DEVELOPMENT AND EVALUATION OF A TECHNIQUE FOR EVALUATING RIPARIAN VEGETATION CHANGE IN THE TALLGRASS PRAIRIE

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By

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The undersigned, appointed by the Dean of the Graduate School,
have examined the thesis entitled.

DEVELOPMENT AND EVALUATION OF A TECHNIQUE FOR EVALUATING RIPARIAN VEGETATION CHANGE IN THE TALLGRASS PRAIRIE

Presented by Mark Andrew MacKay

A candidate for the degree of

Master of Fish and Wildlife Science

And hereby certify that in their opinion it is worthy of acceptance.

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ABSTRACT

North America's tallgrass prairie region is one of the world's most endangered ecosystems. Recent management and research efforts have focused on the effects of anthropogenic change to upland components of the tallgrass prairie, however, little is known regarding change to riparian vegetation. Nevertheless, riparian vegetation habitat plays a significant role in the conservation of both terrestrial and aquatic biodiversity; furthermore, anthropogenic modifications to this system have often occurred before the onset of modern ecological inventories. As a result, managers, planners, and policy makers often make decisions that impact riparian vegetation without sufficient information regarding presettlement vegetation. To provide data that can be used in the decision-making process, we developed and evaluated a technique utilizing General Land Office (GLO) survey notes to characterize historic vegetation, and Digital Orthophoto Quarter Quads (DOQQs) to characterize contemporary riparian vegetation, within a Geographic Information System (GIS). The methodology provides an objective, scientific approach to providing the necessary data to make informed management, planning, and restoration decisions regarding riparian systems. A comparison between historic and contemporary riparian vegetation indicated that profound changes in vegetation have occurred over time and that vegetation differences between riparian zones in different ecological subsections are less pronounced than they were before European settlement. Our findings suggest that, contrary to previous research and speculation, historic riparian zones contained a significant amount of prairie, and that the extent varied among watersheds. We found no

remaining riparian prairie today. This research contributes baseline data to facilitate the evaluation of vegetation change and the success of management and restoration efforts.

INTRODUCTION

Grassland vegetation is of global significance as a result of its rarity and threatened status. Noss et al. (1995) has identified North America's tallgrass prairie region as one of the world's most endangered ecosystems. Anthropogenic actions such as agricultural development, fire suppression, and eradication of large, free-ranging herbivores have contributed to the loss of more than 99 % of Missouri's pre-settlement tallgrass prairie (Samson and Knopf 1994, Noss et al. 1995). Recent management and research efforts have focused on the effects of anthropogenic change on upland components of the tallgrass prairie; however, little is known regarding the historic condition of riparian vegetation in this system.

Although riparian areas make up only a small proportion of the landscape, their importance in maintaining water quality and protecting the biological health of both terrestrial and aquatic systems has been well documented (Peterjohn and Correll 1984, Barling 1994, Verry 2000, Perkins 2003). Much of the available literature has focused on vegetation change in areas protected from development, and ignored historic riparian vegetation condition prior to European settlement. For example, research in one of the largest remaining remnant tallgrass prairies (in Eastern Kansas) indicated that the most significant change to prairie system over the past 100 years has been an increase in forested areas, particularly riparian gallery forests (Briggs et al. 1998). Unfortunately, most anthropogenic modifications to the tallgrass prairie occurred prior to the initiation of ecological inventories, providing managers and policy makers with insufficient information regarding the riparian zone. As a result, land use planning decisions are often based on perception rather than factual information. With this in mind, we set out to establish a technique to assess both historic and contemporary vegetation in northern Missouri's tallgrass prairie riparian zone and to document temporal vegetation changes in this system.

General Land Office notes have been used to reconstruct historic vegetation and address ecological questions in upland systems for many years, however, these notes have not been utilized to their potential as a resource for assessing historic riparian vegetation (Rodgers 1979, Schroeder 1981, Edgin1997). This is unfortunate, considering the significance of the riparian zone and the potential utility of this source of baseline data.

Digital Orthophoto Quarter Quads (DOQQs) have only recently become available and therefore have been used only infrequently by ecologists. By contrast, aerial photographs have been used for decades in ecological research (Barton 1985, DeWitt 1998, Bolduc 1999). We expect that the user-friendly formatting of DOQQs and the wealth of information contained within them will bolster their use in a broad range of research disciplines.

We implemented and evaluated an approach to characterize historic and contemporary riparian vegetation using GLO survey notes and DOQQs in a GIS. Our technique provides an objective, scientific approach to generating the necessary data for making informed management, planning, and restoration decisions regarding this system. Our approach enabled us to determine the extent of prairie vegetation in the historic riparian zone and to measure differences in the vegetation type between Missouri ecological subsections, stream size classes, and across time. Additionally, this research provides valuable contemporary baseline data that should be of great utility in assessing future change in riparian areas that will help in evaluating the efficacy of future management and policy efforts.

Objectives:

1. Develop a methodology for quantitatively analyzing temporal riparian vegetation change since early European settlement of the Tallgrass Prairie in Missouri.
2. Using the approach described above**,** characterize historic (i.e. early settlement) riparian vegetation structure for a sample of streams in Northern Missouri's Central Dissected Till Plains ecological subsection stratified by ecological subsection and stream size.
3. Characterize contemporary riparian vegetation for the same stratified set of streams.
4. Quantify change to the structural characteristics (e.g., general vegetation physiognomy) of riparian buffer zones in the Central Dissected Till Plains between pre-European and contemporary vegetation conditions.

