AN ASSESSMENT OF VEGETATION METRICS AND PLOT TYPES TO MEASURE SEASONAL VARIATION AND GRAZING EFFECTS ON RIPARIAN PLANT COMMUNITIES

by

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ABSTRACT

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The variation that exists in both time and space in riparian plant communities was explored in five streams within the Salmon National Forest and surrounding Bureau of Land Management (BLM) lands of central-eastern Idaho that are managed for cattle grazing. In this study, we evaluated the ability of commonly used vegetation metrics (live vegetation cover, species richness, % forb, litter, bare ground, wetland indicator rating, % graminoid, bank alteration, soil compaction, and % native) and different plot types (static or dynamic) to assess changes in plant communities over time and in areas grazed by cattle. We were particularly interested in evaluating the stability of metrics over time and the responsiveness of metrics to cattle grazing. We found that the metrics wetland indicator rating, % graminoid, and % native were stable across the season, while live vegetation cover, species richness, % forb, litter, bare ground, bank alteration, and soil compaction were affected by seasonal variation. The metrics that responded to grazing similarly at all streams and sites were live vegetation cover, litter, bare ground, and bank alteration, while species richness, % forb, wetland indicator rating, % graminoid, soil compaction, and % native responded differently to cattle grazing at individual streams. The metrics that were most sensitive to cattle grazing within the season were live vegetation cover, species richness, % forb, litter, and bare ground. Plot type did not have an effect on the majority of the metrics at the majority of the streams. This information can be used by land managers to determine which metrics are suitable for short- and long-term monitoring, and which ones are appropriate for monitoring the effects of cattle grazing.

(48 pages)

PUBLIC ABSTRACT

Monitoring changes in vegetation is important on public lands. Observing how plant communities respond to changes in land management can give insightful information about which management practices are sustainable. Because water is scarce in the western United States, many land managers focus their monitoring efforts along streams. However, monitoring streamside vegetation is challenging due to a variety of factors and can be confounded by factors such as seasonal climate variation and management activities, like cattle grazing.

In vegetation assessments, there are a variety of measurements that are taken to glean valuable information. Some attributes of interest include how much vegetation is present, how many species are present, and what the composition of species is. Furthermore, there are a variety of methodologies that can be employed and the type of plot that is used may affect the outcome of the results.

In this study, we were interested in improving the assessments of vegetation monitoring efforts in streamside plant communities. We focused our efforts on understanding how attributes of the plant community responded to seasonal variation and cattle grazing. We also tested two types of plots to see which was most appropriate for streamside monitoring. We found that some attributes responded to seasonal climate variation, while others were unaffected. We also found that some attributes responded to cattle grazing and others did not. Last we found that permanent plots were unnecessary. Research was conducted by Caroline M. Laine and advisor, Dr. Karin Kettenring from 2009-2011.

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Caroline Laine

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CHAPTER 1

INTRODUCTION

Humans subject natural areas to a variety of pressures and management regimes that have the potential to alter plant communities and affect ecosystem functions. Detecting changes in vegetation is important for proper land management, but can be difficult due to the variation that exists temporally across the season and spatially on the landscape. In northern temperate climates, plant communities experience constant environmental change during the short growing season. Annual and seasonal climate variation, in the form of temperature, photoperiod, and precipitation is a major factor controlling species-specific growth responses and more broadly, plant communities over time (Boaler 1966, Houle and Phillips 1989, Rathcke and Lacey 1985, Whittaker 1972). Climate also has indirect effects on plants by driving soil nutrient and moisture availability in all plant communities (Cain et al. 1999, Facelli and Pickett 1991) and fluctuations in hydrology in riparian plant communities. Seasonal fluctuations in hydrology cause changes in stream flow, depth of water table, and the removal and deposition of sediment (Capon 2005), which affect plant growth. Furthermore, flood patterns and water availability vary along the length of the stream (Lite et al. 2005), and both are affected by seasonal variation (Nillson and Dynesius 1994, Pollock et al. 1998). Seasonal climate variation also affects biotic factors, such as plant pathogens (Burdon et al. 1989, Sreeramulu 1959) and variation in herbivore pressure (Clayton and Pogacnick 1986, Evans et al. 2004, Gordon 1989, Parsons et al. 2003).

In the western United States, cattle grazing is an herbivore-driven management activity that is of economic, political, and public interest, and can have an impact on vegetation and the ecosystem as a whole (Belsky et al. 1999, Fleischner 1994). Cattle grazing can affect the landscape through alteration of species composition, changes in species richness, and decreases in biomass; thus, having an effect on ecosystem function. Herbivore selectivity based on palatability and plant tolerance determine the effect that cattle will have on a plant community (Augustine and McNaughton 1998), and native species may be outcompeted by exotic or invasive species that are more resistant or tolerant to cattle grazing (Kimball and Schiffman 2003). Diversity of plant species can be affected by cattle grazing; some researchers have found that species richness increases with cattle grazing (Green and Kauffman 1995, Humphrey and Patterson 2000, Pykälä 2003, Pykälä 2005), while others have seen a decrease (Brady et al. 1989), and no difference (Lucas et al. 2004, Lunt 2007, Robertson and Rowling 2000). In riparian areas, removal of vegetation by livestock can contribute to erosion of streambanks and channel incision (Belsky et al. 1999). Furthermore, the effects of cattle grazing on riparian plant communities vary within a season, due to differential availability of forage in the upland and because of the response of plants to cattle grazing at different times in their growth cycle (Clayton and Pogacnick 1986, Evans et al. 2004, Gordon 1989, Parsons et al. 2003).

Making good decisions about appropriate cattle grazing and other land management strategies requires the monitoring and assessment of ecological attributes over time in response to various treatments. Riparian plant communities are typically studied due to their relative importance on the landscape, and there are a variety of vegetation metrics used for assessment (Coles-Ritchie et al. 2004, Gibbons and Freudenberger 2006, Lennox et al. 2011). However, the vegetation metrics of riparian plant communities are relatively new monitoring tools and they need to be evaluated for their sensitivity to disturbance, stress (Whitford et al. 1998), seasonal variation, and responses at different sites.

An indicator that is sufficiently sensitive should be able to detect changes in management and restoration efforts (Whitford et al. 1998). In assessing ecological health, a suite of metrics is usually preferable because many metrics often respond differently at different sites (DeSoyza et al. 2000, Pyke et al. 2002). The suite of indicators should be sensitive to management activities and should relate to ecosystem functions (Herrick and Lal 1995, Whitford et al. 1998). By evaluating the strengths and weaknesses of the tools that are used, land managers will be more prepared to make informed decisions regarding conservation and sustainable land use.

Since riparian areas experience particularly dynamic conditions, such as a change in stream channel location due to sedimentation and erosion, the type of vegetation plot used should also be taken into consideration. Two commonly used protocols for riparian monitoring on public lands, the Pacific Fish/Inland Fish Biological Opinion (PIBO) (Leary and Ebertowski 2010) and Multiple Indicator Monitoring (MIM) protocols (Burton et al. 2011) are adapted from Winward (2000). These protocols focus their measurements at greenline, defined as "the first perennial vegetation that forms a lineal grouping … on or near the water's edge" (Winward 2000). Because greenline location may vary by date within a season and between years, plot placement also varies, and may be in a different location each time a site is monitored. In comparison, terrestrial studies often use permanent plots because true changes in the plant community due to temporal variation, succession, or the effect of management can be detected while controlling for small spatial differences in an area (Bakker et al. 1996, Pickett et al. 1987, Scherrer and Pickering 2005). Although the use of permanent plots is a common practice in many vegetation assessments, this methodology has not yet been applied to greenline vegetation of riparian areas.

In this study, we evaluated the ability of commonly used vegetation metrics and different types of plots to assess changes in plant communities over time and in areas grazed by cattle. We chose to do this study in riparian plant communities because they are key areas of concern in the western United States, with high priority for ecological monitoring and conservation practices. Although these areas comprise a relatively small portion of the landscape, they are used disproportionately by wildlife, cattle, and humans, and should be managed sustainably (Ffolliott et al. 2004, USDI et al. 2001). The information presented here can be used by land managers to determine if the response of a vegetation metric is due to seasonal variation or to a management activity, or a combination of the two. It can also be used to make informed decisions about which vegetation metrics and plot types to use for both short- and long-term monitoring efforts in riparian areas.

CHAPTER 2

METHODS

Study area

This study was conducted in riparian areas of five streams in the Salmon River and Beaverhead mountain ranges of the Salmon National Forest and BLM in central-eastern Idaho (Fig. 1). The elevation of the study sites is 1,560–2,300 meters (m) and the streams are three to six m wide at bankfull flow. The semi-arid climate is characterized by cold winters and warm summers with most precipitation occurring as spring and summer rain, and winter snow. The mean monthly rainfall during the study season of June to October is 19 mm per month, but has a range of 15.7–22.8 mm during that time (Leadore, Lemhi County, Idaho, USA weather station) (World Climate 2011). The 24-hour average temperature during the study season is 14.7 ˚C, but ranges from 7.3–19.2 ˚C.

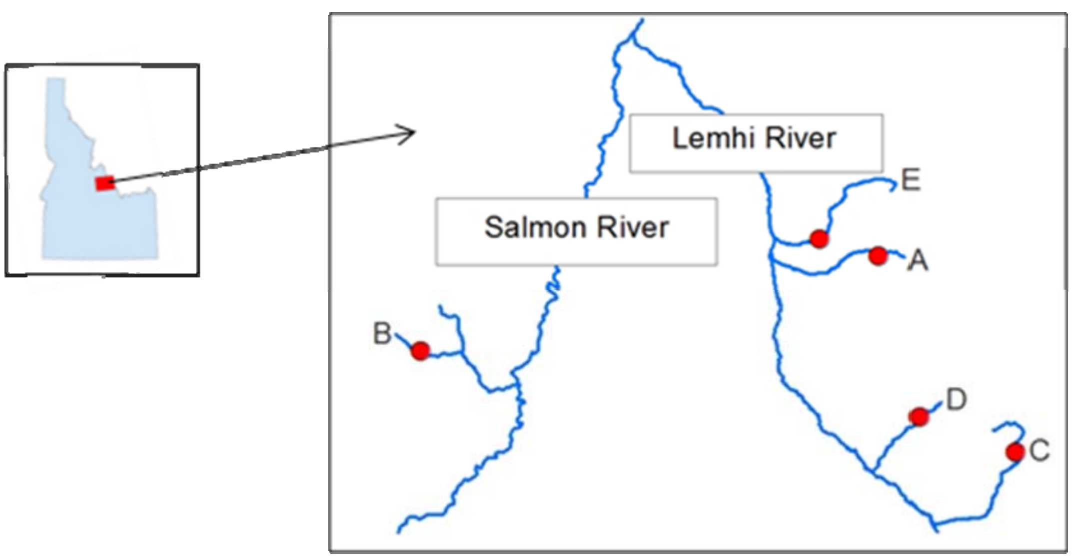

Fig. 1. Streams included in this study were (A) Agency, (B) Big Hat, (C) Canyon, (D) Little Eightmile, and (E) Pattee.

