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An ecological assessment of Oregon's CREP cumulative impact incentive program

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Background

Riparian vegetation is known to have strong effects on stream ecosystems, potentially ameliorating negative impacts resulting from human activities, including agricultural production. Riparian vegetation shades streams and can improve groundwater exchange, both of which result in lower water temperatures (Blann et al. 2002). The roots of riparian vegetation provide structural support for the soil which reduces streambank erosion leading to a decrease in sedimentation and water turbidity (Gosselink et al. 1990; Dosskey 2001). Riparian vegetation also filters nutrients found in runoff from lands used for agriculture and cattle grazing, which results in lowered nutrient input into streams (Likens & Bormann 1974; Dosskey 2001). Finally, riparian vegetation can increase instream structure through inputs of large woody debris and the exposure of roots along the streambanks; this increased structure creates habitat for many aquatic organisms (Benke et al. 1985; Sweeney et al. 2004).

While riparian vegetation has important effects on the condition of streams, little is known about whether these impacts are produced by riparian buffer programs that are generally implemented at small scales and are often spatially isolated from each other. Thus, an important question is: Can these small scale programs influence stream condition either at the scale at which the programs are implemented or in a cumulative fashion such that multiple buffers along a stream influence whole-stream condition? The scale at which riparian buffers influence stream condition has rarely been considered for cropland areas, with the exception of two studies of Midwestern croplands (Roth et al. 1996; Lammert & Allan 1999). The multiple scales in these studies were small sections of riparian buffers and larger areas which included uplands. Notably, these studies came to different conclusions; while one study suggested that small scale riparian buffer condition best explained stream condition (Lammert & Allan 1999), the other study found that larger scales that included upland use best explained stream condition (Roth et al. 1996). A problem with these studies is that while the small scales considered riparian buffer type only, the larger scales incorporated both riparian and upland areas. Any effects of increasing amounts of riparian buffer along the streams might be masked by considering upland use simultaneously since upland use can potentially influence stream condition (Harding et al. 1998).

Exotic weeds in riparian buffers - Invasive, exotic plants are more common in areas that are highly disturbed (Hobbs and Huenneke 1992; Parker et al. 1993; Gentle and Duggin 1997; Anderson 1999; Vujnovic et al. 2002). Riparian areas, with their high flood frequency and scouring, provide such an environment for establishment of exotic plants. In addition, stream flow may provide a convenient mechanism for dispersal of seeds. In fact, spread of invasive plants through riparian areas has been documented (Barton et al. 2004; Thomas et al. 2006; Richardson et al. 2007). Thomas et al. (2006) described movement of an invasive plant (*Dioscorea oppositifolia*) from an upstream population to downstream areas with highly suitable habitat for the species. However, little data is available on subsequent spread of exotics to upland areas. In addition to describing downstream movement, Thomas et al. (2006) also found that upland movement of *D. oppositifolia* was related to soil type, therefore spread to upland areas may be an interaction between time and site conditions. Finally, few studies have

investigated the relationship of seed bank, vegetation and seed rain (Gurnell et al. 2006; 2007). Several studies have found difference in seeds present in the soils seed bank compared to vegetation (Hanlon et al. 1998; Abernathy and Willby 1999; Gurnell 2006).

The purpose of this study is to determine the effectiveness of Oregon's CREP program on a variety of indicators of stream health; stream physical characteristics, macroinvertebrates and presence of invasive plants. Specifically we selected buffers of various lengths for an in depth assessment to determine their effectiveness compared to control (unbuffered) reaches. We sampled at set distances from the upstream end of the buffered or unbuffered area. We proposed to intensively sample at these points and compare differences among distances from the upstream end. This comparison will allow us to assess whether longer buffer lengths had a greater impact on indicators of stream health.

Methods

Site Selection –We were interested in CREP buffers on streams of similar size, geological substrate and surrounding land-use type. To make this initial cut at site selection, we thought it best to look at GIS layers of the data (e.g. CREP buffer locations, aerial photos, geology). We obtained aerial photos, land-use and land-cover maps, and geologic maps from the internet. To obtain a map of the CREP locations, we made contact with Lois Loop and Kent Willett at the Oregon Farm Services Agency office in Tualatin. We requested from them electronic GIS data of landowners in Sherman and Wasco Counties that are participating in the CREP program. We selected Sherman and Wasco Counties because these two counties contain the majority of CREP buffers in Oregon and therefore had a large sample size of similar sites to from which to choose. From these two, we learned that privacy laws enacted as part of the 2002 US Farm Bill prohibited them from providing this information. Instead, we received an electronic, Microsoft Excel file containing the streams or creeks on which there were CREP buffers. This file also included the area of the CREP buffer. After identifying the CREP buffers that were of the most interest to us, Dr. Bartuszevige met with Ms. Loop and Mr. Willett at their office in Tualatin (Dec 2007). We agreed that the next step would be for OSU to request a GIS shape file of the buffers in Sherman and Wasco counties >4.04 ha and < 70.82 ha; these sizes corresponded to the range of CREP buffer sizes. We were provided this data and were able to identify properties with CREP buffers on streams that matched the data in the Excel file. Using a GIS data layer from the Wasco County Tax Assessor's Office, we were able to identify 100 landowners who appeared to have a CREP buffer on their property, according to the two separate data layers. We narrowed our search to Wasco County because matching apparent CREP buffers from the GIS shape file with the buffers described in the Excel file was feasible for this county. In Sherman County, the data from the Excel file could potentially be associated with >3 buffers and thus, many more non-participating landowners could be contacted which we wanted to avoid.

In January 2008, we sent letters to landowners asking permission to access their property and to access the hard and electronic data associated with their CREP buffer. In February 2008, we contacted cooperating landowners and Josh Thompson and Ryan Bessette at the Wasco County Soil and Water Conservation Office in order to make site visits to perform final site selection. We selected nine buffered areas and three unbuffered areas to sample. We concentrated our site selection on Fivemile, Eightmile and Fifteenmile Creeks in Wasco County. These three creeks became the focus of our study because they are geographically close to each other, have similar surrounding land-uses, and differed in the amount of CREP buffers on each creek. We selected two buffered areas and one unbuffered area on Fivemile Creek; three buffered areas and one unbuffered area on Eightmile Creek; and four buffered areas and one unbuffered area on Fifteenmile Creek. Figure 1 shows locations of CREP buffers. Buffer lengths varied and ranged from 0.6 km to 7.3 km. Permission was obtained from all the producers associated with these buffers.

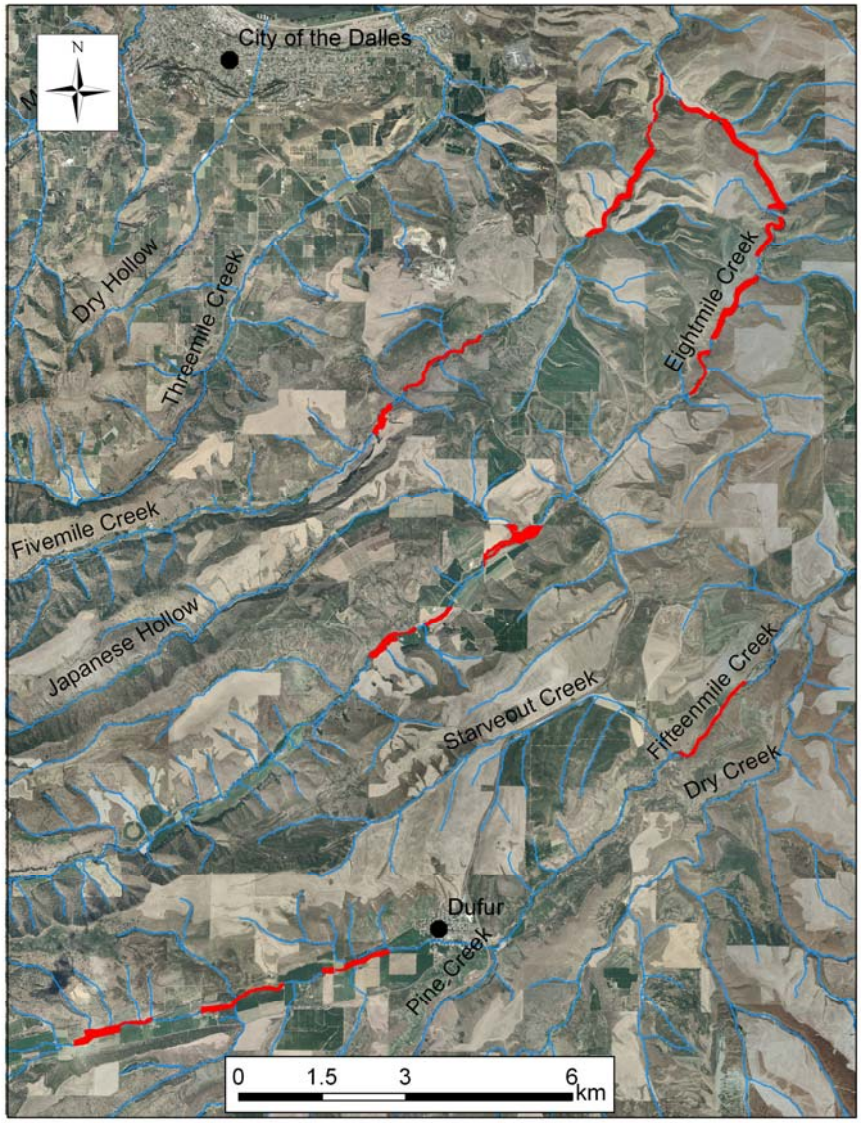


Figure 1. NAIP image of the study area. The red lines are the buffered sites that were sampled in this study. One unbuffered site was located on each stream at the following locations: Five mile creek – between buffers 2 and 3 (counting left to right); Eightmile creek – upstream of the first buffer; and Fifteenmile creek – upstream of the downstream-most buffer.

Within each buffered and unbuffered site, 5 points were sampled the upstream most end of the buffered or unbuffered site (0m), and 500m, 1000m, 1500m, and 2000m downstream points were measured. For macroinvertebrate sampling, one additional point on two different buffers were sampled, the downstream-most end of the buffer (>7000m downstream). These two points were chosen to describe changes in the macroinvertebrate community over the entire span of a long buffer.

Macroinvertebrate Sampling – Benthic macroinvertebrates were sampled following the protocols developed by the Oregon Department of Environmental Quality (outlined by the Oregon Plan for Salmon and Watersheds 1999). At each UTM coordinate location a study reach that was approximately 40 times the wetted channel width was measured. Four sampling locations were randomly chosen in riffle/fast water habitat within each study reach. At each of these locations a D-frame kick net was placed firmly against the substrate and the substrate in a standard area above the net ($0.3m^2$) was agitated for 90 seconds to a depth of approximately 10cm. The four samples taken at each reach were composited into a single sample that was used to characterize the macroinvertebrate community at the study reach. Composited samples were preserved in ethanol and transferred to the Oregon State University laboratory in Hermiston for processing. In the laboratory subsamples were randomly taken from each sample and invertebrates were picked from the subsamples until at least 500 invertebrates had been found.

