Vegetation Index of Biotic Integrity for Southern Rocky Mountain Fens, Wet Meadows, and Riparian Shrublands: Phase 1 Final Report

June 9, 2006

Colorado Natural Heritage Program
Colorado State University
254 General Services Building
Fort Collins, CO 80523

Vegetation Index of Biotic Integrity for Southern Rocky Mountain Fens, Wet Meadows, and Riparian Shrublands: Phase 1 Final Report

Prepared for:

Colorado Department of Natural Resources
1313 Sherman Street Room 718
Denver, Colorado 80203

Colorado Department of Natural Resources
Division of Wildlife, Wetlands Program
6060 Broadway
Denver, CO 80216

U.S. Environmental Protection Agency, Region 8.
999 18th Street, Suite 300
Denver, Colorado 80202

Prepared by:

Joe Rocchio
June 9, 2006

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
254 General Services Building
Fort Collins, Colorado 80523

Cover photograph: *Clockwise* (1) Riparian Shrubland, Middle Fork Swan River, Summit County, CO; (2) High Creek Fen, South Park, CO; and (3) Wet Meadow, San Luis Valley, CO.

All photos taken by Colorado Natural Heritage Program Staff.

EXECUTIVE SUMMARY

The primary objective of the Clean Water Act is to "maintain and restore the chemical, physical, and biological integrity of the Nation's waters," which includes wetlands. In order to make informed management decisions aimed at minimizing loss or protecting wetland acreage and function, credible data on the integrity of Colorado's wetlands need to be collected (U.S. EPA 2002a). An index of biotic integrity is a cost-effective and direct way to evaluate the biotic integrityof a wetland by measuring attributes of the biological community known to respond to human disturbance.

Numerous states (e.g. Ohio, Michigan, Minnesota, North Dakota, Oregon, Wisconsin, Maryland, Pennsylvania, and Montana) have or are beginning to develop vegetation indices of biotic integrity (VIBI) for wetlands to improve their ability to assess wetland biotic integrity. VIBIs are developed by sampling various attributes of the vegetation assemblage in wetlands ranging from poor to excellent (i.e. reference) condition. Those attributes that show a predictable response to increasing human disturbance are chosen as metrics to be incorporated into the VIBI. The resulting VIBI provides a numerical value which can be used to evaluate biotic integrity of a specific wetland over time or used to compare quality of wetlands of a similar type (e.g., same HGM class). The VIBI can be used for applications such as monitoring and evaluating:

- the performance of wetland restoration, enhancement, and creation projects,
- the success of preserving ecological integrity via wetland protection projects,
- the success of management practices,
- overall statewide wetland quality,
- water quality within a watershed, and
- prioritization of funds for wetland restoration and protection projects.

The Colorado Natural Heritage Program has initiated the development of a VIBI model for three Ecological System types (fens, wet meadows, and riparian shrublands) in three watersheds (Upper Blue River, South Platte River Headwaters, and Colorado Headwaters). The VIBI will be developed in three Phases. **Phase 1, which is the content of this report**, determined suitable vegetation sampling methods, data collection, and data analysis. Phase 2 will complete data collection and construct the VIBI model. Phase 3 will test and validate the VIBI model on an independent dataset as well as test geographic variability.

This report (i.e. Phase 1) had five objectives:

1. <u>Classification Analysis</u>: determine which classification system (Ecological Systems, HGM, physiognomy, soils, etc.) best explains the natural variation of reference quality sites of the three targeted Ecological System types: fens, wet meadows, and riparian shrublands.

2. Sample Site Selection: assess the distribution of sample site selection across human disturbance categories based on *a priori* disturbance criteria in order to direct data collection during Phase 2.
3. Development of the Human Disturbance Rating: develop a human disturbance rating method and then use the Delaware Rapid Assessment Procedure to test and calibrate it.
4. Plot Method Comparison: compare two different vegetation plot methods to determine which is best suited for VIBI development.
5. Initial Metric Analysis: begin identifying metrics which may be suitable for inclusion in the VIBI models.

Sample sites were subjectively chosen to strive for adequate representation of the human-disturbance gradient (i.e. low to high disturbance) and equal representation of each Ecological System. At each sample site, the wetland was classified according to its Ecological System, HGM, and soil type. A wetland assessment area was defined at each site and a vegetation plot was subjectively placed within this area to maximize abiotic/biotic variation within the Ecological System in question.

Two vegetation plot methods were used in Plots 1-20 (the transect and reléve methods) while only the reléve method was used in Plots 21-52. The transect method consists of a 50 m line with a 20 x 50 cm Daubenmire frame (microplot) placed every third meter on alternating sides of the 50 m line. Within the microplot, all species are identified and their cover was estimated using the cover classes. The reléve method consists of ten 100 m^2 modules (1000 m^2 or 0.01 hectare) which are typically arranged in a 2 m x 5 m array. All floristic measurements (e.g. presence/absence and cover) were made within at least four of the 100 m^2 modules. The remaining six modules are considered "residuals" and are searched for any species not documented in the intensive modules. Standard site level environmental data such as elevation, slope, soil data, GPS location, etc. were collected from each site.

Nonmetric dimensional scaling, cluster anlaysis, and multi-response permutation procedure were used in PC-ORD for the classification analysis. A scatterplot was used to assess the human disturbance rating. Paired t-tests, Jaccard's diversity index, and scatterplots were used to compare the two different plot methods.

The NMS ordination, cluster analysis, and MRPP suggest that each classification system constrains natural variability. However, classifications based on two groups (e.g. physiognomy, soil type, HGM class) often result in more noise or variability when metrics are compared to human disturbance. The Ecological Systems classification, the *a priori* classification selected for this project, appears to be as or more useful than other systems since it incorporates elements of all the other classification systems such as HGM, soil type, and physiognomy. Since classification grouping can have an impact on correlation between metrics and human disturbance, additional consideration will be given to whether a hierarchical structure of classification systems can be used in the VIBI model.

The plot comparison suggests that the reléve plot method is a more suitable method for VIBI development as the transect method did not pick up most non-dominant species (making richness based metrics less accurate and comprehensive) and therefore was bias toward dominant species and resulted in biased proportions for some guilds (graminoids, forbs, etc.). For some vegetation attributes, the transect data tracks reléve data in terms of their relationship to disturbance; however, metric values are often lower for the transect method reducing the range between high and low values. This can result in metrics which are less sensitive to changes resulting from human disturbances. Thus, the reléve method will be used for VIBI development.

Initial analysis suggests numerous metrics may be suitable for inclusion in the VIBI models. Most metrics are related to non-native species as well as indices derived from the Floristic Quality Assessment. In addition, the proportion of graminoids, annuals, perennials, and the absolute cover of bryophytes may be useful metrics. It also appears that classification can have a large affect on the relationship between potential metrics and human disturbance. Future metric analysis will further explore the impact classification has on metric performance.

Additional data collection during the summer of 2006 will focus on collecting data from impacted and heavily impacted sites for all Ecological Systems. Once these data gaps are filled, classification and metric analysis will be revisited prior to initiating the remaining tasks associated with VIBI model development.

ACKNOWLEDGEMENTS

I'd like to acknowledge U.S. Environmental Protection Agency, Region 8, Colorado Department of Natural Resources, and Colorado Division of Wildlife, Wetlands Program for their financial support and encouragement of this project. I'd especially like to recognize Bill Goosemann, Colorado Division of Wildlife Wetland Program Coordinator, and Jill Minter, U.S. EPA Region 8 Wetland Monitoring and Assessment Coordinator, for their continued support of developing bioassessment tools for Colorado. Many folks provided suggestions for sample site locations and their input is much appreciated. I'd specifically like to thank Anna Higgins for taking a morning of her time to point out potential sample locations she felt would be useful to the project. I'd also like to thank Rich McEldowney and Science Applications International Corporation for sharing data he and others collected as a part of the Summit County wetland functional assessment project and Brian Lorch with Summit County Open Space and Trails for suggesting potential sample sites, allowing access to Summit County Open Space properties, and sharing data collected for the Summit County Special Area Management Plan. The U.S. Forest Service and Bureau of Land Management kindly provided very useful GIS data. I very much appreciate the time Shawn Dekeyser (North Dakota State University), Marc Jones (formerly with Montana Natural Heritage Program), and John Mack (Ohio EPA) spent discussing their experience developing Vegetation Index of Biotic Integrity models and for providing extremely useful guidance. Brad Johnson (Colorado State University) also was gracious in the time he spent providing guidance and thoughtful discussion. Amy Jacobs (Delaware Dept. of Natural Resources and Environmental Control) kindly shared the Delaware Rapid Assessment Procedure which was of great assistance toward calibrating the Human Disturbance Rating method developed for this project. I'd also like to extend much gratitude to Jack Siegrist and Becky Schillo for their assistance and hard work in collecting the data for this project. Josh Haddock has been an immense help toward developing spreadsheet functions which have made data reduction and metric calculations a breeze. I very much appreciate the hallway discussions, technical assistance, and overall guidance my colleagues at the Colorado Natural Heritage Program have provided during the course of this project, especially, John Sovell, Rob Schorr, Jeremy Siemers, Renee Rondeau, Denise Culver, Stephanie Neid, and Joe Stevens. I'd especially like to thank Joe Stevens, Renee Rondeau, Georgia Doyle, and Denise Culver for reviewing and offering many suggested improvements to this document. Finally, I would like to thank Tara Larwick with the Colorado Department of Natural Resources and Mary Olivas and Carmen Morales with Colorado State University for the logistical support they've provided toward this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The primary objective of the Clean Water Act is to "maintain and restore the chemical, physical, and biological integrity of the Nation's waters," which includes wetlands (Federal Water Pollution Control Act, Public Law 92-500). Data indicating the quality of Colorado's wetlands are limited. Simply calculating the amount of wetland acreage lost or protected does not provide information as to the quality of wetlands destroyed, impacted, restored, or protected. In order to make informed management decisions aimed at minimizing loss or protecting wetland acreage and function, credible data on the quality of these wetlands need to be collected (U.S. EPA 2002a). It is not practical to measure every human impact to wetlands since these disturbances are numerous and complex. However, measuring the integrity of the biological community provides a means to evaluate the cumulative effect of all the stressors associated with human disturbance (U.S. EPA 2002a). An index of biotic integrity is a cost-effective and direct way to evaluate the biotic integrity[1] of a wetland by measuring attributes of the biological community known to respond to human disturbance (U.S. EPA 2002a).

Numerous states (e.g. Ohio, Michigan, Minnesota, North Dakota, Oregon, Wisconsin, Maryland, Pennsylvania, and Montana) have or are beginning to develop vegetation indices of biotic integrity (VIBI) for wetlands to improve their ability to assess wetland biotic integrity. The scientific basis for using vegetation in lieu of other taxa is derived from the following (U.S. EPA 2002c):

- vegetation is known to be a sensitive measure of human impacts;
- vegetation structure and composition provides habitat for other taxonomic groups such as waterbirds, migratory songbirds, macroinvertebrates, fish, large and small mammals, etc.;
- strong correlations exist between vegetation and water chemistry;
- vegetation influences most wetland functions;
- vegetation supports the food chain and is the primary vector of energy flow through an ecosystem;
- plants are found in all wetlands and are the most conspicuous biological feature of wetland ecosystems; and
- ecological tolerances for many plant species are known and could be used to identify specific disturbances or stressors that may be responsible for a change in wetland biotic integrity.

VIBIs are developed by sampling various attributes of the vegetation assemblage in wetlands ranging from poor to excellent (i.e. reference) condition. The vegetation attributes are grouped to account for various characteristics of the vegetation community such as functional and compositional guilds. Those attributes that show a predictable response to increasing human disturbance are chosen as metrics to be incorporated into

[1] Biotic integrity is defined by Karr and Dudley (1981) as the ability of a wetland to "support and maintain a balanced adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region"

the VIBI (U.S. EPA 2002a). The resulting VIBI provides a numerical value which can be used to evaluate biotic integrity of a specific wetland over time or used to compare quality of wetlands of a similar type (e.g., same HGM class).

A VIBI will allow land managers to monitor and evaluate:

- the performance of wetland restoration, enhancement, and creation projects,
- the success of preserving ecological integrity via wetland protection projects,
- the success of management practices,
- overall statewide wetland quality,
- water quality within a watershed, and
- prioritization of funds for wetland restoration and protection projects.

Recently, the Colorado Department of Natural Resources, Division of Wildlife (DOW) Wetlands Program initiated a Wetland Projects Monitoring and Evaluation strategy to assess the success of wetland restoration and protection projects funded through the DOW. The utilization of a VIBI as a part of this monitoring strategy can greatly aid DOW in its ability to assess the ecological integrity of the Wetlands Program's projects. A VIBI can also assist other federal, state, and local agencies in monitoring and evaluating their wetland resource.

The Colorado Natural Heritage Program has initiated the development of a VIBI model for three Ecological System types (fens, wet meadows, and riparian shrublands) in three watersheds (Upper Blue River, South Platte River Headwaters, and Colorado Headwaters). The VIBI will be developed in three Phases. **Phase 1, which is the content of this report**, determined suitable vegetation sampling methods, data collection, and data analysis. Phase 2 will complete data collection and construct the VIBI model. Phase 3 will test and validate the VIBI model on an independent dataset as well as test geographic variability.

Sampling is focusing on the Upper Blue and South Platte River Headwaters watersheds while a few reference quality sample sites may be chosen from the Colorado Headwaters watershed. Vegetation plots are being sampled from wetlands exposed to varying degrees of human-induced disturbance. Human disturbance is rated (i.e. scored) at each one of the plots according to the degree of human-induced alterations to the wetland and surrounding buffer's ecological processes. Attributes which show a predictable response to the disturbance gradient are used as metrics in the final VIBI model. Once useful metrics are identified, then a score for each value of that metric will be assigned. The total VIBI score is derived by summing scores for all the metrics. The VIBI score is the quantitative value that is used to assess or monitor biotic integrity of a particular wetland over time or with other similar wetland types.

The following sections describe in detail the specific objectives targeted for this report, Phase 1 of the VIBI project.

1.1. Classification Analysis

One objective of this project was to determine which classification system (Ecological Systems, HGM, physiognomy, soils, etc.) best explains the natural variation of reference quality sites of the three targeted Ecological System types: fens, wet meadows, and riparian shrublands. The VIBI model seeks to discriminate useful vegetation "signals" which indicate ecological degradation from the natural variation or "noise" that is ubiquitous in ecological data sets. Classification aids in constraining or minimizing natural variation by categorizing wetlands into units which share similar biotic and abiotic characteristics. Classification units that are too large may have too much internal variability to provide useful signals whereas units that are too small may pose practical difficulties in application.

Classifications based on hydrogeomorphology (HGM; Brinson 1993) are often used for wetland functional assessments due to their ability to distinguish unique abiotic processes. Associated vegetation types often reflect these different abiotic scenarios and thus may respond to disturbance differently (DeKeyser et al. 2003). This would suggest that HGM would be a useful and practical classification for VIBI development. However, there is often much overlap of physiognomic types (e.g., herbaceous vs. shrubland) among HGM classes. Thus, HGM may not be the best sole classification system to use for VIBI development since physiognomic type has been shown to be an important distinguishing variable for VIBI development (Mack 2004a). Thus, a classification system which utilizes vegetation as well as aspects of HGM is desirable. The Ecological System Classification (Comer et al. 2003), which incorporates both biotic and abiotic criteria, appears to meet such a need.

Ecological Systems are defined using both biotic and abiotic criteria. Comer et al. (2003) define Ecological Systems as "a group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients". In the Southern Rocky Mountain ecoregion, physiognomy, elevation, water source, landform, and substrate were the diagnostic criteria used to define the following wetland and riparian Ecological System types (Rondeau 2001):

- Rocky Mountain Alpine-Montane Wet Meadow
- Rocky Mountain Subalpine-Montane Fen
- Rocky Mountain Subalpine-Montane Riparian Woodlands,
- Rocky Mountain Subalpine-Montane Riparian Shrublands,
- Rocky Mountain Lower Montane Riparian Woodland and Shrublands,
- North American Arid Freshwater Marsh
- Intermountain Basins Playa

Although aspects of HGM and other environmental variables are an integral component to the Ecological System classification, there are instances where Ecological System types cross HGM classes (e.g. wet meadows), physiognomic types (fens), or soil types (riparian shrublands).

1.2 Sample Site Selection

Another objective of Phase 1 was to assess the distribution of sample site selection across human disturbance categories based on *a priori* disturbance criteria. This will determine where data gaps exist and thus direct data collection during Phase 2.

1.3 Human Disturbance Rating

The third objective of this project was to use the Delaware Rapid Assessment Procedure (Delaware Dept. of Natural Resources and Environmental Control 2005) to calibrate the human disturbance rating developed for this project. The human disturbance rating is an important component to VIBI development as it serves as the "independent" variable against which vegetation metrics will be assessed. The Delaware Rapid Assessment Procedure is a rapid assessment of wetland condition based on the presence/absence of human-induced stressors. The method has been successfully calibrated against site-level quantitative data (Amy Jacobs, personal communication),and thus provides an excellent independent calibration tool for the human disturbance rating developed for this project.

1.4 Plot Method Comparison

The fourth objective is to compare two different vegetation plot methods to determine which is best suited for VIBI development. In the original project proposal submitted in December 2002, data collected from the Colorado Wetland and Riparian Classifications (Carsey et al. 2001; Kittel et al. 1999) was proposed as the basis for VIBI development. These data were collected using the transect micro-plot method (transect method). The transect method consists of using a 30-50 m line-transect in which herbaceous vegetation is sampled using 10-20 0.10 m^2 micro-plots, located about every third meter (alternating sides). Woody vegetation was sampled using the line-intercept method along these same transects with (Kittel et al. 1999). Similar transect methods have been shown to be sufficient for collecting cover and dominance data (Stohlgren et al. 1998; Mack et al. 2000) which was a main objective for the classification work. However, the transect method may underestimate species richness and therefore may not be adequate for constructing potential metrics, such as the presence of certain non-native species, life-history based metrics, and the Floristic Quality Assessment Index (Tom Stohlgren, personal communication; Stohlgren et al. 1998; Mack et al. 2000; Gerould Wilhelm, personal communication; Shawn DeKeyser, personal communication).

In order to address this concern, the sample site selection portion of the work plan for Phase 1 was changed from addressing data gaps to testing the adequacy of the transect data while also collecting additional data for the VIBI model. Twenty wetland sites were sampled using both the transect method and a reléve method developed by Peet (1998) to compare the relative strength of the former in capturing total plant species richness in each plant community. The reléve method has been shown to more accurately measure species richness and detect those species whose cover are less than 1% (Stohlgren et al. 1998; Mack et al. 2000). It is expected that the reléve method will prove to be more suitable for VIBI development and if so, will be used for this project.

This comparison resulted in one of two scenarios:

Scenario 1. No significant difference between the two methods: If the transect method is proven to be comparable to the reléve method, then data from the Colorado Wetland and Riparian Classifications (Carsey et al. 2001; Kittel et al. 1999) will be used to develop the VIBI.

Scenario 2. Significant difference exists between the two methods: If the transect method proves insufficient for VIBI development, then the reléve method will be used to collect data in Phase 1 and 2.

1.5 Initial Metric Analysis

The final objective of Phase 1 was to begin identifying metrics which may be suitable for inclusion in the VIBI models. However, since additional data will be collected in Phase 2, such analyses are cursory.

2.0 METHODS

2.1 Study Areas

2.1.1 Upper Blue River Watershed

The Upper Blue River watershed generally corresponds with the political boundaries of Summit County which straddles the west flank of the Continental Divide and is approximately 176,922 hectares (437,183 acres). Elevations range from 4,280 m (14,265 feet) on Quandary Peak to 2,274 m (7,580 feet) where the Blue River leaves Summit County. More than 85% of the county is above 9,000 feet. The watershed is bordered by the Gore Range on the northwest, the Williams Fork Mountains on the northeast, and the Tenmile Range on the west. Hoosier Pass and Loveland Pass lie on the continental divide which forms the watershed boundary to the south and east. Major tributaries include the Swan River, Snake River, and Tenmile Creek. Three major reservoirs (Blue Lakes, Dillon Lake, and Green Mountain) influence the Blue River and its associated wetlands.

The climate is generally characterized by long, cold, moist winters, and short, cool, dry summers. The Town of Dillon, where climate data are recorded, receives approximately 41.58 cm (16.37 in.) of precipitation each year. Average minimum and maximum temperatures are -7.9^{o} C (17.7^{o} F) and 11^{o} C (51.8^{o} F) respectively. The average total snow fall is 334.8 cm (131.8 in.) (Western Regional Climate Center 2005).

The geology of Summit County is complex, as evidenced by the Geological Map of Colorado (Tweto 1979). The Williams Fork Mountains, Gore Range and the Tenmile Range consist of Precambrian granitic rock with several faults (Tweto 1979). The lower Blue Valley at the base of the Williams Fork Mountains consists of Pierre Shale. There are outcrops of Dakota sandstone near the Dillon Dam. High elevation outcrops of Leadville limestone are found in the southern portion of the county. The Blue River Valley was glacially created as evidenced by the numerous boulder-strewn moraines (Chronic 1980).

Typical Southern Rocky Mountain flora is prevalent in Summit County. Elevations between approximately 2,274 m (7,580 ft) to 2,400 m (8,000 ft) are dominated by *Amelanchier alnifolia* (service berry), *Artemisia tridentata* ssp. *vaseyana* (mountain sagebrush) and *Symphoricarpos rotundifolius* (snowberry). At these elevations, wetlands along riparian areas are dominated by *Salix* spp. (willows), *Populus angustifolia* (narrowleaf cottonwood), *Picea pungens* (Colorado blue spruce) and *Alnus incana* (thinleaf alder). Other wetlands within this elevation range include seeps, springs, wet meadows, and fens which are supported by groundwater discharge. These wetland types are mostly dominated by various graminoid species, mostly of the Cyperaceae (sedge) family. Above 2400 m (8,000 ft), *Populus tremuloides* (quaking aspen), *Pinus contorta* (lodgepole pine), *Pseudotsuga menziesii* (Douglas-fir), and *Picea engelmannii*

(Engelmann spruce) dominate upland areas and can occasionally be found in confined riparian areas. The most conspicuous wetland type at these elevations are riparian shrublands or willow carrs which are dominated by various species of willow (*Salix planifolia, S. wolfii, S. brachycarpa,* etc.) and sedges (*Carex utriculata, C. aquatilis, C. canescens,* etc.). Groundwater supported wetlands are common at these elevations as well. In the elevational zone between 3,000 m to 4,267 m (10,000 to 14,000 ft) *Picea engelmannii* (Engelmann spruce), *Abies lasiocarpa* (subalpine fir), *Salix brachycarpa* (short-fruit willow), and *Salix planifolia* (planeleaf willow) occur along riparian zones. Various *Salix* spp. (willow), *Carex* spp. (sedges), and herbaceous species are also found in groundwater discharge sites and snow melt areas.