Study Area:

Our study area was confined to Missouri's Central Dissected Till Plains Ecological Section, which extends north from Missouri into Iowa and west into Kansas and Nebraska (Figure 1). The research area was further restricted to three ecological subsections: the Chariton River Hills, the Claypan Till Plains, and the Deep Loess Hills (Nigh and Schroeder 2002).

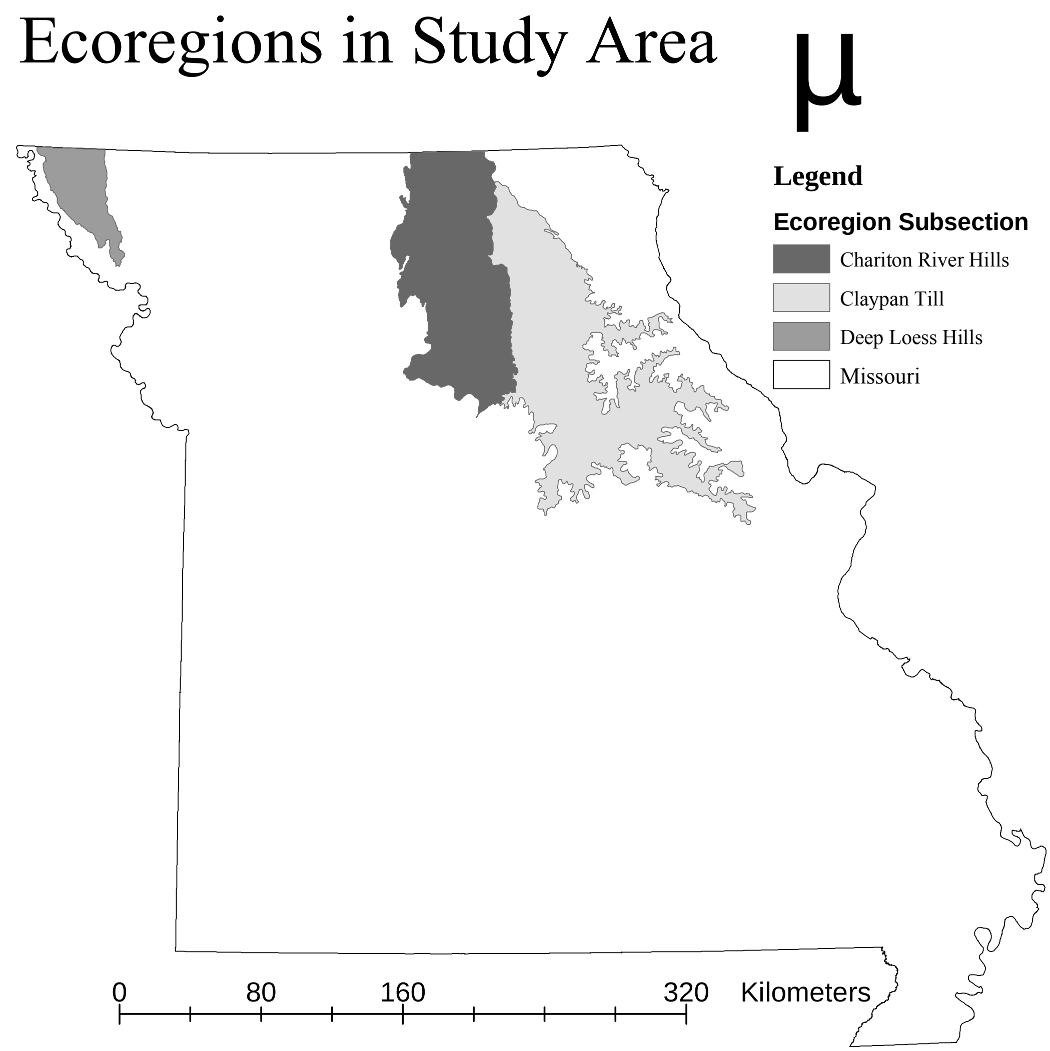

Figure 1.

Figure 1. Ecological subsections selected to stratify study area across the northern Missouri landscape.

The topography of the Central Dissected Till Plains was greatly altered by glaciation. The weight and movement of ice in this region produced relatively flat to undulating plains that were later dissected through fluvial processes (MDC 1997). Streams in this region are generally low in gradient and highly meandering relative to other North American streams (Rabeni 1996). The directionality of the streams in the region varies with subsection (MDC 1997, MDC 1998, MDC 1999). Missouri's glaciated plain is known for its deep, rich soils and parent materials, often reaching depths of 90 m (MDC 1998). These parent materials of these soils were deposited in the Pleistocene period and are essentially of two origins: loess, which is a fine glacial dust blown by the wind; and glacial till, which is a coarser soil resulting from bedrock that was fractured beneath glaciers. Years of postglacial fluvial erosion and deposition exposed previously deposited soils along watercourses and, in some regions, the underlying bedrock (MDC 1994, MDC 1997). Since glaciation, drainage systems have been greatly modified while upland areas have been much less altered.

The climate in this region is considered continental, with average temperatures ranging from January lows of approximately 7° C to July highs of approximately 30° C. Average annual precipitation is approximately 880 mm (MDC 1997). Precipitation generally coincides with the onset of the growing season which is typically followed by extended periods of drought at the end of the growing season (July and August). A general gradient of increasing levels of precipitation eastward across the region exists (Vankat 1979, Ryan 1990).