Macroinvertebrates were identified to the lowest taxonomic category feasible (genus for most insect taxa and order or family for most non-insect invertebrates) using published keys (Thorp and Covich 1991; Merritt and Cummins 2008).

Environmental Variable Sampling – In addition to collecting macroinvertebrates, a suite of physical and chemical measurements were taken at each site following standard protocols (as outlined in Oregon Plan for Salmon and Watersheds 1999 and US EPA 2004). These physical and chemical parameters were measured at the same scale at which the invertebrates were collected (i.e., the reach scale). Previous work has indicated that in stream systems these parameters are important in determining the reach-scale distribution of macroinvertebrates (Griffith et al. 2001; Townsend et al. 2003). Physical attributes included wetted width, substrate composition, water depth, water velocity, and solar exposure. Substrate composition was recorded using a Wohlman pebble count (Oregon Plant for Slamon and Watershed 1999). The amount of solar exposure was measured using a Solar Pathfinder™ at each study site. This method provides a measure of the amount of insolation at a site that is latitude and date specific. Insolation is an important surrogate measure of the potential for heat gain to a stream reach and of the potential primary productivity (which can influence secondary productivity and the structure of the food web. The chemical parameters measured at each site were specific conductance (measured as microSiemens/ second), pH, and turbidity (measured as nephelometric units). Finally, continuous water temperature recordings were made at all sites (using Hobo H8™ dataloggers). Measurements were taken every 30 minutes for one week during the sampling period.

Data Analysis: macroinvertebrate and environmental variables – Stream health was estimated using derived, univariate metrics of aquatic invertebrate community structure. Metrics of community structure used for this report are ones that are frequently used in bioassessments using macroinvertebrates (Karr and Chu 1999). Importantly, these metrics were developed and are most frequently used in Europe and in the northeastern and western United States to reflect conditions in cold-water salmonid-bearing streams (Cairns and Pratt 1993; Karr and Chu 1999). We used three metrics to estimate stream quality. Two metrics involved three taxa: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) and thus are

termed EPT metrics. All three of these taxa are considered sensitive to human disturbances (Johnson et al. 1993) and thus a higher abundance or species richness of these taxa are expected to indicate better quality stream conditions. Thus, these metrics were used to evaluate the overall condition of the sampled area and to compare buffered and unbuffered reaches of the three streams. We used an EPT index calculated as the proportion of EPT taxa at each site (i.e. the EPT relative taxa richness), and another calculated as the proportion all EPT individuals at a site (i.e., EPT relative individual abundance). The other metric we used was a multi-metric index. Multimetric indices, often called Indices of Biotic Integrity (IBI), involve using a variety of composition, tolerance, and richness characteristics of the invertebrate communities to characterize stream condition. This approach is used widely in the U.S. and EPA has developed IBI particular to specific region. For this study, we used EPA's IBI developed for the xeric west ecoregion (Stoddard et al. 2005).

We used two-way analysis of variance (ANOVA) to determine whether buffer type (buffered or unbuffered) and/or stream identity (3 Mile, 5 Mile, or 15 Mile) affected stream quality as measured by these two metrics. We used linear regression to examine the impact of buffer length, buffer age, and elevation on stream quality. To partition out the variation associated with elevation, we used a t-tests to compare residuals from buffered and unbuffered sites from elevation-stream quality regressions. Analyses were conducted at two spatial scales: overall and, if no effect was found at the overall scale, at the stream level scale. In this latter case, finer spatial analyses allowed us to determine if stream to stream variation may have swamped out overall patterns. We used the Shapiro-Wilk test to check for normality, and transformed variables using an arcsine square root transformation, if necessary. All means are reported ± one standard error in the text and figures.

Plant Sampling – During the summer 2007 (July – September), we performed experiments to determine the best method to capture seeds from the streams. These experiments were performed by an Eastern Oregon University undergraduate student supervised by Dr. Bartuszevige. In the first experiment, she identified multiple types of fabric that would potentially capture seeds. They were: cheesecloth, mosquito netting, burlap, and two types of synthetic material. Each material was made into a 31 X 15 cm "net". Then, 100 seeds from three species of plants were poured into a water trough (130 X 51 cm) filled with water. Each net was scooped through the water one time and the number of seeds collected counted. This was repeated 10 times for each net and seed combination. We discovered that cheesecloth and mosquito netting collected the most seeds of all three species (Figure 2). Next, 10 nets each of cheesecloth and mosquito netting were placed into a ditch in front of the Eastern Oregon Agricultural Research Station. Nets were randomly placed on either the right or left side of the ditch approximately 1.5 m apart. The nets were placed at the edge of the flowing water so that seeds floating in the water at the edge would be captured by the nets. Nets remained in place for one week, after the nets were dried, the seeds were counted. The cheesecloth captured a total of 405 seeds and the mosquito netting captured a total of 237 seeds. In addition, we were able to successfully germinate the seeds captured from the water. Species identified include: *Bromus* sp, *Cirsium* sp, *Poa* sp, *Stellaria media*, *Verbasum thapsus*. We have designed a successful method for capturing seeds from the water column. An additional benefit to our design is that they are flat and any vertebrate animal that contacts the nets will not be captured; they can move around the net. This will enhance our permit applications associated with stream sampling.

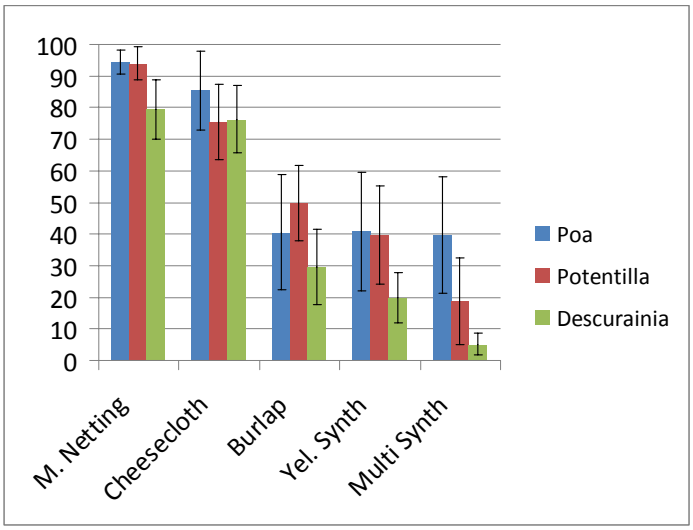


Figure 2. Average number (± 95% Confidence Interval) of seeds collected in nets made of a variety of materials (M. netting = Mosquito netting, Yel. Synthetic = yellow synthetic material). The mosquito netting and cheesecloth nets collected significantly more seeds of all species than the other three materials as evidenced by the non-overlapping confidence intervals.

Between 29 April and 21 May 2008, we conducted plant sampling in each of the buffers. We conducted sampling at the following distances from the upstream end of the buffered or unbuffered area: 0 m, 500 m, 1000 m, 1500 m, and 2000 m.

At each site, we established a 15 m transect that extended inland perpendicular to the stream flow (Figure 3). To avoid the need to cross streams during the early spring (a time of high water flow), we *a priori* determined to sample the vegetation on the same side of the creek as the road on which we drove. Because we had no prior knowledge as to the condition of the vegetation of the creeks on either side, we are confident that the samples are unbiased as to vegetation (e.g. we had no idea that one side would be “easier” to sample or provide “better” results than another). Along each 15 m transect, we identified the woody vegetation within 2.0 m of each side of the transect (15 X 4 m block). In addition, we estimated percent cover of herbaceous vegetation at 6 points along the 15 m transect (0 m, 1 m, 2 m, 4 m, 8 m, 14 m). We placed percent cover estimates into one of seven different cover classes: 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-95%, 7 = 95-100%. We collected soil cores from each of the sites at which we estimated vegetation cover. Soil cores were stored in a refrigerator at 5ºC until they were planted in the greenhouse. We planted soil samples in commercially available organic potting mix. The plants we watered as needed. We kept the temperature of the greenhouse at average spring temperatures for eastern Oregon, and at ambient light and humidity. Plants were identified and removed from pots.

During July 2008, we placed seed traps in the stream to collect seeds that are being dispersed downstream via water. Artificial grass doormats, 20 cm X 20 cm in size, were attached to the stream bottom at the edge of the water so that the entire mat was covered with water (Gurnell et al. 2006; Figure 4). Artificial grass doormats were used in lieu of the seed traps described above due to delays in obtaining permits. Traps were left in place for five days, at which time they were collected, stored for 3 days at 5ºC until they were planted in the greenhouse. Traps and any sediment that was collected on them were planted whole in pots with commercially available potting soil in the greenhouse. Plants were identified and removed from pots.

Figure 3. Vegetation sampling at one of the buffered sites. At the bottom-center of the picture, the yellow transect line extends perpendicular to the stream flow.

Figure 4. Artificial grass seed trap placed at the edge of the water in Fivemile Creek.

Nutrient sampling – Water samples were collected 22-24 July 2008 for total nitrogen and total phosphorus. One upstream (0 m) and one downstream (2000 m) grab sample were taken from 10 of our sites (the remaining 2 sites were not sampled because they were dry when the water samples were collected in late July). These samples were sent to Delta Environmental Services, Inc. for total N and total P analysis. Total N analysis used the SM 4500-NO3 E method and total P used the EPA 365.3 method.

Results

Stream Health of Reaches with CREP Buffers vs. Reaches Without Buffers

EPT Taxa Richness: Of all taxa found at each site, the mean percentage of taxa that were EPT across all streams was 44.0 ± 1.0% (n=51 sites). There were no statistically significant differences in the proportion of EPT taxa between buffered and unbuffered reaches (F=1.5, p=0.23), among streams (F= 0.2, p=0.85), and no significant interaction between the two factors (F=0.8, p=0.43) (Figure 5).

EPT Relative Individual Abundance Of all individuals found at each site, 28.70 ± 1.9% were mayflies, stoneflies, or caddisflies (n=51 sites). Data were arcsine square-root transformed to meet the assumption of normality. Buffered reaches had significantly greater percentages of EPT individuals than unbuffered stream reaches (Figure 6, F=4.9, p=0.03). There were no statistically significant differences among streams (F=2.9, p=0.07) and no significant interaction between the two factors (F=0.5, p=0.63).