Important graminoid species are Kentucky bluegrass (*Poa pratensis* ssp. *pratensis* L.) (nomenclature according to USDA (2011)), Nebraska sedge (*Carex nebrascensis* Dewey), creeping bentgrass (*Agrostis stolonifera* L.), and smallwing sedge (*Carex microptera* Mack.). Both Kentucky bluegrass and creeping bentgrass are introduced species that are generally highly palatable and resistant to cattle grazing. Important shrub species are basin big sagebrush (*Artemisia tridentata* ssp. *tridentata* Nutt.), Geyer willow (*Salix geyeriana* Andersson), and gray alder (*Alnus incana* (L.) Moench).

Sampling design

In 2009, we chose five streams, with two sites each, in the Salmon National Forest and surrounding BLM lands that were within the sagebrush and willow community type. Each individual site had two transects that were a length of 117 m, on each side of the stream. There were 40 plots in each transect spaced at three m intervals, for a total of 80 plots per site. We recorded greenline vegetation at each plot following the PIBO and MIM protocols. This location was defined as the first Daubenmire grid (50 cm x 20 cm) adjacent to the stream that had 25% or greater of perennial vegetation (Burton et al. 2008, Leary and Ebertowski 2010, Winward 2000). However, a few additional stipulations of the PIBO protocol were also followed. The lower limit for greenline plot placement was where the streambed met the streambank, and the upper limit was the first flat depositional feature at or above bankfull (Leary and Ebertowski 2010). As a result, the plot was not placed in the active stream channel, and was also not distant from the stream channel, even if it was devoid of vegetation. We monitored the total percent cover of all live vegetative species, litter, bare ground, rock, and log that had greater than five % cover within the plot, looking down at the plot from one m (Leary and

Ebertowski 2010). Two additional measurements were taken to determine the effects of cattle: bank alteration and soil compaction. From these measurements, 11 vegetation metrics were derived and analyzed (Table 1). In 2010, we re-visited the same streams and sites, with the exception of Stream B (Big Hat) that was not sampled because of adverse road conditions.

Table 1. The list of vegetation metrics that were assessed in this study, and the field methods that were used.

Metric (Abbreviation)	Definition
Live vegetation cover (LVC)	The absolute % of a vegetation plot that was live vegetation. Plant material was counted as live vegetation cover until it broke off the plant.
Species richness (Rsq)	The number of species per plot that had greater than 5% cover.
% Forb (Fsq)	The relative % of live vegetation that was forb species.
Litter (L)	The absolute % of a vegetation plot that was litter. Plant material was counted as litter after it broke off the plant.
Bare ground (BG)	The absolute % of a vegetation plot that was bare ground.
Wetland indicator rating (WIR)	Determined from Reed (1988). Each species that had greater than 5 % cover within the plot was assigned a wetland indicator rating based on its likelihood to be found in a wetland area according to USDA plants database (USDA 2011). The value for a plot was the sum of the relative cover of each species multiplied by its wetland indicator rating.
% Graminoid (Gsq)	The relative % of live vegetation that was graminoid species.
Bank alteration	The number of hoof prints or shearing marks that occurred within a plot. This is a value between 0 and 5. There are 5 horizontal lines on the MIM plot and if a hoof or shearing mark crosses one of the horizontal lines, it is counted (Burton et al 2011).
Soil compaction	A measure of soil resistance, measured with a pocket penetrometer in the center of each plot (Forestry Suppliers Item # 77114).
% Native	The relative % of live vegetation that was native species.

Seasonal variation

To assess the seasonal variation of vegetation metrics, the same sites were sampled repeatedly during the growing seasons of 2009 and 2010, with field sampling occurring from about June 10–October 20 each year. We set up permanent plots by driving rebar into the ground and by flagging them, on the first sample date in June of 2009 and measured the plots repeatedly at two-week intervals during times of peak plant productivity from June until the end of August, and at three-week intervals after senescence of plants began from late August until October. Comparisons of vegetation metrics were made between weeks within a season, in 2009 and 2010. Data gathered in 2009 were used to evaluate the seasonal changes associated with livestock grazing while the 2010 data were used to evaluate different plots and sampling methodology.

Grazing

To obtain information on the effects that cattle grazing had on the riparian areas, each of the five study streams had both a grazed site and an adjacent, ungrazed exclosure site during the 2009 study season. The grazing use was different at each stream and site (Table 2). Although there was cattle grazing on some of the sites in 2010, the effects of cattle grazing were only assessed in 2009, and comparisons of vegetation metrics were made between grazed and ungrazed sites in 2009 only.

Plot type and site

To measure the effects of two different plot types on vegetation metrics, a split-plot design was used in 2010. Forty of the eighty permanent plots that were established in 2009 were measured again in 2010 (i.e, the static greenline plot). In addition, forty

Table 2. The grazing dates and number of cattle grazed at streams A-E in 2009 and 2010.

Stream	Name of Creek	Grazing Dates 2009	Number of Cattle 2009	Grazing time (in weeks) 2009	Grazing Dates 2010	Number of Cattle 2010	Grazing time (in weeks) 2010	Grazed site 2010
A	Agency	6/22-7/27	336	2-7	5/21-6/30	250	1-3	1
B	Big Hat	7/25-9/30	~250	7-17	N/A	N/A	N/A	N/A
C	Canyon	6/5-6/12, 8/29-9/30	480	1, 12-17	8/16-9/14	228	10-14	2
D	Little Eightmile	7/12-9/30	218	5-17	6/26-7/15	159	3-6	1
					7/16-8/21	159	6-11	2
E	Pattee	9/12-10/20	250	14-20	5/16-6/10	300	1	2

dynamic plots were sampled, located along the same transect axis as the permanent plots from 2009, but were placed at each sampling date according to their new greenline location (first plot with >25% perennial vegetation adjacent to the stream flow). Rather than analyzing grazing in 2010, we chose to analyze the site effect. This allowed us to see if there were differences between two sites on the same stream, and how the plot type responded within each of the two sites. Comparisons of vegetation metrics were made between the two plot types within a site, and between the two different sites at a stream.

Data analysis

We treated the four study streams as individual case studies and analyzed them separately because of innate differences in the streams' past and present grazing history (Table 2). Data analysis was obtained using a mixed-model ANOVA (GLIMMIX procedure) in SAS/STAT software version 9.2 in the SAS system for Windows (SAS Institute, Inc. 2008) for the vegetation metrics: live vegetation cover, species richness, % forb, litter, bare ground, wetland indicator rating, and % graminoid. A square-root transformation was used on the metrics species richness, % forb, and % graminoid to better meet the model assumptions of normality and homogeneity of variance. For the 2009 analysis, the fixed effects were week and grazing (one-way ANOVA with repeated measures in time), and the random effect was transect, nested within grazing; for the 2010 analysis, the fixed effects were week, plot type, and site (two-way ANOVA with repeated measures in time), and the random effect was transect, nested within site. A variety of covariance structures were explored for the fixed effect week, but since all yielded the same results of significance, compound symmetry was used in the final model because of low AIC scores. We used an alpha of 0.05 as our measure of confidence. We also calculated means and standard errors for all metrics in SAS 9.2, and all figures were created using descriptive statistics.

Figures for three additional metrics: bank alteration, soil compaction, and % native, were included, and only means and standard errors were obtained since these metrics did not meet normality assumptions, and were thus inappropriate for analysis with a mixed-model ANOVA. Furthermore, figures for a Bray-Curtis time lag analysis were also included. We analyzed changes in species composition by calculating a Bray Curtis dissimilarity index (Bray and Curtis 1957) and regressing the results with time lag analysis (Collins et al. 2000). The square-root of time lag was linearly regressed against the Bray-Curtis dissimilarity value, and the adjusted R-square value for goodness of fit was used to compare grazed sites to ungrazed sites, and the two different plot types. This allowed us to determine which sites underwent a greater change in species composition over time.

CHAPTER 3

RESULTS

Seasonal variation

There were four patterns observed in the metrics that we analyzed for seasonal variation. Patterns for the metrics included a positive unimodal distribution over time, a negative unimodal distribution over time, a positive increase over time, and little to no change over time (Fig. 2). Each of these metrics fell into one category, with the exception of bare ground that fell into three of these categories due to the fact that it responded differently to seasonal variation at individual streams.

Seasonal variation had a strong effect on the metrics live vegetation cover, species richness, % forb, litter, bare ground, bank alteration, and soil compaction and very little effect on the metrics wetland indicator, % graminoid, and % native. Live vegetation cover, species richness, and % forb composition varied significantly by week at all streams in 2009 (Table 3) and 2010 (Table 4), and had a unimodal distribution over time (Fig. 3, 4, and 5). Litter also varied significantly by week at all streams in both years (Table 3 and 4), but had a negative unimodal distribution over time (Fig. 6). Bare ground varied significantly by week at four of the five streams in 2009 (Table 3) and at all four streams sampled in 2010 (Table 4), but did not show a consistent pattern over time, and had distributions that were positive, negative unimodal, or showed little change (Fig. 7). Although statistically significant, both wetland indicator rating and % graminoid had a pattern that showed little change over time (Fig. 8 and 9). Both wetland indicator rating and % graminoid varied significantly by week at three of the five streams in 2009 (Table

3). Wetland indicator rating varied significantly by week at three of the four streams and % graminoid by all streams in 2010 (Table 4). Bank alteration increased over time at grazed sites only (Fig. 10), while soil compaction increased over time at all sites (Fig. 11). Percent native was relatively stable over time (Fig. 12). The Bray-Curtis time lag analysis indicated that all sites became more dissimilar with increasing time lag (Fig. 13-15).