At the time of European settlement, Missouri had at least 6,000,000 ha of prairie (MDC 1997). Since settlement, the Central Dissected Till Plains ecological section has gone through some of the most profound modifications of any region in the country. This system is still driven by disturbance, however, the type and intensity have changed (Samson and Knopf 1994, Bailey 1996). Because the highly productive soils in this region are ideal for grain and livestock production, the predominant contemporary land use in the region is agriculture (MDC 1999). The absence of contemporary natural disturbances such as fire and grazing by native ungulates has allowed many of the remnant prairies not in row crop production to be overtaken by invasive trees and shrubs. Of the 6,000,000 ha of prairie that existed in Missouri at the time of European settlement, less than 36,000 ha of prairie remain today (MDC 1997, MDC 1999). Of this contemporary prairie, little, if any, is found in the riparian zone. More than 90 % of the land in this contemporary agricultural landscape is privately owned (MDC 1999).

The streams in this region have been altered for human purposes, causing major changes to stream morphology and the riparian vegetation. Most of the headwater streams in the contemporary tallgrass prairie have been modified by anthropogenic disturbances such as plowing and draining (Rabeni 1996). Many of the numerous midsize streams in this ecological subsection have been channelized, disturbing the stream's equilibrium by increasing stream bank erosion, lowering ground water levels, and dramatically altering riparian vegetation potential. Large contemporary rivers have also been channelized and frequently separated from their floodplains by levees (Rabeni 1996). Most of these modifications are so severe that bio-technical remediation does not appear to be practical (Pitchford 1994).

Our research focused on three ecological subsections. The following descriptions provide a physiographic context for each of the subsections:

Chariton River Hills

Located in Northcentral Missouri, the Chariton River Hills subsection extends north to the Iowa border and occurs between the Grand River basin and the Claypan Till Plains subsection. The soil in this subsection is primarily developed over a pre-Illinoian till ranging in depth from 1 m to more than 60 m. The till is covered by a thin veneer of loess, typically less than 3 m. The Chariton River Hills are a relatively rugged subsection especially when compared to neighboring Grand River Hills or Claypan Till Plains subsections. Many of the uplands are relatively smooth with a relief of less than 30 m whereas hilly sections and valleys may have a local relief of greater than 60 m. Valley bottoms in the section are generally wide and poorly drained. This subsection contains a wide variety of streams ranging from intermittent creeks to large rivers, all of which generally flow in a southerly direction into the Missouri River. The entire ecological subsection lies inside of the NRCS 1028 4-digit watershed (Nigh and Schroeder 2002).

Claypan Till Plains

The Claypan Till Plains ecological subsection is situated in Northeastern Missouri between the Chariton and the Wyaconda River watersheds. The resistant nature of the clay in this subsection has minimized the effect of fluvial processesin this subsection. Therefore, little of the underlying bedrock or soils have been exposed and the topography of the region has not been as dramatically shaped by fluvial processes. The result is a relatively flat to undulating landscape with local relief of no more than 30 m. The watercourses in this ecological subsection range from small intermittent streams to large, perennial rivers and generally flow southeast into the Mississippi River. This ecological subsection lies entirely within the NRCS 0711 4-digit watershed (Nigh and Schroeder 2002).

Deep Loess Hills

Located in the Northwestern corner of Missouri, the Deep Loess Hills subsection consists of relatively thick loess deposits of up to 30 m, which completely cover the underlying glacial till, shale, and limestone. In areas where the loess has eroded, a steep terrain with relief of more than 61 m often results. This region is so deeply covered in loess and till that the underlying geology has no significant impact on surficial features such as vegetation. Although this subsection is relatively minor in Missouri, it extends into Iowa where it is much more expansive. The subsection contains relatively small perennial and ephemeral streams that generally flow in a southwesterly direction into the

Missouri River. The entire ecological subsection falls in the NRCS 1024 4-digit watershed (Nigh and Schroeder 2002).

METHODS

Site Selection and Stratification Methodology

We selected Missouri's Central Dissected Till Plains ecological subsection, part of the tallgrass prairie, as our study area (Nigh and Schroeder 2002). We used ArcInfo 7.1 to store, represent, and analyze all data and for most of our queries, summaries, and visual representations. ArcGRID was used for the hydrological modeling component while ArcView was used for simple queries and summaries. SAS was used for all inferential analyses.

We stratified our study area by three subsections and three stream size classes. The following subsections were included: the Chariton River Hills, the Claypan Till Plains, and the Deep Loess Hills. In order to identify three stream size classes, we created a hydrological model using Arc Info's Hydrological Modeling Tools and the RF3 100K hydrography layer to determine drainage area and used it as a surrogate for stream order for all stream reaches in the study area. The following stream size classes were selected through our modeling: 1) 2,000-5,000 ha drainage area; 2) 8,000-25,000 ha drainage area; and 3) greater than 75,000 ha drainage area.

In order to identify locations where historic vegetation data were available, we intersected the stream network coverage described above with a 1.6 km fishnet representing the GLO Public Land Survey System (PLSS). This approach enabled us to identify all locations where both our stratification criteria were met and GLO surveys were performed in the riparian zone.

Of the potential riparian sites identified in the process described above, we randomly selected 40 locations for each combination of stream size class and ecological subsection. An exception to this stratification protocol was required for the > 75,000 ha stream size class grouping in Missouri's Deep Loess Hills because no streams of this magnitude were located within this ecological subsection.