Index of Biological Integrity: There were no statistically significant differences in the IBI between buffered and unbuffered reaches (F=0.01, p=0.91). However, there was a difference in IBI among streams (F=4.3, p=0.02). There was not a significant interaction between the two factors (F=0.02, p=0.97) (Figure 7).

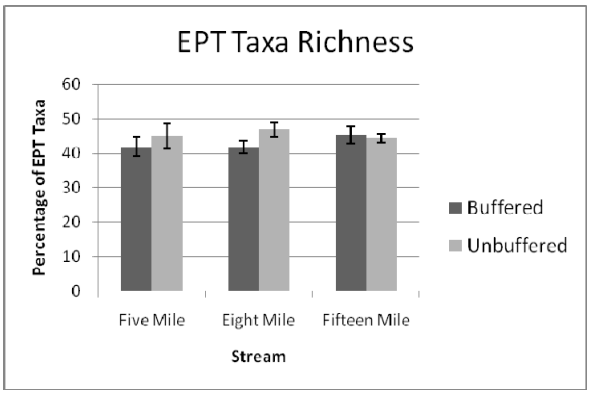


Figure 5. Percentage of total taxa richness that were EPT in buffered and unbuffered stream reaches in three streams. There were no statistically significant differences between buffered and unbuffered stream reaches or among streams. See text for details.

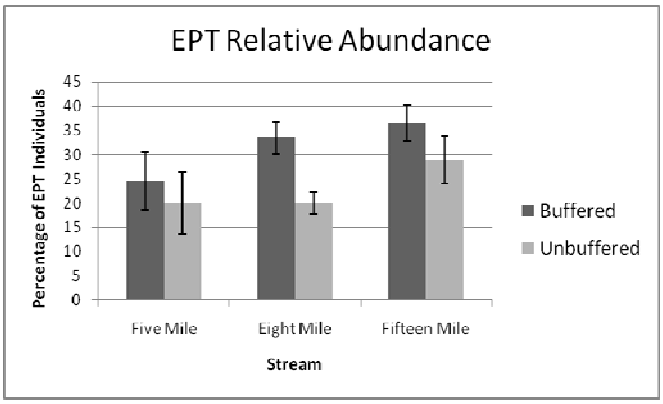


Figure 6. Percentage of all individuals that were EPT in buffered and unbuffered stream reaches
Buffered reaches had significantly greater percentages of EPT individuals than unbuffered stream reaches. There were no statistically significant differences among streams. See text for details.

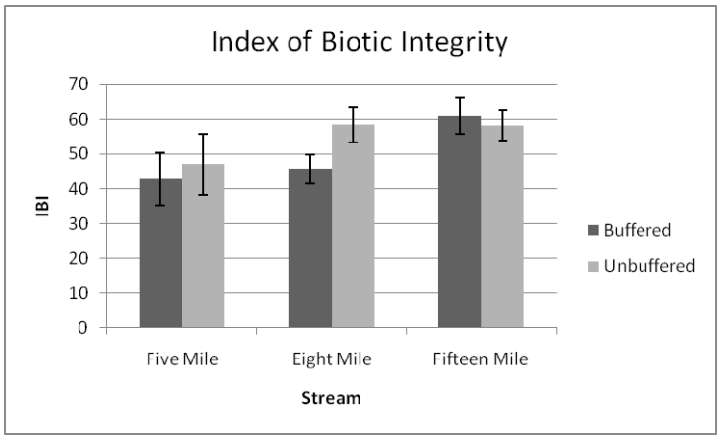
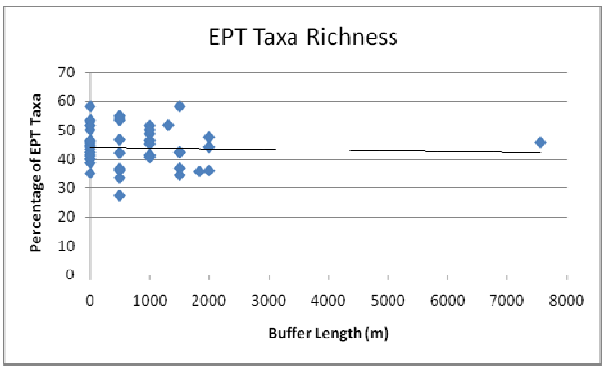


Figure 7. IBI index for buffered and unbuffered stream reaches. There were no statistically significant differences between Unbuffered and buffered stream reaches or among streams. See text for details.

The Effect of Length on Buffer Effectiveness

Not surprisingly, given the lack of response shown for percent EPT taxa and IBI values in response to buffers, there was no relationship between length of buffer and those metrics (r^2 = 0.01, p = 0.45; r^2 = 0.01 , p =0.54, respectively; Figures 8 and 10). However, we also found no statistically significant relationship for the percent individuals belonging to EPT taxa and buffer length (r^2 = 0.04, p = 0.16, Figure 9).



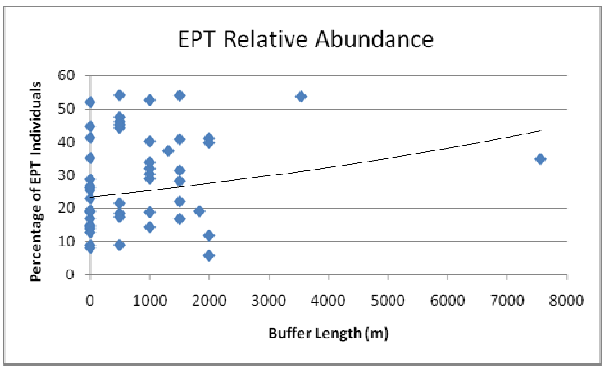


Figure 8. Percentage EPT taxa plotted against buffer length. There was no significant relationship between the two variables. See text for details.

Figure 9. Percentage of EPT individuals plotted against buffer length. There was no significant relationship between the two variables. See text for details.

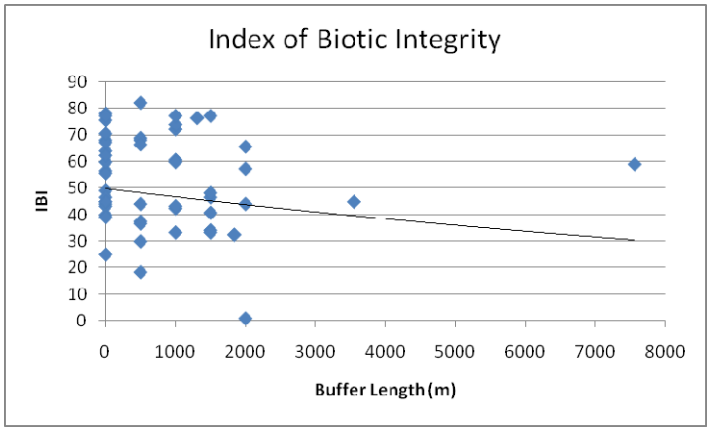


Figure 10. IBI values plotted against buffer length. There was no significant relationship between the two variables. See text for details.

The Effect of Age on Buffer Effectiveness

No statistically significant relationship existed between percent EPT taxa, percentage of individuals belonging to EPT taxa, or the IBI and age of buffers ($r^2 = 0.03$, $p = 0.24$; $r^2 = 0.05$, $p = 0.10$; $r^2 = 0.02$ $p = 0.30$, respectively, Figures 11-13).

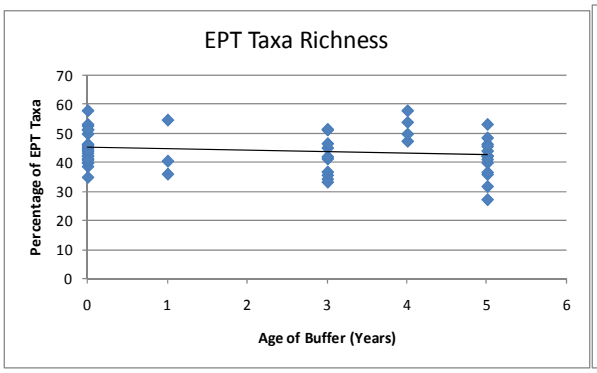


Figure 11. Percentage EPT taxa plotted against buffer age. There was no significant relationship between the two variables. See text for details.

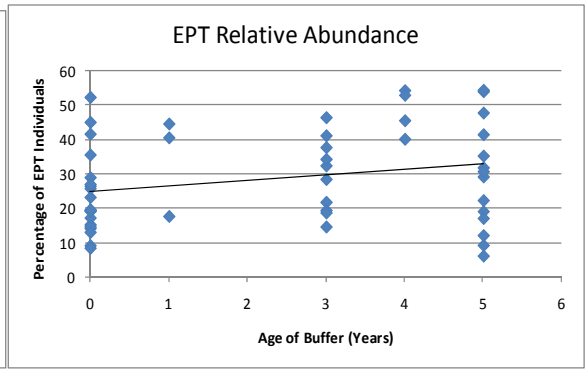


Figure 12. Percentage of individuals belonging to EPT taxa plotted against buffer age. There was no significant relationship between the two variables. See text for details.

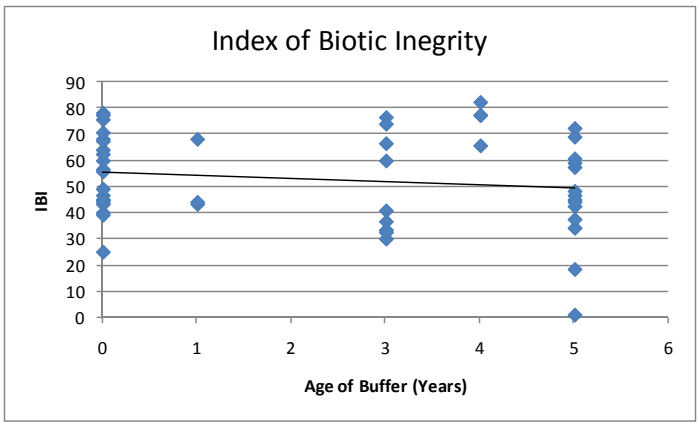


Figure 13. IBI values plotted against buffer age. There was no significant relationship between the two variables. See text for details.

Plant Sampling – Two hundred and twenty two plant species were identified in transects, soil samples, and seed traps (Table 1). One hundred forty-one species were found on transects, 100 of which were unique to transect samples (71%). One hundred eighteen species germinated from soil samples, 74 species were unique to soil samples (63%). Twelve species were identified from seed traps, 2 species were unique to seed traps (17%). We identified 38 species of woody vegetation (e.g. shrubs, trees, and vines). The species are listed in table 2.

A t-test showed there was no difference in plant species richness (number of species) between buffered and unbuffered sites at any distance from the upstream (Table 3).