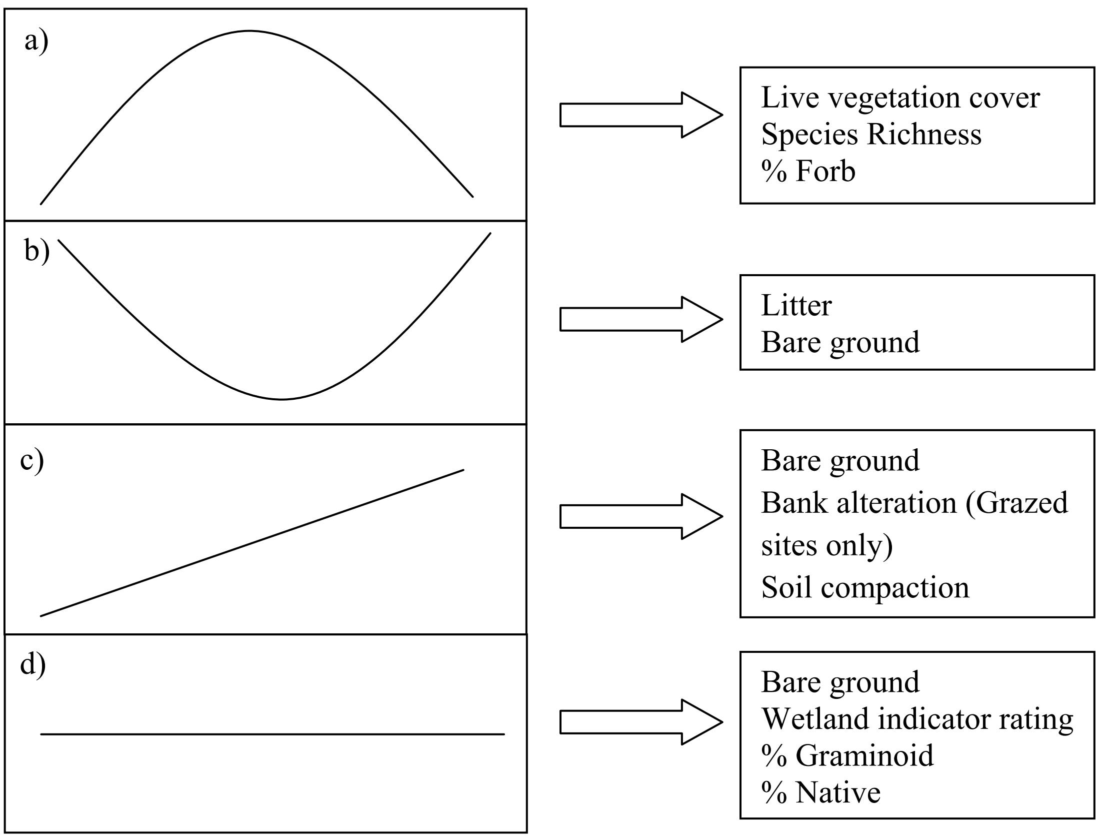

Fig. 2. The responses of vegetation metrics to seasonal variation had four main patterns: a) unimodal distribution over time, b) negative unimodal distribution over time, c) positive increase over time, and d) little change over time.

Table 3. Fixed effects and interactions for a 1-way ANOVA (with repeated measures in time) to test the effects of grazing and week (our measure of seasonal variation) on the response metrics from Table 1 in 2009.

Stream	Response	Grazing			Week			Grazing*Week		
		Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value
A	LVC	1	78.01	25.35***	7	1185.00	12.49***	7	1185.00	13.87***
B		1	78.08	0.94	7	1177.00	33.82***	7	1177.00	6.81***
C		1	78.07	27.47***	6	1024.00	80.54***	6	1024.00	4.81***
D		1	78.00	96.21***	7	1186.00	53.06***	7	1186.00	27.67***
E		1	78.01	3.04	8	1342.00	46.07***	8	1342.00	6.60***
A	Rsq	1	78.02	4.39*	7	1185.00	4.97***	7	1185.00	6.68***
B		1	78.21	0.49	7	1180.00	9.09***	7	1180.00	0.50
C		1	77.98	0.10	6	1025.00	15.72***	6	1025.00	1.02
D		1	78.00	15.76**	7	1186.00	13.47***	7	1186.00	4.30***
E		1	77.94	3.41	8	1342.00	22.76***	8	1342.00	3.53***
A	Fsq	1	78.01	1.60	7	1185.00	5.16***	7	1185.00	4.75***
B		1	78.55	0.58	7	1180.00	2.47*	7	1180.00	0.33
C		1	77.75	1.85	6	1025.00	5.81***	6	1025.00	0.16
D		1	78.00	9.04*	7	1186.00	6.57***	7	1186.00	4.19***
E		1	77.97	9.27**	8	1342.00	12.71***	8	1342.00	4.21***
A	L	1	78.00	4.40*	7	1185.00	7.40***	7	1185.00	4.5***
B		1	78.32	0.33	7	1180.00	28.71***	7	1180.00	5.92***
C		1	78.11	10.65**	6	1025.00	53.53***	6	1025.00	3.48**
D		1	78.00	38.75***	7	1186.00	24.3***	7	1186.00	2.66**
E		1	78.03	3.76	8	1342.00	59.21***	8	1342.00	7.69***
A	BG	1	78.02	10.46**	7	1185.00	5.44***	7	1185.00	13.88***
B		1	78.66	5.70*	7	1180.00	1.88	7	1180.00	1.28
C		1	78.00	25.48***	6	1025.00	8.12***	6	1025.00	6.02***
D		1	78.00	27.26***	7	1186.00	7.77***	7	1186.00	20.80***
E		1	78.00	11.69**	8	1342.00	8.54***	8	1342.00	4.23***
A	WIR	1	78.10	47.22***	7	1157.00	4.56***	7	1157.00	0.63
B		1	78.55	4.57*	7	1166.00	0.92	7	1166.00	0.23
C		1	77.92	18.08***	6	1020.00	2.42*	6	1020.00	2.26*
D		1	78.06	0.50	7	1180.00	1.27	7	1180.00	1.75
E		1	77.58	10.09**	8	1305.00	2.44*	8	1305.00	0.57
A	Gsq	1	77.99	4.52*	7	1185.00	3.35**	7	1185.00	1.42
B		1	78.24	2.13	7	1179.00	2.55*	7	1179.00	0.57
C		1	77.99	9.02**	6	1025.00	0.44	6	1025.00	0.76
D		1	78.00	52.28***	7	1186.00	2.81*	7	1186.00	4.48***
E		1	77.99	0.10	8	1342.00	1.40	8	1342.00	0.37

Notes: *, **, *** Effect significant at P<0.05, 0.01, and 0.001, respectively.

Table 4. Fixed effects and interactions for a 2-way ANOVA (with repeated measures in time) to test the effects of plot type, site, and week on the response metrics from Table 1 in 2010. Stream B was not sampled in 2010.

Stream	Response	Plot type			Site			Plot type*Site			Week			Plot type*Week			Site*Week			Plot type*Site*Week		
		Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value	Num DF	Den DF	F Value
A	LVC	1	156.00	1.13	1	156.00	16.12***	1	156.00	3.89	7	1091.00	43.85***	7	1091.00	0.84	7	1091.00	3.10**	7	1091.00	0.77
C		1	155.80	0.69	1	155.8	24.00***	1	155.80	0.05	7	1089.00	27.51***	7	1089.00	0.41	7	1089.00	26.92***	7	1089.00	1.27
D		1	78.04	5.46*	1	78.00	10.00**	1	78.04	5.43*	7	1089.00	68.72***	7	1089.00	1.09	7	1089.00	18.08***	7	1089.00	0.72
E		1	77.88	1.54	1	78.00	0.39	1	77.88	0.40	8	1237.00	50.22***	8	1237.00	2.57**	8	1237.00	3.65***	8	1237.00	1.54
A	Rsq	1	156.00	0.29	1	156.00	1.41	1	156.00	3.54	7	1091.00	12.45***	7	1091.00	0.87	7	1091.00	2.41*	7	1091.00	1.11
C		1	77.94	0.64	1	78.03	0.03	1	77.94	1.19	7	1089.00	12.11***	7	1089.00	0.29	7	1089.00	3.78***	7	1089.00	2.03*
D		1	77.67	3.42	1	78.04	2.69	1	77.67	2.16	7	1089.00	19.72***	7	1089.00	1.86	7	1089.00	3.09**	7	1089.00	1.10
E		1	155.7	0.02	1	155.70	25.4***	1	155.7	0.48	8	1237.00	6.90***	8	1237.00	1.56	8	1237.00	1.54	8	1237.00	1.29
A	Fsq	1	77.97	1.14	1	78.01	2.46	1	77.97	0.45	7	1091.00	18.42***	7	1091.00	3.60***	7	1091.00	5.92***	7	1091.00	1.31
C		1	77.98	0.06	1	78.00	3.87	1	77.98	0.00	7	1089.00	7.80***	7	1089.00	1.70	7	1089.00	6.19***	7	1089.00	0.99
D		1	77.86	0.15	1	78.02	5.16*	1	77.86	0.19	7	1089.00	7.70***	7	1089.00	2.54*	7	1089.00	4.49***	7	1089.00	0.73
E		1	78.02	0.86	1	78.00	11.79**	1	78.02	1.01	8	1237.00	4.10***	8	1237.00	0.85	8	1237.00	2.31*	8	1237.00	0.76
A	L	1	78.01	2.65	1	78.01	16.80***	1	78.01	0.94	7	1091.00	24.34***	7	1091.00	1.44	7	1091.00	0.35	7	1091.00	1.20
C		1	156.00	3.21	1	156.00	1.31	1	156.00	0.11	7	1089.00	40.48***	7	1089.00	0.49	7	1089.00	9.91***	7	1089.00	0.77
D		1	156.10	0.23	1	156.10	5.07*	1	156.10	0.51	7	1089.00	30.51***	7	1089.00	0.65	7	1089.00	5.89***	7	1089.00	0.53
E		1	78.06	4.43*	1	77.94	0.04	1	78.06	0.02	8	1237.00	56.02***	8	1237.00	2.08*	8	1237.00	10.63***	8	1237.00	0.78
A	BG	1	78.02	0	1	78.01	0.23	1	78.02	6.56*	7	1091.00	6.75***	7	1091.00	1.56	7	1091.00	5.83***	7	1091.00	1.25
C		1	78.02	1.05	1	78.02	17.54***	1	78.02	0.76	7	1089.00	8.64***	7	1089.00	1.48	7	1089.00	9.89***	7	1089.00	1.50
D		1	78.05	5.39*	1	78.00	1.35	1	78.05	3.71	7	1089.00	18.58***	7	1089.00	3.65***	7	1089.00	7.10***	7	1089.00	1.47
E		1	155.4	0.67	1	155.4	7.66**	1	155.40	1.45	8	1237.00	9.60***	8	1237.00	0.27	8	1237.00	12.46***	8	1237.00	1.37
A	WIR	1	156.10	0.1	1	156.10	63.99***	1	156.10	0.00	7	1070.00	24.55***	7	1070.00	0.88	7	1070.00	8.41***	7	1070.00	1.01
C		1	156.10	0.33	1	156.10	16.93***	1	156.10	0.33	7	1082.00	1.97	7	1082.00	1.14	7	1082.00	1.46	7	1082.00	2.18*
D		1	77.98	10.69**	1	77.97	0.67	1	77.98	0.66	7	1088.00	4.77***	7	1088.00	1.92	7	1088.00	3.98***	7	1088.00	1.67
E		1	77.82	0.05	1	78.21	11.14**	1	77.82	0.04	8	1193.00	6.40***	8	1193.00	0.51	8	1193.00	2.12*	8	1193.00	0.73
A	Gsq	1	78.00	0.02	1	78.00	4.00*	1	78.00	4.87*	7	1091.00	10.13***	7	1091.00	5.07***	7	1091.00	11.10***	7	1091.00	1.33
C		1	77.99	0.46	1	78.00	1.15	1	77.99	0.37	7	1089.00	7.05***	7	1089.00	1.99	7	1089.00	4.11***	7	1089.00	0.88
D		1	77.87	1.47	1	78.03	64.46***	1	77.87	0.05	7	1089.00	2.48*	7	1089.00	0.65	7	1089.00	2.90**	7	1089.00	0.79
E		1	78.02	0.00	1	78.01	1.33	1	78.02	0.13	8	1237.00	4.44***	8	1237.00	0.90	8	1237.00	1.49	8	1237.00	1.37

Notes: *, **, *** Effect significant at P<0.05, 0.01, and 0.001, respectively.