Historical hard rock and placer mining and timbering operations have dramatically affected lands throughout the county. Many of the larger rivers have large tailings piled throughout the floodplain and some areas remain effected by acid mine drainage. Currently, ski areas and associated residential and commercial developments are widespread in the county. Additionally, gravel mining and agricultural activities are found in isolated pockets. Three large reservoirs, Blue Lakes, Dillon and Green Mountain, are also significant components of the human influences in the county. These various land uses introduce problems associated with habitat fragmentation, hydrological alterations, topographic alterations, non-native species invasions, and alternation of natural fire regimes.

2.1.2 South Platte River Headwaters Watershed

The South Platte River Headwaters watershed encompasses much of Park County and is approximately 415,244 hectares (1,026,097 acres). Elevations range from five peaks over 4,267 meters (14,000 feet) to approximately 2,225 meters (7,300 feet). Much of the watershed occurs in a prominent physiographic feature in Park County called South Park, a grass-dominated basin, 80 km (50 miles) long and 56 km (35 miles)wide. South Park is one of four intermountain basins in Colorado, and is surrounded on all sides by mountains. It is bordered to the west by the Buffalo Peaks and the Mosquito Range, to the north by the southern end of the Park Range, to the east by the Kenosha Mountains, Tarryall Mountains, and Puma Hills, and to the south by the Black and Thirtynine Mile mountains.

The climate is generally characterized by long, cold, moist winters, and short, cool, dry summers. Climatic data from the Town of Fairplay indicate that this area receives approximately 33 cm (13 inches) of precipitation each year. Average minimum and maximum temperatures are, respectively, -12^{o} and 20^{o} C (9 ^{o} and 69 ^{o} F). The average total snowfall in Fairplay is 213 cm (84 inches) (Western Regional Climate Center 2005). In sub-alpine basins, streams flow over glacial till from the Pinedale and Bull lake glaciations. Elsewhere, streams and tributaries to the South Platte flow over Quaternary alluvial deposits of varying depth (except where bedrock is exposed in narrow canyon reaches). The upper glaciated reaches are in wide U-shaped valleys. Below elevations of glacial terminal moraines, river canyons become narrow, and the rivers are steeper, forming narrow, cool canyons with limited floodplain development. Hydrology of the

South Platte River is primarily driven by spring and early summer snow-melt runoff from the mountains.

The vegetation on the valley floor of South Park is generally short and sparse as a result of the dry, windy climate, historic and current grazing, fires, and, to a much lesser extent, prairie dog activity. The wetlands of South Park are comparable to few others found in the world. The geologic and hydrologic setting found in South Park combines to create wetlands known as "extremely rich fens," so named because of their high concentrations of minerals. These fens provide habitat for a suite of rare plant species and plant communities. Unfortunately, approximately 20% of the fen communities in the study area have been drained or mined for peat (Sanderson and March 1995). Other wetland types include playa lakes, springs, wet meadows, and riparian wetlands.

At higher elevations the vegetation is dominated by willows (*Salix* spp.), spruce-fir *(Picea engelmannii-Abies lasiocarpa)*, ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta* ssp. *latifolia*), bristlecone pine (*Pinus aristata*), quaking aspen *(Populus tremuloides)* and alpine communities.

There are a high percentage of private lands in the watershed, particularly in South Park and on the immediately adjacent slopes. Currently, residential, agricultural (mostly livestock grazing) and commercial developments are widespread. Most of the streams in South Park are used to support some level of irrigation for pasture and/or hay operations. There are three large reservoirs that provide water for Front Range cities. Historical mining and timbering operations have dramatically affected lands throughout the higher elevations of the county.

2.1.3 Colorado Headwaters Watershed

This watershed encompasses approximately 751,180 hectares (1,856,199 acres) of north central Colorado. The elevation ranges for this portion are from 2,225 meters (7,300 feet) where the Colorado River cuts through the Gore Range at Gore Canyon, to 4,066 meters (13,553 feet) at the summit of Pettingell Peak in the Front Range. The principal mountain ranges are: Rabbit Ears Range, Front Range, and Gore Range. The Continental Divide defines the northern and eastern County lines while the Gore Range delineates the southwest boundary. The watershed also encompasses Middle Park intermountain basin. Major tributaries of the Colorado River include the Fraser River, Williams Fork River, Willow Creek, Blue River, Troublesome Creek, and Muddy Creek.

The climate is generally characterized by long, cold, and moist winters, and short, cool, dry summers. Climatic data from the Grand Lake area indicate that this area receives approximately 51 cm (20 inches) of precipitation each year. Average minimum and maximum temperatures are, respectively, -6.5 ^{o} and 11.5^{o} C (20.2 ^{o} and 52.8 ^{o} F). The average total snowfall in Fairplay is 368 cm (145 inches) (Western Regional Climate Center 2006).

Watershed geology consists of crystalline Precambrian rocks underneath thousands of feet of sedimentary rocks including the Jurassic Morrison Formation, Dakota Sandstone, Benton Shale, Niobrara Formation, and Pierre Shale (Tweto 1979).

The diversity of climate, geology, elevation, and soils within the Colorado Headwaters watershed leads to a wide range of Ecological Systems. At the highest elevations, alpine tundra dominated by cushion plants grades into subalpine forests dominated by Engelmann spruce and subalpine fir, which in turn grade into upper montane forests of lodgepole or limber pine (*Pinus flexilis*). Lower montane forests are strongly dominated by lodgepole pine, especially on dry slopes, although Douglas-fir can intermingle on moister, often north-facing slopes with aspen. The basins between mountain ranges are characterized by mountain big sagebrush and Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) shrublands, which dominate the clay soils within Middle Park. Scattered throughout the County are riparian forest and shrublands and other wetland types such as fens, kettle ponds, wet meadows, and freshwater marshes.

Historically, the basin's economy was based on agriculture and livestock activities. Presently, the economy is largely based on recreation and tourism. Approximately 28% of Grand County is privately owned and the majority of private lands are located within Middle Park. The towns of Granby, Fraser, and Winter Park are all located only one hour from Denver and offer easily accessible fishing and hiking in the summer, and snowmobiling, tubing, and skiing in the winter.

2.2 Site Selection and Wetland Assessment Area

2.2.1 Sample Site Selection

Sample sites were subjectively chosen to strive for adequate representation of the human-disturbance gradient (i.e. low to high disturbance) and equal representation of each Ecological System (U.S. EPA 2002b). A potential list of sample sites was first developed by categorizing each study area into *a priori* disturbance categories and identifying wetland sites within each category. These categories provided an initial stratification of the potential sites. However, onsite assessment often placed a wetland into a different disturbance category than the one identified *a priori*. Sample site selection was adjusted accordingly to ensure equal representation of disturbance across Ecological System types.

The following resources were used to identify and categorize potential sample sites into *a priori* disturbance categories ranging from "Reference", "Minimally Impacted", "Highly Impacted", to "Degraded" as well as identify potential sample sites within each of those categories:

- Digital Orthophoto Quadrangles (1 m resolution)
- GIS layers (roads, utility lines, trails, mines, wilderness areas, National Land Cover Dataset, irrigation, ditches, groundwater wells, etc.),

- Element occurrence records from the Colorado Natural Heritage Program's Biodiversity Tracking and Conservation System (Colorado Natural Heritage Program 2004),
- Bureau of Land Management Proper Functioning Condition data (Bureau of Land Management 2004),
- Site data from the Summit County Wetland Functional Assessment (SAIC 2000),
- U.S. Forest Service wetland surveys (Summit County 1999), and
- Road surveys

Once onsite, a different set of criteria was used to apply a human disturbance rating (see Section 2.4). Sample site selection and data collection occurred during the summers of 2004 (Plots 1-20) and 2005 (Plots 21-52).

2.2.2 Classification of Site

At each sample site, the wetland/riparian type(s) present were classified and defined according to their Ecological System type. Ecological System descriptions were used to guide a subjective determination of wetland/riparian boundaries in the field. A description and key to wet meadow, fen, and riparian shrublands Ecological System types can be found in Appendix A. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics were used to define wetland boundaries, regardless of whether they met jurisdictional criteria for wetlands regulated under the Clean Water Act.

Different wetland Ecological Systems often co-occur in the landscape. For example, fens may occur together with riparian shrublands in a basin or along a river (Figure 1). Similarly, wet meadows are often interspersed with riparian shrublands. Thus it is often necessary to delineate the boundaries of these separate Ecological Systems based on the larger riparian shrubland system would be considered a distinct wetland type. For such situations, each Ecological System would be treated as a separate wetland assessment area and thus as an independent sample point (Figure 1). If the wet meadow was < 1 acre it would be considered to be internal variation of the riparian shrubland system and not considered a separate assessment area. There were a few cases where wet meadows and fens which were smaller than their minimum size criteria were chosen as sample locations. For example, Plots 01, 39, and 51 were isolated due to natural topography while Plot 47 was a discrete, highly disturbed portion of a larger fen.

2.2.3 Assessment Area

Once the sample sites were chosen, a wetland assessment area (AA) was defined for each system type. The AA is simply the boundary of the wetland (or a portion of) in which analysis will occur. *The AA is defined for the purpose of developing a vegetation index of biotic integrity, thus different criteria may be used for other project objectives such as those associated with regulatory projects. Guidance will be provided in future reports for these types of projects.*

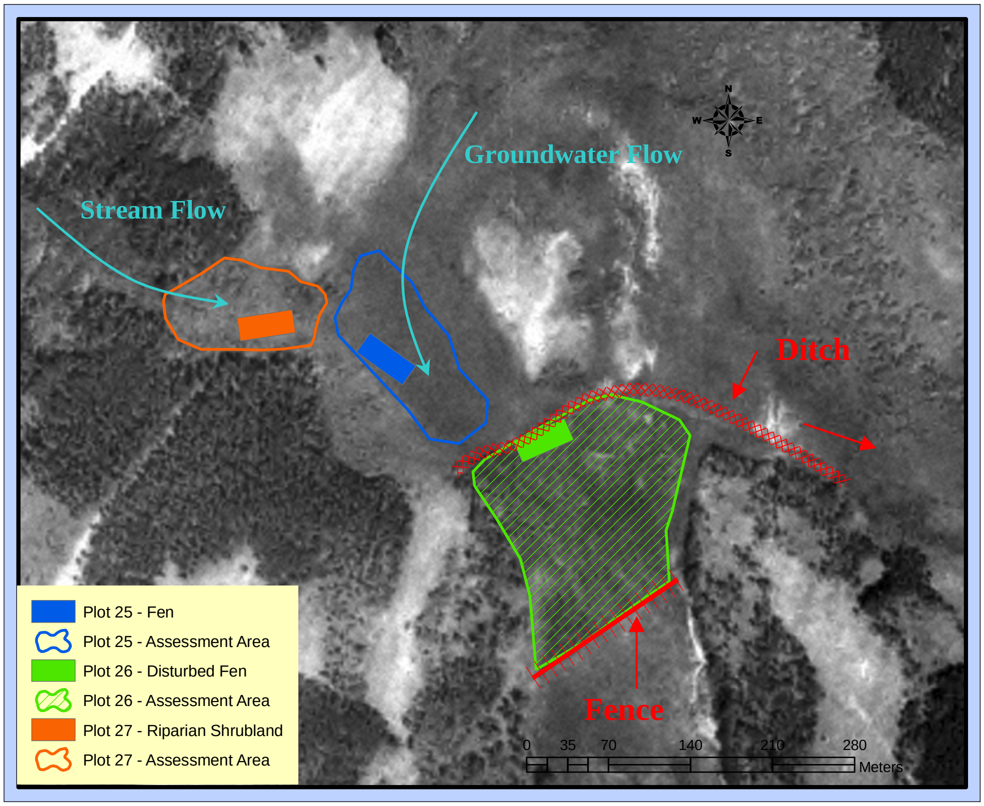


Figure 1. Assessment Area and Plot Delineation Examples. Although contiguous with each other, these three wetlands were delineated as distinct AAs because either they were distinct Ecological System types (e.g. fen vs. riparian shrubland) or due to a human-induced disturbance (e.g. ditch) which significantly altered a large portion of an otherwise contiguous wetland type (e.g. intact vs. disturbed fen).

The important defining criteria for this project was that the AA needed to be small enough that the observer could make a field assessment of human-induced disturbance, yet large enough to capture representative floristic variation and response to these disturbances (Mack 2004b). Thus, the AA represents the area in which human-induced disturbance and vegetation can be practically evaluated as well as reasonably correlated to each other.

Depending on the size or variation of the wetland area, the AA may consist of the entire site or only a portion of the wetland/riparian area. For small wetlands or those with a clearly defined boundary (e.g., isolated fens or wet meadows) this boundary was almost always the entire wetland. In very large wetlands or extensive and contiguous riparian types, a sub-sample of the area was defined as the AA.

The AA was defined using the following guidelines[2]:

---

[2] These guidelines are mostly based on those identified for Mack 2001, Washington State Dept. of Ecology 1993, and Collins et al. 2004.

For Relatively Small Wetlands (< 25 acres or 10 hectares)

1. Wet meadows and fens were often spatially distinct from surrounding uplands or adjacent wetland types and easily identified.
2. AA was typically the entire wetland area.

For Very Large Wetlands (>25 hectares or 10 hectares)

- Significant change in management or land use which result in distinct ecological differences.
- Distinct changes in hydrology.
- Representative sub-sample of the floristic and abiotic micro-variation with the wetland/riparian type in question. For example, in a large wetland such as High Creek Fen, sedge meadows, water tracks, and rills represented micro-variation within the Fen Ecological System type. A representative sub-sample included portions of these variations within the AA.

For Riparian

1. Lateral boundaries were defined by:
   - Abrupt changes in the geomorphology (e.g., upland slopes)
   - Transition of wetland vegetation to upland species.
2. Longitudinal boundaries were defined by:
   - Natural changes in hydrology. For example, a change in channel type (e.g. Rosgen 1996), geomorphic constrictions, the presence/absence of beaver ponds, confluence with a tributary, or rapids/waterfalls.
   - Anthropogenic changes in hydrology. For example, dams, water diversions, dikes, berms, roadbeds, etc. which substantially alter a site's hydrology relative to adjacent reaches.
   - Significant change in management or land use which result in distinct ecological differences. For example, a heavily grazed shrubland on one side of a fence line and ungrazed shrubland on the other.
   - Sub-sample of riparian area that is representative of local human-induced disturbances and floristic variation. For example, if hydrological changes and/or management criteria aren't helpful in defining the AA because the wetland in question is so large (longitudinally or laterally), then a representative sub-sample of the wetland was defined as the AA.

2.3 Plot Establishment and Vegetation Sampling

2.3.1 Plot Location

Vegetation plots were subjectively placed within the AA to maximize plot heterogeneity (yet the plot remains within the Ecological System of interest) and abiotic/biotic variation. The intention of capturing heterogeneity within the vegetation plot is to ensure adequate representation of local, micro-variations produced by such things as hummocks, water tracks, side-channels, pools, wetland edge, micro-topography, etc. in the floristic data.

As discussed previously, two different vegetation sampling methods were compared in Plots 1-20. At those sites, a transect and reléve plot method were compared using the same 50 meter baseline (Figure 2). This allowed a direct comparison between the two methods. For Plots 21-52, only the reléve method was employed.

The following guidelines were used to determine plot locations within the AA[3]

- The plot was located in a representative area of the AA which incorporated as much microtopographic variation as possible.
- If a small patch of another wetland type was present in the AA (but not large enough to be delineated as a separate Ecological System type), the plot was placed so that at least a portion of the patch was in the plot.
- When site characteristics dictated a modification of plot structure, an alternative array of modules was selected to best represent the AA (e.g. 2 m x 2 m for small circular sites or 1 m x 5 m for narrow linear areas)
- Uplands were excluded from plots; however, upland microtopographic features such as hummocks, if present, were included in the plots.
- Localized and small areas of human-induced disturbance were included in the plot according to their relative representation of the AA (large areas of human-induced disturbance dictate that the area be delineated as a separate AA).

2.3.2 Transect Plot Method

The transect plot method consists of a 50 m line with a 0.1 m^2 (20 cm x 50 cm) Daubenmire frame (microplot) placed every third meter on alternating sides of the 50 m line. Within the microplot, all species are identified and their cover was estimated using the same cover class as the reléve method (Section 2.3.3). The following procedure was used to lay out the plot:

- The same 50 m centerline used for the reléve plot (Figures 2 & 3) was used as the centerline for this method.
- 0.1 m^2 microplots were placed along the 50 m transect, every third meter and on alternate sides (Figure 2).
- Within each microplot, canopy coverage was estimated for each species.
- Canopy coverage for each species was summed then divided by the total number of microplots to arrive at average cover for each species in the plot.
- Although the line-intercept method is typically used to record shrub and tree cover when using this method, the overlapping the aerial space above the microplot was used instead.

[3] Most of the guidelines are based on Mack 2004b.

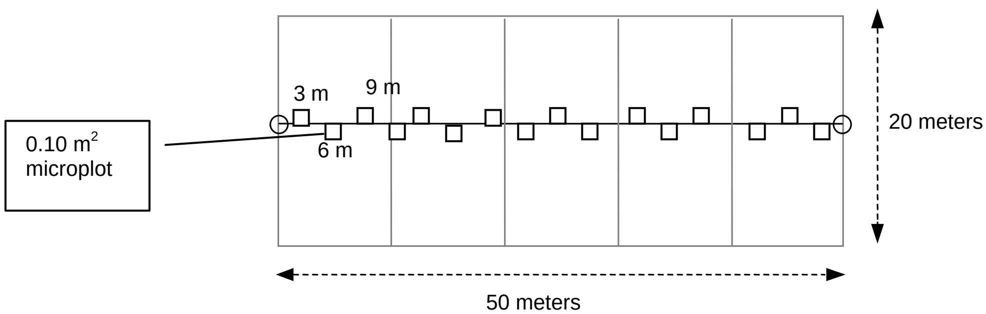


Figure 2. Layout of Transect Plot Method

2.3.3 Reléve Method

This method was developed by Robert Peet and has been in use by the North Carolina Vegetation Survey for over 10 years (Peet et. al 1998). The method has also been used to successfully develop a VIBI in Ohio (Mack 2004a). The structure of the plot consists of ten 100 m^2 modules (1000 m^2 or 0.01 hectare) which are typically arranged in a 2 m x 5 m array (Figure 3). All floristic measurements (e.g. presence/absence and abundance) are made within at least four of the 100 m^2 modules. These are referred to as “intensive” modules. In addition, nested quadrats within each module are established in at least two corners providing data from multiple scales (Figure 3). The remaining six modules are considered “residuals” and are searched for any species not documented in the intensive modules.

To lay out the plot, a 50 m measuring tape was extended (this is the centerline of the plot) from a subjectively chose origin. Starting at zero, a stake flag (or flagging tied to a shrub /tree) was placed at every 10 m tick mark. Red stake flags or flagging were placed at the 0, 40, and 50 m marks and green stake flags/flagging at the 10, 20 and 30 m marks. This helped visualize the four “intensive modules” which occur on either side of the centerline between the 10-30 m marks. Next, a 10 m rope was extended perpendicular on either side of the centerline at each 10 m mark. Red or green flags were placed at the end of the rope to mark the lateral boundaries of each module and the plot.

If the wetland had an irregular shape and the plot did not “fit”, the 2 x 5 array of modules was restructured to fit the wetland. For example, a 1 x 5 array of 100 m^2 modules was used for narrow, linear areas. A 2 x 2 array of 100 m^2 modules was used for small, circular sites (Peet et. al. 1998; Mack 2004b). Regardless of the structure, a minimum of four intensive modules was sampled.

If the wetland was so large that the 20 m x 50 m plot did not capture a significant amount of variation of the wetland, then the 2 x 5 array of 100 m^2 modules was separated into ten individual modules which were subjectively established throughout the wetland to ensure variation of the wetland type was captured (Figure 4). All ten modules were intensively sampled.

Each module in the plot was numbered by standing at the 0 m mark facing the 50 m end, and, starting on the right side, the modules were assigned from 1-5. Modules 6-10 were assigned using a similar method then from the 50 m mark (Figure 3). Intensive modules were typically modules 2, 3, 8, and 9. Within intensive modules, a $\log_{10}$ series of nested subquadrats (nest) were established to obtain estimates of species composition at multiple spatial scales (e.g., 0.01, 0.1, 1.0, and 10 m^2) (Figure 3). The subquadrats were established in one or more corners in each intensive module. For this project, only two corners in each of the four intensive modules were sampled. When facing in the same direction, the corners of each intensive module are numbered in a clockwise direction within each module. To maximize spatial distinction of the sampled corners, the following sequence of corners was sampled: Module 2 (corners 2 and 4), Module 3 (corners 2 and 3), Module 8 (corners 2 and 4), and Module 9 (corners 2 and 3) (Figure 3). For those plots that did not use a 2x5 array of modules (e.g. 1x5 or 2x2), the module numbers may be different; however the same sequence of corners was used.

