8-4-2001

A Comparison of Three Rapid Evaluation Procedures for Pine Savanna Wetlands

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A COMPARISON OF THREE RAPID EVALUATION PROCEDURES FOR PINE SAVANNA WETLANDS

by

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A Thesis
Submitted to the Faculty of
Mississippi State University
In partial Fulfillment of the Requirements
for the Degree of Master of Science
in Biological Engineering
in the Department of Agricultural and Biological Engineering

Mississippi State, Mississippi

August 2001

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Pages in Study: 87

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Inception of the Clean Water Act in 1972 resulted in regulation of activities in wetlands through Section 404. Regulatory agencies like the Mississippi Department of Marine Resources (MDMR) have tried to find methods to rapidly evaluate wetlands. This study compares three rapid evaluation methods, Hydrogeomorphic Approach (HGM), Wetlands Rapid Assessment Procedure (WRAP), and Wetland Evaluation System (WES), based on their scoring of a group of reference and mitigation wetland sites.

Repeatability was studied by scoring a group of sites twice. The non-parametric Spearman's correlation was used to compare the three methods. In this study, HGM was most repeatable followed by WES and WRAP. Comparisons of overall scores using the Spearman correlation found the strongest correlation between HGM and WES, although

all pairings were significantly correlated ($p < 0.05$). This study determined HGM was the optimum method for the MDMR because due to repeatability and producing results similar to the other two methods.

ACKNOWLEDGEMENTS

I am sure that no thesis is written without the help of many people, but I know that I owe many thanks to people who have taken time out of their schedules to help, give advice, and encourage me. Dr. Thomas Cathcart, Dr. Fred Deegen, and Mr. Marc Foster were all integral in giving me the opportunity to pursue a personal interest in the pursuit of my Masters' degree. Buddy Clairain, Jim Wakeley, and Dan Smith at the Waterways and Experiment Station in Vicksburg were instrumental in helping learn how to use the HGM Pine Savanna Model and offered many useful suggestions in shaping my project. Boyd Gunsalus and Tom Roberts were helpful in providing me with the WRAP method and supporting documents. Larry Lewis and James Teaford were generous in letting me use their method and supporting documentation. Larry was also kind enough to offer advice and help with different aspects. At the Mississippi Department of Marine Resources the list becomes very long. Without the technical assistance of Marc Foster, this study would have been far more difficult if not impossible. Jeff Clark was generous in teaching me plant identification skills and generous with his time when I brought samples back. The permitters collectively were all helpful, especially Paul Necaise, Leah Bray, and Tim Blocker. Without all of these people, this project would not have been as rich an experience as it was.

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CHAPTER I

INTRODUCTION

Background

Attitudes towards wetlands have shifted radically in the history of the United States. The initial attitude of the United States can be seen in an 1849 piece of legislation from the U.S. Congress which granted wetlands to the state of Louisiana to facilitate the construction of levees and drains to make productive land out of the area (NRC, 1995). This was followed in 1850 by other states seeking similar rights to their swamplands for conversion to farmland in the Swamp Land Act of 1850 (NRC, 1995). The earliest indication of a shift in public opinion of wetlands was during the 1930's when decreases in the numbers of waterfowl elicited concern. The Federal Duck Stamp Act of 1934 began to furnish money for the purchase or protection of wetlands, although the U.S. Department of Agriculture (USDA) and U.S. Army Corps of Engineers (USACE) were still subsidizing conversion to agricultural uses. The major change came in the 1970's with the environmental movement and realization that wetlands contributed many things to society (NRC, 1995). It was during that time that the Federal Water Pollution Control Act Amendment, better known as the Clean Water Act, was passed in 1972 (EPA 1, 2000).

Section 404 of the Clean Water Act became well known since it created a permitting process that regulates the deposition of any dredge and fill material in waters of the U. S. (EPA 1, 2000). "Waters of the U.S." was interpreted to include any wetlands, even isolated 20ground water driven wetlands since they can affect water quality. This act represented a significant change in public opinion. In a June 1994 Times Mirror-Roper poll quoted in a March 1997 Testimony before Congress, 77% of Americans support wetland regulations at least as stringent as they are now (Perciasepe, 1997). Locally, on the Mississippi Gulf Coast, many of the local population are aware of the significance of salt marshes to marine fisheries and are advocates for their preservation.

While wetlands were once viewed as wasted space, public and scientific opinion has started to acknowledge their functional value as it pertains to society. Their aesthetic contributions can be appreciated by any passerby, but research has shown that wetlands contribute habitat to commercially and recreationally valuable species, they aid in control of storm water runoff to reduce flooding, and they facilitate the purification of water through microbial degradation and sequestering of pollutants (EPA 2, 2000). As attitudes have changed, the goals of policy makers have also changed. The National Wetlands Policy Forum in 1988 recommended a national wetlands protection policy to achieve no overall net loss of the nation's remaining wetlands (Swarth, 1998). This included placing an emphasis on restoring degraded wetlands. In 1995, this policy was reinforced by a statement from President Clinton in Executive Order 12962 which encouraged sustainable development of fisheries and conservation and restoration of aquatic systems.

The U. S. Department of the Interior, Fish and Wildlife Service summarized their most recent research into wetlands loss in *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997* (Dahl, 2000). Their data show that policy improvements have led to significant reductions in wetlands loss, but wetlands are still being lost at an estimated rate of 23,674 hectares per year for the period from 1986 to 1997 (Dahl, 2000). In an effort to maintain a 'no net loss' policy, regulatory agencies such as the MDMR have been requiring compensation in the form of creation, restoration, or preservation of a wetland in return for the destruction or degradation of a natural system since the 1970s. These restored, created, or preserved wetlands are referred to as mitigation marshes or wetlands. Regulatory and permitting agencies are currently moving towards adopting prescribed procedures for evaluating wetland sites with respect to functions lost due to development, determining when mitigation obligations have been fulfilled, and to better evaluate the success of the mitigation process itself.

Pine savannas are a palustrine-forested wetland and are one of the most highly impacted types of wetlands in the Gulf of Mexico coastal plain. They are also a type of wetland that the MDMR routinely reviews in 404 permitting. The Fish and Wildlife Service report stated that 98% of the wetlands lost between 1986 and 1997 were freshwater wetlands (Dahl, 2000). Of the freshwater wetlands lost, 485,625 hectares were forested wetlands; urban and rural development accounted for 51% of that loss (Dahl, 2000). Historically, coastal pine savannas extended some 644 kilometers from Louisiana to Florida; currently only 3 % of that habitat remains. The remaining 97 % of this habitat has been impacted by drainage, fire suppression, development, and silviculture (Larson, 1998). These facts taken together show why the interactions of the 404 permitting process and mitigation policies with the pine savanna habitat that still exist are of importance to the MDMR.

Regulatory agencies began issuing permits for activities that impact wetlands in the mid-1970s. Since that time a variety of wetland assessment methods have been developed beginning with the *Habitat Evaluation Procedure* (HEP) by the Fish and Wildlife (U.S. Fish and Wildlife Service, 1980). HEP was an intensive biological assessment of habitat suitability focusing on a few species. Through the 1980s and 1990s, the evolution of evaluation methods moved toward rapid assessments that determined the functionality of the wetland and broadened the scope beyond a few species. That evolution led to the development of procedures with a regional emphasis like the *Hydrogeomorphic Approach* (HGM), developed by the USACE (Smith *et al*., 1995). Procedures have also been developed on a state-by-state basis with some of those methods being used in other states. An example would be the *Wetland Rapid Assessment Procedure* (WRAP) developed in Florida and customized for use in Mississippi pine savannas (Miller & Gunsalus, 1999). A third type of evaluation procedure are those developed on a local level for the types of wetlands located specifically in an area by local experts. *Wetland Evaluation System* (WES) (Lewis and Teaford, 1995) is an example of that on the Mississippi Gulf Coast. Each assessment method has an end product that ranks a wetland based on a score against other wetlands scored using that method.

Objectives of Study

This study was designed to address the evaluation of mitigation wetlands with different methods and to determine which of these methods was feasible for regulatory use. Reference wetland sites (n = 3) and mitigation wetland sites (n = 16) were evaluated using 3 different evaluation methods and the scores were compared using correlation statistics. Repeatability of the methods was also analyzed by evaluating some sites twice and comparing the scores using correlation statistics. The time to complete each method was recorded to determine if there are significant differences in the amount of time necessary to complete the different evaluations.

Justification and Usefulness

This research was designed to help the MDMR select an evaluation procedure based on the time required and information needed in the regulatory process. It also provided a base line assessment of the status of the 16 mitigation projects examined in the course of this project.

Scope and Limitations

This project was a comparison of three wetland evaluation methods for pine savannas in the three coastal counties of Mississippi. Comparison of the methods for use with other types of wetlands is not applicable using these data. While conclusions may be drawn about the specific mitigation sites listed here, conclusions about the status of mitigation on the Mississippi Gulf Coast should be avoided since it is not known if these sites are representative of all sites. Conclusions about mitigation in other habitats besides pine savanna should also be avoided. Evidence has shown that other habitats may be mitigated either more or less frequently (Race and Fonseca, 1996).

CHAPTER II

LITERATURE REVIEW

Several types of coastal wetlands in Mississippi are commonly impacted by development. These wetland types include the familiar salt marsh (dominated by *Spartina alterniflora* and *Juncus roemarianus*) as well as less familiar wetlands like bottomland hardwood forests (dominated by *Taxodium ascendens* and *Nyssa sylvatica* var *biflora*), forested bayhead swamps (dominated by *Magnolia virginca*, *Nyssa sylvatica*, and *Acer rubrums*), and wet pine savannas (dominated by *Pinus spp*. and grasses) (Teaford *et al*., 1995). Wet pine savannas were chosen as the focus of this research due to the ready availability of multiple methods of evaluation including a locally-developed method, WES, by Lewis and Teaford (1995), a regionally developed method by Rheinhardt *et al*. (2000) (HGM), and a method that was adapted for this habitat by Roberts (2000) based on a method by Miller and Gunsalus (1999) (WRAP). Understanding the evaluation methods requires a base knowledge of the habitat. A characterization of the habitat leads into descriptions of the scoring breakdown of each method in the following chapters.

Description of the Pine Savanna Habitat

Pine savannas are characterized by specific hydrologic, plant, and soil characteristics, which do not necessarily fit the popular concept of a wetland. The hydrology of these sites is defined as palustrine, or having no inlet or outlet resulting in a precipitation driven system. As a result, these sites tend to be drier in summer months when rainfall is low and remain relatively saturated during the winter when rainfall is high. Hydric soils and, typically, a perched water-table help maintain the site's water-table (Lewis and Teaford, 1995). A perched water table refers to a water table confined to a shallow clay lens.