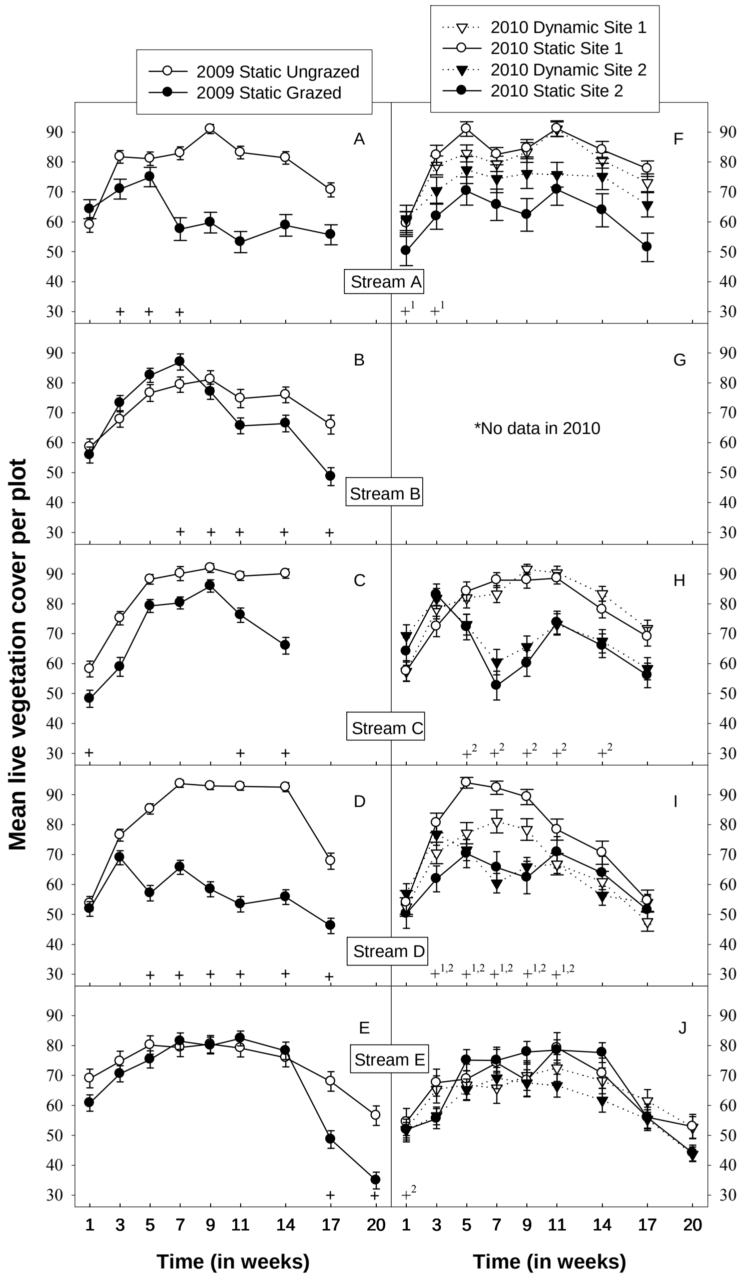

Fig. 3. The effect of grazing (A-E) and plot type (F-J) on mean live vegetation cover (± 1 SE) per plot over the 20-week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

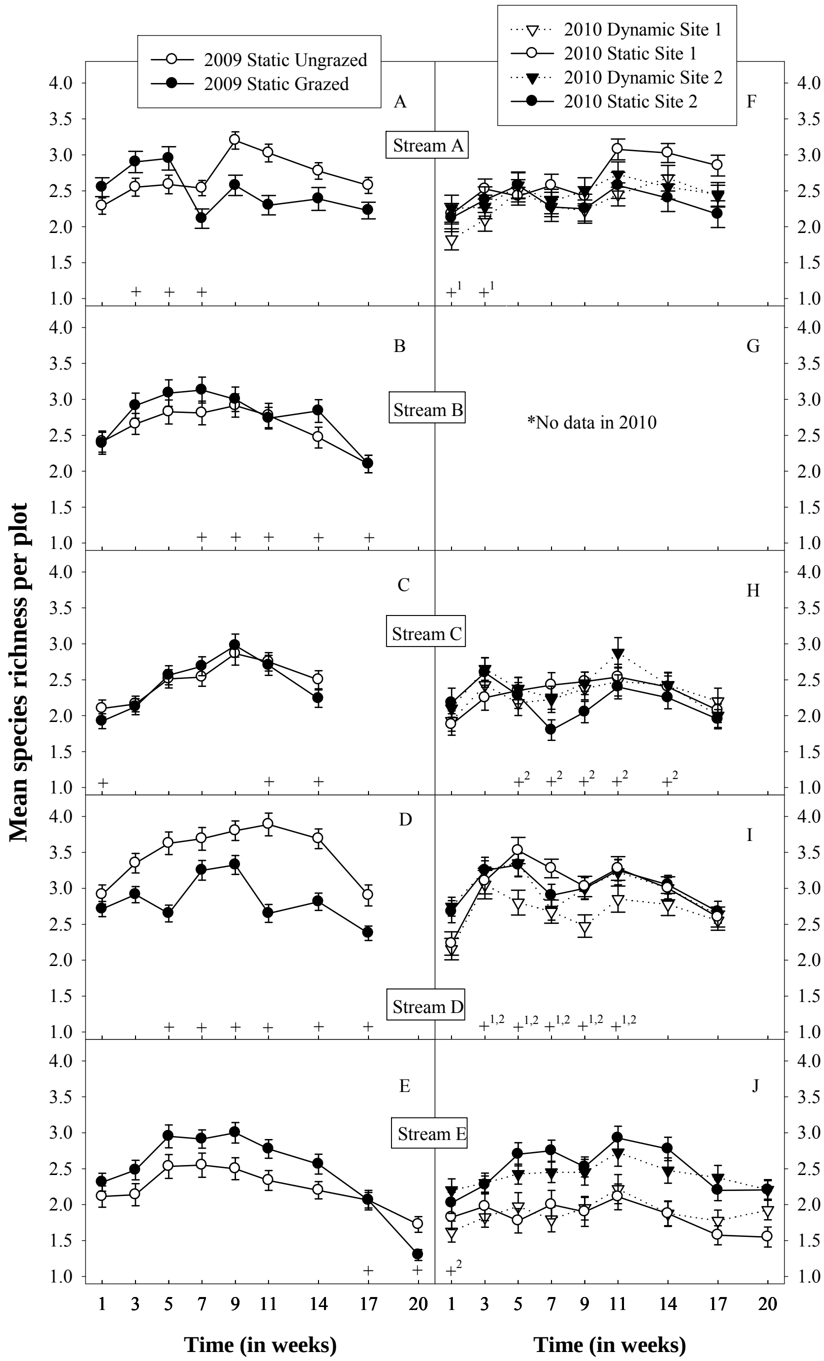

Fig. 4. The effect of grazing (A-E) and plot type (F-J) on mean species richness (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

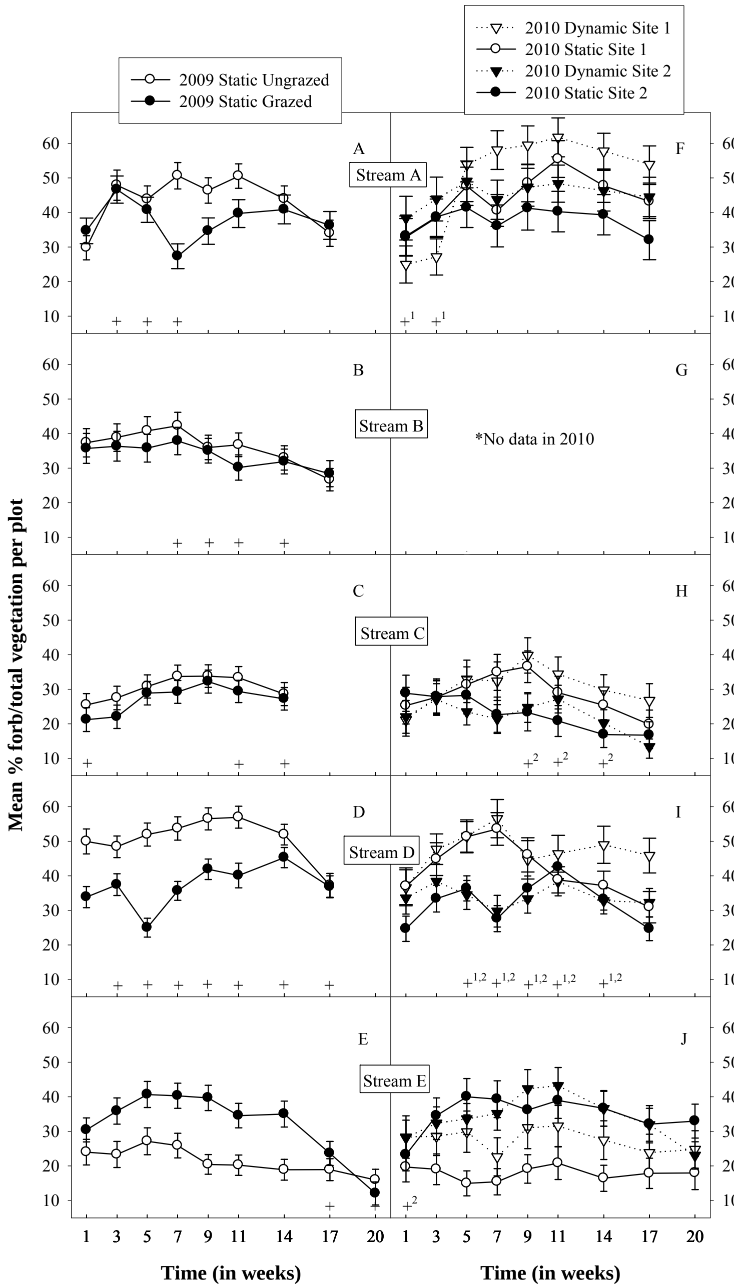

Fig. 5. The effect of grazing (A-E) and plot type (F-J) on mean % forb/total vegetation (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