The number of subquadrats in a nest is referred to as depth, where a depth of 5 indicates presence recorded in the 0.01 m^2 subquadrat, depth of 4 (0.1 m^2), depth of 3 (1.0 m^2), depth of 2 (10.0 m^2), and depth of 1 (100.0 m^2). Sampling began at the smallest subquadrat and each species received a number corresponding to the depth at which it is initially encountered. During 2004, all five depths (subquadrats) were sampled; however,

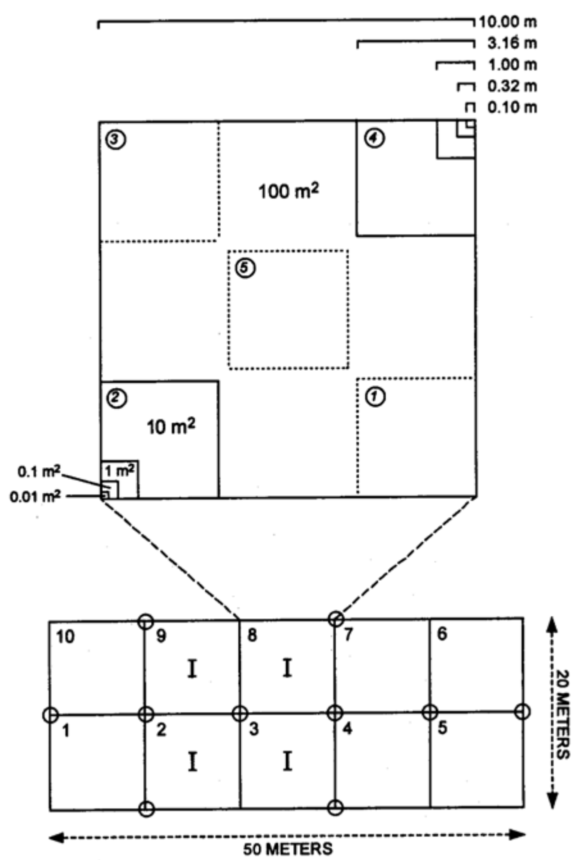


Figure 3. Reléve Plot Method (from Peet et al. 1998)

to increase efficiency and due to a lack of utility of the finer scaled depths, only 3 subquadrats (1, 10, and 100 m^2) were sampled in 2005. Presence recorded for a particular depth implies presence at all lower-numbered depths, thus both corners were sampled before documenting which species occur at depth 1 (100 m^2). Cover was visually estimated at the level of the 100 m^2 module (depth 1) using the following cover classes (Peet et al. 1998):

1 = trace (one individual)
2 = 0-1%
3 = 1-2%
4 = 2-5%
5 = 5-10%
6 = 10-25%
7 = 25-50%
8 = 50-75%
9 = 75-95%
10 = > 95%

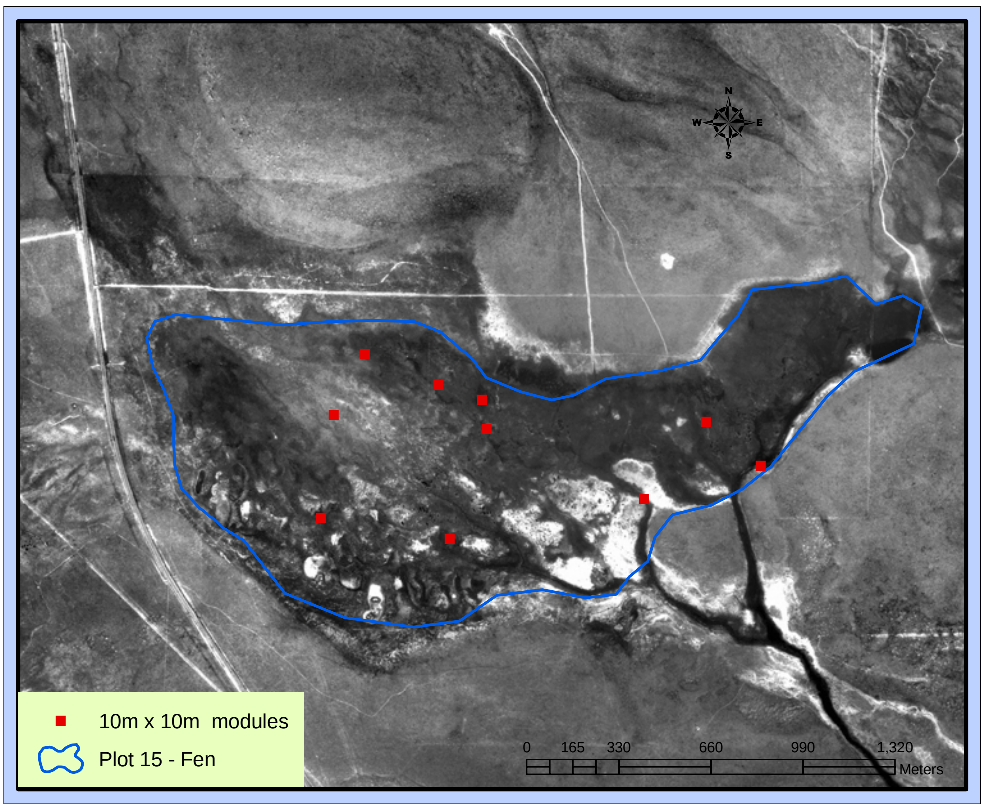


Figure 4. Example of 20m x 50m plot broken into ten $100m^2$ modules due to very large size of wetland.

These values were recorded on the field form behind the depth notation. For example, a species occurring in Depth 2 with an estimated cover of 10-25% was recorded as 2/6 on the field form (Appendix B). After sampling each of the intensive modules, the remaining (i.e. residual) modules were walked through to document presence of any species not recorded in the intensive modules. Percent cover of these species is estimated over the entire 1000 m^2 plot. Cover was the only abundance measurement for all species. Cover for each species was averaged across the intensive modules and used in data analysis. For those species only occurring in the residual plots, the cover value for the residual plots was used for analysis.

2.4 Human Disturbance Rating

The human disturbance rating provides an independent measure of wetland condition against which vegetation attributes are assessed to determine their relationship with increasing human disturbance. In order to assess the deviation of vegetation attributes from reference conditions (i.e. no or minimal human-induced disturbance) each site was ranked according to the degree of human-induced disturbance observed using a human disturbance rating form (Appendix C). This form was developed using rapidly employed metrics extracted from a related wetland condition assessment called Ecological Integrity Scorecards (Faber-Langendoen et al. 2005). In addition, the Delaware Rapid Assessment Procedure V. 2.0 (Delaware Dept. of Natural Resources and Environmental Control 2005), which has been successfully calibrated against site-level quantitative data (Amy Jacobs, personal communication), was applied to each plot to assist in calibrating the rating form developed for this project. Both methods assume that the absence of historic and/or contemporary human disturbance indicates that the wetland or riparian area exists under reference ecological condition and that increasing human disturbance results in a more or less linear deviation from the ecological reference benchmark (see below).

2.4.1 Reference Condition and Human Disturbance

In order to assess floristic response to human-induced disturbance a baseline reference condition representing no or minimal human disturbance must be defined. Since the temporal variability of ecological systems is very high, the reference condition must be defined for a specific and relevant time frame in order for the concept to be practically useful. For this project, reference condition is defined using the concept of historic or natural range of variability (NRV) which is based on the range of climatic, edaphic, topographic, and biogeographic conditions under which contemporary ecosystems evolved (Morgan et al. 1994; Quigley and Arbelbide 1997). When the NRV is altered by human-induced disturbances, biodiversity and ecological functions are often degraded (Morgan et al. 1994). Accounting for natural ecological variation makes the NRV very useful for establishing a reference benchmark from which the effects of human disturbance can be assessed and provides a useful model for restoring and/or maintaining conditions to which most species are adapted (Quigley and Arbelbide 1997; Wong and Iverson 2004).

Disturbances resulting from Native Americans' interaction with the landscape are assumed to have occurred over spatial and temporal scales which native flora and fauna were able to adapt and thus are included within the NRV (Quigley and Arbelbide 1997). However, recent human-induced disturbances (post European settlement) have occurred at a rate and magnitude which are unprecedented in the evolutionary history of contemporary ecosystems (Morgan et al. 1994; Quigley and Arbelbide 1997). Thus, the NRV for the Ecological Systems targeted in this project was considered to be the:

> *"spatial and temporal distribution of ecological processes which existed prior to European settlement of the Southern Rocky Mountain region"* (Wong and Iverson 2004).

This definition provides a reference benchmark from which floristic response to human-induced disturbance (i.e. the VIBI model) can be assessed.

Contemporary and historic literature, comparisons with relatively undisturbed, biogeographically comparable regions, and best professional judgment were all used to define the reference condition of the wet meadow, fen, and riparian shrubland Ecological Systems targeted in this project. Although contemporary human disturbances have directly or indirectly affected much of the Southern Rocky Mountain landscape (Wohl 2001), many areas located on U.S. Forest Service and U.S. National Park Service lands still remain in relatively unaltered condition and thus allow direct observation of conditions which are likely very similar to what occurred prior to European settlement. In addition, the wetlands and riparian areas in the project area possesses a mostly circumboreal flora. As such, wetland and riparian areas of the Southern Rocky Mountains share many floristic elements of circumboreal regions, especially those of North America. Descriptions of wetlands found in boreal North America where human alteration have been less widespread and intense and where ecosystems are functioning within their natural range of variability (Boggs 2000 and National Wetlands Working Group 1988), as well as early descriptions of the Southern Rocky Mountain wetland flora (Ramaley and Robbins 1909, Ramaley 1919, Ramaley 1920) were very useful in identifying and describing the floristic, as well as the hydrogeomorphic template, of the wetland and riparian areas of the project area. More specific descriptions of reference conditions can be found in the Rocky Mountain Sublapine-Montane Riparian Shrubland, Alpine-Montane Wet Meadow, and Subalpine-Montane Fen Ecological Integrity Scorecards which are located online at http://www.cnhp.colostate.edu/reports.html (Faber-Langendoen et al. 2005).

2.4.2 Human Disturbance Rating

This method utilizes a series of metrics related to three major categories of human-induced disturbance commonly affecting wetlands and riparian areas in Colorado. The categories and their respective metrics are listed below:

Buffers

- Average Buffer Width
- Land Use in 100 m Buffer
- Percentage of Unfragmented Landscape within 1 km (0.6 miles)

- Riparian Corridor Continuity

Hydrology

- Hydrological Alterations
- Upstream Surface Water Retention
- Upstream/Onsite Water Diversions/Additions
- Floodplain Interaction

Physical/Chemical Disturbance

- Substrate/Soil Disturbance
- Onsite Land Use
- Bank Stability
- Algal Blooms
- Cattail Dominance
- Sediment/Turbidity
- Toxics/Heavy Metals

Each metric has descriptive criteria indicating how many points are assigned to each (see form in Appendix C). The two lowest scores from each category are summed then multiplied by a weighting factor to arrive at a final score ranging from 0 (extremely disturbed) to 100 (reference condition; no human-induced disturbance). Since hydrology is the most important ecological process defining wetlands, that category is weighted more than the other two.

2.4.3 Delaware Rapid Assessment Procedure

This method is a rapid assessment of wetland condition based on the presence/absence of human-induced stressors (Delaware Dept. of Natural Resources and Environmental Control 2005). The stressors are placed into three categories: Hydrology, Habitat/Plant Community, and Buffer. Each stressor is assigned points according to its relative impact to wetland condition. Each category starts with 10 points and stressor points are subtracted from this to arrive at a final score for each category. Category scores are summed to arrive at a final score between 0 (extremely disturbed) to 30 (reference condition; no human-induced disturbance). A second grazing stressor (-5 points; included as "Other") was often used in both the Habitat/Plant Community and Buffer sections to reflect the variable and widespread impact livestock grazing has on Colorado wetlands.

2.5 Environmental Data

Standard site level environmental data were collected from each site. This included:

- HGM classification (Johnson 2005)
- Classification of plant association(s) (Carsey et al. 2003)
- Cowardin classification (Cowardin et al. 1979)
- GPS location

- Elevation
- Slope between 0 and 50 m mark of vegetation plot
- Compass direction of plot
- Selected soils data – depth and identification of soil horizons, texture, and color.
- Water table depth
- Nearby landforms (alluvial fans, narrow bedrock valley, alluvial valley, etc.)
- Description of onsite and adjacent ecological processes and land use.
- Description of general site characteristics.
- Photos
- Water pH, conductivity, and temperature were measured using a Hanna Instruments hand-held meter (Model # HI98129).

2.6 Data Management

Plot data were entered into a Microsoft Excel™ spreadsheet where data were "reduced" from raw cover class scores in each module to average and relative cover values of each species. To eliminate spelling errors, a drop-down list was used for species entry. The Colorado Floristic Quality Assessment (FQA) database (Rocchio *In Progress*) was used to populate life history traits, wetland indicator status, and C-values in the data reduction spreadsheet for each species in the plot.

Species nomenclature follows USDA PLANTS Database (http://plants.usda.gov/) as of January 2005. Since many practitioners in Colorado use Weber's Colorado East/West Slope floras (Weber and Wittmann 2001a, 2001b) as a nomenclature reference, these names are cross-referenced to the PLANTS names in the Colorado FQA database. Life history traits and wetland indicator status were downloaded from PLANTS. The USFWS Region 5 and 8 Wetland Indicator Status lists were also used to ensure that PLANTS information were correct (Reed 1988). However, these lists are not complete and many species did not have a wetland indicator status listed. For such species, a wetland indicator status was estimated using input from members of the Colorado Floristic Quality Assessment Panel as well as the author's personal experience with the flora.

The Colorado FQA database along with cover data, were used to calculate metric values. Calculations were performed in a Microsoft Excel™ spreadsheet using pivot tables. Calculations made by pivot tables were randomly checked via hand-calculations to ensure that pivot tables were constructed correctly. Environmental data and human disturbance rating scores were also entered into a Microsoft Excel™ spreadsheet. These data were combined with metric values from each plot into a new spreadsheet. This spreadsheet served as the basis for analysis. These data were also imported into a Microsoft Access™ database.

For a few vegetation plots, a number in a couplet (depth/cover) was missing. Because one value was recorded, it was assumed that the species was present in the plot and that the second value was simply overlooked. For these situations, a default value of 1 was entered no matter whether the missing value was depth or cover. Unknown or ambiguous species were recorded but not included in metric calculations. Data entry was reviewed by an independent observer for quality control.

2.7 Data Analysis

2.7.1 Classification Analysis

Multivariate analysis was used to determine which *a priori* classification system accounts for the most variation of the sampled plots or best explains the separation of the data. The *a priori* classification systems tested were (1) Ecological Systems; (2) HGM; (3) physiognomy, and (4) soil type. Each classification system is comprised of at least two different classes and/or subclasses (Table 1).

Table 1. Classification Systems

Classification System	Class	Subclass
Ecological Systems (Comer et al. 2003)	Rocky Mountain Alpine-Montane Wet Meadows	
	Rocky Mountain Subalpine-Montane Fens	Extremely Rich Fens*
		Intermediate/Rich Fens*
	Rocky Mountain Upper Montane-Subalpine Riparian Shrublands	
Hydrogeomorphic Types (Brinson 1993 and Johnson 2005)	Slope	Isolated Slope
		Outflow Slope
		Throughflow Slope
	Riverine	Low-order, low-gradient, unconfined Riverine
Physiognomy	Herbaceous	
	Shrub	
Soil Types	Mineral	
	Organic	

*based on classification analysis performed in this report (see Section 3.1)

Data Transformations

In order to constrain noise in the dataset, only those plots considered "reference" were analyzed for classification purposes. This is both ecologically and practically useful since natural variability is best constrained using only natural "reference" quality sites. Disturbed sites introduce variability outside the natural range. Classification serves the purpose of identifying groupings of the dataset which constrain natural variability and thus allow more sensitive detection of signals resulting from increasing human disturbance. Using the human disturbance rating, the 52 reléve plots were categorized into three disturbance categories: Highly impacted (scores 0-33), Impacted (scores 34-67) and Reference (68-100). Twenty six plots were identified as "reference" and were used in the classification analysis. Species composition and abundance (absolute cover) from each of the 26 reference plots were imported into PCORD Software (McCune and Mefford 1999). Unknown or ambiguous species (e.g. *Carex* sp. or unknown grass, etc.) were removed and species occurring in less than three plots were deleted.

Due to high coefficient of variation (CV) of species data they were transformed using Beal's Smoothing to improve homogeneity of variance of the dataset (61%; Table 2). High CV indicates large variance in the dataset which does not meet the assumptions of many statistical analyses and thus hinders the ability to detect useful patterns from the dataset. Beal's Smoothing is a powerful transformation which can reduce noise by enhancing the strongest patterns in a dataset and is particularly effective on heterogeneous data (McCune and Grace 2002). This transformation calculates a probability for each cell in the plot x species matrix that the corresponding species would occur in that cell (e.g. plot) based on its joint occurrences with species that are actually in the plot (Beals 1984; McCune and Grace 2002). In other words, Beal's Smoothing represents the favorability of each plot for each species (McCune and Grace 2002).

Ordination

A Nonmetric Multidimensional Scaling (NMS) ordination (Kruskal 1964) was performed in PCORD on the Beal's Smoothing transformed dataset to determine which classification system best explains variation in the dataset. NMS is increasingly used for ecological data analysis due to its suitability for nonnormal, arbitrary, or disconintuous scales (McCune and Grace 2002). NMS avoids the assumption of linearity among variables, relieves the "zero-truncation" issue common with biological data through its use of ranked distances, and allows the use of any distance measure (McCune and Grace 2002). NMS seeks a reduced representation or dimensional configuration of the multidimensional relationship among samples and species (McCune and Grace 2002). The difference between ranked distance in the original multidimensional space and ranked distance in the reduced ordination space is called "stress" (McCune and Grace 2002). Final stress values less than 20 (lower values are most accurate) are sought for ecological community data (McCune and Grace 2002).

Cluster Analysis

A hierarchical, agglomerative cluster analysis was performed in PCORD using Flexible Beta linkage method (-0.25 beta value) and Sorenson (Bray-Curtis) distance measure (McCune and Grace 2002). The cluster analysis was used as a supplementary analysis to the NMS ordination to determine which classification systems best explains the separation of the data.

Multi-response Permutation Procedure

A multi-response permutation procedure (MRPP) using the Sorenson (Bray-Curtis) distance measure was used to determine whether significant differences exist between various classification groups of the reference plot data. MRPP is a nonparametric procedure comparable to discriminant analysis or multivariate analysis of variance and thus is recommended for ecological data which often do not meet the required assumptions of parametric statistical methods (McCune and Grace 2002). The average distance within group measure indicates the dispersion within each grouping. The T-statistic describes the separation between the groups with a more negative value of T indicating a stronger separation. The *p*-value assists in evaluating how likely it is that an

Table 2. Statistics for Raw Plot x Species Matrix

	Gamma Diversity	Average Alpha Diversity	Beta Diversity	% Empty Cells	Average Skewness	Coefficient of Variation of Species Total
Raw Rows (Plots)	128	34.8	3.68	72.84 %	8.62	32.5 %
Beal's Rows (Plots)	N/A	N/A	N/A	0.00	0.97	11.33 %
Raw Columns (Species)	26	7.1	3.66	72.84 %	2.98	362 %
Beal's Columns (Species)	N/A	N/A	N/A	0.00	0.45	61.33 %

observed difference is due to chance. A *p*-value of 0.05 was used to assess a statistical difference. The A-statistic describes the within-group homogeneity compared to random expectation. An A=1 indicates all items within a group are identical while an A=0 indicates heterogeneity within groups equals expectation by chance. McCune and Grace (2002) indicate that in community ecology, A values are typically < 0.1 while an A > 0.3 is considered fairly high.

2.7.2 Human Disturbance Rating

Using Minitab® Release 14, the human disturbance rating scores were plotted against the Delaware Rapid Assessment Procedure score for each plot. The Pearson correlation coefficient was used as a measure of the strength of the relationship between the two methods.

2.7.3 Vegetation Sampling Method Comparison

Two different vegetation sampling methods were compared in Plots 1-20 (collected in 2004). At those sites, both transect and reléve plot methods were employed using the same 50 meter baseline (Section 2.3). This allowed a direct comparison between the two methods. Paired t-tests were used to determine whether significance differences in species richness (total), species richness of non-native species, % of graminoid species, absolute % cover of non-native species, % tolerant species, and Adjusted FQAI (Miller and Wardrop 2006) exists between the two methods. Not all potential metrics were compared; however, these metrics were chosen to show comprehensiveness (total species richness), ability to detect degradation (non-natives, Adjusted FQAI, % tolerant/intolerant species, etc.), and to detect other disparities (% graminoids). Most of these metrics also showed a correlation with human disturbance and thus allows a comparison of how each potential metric differs when derived from the different plot methods. In addition, species diversity, as measured by Jaccard's index (Magurran 1988), was compared for each method in each plot.

Data analysis was conducted using Minitab® Release 14. A *p*-value of 0.05 was used to assess a statistical difference.

2.7.4 Metric Analysis

Potential metrics, representing differing aspects of the vegetation community such as functional and compositional guilds, were calculated from the reléve plot dataset (total of 52 plots). Different measures such as presence/absence, relative cover, absolute cover, and proportion of species composition were considered for most metrics. These measures correlated to the human disturbance rating. This analysis was cursory and was only intended to indicate which potential metrics may be useful in the VIBI model. In addition, a few metrics were grouped by various classification systems to discern what effect classification has on metric relationship with human disturbance. Data analysis was conducted using Minitab® Release 14.

Following additional data collection during the summer of 2006 (i.e. VIBI Phase 2), metric analysis will follow a more formal protocol to screen and identify the final list of metrics (Jones 2005; Blocksom et al. 2002). This protocol will include the following steps:

1. Discriminatory Power/Range of Values: Box plots will be used to assess the range of values and ability of each metric to discriminate between different levels of disturbance. Those metrics able to discriminate between disturbance groups will be considered further.
2. Correlation to Disturbance: The relationship of each metric to increasing human disturbance will be assessed using scatterplots and either Spearman rank or Pearson correlation coefficients. Those metrics with the strongest correlation to human disturbance will remain under consideration.
3. Redundancy: Metrics redundancy will be assessed based on their correlation with each other and content of information each contains. When redundant metrics are identified, the one with the strongest correlation to human disturbance and most effective discriminatory power will be retained.

3.0 RESULTS

3.1 Classification

3.1.1 Nonmetric Dimensional Scaling Ordination

The summary and results of the Nonmetric Dimensional Scaling ordination (NMS) are shown in Table 3 and Figures 5-11. The reduction of stress in the ordination greatly decreased beyond two dimensions (Figure 12). Since the ordination seeks the least amount of dimensions which best explain variation in the dataset (i.e., reduction of stress), a two dimensional solution was recommended for the ordination (Figure 12). Axis 1 explained 92% of the variation in the dataset and appears to represent a nutrient/pH gradient as indicated by the strong separation of extremely rich/calcareous fens (Figure 5). Axis 2, while only explaining a small proportion of variation (7%), appears to represent soil type (Figure 9). Because the Beal's Smoothing transformation is so powerful it may produce the appearance of reliable patterns when in fact none occur (McCune and Grace 2002). However, upon inspecting the raw plot data, it was concluded that the pattern of the ordination was well represented in the actual data (except Plot 03).

