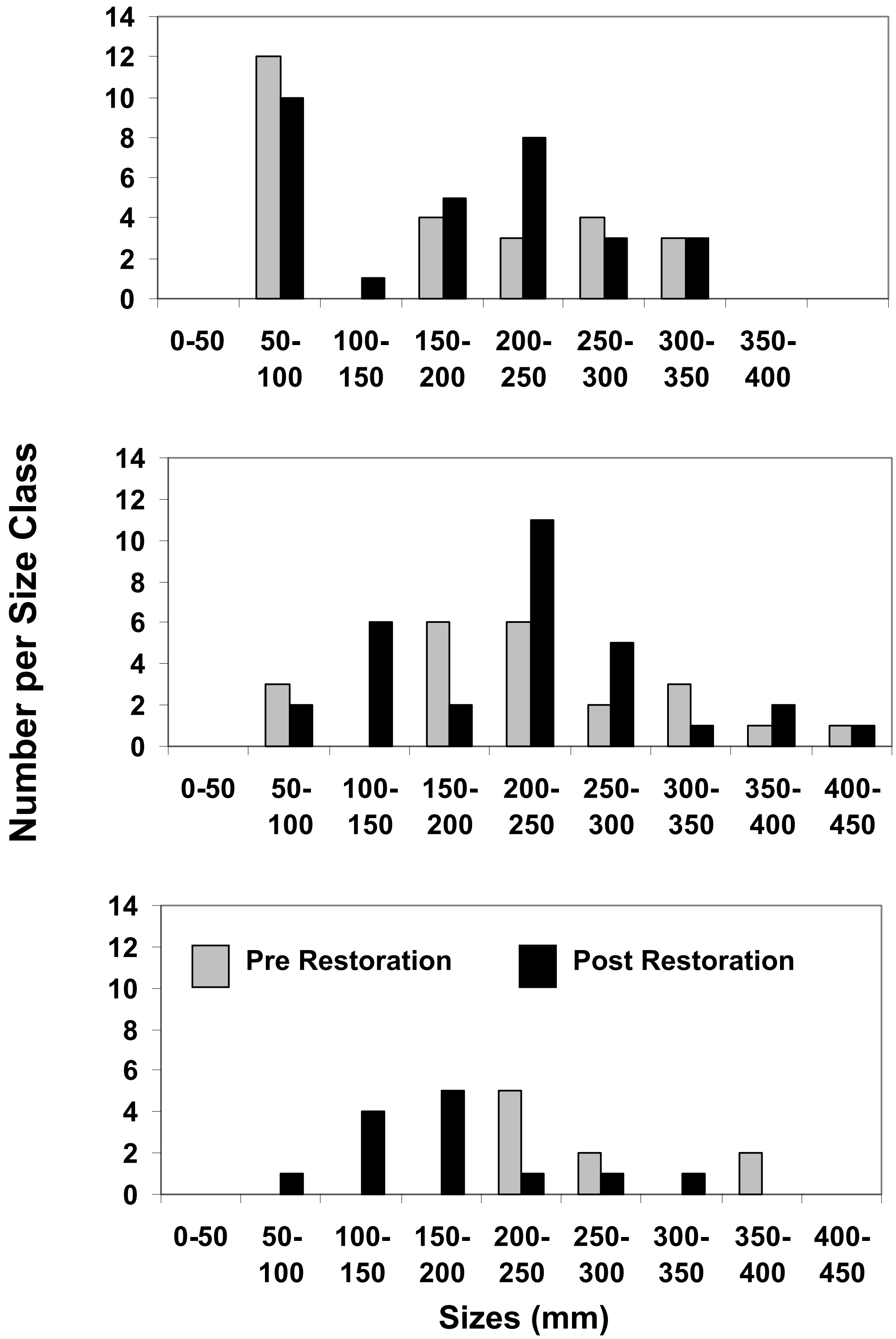

Figure 7. Comparisons of size of brown trout among the three Blue River sites before and after restoration activities in summer 2004. Site 2 (middle graph)is where restoration occurred, Site 1 (top graph) is downstream and Site 3 (bottom graph) is upstream.

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