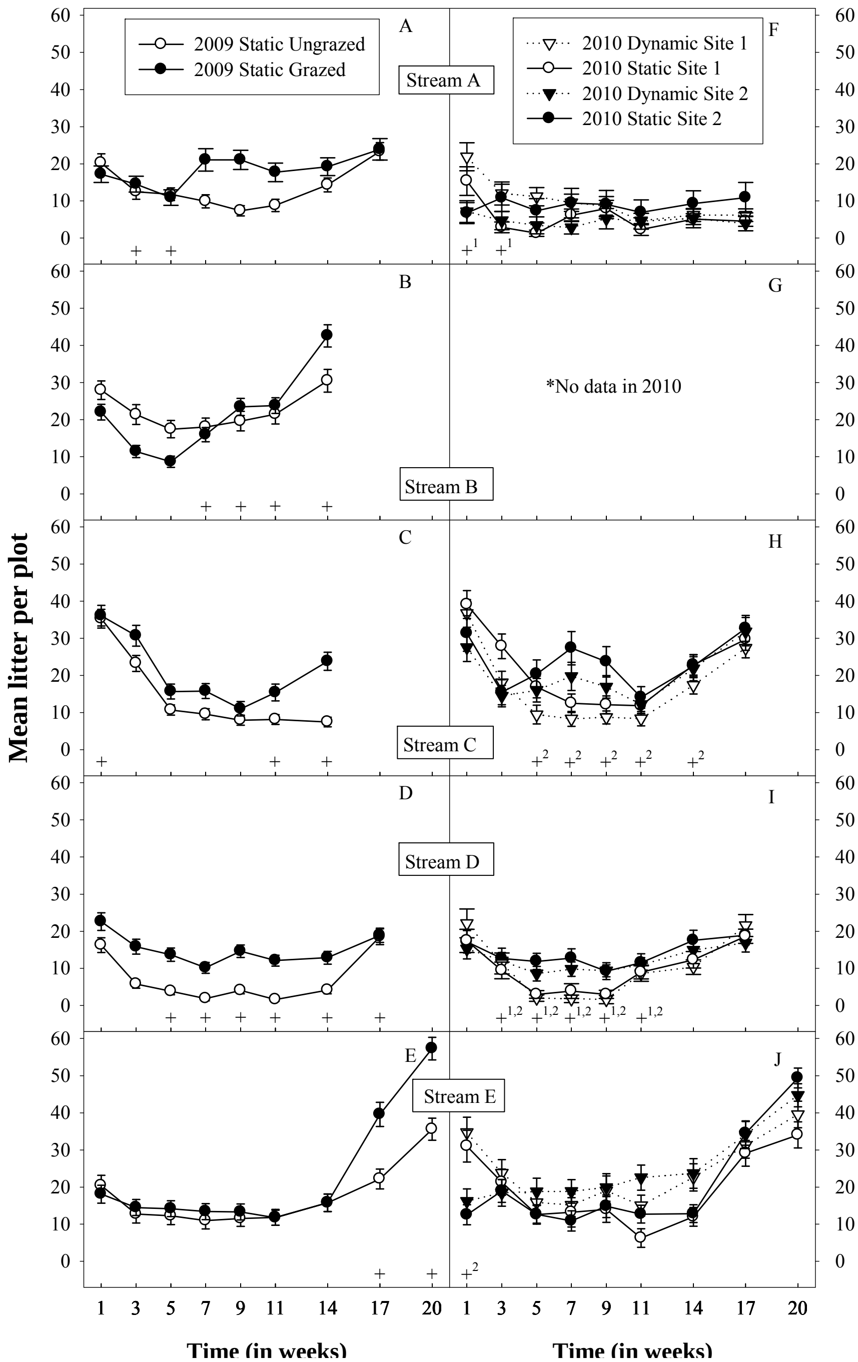

Fig. 6. The effect of grazing (A-E) and plot type (F-J) on mean litter (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

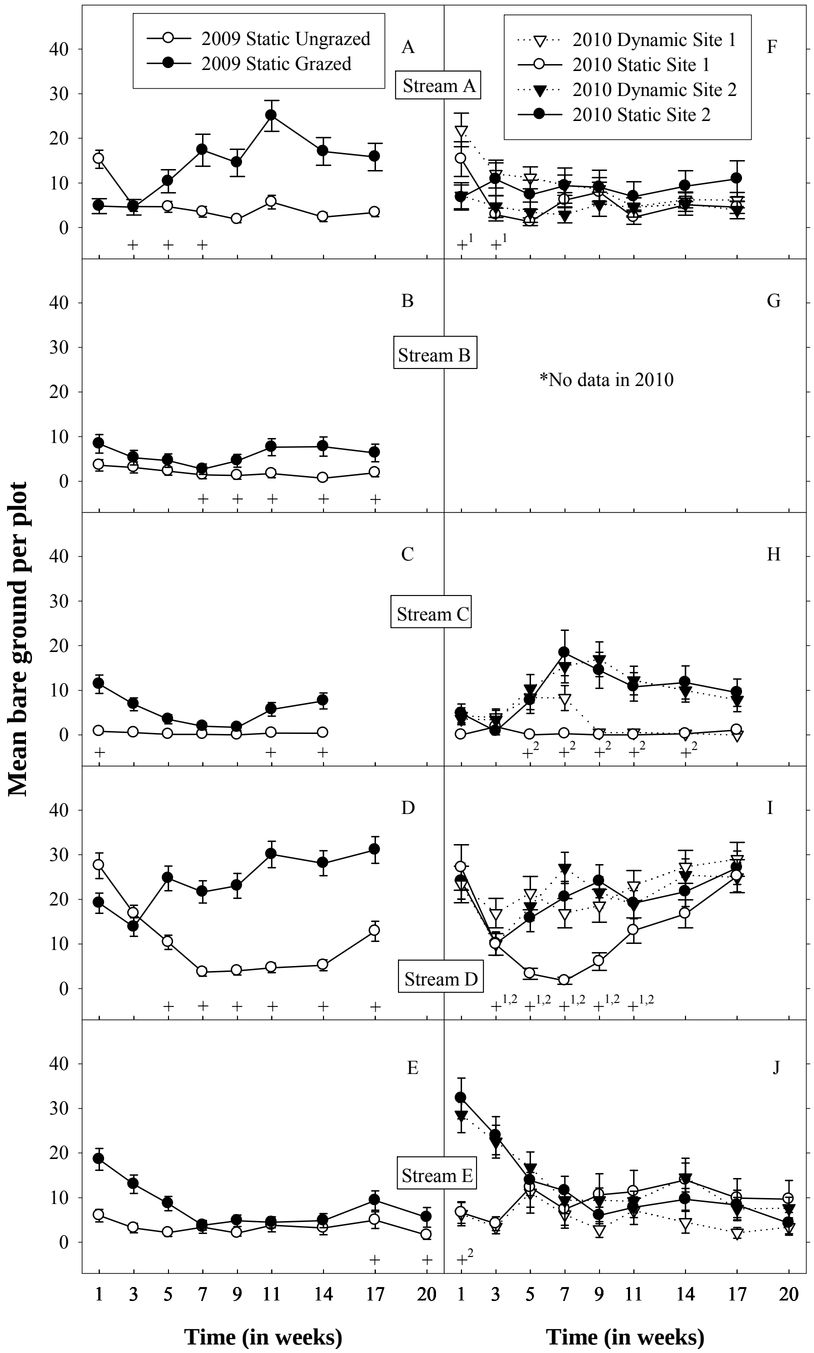

Fig. 7. The effect of grazing (A-E) and plot type (F-J) on mean bare ground (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

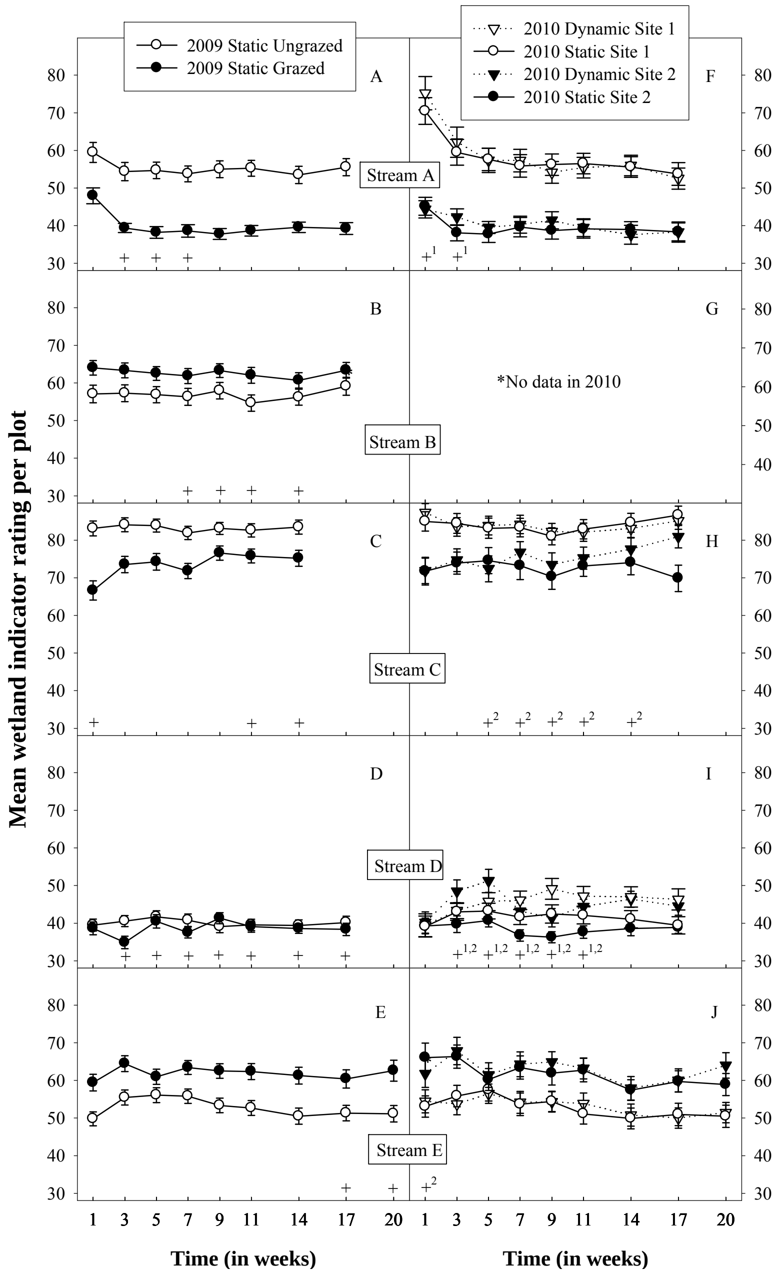

Fig. 8. The effect of grazing (A-E) and plot type (F-J) on mean wetland indicator rating (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