The pine savanna plant community is always considered in terms of the overstory and the understory. Fire is a defining feature of this habitat, due to historical frequency, and has resulted in many fire-adapted species. Longleaf (*Pinus palustris*) and Slash Pine (*Pinus elliottii*) usually dominate the overstory in Mississippi and are very sparsely distributed over the area, forming canopy coverage of 5-10% with little natural recruitment of saplings (Lewis and Teaford, 1995). Due to the saplings being fire-adapted, Longleaf Pine are expected to dominate the overstory. Fire suppression in many areas has allowed Slash Pine to become more numerous and, in many cases, the only pine species present (Rheinhardt *et al*., 2000). There are also pine savannas with longer periods of inundation that have Pond Cypress (*Taxodium ascendens*) in the overstory (Rheinhardt et al., 2000). An example of a Bunchgrass dominated Pine Savanna can be seen in Figure 1. The photo shows the sparse overstory, the herbaceous ground cover and a developing shrub layer.

Figure 2.1: Pine Savanna habitat on the Sandhill Crane National Wildlife Refuge, Gautier, Mississippi.

Grasses and herbaceous perennials dominate the understory. The grasses include bunchgrass species that are specially adapted to a fire-maintained environment. These bunchgrasses, which grow in characteristic tussocks, include wiregrasses (*Aristid*a spp.), bluestem grass (*Shizachyrium scoparium*), and Muhly grass (*Muhlenbergia expansa*). Herbaceous perennials include a number of flowering species of the sunflower family (*Helianthus* spp.), meadow beauties (*Rhexia* spp.), and yellow-eyed grasses (*Xyris* spp.) to name just a few (Teaford *et al*., 1995). In fact, with an estimated at 30 to 40 plant species per square meter, the herbaceous layer composed of grasses and flowering perennials has a very high diversity (La Salle, 1998). Pine savannas are also well known for supporting carnivorous plants such as pitcher plants (*Sarracenia* spp.) and sundews (*Drosera* spp.) (Teaford *et al*., 1995). In sites with longer periods of inundation, sedges also make up a significant part of the herbaceous layer (Rheinhardt, 2000).

The soil and topography of pine savannas have several characteristics that are important in understanding evaluations of them. Pine savannas are characterized by a slope of 2 % or less and low topography (Teaford *et al*., 1995). As a result, any ditching or rutting can be detrimental to the hydrology due to a lack of a defined water flow. The soils of Pine savannas are described as mineral flats because the soil sandy and or loamy with a low organic content. Low pH and nutrient levels are conditions affecting plant adaptations to the environment (Larson, 1998). Common soil types in this habitat for Mississippi include Plummer, Smithton, and Atmore and additionally Escambia, Ocilla, and Hyde, although these are usually considered of poorer quality due to fewer hydric features (Lewis and Teaford, 1995).

Available Methodologies

As regulations and policies have evolved since the 1970's, the need for methods which can rapidly assess the functionality of a wetland, have become more pronounced, especially in regulatory work. During the regulatory process, there is often a need to evaluate wetlands that will be impacted, to determine the degree of degradation in some circumstances, and to evaluate mitigation efforts to determine their compliance. As summarized by Bartoldus (1999), the evolution in evaluation methods has, in general, ranged from very technical methods like HEP developed by the Fish and Wildlife Service in 1980 to less technical and more rapid approaches including HGM, WRAP, and WES. Rapid assessments initially appeared in the 1980's in reaction to the implementation of the 404 permitting process. The *HGM Approach* (Smith *et al*., 1995), a guide manual for developing HGM models, has been a part of that movement and has been a foundation from which localized methods have evolved. Those methods include evaluations developed by Connecticut, New Hampshire, and Minnesota along with many other states (Bartoldus, 1999).

In the evaluation of a specific type of wetland in a specific region, the choices of evaluation methods may be many or few. The availability usually depends on the amount and quality of information desired and the relative abundance of the habitat in the area. The Wet Pine Savanna habitat is represented on a regional scale from North Carolina to Texas and down into central Florida (Rheinhardt *et al*., 2000). This regional distribution has resulted in the development of an HGM model, the more general WRAP method is a specialized version developed for pine savanna, and a local method, WES, has been developed. The development of numerous methods has led to the need to determine if any particular method is more applicable in regulatory situations. Previously, these methods have not been compared and, in fact, the literature supports no instances of any rapid wetland evaluation methods being directly compared. There have been some published instances of rapid methods being compared to longer-term biological assessments (Spencer *et al.*, 1998), but not to each other. Personal communication with regulatory personnel has suggested that some informal comparisons have been done.

According to Bartoldus (1999), of the 40 most well-known wetland evaluation procedures, HEP, WET, and the Synoptic Approach are 3 methods considered suitable or have been used in Mississippi. She does not mention the three methods used in this paper because of their development dates. WRAP was specialized for use in pine savannas in Mississippi in 2000 by L. Thomas Roberts, a consultant with Environmental Management Systems, Inc. (Roberts, 2000). WES was only known locally since it was developed by two local consulting biologists working mostly in coastal Mississippi (Lewis, 2001). The HGM Model creating the baseline for this habitat was completed in 1999 but is not expected to be officially published until perhaps 2001 (Clairain, 2000), even though the data sheets were available to regulatory personnel in the Fall of 2000.

Review of Methodologies

The following sections describe the development, information gathered, and the current known usage of each method. Each method is detailed and a concluding section shows some of the similarities and differences in the methods.

HGM

Development of Original Procedure

The HGM Model for Wet Pine Savannas (Rheinhardt *et al*., unpub) was created using the procedures outlined in the *HGM Approach* (Smith *et al.*, 1995). In the development phase of HGM, a wetland regional subclass must be defined based on its water source, geomorphic setting, and hydrodynamics. Scientists working in the development phase then assess a group of wetlands exhibiting the range of conditions from reference sites to degraded sites that occur in that wetland type. This phase culminates in the publication of a regional guidebook for the wetland subclass. In the application phase of HGM, regulatory personnel or resource management specialists apply the regional guidebook to specific projects. In the development of the Wet Pine Savanna Model, R.D. Rheinhardt, M.C. Rheinhardt and M.M. Brinson collected data from 71 reference sites during a period from May to October of 1997. Local experts were utilized to locate sites exhibiting the range of conditions (Rheinhardt *et al*., unpub).

Functions Assessed

Four functions are used in the HGM method to assess the wetland. These functions are Maintaining Characteristic Water Level Regime (Hydrology), Maintaining Characteristic Plant Community (Plants), Maintaining Characteristic Animal Community (Animal), and Maintaining Characteristic Biogeochemical Processes (Biogeo). The following descriptions of these functions are based on the data sheets (Appendix B) and the unpublished report by Rheinhardt *et al*. (2000). The functions are scored from 0.0 to 1.0 based on the score sheets with the variables listed here contributing to the function scores. A flow chart shows how the field-scored variables contribute to each function and how some functions are interrelated (Figure 2). The mathematical relationships can also be seen in the flow chart. These relationships can also be seen in the data sheets included in Appendix B.

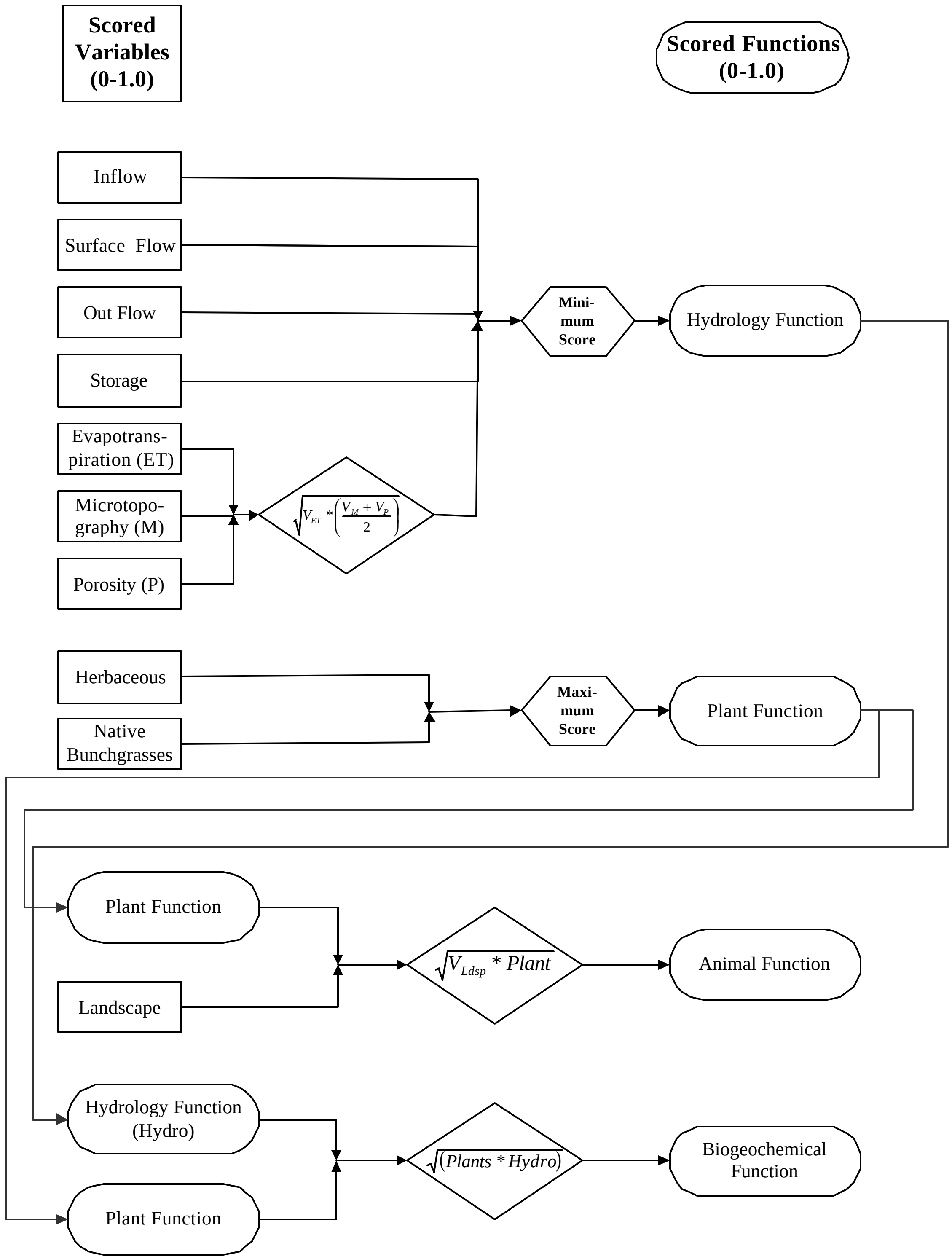


Figure 2.2: Flow chart of HGM Wet Pine Savanna Model showing scored variables, mathematical operations and calculated function scores for a bunchgrass pine savanna.

