Plant Diversity Along Bicycle Paths and Path-less Nature Areas in Columbia, Missouri

An Inquiry Action Project

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Abstract

The City of Columbia, Missouri, has faced controversy over the expansion of a bicycle path system through its urban nature areas. Proponents argue that increasing bicycle infrastructure will cut down on car use and create a net environmental gain; opponents argue that building concrete bicycle paths through precious remaining natural areas will damage habitats. I investigated whether a difference in plant diversity and richness could be found in nature areas with bicycle paths versus nature areas without bicycle paths, and found no significant differences. This may be attributable to the fact that Columbia's nature areas are already compromised by fragmentation and large populations of invasive species like honeysuckle. However, I discovered a trend towards wider variability of diversity within pathless areas than within bike path areas. This indicates that there may be hotspots of plant diversity in pathless areas that should be protected if path development occurs in those sites in the future. I recommend further studies of wildlife, erosion and water quality along bike paths to gain a clear picture of how cities could expand alternative transportation networks with least damage to their remaining urban habitat fragments.

Introduction

The expansion of Columbia, Missouri's bicycle trails through urban natural areas has sparked controversy in the last decade. The city government and alternative transportation advocacy group PedNet have been proponents of new trails, while citizen groups have formed to protect particular pieces of land proposed for development. The local Audubon Society estimated that 15 new members joined in 2011 in order to oppose trail construction through the Audubon's part of Bonnie View Nature Sanctuary (Denney, 2011). In the Bluffdale neighborhood, some residents formed a non-profit named "It's Our Wild Nature" to oppose building bike paths through a large natural area along Hinkson Creek. They appeared on community radio stations giving interviews and playing a jingle of singing children (personal communication). At city council meetings, these opponents cited concerns about destructive environmental impact from building 10-foot-wide concrete paths through treasured urban fragments, where residents often encounter wildlife and plant life.

The trail system is explicitly linked to a city policy goal of "transportation shift": an increase in the number of people choosing bicycles, buses, and walking over private car transportation. The initiative is called "GetAbout Columbia," and has largely been pushed forward by a four-year, $22.6-million grant from the Federal Highway Administration to "non-motorized transportation pilot cities." (Columbia Public Works Department, n.d.). Advocates of the new trails have argued that an investment in alternative infrastructure will ultimately benefit local plants and wildlife by decreasing use of cars and roads. Opponents have feared the bicycle trails cause habitat destruction. I set out to see whether I could find a difference in ecological quality, specifically in vegetation, between nature areas with bicycle paths and path-less urban nature areas.

The impact of bicycle paths like those used in Columbia has gone mostly unresearched. Some research does exist on the impact of dirt bike trails, but these studies address concerns of sediment dynamics like erosion, skidding and trail widening on dirt trails (Pickering et al., 2010; Wilson and Seney, 1994; Bjorkman, 1998; Davies and Newsome, 2009; White et al, 2006). These are not relevant to Columbia's bicycle trails, which are generally 8- to 10-foot-wide paths made of concrete or, for older trails, crushed limestone aggregate. These wide paths, paved and frequented by casual cyclists rather than mountain bikers, would not logically be impacted by the ruts, sedimentation or unauthorized new trail creation that are discussed in the mountain bike trail literature. Changes to vegetation or wildlife surrounding mountain bike trails is less studied, but a handful of studies on vegetation have shown that mountain bike trails impacted vegetation no more than hiking trails (Pickering et al., 2010; Thurston and Reader, 2001), and hiking already occurs in the city's nature areas. Thurston and Reader (2001) found that vegetation recovery occurred rapidly after mountain bike trails were closed off, but such recovery would likely not occur on the paved city paths. Another concern is that bicycle tires have the potential to spread weed seeds, and spores of harmful plant species have been found on bicycle tires; however, no studies have yet documented an increase in weeds along mountain bike trails (Pickering et al., 2010). I was unable to locate any studies on the impact on paved bike paths or bike paths for commuters and casual cyclists.

If we compare Columbia's city paths to mountain bike trails, we may expect to see minimal impact of the bike paths on vegetation, with a possibility of increased weedy and invasive plants. Yet the heavier-duty construction and frequent traffic on the city bike paths might ecologically resemble roadways more than dirt mountain bike paths.