Plant data from transects were analyzed with a Nonmetric Multidimensional Scaling (NMS) ordination. The purpose of this analysis was to determine if plant community composition was different in buffered and unbuffered areas. The autopilot setting at medium was used in the ordination. A three dimensional solution was determined to be optimal. However, there was no difference in plant community composition between buffered and unbuffered sites (Figure 14). Additional NMS ordinations were completed to determine if there was a difference in plant community composition among 1) distances from the upstream end of the buffer, 2) creeks, and 3) age of buffers. There were no differences in plant community composition in any of the comparisons (Figures 15-17). Age of buffers was classified into three different age classes 0 = unbuffered, 1 = buffers aged 1-3 years (5 buffers), 2 = buffers aged 4-6 years (4 buffers). Age classes were used to have a large enough sample size to make statistical comparisons.

An NMS ordination was completed to determine plant community composition in soil samples collected at transects. There were no differences in community composition in any of the comparisons [buffered vs unbuffered (figure 18), distance from the upstream end of the buffer (figure 19), creeks (figure 20), and age of buffers (figure 21)].

Nutrient Sampling – Paired t-tests of total N and total P in upstream and downstream samples at buffered sites showed no significant difference in nutrient levels (total N: $t = 0.16$, $df = 7$, $p > 0.05$; total P: $t = 0.2$, $df = 7$, $p > 0.05$). At only 2 sites did nutrient loads decrease in the predicted direction. One site on Fivemile Creek and one site on Fifteenmile Creek had lower total N at downstream sites than at upstream sites. No sites on any creek had the predicted pattern of lower total P at downstream sites compared to upstream sites (Table 4).

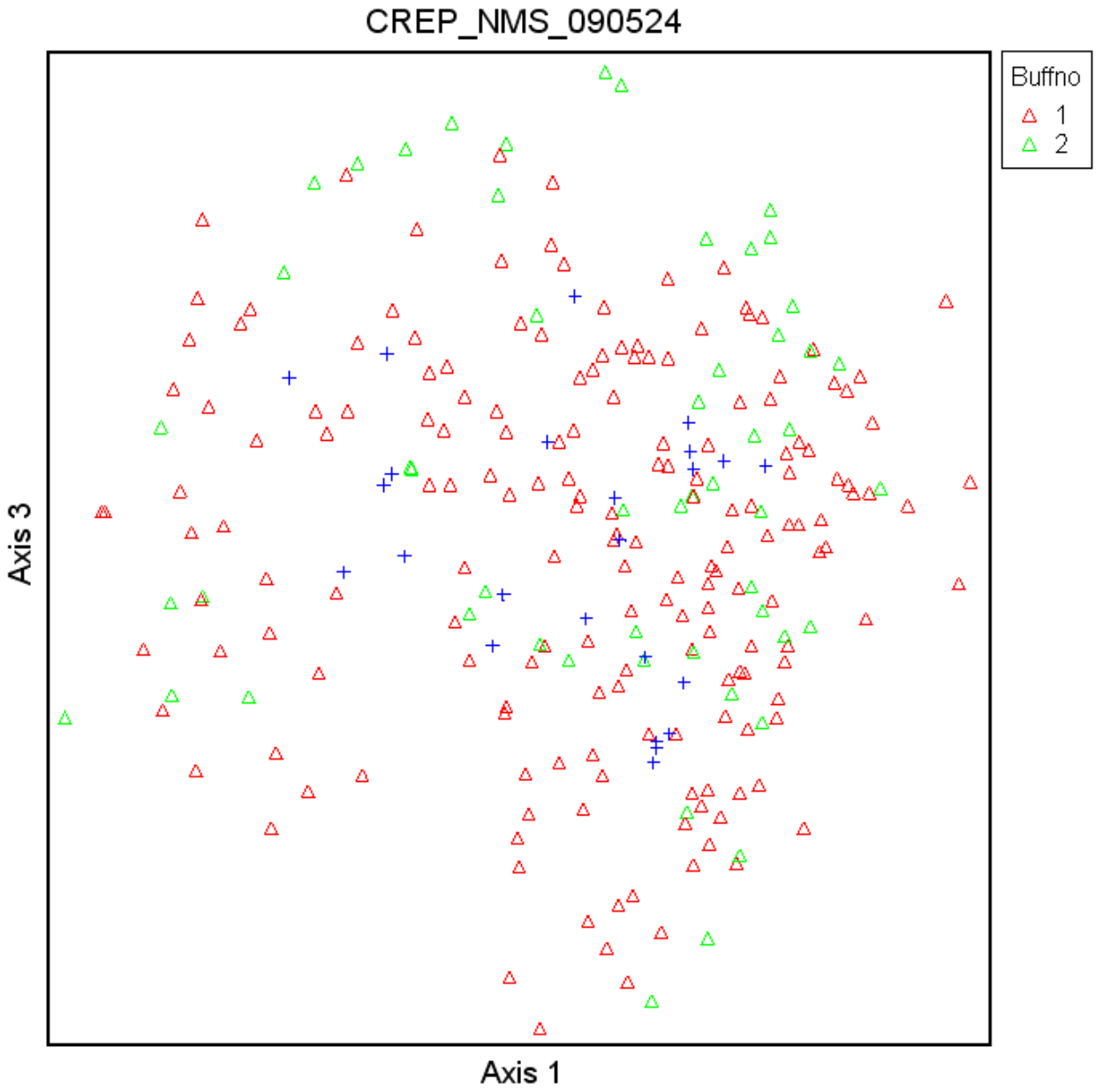


Figure 14. NMS ordination graph of plant community composition in buffered (red triangles; #1) versus unbuffered (green triangles; #2) sites. Note the overlap in plant community composition in buffered and unbuffered sites. The blue crosses are an artifact of the PC-ORD program. In this graph, axes 1 and 3 are used to illustrate but a similar pattern is found no matter what axes are used.

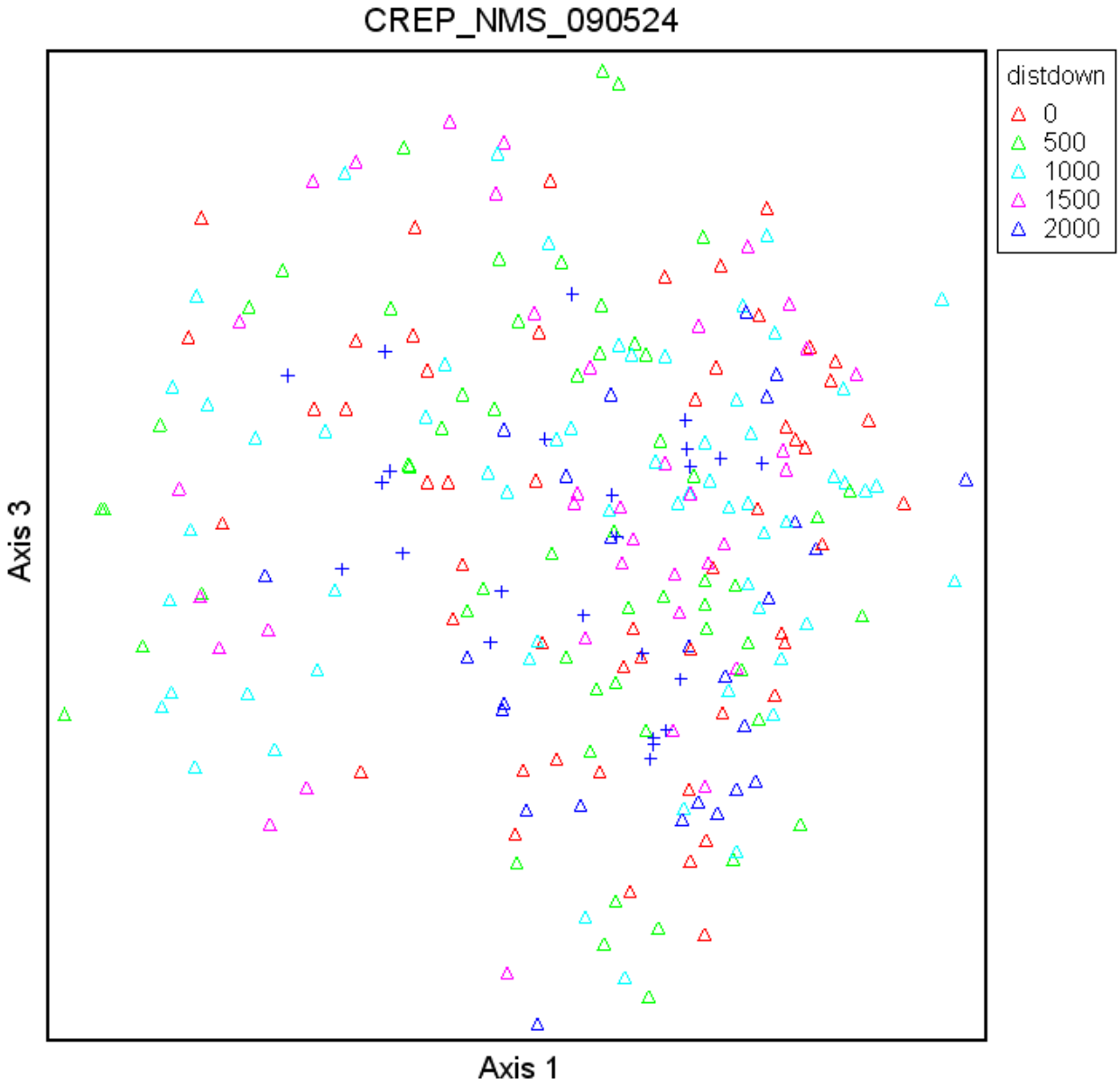


Figure 15. NMS ordination of plant community composition at different distances from the upstream site (upstream = 0, red triangles; 500 m downstream, green triangles; 1000 m downstream, light blue triangles; 1500 m downstream, pink triangles; 2000 m downstream, dark blue triangles). Note the overlap in plant community composition at different distances along the stream. The blue crosses are an artifact of the PC-ORD program. In this graph, axes 1 and 3 are used to illustrate but a similar pattern is found no matter what axes are used.