The ordination shows two distinct groups: Riparian Shrublands and Fens (Figure 5). The riparian shrubland group is obvious and well delineated. Further ordinations did not show any significant variation within this group. The fen group, however, does show additional groups (Figure 5). Extremely rich/calcareous fens clearly separate from other fen types and probably should be considered separately during VIBI development. Plot 13, which was initially classified as a riparian shrubland and was lacking soils data, was grouped with fen plots. This subalpine willow carr very likely has alternating pockets of organic and mineral soils. The presence of organic soils is likely the reason this plot appears to be floristically similar to fens. This also suggests that riparian shrublands with organic soils may be more appropriately considered as fens for VIBI development and application. Additional data from riparian shrublands with organic soils will be sought to confirm this speculation.

Three "outlier" Plots (03, 27, and 48) appear in the ordination. Plot 03 is a riverine wet meadow located adjacent to Plot 20 (an extremely rich fen). Plot 03 and 20 share a few species in common such as *Carex utriculata*, *C. simulata*, and *Deschampsia caespitosa* due to their proximity to each other and it appears that the Beal's Smoothing transformation overemphasized their similarity based on these shared species as they are clearly two very different wetland types. Plot 27 is a shrubby fen which contained a few extremely rich fen species, thus its transitional position between extremely rich and other fen types. Plot 48 has been impacted by acid-mine drainage and barely "scored" within the reference range.

Table 3. Non-metric Dimensional Scaling Ordination Results.

Software	PCORD (NMS Autopilot Mode used)		
Distance Measure	Sorenson		
Starting Configuration	Random		
Number of Runs with Real Data	40		
Number of Dimensions Assessed	6		
Number of Dimensions in Final Solution	2		
Monte Carlo Test Result	50 randomized runs; p = 0.0196 (for all axes)		
Number of Iteration in Final Result	61		
Stability Criterion	0.000010		
Proportion of Variance of Each Axis (Sorenson Distance)		Increment	Cumulative
	Axes 1 =	$r^2 = 0.916$	$r^2 = 0.916$
	Axes 2 =	$r^2 = 0.070$	$r^2 = 0.986$
Final Stress (for 2-D solution)	4.94644		
Final Instability	0.00001		

Only three plots were representative of wet meadows (Plots 03, 39, and 49). In addition, two of these plots were suggested in the ordination to actually be a different system type (Plot 39 a fen and Plot 49 a riparian shrubland). Plot 39 had an O-horizon about 6 inches thick and a deep, thick A-horizon. Although not technically classified as an organic soil, the thick O and A horizons, and high water table due to groundwater discharge in late summer may support the plot being classified as a fen as opposed to a wet meadow. Plot 49 is a one-acre patch of wet meadow within a larger riparian complex (interspersion of meadow and shrublands). It appears this plot is more representative of riparian shrublands despite low shrub cover. Additional wet meadow reference plots need to be collected to confirm if distinct wet meadow types can be delineated from fens and riparian shrublands.

Figures 5-11 show the NMS ordination grouped by various classification and environmental variables. Some of the variables appear to be redundant in terms of variation explained in the dataset. The Ecological System (Figure 5), HGM (Figure 6), HGM Subclass (Figure 7), and Soil Type (Figure 9) classifications all appear to adequately explain variation in the dataset, especially for Riparian Shrublands. Elevation was not able to adequately explain variation in the dataset (Figure 11). The HGM Subclass classification appears to explain some variation of fens with the Outflow (fen with an outlet but no inlet) subclass clustering together. However, the unmeasured nutrient/pH gradient (Figure 5) seems to be the most important explanatory variable for fens and suggests that at least two fen Ecological System types should be considered: (1) extremely rich fens and (2) intermediate/rich fens.

The *a priori* Ecological System classification grouped all sites with organic soils as fens, regardless of physiognomy or HGM class. The position of Plot 13 in the ordination (Figure 5) seems to confirm this decision. Future data analysis may add further confirmation to this if, for example, Plot 13 is found to be an "outlier" in many of the riparian shrubland metric analysis graphs.

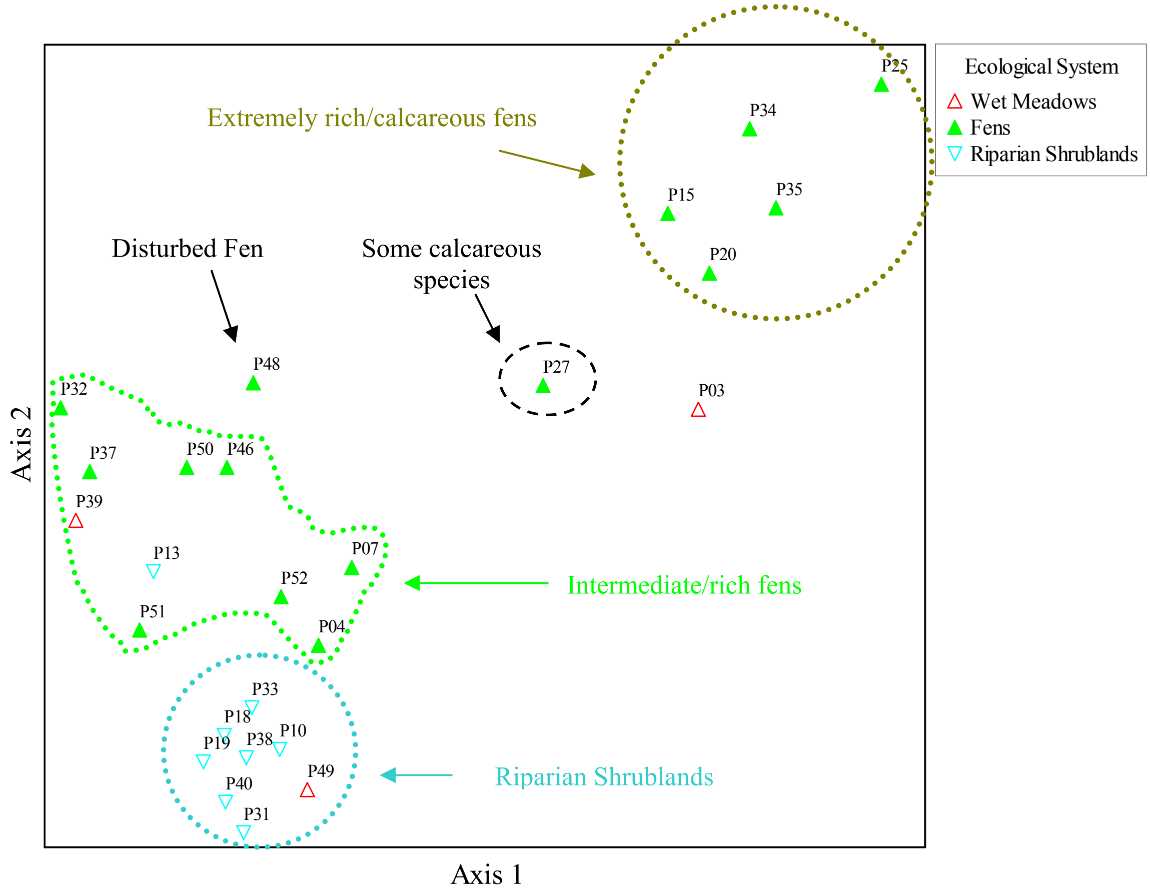


Figure 5. NMS Ordination of Reference Plots (Grouped by Ecological Systems)

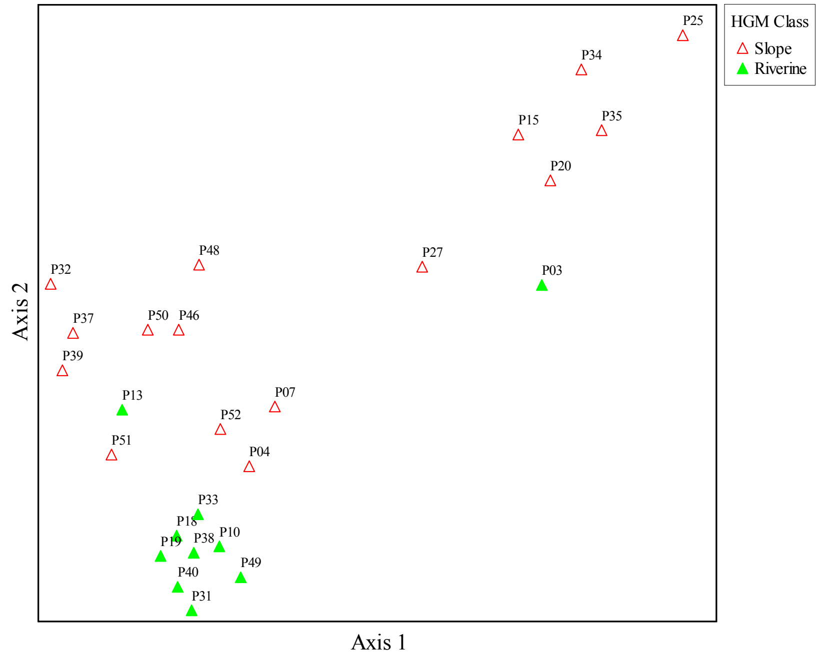


Figure 6. NMS Ordination of Reference Plots (Grouped by HGM Class)

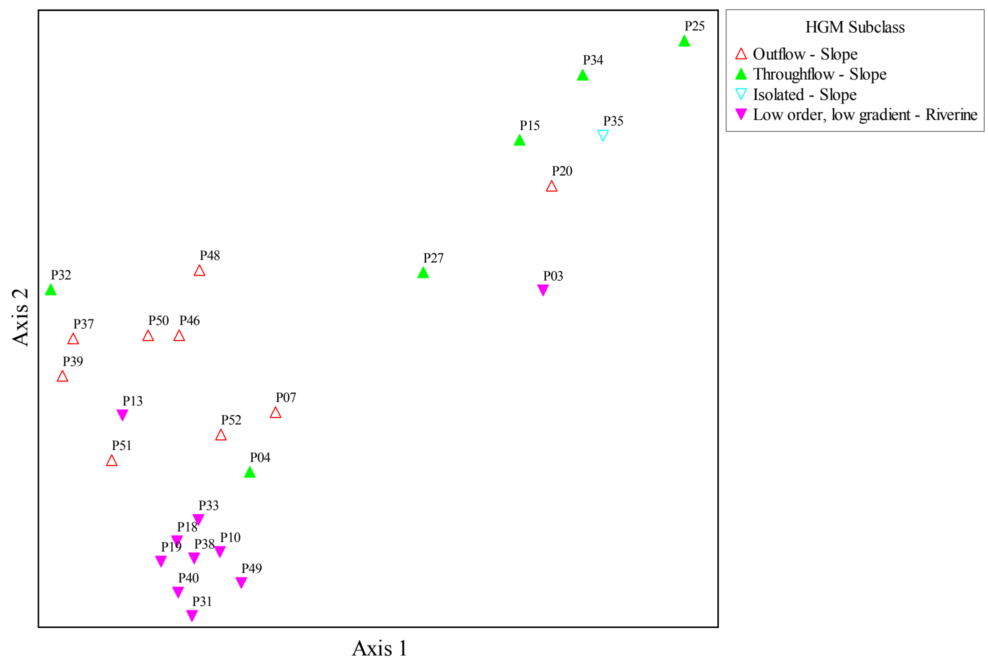


Figure 7. NMS Ordination of Reference Plots (Grouped by HGM Subclass)

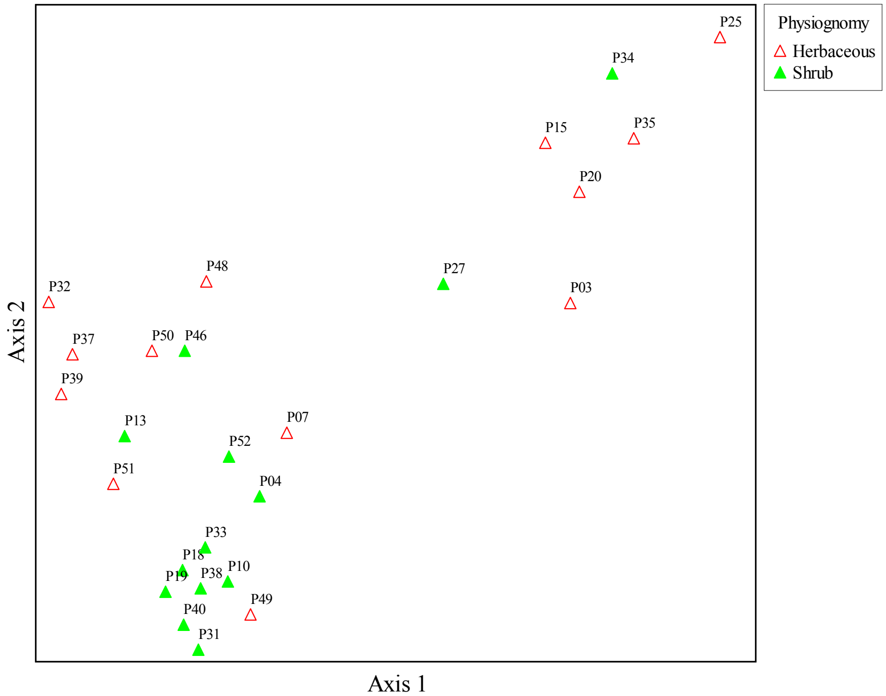


Figure 8. NMS Ordination of Reference Plots (Grouped by Physiognomy)

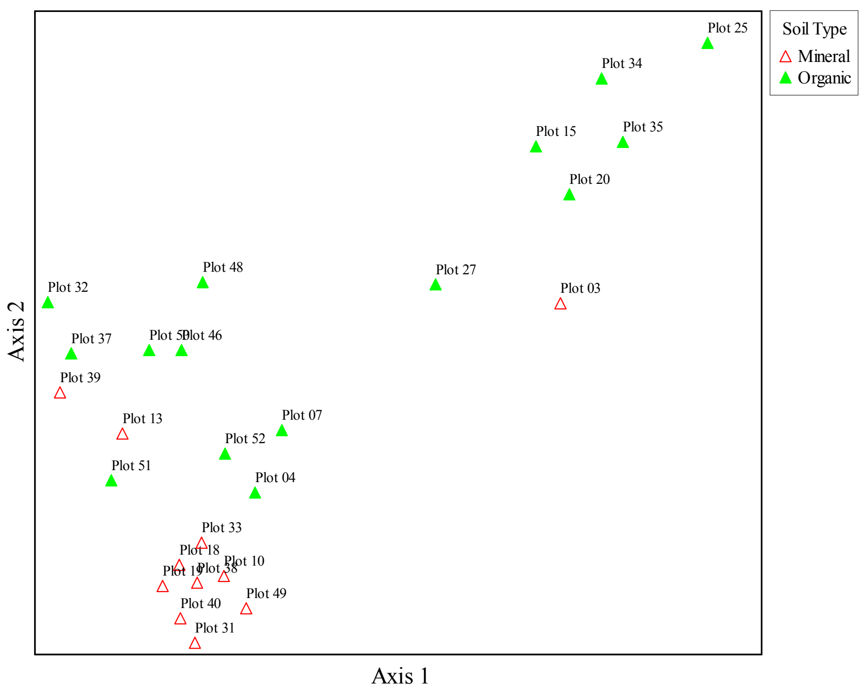


Figure 9. NMS Ordination of Reference Plots (Grouped by Soil Type)

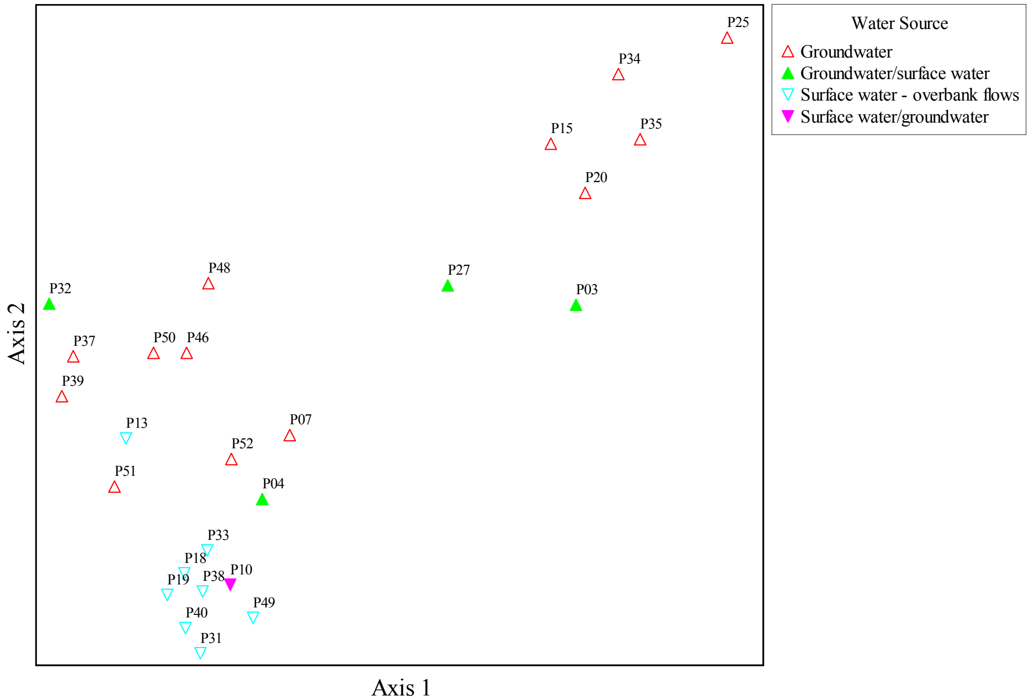


Figure 10. NMS Ordination of Reference Plots (Grouped by Water Source)

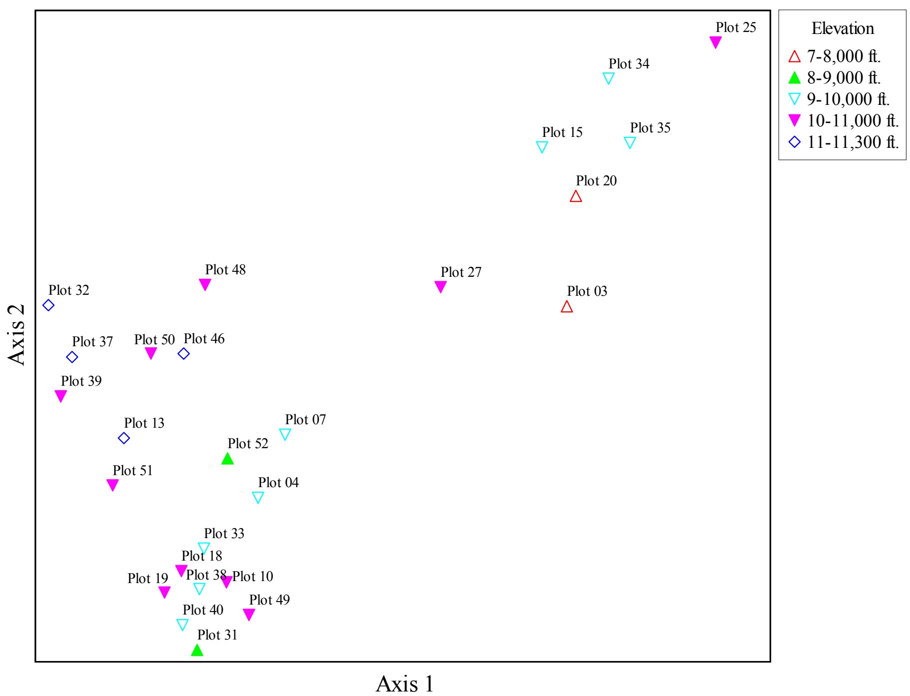


Figure 11. NMS Ordination of Reference Plots (Grouped by Elevation)

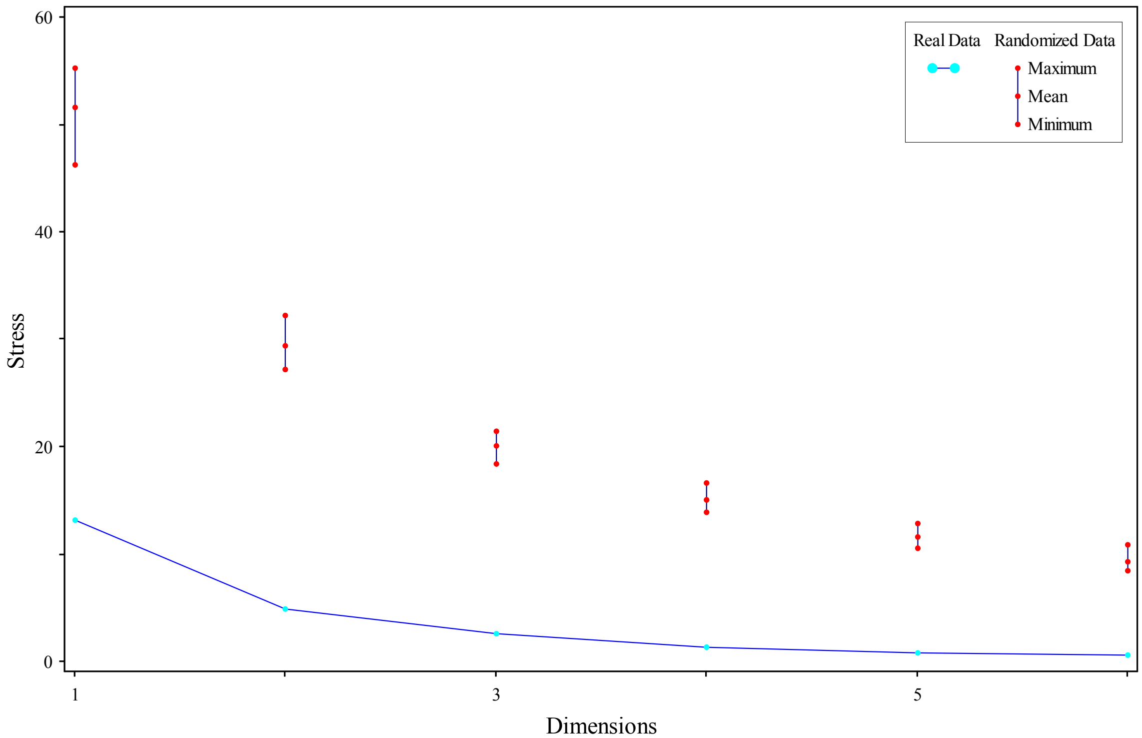


Figure 12. NMS Scree Plot

3.1.2 Cluster Analysis

The cluster analysis resulted in very similar groupings as elucidated in the NMS ordination making pruning a straightforward exercise (Figure 13).