The Hydrology score sheet lists variables that are scored to determine the possible alterations to the site and the potential for optimal functioning of the hydrology of the wetland. The variables scored include surface flow, which looks for the presence of an impediment to flow like a dam. Outflow takes into consideration the presence and possible effects of ditches on the wetland area: wetlands are considered to be within or outside of the effect distance of the ditch, based on soil conductivity and depth of the ditch using the van Schilfgaarde equation. The storage variable considers whether fill is present in areas delineated as wetland. Evapotranspiration potential is based on the burn history or the leaf area index of plants on the site. The mechanism by which evapotranspiration affects the hydrology is by lowering the water table through water lost to the air. Inflow looks examines the water that may be flowing into the wetland from other sources, which could affect the hydroperiod by increasing water flow. Two soil features are examined as variables, microtopography and porosity. These soil alterations could also change the flow of water through a wetland having very little topography or slope.

The Plant function score sheet is used to assign scores for the presence of characteristic plants. A specific group of herbaceous plants are scored on their presence within a certain distance of a chosen point. The coverage of native bunchgrasses is also examined for another variable. For savannas on the wettest end of the gradient, sedges are scored by coverage as well. In a switchcane pine savanna, a pine variable looks at the number of pines within a certain distance from a chosen point. In the cypress savanna subtype, cypress trees are also counted.

The Animal function is based on the landscape variable, which is the area of the site, and the Plant function score. The Plant function score is included in the Animal function based on the rationale that the characteristic plants must be present to support the characteristic animals. The area needed to obtain a score of 1.0 was 100 hectares.

The Biogeo function is completely dependent on the Plant and Hydrology function. This function scored the ability of the wetland to cycle nutrients. Since plants are the primary producers of the system and microbes are the primary decomposers, conditions which maintain the plant and soil conditions are the most conducive to maintaining the biogeochemical cycling.

An additional consideration with the HGM Model was division of the pine savanna habitat into 3 subtypes by Rheinhardt (2000) when evaluating the Plant function. The subtypes based on "cover-type" are Bunchgrass, Cypress, and Switchcane pine savannas. These subtypes have slightly different plant communities and, as a result, their scores incorporate additional plant species. This only changes the internal scoring of the Plant function. No other functions are affected. Cypress savannas usually have a longer period of inundations and include savanna species that prefer wetter conditions, including sedges. Switchcane pine savannas are only known to exist in South Carolina and are dominated in the understory by switchcane (*Arundinaria tecta*). Bunchgrass pine savannas are dominated in the understory by herbaceous plants and bunchgrass species like wiregrass, bluestem, and Muhly grass. In Mississippi, both Cypress and Bunchgrass pine savannas occur.

Current Usage

The current usage of this model by regulatory agencies is not known precisely. Due to the unpublished status of the report, it is limited to USACE personnel and, specifically, the personnel at the Waterways and Experiment Station in Vicksburg, Mississippi. Personnel there are involved in the Application Phase and early testing prior to the publication of the regional guidebook. The field data collection sheets were made available in a workshop in October 2000 to regulatory personnel including personnel at the MDMR. The field sheets could be used without the additional documentation due to the information available on the data sheets.

WRAP

Development of Original Procedure

The Wetland Rapid Assessment Procedure (WRAP) was developed by the South Florida Water Management District to use as a rating index for evaluating mitigation projects requiring creation, restoration, enhancement, or preservation of wetlands on projects permitted by Florida regulatory agencies. WRAP is based on ecological and anthropogenic factors derived from field observations and the evaluator's best professional judgment. The method was developed to allow comparison of wetlands with other wetlands of the same type. The following description is based on the customized version of WRAP written by Roberts (2000).

Functions Assessed

WRAP examines a number of ecological and anthropogenic factors in its evaluation and produces an overall score that can be broken down into 5 scored functions. The functions assessed by WRAP are the Wildlife Utilization Matrix (Wildlife), Wetland Overstory/Shrub Canopy of Desirable Species Matrix (Overstory), Wetland Vegetative Ground Cover of Desirable Species (Ground Cover), Adjacent Upland/Wetland Buffer Matrix (Buffer), Wetland Hydrology (Hydrology), and Water Quality Input and Treatment Matrix (Water Quality) (Figure 3). A specific set of observations are made, then the function is scored on a scale from 0.0 to 3.0. The flow chart seen in Figure 3 shows how the observations are incorporated into each function. Data sheets for the method can be found in Appendix C.

Each function's score depends on a list of variables that must be considered by the evaluator when determining the score. Wildlife Utilization is used to score whether there is evidence of utilization by target wildlife, the amount of human impact the wetland has had, the availability of adjacent upland food sources, and the habitat available to the wildlife. Overstory is scored based on the amount of areal coverage of trees and shrubs and the amount of natural recruitment of shrubs and saplings taking place. Ground Cover takes into consideration the amount of areal cover of target ground cover vegetation, the amount of woody vine stratum that is present in terms of coverage, and the number of

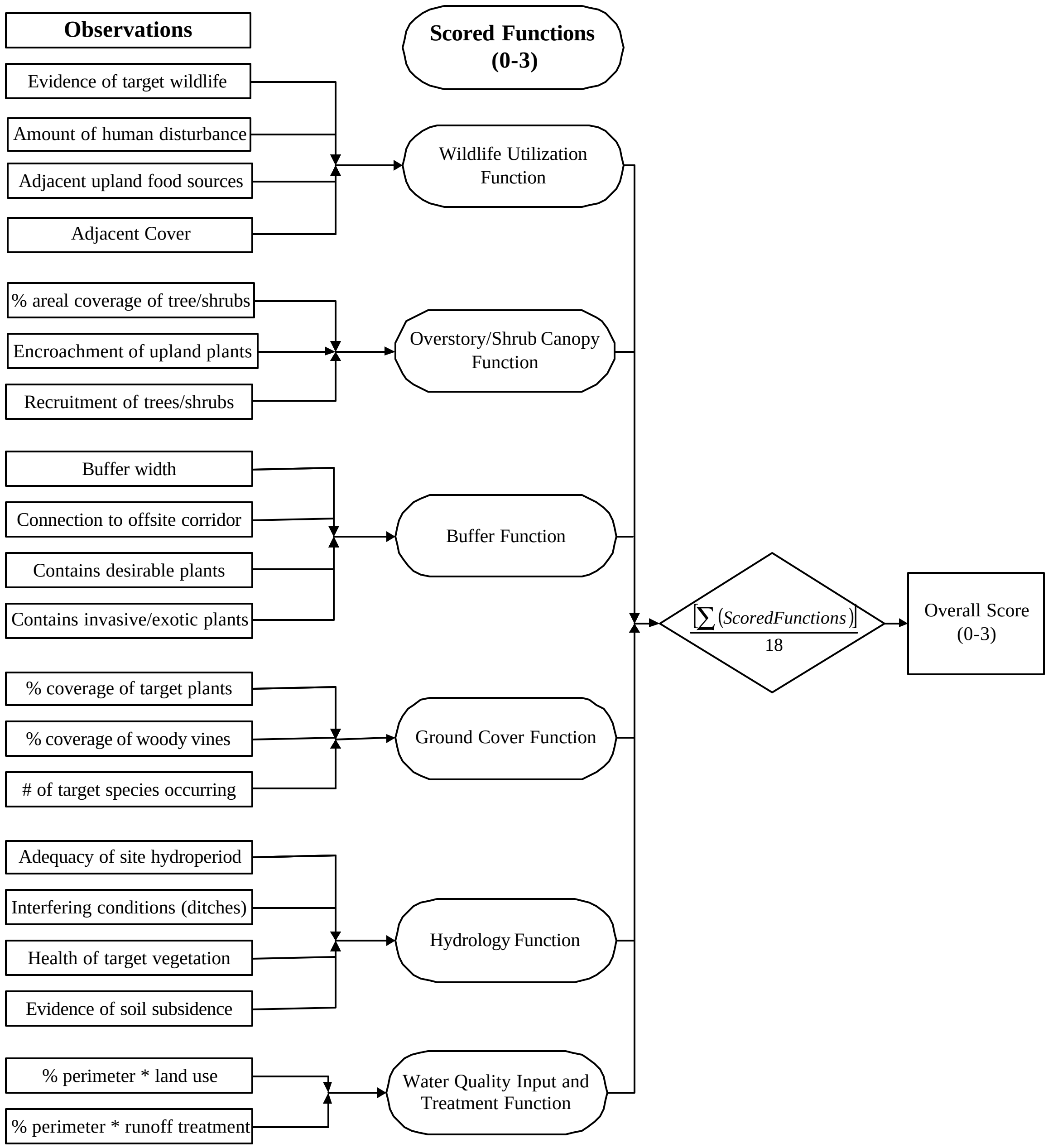


Figure 2.3: Flow chart showing observations affecting scored functions averaged to produce the Overall Score for the WRAP method.

target vegetation species that occur. The Buffer function requires consideration of the width of the buffer from development, the plant community makeup of the buffer, whether the buffer connects to an offsite wildlife corridor, and the number of invasive species in the buffer. Hydrology is used to score whether the site's hydroperiod is adequate to maintain the target plant community and the relative health of the plant community, the distance to an offsite feature that could affect hydroperiod (*e.g.* a ditch, canal), and whether there is any evidence of soil subsidence.

Current Usage

The WRAP method has been used in Florida and has been used in preliminary work in Mississippi and Alabama, though it has not found widespread usage. The method has also found use in New Mexico and Colorado (Gunsalus, 2000). That usage was not verified by Bartoldus (1999) but may have happened recently, so the complete extent of use is unknown. WRAP is usually customized to the environment that it is being used to evaluate which gives it great flexibility for use in different systems. The customized version for Mississippi's Wet Pine Savannas was created after an interagency meeting that included personnel from the MDMR, the Environmental Protection Agency (EPA), and the U. S. Fish and Wildlife Service on January 6, 2000 (Roberts, 2000).

WES

Development of Procedure

The actual development of WES is not outlined in the document containing the evaluations but was obtained through personal communication from Philip L. Lewis

(Lewis, 2001). The method was developed in 1995 by Philip L. Lewis, a consultant with Brown & Mitchell, Inc. of Gulfport, MS, and James Teaford, the principal consultant of J.W. Teaford & Company of Vicksburg, MS. The method is based on HEP with modifications to incorporate specific habitat characteristics. The method was based on several years of professional experience and observation by both consultants. A minimum of 4 reference wetland sites were used during the development for each wetland type and the sites were located in Harrison or Jackson County. The method was then field tested on a minimum of 4 sites (Lewis, 2001). The following function descriptions are based on the data sheets and supporting documentation in the unpublished report by Lewis and Teaford (1995). The overall score is based on a scale from 0-100 where the variable scores are summed to produce the final score (Figure 4). Data sheets for this method are included in Appendix A.