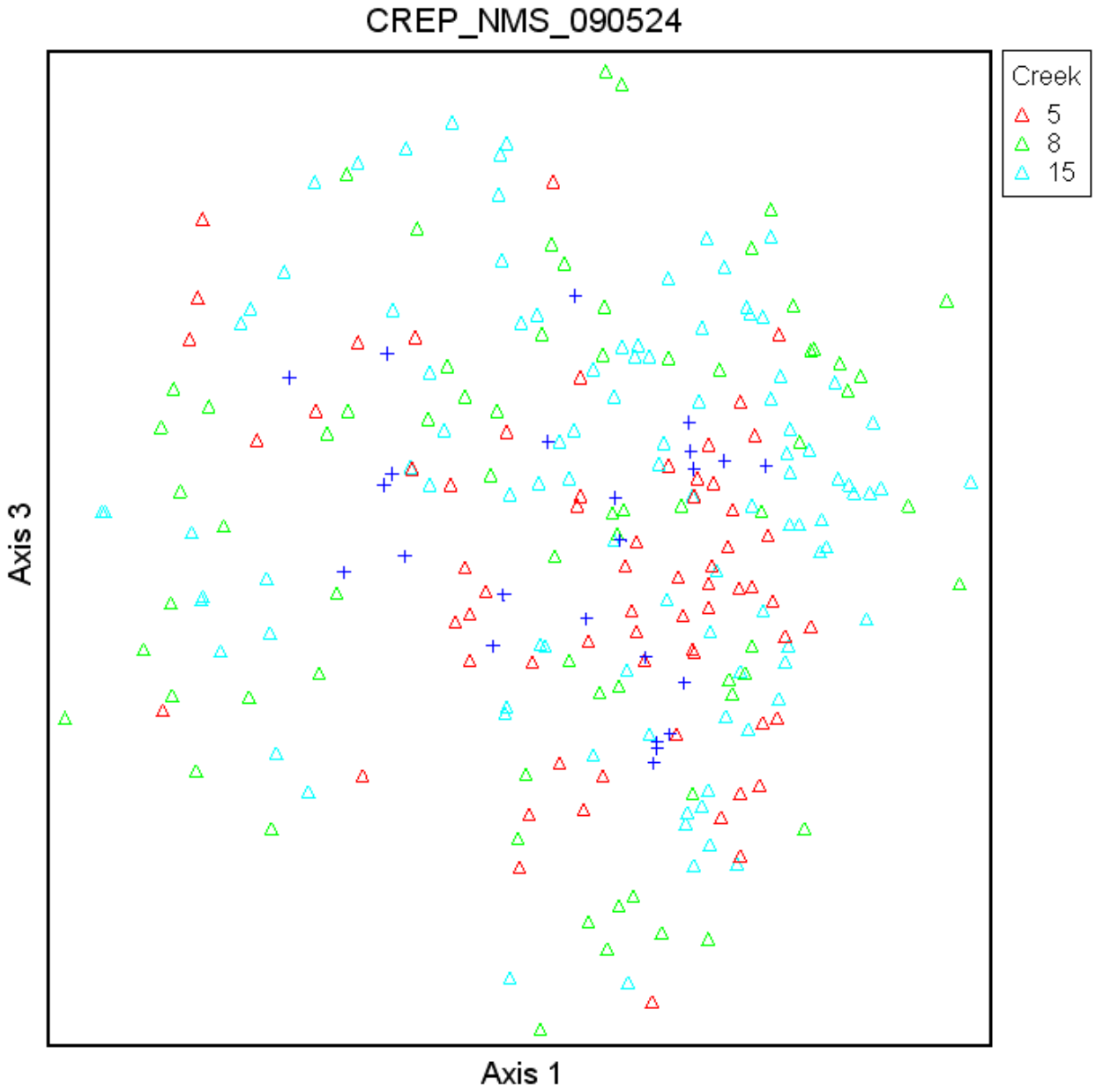


Figure 16. NMS ordination of plant community composition of the different creeks used in the sampling (Fivemile Creek, red triangles; Eightmile Creek, green triangles; Fifteenmile Creek, light blue triangles). Note the overlap of plant community composition of the different creeks. The blue crosses are an artifact of the PC-ORD program. In this graph, axes 1 and 3 are used to illustrate but a similar pattern is found no matter what axes are used.

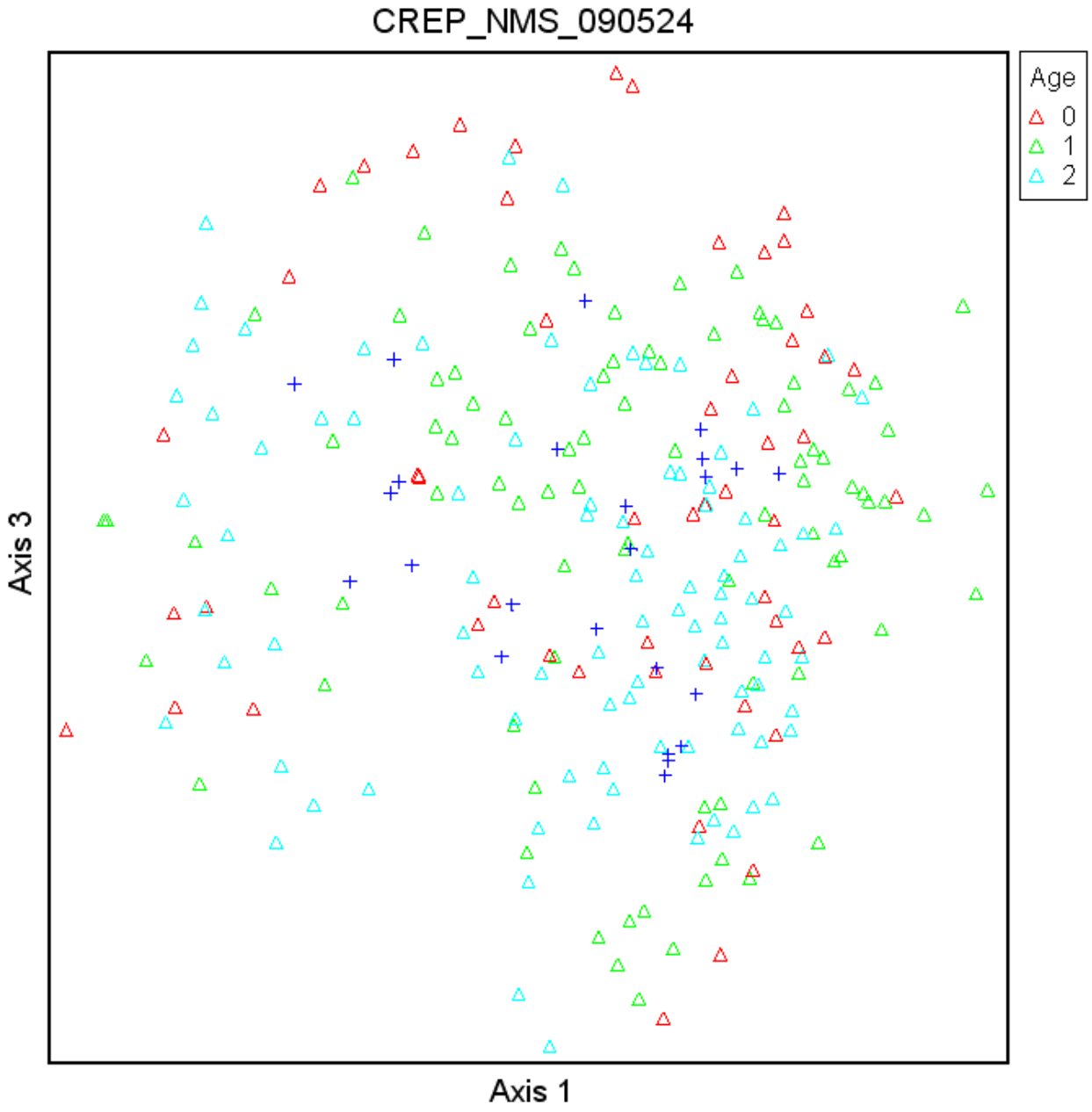


Figure 17. NMS ordination of plant community composition in different aged buffers (0 = unbuffered, red triangles; 1 = buffers aged 1-3 years, green triangles; 2 = buffers aged 4-6 years, light blue triangles). Note overlap of plant community composition in different aged buffers. The blue crosses are an artifact of the PC-ORD program. In this graph, axes 1 and 3 are used to illustrate but a similar pattern is found no matter what axes are used.

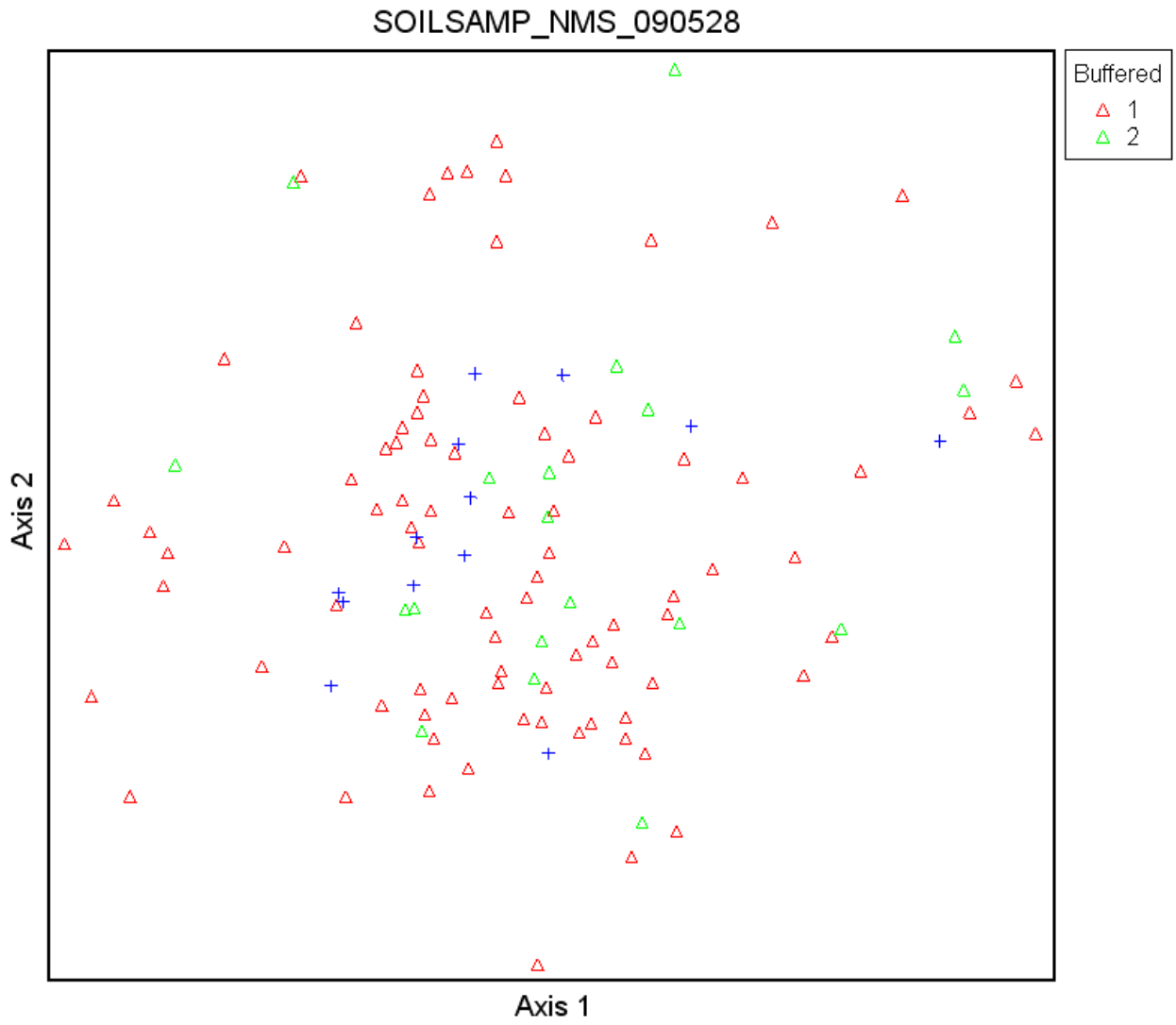


Figure 18. NMS ordination graph of plant community composition in soil samples collected at buffered (red triangles; #1) and unbuffered (green triangles; #2) sites. Note the overlap in plant community composition in buffered and unbuffered sites. The blue crosses are an artifact of the PC-ORD program.