Historic Database Development:

GLO Notes.--The Public Land Survey System, mandated in the ordinance of 20 May 1785, provided the basis for surveys and legal land descriptions for what is presently considered the United States. This system, as administered through the GLO since 1812, was the official means of dispensing land in the public domain. Settlers could not acquire a title for a parcel of land until a survey was completed. Land was parceled into 6 x 6 grids of 2.6 km^2 (1 mi^2) sections, each grid represented a 93.6 km^2 (36 mi^2) area known as a township. Although the primary objective of the PLSS was to survey the land for settlement, a secondary objective was to describe the condition of the surveyed land. Surveyor notes included systematic descriptions depicting water features, vegetation condition, and a qualitative description of the land's suitability for cultivation or timbering. GLO surveys for our study area were completed in the early to mid 1800s (between 1816 and 1846), a time when European anthropogenic influence was nominal. Subsistence agriculture was the primary land use practiced by the few European settlers in the area during this period and such practices had a negligible impact on the study area. However, we only found a few descriptions of subsistence agricultural fields while interpreting the GLO surveyor notes for our entire study area. Nevertheless, the presence of these few settlers negates the use of GLO data to provide a true assessment of “pre-European settlement” vegetation. We therefore chose to use the term “historic” rather than the conventional and inappropriate term “pre-European settlement” to describe the vegetation condition of this period. Semantics aside, the GLO survey notes serve as a source of data prior to the profound changes that resulted from intense European settlement and the agricultural revolution.

Arc Macro Language.-- The Government Land Office notes were put into a digital format using an Arc Macro Language (AML) program which acted as an interface to capture, store, convert measurement units, geo-reference, and project information transcribed from the GLO notes into a GIS (Compass 1994). Microfiche copies of the GLO survey notes were transcribed by a single individual to ensure consistency and quality control. The individual responsible for GLO note transcription trained for several weeks by transcribing townships in other prairie areas to ensure better familiarity with the GLO notes, the transcription process and to develop a standardized protocol. The surveyor’s original measurement units of chains (66 ft or 20.12 m) and links (7.92 in or 20.11 cm) were converted into metric units and georeferenced based upon the “corrected” survey locations provided in the notes. These data were then projected using the Universal Transverse Mercator (UTM) zone 15 projection with the North American 1983 datum (NAD83).

Our interest was in characterizing the general vegetation structure and distribution rather than detailing species occurrences or vegetation associations. More specifically, our primary objective was to assess the amount of prairie, if any, in the historic and contemporary riparian zones. To accomplish this, we transcribed the surveyor line descriptions directly into our database exactly as they were written in the GLO notes. We believed that maintaining as much detail as possible would ultimately better facilitate unanticipated future queries. Surveyors generally described vegetation as timber or prairie, rarely a combination of the two (e.g., savanna) (Batek, 1998). After the historic vegetation transcription process was completed, we added a new vegetation classification field and reclassified our database. The new field contained slightly broader general vegetation classifications conditions (e.g., prairie or wooded). For instance, the wooded class in this new field included the various descriptions used by different surveyors to describe forested or otherwise wooded conditions (e.g., light timber, brushy timber, tree species listings, or good timber). This dichotomous approach worked well for characterizing riparian vegetation physiognomy. In addition to the vegetation line descriptions, we recorded understory vegetation condition, cardinal directions for all survey lines, subsection, stream size class, stream width, and direction of stream flow (ranging from 0° to 360°). Lastly, surveyor name, contract, survey date, microfiche film number, volume, and page number were all captured in our historic database.

Contemporary Database Development

In developing our contemporary database, we used data derived from DOQQs to establish contemporary baseline riparian vegetation conditions for a sample of transects in each of three stream classes and three ecological subsections.

Digital Orthophoto Quarter Quadrangles.-- Digital Orthophoto Quarter Quadrangles are “distortion-free”, digital aerial photographs produced by the U.S. Geological Survey (USGS). DOQQs have been georeferenced and rectified, providing the image attributes of an aerial photograph and the geometric qualities of a map. The digital format in which DOQQs are stored easily overlays with other data in a GIS. DOQQ images are projected into UTM using the NAD83 with boundaries that are based on the familiar USGS 7.5 minute, 1:24,000 topographic maps. More detailed information regarding DOQQs can be found at the USGS website:

http://geography.wr.usgs.gov/doq

A DOQQ is essentially a raw image, requiring either manual or automatic classification to have any utility in characterizing vegetation. We chose a manual approach under the assumption that it would result in a more accurate characterization of the contemporary riparian vegetation and require less time to edit corrections. We characterized contemporary (1995-1997) riparian vegetation for the same randomly selected, stratified transects used in the historic database. However, some of the transects had to be adjusted to compensate for stream channel migration occurring between the time the GLO surveys were compiled and when the DOQQ images were acquired.

We classified contemporary riparian vegetation along 4 km transects (2 km on each side of the stream) using DOQQ images as a background land cover layer. We used a “heads up” approach to digitizing transects in the ArcEdit module of ArcINFO. Nodes were placed at all breaks in the land cover by zooming into a portion of each transect, identifying the location of the vegetation break, and panning to the next segment to repeat the process. After all transect breaks were identified, all arcs between nodes were attributed with the appropriate land cover classification (e.g., wooded, row crop agriculture, grassland, open water, and bare ground). Upon completion of a transect, each arc segment was verified to ensure that it was attributed appropriately prior to importing another DOQQ and repeating the process. Ancillary cartographic data were used to supplement the DOQQs in identifying prairie because this land cover was difficult, if not impossible, to assess from a raw DOQQ image alone. Even with the inclusion of these ancillary data, relatively little prairie riparian vegetation was found in the contemporary time period.

Prior to analyzing our data we reclassified our initial land cover classification of the contemporary vegetation: grassland, row crop agriculture, other agriculture and bare-ground, shrub, wooded, open water, and urban. In the process we aggregated grassland, row crop agriculture, other agriculture and bare-ground into one general agriculture category. These seemingly disparate groups were lumped together because 1) the vegetation condition represented in the image is only truly representative of a specific season or year and land use practices in this agricultural landscape changed frequently and 2) some agricultural land use types are difficult to differentiate from one another using DOQQs. Also, our objective in characterizing the contemporary riparian vegetation was to make a general assessment of contemporary vegetation and how it has changed from historic times, rather than differentiating between contemporary vegetation in agricultural land cover types. Lastly, from the perspective of water quality and aquatic and terrestrial biotic integrity, agriculture is neither a natural nor beneficial land cover. This rationale allowed us to aggregate all agricultural land uses into a single category.

