Biodiversity of riparian vegetation on City of Boulder Open Space: a comparative study of irrigation canals and natural streams

Final Report

Erick A Carlson, Colorado State University

Abstract:

The negative effects of water diversions on streams is well known, however the ancillary effects of moving water in man-made channels into uplands has received little attention. Man-made channels along the Colorado Front Range are numerous and could be supporting significant and high quality riparian habitat. I examined the physical and vegetation of irrigation canals and natural streams on City of Boulder Open Space and Mountain Parks land. Vegetation was diverse across the 45 sites, with 268 species identified. Vegetation communities at the coarse scale were different when grouping sites as either canal or stream. However, when we add dominant cover (e.g. heavy canopy or shrub) to further characterize the canal or stream, the vegetation was statistically similar for 3 of 4 comparisons. This work has implications for protecting riparian ecosystems, even those created by human activities. Irrigation canals on private land often have intensive vegetation maintenance that could be limiting the development of quality riparian habitats. This study along with a pair study in Larimer County can be used to inform public and private groups on the potential benefits of specific vegetation communities, and what types of maintenance activities would be appropriate to develop high quality riparian ecosystems along irrigation canals.

Introduction:

Channels created to transport water from natural streams to agricultural lands also support aquatic and riparian ecosystems, but relatively little is known about irrigation canal biodiversity (Patten 1998), or how they compare with natural stream and riparian ecosystems. Hydrological and sedimentological processes create the physical setting for biota and combined with the disturbance regime control the communities of plants and animals that colonize and persist (Shafroth et al 2002; Katz et al 2009). Irrigation canals are subject to natural processes but human activities also influence riparian and aquatic conditions and communities. Hydrologic processes used to characterize streams, such as overbank flooding and channel migration, are rarely relevant in canals. Natural variability in flows and spatial heterogeneity of landforms created by local erosion and aggradation are specifically designed to not occur in irrigation canals through engineering to minimize turbulent flow (Swamee 1995) and maximize conveyance and structural integrity. Maintenance activities further limit the development of microhabitats through removal of sediment and woody debris further homogenizing the channel and riparian ecosystems. Furthermore, irrigation canals are largely decoupled from the surrounding landscape reducing sediment and organic matter inputs. However, through the connectivity of surface waters between canals and streams, potential colonization of riparian plants and aquatic insects through drift and high flow dislodgement is high (Ernegger et al 1998).

Irrigation canals do not replace natural streams but are added to the landscape, increasing total channel length and potentially increasing riparian habitat. The prevalence of irrigation canals on the landscape can be easily overlooked as canals may visually resemble natural streamside habitats (Figure 1), yet lack some ecosystem functions (Cox and Franklin 1989; Chester and Robson 2013) such as nesting habitat for birds or food for wildlife. The City of Boulder Open Space and Mountain Parks (OSMP) contains hundreds of kilometers of irrigation canals that remain from 150 years of agriculture in the area. Many canals are still operated to support the irrigation of crop- and pasture land. In this study we examine the riparian vegetation and structure of irrigation canals and streams on OSMP properties with the goal of understanding the if diversity and structure of vegetation varies between canals and streams. I asked the questions: 1) Do irrigation canals support similar riparian plant species as natural streams? 2) Does the composition of functional groups change between canals and streams? 3) Is woody canopy correlated to the presence or abundance of native vegetation?