3.1.3 Multi-response Permutation Procedure

All of the classification groups analyzed had negative T-statistics indicating that between group differences are strong and all classification groupings were statistically significant (Table 4). A-values ranged from 0.08 to 0.24, although most values were above 0.15. As indicated previously, A values in community ecology are typically < 0.1 while an A > 0.3 is considered to be high (McCune and Grace 2002). This would suggest that within group homogeneity in this dataset is relatively high when compared to these expected values. The average within group distance was smallest for Riparian Shrubland Ecological System types, riverine HGM class, low-order, low gradient HGM subclass, shrubs, and mineral soil types (Table 4). Since the concept of Riparian Shrubland Ecological Systems includes all of these variables it is not a surprise it had the lowest within group distance among these variables (Table 4). Wet meadows had the highest within group distance which confirms the noisy pattern observed for this Ecological System in the NMS ordination and cluster analysis and may be a result of low sample size (three plots). The within group distance for the slope class and organic soil type was almost identical to that of fens. This is expected since fens and organic soils have a 1:1 relationship while the majority of slope types were fens. The ability of the HGM Subclass Outflow to explain some of the fen variation is again expressed through its relatively low within group distance (Table 4). Pairwise comparisons indicate that HGM Subclass (isolated type was excluded since it was represented by one plot) results in the strongest grouping of the dataset although Riparian Shrubland and Fens showed the strongest separation suggesting Ecological Systems may also be a powerful classification method. Given the small sample size of wet meadows, it remains unclear whether the Ecological System or HGM Subclass classification best constrains natural variability.

3.2 Sample Site Selection

Site data for those plots sampled during the 2004 and 2005 field seasons are shown in Table 5. The distribution of sampled plots across the human disturbance gradient is currently skewed toward higher quality sites for all systems except wet meadows (Figure 14). Except for riparian shrublands, all Ecological System types are lacking adequate data from heavily impacted, and to a lesser extent, impacted sites. Data collection in 2006 will focus on filling these data gaps (Table 6).

3.3 Human Disturbance Rating

The human disturbance rating was strongly correlated to the Delaware Rapid Assessment Procedure (Figure 15) for each Ecological System, suggesting the method developed for this project is adequately documenting human-induced disturbance at each sample site.

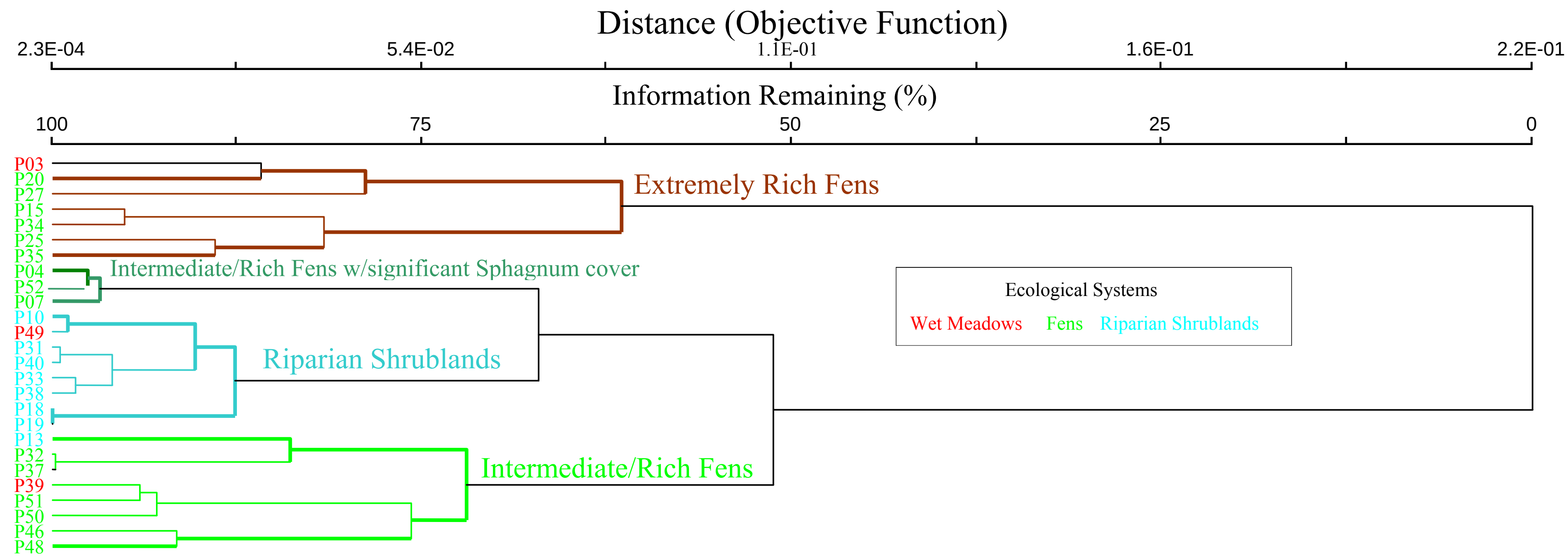


Figure 13. Dendrogram of Reference Plots (Grouped by Ecological System Type)

Table 4. Multi-Response Permutation Procedure Analysis

	Ecological Systems			**HGM**		**HGM Subclass**				**Physiognomy**		**Soil**	
	Wet Meadow	Riparian Shrublands	Fen	Slope	Riverine	Isolated	Outflow	Throughflow	Low order, low gradient	Herbaceous	Shrub	Mineral	Organic
Size of Group	3	8	15	16	10	1	9	6	10	13	13	11	15
Average within Group Distance	0.659	0.144	0.515	0.512	0.258	N/A	0.369	0.576	0.269	0.554	0.366	0.297	0.515
T	-4.11			-6.53		-6.49				-3.08		-5.92	
p	0.003			0.0004		0.00007				0.016		0.0007	
A	0.165			0.171		0.242				0.080		0.155	

	Pairwise Comparison				**Pairwise Comparison**				
	Wet Meadow vs. Fen	Wet Meadow vs. Riparian Shrublands	Fen vs. Riparian Shrublands	N/A	Outflow vs. Throughflow	Outflow vs. Low order, low gradient	Throughflow vs. Low order, low gradient	N/A	N/A
T	0.58	0.79	-7.47		-2.66	-6.78	-4.96		
p	0.668	0.197	0.0001		0.024	0.0002	0.003		
A	0.028	0.032	0.223		0.129	0.216	0.199		

Note: See section 3.1.3 for explanation of T and A.

Table 5. Site Characteristics of Sampled Plots

Plot	A priori Disturbance Category	Dominant Land Use	Human Disturbance Rating	Sampling Date	Site Name	Ownership	County	Watershed	Elevation (ft)	Ecological System	UTM Zone	UTM NAD83 Easting	UTM NAD83 Northing	Soil Type	WAA Size (hectares)
1	Minimal Impact	Recreation	63.50	07/0704	Cataract Lake	USFWS	Summit	Blue River	8750	Wet Meadow	13	387366	4410496	Mineral	0.18
2	Moderate Impact	Grazing	40.00	07/08/04	Cataract Lake- Irrigated Meadow	Private	Summit	Blue River	8454	Wet Meadow	13	389494	4411631	Mineral	1.89
3	Minimal Impact	Grazing	77.73	07/-9/04	County Line Meadow	BLM	Grand	Blue River	7740	Wet Meadow	13	386743	4419368	Mineral	0.35
4	Minimal Impact	Natural	85.63	07/13/04	Frisco Boardwalk Fen	USFS	Summit	Blue River	9120	Fen	13	405649	4380424	Organic	0.58
5	Moderate Impact	Suburban	27.50	07/14/04	Frisco Bike Path Shrubland	USFS	Summit	Blue River	9120	Riparian Shrubland	13	405735	4380438	Mineral	1.24
6	High Impact	Urban	17.03	07/15/04	Straight Creek - Silverthorne	Municipal	Summit	Blue River	8888	Riparian Shrubland	13	408776	4387160	Mineral	1.51
7	Reference	Natural	84.75	07/20/04	Lost Park Campground	USFS	Park	Upper South Platte River	9960	Fen	13	456222	4348380	Organic	0.24
8	Minimal Impact	Grazing	54.00	07/21/04	BLM 94	BLM	Park	South Platte River Headwaters	9600	Wet Meadow	13	424978	4350609	Mineral	0.24
9	High Impact	Grazing	19.13	07/22/04	Teter SWA Parking Lot	CDOW	Park	South Platte River Headwaters	9665	Riparian Shrubland	13	426853	4359100	Mineral	1.34
10	Reference	Natural	86.50	07/23/04	Michigan Creek Campground	USFS	Park	South Platte River Headwaters	10000	Riparian Shrubland	13	424353	4362357	Mineral	6.34
11	Moderate Impact	Suburban	63.50	07/27/04	Breckenridge Golf Course	Municipal	Summit	Blue River	9300	Riparian Shrubland	13	411402	4375350	Mineral	1.1

Plot	A priori Disturbance Category	Dominant Land Use	Human Disturbance Rating	Sampling Date	Site Name	Ownership	County	Watershed	Elevation (ft)	Ecological System	UTM Zone	UTM NAD83 Easting	UTM NAD83 Northing	Soil Type	WAA Size (hectares)
12	High Impact	Grazing	31.13	07/28/04	Horse Creek Fen 1	County	Summit	Blue River	8000	Fen	13	389963	4416033	Organic	0.53
13	Reference	Natural	86.25	07/29/04	Deer Creek	USFS	Summit	Blue River	11000	Riparian Shrubland	13	425236	4377901	Mineral	2.07
14	High Impact	Suburban	32.75	07/29/04	Soda Creek	County	Summit	Blue River	9020	Wet Meadow	13	413041	4383563	Mineral	2.21
15	Reference	Natural	91.75	08/06/04	High Creek Fen	Private	Park	South Platte River Headwaters	9290	Fen	13	415981	4328230	Organic	26.32
16	High Impact	Mining	28.25	08/06/04	High Creek Fen	Private	Park	South Platte River Headwaters	9290	Fen	13	416069	4328353	Organic	2.72
17	High Impact	Suburban	63.88	08/09/04	Bemrose Creek	County	Summit	Blue River	10700	Fen	13	409433	4359579	Organic	0.19
18	Reference	Natural	90.00	08/10/06	Middle Fork Swan River	USFS	Summit	Blue River	10000	Riparian Shrubland	13	419389	4372351	Mineral	4.94
19	Reference	Natural	92.50	08/11/04	Indiana Creek	USFS	Summit	Blue River	10600	Riparian Shrubland	13	414071	4364864	Mineral	3.63
20	Minimal Impact	Natural	87.50	08/13/04	County Line Fen	CDOW	Grand	Blue River	7750	Fen	13	386715	4419389	Organic	0.2
21	High Impact	Grazing	31.13	07/28/04	Horse Creek Fen 2	County	Summit	Blue River	8000	Fen	13	389963	4416033	Organic	0.53
22	High Impact	Grazing	8.25	07/07/05	Horse Creek-irrigated meadow	County	Summit	Blue River	8000	Wet Meadow	13	389811	4416186	Mineral	1.29
23	Moderate Impact	Grazing	30.75	07/07/05	Horse Creek-Riparian	County	Summit	Blue River	8060	Riparian Shrubland	13	390055	4416443	Mineral	0.88
24	Moderate Impact	Grazing	47.50	07/08/05	Iron Springs	County	Summit	Blue River	9242	Fen	13	408451	4380581	Organic	1.34

Plot	A priori Disturbance Category	Dominant Land Use	Human Disturbance Rating	Sampling Date	Site Name	Ownership	County	Watershed	Elevation (ft)	Ecological System	UTM Zone	UTM NAD83 Easting	UTM NAD83 Northing	Soil Type	WAA Size (hectares)
25	Minimal Impact	Grazing	70.00	07/12/05	Crooked Creek Fen 1	USFS	Park	South Platte River Headwaters	10037	Fen	13	415122	4347238	Organic	1.13
26	High Impact	Grazing	11.63	07/13/05	Crooked Creek Fen 2	USFS	Park	South Platte River Headwaters	10016	Fen	13	415214	4347174	Organic	1.71
27	Minimal Impact	Natural	87.20	07/13/05	Crooked Creek Fen 3	USFS	Park	South Platte River Headwaters	10050	Fen	13	415024	4347285	Organic	0.92
28	High Impact	Grazing	39.25	07/14/05	Tomahawk SWA	CDOW	Park	South Platte River Headwaters	9096	Riparian Shrubland	13	425184	4326976	Mineral	0.7
29	Moderate Impact	Grazing	49.00	07/14/05	Tomahawk SWA2	CDOW	Park	South Platte River Headwaters	9088	Riparian Shrubland	13	425166	4327352	Mineral	0.4
30	Minimal Impact	Exurban	44.25	07/15/05	Tarryall Creek	USFS	Park	South Platte River Headwaters	10306	Riparian Shrubland	13	418023	4357048	Mineral	7.44
31	Reference	Natural	100.00	07/19/05	Trail Creek	USFS	Grand	Colorado River Headwaters	8984	Riparian Shrubland	13	406499	4459712	Mineral	0.41
32	Reference	Natural	100.00	07/21/05	Second Creek	USFS	Grand	Colorado River Headwaters	11268	Fen	13	432956	4408597	Organic	0.26
33	Minimal Impact	Natural	82.50	07/22/05	St. Louis Creek	USFS	Grand	Colorado River Headwaters	9388	Riparian Shrubland	13	423068	4414284	Mineral	1.21
34	Reference	Natural	91.75	07/27/05	High Creek Fen - Shrubland	Private	Park	South Platte River Headwaters	9276	Fen	13	415702	4327905	Organic	0.25

Plot	A priori Disturbance Category	Dominant Land Use	Human Disturbance Rating	Sampling Date	Site Name	Ownership	County	Watershed	Elevation (ft)	Ecological System	UTM Zone	UTM NAD83 Easting	UTM NAD83 Northing	Soil Type	WAA Size (hectares)
35	Moderate Impact	Grazing	67.63	07/27/05	Teter-Michigan Creek SWA	CDOW	Park	South Platte River Headwaters	9672	Fen	13	426459	4358616	Organic	0.93
36	High Impact	Grazing	12.38	07/27/05	Teter-Michigan Creek SWA2	CDOW	Park	South Platte River Headwaters	9686	Wet Meadow	13	426464	4358731	Mineral	0.63
37	Reference	Natural	90.38	07/29/05	Michigan Creek Headwaters	USFS	Park	South Platte River Headwaters	11292	Fen	13	420999	4367487	Organic	0.21
38	Moderate Impact	Suburban	69.88	08/01/05	Mesa Cortina-Wilderness	County	Summit	Blue River	9600	Riparian Shrubland	13	405626	4386288	Mineral	0.64
39	Reference	Natural	95.88	08/02/05	Spruce Creek	USFS	Summit	Blue River	10757	Wet Meadow	13	408443	4364948	Mineral	0.16
40	Minimal Impact	Recreation	81.50	08/03/05	N. Fork Swan River	USFS	Summit	Blue River	9850	Riparian Shrubland	13	418977	4374191	Mineral	1.11
41	High Impact	Mining	20.00	08/04/05	N. Fork Swan River2	USFS	Summit	Blue River	9698	Riparian Shrubland	13	417440	4375082	Mineral	0.47
42	Moderate Impact	Grazing	36.88	08/15/05	Tarryall Creek SWA	CDOW	Park	South Platte River Headwaters	8900	Wet Meadow	13	446707	4342923	Mineral	2
43	Moderate Impact	Grazing	42.50	08/16/05	Hwy. 9/FR 258	USFS	Park	South Platte River Headwaters	9183	Riparian Shrubland	13	443174	4301507	Mineral	0.42
44	Minimal Impact	Grazing	60.50	08/16/05	Badger Creek SWA	CDOW	Park	South Platte River Headwaters	8955	Fen	13	428314	4321085	Organic	1.27
45	High Impact	Mining	15.75	08/17/05	Middle Fork S. Platte River-Fairplay Beach	Municipal	Park	South Platte River Headwaters	9922	Riparian Shrubland	13	413526	4341839	Mineral	3.17

Plot	A priori Disturbance Category	Dominant Land Use	Human Disturbance Rating	Sampling Date	Site Name	Ownership	County	Watershed	Elevation (ft)	Ecological System	UTM Zone	UTM NAD83 Easting	UTM NAD83 Northing	Soil Type	WAA Size (hectares)
46	Reference	Natural	94.38	08/18/05	Montezuma Iron Fen	USFS	Summit	Blue River	11193	Fen	13	427923	4378064	Organic	0.57
47	High Impact	Mining	33.50	08/18/05	Pennsylvania Mine	USFS	Summit	Blue River	10881	Wet Meadow	13	430201	4383761	Mineral	0.17
48	Moderate Impact	Mining	72.50	08/18/05	Pennsylvania Mine2	USFS	Summit	Blue River	10982	Fen	13	430164	4383783	Organic	0.68
49	Minimal Impact	Recreation	89.25	08/19/05	Ten Mile Creek	USFS	Summit	Blue River	10000	Wet Meadow	13	403054	4381500	Mineral	0.31
50	Reference	Natural	100.00	08/23/05	Iron Creek	USFS	Grand	Colorado River Headwaters	10118	Fen	13	421121	4412805	Organic	0.78
51	Reference	Natural	100.00	08/23/05	Iron Creek	USFS	Grand	Colorado River Headwaters	10112	Fen	13	421323	4412852	Organic	0.17
52	Minimal Impact	Natural	88.25	08/25/05	Monarch Lake	USFS	Grand	Colorado River Headwaters	8375	Fen	13	437374	4439314	Organic	0.53

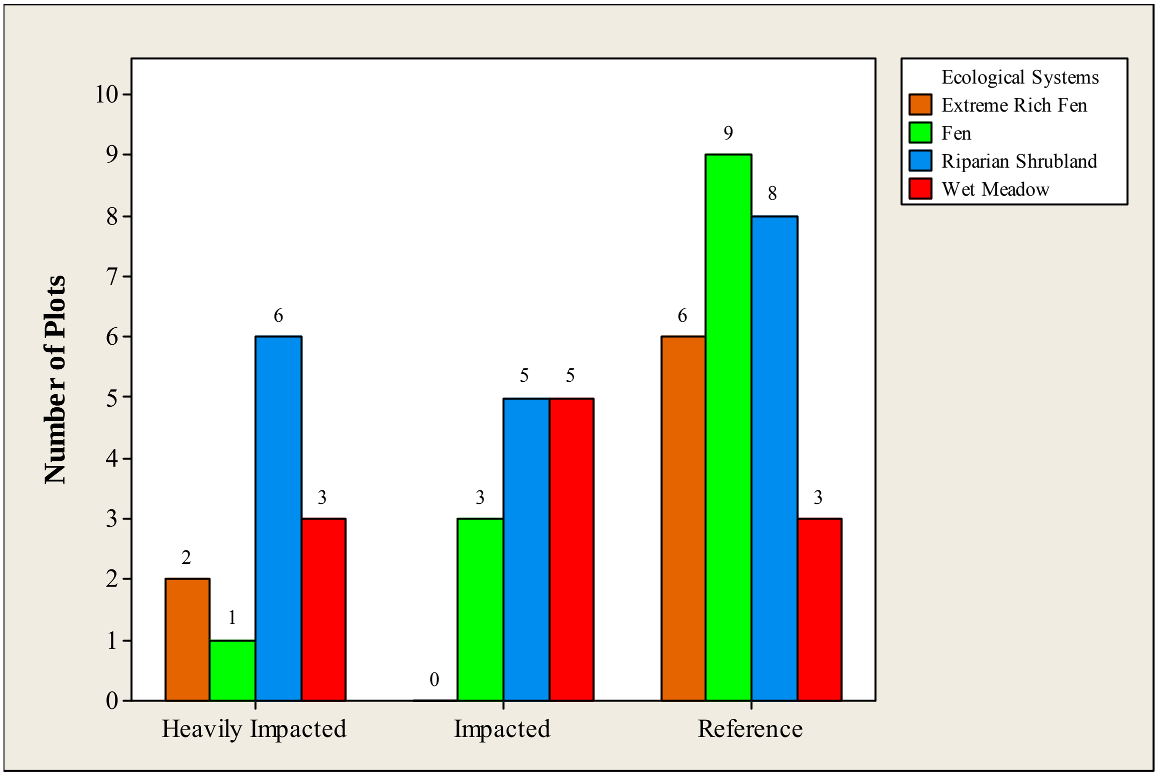


Figure 14. Plot Distribution Across Ecological System Types and Degree of Human Disturbance

Table 6. Plot Data Gaps

	Extremely Rich Fens	**Fens**	**Riparian Shrublands**	**Wet Meadows**	**TOTALS**
Reference					
Number of plots sampled	6	9	8	3	26
Plots to be sampled in 2006	*2*	*0*	*0*	*5*	*7*
Sub-Total	**8**	**9**	**8**	**8**	**33**
Impacted					
Number of plots sampled	0	3	5	5	13
Plots to be sampled in 2006	*8*	*5*	*3*	*3*	*19*
Sub-Total	**8**	**8**	**8**	**8**	**32**
Heavily Impacted					
Number of plots sampled	2	2	6	3	13
Plots to be sampled in 2006	*6*	*6*	*2*	*5*	*19*
Sub-Total	**8**	**8**	**8**	**8**	**32**
TOTAL	**24**	**25**	**24**	**24**	**97**

3.4 Transect vs. Reléve Plot Method

Jaccard's diversity index (Magurran 1988) was used to compare composition of each plot method for each sampled plot (Table 7). A value of 0.0 indicates no similarity while a value of 1 indicates identical species composition. No plot had a Jaccard index > 0.60, while most were < 0.50. These values suggest that the two plot methods result in a species list with very different composition.

For paired t-tests, significant differences were found between transect and reléve plot methods for all but two of the potential metrics analyzed (Table 8). The range of values for those metrics are indicated in Figure 16. Transect plots did not document as many species as the reléve plots (Tables 7 & 8, Figure 17) which not only affects richness based metrics but overemphasizes proportion based metrics such as % graminoids and may underemphasize other proportion metrics based on non-dominant species. However, there was no significant difference in absolute % cover of non-native species between the two plot methods. This isn't surprising since the transect method has been shown to be adequate for cover and dominance data (Stohlgren et al. 1998; Mack et al. 2000). Nonetheless, a plot by plot comparison shows that the methods aren't always comparable in documenting percent cover (Figure 18).