Ground Truthing/ Accuracy Assessment.--Verification of contemporary land cover types was easy relative to historic land cover, which had only one suitable source for vegetation condition (the GLO survey notes). Accordingly, we were able to perform accuracy assessments by ground truthing the contemporary riparian vegetation condition. In order to ground truth, we produced maps for use in field verification. These maps contained only the essential information needed to locate and verify our riparian transects (i.e., county roads, perennial stream network, study transect line work, and a scale bar). These maps were taken into the field and an assessment was performed on all classifications.

RESULTS

Data Analysis

We used a stratified sampling design to compare spatial, temporal, and stream size class differences in riparian vegetation. Three ecosystem subsections, three stream size classes, and interactions of the subsections and size classes were compared to determine whether significant relationships ($P \leq 0.05$) existed within and between the two time periods. Coarse summary analyses were performed by calculating frequencies to assess total land cover means for all transects within each stream size class and ecological subsection. We also summarized and compared combinations of our stratification parameters such as mean, median, standard deviation, and variance. This analysis allowed us to look for broad patterns within and between time periods.

Prior to performing any inferential analyses, we ran a Wilkes-Shapiro test to determine the distribution of our data. This procedure indicated that our data were not normally distributed ($P = 0.0001$). Without a normally distributed data set, we had two options: 1) use a nonparametric test; or 2) transform our data prior to running an Analysis of Variance (ANOVA). The latter was chosen because it provided a more robust design (Conover and Iman 1981). We ran a rank transformation procedure on our data prior to performing a General Linear Model (GLM) on the transformed (i.e. ranked) data (SAS Institute 1989). The ANOVA GLM was used to determine whether the patterns we predicted in addition to those observed in the summary statistics were truly meaningful. The GLM allowed us to perform numerous specific planned comparisons within our dataset. Rather than simply identifying whether there were differences between ecological subsections or stream size classes, the GLM enabled us to test which ecological subsections, stream size classes, or combinations of the two, were significantly different. The GLM also worked well in analyses with an unbalanced design (e.g., we did not have any streams in the > 75,000 stream size class in the Deep Loess Hills).

Historic (Prairie)

The amount of historic riparian prairie in our selected ecological subsections was quite variable; the Deep Loess Hills ecological subsection had a significant amount of prairie (86 %) in the historic period, while the other two ecological subsections were each comprised of little more then 13 % prairie. A one-way ANOVA indicated that the differences between the three ecological subsections were significant in amount of prairie found in each riparian zone. The F-value was 558.64 (df = 2, P = 0.0001). A probability difference using least square means was performed to determine which of the subsections were significantly different from one another. The Deep Loess Hills ecological subsection, where prairie dominated the historic riparian landscape, was found to be significantly different from both the Chariton River Hills and the Claypan Till Plains ecological subsections (P = <0.05). No significant differences in the amount of riparian prairie vegetation in the Claypan Till Plains and the Chariton River Hills subsections were found (P = 0.9686).

Stream Size Class

The amount of riparian prairie amongst the historic stream size classes ranged from less than 3 % in the largest stream size class (> 75,000 ha) to more than 15 % in the 8,000-25,000 ha class (Table 1). Because the Deep Loess Hills did not contain any streams in the largest stream size class (>75,000 ha), we performed two separate analyses of stream size class. The first analysis included the Deep Loess Hills and therefore compared only the smaller two stream size classes, while the second compared all three stream size classes without the Deep Loess Hills. In comparing the smallest two stream size classes, the amount of riparian prairie vegetation did not vary greatly, and a one-way ANOVA indicated that the small differences between the two were not significant (P = 0.6140).

However, in comparing all three stream size classes, without the Deep Loess Hills ecological subsection, the amount of prairie in the riparian zone was found to vary between stream size classes, ranging from less than 3 % in the largest stream size class to more than 15 % in the 8,000-25,000 ha stream size class. A one-way ANOVA indicated that these differences were significant (P = 0.0001).

A probability difference using least square means indicated that the > 75,000 ha size class was significantly different from both the 2,000-5,000 and the 8,000-25,000 ha size classes (P = 0.0001), but no significant differences were detected between the 2,000-5,000 and the 8,000-25,000 ha stream size classes (P = 0.8611).

Historic (Wooded)

Riparian wooded vegetation ranged from a mean of approximately 34 % in the Deep Loess Hills to almost 61 % in the Claypan Till Plains during the historic period.

A one-way ANOVA performed on all three ecological subsections in the historic time period indicated that these differences were significant ($F = 3.56$, df = 2, $P = 0.0001$). While a probability difference using least square means determined that each ecological subsection subsections was significantly different from the others ($P < 0.005$).

Change

Temporal Change (Prairie Vegetation).--Prairie vegetation occupied between 2 % to almost 90 % of the historic riparian zones we evaluated (Table 1). Conversely, no riparian prairie was found in this system during the contemporary time period. Agricultural means ranged from 39 % in the Claypan Till Plains to more than 66 % in the Deep Loess Hills (Tables 1 and 8) during the contemporary period.