Functions Assessed

In contrast to the previous two methods, WES does not use specific functions, which are scored and, in the case of WRAP, then used to create a composite. Instead, the WES procedure scores variables considered by the authors to be central in determining the functionality of the wetland and then each of those variable scores are summed to form a composite score. For discussion purposes, 19 scored variables are collapsed into 9 unscored groupings. These groups are Soils, Tree Cover, Sapling Cover, Shrub Layer, Woody Vine Cover, Herbaceous Layer, Disturbance, Undesirable Species Composition,

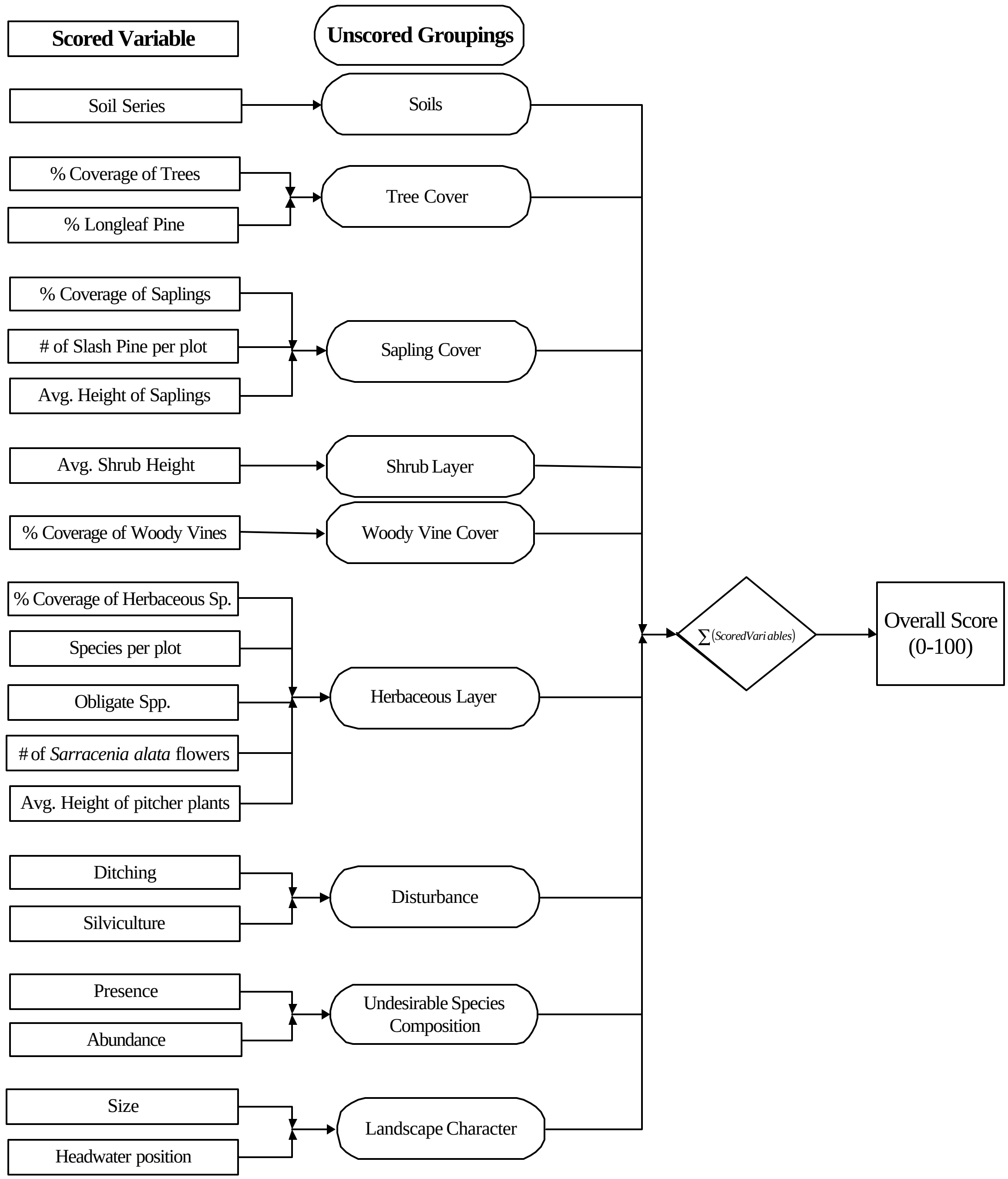


Figure 2.4: Flow chart for the WES Method showing how the scored variables form groups and then are used to form the composite score.

and Landscape Character. The composite or overall score is the additive product of all of the variable scores.

Each grouping is composed of 1 to 5 variables. Soils simply depend on the type underlying the site and how well that soil type supports wetland function. Tree Cover is composed of percent cover of pine trees and percent of Longleaf Pines. Sapling cover looks at the percent cover of saplings, the number of sapling slash pine per plot, and the mean height of the saplings. Shrub layer simply assesses the height of the shrub layer. Woody Vine Cover assesses the percent coverage of woody vines. Herbaceous Layer considers the percent cover of herbaceous species, species per plot, number of obligate species, number of *Sarracenia alata* flowers per plot, and the mean height of the pitcher plants in the plot area. The Disturbance grouping includes variables used to score the presence and depth of ditches and the effects of silviculture (*e.g*. rutting by machinery). Undesirable Species Composition looks at the presence and abundance of nonnative or nontypical species for a pine savanna. Landscape Character scored the size and headwater position of the site.

WES also distinguished between two types of pine savannas, pine savanna and pine flatwoods, which were not recognized by the other methods. Pine savannas are inundated for longer periods and to have an overstory of fewer trees. Pine flatwoods have higher areal tree coverage and are usually inundated for shorter periods of time or not at all, although they are still considered a wetland based on hydrology and soils. The difference between the two evaluations is that the pine flatwoods evaluation allowed for more tree coverage and more recruitment of saplings and a less developed herbaceous layer.

Current Usage

The current usage of this method is non-existent since the method was not completed beyond the final draft stages and was never released to the public. Lewis (2001) indicated that this method had been used in the 404 permit process for sites in Jackson and Harrison Counties.

Conclusions

These three methods have slightly different foci. HGM is a regionally developed method focusing heavily on hydrology and plants. WRAP is a more general approach customized for a specific habitat type and scoring all functions fairly equally without the overlap seen in HGM. WES is a locally developed approach that focuses heavily on soil types while dividing the remaining score equally among the other groups. With the focus of each method being slightly different, it is of interest from a regulatory standpoint if the final score of the different methods are correlated. Table 5 shows a list of common characteristics observed in pine savannas and then shows which observations are included in each method. Observations common to multiple methods can be seen as well as observations used in only one method.

Table 2.1: Comparison of information observed and or scored in each method.

	Methodologies and variable associated with each factor		
Factors in Methods	**HGM**	**WRAP**	**WES**
Ditching	Hydro	Hydro	Disturbance
Soils			Soils
Soil Subsidence		Hydro	
Soil Alterations	Hydro	Hydro	Disturbance
Water Inflow	Hydro		
Fill	Hydro		
Tree coverage	Hydro/Plant	O/SC	Tree Cover
Sapling Coverage	Hydro	O/SC	Sapling Layer
Shrub Layer	Hydro	O/SC	Shrub Layer
Woody Vine		GC	Woody Vine
Herbaceous Sp.	Plant	GC	Herbaceous Layer
Native Grass Sp.	Plant	GC	
Health of Plants		Hydro	
Exotic Sp.		Buffer/	Undesirable Sp.
Undesirable Sp.		Buffer/GC	Undesirable Sp.
Headwater Position			Landscape Character
Buffer Zone		WU/Buffer	
Evidence of Wildlife		WU	
Acreage	Animal		Landscape Character

Hydro = Hydrology
O/SC= Overstory and Shrub Canopy
WU= Wildlife Utilization

CHAPTER III

METHODOLOGY

Overview of Methodologies versus Output

Results from this study were based on 3 reference sites and 16 mitigation sites distributed across Jackson, Harrison, and Hancock Counties in coastal Mississippi. The sites were evaluated using the HGM Wet Pine Savanna model, the Florida WRAP method customized to pine savannas, and the WES method for pine savannas according to their procedures.

Repeatability was studied by evaluating a group of sites two different times with all 3 methodologies. Score comparisons of the 3 evaluation methods were done by scoring the entire group of reference and mitigation sites and then using statistics to determine the level of correlation between the scores. Finally, the amount of time necessary to complete each evaluation including on-site and off-site time was examined. An on-site procedure was developed to use all 3 methods in one field visit. The actual procedure detailing requirements for each procedure follows the description of the overall procedure.

Description of Actual Procedure Used With All Three Methods

Off-Site Procedure

Sites used in this study were obtained from data in the MDMR's 404 permit files, and cross-referenced with the USACE files with additional information being supplied from biologists on staff at the MDMR. Mitigation and reference sites were located on maps and created as shape files in ERDAS Imagine for use in ArcView. Prior to the field site visit, I determined the soil type, adjacent land uses, major features that might affect the wetland, and relative position of features such as buffer zones, wildlife corridors, and salt marshes These features were examined using NRCS county soil surveys, LandSat land use coverages generated at the MDMR, and satellite imagery.

After gathering the background information, ArcView was used to generate random points within each assessment area. The number of points was required to be greater than 3 and usually between 10-25 were generated, based on the size of the assessment area. ArcView was then used to assign latitude and longitude to those points. Only 3 sampling points were actually used in each site's HGM and WES evaluation. Actual selection of the sample points was left until the field visits because some points were too close to edges, some fell on non-wetland areas within the assessment area, and the computer would sometimes clump points. The points actually used for evaluation were chosen by the evaluator to be spread out geographically if possible and to exhibit the conditions of the site. This method of having the computer assign random points was used to minimize the evaluator's effect on the evaluation methods. The final step was locating the property as exactly as possible using road maps to facilitate finding the mitigation for the on-site assessments.

On-Site Procedure

After arriving on-site, the first step in the evaluations was to complete a perimeter survey (WRAP). The perimeter survey required walking a minimum of 50 % of the perimeter and visually inspecting as much of the perimeter as was accessible. After the perimeter survey, walking into the interior of the site was usually necessary to determine the homogeneity of the site. The time to complete the perimeter inspection and walk into the interior was recorded as one time. The time to complete the evaluation score sheet was added to the walking time to calculate the total time to complete the field portion of the assessment method.

A GPS unit was then used to locate the first of the randomly selected sampling points within the wetland. The time to walk to the first point was recorded and if that sampling point was a reasonable representation of the site, the HGM evaluation was carried out. The HGM analysis was timed from the point when the rebar was pushed into the soil until the last applicable step had been done. After completing the HGM evaluation, the WES evaluation was also done while being timed.

This process was repeated for all three sampling points for each site with any points considered non-representative (*e.g.* located on a road, located in a ditch) being discarded in favor of another more representative point. The time to walk between each of the points was recorded and included in the time to complete the assessments.

After completing all of the field observations for the evaluations, changes to perimeter estimates were made to compensate for geo-referencing errors, changes to the site, or features not included in the site layout on-file. Soils were re-verified from NRCS County Soil Survey Maps. All of the information gathered was entered into an Excel spreadsheet and final calculations of the variable and function scores were made. Any additional analysis necessary based on field observation were carried out for each method and timed. In the course of this study, problems involving individual methods may be resolved by rescoring the sites or reanalyzing the data.