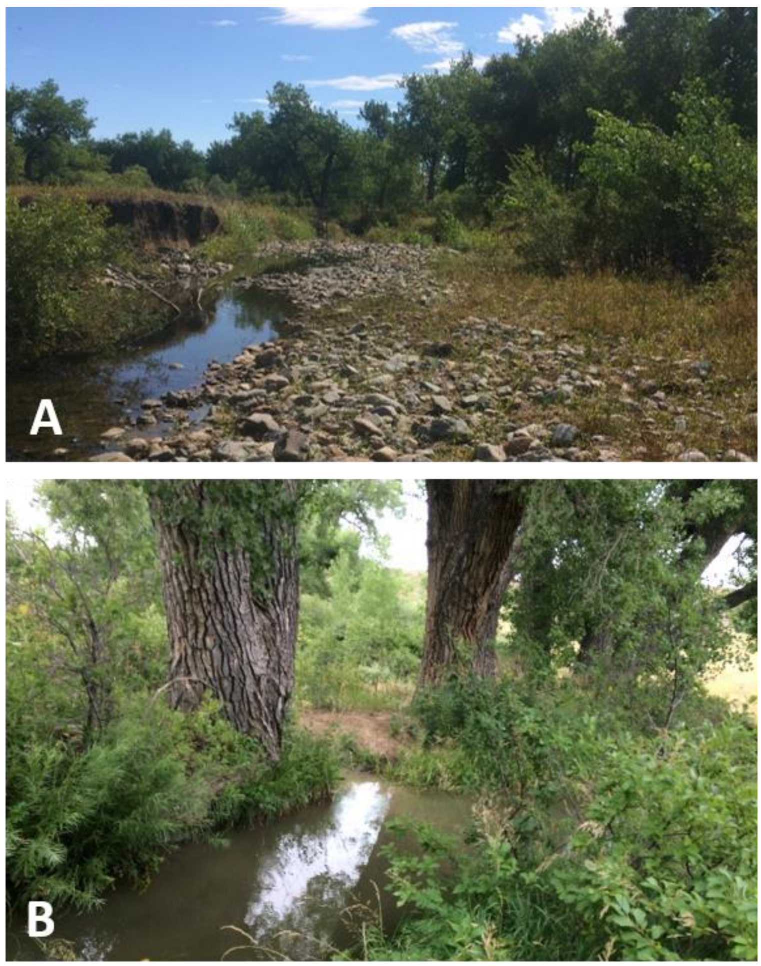

Figure 1: Typical stream site (A) on Coal Creek and canal site (B) on Farmers Ditch.

Study Area and Methods:

The study area in Boulder County, Colorado (Figure 2) averages 300 millimeters during the summer and 225 mm during winter (www.usclimatedata.com). A total of 34 OSMP property units containing over 25 miles of irrigation canals were visited. Vegetation along canals was stratified into four cover types: heavy canopy, light canopy, shrub, and herbaceous, using aerial and satellite imagery in ArcGIS v10.3. Forty-five sites were selected randomly across the canal and stream network on OSMP land, attempting to balance sampling efforts by cover type (Table 1).

At each site, two transects perpendicular to the channel were sampled by placing 4 plots on the bank and top/floodplain surface on both sides of the channel at both transects for a total of 32 1m^2 plots per site. Plant cover was visually estimated in the field and vertical structure was categorized for each species using height classes (<1 m, 1-2 m, 2-5 m, 5-10 m, >10 m). Species were identified using Colorado Flora: Eastern Slope 4th Ed. (Weber and Whitman 2012). Species cover were averaged by site for statistical analysis. Cover weighted Mean C-value (Rocchio 2007) and the wetland prevalence index (Wentworth 1988) were calculated. Species were placed into functional groups based on origin (native or introduced) and growth form (grass, forb, shrub, tree).