Temporal Change (Wooded Vegetation).--In the historic time period, we found greater than 85 % woody vegetation in both the Chariton River Hills and Claypan Till Plains subsections, while there was less than 15 % woody vegetation in the Deep Loess Hills. Interestingly, the woody vegetation in the Deep Loess Hills more than doubled to almost 34 % in the contemporary period, while the amount of woody vegetation in the Claypan Till Plains and Chariton River Hills dropped precipitously by more than 25 % and 35 %, respectively (Tables 5 and 6). All of these changes were found to be significant ($P = 0.0001$) (Tables 4 and 5). Riparian zones with little woody vegetation in the historic period increased significantly while those with an abundance of woody vegetation in the historic period declined.

Table 1. Historic Prairie Riparian Transect Summaries Stratified by Ecological Subsection and Stream Size Class:

Total Transects (Na); Median percentage of prairie vegetation among transects (Median); Mean percentage of prairie vegetation among transects (Mean); and Standard Deviation for prairie vegetation among transects (Standard Deviation):

Stream Size Class	Na	Median	Mean	Standard Deviation
Deep Loess Hills (DLH)				
DLH 2,000-5,000 ha	45	0%	83.74%	30.72
DLH 8,000-25,000 ha	37	0%	88.95%	23.67
Chariton River Hills (CRH)				
CRH 2,000-5,000 ha	49	100%	12.07%	26.85
CRH 8,000-25,000 ha	37	100%	17.01%	28.53
CRH > 75,000 ha	46	100%	2.83%	11.08
Claypan Till Plains (CPT)				
CPT 2,000-5,000 ha	37	100%	13.12%	28.88
CPT 8,000-25,000 ha	44	100%	13.11%	27.65
CPT > 75,000 ha.	44	100%	2.04%	13.57

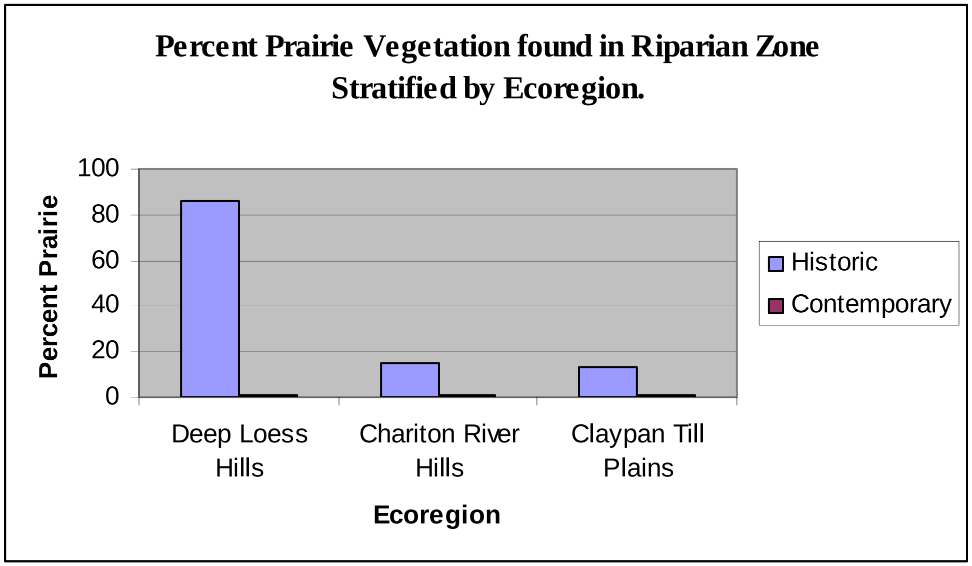

Figure 2. Percent Prairie Vegetation Found in Riparian Zone Stratified by Ecological Subsection Without > 75 Stream Size Class.

Table 2. Historic Wooded Summary Statistics Stratified by Stream Size Class Without Deep Loess Hills.

Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Stream Size Class	Na	Median	Mean	Standard Deviation
2,000-5,000 ha drainage area	86	100%	87.47%	27.57
8,000-25,000 ha drainage area	102	100%	84.67%	28.08
> 75,000 ha drainage area	90	100%	97.55%	12.29

Table 3. Contemporary Wooded Summary Statistics Stratified by Ecological Subsection Without Deep Loess Hills.

Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Stream Size Class	Na	Median	Mean	Standard Deviation
2,000-5,000 ha drainage area	89	59.74%	56.86%	36.12
8,000-25,000 ha drainage area	101	52.72%	52.39%	35.64
> 75,000 ha drainage area	89	72.93%	65.83%	34.97

Table 4. Historic Wooded Summary Statistics Stratified by Ecological Subsection Without > 75,000 ha Stream Size Class.

Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Ecological Subsection	Na	Median	Mean	Standard Deviation
Deep Loess Hills	82	0%	13.91%	27.73
Chariton River Hills	107	100%	85.25%	27.75
Claypan Till Plains	81	100%	86.88%	28.04

Table 5. Contemporary Wooded Summary Statistics Stratified by Ecological Subsection without > 75,000 ha Stream Size Class.
Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Ecological Subsection	Na	Median	Mean	Standard Deviation
Deep Loess Hills	79	28.97%	33.89%	29.84
Chariton River Hills	106	48.78%	49.57%	33.86
Claypan Till Plains	84	66.62%	60.68%	37.48

Table 6. Historic Wooded Ecological Subsection Stream Size Class Interactions.

Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Stream Size Class	Na	Median	Mean	Standard Deviation
Deep Loess Hills (DLH)				
DLH 2,000-5,000 ha	45	0%	16.26%	30.72
DLH 8,000-25,000 ha	37	0%	11.05%	23.67
Chariton River Hills (CRH)				
CRH 2,000-5,000 ha	49	100%	87.93%	26.85
CRH 8,000-25,000 ha	37	100%	82.99%	28.53
CRH > 75,000 ha	46	100%	97.17%	11.08
Claypan Till Plains (CPT)				
CPT 2,000-5,000 ha	37	100%	86.88%	28.88
CPT 8,000-25,000 ha	44	100%	86.89%	27.65
CPT > 75,000 ha	44	100%	97.96%	13.57

Table 7. Contemporary Wooded Ecological Subsection Stream Size Class Interactions.

Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Stream Size Class	Na	Median	Mean	Standard Deviation
Deep Loess Hills (DLH)				
DLH 2,000-5,000 ha	44	27.29%	29.74%	29.74
DLH 8,000-25,000 ha	35	28.97%	31.52%	30.23
Chariton River Hills (CRH)				
CRH 2,000-5,000 ha	52	37.85%	47.39%	33.91
CRH 8,000-25,000 ha	54	50.62%	51.68%	33.99
CRH > 75,000 ha	43	44.75%	47.62%	34.52
Claypan Till Plains (CPT)				
CPT 2,000-5,000 ha	37	84.00%	70.18%	35.33
CPT 8,000-25,000 ha	47	55.00%	53.22%	37.79
CPT > 75,000 ha	46	100%	82.86%	25.81

Table 8. Contemporary Agriculture Summary Statistics Stratified by Ecological Subsection Without > 75,000 ha Stream Size Class.
Total Transects (Na); Median percentage of wooded vegetation among transects (Median); Mean percentage of wooded vegetation among transects (Mean); and Standard Deviation for wooded vegetation among transects (Standard Deviation):

Ecological Subsection	Na	Median	Mean	Standard Deviation
Deep Loess Hills	79	71.03%	66.11%	29.84
Chariton River Hills	106	51.22%	50.43%	33.86
Claypan Till Plains	84	33.38%	39.32%	37.48

DISCUSSION

Historic (Prairie)

The amount of prairie vegetation in the historic riparian zone of some subsections (e.g. Deep Loess Hills) was much greater than we anticipated. Our findings suggest, contrary to previous research and speculation, (Transeau 1935, Anderson 1970, Schroeder 1981, Nigh and Schroeder 2002), that there was a significant amount of prairie in much of the historic riparian zone (Table 1). This difference may be partially explained by the small scale data used for resolving riparian vegetation in many of these previous studies. In comparison, although these rivers were significantly larger than the streams we examined in our study, recent literature has indicated that prairie was the dominant vegetation along some reaches of tallgrass prairie large river systems including the Missouri and Mississippi Rivers (Nelson et al. 1999, Haithcoat 2000).

The amount of historic riparian prairie in our selected subsections was quite variable. However, no significant differences in the amount of riparian prairie vegetation in the Claypan Till Plains and the Chariton River Hills subsections were found. The reason the historic riparian conditions of these two ecological subsections were so similar was unclear; however we offer the following explanations: 1) spatial dependence theory suggests that the proximity of these contiguous ecological subsections may contribute to the similarities between the riparian vegetation found in each; and 2) perhaps the hydrology of these two ecological subsections was so similar that the historic riparian vegetation differences between them were not too pronounced. The Chariton River Hills and the Claypan Till Plains are apparently similar to one another as they were originally combined with the Wyaconda River Hills in a single subsection, but were later divided due to the noticeable differences in topography and soils (Nigh 1999). These subsection divisions have recently been disputed, making it unclear whether the Chariton River Hills and the Claypan Till Plains should be aggregated as a single subsection or remain independent (Nigh 2000).

Change

Temporal Change (Prairie Vegetation).--The primary objective of our research was to document riparian vegetation change in this system. Prairie vegetation occupied between 2 % to almost 90 % of the historic riparian zones we evaluated (Table 1). Conversely, no riparian prairie was found in this system during the contemporary time period. Agricultural ranged from 39 % in the Claypan Till Plains to more than 66 % in the Deep Loess Hills (Tables 1 and 8) during the contemporary period, which partially explains the disappearance of prairie.

Temporal Change (Wooded Vegetation).--In the historic time period, we found greater than 85 % woody vegetation in both the Chariton River Hills and Claypan Till Plains subsections, while there was less than 15 % woody vegetation in the Deep Loess Hills. Interestingly, the woody vegetation in the Deep Loess Hills more than doubled to almost 34 % in the contemporary period, while the amount of woody vegetation in the Claypan Till Plains and Chariton River Hills dropped precipitously by more than 25 % and 35 %, respectively (Tables 5 and 6). Riparian zones with little woody vegetation in the historic period increased significantly while those with an abundance of woody vegetation in the historic period declined. Perhaps this could be a result of differences in hydrology.

These results indicate that in the contemporary time period:

1) Prairie vegetation was essentially eliminated from this riparian zone
2) The differences in woody vegetation between ecological subsections were less pronounced in the contemporary period. At the same time, variability within each ecological subsection increased relative to the historic period, as evidenced by the standard deviation.

We believe that the contemporary homogeneous riparian vegetation was driven, for the most part, by anthropogenic actions, and in particular agricultural practices. The conversion of vast amounts of land to agriculture and the removal of disturbance factors (e.g., fire and grazing herbivores) have resulted in a nearly complete loss of prairie vegetation from this system (Samson and Knopf 1994, Noss et al. 1995). Additionally, we believe some misguided "conservation" policies (*see page 43 of this manuscript for examples*) have fostered further increases in riparian woody vegetation. Nevertheless, the temporal changes that have occurred in this region have been quite variable. We found vegetation change to vary with ecological subsection, stream size class, and combinations of the two.

MANAGEMENT IMPLICATIONS

The tallgrass prairie has been highly modified by agricultural activities and now faces anthropogenic threats well outside limits that the system has evolved to tolerate. In order to determine the most appropriate approaches to management, policy, or prioritizing areas to be protected, decision-makers must have a firm understanding of historic, contemporary, and potential vegetation.