Two metrics based on the Floristic Quality Assessment were compared between the two plot methods: % tolerant Species[4] and the Adjusted Floristic Quality Assessment Index[5] (Adjusted FQAI). Paired t-tests showed a significant difference for % tolerant species and no significant difference for the Adjusted FQAI metric (Table 8).

Although the two plot methods differ in their ability to document composition and abundance, for those metrics which show a correlation with increasing human disturbance, both the transect and reléve method document the trend (Figure 19). However, because the transect method underreports values for all metrics and has narrower range it would result in lower and perhaps less accurate metric scores in an VIBI model than the reléve method (Figure 19). Thus, resulting VIBI scores from each method would likely be different.

[4] those species with a coefficient of conservatism < 3; Rocchio *In Progress*
[5] The Adjusted FQAI is calculated as a percentage of the maximum attainable FQAI score for a site (incorporates influence of non-native species and species richness) ; see Miller and Wardrop 2006

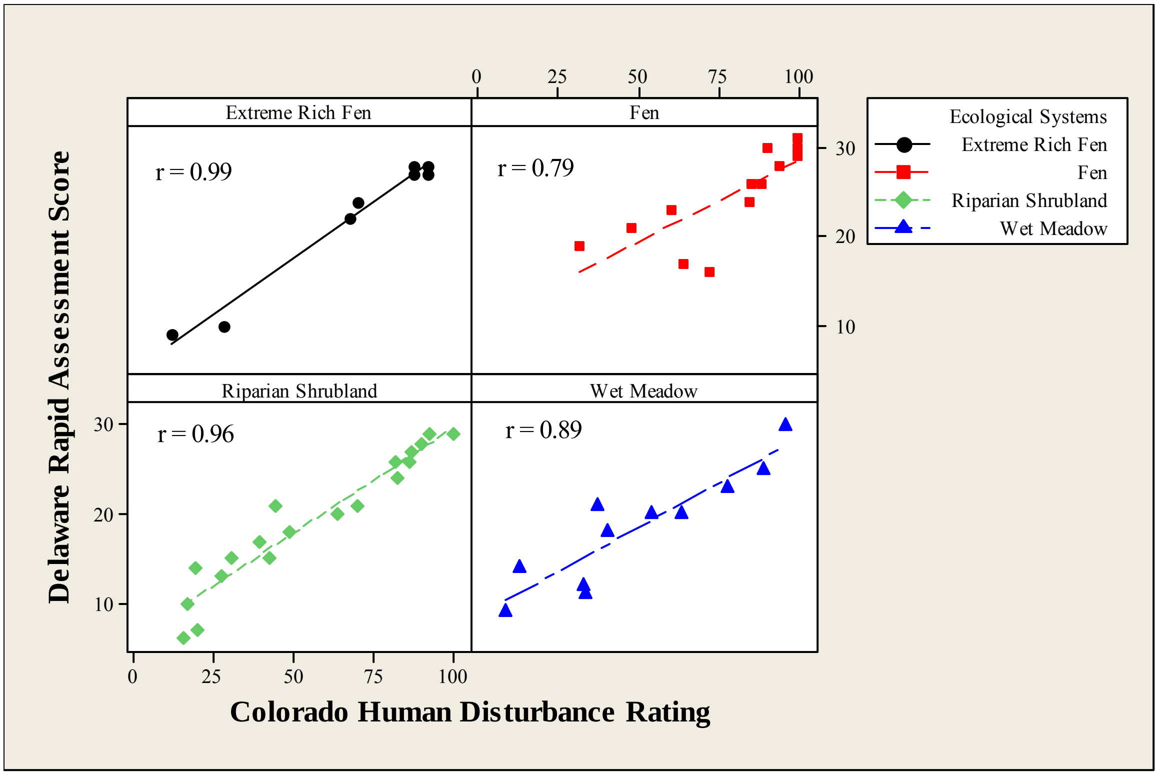


Figure 15. Calibration of Human Disturbance Rating

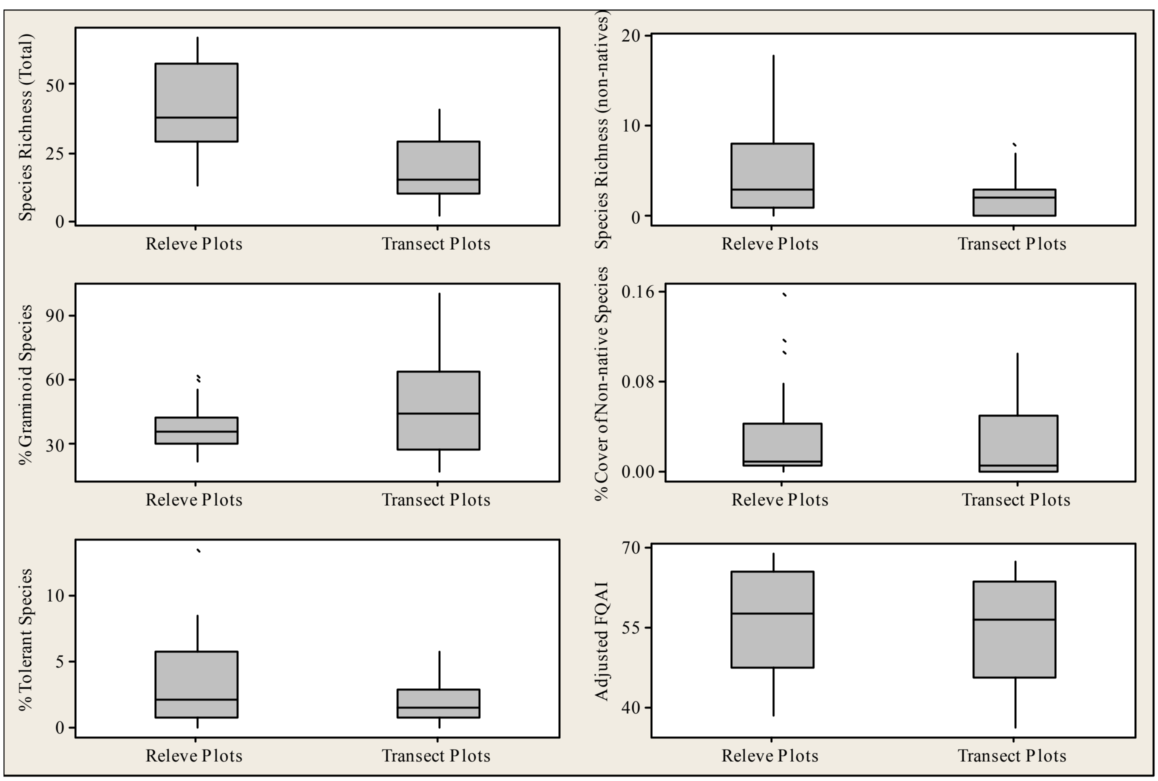


Figure 16. Boxplots of Selected Metrics for Reléve and Transect Plot Methods

Table 7. Comparison of Species Richness and Diversity Indices Between Transect and Reléve Plot Methods

Reléve Plots	Transect Plots	Species Richness (Reléve Plots)	Species Richness (Transect Plots)	Shared Species Between Plots	Jaccard Index[6]
Plot_01	TM_01	36	7	7	0.19
Plot_02	TM_02	20	10	10	0.50
Plot_03	TM_03	13	2	2	0.15
Plot_04	TM_04	38	23	21	0.53
Plot_05	TM_05	54	29	26	0.46
Plot_06	TM_06	53	22	22	0.42
Plot_07	TM_07	25	11	11	0.44
Plot_08	TM_08	31	14	13	0.41
Plot_09	TM_09	57	22	21	0.36
Plot_10	TM_10	39	9	9	0.23
Plot_11	TM_11	62	32	28	0.42
Plot_12	TM_12	22	8	6	0.25
Plot_13	TM_13	67	39	35	0.49
Plot_14	TM_14	38	15	14	0.36
Plot_15	TM_15	60	34	32	0.52
Plot_16	TM_16	29	11	11	0.38
Plot_18	TM_18	58	24	24	0.41
Plot_19	TM_19	61	41	38	0.59
Plot_20	TM_20	30	14	14	0.47

[6] Jaccard index is expressed as $C = j/(a + b - j)$, where j is the number of species found common to both samples or sites, a is the number of species in sample A, and b is the number of species in sample B (Magurran 1988)

Table 8. Paired T-Test Results Between Transect and Reléve Plots

Variables	N	Mean	Standard Deviation	SE Mean	T-Value	P-value
Species Richness (total)						
Transect	19	19.2632	11.3912	2.6133		
Reléve	19	41.7368	16.6127	3.8112	-12.15	0.000
Species Richness (non-natives)						
Transect	19	2.26316	2.37679	0.54527		
Reléve	19	4.52632	4.77689	1.09589	3.25	0.004
% Graminoid Species						
Transect	19	47.3617	22.1584	5.0835		
Reléve	19	38.4995	11.3124	2.5952	-2.61	0.018
Absolute % Cover of Non-natives						
Transect	19	2.10064	2.94197	0.67493		
Reléve	19	3.62947	4.62483	1.06101	1.65	0.116
% Tolerant Species						
Transect	19	1.81616	1.68157	0.38578		
Reléve	19	3.59526	3.42510	0.78577	3.48	0.003
Adjusted FQAI						
Transect	19	54.9221	9.9107	2.2737		
Reléve	19	56.4621	9.6595	2.2160	1.41	0.176

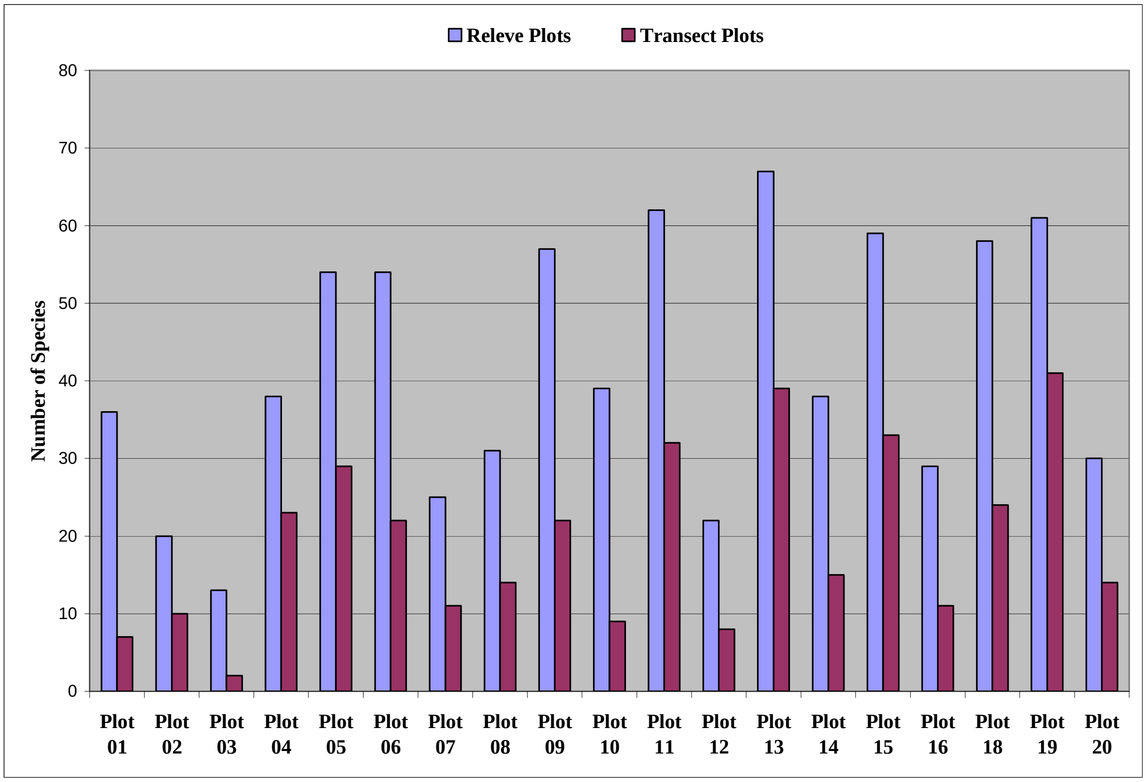


Figure 17. Plot Comparison of Species Richness

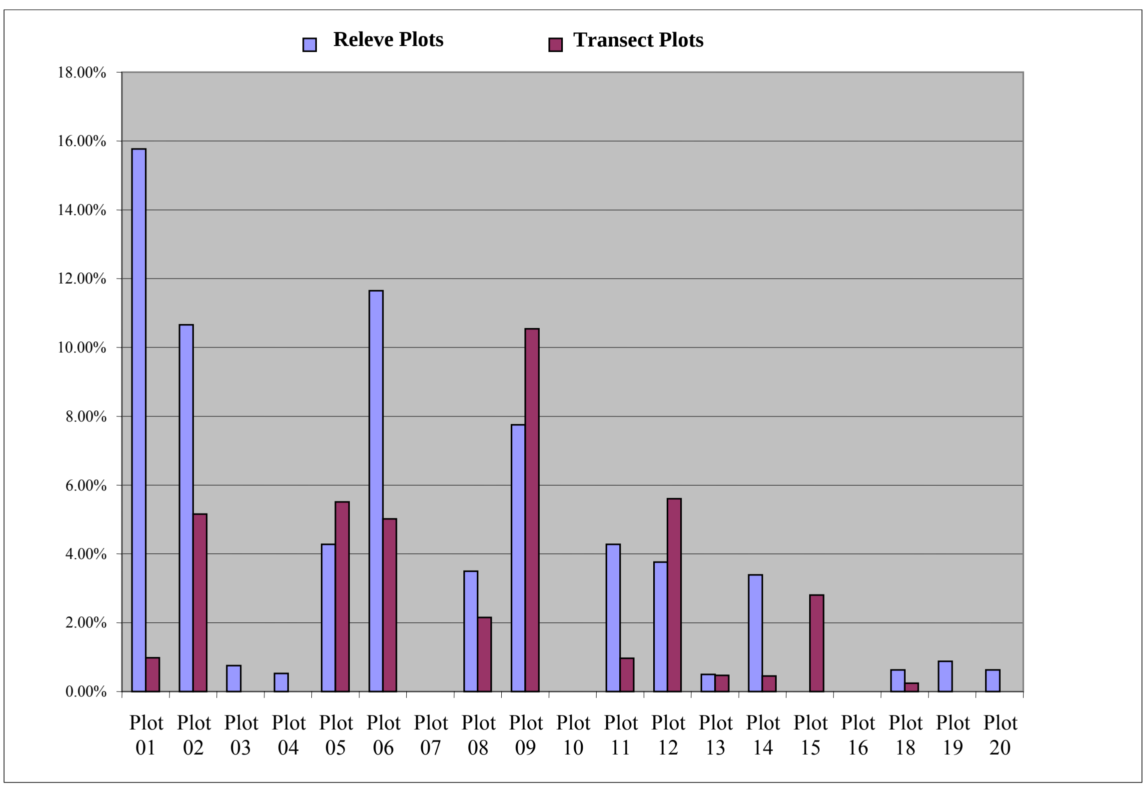


Figure 18. Plot Comparison Absolute % Cover of Non-native Species

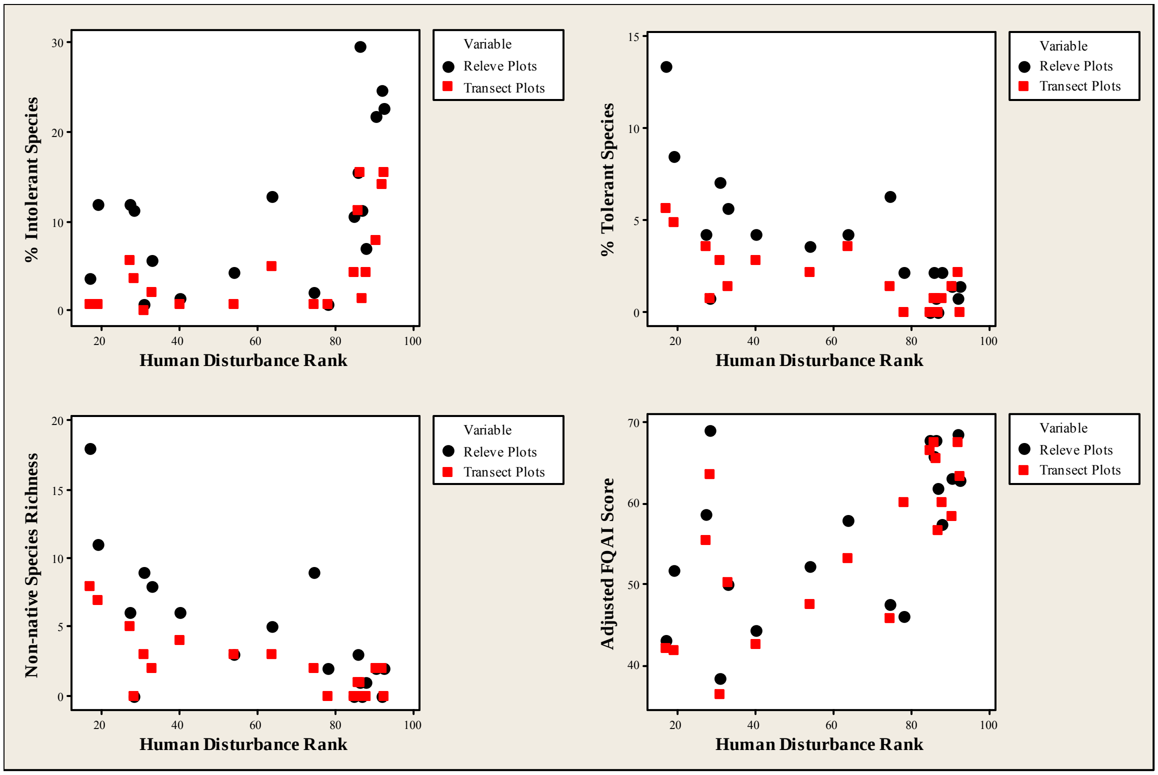


Figure 19. Select Metric-Human Disturbance Relationships Derived from Transect and Reléve Plot Methods.

3.5 Metric Analysis

Table 9 lists the vegetation attributes or potential metrics that were screened for inclusion in the VIBI model. Based on scatterplots, numerous metrics show promise for each Ecological System (Table 10). For a few of the metrics which showed correlations to human disturbance (% non-native species, Adjusted FQAI, and absolute % cover of perennial species), scatterplots were grouped according to the various classification systems (Figures 20-22). These graphs show that classification can have a large affect on the relationship between metrics and human disturbance. Similar scatterplots for all potential metrics will be used in future analysis to discern which classification system results in the strongest relationship for each metric. The result may be that one classification system determines which potential metrics are included in the VIBI model while another classification is used to "score" those metrics (sensu Mack 2004a).

Table 9. List of Potential Metrics

% non-natives	% native perennial graminoid	% dicot
% non-native cover-absolute	carex richness	% dicot cover-relative
% non-native cover-relative	% carex	% dicot cover-absolute
% dominant non-native cover-relative	% carex cover-relative	% native dicot
% dominant non-native cover-absolute	% carex cover-absolute	% non-native dicot
% dominant native cover-relative	% bryophyte cover-relative	% monocot
% dominant native cover-absolute		% monocot cover-relative
Species Richness (Total)	% bryophyte cover-absolute	% monocot cover-absolute
Species Richness (native)	% shrub cover-relative	% native monocot
Non-native Richness	% shrub cover-absolute	% non-native monocot
FQAI (native)	% bare ground	% native dicot Absolute cover
FQAI (total)	% water	% native dicot relative cover
Adjusted FQAI	% litter	% non-native dicot Absolute cover
Mean C (natives)	Annual Richness	% non-native dicot relative cover
Mean C (all)	Perennial Richness	% native monocot Absolute Cover
Mean C(natives)-cover	Invasive Richness	% native monocot relative cover
Mean C(all)-cover	% Invasive Cover-relative	% non-native monocot absolute cover
FQAI(Native)-cover	% Invasive Cover-absolute	% non-native monocot relative cover
FQAI(All)-cover	Cyperaceae Richness	% annuals
Adjusted FQAI-cover	Cyperaceae Cover-relative	% annual cover-relative
Wet Indicator (Total)	Cyperaceae Cover-absolute	% annual cover-absolute
Wet Indicator (Native)	% native graminoids	% native annual
% hydrophyte (OBL - FACW -)	% native graminoids Absolute Cover	% perennial
% hydrophyte cover-relative	% native graminoids relative cover	% perennial cover-relative
% hydrophyte cover-absolute	% native forbs Absolute Cover	% perennial cover-absolute
% forbs	% native forbs relative cover	% native perennial
% native forbs	% native annual Absolute Cover	% intolerant
% forb cover-relative	% native annual relative cover	% intolerant absolute cover
% forb cover-absolute	% native perennial Absolute Cover	% intolerant relative cover
% graminoids	% native perennial relative cover	% tolerant
% graminoid cover-relative	% native perennial graminoid Absolute Cover	% tolerant absolute cover
% graminoid cover-absolute	% native perennial graminoid relative cover	% tolerant relative cover

Table 10. Potential Metrics Correlated with the Human Disturbance Rating (metrics shared among all Ecological System types are highlighted)

	Ecological Systems			
Metric	Wet Meadow	Riparian Shrubland	Fen	Extremely Rich Fen
% non-native	X	X	X	X
% dominant non-native cover-relative	X			
% dominant native cover-absolute	X	X	X	X
FQAI (Native)	X	X		X
FQAI-(Total)	X	X		X
Mean C(Natives)	X	X	X	X
Mean C(All)	X	X	X	X
Adjusted FQAI	X	X	X	X
Mean C(Native-cover)	X	X	X	X
Mean C(All-cover)	X	X	X	X
FQAI (Native)-cover	X	X	X	X
Adjusted FQAI-cover	X	X	X	X
Wetland Indicator Status	X	X		
% hydrophyte cover-absolute		X	X	
% annual				X
% perennial cover-absolute	X	X	X	X
% native perennial	X	X	X	X
% native perennial cover-absolute	X	X	X	X
% dicot			X	
% native dicot			X	
% non-native dicot	X	X	X	X
% monocot			X	
% native monocot			X	
% non-native monocot	X	X	X	X
% bryophyte cover-absolute			X	X
% litter			X	
% intolerant species	X	X	X	X
% tolerant		X	X	
Non-native richness		X	X	
% native graminoids			X	
% native annuals-cover-relative				X
% native perennial graminoids-cover absolute			X	X