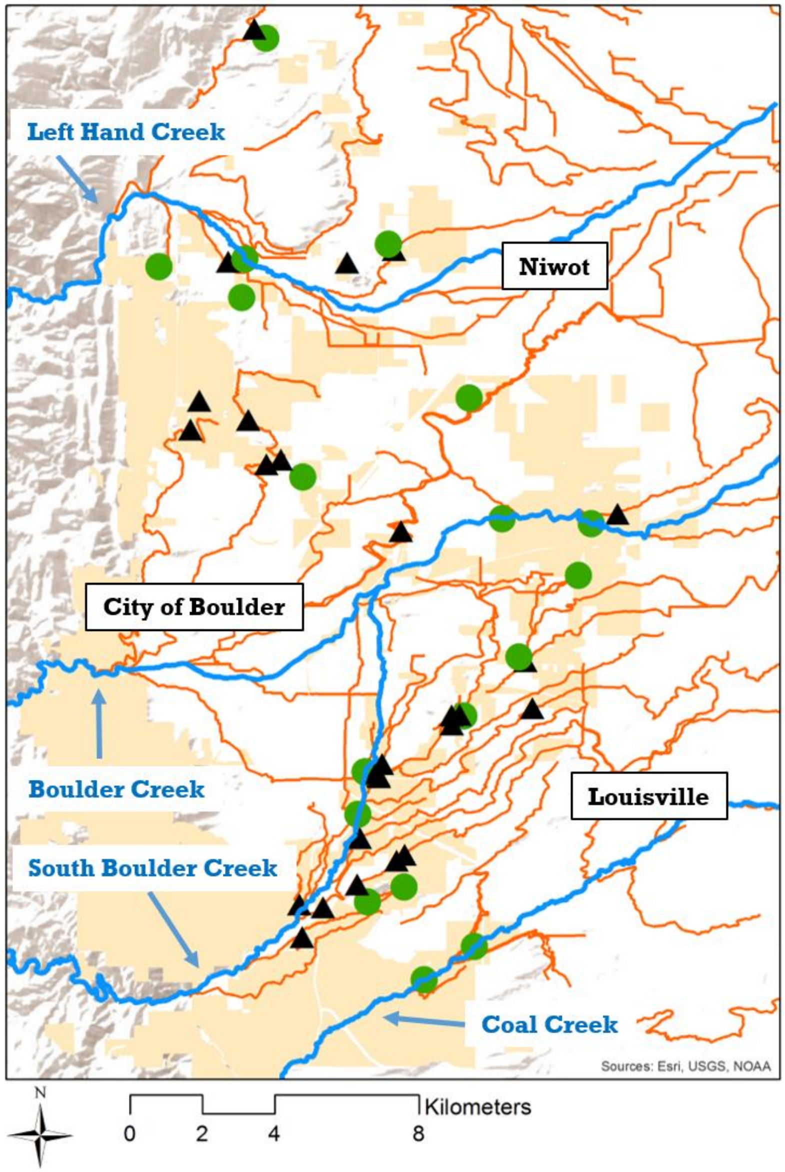

Figure 2: Study area map. Region with City of Boulder OSMP land in tan, large streams are blue lines, irrigation canals are red lines, green circles are sites on streams, black triangles are sites on canals.

Table 1: Number of sites in each channel and cover type.

Channel and Cover Type	***Sites***	***Channel and Cover Type***	***Sites***
Canal Herbaceous	9	Stream Herbaceous	5
Canal Shrub	7	Stream Shrub	5
Canal Light Canopy	6	Stream Light Canopy	4
Canal Heavy Canopy	5	Stream Heavy Canopy	4
CANAL TOTAL	27	STREAM TOTAL	18

Analytical Methods

Community analysis for plants was conducted using Primer v.7 software (Clarke et al 2014). For all statistical tests an alpha < 0.05 indicated a significant result. Diversity metrics were calculated using all species, then species present in fewer than 5 % of sites were identified as rare and removed (McCune and Grace 2002). This reduced the number of species to 128. Sites had an average of 90% of plant cover included in the analysis after rare species were removed. Vegetation cover data were square-root transformed and a Bray-Curtis similarity matrix was calculated. Permutational multivariate analysis of variance (PerMANOVA) was used to test the effects of channel type and canopy cover on vegetation composition. Permutational analysis of multivariate dispersions (PermDISP) was conducted to test for variance and the data support PerMANOVA results.

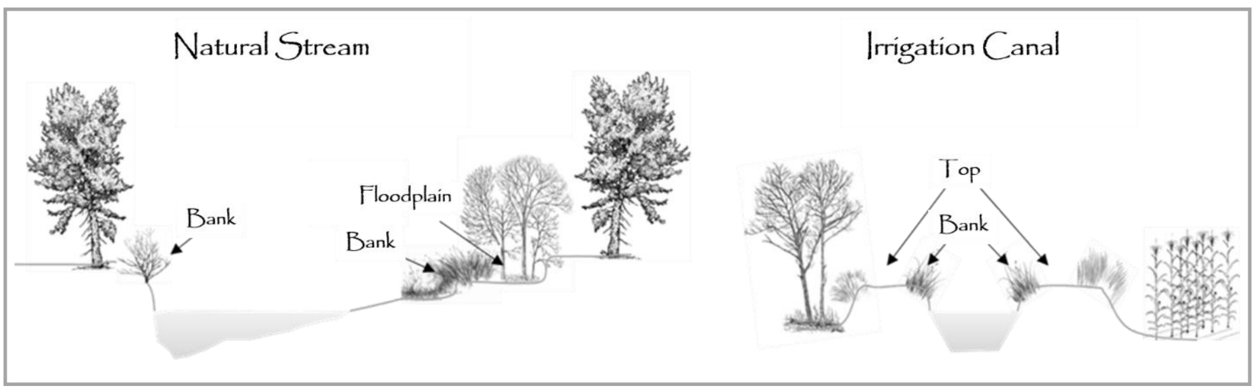

Figure 3: Cross-section of a natural stream and irrigation canal, highlighting the geomorphic structure of the channel and riparian areas.

Results:

Results and Discussion

Q1: Do irrigation canals support similar riparian plant species as natural streams?

A total of 258 taxa were observed with 240 identified to species. Shrub dominated canals were the had the highest species richness at 32.1 species and 16.4 native species, while streams with a heavy canopy had the lowest richness of 21.3 species. Overall, canals had higher richness values than streams when comparing the same cover type, except for light canopy sites (Table 2). The diversity of sites and overlapping of vegetation composition is visualized by a non-metric multidimensional scaling plot (Figure 3). Points in the plot that are closer tougher or more similar than those farther away. The lack of separation by canal or stream (Panel A) indicates that both channel types have a wide range of riparian plants. A trend can be seen when the plot is code by dominant canopy cover (Panel B). Sites dominated by herbaceous vegetation (grasses and forbs) are located on the lower right with increasing height of woody vegetation to the upper left.