The impacts of roads on ecological systems, as transportation shift advocates remind us, is very well-documented. In 1998, Richard T.T. Forman dubbed this area of study "road ecology" (Forman, 1998). Roads fragment landscapes, introduce pollutants, alter animal behavior, and kill wildlife (Coffin, 2006; Forman et al., 2003). Despite the smaller size and slower, less dense traffic of city bicycle paths compared to roads, they may still have the ability to deter wildlife passage and fragment the landscape as roads do (Coffin, 2006; Forman et al., 2003). While bicycles are unlikely to create roadkill, certain birds, bobcats and coyotes have been found to avoid roads because of their noise and the simple presence of human activity (Coffin, 2006). Any given Saturday morning sees a fairly constant stream of cyclists, runners, and strollers along Columbia's bike trails. As for vegetation, canopy gaps, emissions, and changes in soil composition encourage different kinds of plants to grow along roads than in surrounding natural habitat. These roadside "edge effects" favor plants that compete well in greater sunlight and increased amounts of nitrogen/phosphorus or the minerals found in road material. Edge effects also encourage more understory biomass (Avon et al., 2010; Honu and Gibson, 2006; Rotholz and Mandelik, 2013). While bicycles don't emit nitrogen and phosphorus, the city bike trails could create canopy gaps and contribute lime and other trail materials to the soil, as roads do. The trails may also offer a foothold to invasive species: exotic species often spread through road corridors, due to road-caused disturbance, edge habitat and seeds that hitch a ride on vehicles (Gelbard and Belnap, 2003).

Using the variety of impacts caused by roads as a guide, there are many different measurements that one might use to assess the impact of bicycle paths. Since roads can cause sedimentation and increased runoff, resulting in decreased water quality, concrete bike paths might also impact water quality, especially during construction. However, I ruled out a water quality study due to the difficulty in controlling variables in an already compromised urban creek, and the short timeline and season of this study. Similarly, although roads have a well-documented impact on wildlife, as described above, lack of resources ruled out a wildlife study. This left plant communities as a realistic study choice.

This inquiry compared the diversity of plant communities along bicycle paths to path-less natural areas in Columbia, Missouri, as measured by the Shannon index, species richness (number of species per plot), and number of individuals per plot. The above literature on both mountain bike trails and roads indicates that the city bike trails could be vectors for the spread of invasive species, due to canopy gaps and disturbance. This indicated that I might find dominance of a few aggressive or sunlight-thriving species, reflected by a low Shannon index and low richness. On the other hand, the bicycle paths would not be expected to contribute any eutrophying emissions, as in the roads in Honu and Gibson's study (2006), and they run through urban natural areas that are already characterized by high levels of disturbance, fragmentation and invasive species. Furthermore, as nature areas recovered from bike path construction, canopy gaps may have closed and encouraged vegetation recovery near paths, as Avon et al. (2010) found along forest roads. As such, it seemed possible that path-less areas may not be significantly better off than areas along bike paths, and might also have low Shannon Indices and plant richness due to the domination of invasives. Additionally, the Avon et al (2010) road study offers evidence that the impact of bike paths could be more pronounced in the five meters immediately adjacent to the paths, and less likely to be detected in plots up to 20 meters from the paths.

Methods

Columbia's bicycle paths run through forest fragments, located in official nature areas that are woven into urban neighborhoods. Study plots were placed along sections of path that met certain criteria: paths had to be 8' to 10 wide' concrete or limestone aggregate, within forested landscape, and placed at minimum 10m away from roads, since roads would likely have stronger effect than paths on the ecosystem. Avon et al (2010) found a road effect on vegetation extended 5m into the forest. In practice, all plots were at minimum 20m from the roads. Plot transect were placed at two sites, the Grindstone Nature Area (concrete trail, less than 1 year old) and the MU Recreation/Hinkson Creek Trail (limestone aggregate, 14 years old).

Control plots were located in the two largest forested areas in the city that do not yet have trails: the Walter-Moss Wildlife Area and the Bluffdale site (a private site by the Bluffdale neighborhood along the Hinkson Creek valley). The Bluffdale site is in planning stages for trail development. For the purposes of making decisions about city planning, it is not appropriate to use pristine natural areas as the yardstick against which bicycle paths' impacts are measured. Rather, I chose as controls the urbanized, albeit compromised, natural areas that are the realistic alternative to installing paths. The Waters-Moss and Bluffdale sites are large enough to have buffers from the influence of roads, but are still within similarly urban conditions as the nature areas with paths. As with the treatment sites, plots had to be at least 10m from the road, and in practice were all well over 20m.

At each site, two transects were placed perpendicular to the paths (or set at an arbitrary forested location in the control sites). Each transect contained three circular plots that covered the intervals of 0-5m, 5-10m, and 15-20m from the paths. Each plot's diameter of five meters resulted in a $20m^2$ plot. This follows Roth's (1984) recommendation for circular plots for heterogeneous landscapes, and areas of 10- to $20\text{-}m^2$ for species up to the size of shrubs and saplings. In total, there were 4 treatment and 4 control transects, or 12 treatment plots and 12 control plots.