Analysis of Data

To compare these three evaluation methods, the data had to be normalized to the same scale and an overall score had to be produced for the HGM method. The scale chosen for the comparison was a 0 to 1.0 scale. For the WRAP data, the 3.0 score was considered equal to a 1.0 when converted. This resulted in all of the functions and the overall score being divided by 3.0. The WES data was considered equal to 1.0 at 100 so all of the overall scores were divided by 100. HGM was already on a 0-1.0 scale but an overall score had to be developed to compare it to the other methods. The four HGM function scores, Hydrology, Biogeochemical, Animal, and Plant, were averaged to produce one overall score. Although the developers of HGM do not support the creation of a single overall score for reasons cited in the *Pine Savanna Model* (Rheinhardt *et al*., 2000), this was done to produce a score for comparison with the other methods.

Overview of HGM

Off-site Review

For HGM, the off-site review began with site characterization of geology, hydrology, plants, and current land use from maps and aerial photography. Any red flag features were identified such as historic or archeological landmarks or special protection areas such as watersheds or coastal management areas. The area of the wetland assessment was defined as well as possible according to site conditions and vegetation. The wetland assessment area was occasionally changed once on-site due to unforeseen circumstances such as ditches.

On-site Review

The evaluator traveled to the location of the first evaluation point for the site. The point was located as precisely as possible using a GPS unit. Once at the point, a 1.2 meter piece of steel rebar was driven into the soil for a short distance to form a defined, non-moving center point. Two pieces of PVC pipe were then used to create a 1 m^2 plot centered on the rebar while the other two sides were simply visualized. The sides of the plot were aligned with the cardinal directions (*e.g.* North, South, East, and West). At this point the plot was surveyed for the presence of the herbaceous indicator plants. After completing the 1 m^2 survey, a 2-meter long string was used to circumscribe a circle around the rebar (12.6 m^2 area). Any indicator plants located in the circumscribed area and not counted in the previous survey were scored.

If the assessment area was a cypress pine savanna, the next step included counting all of the stems at 1 m height and with < 7.5 cm dbh (diameter at breast height) within a

50 m^2 square centered on the rebar. Otherwise, the next step was to score any soil disturbances (*e.g*. ruts, bedding for silviculture, fire breaks, *etc*.) for the porosity and microtopography variables. Microtopography and porosity were scored in terms of percent coverage of a plot of 1250 m^2 located by measuring 5 m from the rebar central point in 4 directions to form a square. Coverage of native bunchgrasses and, if appropriate, for sedges was next. Then, the percent coverage of the ground cover, shrubs, subcanopy, midcanopy, and canopy were scored for the evapotranspiration variable. Those coverage variables were all scored within the 2 m radius circle.

For the cypress savannas, the next scoring was for the distances to the nearest sapling tree, midcanopy tree, and canopy tree of Pond Cypress (*Taxodium ascendens*). For switchcane pine savannas, the number of Longleaf (*Pinus palustris*), Slash (*Pinus elliottii*), Loblolly (*Pinus taeda*), and Pond Pine (*Pinus serotina*) within a circumscribed 10 m radius circle of more than 15cm dbh were counted. The slight differences in the cypress and switchcane pine savannas are taken into account through the addition and deletion of a few variables in the methods; those variables are still included in the same four functions.

The area of the mitigation site that burns regularly was determined with acquired field knowledge of the site and aerial photos. The presence of illegally located fill within the assessment area was also scored. Using maps and ground knowledge, if any water was being imported into the site, the area of the corresponding watershed was measured. The last step was to compute the final function scores of the site from the data gathered on-site and off-site (Rheinhardt *et al*., unpub.). The many variables were all calculated and put into the Hydrology, Animal, Plants, and Biogeochemical functions with the final output being a function score between 0.0 and 1.0. Relationships of variables to function scores can be seen in Figure 2.

Overview of WRAP

Off-site Review

The initial review of a site began with an off-site review of the information available for the site including aerial photos/maps, evaluation of adjacent land uses, and identification of the wetland itself. Aerial photos or maps were used to establish project boundaries. Adjacent land uses were identified to establish the potential impact of those land uses on the wetlands along with factors affecting water quality such as pretreatment in detention basins. Identification of the wetland areas and verification with soil maps was done along with determination of wetland types, identifying access points and establishing major topographic features such as canals.

On-site Review

For the WRAP evaluation, the perimeter of the wetland was surveyed on foot for a minimum of 50 % of the perimeter. In some cases, more of the perimeter and walking into the interior was necessary to gain a complete picture of the habitat quality and possible impacts. After visually examining the area, the evaluation was used to score the site based on the criteria listed for each function. The Overstory, Ground Cover, Wildlife Utilization, and Hydrology Functions were scored according to the criteria on the score sheet.

After the field visit, the WRAP function scores were calculated at this point to determine the wetland's ranking. The percent of the perimeter affected by various adjacent land uses was calculated using field observations, aerial photography, and landcover maps. That information was used to calculate the Water Quality function. The other functions that were scored in the field were reviewed to validate the scores and then the final composite score was calculated (Roberts, 2000). The results were scores of between 0.0 and 3.0 for the functions, Wildlife Usage, Ground Cover, Overstory/Shrub Cover, Water Quality, and Hydrology. A mean was calculated with the function scores to obtain the site's overall score. Figure 3 also shows these relationships.

Overview of WES

Off-Site Review

There were no specific guidelines for an off-site review of WES, but based on the information required to accurately answer questions on the evaluation sheet (See Appendix A), the following information was gathered. A soils map was consulted to determine what types of soil underlie the wetland site. Aerial photos and GIS information were examined in ArcView to determine the site's location in relation to streams, salt marshes, and cypress-tupelo drains.

On-Site Review

The methodology did not indicate whether the method should be used on one or on multiple points within the wetland assessment area. The decision was made use the

WES evaluation worksheet in a framework similar to HGM. Three randomly chosen points within the wetland assessment area were evaluated using the method.

At the first sample point, the evaluation worksheet was filled out. The worksheet required observations of Tree Cover, Sapling Cover, Shrub Layer, Woody Vine Cover, Herbaceous Layer, Disturbances, Undesirable Species Composition, and Landscape Character (Teaford *et al*., 1995). This process was then repeated at the remaining 2 randomly chosen sample points. A flow chart showing the scored variables can be seen in Figure 4.

Description of Statistical Analyse Used

Site Characterizations and Descriptive Statistics

Sites were characterized using basic descriptive statistics based on size, age of permitted activity, and ownership. The descriptive statistics included the mean and range of size and age; the mean, mode and standard deviation of the function and overall scores; and standard deviation for the total and point time values.

Repeatability and Comparisons

To study repeatability and comparison of the scores, the two different data sets underwent several tests. The first step in this research was to test the normality and homogeneity of variance of each statistic to determine if parametric or non-parametric statistics were appropriate. Normality was tested using a Kolmogorov-Smirnoff Test and homogeneity of variance was tested using a Levene's Test (George & Mallery, 2000). Assuming the data were normal and had homogeneous variances, a Pearson R

Correlation was used to determine the presence and relative strengths of correlations (George & Mallery, 2000). For data not meeting the requirements of being normal and homogeneous, a simple log-transformation (base 10) was applied. For data that were still non-normal, the non-parametric correlation, Spearman-Rho, was used to determine the presence of correlations (George & Mallery, 2000). Results from all statistical tests were considered significant at $p < 0.05$.

Repeatability compared the scores of a selected group that were evaluated twice with all three methods. Correlations between Score 1 and Score 2 were compared for HGM, WRAP, and WES for that group of sites.

To compare the different evaluation methods, all of the sites were evaluated with the three methods testing the correlation with Spearman's Rho. Specific comparisons between the Animal and Wildlife Usage, Plant and Ground Cover, and Hydrology Functions were made for WRAP and HGM. Overall scores were compared between HGM and WRAP, HGM and WES, and WRAP and WES.

CHAPTER IV

RESULTS & DISCUSSION

Overview of Data Obtained

The data obtained from this study were from 16 mitigation and 3 reference sites. The reference sites were used in the original development of the USACE Wet Pine Savanna Assessment Model and were considered high quality examples of this habitat type. They are government owned and managed areas maintained through prescribed burns. The mitigation sites used were required in 404 permitting, were spread out over the three coastal counties, and had never been evaluated.

Data were collected on the repeatability of the methods and the comparisons of the 3 methods. In the collection of the repeatability data, the first 8 sites where data were collected in Jackson County were evaluated using the same methodology twice. Those eight sites included the 3 reference sites and an additional 5 mitigation sites. For the comparisons of the different methods, data were compared for the 3 reference sites and 16 mitigation sites. At each site, HGM, WRAP, and WES were used to evaluate the site. The analysis shows the statistical comparisons between the different methods for each site.

Mean size, age, and ownership statistics of the sites were generated to understand their variability (Table 4.2). The reference sites ranged in size from 24.2 to 223.9 hectares with a mean of 100.5 hectares. Size of the mitigation sites ranged from 0.6 to 24.1 hectares with a mean of 6.2 hectares. For the mitigation sites, the mean age was 5.6 years with a range from 2 to 8 years. Age was based on the time at which the project was permitted by the MDMR. Of the 16 mitigation sites, 5 were private developments and 11 were municipally or federally held land.

Table 4.2: Site characterizations by age, size, and ownership for all sites included in study.

	Age (years)		Size (hectares)		Ownership	
	Mean	Range	Mean	Range	G	P
Reference Sites	NA	NA	100.5	24.2-223.9	3	0
Mitigation Sites	5.6	2-8	6.2	0.6-24.1	11	5