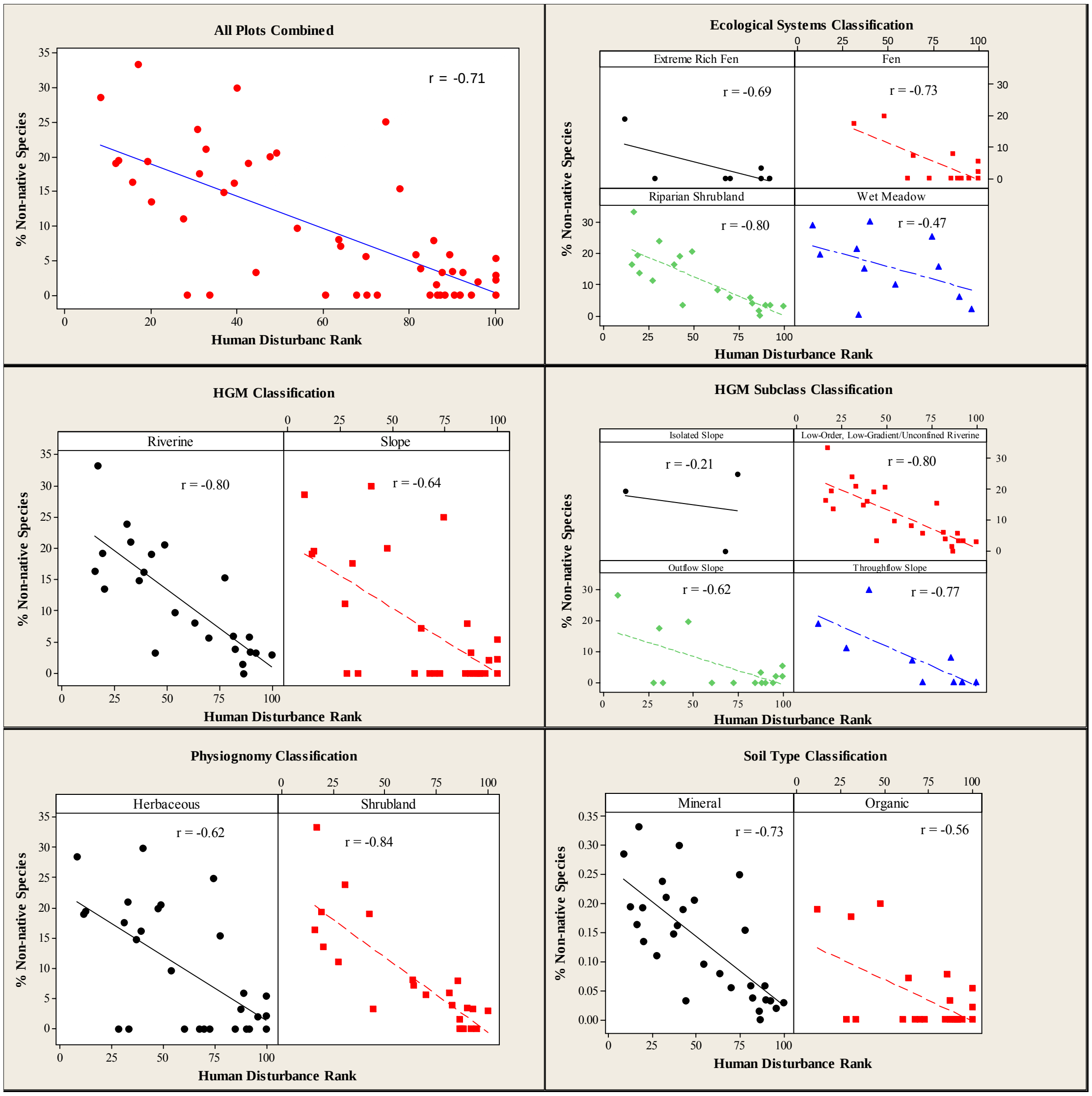


Figure 20. Percent non-native species across classification groups.

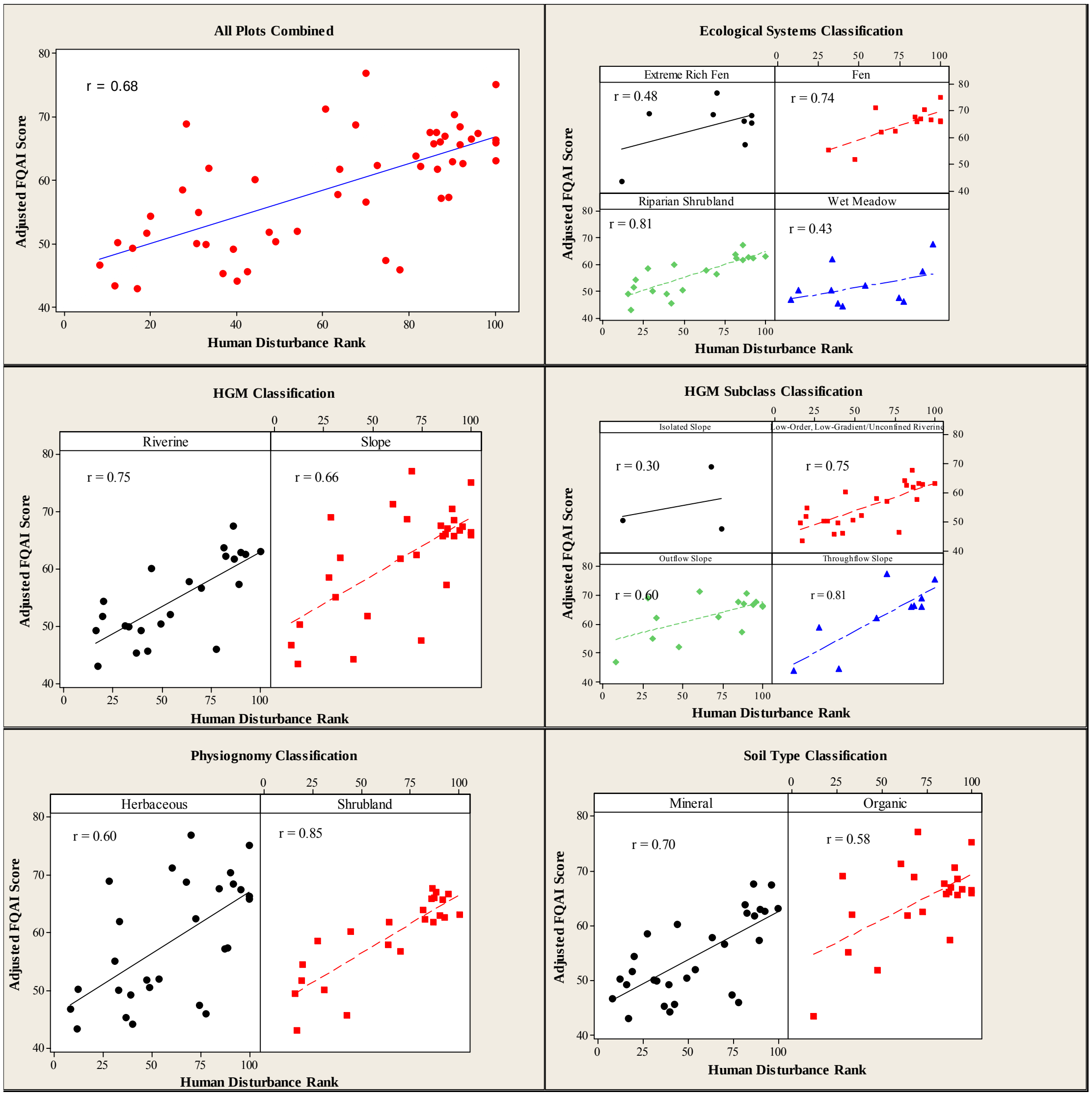


Figure 21. Adjusted FQAI across Classification Groups

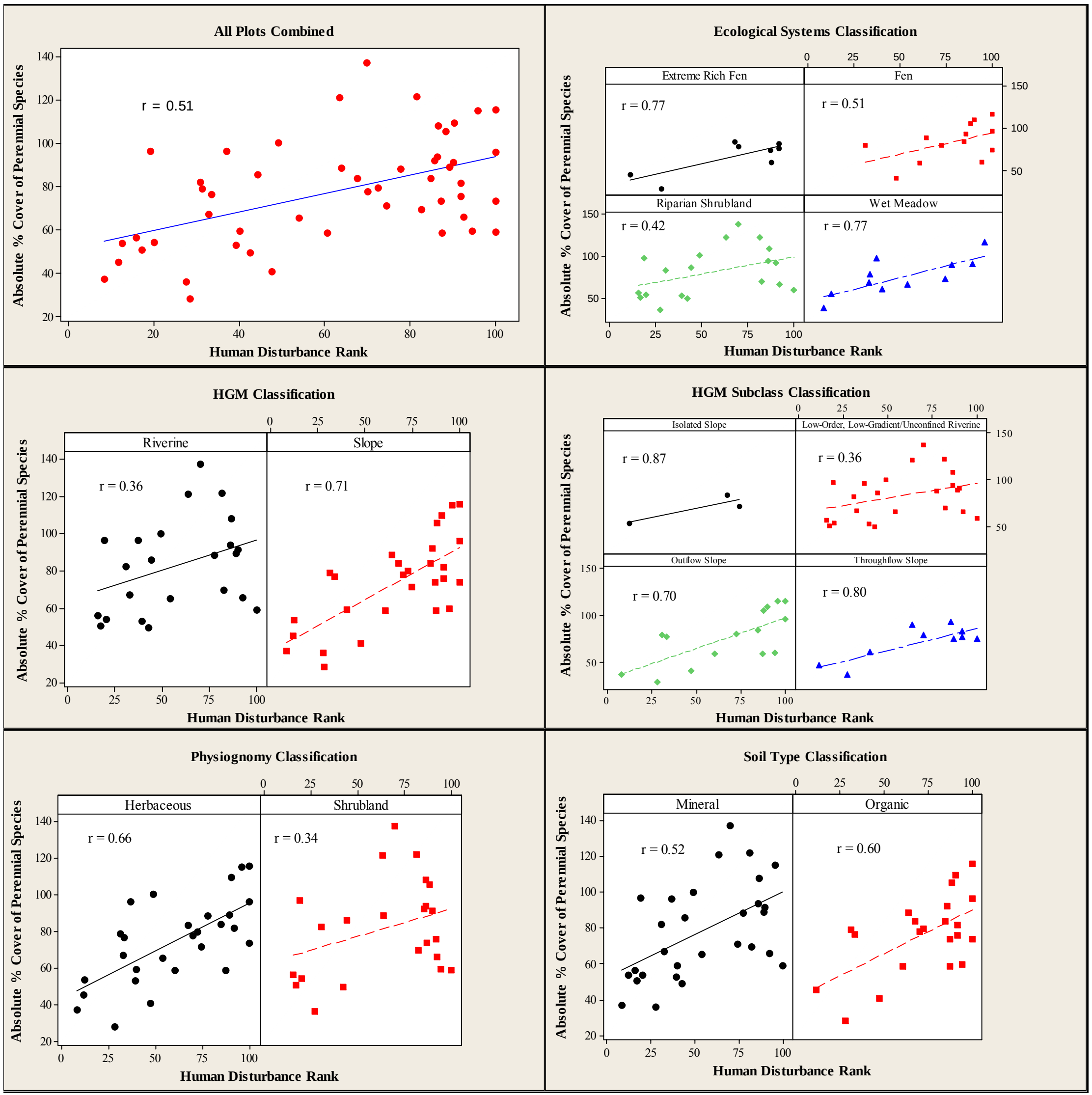


Figure 22. Percent perennial cover (absolute) across classification groups.

4.0 DISCUSSION

4.1 Classification

The NMS ordination, cluster analysis, and MRPP suggest that each classification system constrains natural variability. However, classifications based on two groups (e.g. physiognomy, soil type, HGM class) often result in more noise or variability when metrics are compared to human disturbance (Figures 20-22). As additional groups are added, the noise appears to be reduced, as seen in the Ecological System and HGM subclass classifications, suggesting that these classifications may provide more accurate "scores" for each metric.

The Ecological Systems classification, the *a priori* classification selected for this project, appears to be as or more useful than other systems since it incorporates elements of all the other classification systems such as HGM, soil type, and physiognomy. However, very few wet meadow reference plots have been sampled, thus following data collection in 2006 the classification will be reanalyzed. Since classification grouping can have an impact on correlation between metrics and human disturbance, additional consideration will be given to whether a hierarchical structure of classification systems can be used in the VIBI model. For example, the VIBI models (in terms of which metrics are selected) might be based on physiognomy but the scoring criteria for each metric could be based on Ecological Systems or HGM subclasses (sensu Mack 2004a). In other words, when assessing a wetland, an Herbaceous or Shrub VIBI model would be used depending on the physiognomic type of the vegetation, and one of four different scoring criteria would be applied depending on the Ecological System or HGM type of the wetland being assessed.

4.2 Preferred Plot Method

The transect method was found to be significantly different from the reléve method, in terms of the composition, abundance, and metric relationships. Although the transect method was often able to detect similar trends with human disturbance as the reléve method, there remained a disparity in the range of the metric values among the two methods. However, it appears that for metrics based on dominant species and/or absolute cover, the transect method may be equivalent to the reléve method. Because the transect method is poor at documenting less dominant species, it produced very different results for metrics based on species proportions (% graminoids, % annuals, etc.). The narrower range of metric values resulting from the transect method would likely result in less sensitivity and discriminatory power of transect-derived metrics. However, for Floristic Quality Assessment based metrics such as the Adjusted FQAI, the transect method appears to result in equivalent values as the reléve method.

In summary, it appears that the reléve plot method is a more suitable method for VIBI development based on:

- Transect method does not pick up most non-dominant species (making richness based metrics less accurate and comprehensive)
- Due to bias toward dominant species, the transect method results in biased proportions for some guilds (graminoids, forbs, etc.)
- Even when transect data tracks reléve data, metric values are often lower for the transect method reducing the range between high and low values. This can result in metrics which are less sensitive to changes resulting from human disturbances.

Thus, Scenario 2 (i.e. reléve method; Section 1.4) will be used for VIBI development for wet meadows, fens, and riparian shrublands. However, once these initial VIBI models have been developed using the reléve method, an attempt may be made to calculate an VIBI score for each of the transect plots to allow a comparison of final VIBI scores resulting from the different plot methods. Based on the findings in this report, it is expected that there would be significant differences; however, should this assumption prove to be false then it would suggest that future VIBI models (for additional Ecological Systems in the Southern Rocky Mountain and systems in the Central Shortgrass Prairie and Colorado Plateau ecoregions) could be constructed using transect data such as those in the Colorado Wetland and Riparian plot database (Carsey et al. 2001).

4.3 Potential Metrics

Initial analysis suggests numerous metrics may be suitable for inclusion in the VIBI models. Most metrics are related to non-native species as well as indices derived from the Floristic Quality Assessment. In addition, the proportion of graminoids, annuals, perennials, and the absolute cover of bryophytes may be useful metrics.

It appears that classification can have a large affect on the relationship between potential metrics and human disturbance (as discussed in Section 4.1). Future metric analysis will further explore the impact classification has on metric performance. As noted in Section 4.1, the result may be that one classification system determines which potential metrics are included in the VIBI model while another classification is used to "score" those metrics.

4.4 Future Data Collection & Model Development

Additional data collection during the summer of 2006 will focus on collecting data from impacted and heavily impacted sites for all Ecological Systems. A few reference sites for extremely rich fens and wet meadows will also be targeted. An attempt will be made to ensure each system has approximately eight sites from each disturbance category (Table 6). Once these data gaps are filled, classification and metric analysis will be revisited prior to initiating the remaining tasks associated with VIBI model development.

REFERENCES

Beals, E.W. 1984. Bray-Curtis Ordination: An Effective Strategy for Analysis of Multivariate Ecological Data. Advances in Ecological Research 14: 1-55.

Blocksom, K. A., J. P. Kurtenbach, D. J. Klemm, F. A. Fulk, and S. M. Cormier. 2002. Development and Evaluation of the Lake macroinvertebrate Integrity Index (LMII) for New Jersey Lakes and Reservoirs. Environmental Monitoring and Assessment **77**:311-333.

Boggs, Keith. 2000. Classification of Community Types, Successional Sequences, and Landscapes of the Copper River Delta, Alaska. Gen. Tech. Rep. PNW-GTR-469. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 244 p.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Technical Report WRP-DE-4. Washington D.C. U.S. Army Corps of Engineers.

Bureau of Land Management. 2004. Proper Functioning Condition Data. Kremmling Field Office.

Carsey, K., D. Cooper, K. Decker, and G. Kittel. 2001. Comprehensive Statewide Wetlands Classification and Characterization: Wetland Plant Associations of Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Carsey, K., G. Kittel, K. Decker, D. J. Cooper, and D. Culver. 2003. *Field Guide to the Wetland and Riparian Plant Associations of Colorado.* Colorado Natural Heritage Program, Fort Collins, CO.

Chronic, H. 1980. Roadside Geology of Colorado. Mountain Press, Missoula, MT.

Colorado Natural Heritage Program 2004. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, Colorado, U.S.A. Data exported March 2004.

Collins, J.N., E. Stein, and M. Sutula. 2004. Draft California Rapid Assessment Method for Wetlands v.3.0, User's Manual and Scoring Forms. Online at: http://www.wrmp.org/cram.html

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA.

Cooper, D.J. 1986. Community structure and classification of Rocky Mountain wetland ecosystems. Pages 66-147 *in* J.T. Windell, B.E. Willard, D.J. Cooper, S.Q. Foster, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis, editors. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U.S. Fish and Wildlife Service, Biological Report 86.

Cooper, D.J. 1990. Ecology of Wetlands in Big Meadows, Rocky Mountain National Park, Colorado. U.S. Fish and Wildlife Service, Biological Report 90(15).

Cowardin, L. M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States, U. S. Department of the Interior, Fish and Wildlife Services, Office of Biological Services, Washington D.C.

DeKeyser, E.S., D.R. Kirby, and M.J. Ell, 2003. An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. Ecological Indicators 3, 119-133.

Delaware Department of Natural Resources and Environmental Control. 2005. Delaware Rapid Assessment Procedure V. 2.0: User's Manual and Data Sheets. Dover, DE.

Faber-Langendoen, D., J. Rocchio, M. Shafale, C. Nordman, M. Pyne, J. Teague, and T. Foti. 2005. Ecological Integrity Scorecards and Performance Measures for Wetland Mitigation. NatureServe, Arlington VA. *Note:* Rocky Mountain Wetland/Riparian Ecological Integrity Assessment Scorecards are available online at: http://www.cnhp.colostate.edu/reports.html

Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain Jr., and R.D. Smith. 2002. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains. U.S.Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. ERDC/EL TR-02-21.

Jones, W. M. 2005. A vegetation index of biotic integrity for small-order streams in southwestern Montana and a floristic quality assessment for western Montana wetlands. Report to the Montana Department of Environmental Quality and U.S. Environmental Protection Agency, Montana Natural Heritage Program, Helena, Montana. 29 pp. plus appendices.

Johnson, J.B. 2005. Hydrogeomorphic Wetland Profiling: An Approach to Landscape and Cumulative Impact Analysis. EPA/620/R-05/001. U.S. Environmental Protection Agency, Washington D.C.

Karr JR and DR Dudley. 1981. Ecological perspective on water quality goals. Environmental Manager 5:55-68.

Kittel, G., E. Van Wie, M. Damm, R. Rondeau, S. Kettler, A. McMullen, and J. Sanderson. 1999. A Classification of Riparian Wetland Plant Associations of Colorado: User Guide to the Classification Project. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Kruskal, J.B. 1964. Nonmetric Multidimensional Scaling: A Numerical Method. Psychometrika 29: 115-129.

Mack. J.J., M. Micacchion, L.D. Augusta, and G.R. Sablak. 2000. Volume 1: Vegetation Indices of Biotic Integrity (VIBI) for Wetlands and Calibration of the Ohio Rapid Assessment Method for Wetlands v. 5.0. Final Report to U.S. EPA Grant No. CD985276, Interim Report to U.S. EPA Grant No. CD985875.

Mack, J.J., 2001. Ohio rapid assessment method for wetlands v. 5.0, user's Manual and scoring forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Mack, John J. 2004a. Integrated Wetland Assessment Program. Part 4: Vegetation Index of Biotic Integrity (VIBI) and Tiered Aquatic Life Uses (TALUs) for Ohio wetlands. Ohio EPA Technical Report WET/2004-4. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Mack, John J. 2004b. Integrated Wetland Assessment Program. Part 9: Field Manual for the Vegetation Index of Biotic Integrity for Wetlands v. 1.3. Ohio EPA Technical Report W ET/2004-9. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Princeton University Press. Princeton, NJ.

McCune, B. and J.B. Grace. 2002. Analysis of Ecological Communities. MjM Software, Gleneden Beach, Oregon, U.S.A.

McCune, B. and M. J. Mefford. 1999. PC-ORD. Multivariate Analysis of Ecological Data. Version 4.39. MjM Software, Gleneden Beach, Oregon, U.S.A.

Miller, S.J. and D.H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. Ecological Indicators Vol. 6 Issue 2. pages 313-326.

Montana Department of Environmental Quality. 2005. Draft Montana Wetland Rapid Assessment Method Guidebook(Version 2.0). Montana Department of Environmental Quality, Helena, MT.

Morgan, P., G.H. Aplet, and J.B. Haufler. 1994. Historical Range of Variability: A Useful Tool For Evaluating Ecosystem Change. *In:* N. Sampson and D. L. (editors)

Assessing Forest Ecosystem Health in the Inland West. Haworth Press. New York, NY. Pages 87-111.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec. 452 pages.

Peet, R.K., T.R. Wentworth and P.S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274

Quigley, T. M. and S.J. Arbelbide (technical editors). 1997. An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins: Volume 2. Gen. Tech. Rep. PNW-GTR-405. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 4 Volumes. (Quigley, T.M., technical editor; The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment).

Ramaley. F. 1919. The Role of Sedges in Colorado Plant Communities. American Journal of Botany Vol. 6 No. 3. pp. 120-130.

Ramaley. F. 1920. Subalpine Lake-shore Vegetation in North-Central Colorado. American Journal of Botany Vol. 7 No. 2. pp. 57-74.

Ramaley, F. and W.W. Robbins. 1909. Studies in Streamside and Lake Vegetation, Redrock Lake Near Ward, Colorado. Univ. Colo. Studies 6: 133-168.