Within each plot, the number of individuals of herbs, shrubs, and saplings under six feet in height was counted and used to calculate a Shannon index as a measurement of evenness and species per plot as an indicator of species density. Populations of larger trees were unlikely to have been impacted by bicycle paths, given that some of the paths have only been around for 1 to 5 years. Plants smaller than 4-inches were excluded from the counts due to high probability of overlooking many of them, and grasses and fescues were also excluded. Plants that share a root system, such as pawpaws, were counted as individuals based on where stems emerged separately from the ground; plants that grow in clumps, with multiple stems emerging from a single point in the ground, counted each clump as an individual. When a plant could not be positively identified by common name, I assigned it a label of my own invention, took a picture, and made note of identifying characteristics. The study was conducted in mid- to late October.

Some of the recently constructed bicycle paths have a buffer of planted or maintained grass, precisely in the 0-5m zone where greatest impact on plant diversity may be expected. I collected data on these zones as well as on plots more distant from the paths, and in the data analysis compared data both with and without these sparse zones included.

In the analysis, Shannon indices, richness (number of species per plot), and number of individuals were averaged for all pathed plots and all pathless plots. The tests were repeated with the treatment sites' plot 1 (plots '1' contained sparse grass buffers lining bike paths) removed from the data. A t-test was used to test for significant differences between averages of pathed plots and pathless plots.

Then, to test for difference in vegetation at varying distances from the bicycle paths, average Shannon index, richness, and number of individuals was calculated for each bicycle path plot distance: 0-5m, 5-10, and 15-20m. A one-way ANOVA test checked for significant differences in the averages of each plot distance.

Results

No significant differences were found between bicycle path and pathless sites along any measurements. The average Shannon index (n=12, 12; p=.31), average number of individual plants per plot (n=12, 12; p=.46) and average number of species per plot (n=12, 12,; p=.23) showed no significant differences between control and treatment plots (figure 1). The tests were repeated with the treatment sites' 0-5m plots, those that contained grass path buffers, removed from the data (figure 2). Although the standard deviation decreased and the average of all measurements did increase when only 5-10m and 15-20m plots were included, no significant differences were found between these sites and the control sites either.

No significant differences were found between plant communities at the three different distances from the bike paths, not in average Shannon index (n=4; p=), number of species (n=4; p=) or number of individuals (n=4; p=)(figure 3).

The plots were characterised by wide variability. Wide variability was present among bike path plots in particular, with the average Shannon index at 1.54 and its standard devision at 0.78.

		Average richness per plot	**Average number of individuals per plot**	**Average Shannon Index per plot**
Control Sites		**12.17** **st dev: 3.486**	**84.25** **st dev: 42.93**	**1.80** **st dev: .30**
	Waters-Moss	12.50 st dev: 1.38	98.33 st dev: 45.90	1.86 st dev: 0.20
	Bluffdale	11.83 st dev: 4.96	70.17 st dev: 38.37	1.73 st dev: 0.38

Bike Path Sites		**9.75** **st dev: 5.83**	**69.58** **st dev: 51.70**	**1.54** **st dev: 0.78**
	Grindstone	10.5 st dev: 7.29	71.17 st dev: 63.23	1.55 st dev: 0.91
	MU Rec/Hinkson Creek	9 st dev: 4.52	68 st dev: 43.33	1.53 st dev: 0.72
p-value (control site average vs bike path site average)		**.23**	**.46**	**0.31**

Figure 1: Average results for control sites compared to bike path sites, plus detailed results by site. P-values calculated with t-test.

		Average richness per plot	**Average number of individuals per plot**	**Average Shannon Index per plot**
Bike path sites with grass buffer plots removed (5-10m and 15-20m plots only)		**11.375** **st dev: 4.87**	**90.25** **st dev: 47.95**	**1.67** **st dev: 0.68**
Control Sites		**12.17** **st dev: 3.486**	**84.25** **st dev: 42.93**	**1.80** **st dev: .30**
p-value (control sites vs bike path sites with grass buffers removed)		**0.70**	**0.78**	**0.64**

Figure 2: Average results for control sites compared to bike path sites with grass buffer zones removed; p-values calculated with t-test.