G = Government ownership (County, State, or Federal)
P = Private ownership

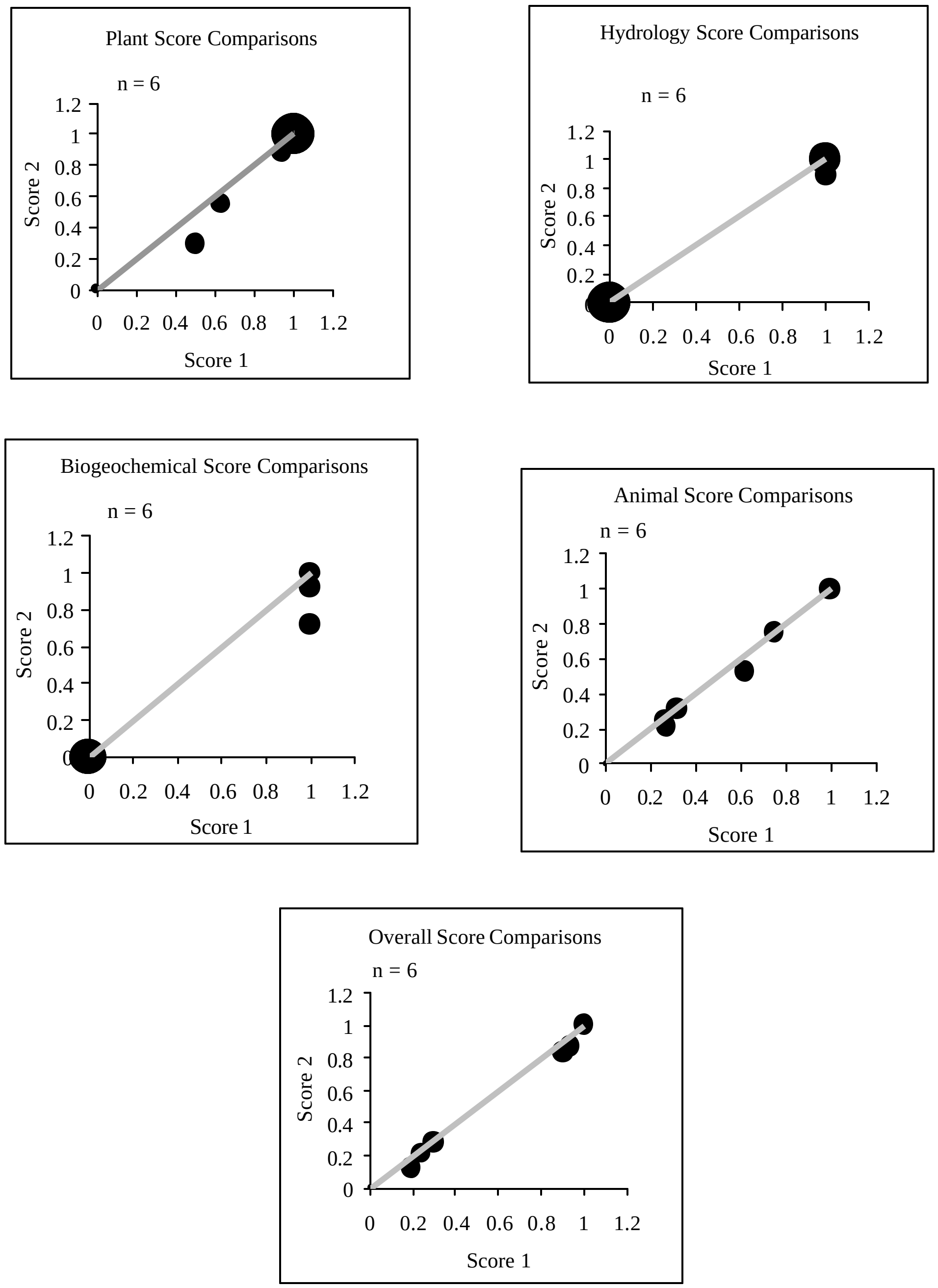
Repeatability Results

Evaluations were initially done from September 27, 2000 to October 20, 2000 and again from December 20, 2000 to January 22, 2001. The mitigation sites included 3 private development sites and 2 county government-owned sites. The following sections include results of the evaluations and a discussion of repeatability of each method. An overview of the repeatability of all three methods is included at the end.

Normality and homogeneity of variance were calculated for the data to determine what statistical procedure was appropriate in the analysis. As outlined in the methods section, a Kolmogorov-Smirnov Test was used to establish normality of the data. Using that test, 7 cases had non-normal data. Transforming the data, only affected 2 of 7 cases. Levene's Test was used to test the homogeneity of variance of the data comparing Score 1 to Score 2. None of the scores showed significantly different variances between Score 1 and Score 2. The conclusion for these tests was that the data is non-normal with homogeneous variance. Non-normality violates the assumption of parametric tests. Other considerations include data that are ordinal in nature and the small sample size. As a result, non-parametric correlations are used to study the degree of correlation between Score 1 and Score 2 of the repeatability data. Rs is the correlation coefficient and p_s is the significance level.

HGM

Six sites were used in the analysis of the HGM data for repeatability. The original pool of sites included 8, of those 2 were eliminated due to site conditions that had changed due to human modification. Hydro, Animal, Plant, and Biogeo functions along with the Overall scores were significantly correlated (Table 4.3) ($p< 0.05$). Figure 4.5 shows Scatter plots of Score 1 versus Score 2. These scatter plots, if perfectly correlated would be along the 45° line; for the HGM scores, the data points on all of the graphs are very close to that line.



Legend: ● = 1 site ● = 2 sites ● = 3 sites
*Size of the dot represents the number of sites with the same score.

Figure 4.5: HGM Score Comparisons for Score 1 versus Score 2 for the sites.

Table 4.3: The Spearman Correlation coefficients and corresponding p-values for the comparisons of HGM Score 1 versus Score 2 functions.

HGM Functions	Spearman	
	Rs	p_s
Hydro	0.95	0.004
Animal	0.94	0.005
Plant	1.00	
Biogeo	0.93	0.007
Overall	1.00	

WRAP

Eight sites were used to examine WRAP's repeatability. The functions Wildlife Utilization, Ground Cover, and Buffer were significantly correlated (Table 4.4) ($p < 0.05$). The other two functions, Overstory/ Shrub Cover and Hydrology, as well as the Overall scores did not show a significant level of correlation ($p > 0.05$). These statistical results, shown in Table 4.4, indicate that WRAP was not as repeatable as HGM. The variability in the scoring is evident on the scatter plots by the distance of some points from the 45° line in Figure 4.6.

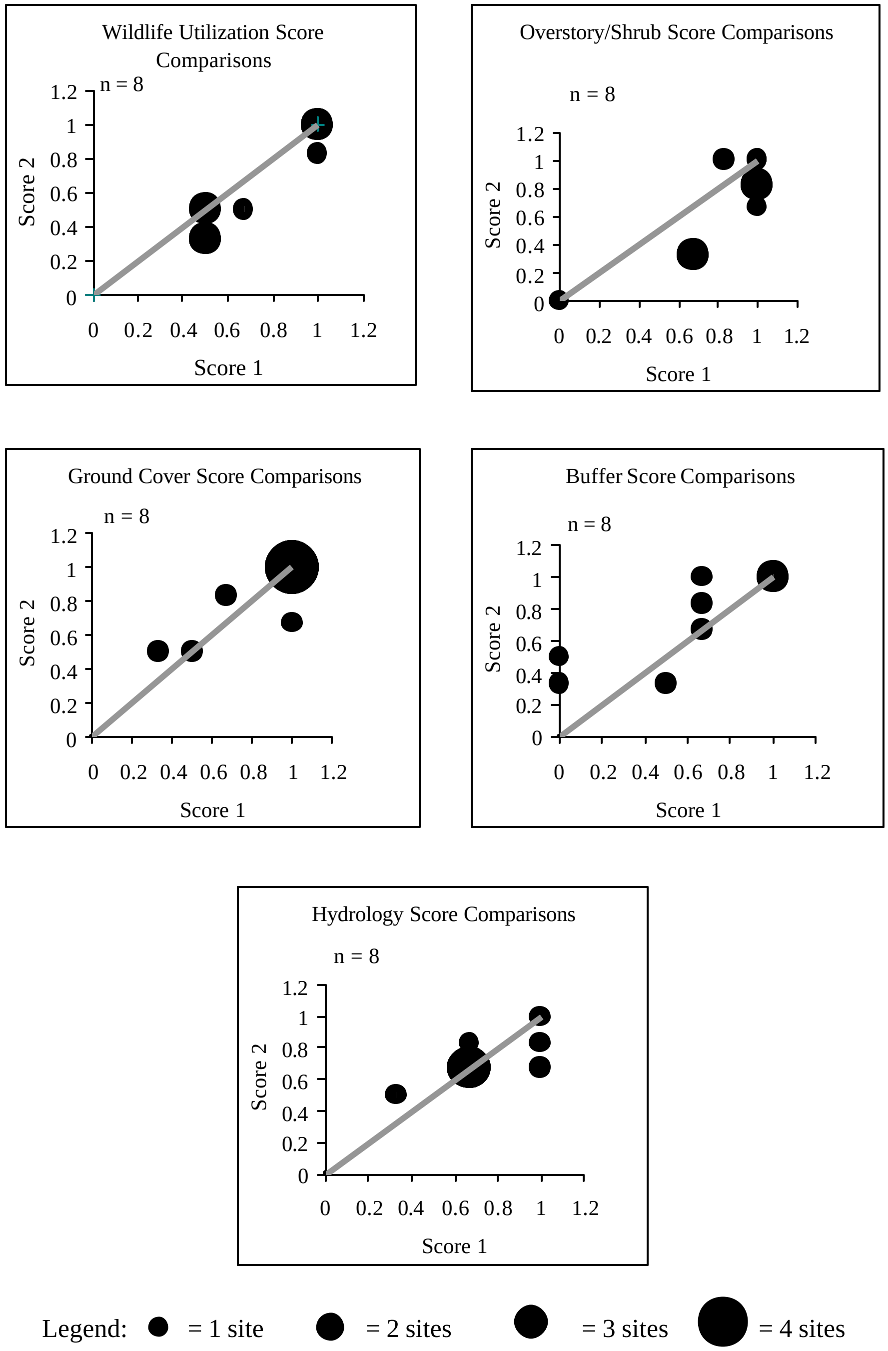


Figure 4.6: Scatterplots showing WRAP score comparisons for Score 1 and Score 2.

Table 4.4: The Spearman Correlation coefficients and corresponding significance levels for the comparisons of WRAP Score 1 versus Score 2 functions for each function.

WRAP Functions	Spearman	
	Rs	**p_s**
Wildlife Utilization	0.88	0.004
Overstory/Shrub	0.63	0.092
Ground Cover	0.83	0.010
Buffer	0.87	0.005
Hydrology	0.63	0.093
Overall	0.58	0.131

WES

There are only 6 sites in this WES analysis due to the evaluation method being included in the experiment after the first two sites had been evaluated. The Overall score comparisons for repeatability were significantly correlated (Table 4.5) ($p < 0.05$). A scatter plot of the Score 2 vs. Score 1 showed that the data were fairly consistent and very close to the 45° line with one site being noticeably distant from the line (Figure 4.7). An analysis of the field notes showed no particular variable scored differently; there was simply a cumulative difference in scoring.

Table 4.5: The Spearman Correlation coefficients and corresponding p-values for the comparisons of WES Score 1 versus Score 2 for overall scores.

WES	Spearman	
	Rs	**p_s**
Overall	0.83	0.042

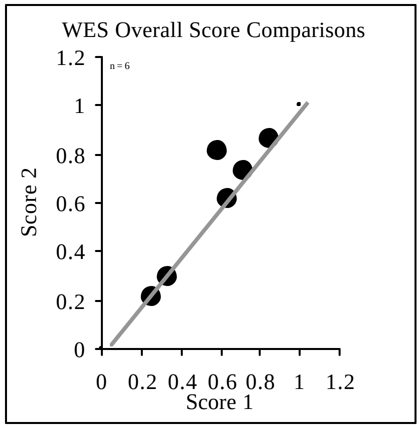


Figure 4.7: Scatter plot showing WES Overall score comparisons.

Overall Repeatability Findings

Of the three methods studied here, the Spearman correlations indicated that HGM was the most repeatable method having significant correlations and high Rs values (Table 4.4). WES was potentially as repeatable except for an unexplained data point, which lowered its Rs value (Rs = 0.83). WRAP was the least repeatable evaluation in this analysis having the lowest Rs values and with the Overall and Animal and Hydrology function scores not significantly correlated.