Reed, P. Jr. 1988. National List of Plant Species That Occur in Wetlands: National Summary. U.S. Fish and Wildlife Service. Biological Report 88(24). Region 5 and 8 Regional Lists. Online at http://www.fws.gov/nwi/bha/list88.html

Rink, L.P. and G.N Kiladis. 1986. Geology, hydrology, climate, and soils of the Rocky Mountains. Pages 42-65 *in* J.T. Windell, B.E. Willard, D.J. Cooper, S.Q. Foster, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis, editors. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U.S. Fish and Wildlife Service, Biological Report 86.

Rocchio, J. *In Progress*. Development and Application of the Floristic Quality Assessment Tool in Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Rondeau, R. 2001. Ecological System Viability Specifications for Southern Rocky Mountain Ecoregion. 1st Edition. Unpublished report for The Nature Conservancy. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

SAIC (Science Applications International Corporation). 2000. Summit County Wetland Functional Assessment. Unpublished report prepared for Summit County Community Development Division, Frisco, Colorado.

Sanderson, J. and M. March. 1995. Extreme Rich Fens of South Park, CO: Their Distribution, Identification, and Natural Heritage Significance. Unpublished report prepared for Park County, Colorado Department of Natural Resources, and U.S. Environmental Protection Agency, Region VIII. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Smith, R. D. 2001. "Hydrogeomorphic Approach to Assessing Wetland Functions: Guidelines for Developing Regional Guidebooks; Chapter 3, Developing a Reference Wetland System". ERDC/ELTR-01-29, U.S. Army Engineer Research and Development Center,Vicksburg, MS.

Stohlgren, T.J., K.A. Bull, and Y. Otsuki. 1998. Comparison of rangeland vegetation sampling techniques in the Central Grasslands. Journal of Range Management 51: 164-172.

Summit County 1999. Data collected toward the development of a Special Area Management Plan (SAMP) for Summit County, Colorado.

Tweto, O. 1979. Geological Map of Colorado. Scale 1:500,000, colored. U.S.G.S., Denver, CO.

USDA, PLANT Database. http://plants.usda.gov/ Accessed January 2005.

U.S. EPA. 2002a. Methods for Evaluating Wetland Condition: Introduction to Wetland Biological Assessment. Office of Water, U.S. Environmental Protection Agency, Washington D.C. EPA-822-R-02-014.

U.S. EPA. 2002b. Methods for Evaluating Wetland Condition: Study Design for Monitoring Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-015.

U.S. EPA. 2002c. Methods for Evaluating Wetland Condition: Using Vegetation to Assess Environmental Conditions in Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington D.C. EPA-822-R-02-020.

Washington State Department of Ecology. 1993. Washington State Wetlands Rating System: Western Washington. Second Edition. Publication #93-74.

Weber, W.A.(1965). Plant Geography in the Southern Rocky Mountains. *In* The Quaternary of the United States (eds. H.E. Wright Jr. and D.G. Frey), pp.453-468. Princeton University Press, Princeton, NJ.

Weber, W. and R.C. Wittmann. 2001a. Colorado Flora: Eastern Slope. Third Edition. University Press of Colorado. Boulder, CO.

Weber, W. and R.C. Wittmann. 2001b. Colorado Flora: Western Slope. Third Edition. University Press of Colorado. Boulder, CO.

Western Regional Climate Center. 2006. http:\\ www.wrcc.dri.edu

Wohl, E. 2001. Virtual Rivers: Lessons from the Mountain Rivers of the Colorado Front Range. Yale University Press, New Haven, CT.

Wong, C. and K. Iverson. 2004. Range of Natural Variability: Applying the Concept to Forest Management in Central British Columbia. BC Journal of Ecosystems and Management. Vol. 4, No. 1. pages 1-14.

APPENIDX A: DESCRIPTIONS AND KEY TO WETLAND ECOLOGICAL SYSTEM TYPES

ECOLOGICAL SYSTEM DESCRIPTIONS

Rocky Mountain Alpine-Montane Wet Meadow: Wet meadows are dominated by herbaceous species and range in elevation from montane to alpine (3,280 to 11,800 ft.). These types occur as large meadows in montane or subalpine valleys, as narrow strips bordering ponds, lakes, and streams, and near seeps and springs. They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10%. In alpine regions, sites typically are small depressions located below late-melting snow patches or on snowbeds. Soils of this system are mineral but may have large amounts of organic matter. Soils show typical hydric soil characteristics, including high organic content and/or low chroma and redoximorphic features. This system often occurs as a mosaic of several plant associations, often dominated by graminoids. Often riparian shrublands, especially those dominated by willows (*Salix* spp.), are immediately adjacent to wet meadows. Wet meadows in the alpine are tightly associated with snowmelt and typically not subjected to high disturbance events such as flooding, however montane wet meadows may be seasonally flooded. Wet meadows also occur near the fringes of lakes and ponds as well as near ephemeral groundwater discharge sites where the water table is high enough to support hydrophytic vegetation but fluctuates or is deep enough to restrict the development of organic soils.

The size of wet meadows can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (< 1 acre) while others can be very large (> 75 acres). In order for a patch of wet meadow to be considered a distinct "ecological system", it must meet a minimum size of 1 acre.

Rocky Mountain Subalpine-Montane Fen: Fens are confined to specific environments defined by ground water discharge, soil chemistry, and peat accumulation of at least 40 cm. Fens remain saturated primarily as a result of discharging groundwater, seasonal and/or perennial surface water input, or due to their location on the fringes of lakes and ponds (Cooper 1990). Fens form at low points in the landscape or on slopes where ground water intercepts the soil surface. Ground water inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to accumulation of organic material. In addition to peat accumulation and perennially saturated soils, the extremely rich fens have distinct soil and water chemistry, with high levels of one or more minerals such as calcium and magnesium. Fens usually occur as a mosaic of several plant associations. Shrubs may be dominant. Mosses are an integral floristic as well as functional component to fens. Mosses provide a critical role in the accumulation of peat, formation of hummocks, and nutrient cycling. Most fens in the Southern Rocky Mountains are dominated by brown mosses such as *Drepanocladus aduncus, Tomenthypnum nitens,* and *Aulacomnium palustre*. *Sphagnum* species are not as common as brown mosses in intermediate and rich fens however *Sphagnum* is an important and conspicuous component of poor and iron fens.

A distinguishing characteristic between wet meadows and fens is the depth of the water table. In fens, ground water maintains a fairly constant water level year-round, with water at or near the surface most of the time whereas water tables in wet meadows are more variable and tend to fluctuate or decline throughout the growing season.

The size of fens can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (< 0.5 acre) while others can be very large (> 2.5 acres). In order for a patch of fen to be considered a distinct "ecological system", it must meet a minimum size of 0.5 acre.

Rocky Mountain Subalpine-Montane Riparian Shrubland: This system is located in the montane to subalpine and occurs as narrow to wide bands of shrubs lining stream banks and alluvial terraces in narrow to wide, low gradient valley bottoms and flood plains with sinuous stream channels. In general, most riparian shrublands in the Southern Rocky Mountains are dominated by various assemblages of willow (*Salix* spp.). Valley geomorphology and substrate dictate the types of riparian shrublands which typically develop. For example, thinleaf alder (*Alnus incana*), Drummonds willow (*Salix drummondiana*), and red-osier dogwood (*Cornus sericea*) are often dominant shrublands on steep and/or gravelly streams whereas a variety of willows (*Salix* sp.) occupy more gently sloped streams with finer sediment or peat substrates. However, riparian shrublands in the Southern Rocky Mountains are most commonly found in wide glaciated valleys or open parks where they often occupy a substantial portion of the valley floor. It has been reported that most riparian shrublands below 9000 ft. have mineral soils, while those above this elevation generally have peat or organic soils (Cooper 1986). For the purpose of VIBI development and application, the latter types may be separated as a distinct variation of riparian shrublands or included within the fen Ecological System type. Additional data collection and future classification analysis is needed to confirm whether this separation is needed.

The size of riparian shrublands can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very large (> 1.5 linear miles) while others can be very small (< 0.5 linear miles). In order for a patch of riparian shrubland to be considered a distinct "Ecological System", it must meet a minimum size of 0.5 miles long by 30 feet wide.

KEY TO ECOLOGICAL SYSTEM TYPES

1

Mineral soils; sometimes organic soil horizon (histic epipedon) present but <40 cm 2
Organic soils, >40 cm depth, present. If < 40 cm then organic soil layer occurs on lithic material 3

2

Shrubs dominate overstory; sometimes with scattered trees, but not densely forested
Usually occurs in riparian landscape but can be found on slopes near seeps/springs ....
ROCKY MOUNTAIN SUBALPINE-MONTANE RIPARIAN SHRUBLAND

Herbaceous vegetation is predominant; located in riparian landscape, near open water, or associated with groundwater discharge sites...
.... ROCKY MOUNTAIN ALPINE-MONTANE WET MEADOW

3

Wetland occurs on slope and/or is supported by groundwater discharge; Generally at elevations above 8000 ft; Shrubs or herbaceous species may dominate.
.........ROCKY MOUNTAIN SUBALPINE-MONTANE FEN

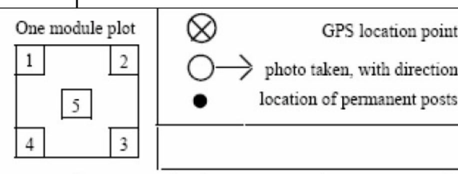
Wetland occurs in a riverine setting and is supported by surface and subsurface hydrology; Shrubs dominate overstory; sometimes with scattered trees, but not densely forested..
ROCKY MOUNTAIN SUBALPINE-MONTANE RIPARIAN SHRUBLAND

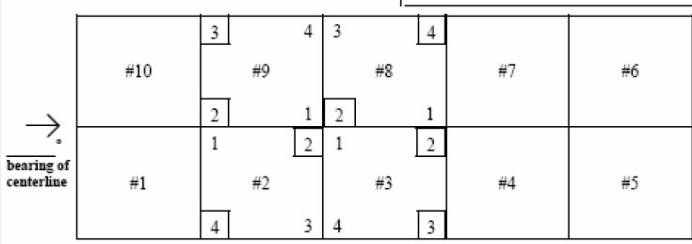
APPENDIX B: PLOT FORM

VIBI Plot Form

General Information	Location	Site Characteristics
Project VIBI – Phase 2	General:	Ecological System:
Team: Rocchio/ Schillo	County:	Elevation (m/ft):
Plot:	USGS quad:	Slope (deg):
Date (Start): / /	Ownership:	Aspect (deg):
Date (End): / /	GPS location in plot:	Compass:
	UTM Zone:	Buffer width:
Plot Documentation	UTM-E:	
Cover method:	UTM-N:	**Land use w/in 100m of wetland**
	Accuracy:	Types: / Relative %:
Photos		
Photographer:	GPS File Name:	
Film roll:	T: R: S:	
Frame(s):		

Map: Fill in the template below (2 modules or more) or right (1 module plot), using the guide at far right. Also note actual arrangement of modules, which corners were sampled, and location of any witness trees.





Land use in contributing watershed

Types	Relative %
Ground watershed	
Surface watershed	

Plot Notes:

Community Classification*

CNHP ______________________

Cowardin ___________________

HGM_______________________

Soil Chemistry*

___________ pH

___________ Conductivity

___________ Temperature

Broad Disturbance Category

	Reference
	Minimal Impact
	Moderate Impact
	High Impact

Land Use in Wetland

Types:	Relative %:

					⇦ Strata			M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	Residual	
H	S	U	C	E	species	c	code																		

Cover classes: trace=1; 0-1%=2; 1-2%=3; 2-5%=4; 5-10%=5; 10-25%=6; 25-50%=7; 50-75%=8; 75-95%=9; 95-100%=*

Presence classes: overhanging=0; 10 x 10m=1; 3.16 x 3.16m=2; 1 x 1m=3; 32 x 32cm=4; 10 x 10cm=5 version 01.1

APPENDIX C: HUMAN DISTURBANCE RATING FORM

Plot #: **Date:** **Observers:** **County:**

Metric 1. Buffers	Score
1a. Average Buffer Width. (ALL) This metric is measured by estimating the width of the buffer surrounding the wetland. Buffers are natural vegetated areas with no or minimal human-use. Buffer boundaries extend from the wetland edge to intensive human land uses which result in non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the wetland and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc. .	
10pts EXCELLENT Wide > 100 m	
7pts GOOD Medium. 50 m to <100 m	
3pt FAIR Narrow. 25 m to 50 m	
0pts POOR Very Narrow. < 25m	
1b. Adjacent Land Use. (ALL) This metric is measured by documenting surrounding land use(s) within 100 m of the outer buffer boundary. To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m of the buffer boundary under each Land Use type and then plug the corresponding coefficient (Table 1) with some manipulation to account for regional application) into the following equation: *Sub-land use score* = ∑ LU x PC/100 where: LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type. Do this for each land use within 100 m of the buffer edge, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).	
10pts EXCELLENT Average Land Use Score = 1.0-0.95	
7pts GOOD Average Land Use Score = 0.80-0.94	
3pt FAIR Average Land Use Score = 0.4-0.79	
0pts POOR Average Land Use Score = < 0.4	
1c. Percentage of Unfragmented Landscape Within One Kilometer (ALL) This metric is measured by estimating the amount of unfragmented area in a one km buffer surrounding the wetland and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.	
10pts EXCELLENT Embedded in 90-100% unfragmented, roadless natural landscape;	
7pts GOOD Embedded in 60-90% unfragmented, roadless natural landscape;	
3pt FAIR Embedded in 20-60% unfragmented, roadless natural landscape;	
0pts POOR Embedded in < 20% unfragmented, roadless natural landscape;	
1d. Riparian Corridor Continuity (RIPARIAN ONLY) This metric is measured as the percent of anthropogenic patches within the riparian corridor. Anthropogenic patches are defined as areas which have been converted or are dominated by human activities such as heavily grazed pastures, roads, bridges, urban/industrial development, agriculture fields, and utility right-of-ways. The riparian corridor itself is defined at the width of the geomorphic floodplain. Using GIS, field observations, and/or aerial photographs the area occupied by anthropogenic patches is compared to the area occupied by natural vegetation with the riparian corridor.	
10pts EXCELLENT < 5% of riparian reach with gaps / breaks due to cultural alteration	
7pts GOOD > 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	
3pt FAIR >20 - 50% of riparian reach with gaps / breaks due to cultural alteration	
0pts POOR > 50% of riparian reach with gaps / breaks due to cultural alteration	

Calculation	Score
(Sum of two lowest scores/20) * 100	

Metric 2: Hydrology	Score
2a. Hydrological Alterations (NON-RIPARIAN ONLY) Measured by evaluating stressors within or near the wetland which appear to be altering hydrology of the site.	
20pts EXCELLENT No alterations. No dikes, diversions, ditches, flow additions, pugging, or fill present in wetland that restricts or redirects flow	
16pts GOOD Low intensity alteration such as roads at/near grade, pugging (hummocking from livestock hooves), small diversion or ditches (< 30 cm (1 ft.) deep) or small amount of flow additions	
8pts FAIR Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (30 – 90 cm (1-3 ft.) deep) or moderate flow additions.	
0pts POOR High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (> 90 cm (3 ft.) deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions	
2b Upstream Surface Water Retention (RIPARIAN ONLY) Measured as the % of the contributing watershed that occurs upstream of a surface water retention facility. (1) Sum the area of the contributing watershed. (2) Determine/sum area of the contributing watershed upstream of the surface water retention facility furthest downstream for each contributing stream reach (e.g., main channel and/or tributaries). (3) Divide this by the total area of the contributing watershed, (4) multiply by 100. For example if a dam occurs on the main channel, then the entire watershed upstream of that dam is calculated whereas if only small dams occur on tributaries then the contributing watershed upstream of each dam on each of the tributaries would be calculated then summed.	
10pts EXCELLENT < 5% of drainage basin drains to surface water storage facilities	
7pts GOOD >5 - 20% of drainage basin drains to surface water storage facilities	
3pt FAIR >20 - 50% of drainage basin drains to surface water storage facilities	
0pts POOR > 50% of drainage basin drains to surface water storage facilities	
2c. Upstream/Onsite Water Diversions/Additions (RIPARIAN ONLY). Calculate the total number of water diversions occurring in the contributing watershed as well as those onsite. Consider the number of diversions with the size of the contributing watershed to assess their impact.	
10pts EXCELLENT No upstream or onsite water diversions/additions present	
7pts GOOD Few diversions/additions present or impacts minor relative to contributing watershed size. Onsite diversions/additions, if present, have minor impact on local hydrology.	
3pt FAIR Many diversions/additions present or impacts moderate relative to contributing watershed size. Onsite diversions/additions, if present, have a major impact on local hydrology.	
0pts POOR Water diversions/additions are very numerous or impacts high relative to contributing watershed size. Onsite diversions/additions, if present, have drastically altered local hydrology.	
2d. Floodplain Interaction (RIPARIAN ONLY) This metric is estimated in the field by observing signs of overbank flooding, channel migration, and geomorphic modifications that are present within the riparian area.	
10pts EXCELLENT Floodplain interaction is within natural range of variability. There are no geomorphic modifications (incised channel, dikes, levees, riprap, bridges, road beds, etc.) made to contemporary floodplain.	
7pts GOOD Floodplain interaction is disrupted due to the presence of a few geomorphic modifications. Up to 20% of streambanks are affected.	
3pts FAIR Floodplain interaction is highly disrupted due to multiple geomorphic modifications. Between 20 – 50% of streambanks are affected.	
0pts POOR Complete geomorphic modification along river channel. The channel occurs in a steep, incised gulley due to anthropogenic impacts. More than 50% of streambanks are affected.	

	Calculation	Score
Non-Riparian	(Score/20) * 100	
Riparian	(Sum of two lowest scores/20) * 100	

Metric 3: Physical Disturbance	Score
3a. Substrate/Soil Disturbance[7] (ALL) This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.	
10pts EXCELLENT No disturbance to soil environment.	
7pts GOOD Past disturbance but site recovered; OR recent but minor disturbances	
3pts FAIR Site is recovering OR recent and moderate disturbances	
0pts POOR Recent and severe disturbances	
3b. Onsite Land Use. (ALL) This metric is measured by documenting surrounding land use(s) occurring in the wetland or riparian area. Follow the same procedures as in Metric 1a. Adjacent Land Use	
10pts EXCELLENT Average Land Use Score = 1.0-0.95	
7pts GOOD Average Land Use Score = 0.80-0.94	
3pt FAIR Average Land Use Score = 0.4-0.79	
0pts POOR Average Land Use Score = < 0.4	
3c. Bank Stability (RIPARIAN ONLY) Walk the streambanks and observe signs of eroding and unstable banks. These signs include crumbling, unvegetated banks, exposed tree roots, exposed soil, as well as species composition of streamside plants. Stable streambanks are vegetated by native species that have extensive root masses (*Alnus incana*, *Salix* spp., *Populus* spp., *Betula* spp., *Carex* spp., *Juncus* spp., and some wetland grasses). In general, most plants with a Wetland Indicator Status of OBL (obligate) and FACW (facultative wetland) have root masses capable of stabilizing streambanks while most plants with FACU (facultative upland) or UPL (upland) do not.	
10pts EXCELLENT Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	
7pts GOOD Mostly stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	
3pt FAIR Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	
0pts POOR Unstable; many eroded areas; "raw". Areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)	

	Calculation	Score
Non-Riparian	(Score/20) * 100	
Riparian	(Sum of two lowest scores/20) * 100	

[7] Adapted from Mack 2001.

Note: Only assess Metric 4 if standing water is present.

Metric 4. Water Quality[8]	
4a. Algae Large patch = 50% cover of standing water	
10pts EXCELLENT Algae growth is minimal	
7pts GOOD Algae growth in small patches	
3pt FAIR Algae growth in large patches	
0pts POOR Abundant algae growth in continuous mats	
4b. Cattail Dominance Dominance = 70% of vegetated component	
10pts EXCELLENT Cattails, if present, occur in sporadic stands but do not dominate the wetland/riparian area.	
0pts POOR Cattails dominate and form a monoculture in the wetland/riparian area. Very few, if any, additional species are present. Co-dominants may include other aggressive native/non-native species.	
4c. Sediment & Turbidity	
10pts EXCELLENT No evidence of excessive sediment in wetland/riparian area due to human-induced activities (bare ground, row crops, erosion, etc.); Water is not turbid.	
7pts GOOD Slight evidence of excessive sediment in wetland/riparian area due to human-induced activities (bare ground, row crops, erosion, etc.); Water is slightly turbid.	
3pt FAIR Moderate evidence of excessive sediment in wetland/riparian area due to human-induced activities (bare ground, row crops, erosion, etc.); Water is moderately turbid.	
0pts POOR High evidence of excessive sediment in wetland/riparian area due to human-induced activities (bare ground, row crops, erosion, etc.); Water is highly turbid.	
4d. Toxics/Heavy Metals Mine tailings, mine drainage, hydrocarbons, pesticides, etc. Indicators include different color of water (e.g. orange), odors, no aquatic life, or obvious point source. For oil sheens…poke with stick. If the sheen immediately comes back together it is likely petroleum, otherwise it is natural.	
10pts EXCELLENT No evidence of toxics	
5pts GOOD/FAIR Evidence of toxics; diversity/abundance of organism slightly affected.	
0pts POOR Evidence of toxics with drastic affect on organisms.	

	Calculation	Score
All Types	(Sum of two lowest scores/20) * 100	

Human Disturbance Score	Subtotal	Standing Water Weight	No Standing Water Weight	Final Score
Metric 1. Buffers		0.25	0.275	
Metric 2. Hydrology		0.40	0.45	
Metric 3. Physical Disturbances		0.25	0.275	
Metric 4. Water Quality		0.10	N/A	
			TOTAL SCORE	

[8] All four metrics adapted from Montana Department of Environmental Quality 2005.

Land Use Coefficient Table[9]

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Land Use Calculations:

LU Type #1 Coeff _______ x % of Area ________/________ /100 = Sub-land use score ______
LU Type #2 Coeff _______ x % of Area ________/________ /100 = Sub-land use score ______
LU Type #3 Coeff _______ x % of Area ________/________ /100 = Sub-land use score ______
LU Type #4 Coeff _______ x % of Area ________/________ /100 = Sub-land use score ______
LU Type #5 Coeff _______ x % of Area ________/________ /100 = Sub-land use score ______

Total Land Use Score______

[9] Adapted from Hauer et al. 2002