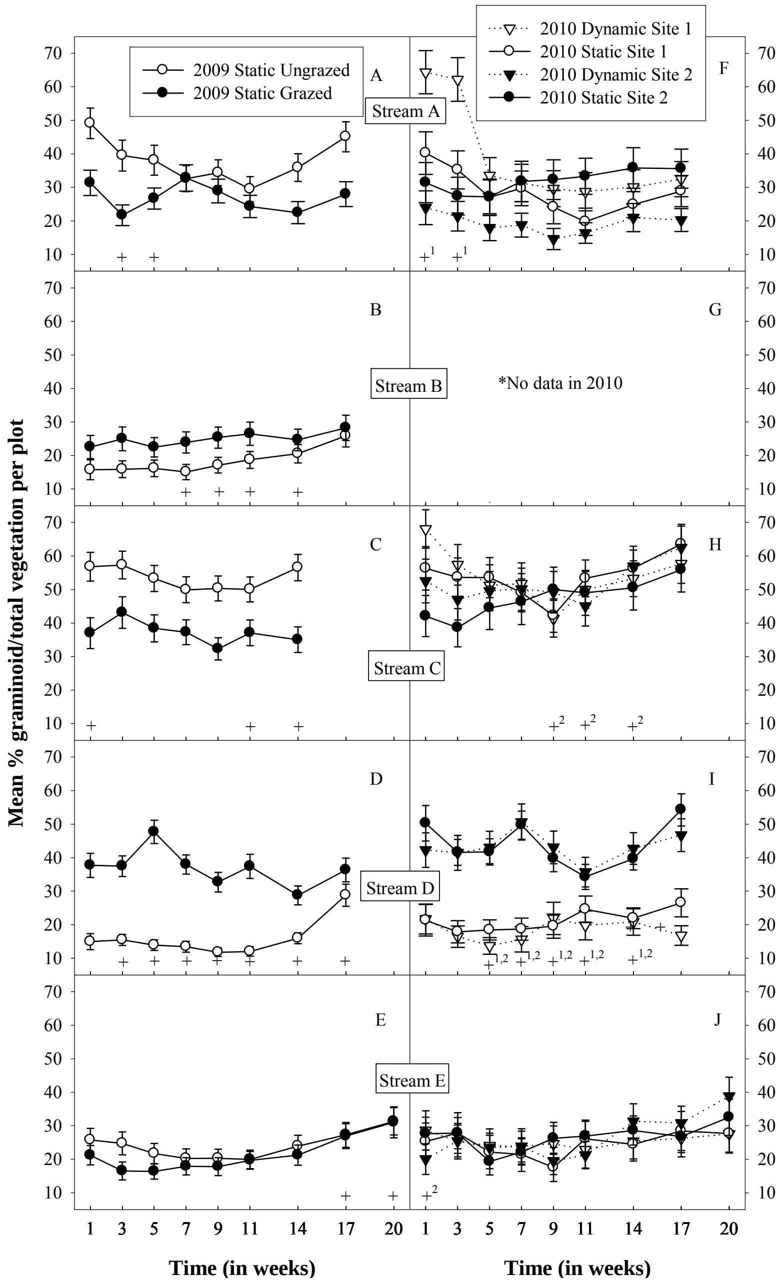

Fig. 9. The effect of grazing (A-E) and plot type (F-J) on mean % graminoid/total vegetation (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

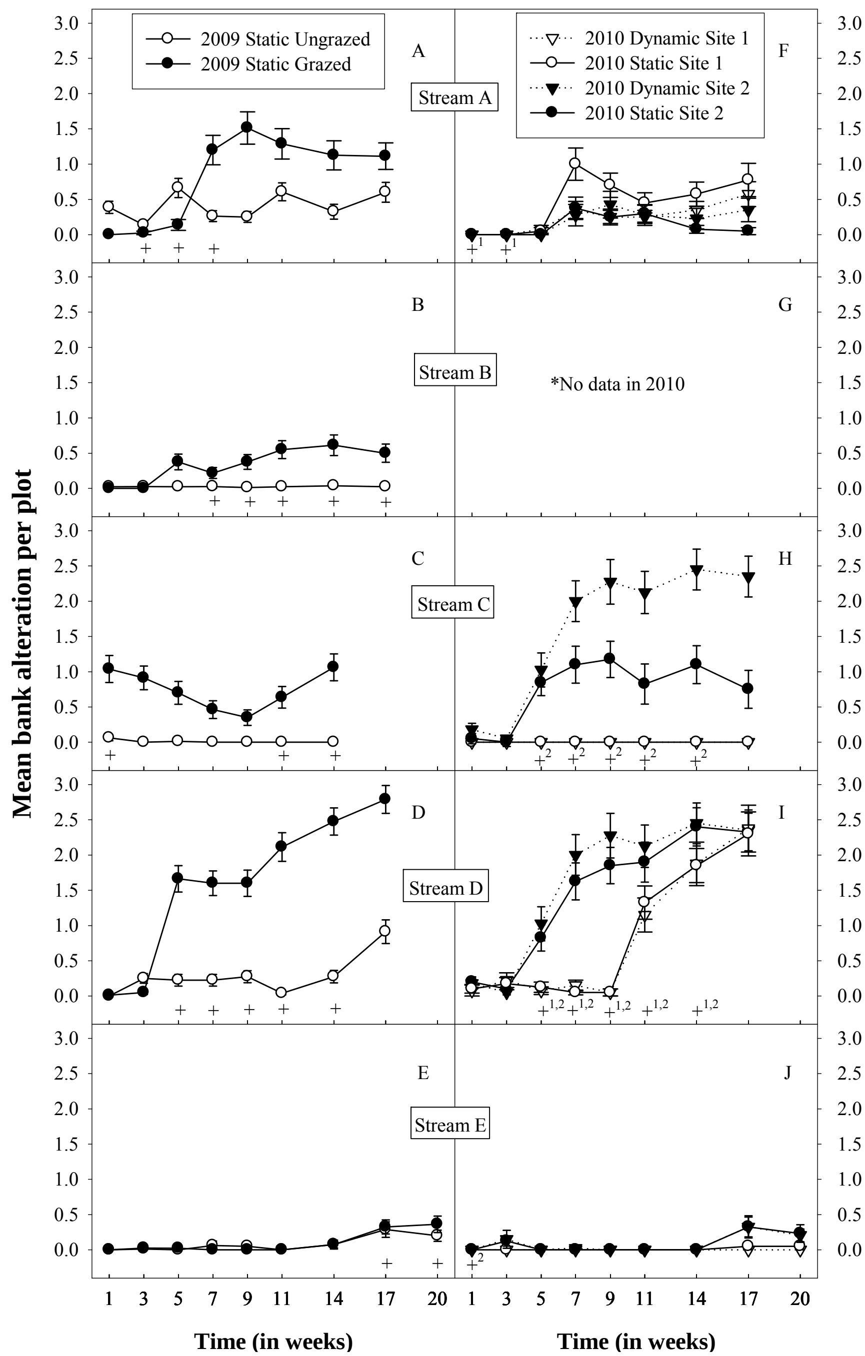

Fig. 10. The effect of grazing (A-E) and plot type (F-J) on mean bank alteration (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

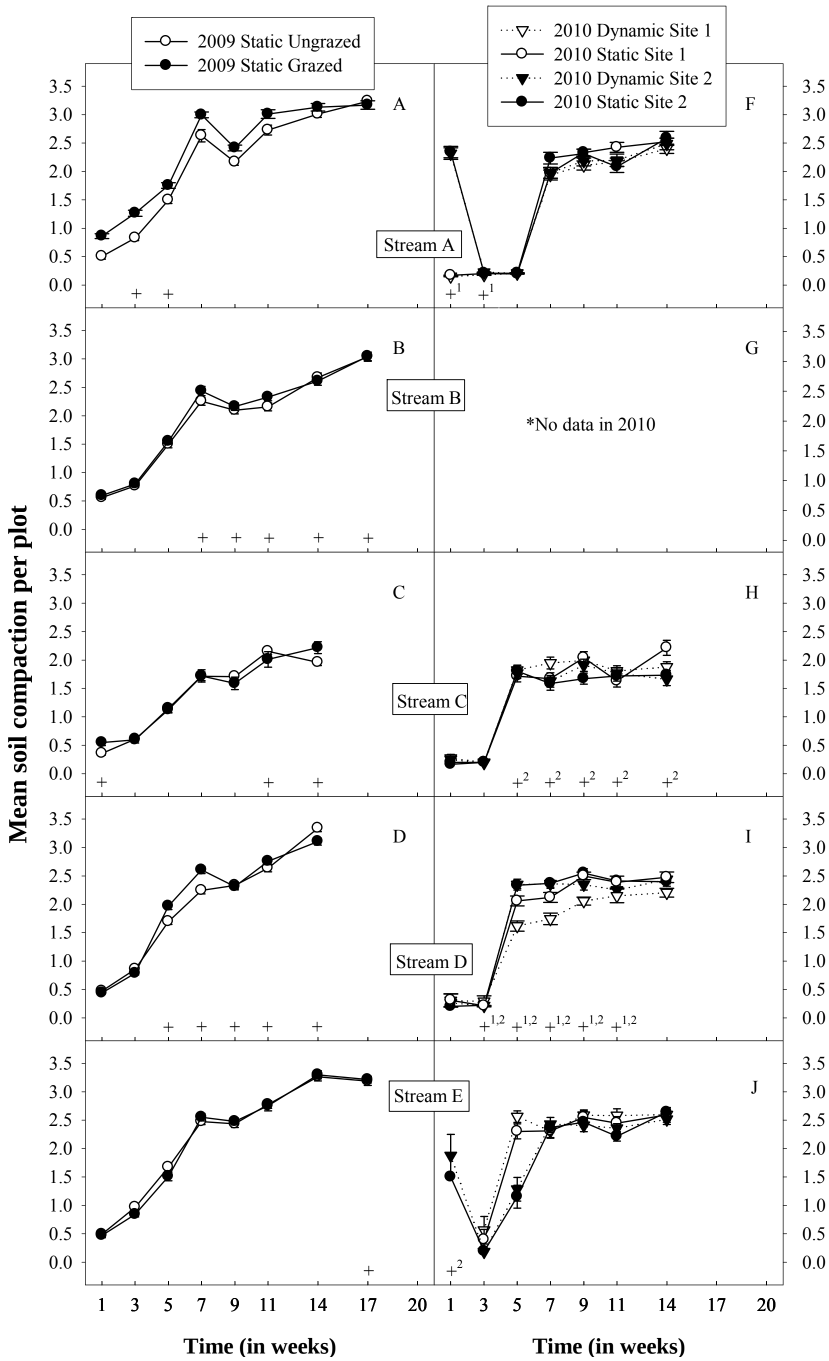

Fig. 11. The effect of grazing (A-E) and plot type (F-J) on mean soil compaction (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