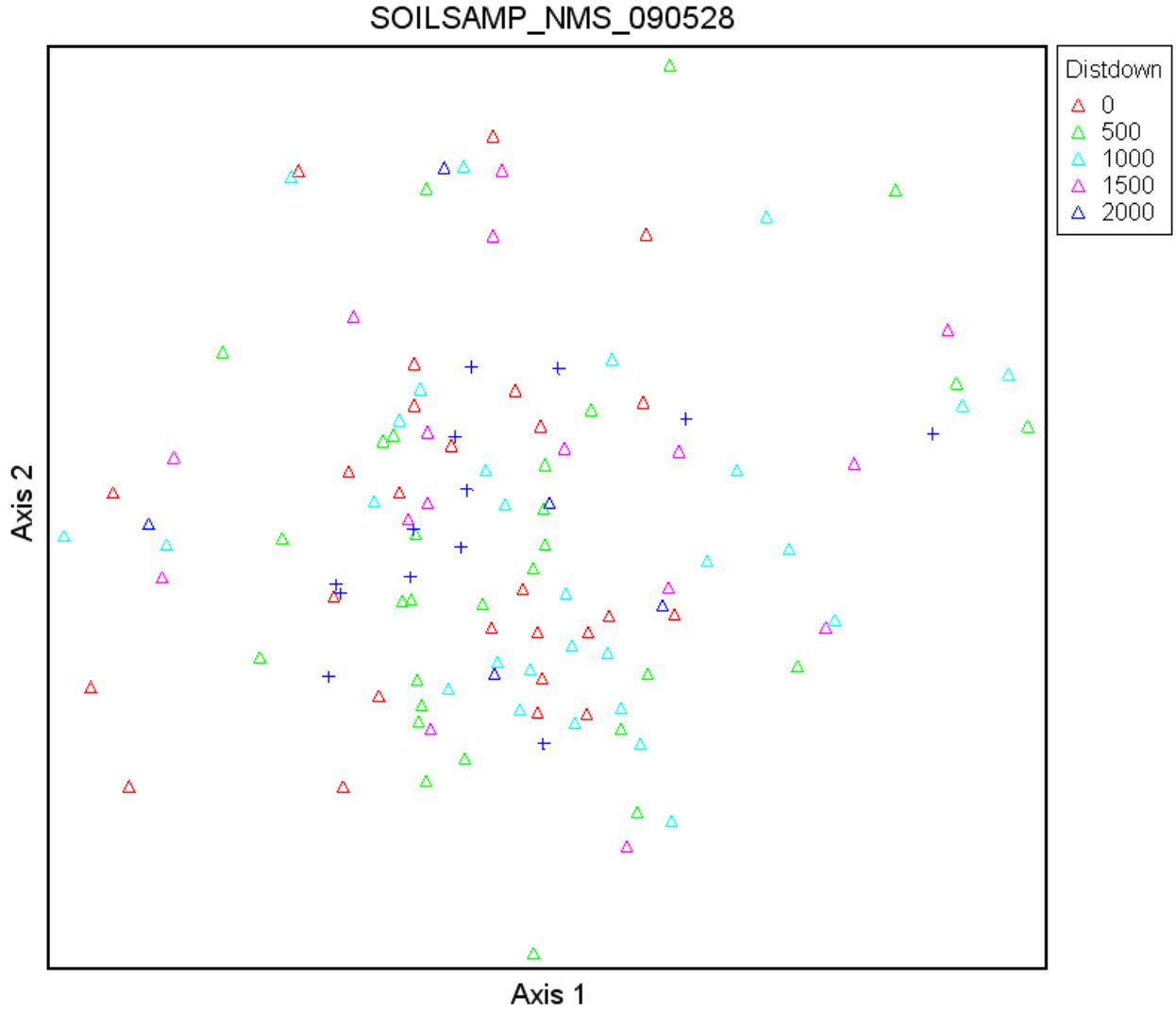


Figure 19. NMS ordination of plant community composition from soil samples collected at different distances from the upstream site (upstream = 0, red triangles; 500 m downstream, green triangles; 1000 m downstream, light blue triangles; 1500 m downstream, pink triangles; 2000 m downstream, dark blue triangles). Note the overlap in plant community composition at different distances along the stream. The blue crosses are an artifact of the PC-ORD program.

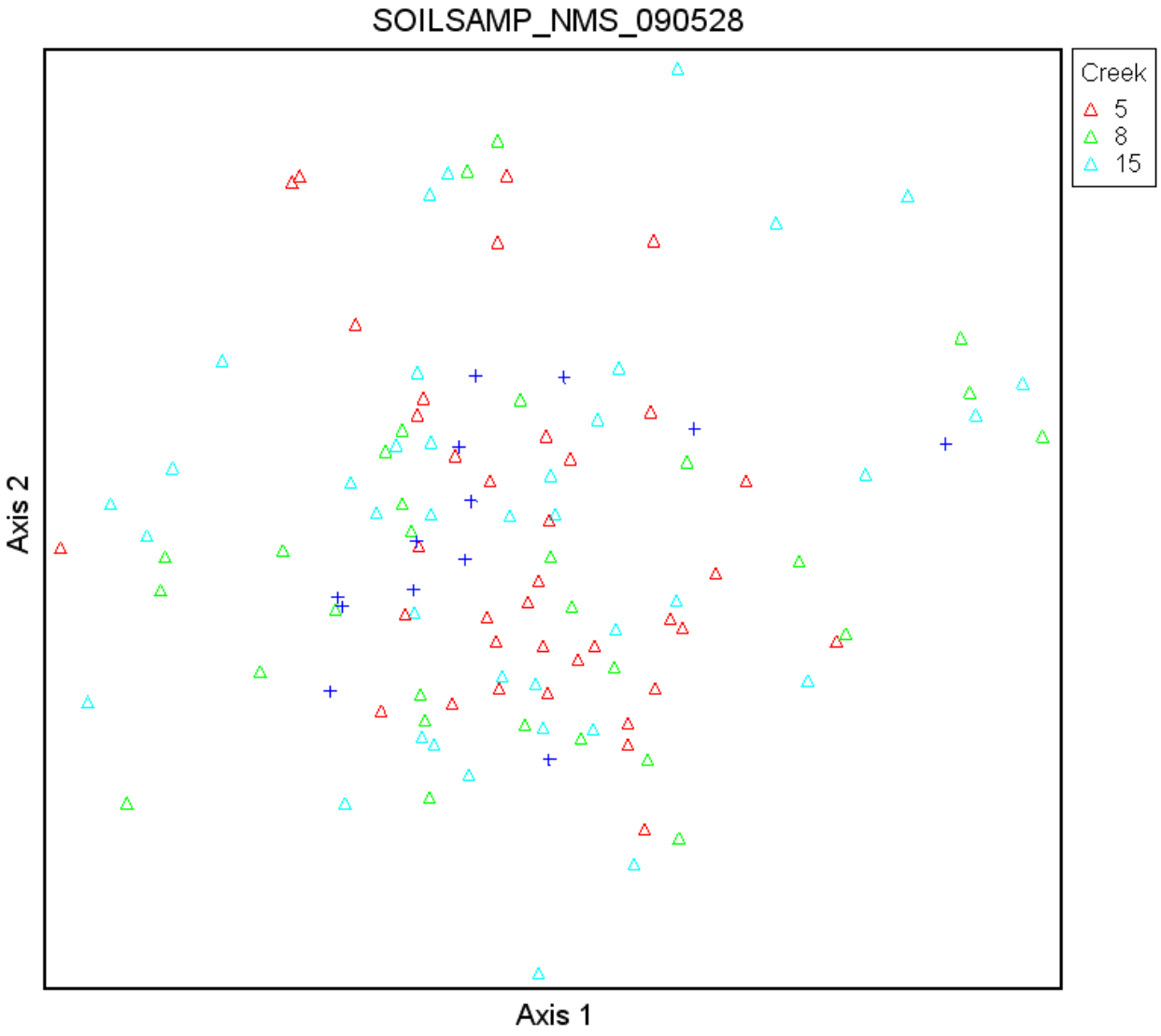


Figure 20. NMS ordination of plant community composition in soil samples collected along transects of the different creeks used in the sampling (Fivemile Creek, red triangles; Eightmile Creek, green triangles; Fifteenmile Creek, light blue triangles). Note the overlap of plant community composition of the different creeks. The blue crosses are an artifact of the PC-ORD program.