The fairly high repeatability of HGM and WES versus WRAP should be examined in several ways. HGM and WES had very defined variables that were observed and scored versus the WRAP method where similar observations were made but were used to form a composite function score without being scored themselves. For example, in the Ground Cover function of WRAP, coverage of target vegetation, the coverage of woody vines, and relative numbers of target species are all observed but no scores are given to them individually, they just factor into the Ground Cover function. In

WES, percent coverage of herbaceous species, percent coverage of woody vines, and species per plot were all scored individually and then added into the Overall Score.

These types of differences in the methods increased the opportunity for the evaluator to influence the WRAP evaluation because specific variables were not scored separately. It is important to consider that in the original version of the WRAP method, testing in Florida showed it to be repeatable with differences in scores being due to sites and not different evaluators (Miller & Gunsalus, 1999). The circumstances around that testing included the identification of specific sites and scoring those sites and then evaluators had a two-day training course on how to score those sites (Miller & Gunsalus, 1999). Repeatability of the same evaluators on the same sites was not addressed in that study though. The training probably helped reduced the variability of the method.

In essence, if the evaluator is highly trained, the methods may very well exhibit the same and relatively low levels of variability. The evaluator in this case received equal amounts of training for each method from talking with authors or users after extended review of each method's documentation. Since WES and HGM already show significant levels of correlation, training might also reduce their variability but it would have a lesser effect than on WRAP evaluations. It should be noted that this was a small number of sites and sampling a larger number of sites might also reduce the variability.

Score Comparisons Between Methods

Nineteen sites were used to compare scorings between the three methods; the sites included 3 reference sites and 16 mitigation sites. Normality and homogeneity of variance were examined to determine which statistical procedures were most appropriate.

Testing for normality showed that WRAP's Wildlife Utilization and Hydrology had non-normal distributions. Transforming the data improved the Wildlife Utilization but not Hydrology. For HGM, Hydrology and Animal Functions were non-normal and were unaffected by transformation. Histograms of those data validate this finding by showing a bi-modal distribution. Using Levene's Test for homogeneity of variance, the comparison between the Hydrology scores of WRAP and HGM had significantly different variances ($p < 0.5$). Comparisons of Plant and Animal scores between HGM and WRAP and comparing HGM, WRAP, and WES Overall scores all showed homogeneity of variance. As a result of these statistics, a non-parametric test was chosen as most appropriate. A relatively small data pool also reinforces using a non-parametric correlation.

WRAP and HGM

Score Comparisons between WRAP and HGM for the evaluated sites, including mitigation and reference sites, show different central tendencies in the data and varying correlations. The data showed that the mean values for some functions were very different and for other functions were fairly similar. The Hydrology and Animal functions showed large differences in central tendency between HGM and WRAP while the Plant function showed relatively similar central tendencies. The Overall score mean value showed that the scores were not exactly the same but were close (Table 4.6).

Table 4.6: Mean, mode and standard deviation for the comparison of HGM and WRAP by function and overall score.

Method/Function	Mean	Mode	Standard Deviation	n
HGM/Hydro	0.32	0.00	0.42	19
WRAP/Hydro	0.61	0.67	0.24	19
HGM/Animal	0.31	0.20*	0.23	19
WRAP/Animal	0.60	0.50	0.21	19
HGM/Plant	0.65	1.00	0.32	19
WRAP/Plant	0.62	0.50	0.29	19
HGM/Overall	0.54	0.47	0.22	19
WRAP/Overall	0.62	0.58	0.20	19

* Indicates that more than one mode existed and the lowest is shown

Statistical analysis of the WRAP and HGM comparison data showed the Plant function and Overall score were significantly correlated (Table 4.7) ($p < 0.05$). The Animal function, which showed one of the two largest differences in central tendency, was not significantly correlated. Hydrology also had a large difference in central tendency but showed up as being significantly correlated with a low Rs values (Table 4.7) ($p < 0.5$). The scatter plots of the Hydrology scores show large differences in the scores (Figure 4.8).

Table 4.7: Spearman Correlation coefficients and p-values for the comparison of HGM and WRAP by functions and overall scores.

HGM/WRAP Functions	Spearman	
	Rs	p_s
Hydro	0.56	0.013
Animal	0.42	0.072
Plant	0.77	0.000
Overall	0.64	0.003

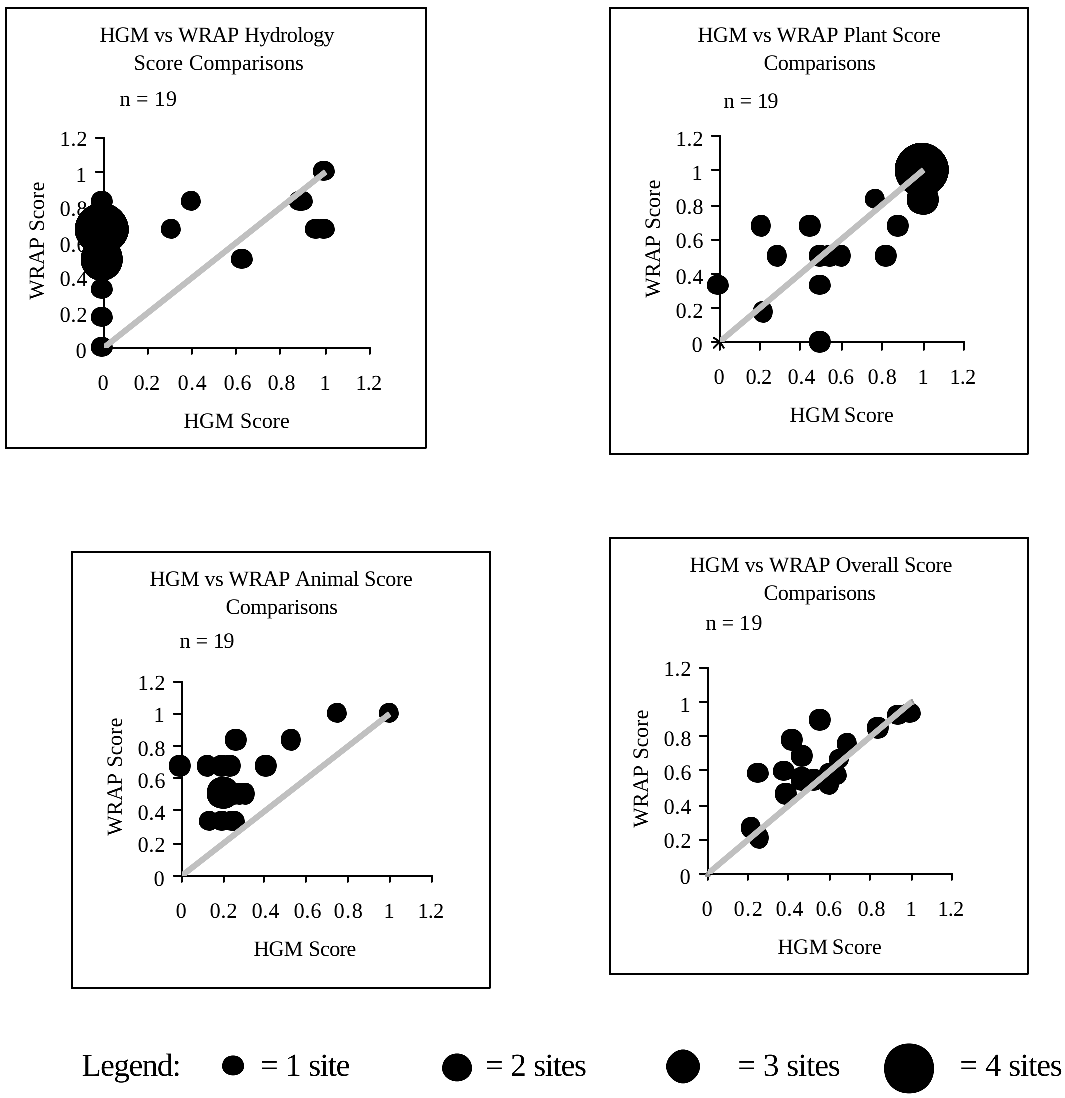


Figure 4.8: WRAP scores versus HGM scores for functions and Overall scores.

WES and WRAP

The mean for WES's overall score was 0.55 and for WRAP was 0.62, which suggests that the methods are scoring somewhat similarly (Table 4.8 & Figure 4.9). Comparison of the overall scores between WES and WRAP showed a low Rs value but a significant correlation ($p_s < 0.05$, Rs= 0.505). The scatter plot of WES versus WRAP verifies a correlation but not a strong one (Figure 4.9).

Table 4.8: Mean, mode and standard deviation for the comparison of WES and WRAP by overall score.

Method/Function	Mean	Mode	Standard Deviation	n
WES/Overall	0.55	0.52	0.16	19
WRAP/Overall	0.62	0.52	0.20	19

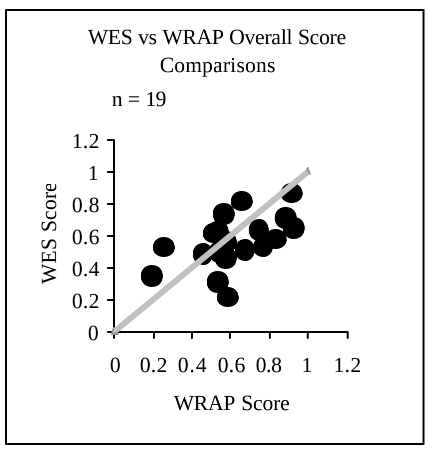


Figure 4.9: Plot of WES versus WRAP Scores

WES and HGM

Comparing WES and HGM indicates a moderately high Rs value (R= 0.802) and a significant correlation ($p_s < 0.05$). The mean value for HGM was 0.54 and for WES it was 0.55 (Table 4.9). The scatter plot shown in Figure 4.10 shows the points are relatively close to the 45° similar to WES and WRAP. The similarity in the means and high Rs value indicate a stronger correlation than the comparison of WES and WRAP or WRAP and HGM.

Table 4.9: Mean, mode and standard deviation for the comparison of WES and HGM by overall score.

Method/Function	Mean	Mode	Standard Deviation	n
WES/Overall	0.55	0.52	0.16	19
HGM/Overall	0.54	0.47	0.22	19

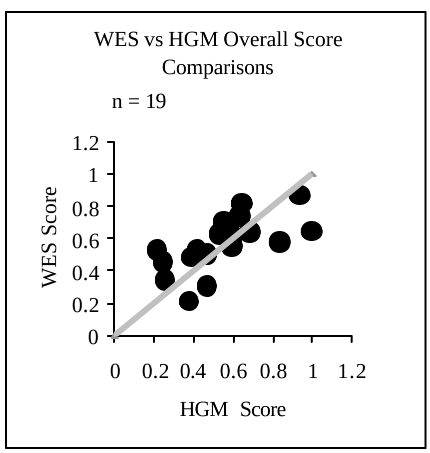


Figure 4.10: Plot of WES versus HGM scores

Overall Comparison of WRAP, WES, and HGM

Figure 4.11 shows the scores of all three methods by site followed the same general trends. Close analysis of the scores on a site-by-site basis show that the scores were rarely exactly the same and occasionally were very different. The differences are accounted for in the way the methodologies placed importance on different factors.