	Average species richness	Average number of individuals per plot	Average Shannon index
0-5m from bike path	**6.5** var 48.33	**23.25** var: 1022.25	**1.28** var: 1.03
5-10m from bike path	**13.5** var: 15	**78.5** var: 1311	**2.10** var: 0.18
15-20m from bike path	**9.25** var: 28.25	**102** var: 3684.667	**1.25** var: .43
p-value	**0.25**	**0.11**	**0.24**

Figure 3: One-way ANOVA test for differences between plots set at varying distances from bike paths.

Discussion

This inquiry found no overall difference in plant diversity or richness along bike paths compared to urban nature areas without bike paths. Given the high variability of conditions within both bike path and path-free sites, as well as high p-values across the board, there is little evidence of biologically or statistically significant differences. A larger sample size could potentially allow for stronger conclusions; however, with the standard deviations seen in these samples, the study would have to include six to 12 times as many plots to reject the null hypothesis.

The wide variation of conditions amongst plots, both within control and bike path sites, implies that other variables are stronger influences on plant communities than bike paths are in Columbia's nature areas. Without a significant difference in the Shannon index or richness, there is not evidence to support the idea that bike paths enabled aggressive or exotic species to dominate vegetation or suppress competition. However, honeysuckle, an invasive species, was a dominant species in many sites, pathed and path-free alike. Even if bicycle paths are creating favorable conditions for the spread of exotics, as Pickering et al. (2010) and Gelbard and Belnap's (2003) research suggests, the near-universal presence of honeysuckle at all sites is a clue that invasive species are already well-established in Columbia's nature areas. Despite Avon et al. (2010)'s research that shows the effect of roads in forests only extends 5m from the road, the dense network of roads in an urban environment may have a compounding effect, and the bike-pathed nature areas of Columbia may already be experiencing an impact from fragmentation and roads that overshadows any impact from bike paths.

The fragmentary nature of all the sites, which are narrow at some locations and expansive at others, seems likely to be a large contributor to condition variability. For example, at the control Bluffdale site, a transect on the east side of the creek averaged a Shannon index of 2.03, one of the higher indicators of diversity. But a transect on the west side of the creek, which is part of a city park but is not quite as deep an area of land as the east side, had a significantly different Shannon index average of just 1.44 (N=3,3; p=.04). Similarly, within the other control site, the Water-Moss Wildlife Area, one transect averaged 2.01 and the other transect averaged 1.71 (N=3,3; p=.10). While this difference was not statistically significant, it may indicate a trend of microhabitat variability.

This difference between transects within the control sites suggests that conditions change very rapidly within Columbia's undeveloped areas. By contrast, bike path transects within each site resembled each other more closely: the two transects along the Grindstone Trail had very similar average Shannon indices (1.53 and 1.58; n= 3, 3; p=0.96), and the two transects along the MU Rec/Hinkson Creek Trail also showed no meaningful difference (1.33 and 1.73; n=3, 3; p=0.56) . There is also evidence that the two bike path sites overall, the Grindstone and MU Rec/Hinkson Creek Trail, are quite similar, with average Shannon indices of 1.56 and 1.53 respectively (n=6, 6; p=.96). The high p-value implies that there is likely no meaningful difference between the two bike path sites' plant evenness, and that conditions from bike path to bike path are similar -- even though the MU Rec/Hinkson Creek Trail was built 14 years ago, and the Grindstone Trail was built just this year. This casts doubt on whether species diversity along bike paths recover easily from construction, as Avon et al. (2010) concluded happens when canopy gaps regrow over forest roads; however, without knowing the condition of the sites before the paths were built, that remains speculation. Furthermore, since there was no significant difference in any measurement between plots next to bike paths and plots farther from bike paths, that implies that canopy gaps over the path-adjacent plots were not necessarily significant to plant community diversity, richness, or even the number of individuals, which I had expected might increase due to greater sunlight.

Because conditions changed significantly from transect to transect at pathless sites, but not bike path sites, this suggests that there may be small-scale, high priority, higher diversity areas within Columbia's undeveloped nature areas, even if the nature areas as wholes cannot be characterized as meaningfully more diverse than areas with bicycle trails. These areas could be identified during the bicycle trail planning process, so that plans could intentionally avoid these areas.

Furthermore, plant diversity is just one dimension that might be impacted by bicycle paths. Investigation into bike paths' possible impacts on wildlife and water quality would be worthwhile, and may yield more significant results.

Action and Reflection

The debate over bike paths in Columbia has created division amongst residents who should be natural allies: alternative transportation advocates and conservationists. From my perspective, there has been few engagements around compromise or examinations of ways to meet both groups' desires. On occasion, opponents have proposed alternative bike routes that avoid undeveloped natural areas, but these have been rejected by bike path advocates as insufficient routes that are uninviting to all but the most confident cyclists and do not improve trail connectivity well. Instead of this locked heads situation, I would like to see specific areas of potential environmental impact identified, and for bike path planners to design paths that avoid or minimize those specific environmental impacts.