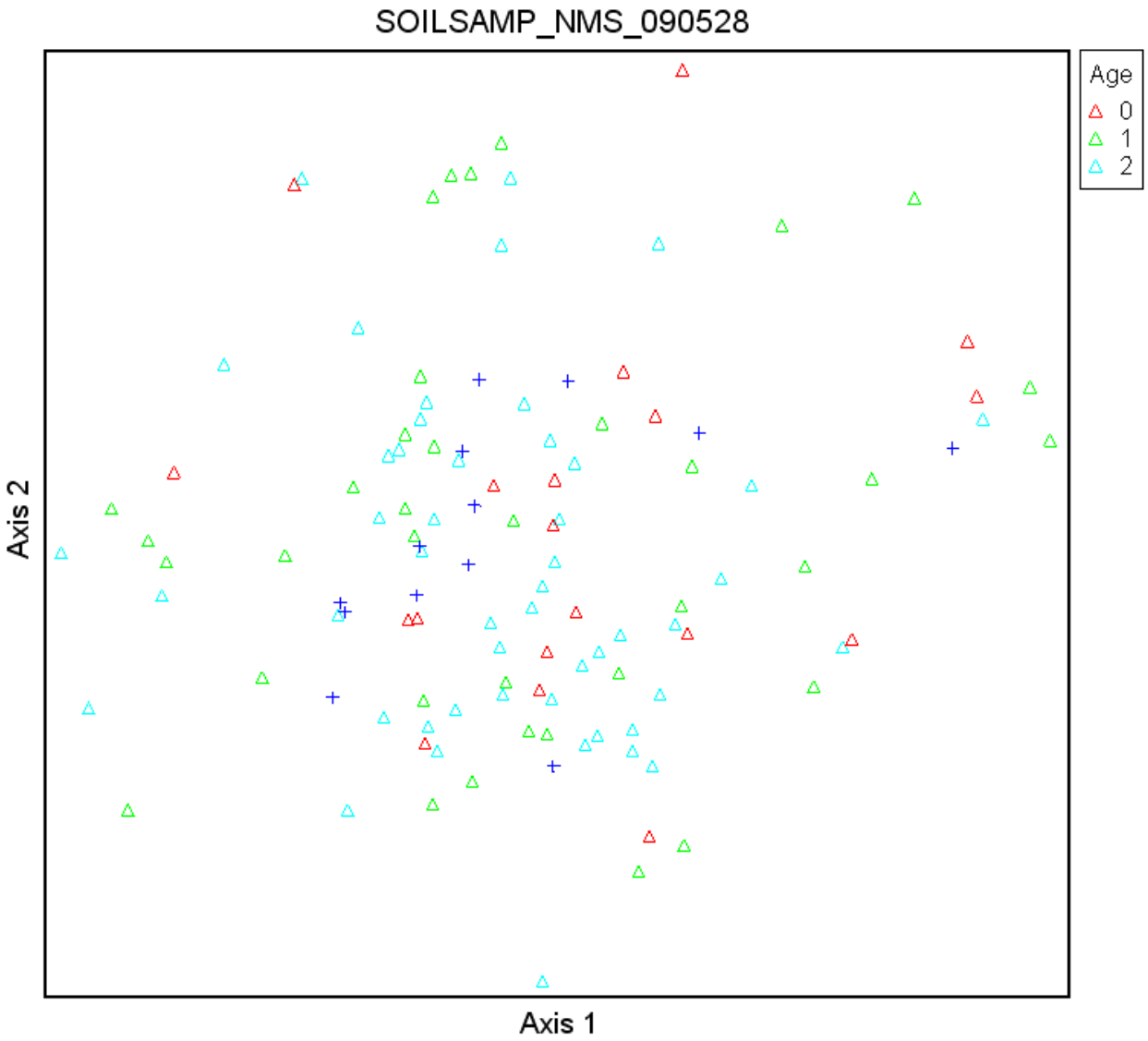


Figure 21. NMS ordination of plant community composition in soils samples collected along transects in different aged buffers (0 = unbuffered, red triangles; 1 = buffers aged 1-3 years, green triangles; 2 = buffers aged 4-6 years, light blue triangles). Note overlap of plant community composition in different aged buffers. The blue crosses are an artifact of the PC-ORD program.

Discussion

- The sites selected on Fivemile, Eightmile and Fifteenmile Creeks had similar upland landuses, geography, and were located nearby each other. Because of these characteristics, statistical comparisons could be made among sites. However, long lengths of all three creeks had large amounts of vegetation along creek-sides, which can be interpreted as buffers. The large amount of vegetation, even in unbuffered sites, may have tempered the effects of the CREP buffers along these creeks.

Macroinvertebrate and environmental variables

- Do CREP buffers lead to improved stream quality? Yes. However, this effect is subtle as only a single metric, percentage of individuals belonging to EPT taxa, responded to the presence of buffers. As expected if buffers improve stream reach quality, the percentage of EPT individuals was higher in areas with buffers as compared to unbuffered areas. A higher abundance of these individuals indicates that conditions within buffered areas are a more suitable environment than areas outside of the buffers. The lack of a response by the percentage of EPT taxa suggests that conditions outside of buffers are not so poor that these taxa are not present in these areas. The lack of a response by the EPA IBI was surprising. However, this index was developed as part of the national EPA EMAP survey of water quality (Stoddard et al. 2005) and was developed over a wide geographic range (the xeric western ecoregion) and designed to make comparisons over a large spatial extent (i.e., compare watersheds or basins). Therefore, it is possible that it is too coarse of a tool to use for comparing among sites within a single basin.
- Does there appear to be a cumulative effect, whereby longer buffers have are more effective, per unit length, than shorter buffers? No. No significant relationships existed between buffer length and any of the metrics examined. This effect was also surprising. Buffer length has been found to be positively related to stream reach quality as measured by macroinvertebrate metrics (Parkyn et al. 2003; Wooster and DeBano 2006). It is not clear at this time why no relationships were found.
- Are older buffers associated with increased stream reach quality? No. There was no relationship between age of a buffer and the three metrics of stream reach quality. The range in buffer ages, one year to five years, was not great and it is possible that differences would have been observed if it would have been possible to include buffers greater than five years old.
- Future plans. The environmental variables are collated and entered into a database and additional analyses examining the relationship of these variables to macroinvertebrate community structure will be conducted for the manuscript to be submitted to a peer-reviewed scientific journal in the next six months.

Vegetation sampling

- The primary purpose of the vegetation sampling was to describe the plant communities in CREP buffers. This portion of the proposal was inserted to respond to producer's observations that CREP buffers become invaded by noxious weeds, many of whom are required to be eliminated by Oregon law.
- Noxious weeds were identified in CREP buffers (table 1). However, except for *Rubus armenicacus* (Himalayan blackberry) they were not the dominant species in the transect plots.
- Regardless of their current dominance, noxious weeds are an important consideration in planting buffers. Their seeds may disperse downstream (Barton et al. 2004, Thomas et al. 2006) to invade new areas, which can cause further damage. Therefore, it is important that CREP buffers be installed with as little disturbance as possible because many invasive weeds are found in disturbed areas (Hobbs and Huennekke 1992). Also, follow-up treatments to remove invasive weeds will help prevent downstream dispersal.
- No significant differences were found in plant community composition in the extant plant community on transects and in the soil samples. Riparian communities experience high levels of disturbance which encourages a ruderal plant community to develop. Helfield et al. (2007) found a similar species composition at their restored and unrestored sties. However, in their study, dominance changed between sites, unlike our study. They

conclude that high levels of disturbance encourage similar species to grow at all sites, but small differences in the frequency of disturbance can change competition interactions cause dominance changes. It is possible that the disturbance frequencies at the three creeks were similar and therefore community composition and species richness are similar among sites.

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Table 1: List of herbaceous species, their functional type (graminoid/forb), and origin (native/exotic) found in soil samples from Wasco County CREP buffers, soil samples and seed traps. Species in bold are listed as noxious weeds (classes A & B) in the state of Oregon. Species with the origin listed as N &E (Native & Exotic) indicates that there is some disagreement regarding the origin of the species.

Species name	**Graminoid/Forb**	**Native/Exotic**	**Field transect**	**Soil sample**	**Seed trap**
Achillea millefolium	Forb	Native	X		
Agropyron spp	Graminoid				
Agrostis gigantean	Graminoid	Exotic	X		
Agrostis stolonifera	Graminoid	Exotic		X	
Agrostis spp	Graminoid		X	X	X
Agastache urticifolia	Forb	Native	X	X	
Alopercurus myosuroides	Graminoid	Exotic		X	
Alopecurus pratensis	Graminoid	Exotic	X		
Amaranthus albus	Forb	Exotic		X	
Amaranthus retroflexus	Forb	Native		X	
Amaranthus spp	Forb			X	
Amsinckia menziesii	Forb	Native	X	X	
Anthemis cotula	Forb	Exotic		X	
Anthriscus caucalis	Forb	Exotic		X	
Anthriscus scandacina	Forb	Exotic	X		
Arrhenatherum elatius	Graminoid	Exotic	X		
Artemisia douglasiana	Forb	Native	X		
Artemisia ludoviciana	Forb	Native	X		
Aster spp	Forb			X	
Avena fatua	Graminoid	Exotic		X	
Barbarea orthoceras	Forb	Native	X		
Bidens frondosa	Forb	Native		X	
Bidens vulgate	Forb	Native		X	
Bromus spp	Graminoid			X	X
Bromus diandrus	Graminoid	Exotic	X		
Bromus hordeaceus	Graminoid	Exotic	X		
Bromus secalinus	Graminoid	Exotic	X	X	
Bromus sterilis	Graminoid	Exotic	X		
Bromus tectorum	Graminoid	Exotic	X	X	
Bromus vulgaris	Graminoid	Native	X	X	X
Cacalia decomposita	Forb	Native	X		
Calandrinia ambigua	Forb	Native	X		
Capsella bursa-pastoris	Forb	Exotic		X	
Carex aquatilis	Graminoid	Native	X		

Carex lenticularis	Graminoid	Native	X		
Carex spp	Graminoid			X	X
Centaurea cyanus	Forb	Exotic	X		
Centaurea diffusa	**Forb**	**Exotic**	**X**		
Centaurea stoebe macranthos	**Forb**	**Exotic**		X	
Centaurium beyrichii	Forb	Native		X	
Cerastium dubium	Forb	Exotic	X		
Cerastium fontanum vulgare	Forb	Exotic		X	
Cerastium glomeratum	Forb	Exotic	X		
Cerastium nutans	Forb	Native	X		
Cerastium spp	Forb			X	
Chamaesyce maculata	Forb	Native		X	
Cheilanthes villosa	Forb	Native	X		
Chenopodium album	Forb	Native&Exotic	X	X	
Chorispora tenella	Forb	Exotic	X		
Cirsium arvense	**Forb**	**Exotic**	**X**	**X**	
Cirsium vulgare	**Forb**	**Exotic**	**X**		
Clarkia gracilis	Forb	Native	X		
Clarkia lassenensis	Forb	Native		X	
Clarkia spp	Forb		X		
Claytonia spp	Forb			X	
Claytonia perfoliata	Forb	Native	X		
Collinsia parviflora	Forb	Native	X		
Conium maculatum	**Forb**	**Exotic**	**X**		
Convulvulus arvensis	**Forb/Vine**	**Exotic**	**X**	X	X
Conyza bonariensis	Forb	Exotic		X	
Conyza canadensis glabrata	Forb	Native		X	
Crataegus monogyna	Tree	Exotic		X	
Cryptantha spp	Forb		X		
Cynoglossum officinale	**Forb**	**Exotic**	**X**		
Cyperus cephalanthus	Graminoid	Native	X		
Dactylis glomerata	Graminoid	Exotic	X		X
Danthonia californica	Graminoid	Native		X	
Daucus carota	Forb	Exotic	X	X	
Deschampsia elongate	Graminoid	Native		X	
Descurainia pinnata	Forb	Native		X	
Descurainia sophia	Forb	Exotic	X		
Dicentra cucullaria	Forb	Native	X		
Digitaria sanguinalis	Graminoid	Native		X	