Historically, such management decisions were based upon intuition or perceptions of historic condition and change in this system. We developed, evaluated, and are now offering an objective, science-based approach (using a GIS) to characterizing historic and contemporary vegetation and assessing change between the two periods. Our approach can easily be adapted and implemented anywhere in the United States where GLO surveys were completed. The results of our research provide one of the first historic riparian vegetation characterizations in Missouri's tallgrass prairie and should be useful in directing and assessing management, policy, and restoration efforts in this system. The results from the contemporary riparian vegetation characterization should be of utility in evaluating the efficacy of future management, policy, and restoration efforts because they provide baseline data to use in evaluating the impacts of future riparian vegetation change in this system under various anthropogenic management scenarios.

BIOLOGICAL IMPLICATIONS

Our findings document the disappearance of all riparian prairie vegetation from the contemporary landscape. Although we do not provide supporting empirical evidence, we suspect that along with the loss of habitat, an associated loss of species, genetic, and perhaps other levels of biodiversity has occurred. Our research also detected a general trend indicating that the amount of woody riparian vegetation was becoming more similar among ecological subsections during the contemporary time period relative to the early to mid 1800s.

If biodiversity is deemed desirable, our findings indicate that an attempt at restoration is necessary to remedy this situation. Restoration, however, can be a real challenge because this system has been so highly modified by contemporary alterations that recreating riparian prairie vegetation can be a significant challenge. Nevertheless, effective approaches to ecosystem management require comprehensive datasets. We contributed to this end by providing an assessment of how riparian habitat in this system has changed over time. However, more information is needed regarding the status of biodiversity in this system. For instance, biologists need to have a better understanding of the types of habitat alteration that have occurred and thus resulted in an altered landscape (e.g., changes in the shape, pattern, and juxtaposition of patches of riparian vegetation).

In addition to documenting changes in habitat, we need to determine the impact such changes have had on local biota and ecosystem processes. Although the impact of riparian vegetation modifications on terrestrial biodiversity is relatively easily observed and documented, the impact of these changes on aquatic systems is less apparent. Our findings indicate that the riparian vegetation along many low order streams and those in certain subsections (e.g. Deep Loess Hills) were often historically dominated by grasses. If this is the case, such open, treeless conditions would likely have enabled autotrophic processes to dominate instream productivity in the historic period (Rabeni 1996). Processes such as energy cycling and biotic integrity in contemporary headwater streams were likely compromised by recent terrestrial riparian habitat alteration. Meanwhile, the majority of higher order streams streams' riparian zones, especially those found in the Chariton River Hills and the Claypan Till Plains were dominated by trees historically resulting in much more shaded and cooler in stream conditions than we find today. This likely has a profound impact on the faunal communities found in these streams. Again, more research is needed to determine the degree to which this may be the case along with the impact of the numerous other alterations that have occurred in this system.

POLICY IMPLICATIONS

Another problem is the lack of protection afforded to riparian areas. More than 93 % of the land in Missouri's Central Dissected Till Plains Ecological Section is privately owned and none of the riparian areas selected in our random sampling design were found in public ownership. However, public acquisition alone may not be a viable conservation strategy because the riparian vegetation has been so degraded from its original condition that it will likely require major rehabilitation efforts to restore a truly functional system.

If rehabilitation of riparian areas on private lands is deemed desirable, fostering a stewardship ethic among landowners may be a challenge. We already have vast quantities of land in the United States enrolled in state and federal policy initiatives intended to encourage future protection and restoration on private lands. The amount of land presently entered into the Conservation Reserve Plan (CRP) alone exceeds all other federally protected land in the United States (e.g., national parks and refuges). In addition to CRP, other federal conservation programs such as the Wetland Reserve Program (WRP), Open Lands Initiative (OLI), Wildlife Habitat Incentive Program (WHIP), and Environmental Quality Incentive Program (EQIP) are available to the public. These federally subsidized conservation programs were established to lend financial assistance to farmers while promoting conservation practices that reduce soil erosion and provide better wildlife habitat. Unfortunately, these programs have rarely been the panacea that many had hoped they would be.

Federal initiatives are often too centralized and frequently attempt to provide a single prescriptive solution to the many disparate local issues. For instance, although CRP cost sharing funds are provided for riparian woody species restoration efforts, these funds are not available for restoring historical riparian prairie vegetation to grass. Consequently, the federal government's "conservation" program is failing to promote riparian prairie restoration in those areas where prairie dominated historically while inadvertently promoting prairie remnant destruction in the few places outside our study area where it remains. Centralized, regionally coordinated conservation strategies are essential for effective landscape level approaches to ecosystem management, however, such plans also need to provide the flexibility to handle pertinent local issues. Our research indicates that historic riparian vegetation varied both with ecological subsections and stream size classes. Thus conservation programs may be more effective at promoting biodiversity by also examining the historic local condition. A paradigm shift that encouraged adaptive management strategies implemented by experienced local managers, who have been provided with appropriate information (e.g., transcribed GLO notes or research such as ours) to make informed decisions regarding the implementation of conservation policy at a more local scale may be more effective. Such programs would also likely be more effective if they promoted plans to target specific focus areas and habitat types in order to accomplish something that could not otherwise be accomplished by working in smaller units. If all the land currently enrolled in such programs (e.g. CRP, WRP, OLI, WHIP, and EQIP) was managed in a manner that was more conducive to local conservation needs, such as riparian vegetation restoration, these programs would likely be much more effective in accomplishing their objectives. The Farm Bill, which dealt with such policy issues, was reissued in 2002, yet many of these problems inherent in such programs have yet to be fully resolved.

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