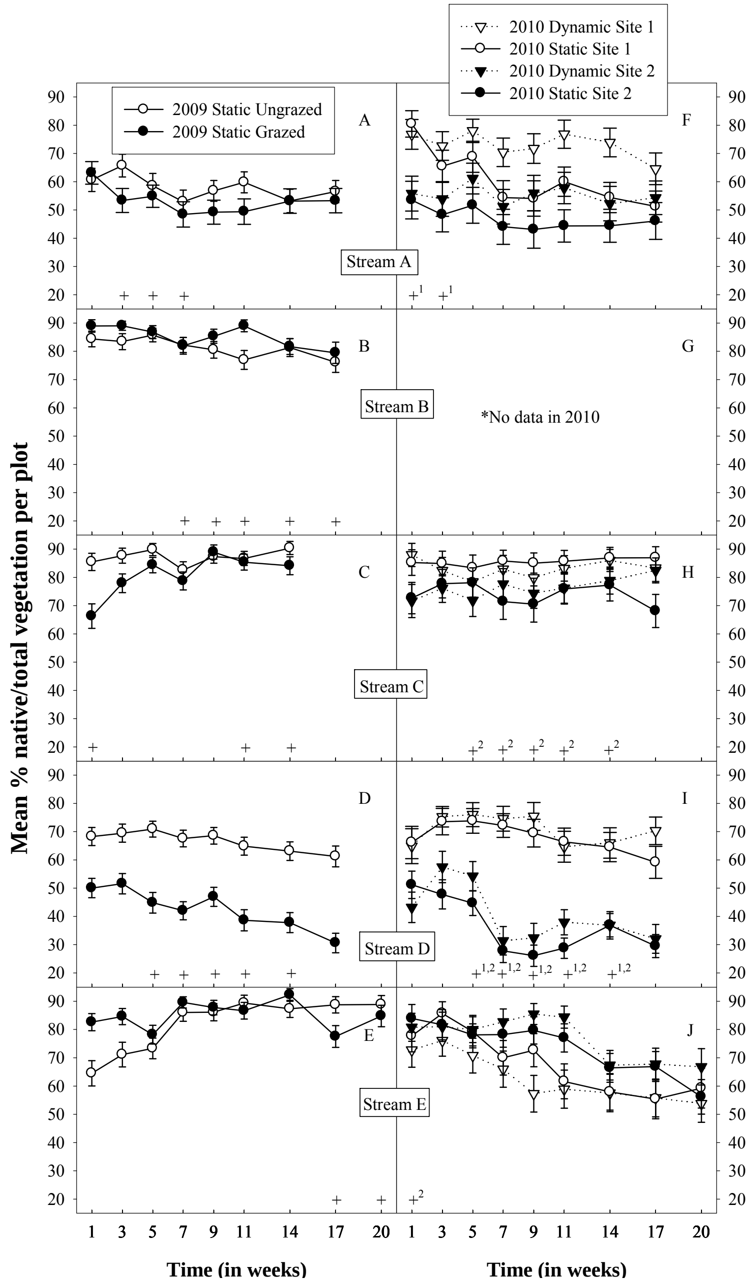

Fig. 12. The effect of grazing (A-E) and plot type (F-J) on mean % native/total vegetation (± 1 SE) per plot over the 20 week growing season for 5 streams, from ~June 10th to October 20th in 2009 and 2010. Plus signs above the week axis indicate times when cattle were present on the site. Subscripts above the plus signs indicate which site was grazed in 2010.

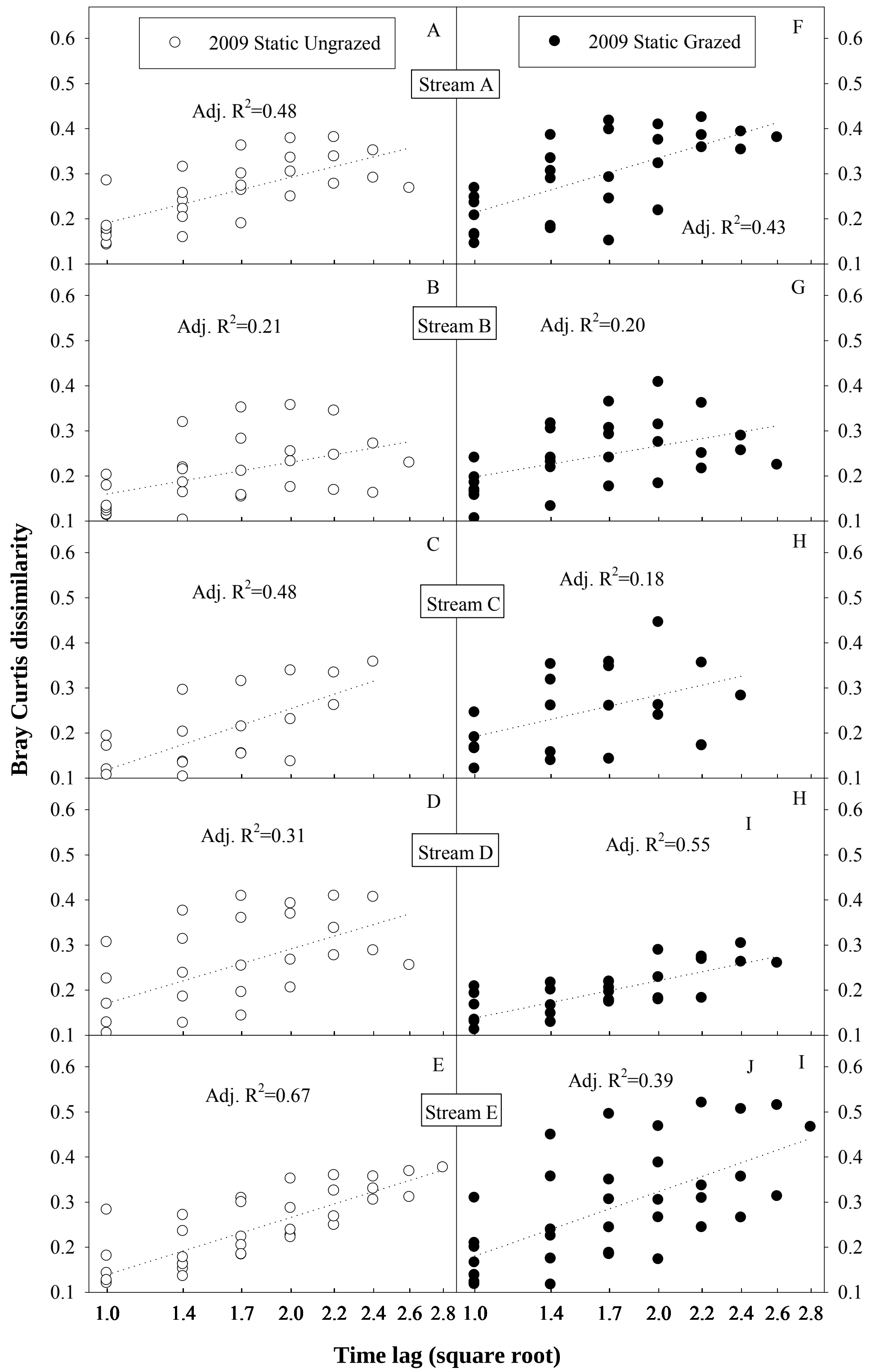

Fig. 13. Bray-Curtis dissimilarity index regressed against time lag (square-root) for the 2009 seasonal trend and comparisons of grazed and ungrazed sites (A-J).

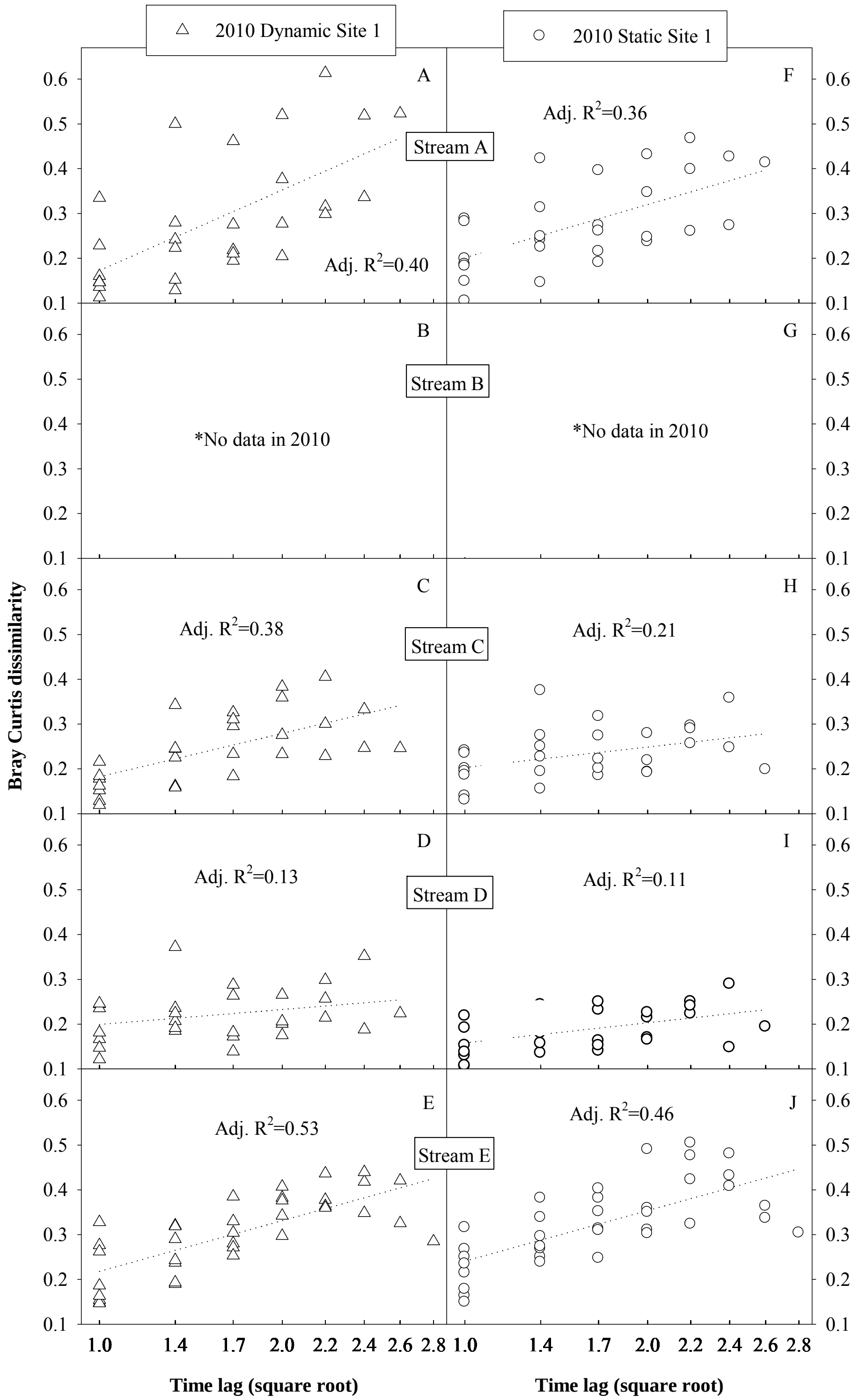

Fig. 14. Bray-Curtis dissimilarity index regressed against time lag (square-root) for the 2010 seasonal trend and comparisons of dynamic and static plots at site 1 (A-J).