Draba verna	Forb	Exotic	X		
Echinochloa crus-galli	Graminoid	Exotic		X	
Echinochloa spp	Graminoid			X	
Eleocharis spp	Graminoid		X		
Eleusine indica	Graminoid	Exotic		X	
Elymus caninus	Graminoid	Exotic	X		
Elymus glaucus	Graminoid	Native	X		
Elymus repens	Graminoid	Exotic	X	X	X
Elymus spp	Graminoid		X		
Epilobium brachycarpum	Forb	Native	X	X	
Epilobium glaberrimum	Forb	Native	X		
Epilobium watsonii	Forb	Native		X	
Epilobium spp	Forb			X	
Equisetum arvense	Graminoid	Native	X		
Equisetum palustre	Graminoid	Native	X		
Equisetum pratense	Graminoid	Native	X		
Equisetum spp	Graminoid		X		
Eragrostis cilianensis	Graminoid	Exotic	X		
Eragrostis spp	Graminoid			X	X
Eriogonum compositum	Forb	Native	X		
Festuca arizonica	Graminoid	Native		X	
Festuca idahoensis	Graminoid	Native	X		
Festuca occidentalis	Graminoid	Native	X		
Festuca ovina	Graminoid	Exotic	X		
Festuca pratensis	Graminoid	Exotic	X		
Festuca rubra	Graminoid	Native&Exotic	X		
Festuca spp	Graminoid				X
Fraxinus spp	Tree			X	
Galium aparine	Forb	Native	X	X	
Gaura mollis	Forb	Native		X	
Glechoma hederacea	Forb	Exotic	X	X	
Glyceria striata	Graminoid	Native		X	
Glyceria spp	Graminoid		X		
Gnaphalium palustre	Forb	Native		X	
Hackelia spp	Forb		X		
Helianthus xlaetiflorus	Forb	Native	X		
Heracleum maximum	Forb	Native	X		
Holcus lanatus	Graminoid	Exotic	X	X	
Holosteum umbellatum	Forb	Exotic	X		
Hordeum depressum	Graminoid	Native	X		

Hordeum murinum	Graminoid	Exotic	X		
Hypericum perforatum	**Forb**	**Exotic**	**X**	**X**	
Juncus bufonius	Graminoid	Native		X	
Juncus spp	Graminoid		X		
Lactuca seriola	Forb	Exotic		X	
Lactuca spp	Forb		X		
Lamium amplexicaule	Forb	Exotic	X		
Lappula occidentalis	Forb	Native		X	
Lemna spp				X	
Lepidium spp	Forb			X	
Leymus cinereus	Graminoid	Native	X		
Leymus triticoides	Graminoid	Native	X		
Ligusticum spp	Forb		X		
Lithophragma parviflorum	Forb	Native	X		
Lomatium dissectum	Forb	Native	X		
Lomatium nudicaule	Forb	Native	X		
Madia spp	Forb		X		
Malva neglecta	Forb	Exotic		X	
Marrubium vulgare	Forb	Exotic		X	
Medicago lupulina	Forb	Exotic	X	X	
Medicago sativa	Forb	Exotic	X	X	
Mentha aquatica	Forb	Exotic	X		
Mentha arvensis	Forb	Native	X		
Mentha spicata	Forb	Exotic	X		
Microsteris gracilis	Forb	Native	X		
Mimulus guttatus	Forb	Native	X	X	
Mitella spp	Forb		X		
Muhlenbergia spp	Graminoid				X
Myosurus minimus	Forb	Native	X	X	
Nasturtium officinale	Forb	Exotic	X	X	
Nemophila pedunculata	Forb	Native	X		
Nemophila spp	Forb		X		
Nepeta cataria	Forb	Exotic	X	X	
Oenothera caespitosa	Forb	Native		X	
Onopordum acanthium	**Forb**	**Exotic**		**X**	
Packera indecora	Forb	Native	X		
Panicum milleaceum	Graminoid	Exotic	X	X	
Panicum spp	Graminoid			X	
Phacelia argentea	Forb	Native	X		
Phacelia lemmonii	Forb	Native		X	

Phalaris arundinacea	Graminoid	Native		X	
Plagiobothrys spp	Forb		X		
Plantago lanceolata	Forb	Exotic	X	X	
Plantago major	Forb	Exotic	X	X	
Poa arachnifera	Graminoid	Native		X	
Poa bulbosa	Graminoid	Exotic	X	X	
Poa compressa	Graminoid	Exotic	X	X	X
Poa palundigena	Graminoid	Native		X	
Poa palustris	Graminoid	Native	X		
Poa pratensis	Graminoid	Exotic	X	X	
Poa secunda	Graminoid	Native	X		
Poa trivialis	Graminoid	Exotic	X	X	
Poa spp	Graminoid		X	X	
Polygonum achoreum	Forb	Native		X	
Polygonum aviculare	Forb	Exotic		X	
Polygonum bistortoides	Forb	Native		X	
Polygonum lapathifolium	Forb	Exotic		X	
Polygonum persicaria	Forb	Exotic		X	
Polygonum spp.	Forb		X	X	X
Polypogon monspeliensis	Graminoid	Exotic	X	X	
Portulaca oleracea	Forb	Exotic		X	
Potentilla norvegica	Forb	Native		X	
Psathyrostahcys juncea	Graminoid	Exotic	X		
Pseudoregnaria spicata	Graminoid	Native	X		
Puccinellia spp	Graminoid		X	X	
Ribes aureum	Shrub	Native		X	
Rorippa sylvestris	**Forb**	**Exotic**	**X**		
Rumex acetosa	Forb	Native		X	
Rumex crispus	Forb	Exotic	X	X	
Schedonorus phoenix	Graminoid	Exotic	X		
Scirpus spp	Graminoid		X		
Secale cereale	Graminoid	Exotic	X	X	
Senecio vulgaris	Forb	Exotic		X	
Setaria viridis	Graminoid	Exotic		X	
Setaria spp	Graminoid			X	
Sisymbrium altissimum	Forb	Exotic	X	X	
Solanum dulcamara	Vine	Exotic		X	
Solidago canadensis	Forb	Native	X	X	
Solidago spp	Forb			X	

Sonchus arvensis	Forb	Exotic		X
Sonchus asper	Forb	Exotic		X
Sonchus oleraceus	Forb	Exotic		X
Sonchus spp	Forb		X	
Sorghum halepense	**Graminoid**	**Exotic**	**X**	
Spergula arvensis	Forb	Exotic		X
Stellaria media	Forb	Exotic		X
Stipa spp	Graminoid			X
Symphyotrichum eatonii	Forb	Native	X	
Taraxacum officinale	Forb	Exotic		X
Taraxacum spp	Forb		X	
Thlaspi arvense	Forb	Exotic	X	
Tonella floribunda	Forb	Native	X	
Tragopogon dubius	Forb	Exotic	X	
Tragopgon lamotteii	Forb	Exotic	X	
Trifolium repens	Forb	Exotic	X	
Tripleurospermum maritimum	Forb	Native&Exotic	X	
Trisetum wolfii	Graminoid	Native	X	
Triticum aestivum	Graminoid	Exotic	X	
Urochloa ciliatissima	Graminoid	Native	X	
Urtica dioica	Forb	Native		X
Verbascum blattaria	Forb	Exotic	X	X
Verbascum thapsus	Forb	Exotic	X	X
Verbena bracteata	Forb	Native		X
Veronica americana	Forb	Native	X	X
Veronica arvensis	Forb	Exotic	X	
Veronica spp	Forb			X
Vicia villosa	Forb	Exotic	X	
Viola spp	Forb		X	
Vulpia myuros	Graminoid	Exotic	X	X

Table 2: List of woody species identified along transects at buffered and unbuffered stream sites.

Acer saccharum	Tree
Alnus incana tenuifolia	Shrub
Alnus rhombifolia	Tree
Alnus rubra	Tree
Clematis ligusticifolia	Vine
Cornus sericea occidentalis	Shrub
Crataegus douglasii	Shrub
Holodiscus discolor	Shrub
Lonicera utahensis	Shrub
Mahonia aquifolium	Shrub
Malus spp	
Philadelphus lewisii	Shrub
Physocarpus capitatus	Shrub
Pinus ponderosa	Tree
Populus balsamifera	Tree
Prunus virginiana	Shrub
Quercus garryana	Tree
Ribes divercatum	Shrub
Ribes spp	
Robinia pseudoacacia	Tree
Rosa gymnocarpa	Shrub
Rosa nutkana	Shrub
Rubus armeniacus	Shrub
Rubus ideaus	Shrub
Rubus ursinus	Vine
Salix alba x fragilis	Tree
Salix exigua	Shrub
Salix lasiolepis	Tree
Salix monochroma	Shrub
Salix prolixa	Shrub
Salix sitchensis	Shrub
Salix spp	
Sambucus nigra caerulea	Shrub
Solanum dulcamarum	Shrub
Spirea douglasii	Shrub
Symphoricarpus albus	Shrub
Toxicodendron radicans	Shrub

Table 3: T-test results of mean number of species at buffered and unbuffered sites at different distances downstream. The 2000 m distance was not tested because no unbuffered sites were 2000 m long, therefore no samples were taken.

Distance	Mean Buffer (95% CI)	Mean Unbuffered (95% CI)	P-value
0 m (upstream end)	15.0 (6.1 – 21.9)	7.3 (0.6 – 10.2)	0.18
500 m	13.6 (5.0 – 19.2)	12.7 (2.3 – 23.9)	0.85
1000 m	13.5 (2.2 – 16.3)	13.7 (1.8 – 22.4)	0.94
1500 m	13.3 (4.1 – 20.2)	7 (0 – 7)	0.24

Table 4: Total N and total P concentrations in upstream and downstream sites on buffered and unbuffered streams.

Location	Creek	Buffered	Up N	Down N	Up P	Down P
KWT	5	Buffered	0.68	nd	0.09	0.21
UNDE	8	Buffered	0.12	0.11	0.02	0.02
FORDM	8	Buffered	0.3	0.3	0.03	0.03
BWS	8	Buffered	0.12	0.13	0.03	0.02
RWS	8	Unbuffered	0.18	0.16	0.02	0.02
CH	15	Buffered	0.18	0.21	nd	Nd
UNDES	15	Buffered	0.14	0.04	nd	Nd
BOLT	15	Buffered	0.44	0.48	nd	Nd
JUNDE	15	Buffered	0.3	0.28	nd	Nd
LIME	15	Unbuffered	0.26	0.41	nd	Nd

No data: dry creekbed; WEIM (5 mile, unbuffered) and MF (5 mile, buffered)