I intend to share the results of my study with advocacy groups on both sides of the issue, as well as with the city parks and recreation department. Due to its limitations, my study is better seen as a pilot study than a definitive statement that trails are harmless. However, I hope it can be a spark that encourages greater fact-based action and planning around the bike path issue. More specific knowledge would allow an honest appraisal of the gains and losses caused by building paths, and perhaps the chance to mitigate them. With sufficient public interest, more and better studies could be conducted on bike paths in Columbia. Columbia's status as an FHA "non-motorized transportation pilot city" means that its experiences may be used to inform bike infrastructure programs in other U.S. cities. An honest understanding of the impact of our bike paths, on wildlife and water as well as plants, could aid other cities as they work towards transportation mode shifts.

Based on the trends seen in the transects in my inquiry, I would like to suggest to the city that planners visit the sites under debate to identify sensitive areas, and possibly design paths to avoid those areas. Undeveloped areas that already have a Shannon index close to 1.5, the average Shannon index along Columbia's bike paths, could have new paths added without significantly hurting plant diversity. Undeveloped areas that have an index over 2, by contrast, could be given deference. Concerned community members may be willing to help with such an analysis, as well as with helping on additional studies of trail impact. The mobilization of community members around the bike paths is, to me, a resource that could be put towards creating better bike paths and natural areas than a city department alone might create.

Appendix: Detailed Data

Site	Transect	Plot	Number of Species	Number of Individuals	Shannon-Weiner Index
Grindstone Trail	Transect 1	Plot 1	0	0	0
Grindstone Trail	Transect 1	Plot 2	18	53	2.6423
Grindstone Trail	Transect 1	Plot 3	12	156	1.9592
Grindstone Trail	Transect 2	Plot 1	3	3	1.0986
Grindstone Trail	Transect 2	Plot 2	15	100	1.9875

Grindstone Trail	Transect 2	Plot 3	15	115	1.6413
MU Rec/Hinkson Creek	Transect 1	Plot 1	7	45	1.6
MU Rec/Hinkson Creek	Transect 1	Plot 2	9	118	1.6188
MU Rec/Hinkson Creek	Transect 1	Plot 3	7	122	0.7577
MU Rec/Hinkson Creek	Transect 2	Plot 1	16	65	2.4246
MU Rec/Hinkson Creek	Transect 2	Plot 2	12	43	2.1418
MU Rec/Hinkson Creek	Transect 2	Plot 3	3	15	0.6277
Bike paths average			**9.75**	**69.58333333**	**1.541625**
St dev			5.832900417	51.70626537	0.784305632
Grindstone average			**10.5**	**71.16666667**	**1.554816667**
St dev			7.286974681	63.23105777	0.912844853
MU Rec/Hinkson Creek average			**9**	**68**	**1.528433333**
St dev			4.516635916	43.331282	0.720828925

Figure 4: Measurements of plant diversity by plot at bike path (treatment) sites

Site	Transect	Plot	Number of Species	Number of Individuals	Shannon-Weiner Index
Waters-Moss	Transect 1	Plot 1	13	149	7.45
Waters-Moss	Transect 1	Plot 2	11	130	6.5
Waters-Moss	Transect 1	Plot 3	11	140	7
Waters-Moss	Transect 2	Plot 1	14	51	2.55
Waters-Moss	Transect 2	Plot 2	12	65	3.25
Waters-Moss	Transect 2	Plot 3	14	55	2.75
Bluffdale site	Transect 1	Plot 1	14	114	5.7
Bluffdale site	Transect 1	Plot 2	20	120	6
Bluffdale site	Transect 1	Plot 3	13	62	3.1
Bluffdale site	Transect 2	Plot 1	7	32	1.6
Bluffdale site	Transect 2	Plot 2	10	59	2.95
Bluffdale site	Transect 2	Plot 3	7	34	1.7

Control Sites average			**12.16666667**	**84.25**	**4.2125**
st dev			3.485902344	42.9336168 4	2.146680842
Waters-Moss average			**12.5**	**98.3333333 3**	**4.916666667**
st dev			1.378404875	45.9027958 5	2.295139792
Bluffdale average			**11.83333333**	**70.1666666 7**	**3.508333333**
st dev			4.956477244	38.3688241 5	1.918441208

Figure 5: Measurements of plant diversity by plot at path-less (control) sites.

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