The wetland PI indicated that canals had a higher cover of wetland plants than streams, but only sites with tall woody canopies met the criteria (PI < 3) to be considered a hydrophytic plant community. Streams consisted of more conservative species with a higher Mean-C score which is reflected in part by the higher percentage of native cover. Most streams with heavy woody canopy had low diversity scores and significantly lower cover of native plants compared to other stream cover types except for one site with 97 % cover of natives. Shrub dominated canals (ex. Figure 4) had the highest species richness, native richness, and % native cover.

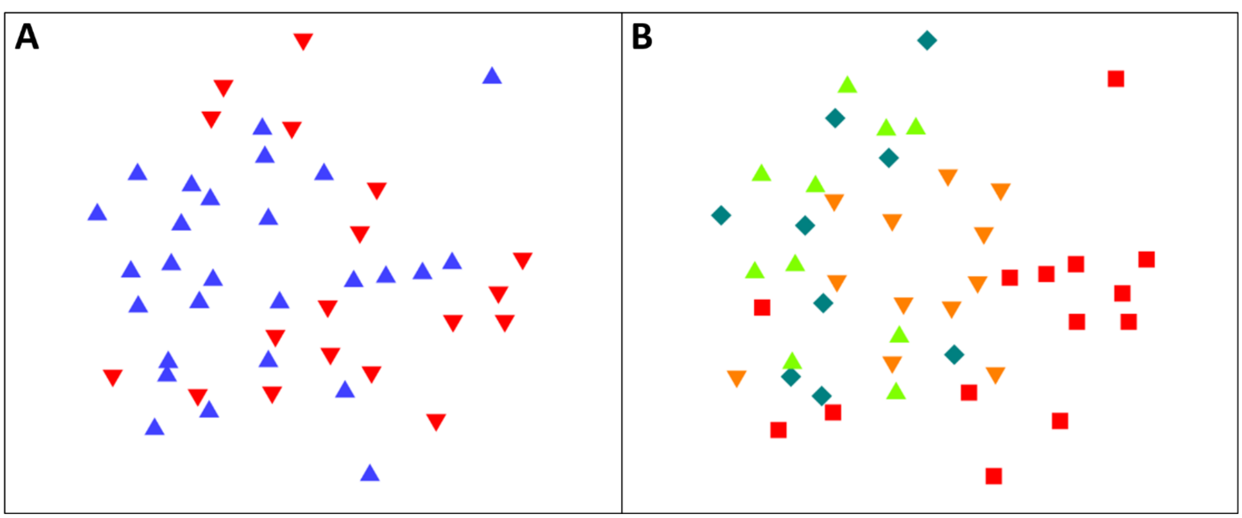

Figure 3: A non-metric multidimensional scaling plot of site vegetation calculated from Bray-Curtis resemblance matrix. Panel A: Blue triangles are canals and red triangles are streams. Panel B: red squares are herbaceous, orange triangles are shrub, light green triangles are light canopy, dark green diamonds are heavy canopy.

Table 2: Summary of average values for diversity metrics and indices of wetland prevalence, conservative species cover, native richness and cover. Calculated on the reduced dataset, which excludes rare species.

	Species Richness	***Native Richness***	***Shannon Diversity***	***Simpson's Index***	***Wetland PI***	***Cover Weighted Mean C***	***Native Cover %***
CANALS	28.1	13.8	1.7	0.69	3.27	1.99	46.2
Herb	29.1	15.3	1.6	0.64	3.25	1.66	35.3
Shrub	32.1	16.4	1.8	0.71	3.86	2.42	66.4
L. Canopy	24.0	13.5	1.8	0.75	2.87	2.40	51.6
H. Canopy	25.6	13.4	1.6	0.65	2.95	1.51	34.8
STREAMS	23.3	12.2	1.8	0.73	3.69	2.45	59.5
Herb	25.0	13.2	2.0	0.82	4.12	2.40	61.8
Shrub	22.2	10.0	1.6	0.70	3.58	2.84	65.8
L. Canopy	24.8	13.8	1.9	0.79	3.62	2.54	53.9
H. Canopy	21.3	10.8	1.5	0.60	3.36	2.02	40.3

Figure 4: Typical shrub community along an intermittently flowing irrigation canal.