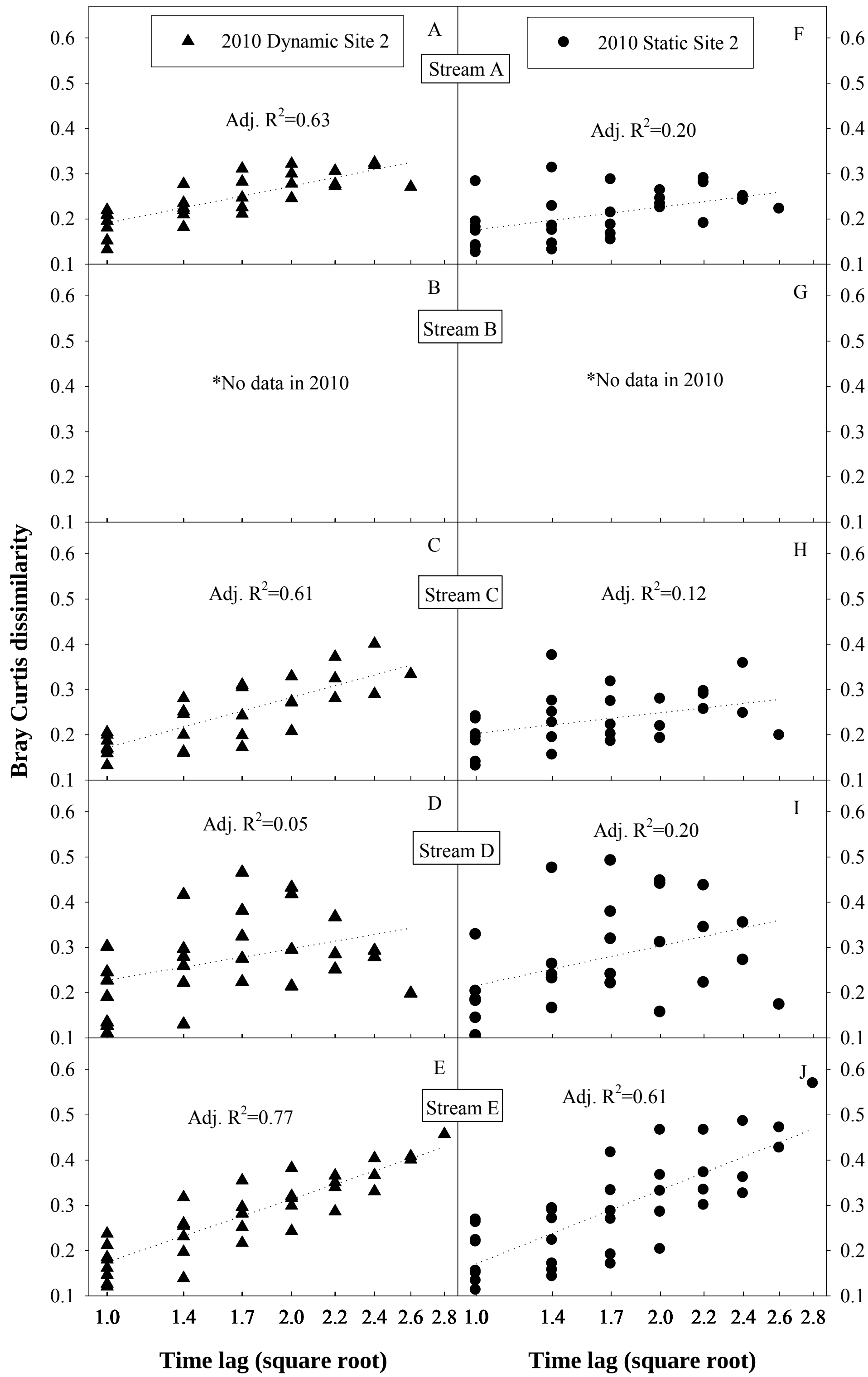

Fig. 15. Bray-Curtis dissimilarity index regressed against time lag (square-root) for the 2010 seasonal trend and comparisons of dynamic and static plots at site 2 (A-J).

Grazing

Cattle grazing had a similar effect on the metrics live vegetation cover, litter, bare ground, and bank alteration at all streams, while species richness, % forb, wetland indicator rating, % graminoid, soil compaction, and % native responded differently to cattle grazing at individual streams. Live vegetation cover and litter varied significantly by grazing at three of the five streams (Table 3), but litter values tended to be higher in grazed sites (Fig. 6A-E), and live vegetation cover to be lower in grazed sites (Fig. 3A-E). Bare ground varied significantly by grazing at all streams (Table 3), and was generally higher in grazed sites (Fig. 7A-E). Wetland indicator rating varied significantly by grazing at four of the five streams (Table 3), but there were mixed results with some streams having a positive effect and others having a negative effect (Fig. 8A-E). Species richness, % forb, and % graminoid varied significantly by grazing at two of the five streams (Table 3), although both also had a mixed effect (Fig. 4A-E, 5A-E, and 9A-E). Bank alteration increased with grazing (Fig. 10A-E), while soil compaction was unaffected (Fig. 11A-E), and % native had mixed results (Fig. 12A-E). Live vegetation cover, species richness, % forb, litter, bare ground, and bank alteration were responsive to grazing within the season, showing some decreases and spikes in grazed sites, whereas wetland indicator rating, % graminoid, soil compaction, and % native showed little response to cattle grazing (Fig. 3A-E to 12A-E). There were varying levels of significance for the interaction of grazing with week. Live vegetation cover and litter varied significantly by the interaction of grazing and week at all streams, and bare ground, by four of the five streams (Table 3). Species richness and % forb varied significantly by the interaction of week and grazing at three of the five streams, while wetland indicator rating and % graminoid varied by only one of the five streams (Table 3). Bray-Curtis analysis indicated that grazed sites experienced less seasonal variation than ungrazed sites, demonstrated by higher R-squared values in the grazed sites than in the ungrazed sites (Fig. 13).

Plot type and site

Plot type (i.e. static or dynamic) did not have a strong effect on any of the metrics in this study, and site (i.e., 1 or 2) was more important than the type of plot used. For all vegetation metrics, the two plot types within a site mirrored one another, and there was little difference between the two plot types (Fig. 3F-J to 12F-J). Live vegetation cover, litter, bare ground, and wetland indicator rating varied significantly by plot type at only one of the four streams, while species richness, % forb, and % graminoid did not vary significantly by plot type at any of the streams (Table 4). On the other hand, live vegetation cover and wetland indicator rating varied significantly by site at three of the four streams, while % forb, litter, bare ground, and % graminoid varied significantly by site at two of the four streams, and species richness varied significantly at one of the four streams (Table 4). The interaction of plot type and site did not have many significant results either. Species richness, % forb, litter, and wetland indicator rating did not vary significantly by the interaction of plot type and site at any of the streams (Table 4). Live vegetation cover, bare ground and % graminoid varied significantly by the interaction of plot type and site at only one of the four streams (Table 4). Live vegetation cover, % forb, and bare ground varied significantly by the interaction of week and site at all streams, while species richness, litter, wetland indicator rating, and % graminoid varied significantly at three of the four streams (Table 4). Percent forb varied significantly by the interaction of week and plot type at two of the four streams while live vegetation cover, litter, and bare ground, and % graminoid varied significantly at only one of the four streams, and neither richness nor wetland indicator rating varied significantly at any of the streams (Table 4). Neither bank alteration, soil compaction, nor % native was affected by plot type (Fig. 10-12F-J). The Bray-Curtis time lag analysis indicated that there was less dissimilarity at a site when a dynamic plot was used than a static plot (Fig. 14 and 15).

CHAPTER 4

DISCUSSION

Seasonal variation

Metrics that are stable across a season are suitable for long-term monitoring projects because they allow the land manager and researcher to take a measurement at any time within a season, and can be used to compare results over time. However, a metric that is stable across a season may not be able to capture the effects of management, since it may not respond quickly to change. Since some metrics are very sensitive to within-season variation, sampling time should be an important consideration when using these metrics for long-term monitoring. If there is a predictable seasonal pattern, then a manger should either sample at a similar time within the season in subsequent years, or may also choose to take measurements more than one time within a season for future comparisons.

In this study, the metrics that were highly sensitive to seasonal variation were live vegetation cover, species richness, % forb, litter, bank alteration, soil compaction, and to a lesser extent, bare ground. The effect of seasonal variation was strongest early and late in the growing season. This was evident by strong unimodal and negative unimodal relationships in many of the metrics, which could have been avoided by not sampling in the beginning and end of the season. To maintain consistent results across years, land managers should sample at the same time each year and avoid sampling on extreme ends of the growing season. In this study, the extreme ends of the season were in June (weeks 1 and 3) and October (Weeks 17 and 20), while the time period from July-September (weeks 5 to 14) was less affected by seasonal variation, and would be a good time for monitoring activities to take place. The metrics that were stable across the season were wetland indicator rating, % native, and to a lesser extent, % graminoid. These metrics would be suitable only for long-term monitoring of changes in the community since they were generally unresponsive to management within the season. Bray-Curtis time lag analysis indicated that sites become more dissimilar with increasing time lags across a season, which was in agreement with most time lag studies (Collins et al. 2000).

Grazing

The metrics that responded rapidly to cattle grazing within the season were live vegetation cover, species richness, % forb, litter, bare ground, and bank alteration, and would be suitable for assessing the effects of management on the short-term at an individual site. The metrics that responded to grazing similarly at all sites were bare ground, litter, and live vegetation cover, and would be useful metrics for comparing sites with differing grazing strategies to determine which one causes the least disturbance. These results were in agreement with those of other studies that found cattle grazing to be associated with an increase in bare ground (Hayes and Holl 2003, Schulz and Leininger 1990, Wahren et al. 1994) and litter (Wahren et al. 1994), and a decrease in live vegetation cover (Hayes and Holl 2003, Schulz and Leininger 1990).

Plot type and site

Generally the static and dynamic plots within a site mirrored one other, and the two sites at a stream were more different from one another than the two plot types within a site. This was probably due to the fact that we used the PIBO (2010) protocol for sampling, which places the greenline plot between the lower limit, where the streambed meets the bank, and the upper limit, which is the first flat depositional feature above bankfull, even if it contains only bare ground (Leary and Ebertowski 2010). In small western streams, this comprises a relatively small area, and acts to constrain the location of the greenline plot to be within the streambank. Recording the vegetation of the streambank is important in riparian areas because these plants act to stabilize the bank from degradation and erosion, an important ecosystem function (Micheli and Kichner 2002). This constrained greenline location has advantages over similar greenline protocols like that of the MIM or Winward that base the location of greenline on a "continuous line of vegetation" (Winward 2000), or the first plot with > 25% perennial cover up to 6 m from the stream edge (Burton et al. 2011). These are vague descriptors and may result in a plot that is not within the streambank.

By using the PIBO protocol, there does not appear to be a need for permanent plots since the protocol that is currently being used (with dynamic plots) yields similar responses in the metrics. Furthermore, the PIBO protocol utilizes a great number of plots at each sampling reach which controls for variation between plots and small spatial differences in an area. While permanent plots may be appropriate for a terrestrial system, riparian plant communities are in a constant flux, and dynamic plots are able to capture the dynamic nature of the stream. While there was not any difference between the two types of plots, permanent plots are time consuming, may be destroyed by a naturally-changing river, and are difficult to re-locate (Beever et al. 2005, Gerber et al. 2008). Since dynamic plots are much quicker to place and less costly, they are a superior choice for riparian areas.

CHAPTER 5

CONCLUSIONS

In conclusion, monitoring riparian vegetation is important for understanding the effects of management on an ecosystem. From this study, we found that seasonal variation is an important consideration for some metrics, and does not affect others. Additionally, we found that some vegetation metrics are better suited for assessing short-term effects of cattle grazing, while others are better-suited for long-term management goals. Last, we found that permanent plots are not suitable or necessary in riparian vegetation monitoring. We hope that this information will be a valuable resource for land mangers interested in monitoring riparian resources to aid in both implementing a monitoring plan and understanding the results of an assessment, and ultimately aid in better land management practices.

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