Pairwise comparisons of vegetation composition show a difference between canals and streams (F = 2.02, p = 0.009). Vegetation was significantly different between canopy cover class (except for heavy canopy and light canopy). Thus, I tested the combination of channel type (canal or stream) and cover type for differences in riparian vegetation. Canal herbaceous sites differed significantly from stream herbaceous sites while all other comparisons were not significantly different (Table 3).

Table 3: Comparisons of channel type controlling for cover type. * indicates a significant difference at alpha = 0.05 level.

	T-statistic	***p-value***
Canal Herb vs. Stream Herb	1.64	0.006*
Canal Shrub vs. Stream Shrub	1.05	0.304
Canal Light Canopy vs. Stream Light Canopy	1.17	0.162
Canal Heavy Canopy vs. Stream Heavy Canopy	0.79	0.841

Q2: Does the composition of functional groups change between canals and streams?

Overall canals and streams had very similar cover of introduced trees (~20 %), native forbs (~5 %) and native trees (~9 %). Other functional groups showed statistically significant differences between the two channel types. When canopy cover is controlled, statistically significant differences are also observed. Herbaceous streams had significantly more native grass and introduced forb cover compared to canals. Light canopy canals had higher introduced tree cover yet significantly more native shrub cover in the understory. Tree cover for heavy canopy stream and canal sites was dominated by introduced species including *Salix fragilis*. Native grass species were noticeable absent from canals with heavy canopy, being replaced by introduced grasses.

Table 4: Summary of average percent cover of functional plant groups. Calculated on the reduced dataset, which excludes rare species.

	Introduced Grasses	***Introduced Forbs***	***Introduced Trees***	***Native Grasses***	***Native Forbs***	***Native Trees***	***Native Shrubs***
CANALS	27.3	3.9	18.5	5.4	6.1	9.1	18.8
Herb	31	4.3	0.2	12.1	6.4	0.3	2.2
Shrub	16	5.8	5.3	3.8	5.8	4	42.2
L. Canopy	34.1	1	20	1	4.8	15.7	25.8
H. Canopy	28.3	4.1	68.1	1	7.6	24.4	7.6
STREAMS	18	6.1	21	14.3	4.7	9	13.4
Herb	16.3	7.3	0.4	36.5	2.6	0	0.7
Shrub	11	9.3	4.5	3.2	5.5	0.2	39.3
L. Canopy	31.6	3	9.5	8.2	5.2	18.4	3.5
H. Canopy	15.7	3.8	78.9	6.8	5.9	21.7	6.9

Q3: Is woody canopy correlated to the abundance of native vegetation?

For this analysis I included rare species. There were no significant correlations between the site variables species richness, percent native vegetation, number of woody strata, and percent woody cover. This was not unexpected considering the prevalence of introduced species and the aggressive nature of several dominant species including smooth brome (*Bromus inermis*), reed canary grass (*Phalaris arundinacae*) and Canada thistle (*Breea arvensis*) which can exclude native species.

Conclusions:

Irrigation canals on City of Boulder Open Space had diverse riparian vegetation communities which differed from streams. However, when controlling for dominant canopy, only sites dominated by grasses and forbs maintained this distinctness. Irrigation canals dominated by shrubs, light canopy and heavy canopy were not statistically different from streams with the same dominant vegetation structure. These results suggest that the flow regime and vegetation management strategies for irrigation canals on City of Boulder Open Space has resulted in similar riparian ecosystems to natural streams when woody vegetation is present. Differences in herbaceous communities between streams and irrigation canals could be related to higher cover of introduced grasses along canals (31 %) and a correspondingly high cover of native grasses (36.5 %) along streams. In general streams had more varied physical structure with different vegetation occupying surfaces at various heights. Irrigation canals are trapezoidal (Figure 3) and lack floodplain surfaces on which plants with varying degrees of tolerance to flooding can colonize.

These results suggest that irrigation canals on OSMP land are equivalent to natural streams when woody riparian vegetation present. This does not, however, designate canal riparian vegetation as high quality. Streams along the Colorado Front Range have a long history of water extraction, physical straightening, disconnection from floodplains, bank stabilization and vegetation management that have degraded the hydrogeomorphic and biological processes. For instance, this study found that an average of ~60 % of vegetative cover was introduced species on streams and irrigation canals alike. Irrigation canals add significant riparian ecosystem area and length, connecting critical habitat for a number of wildlife species (Meany et al 2003). Canals with predominantly grass and forb cover are an area for habitat enhancement and should be studied to identify if woody species are suitable and beneficial for habitat connectivity.

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Holland Ditch