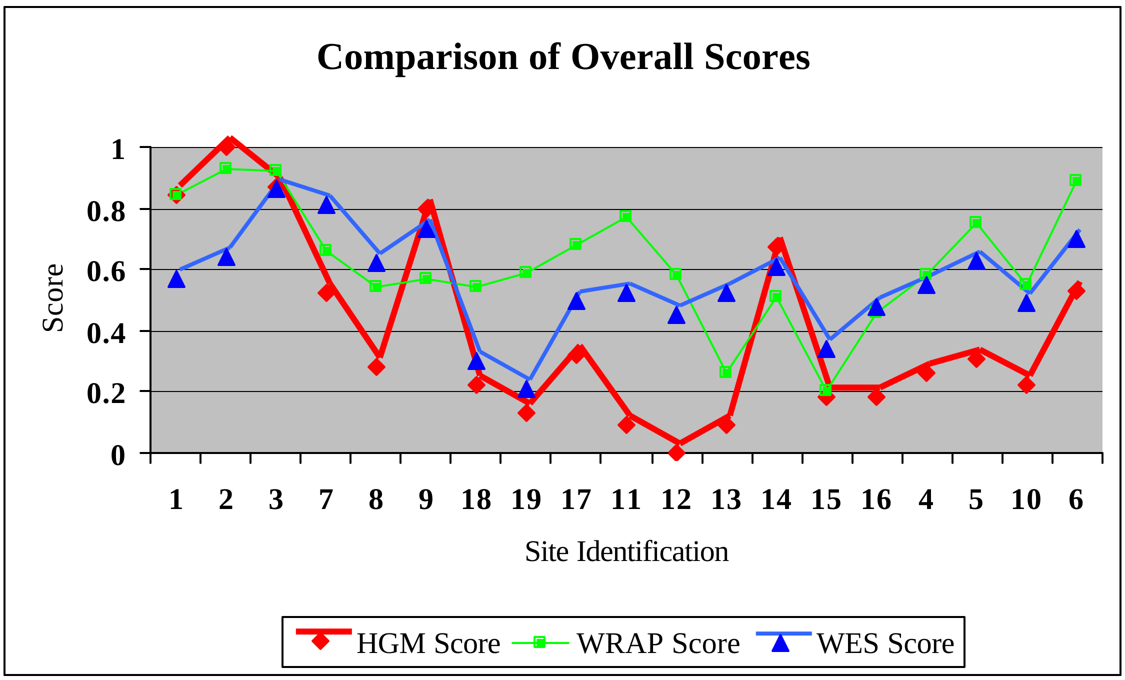


Figure 4.11: Plot of score comparisons by site for HGM, WRAP, and WES.

The HGM method focuses heavily on hydrology and plants. For both of those functions, they are a scored function and additionally are half of another function. For instance, the scored Hydrology function is included in the Biogeo function. The Plant function is also included in the Biogeo and Animal functions. HGM is also heavily influenced by acreage.

The WRAP method does not focus on any one variable. Two variables that score plant features are included, but they are scored independently of each other, as are all of the other variables. WRAP has much more flexibility because the method only generally outlines the factors on-site to be scored. This contrasts to HGM, which requires specific things to be scored. For example, HGM requires the identification of 20 specific plant species versus WRAP which scores the Plant function in part on the "target pine savanna herbaceous species occurring" (Roberts, 2000), and then includes an appendix list of plants without specifying which plants to look for or ranking them.

WES is a method heavily focused on the type of soil of the wetland area. The soil score makes up 25% of the WES Score while the other groups looked at vary from 10% to 20% of the score. The general trends of the overall scores of the methods can be seen in Figure 4.11. These line graphs of the scores categorized by the site shows a general trend of HGM scoring the lowest and WRAP typically scoring higher with WES usually falling in between. These are only very general trends and in several sites this was different.

The comparisons of WRAP and HGM on a function-by-function basis showed that the Animal function was not significantly correlated, whereas the Plant function and Overall scores were significantly correlated. The Hydrology function was also significantly correlated even though the means and scatter plot of that data indicated the correlation was not strong. Comparing WRAP to WES showed a significant correlation in their overall scores ($p < 0.05$) (Table 4.10). WES and HGM showed the strongest correlation in overall scores with a low p-value and a moderately high Rs value ($p < 0.05$). The paired score comparisons of the three methods to each other shows that HGM and WES have the most significant correlation with the relationship between HGM and WRAP coming next and the relationship of WES and WRAP being the worst correlation based on Rs values, although all comparisons were significant.

Table 4.10: Comparison of statistics for Overall scores between the 3 methods.

	Spearman	
Compared Methods	**Rs**	**p_s**
HGM/WRAP	0.64	0.003
HGM/WES	0.80	0.000
WES/WRAP	0.51	0.027

The comparison of all three methods showed that the focus of each method may tend to make the scoring very different for functions within the method or the scoring may be very different for individual sites, but generally all three methods followed similar trends.

Time Comparisons

An important consideration when using a method of wetland evaluation in regulatory work is the amount of time that must be spent to complete the method and the amount of information gathered from the method. This analysis looked at the time to complete each method including on-site observations and off-site analysis. Sixteen sites were used in the time analysis; of the 19 sites evaluated, 3 were eliminated due to variations in the times caused by human error. The mean total times and standard deviations are seen in Table 4.11. Units for time are in hour, minute, and second format (HH:MM:SS).

Table 4.11: Comparison of total times to complete each method and point evaluation times.

	Total Evaluation Time*	Std Deviation	Point Evaluation Time**	Std Deviation
HGM	1:08:39	0:19:51	0:09:05	0:02:11
WRAP	0:31:21	0:18:23	0:05:24	0:00:49
WES	0:34:11	0:10:45	0:01:50	0:00:20

*Total Evaluation Time included all time spent in evaluation both on-site and off-site.
**Point Evaluation Time was the time to evaluate one point of the three chosen for HGM and WES or the one point for WRAP.

The mean time to complete an HGM evaluation was 1:08:39 with a standard deviation of 0:19:51. HGM was dependent on the size of the area since the time to walk between assessment points was included. The mean time require to complete the written evaluation at one sample point on site was 0:09:05 with a standard deviation of 0:02:11. There were 3 sample points evaluated per site.

For WRAP, the mean time was 0:31:37 with a deviation of 0:17:50. A lot of the variability in time for WRAP was in the calculation of the water quality variable, which necessitated referencing various imagery and land use maps to determine the scoring of individual types of sites and also measuring the perimeter of the wetland in contact with adjacent land uses. The actual mean time to do the point evaluation was 0:05:24 with a standard deviation of 0:00:49. Included in the WRAP evaluation time was the time to walk at least half of the perimeter of the site and walk into the site far enough for the evaluator to feel they had gained an understanding of the site's characteristics.

WES mean time to completion was 0:34:11 with a standard deviation of 0:10:24. The way WES was implemented here was similar to HGM in that the time was influenced by the size of the site because time spent walking between evaluation points was included in the total. For each written evaluation at a sample point, the mean time was 0:01:50 with a deviation of 0:00:20.

Overall, even though WES and WRAP had similar evaluation times, the actual time to do an individual evaluation for WES was much lower than HGM and more than 3 minutes less than the time to do the WRAP evaluation. HGM takes the longest of these methods and even the individual sample point evaluations took almost twice as long as WRAP and a little more than 4 times as much as the WES evaluation to complete.

CHAPTER V

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

Summary of Results

Of the evaluation methods examined in this study, HGM produced the most repeatable results. WES was still a very repeatable method and more data might have indicated it to be as repeatable as HGM. WRAP did not show up as being a very repeatable method in this study. The reliance on "Professional Judgment" as opposed to defined, scored variables probably accounted for much of the difference.

The comparisons of the overall scores of the methods actually showed that the comparisons of WRAP to HGM, HGM to WES, and WRAP to WES were all significantly correlated at the 0.05 level. The most significant pairing was between HGM and WES, with HGM and WRAP being slightly lower, and WES and WRAP being the weakest correlation. So while the different methodologies all have different focuses, the results are still significantly correlated.

The time to complete the different methods showed HGM taking by far the longest at just over one hour. WES and WRAP averaged around half of an hour to complete.

Implications of Results

Taken together, the above facts indicate that HGM and WES are methods yielding similar results. Based on the time data, WES is somewhat more preferable than HGM because the time is almost half of the HGM score. A consideration that might make HGM more useful for regulatory work is the repeatability of HGM, which would translate into defendable results in legal settings or controversial situations with competing interests, which is occasionally an issue for the MDMR.

Overall Conclusions

Based on this analysis, HGM would be the best choice of methods although WES has potential if further developed to produce similar results in half the time. WRAP seems to be too reliant on Professional Judgment. This becomes a problem for the MDMR because of a relatively high employee turnover in positions overseeing mitigation. Typical tenure in the wetland permitting positions is 11.53 months (Daniel, 2001). Use of HGM would be reproducible between employees and over time while requiring little training.

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APPENDIX A

DATA SHEET FOR WES

Appendix A.1: Continued.

PINE SAVANNAH ASSESSMENT SHEET								
SITE NAME:					SIZE:			
DATE:					ASSESSOR:			
SOILS								
Soil Series	Atmore Plummer Smithton	25 25 25	Daleville Guyton Myatt Trebloc	15 15 15 15	Escambia Harleston Ocilla	6 6 6	Beauregard Grady Hyde Robertsdale	2 2 2 2
TREE COVER								
% Cover	0-15%	5	15-25%	3	26-60%	2	>60%	-5
% Longleaf Pine	>50%	5	26-50%	3	15-25%	2	<15%	1
SAPLING COVER								
% Cover	<10%	6	10-20%	4	21-40%	2	>40%	1
Slash Pine	<10/Plot	2	10-20/Plot	1	21-40/Plot	0	>40/Plot	-2
Ave. Height	<5 ft.	2	5-10 ft.	1	11-25 ft.	0	>25 ft.	-1
SHRUB LAYER								
Ave. Height	<2 ft.	4	2-4 ft.	3	4-8 ft.	1	>8 ft.	-2
WOODY VINE COVER								
% Cover	<10%	6	10-20%	4	21-40%	2	>40%	-2
HERBACEOUS LAYER								
% Cover	>85%	4	70-85%	3	50-70%	2	<50%	1
Sp/Plot	>40/Plot	4	26-40/Plot	3	15-25/Plot	2	<15/Plot	1
OBL Species	≥ 4/Plot	2	3/Plot	1	2/Plot	1	1/Plot	1
# Flowers /Plot	≥ 250/Plot	3	180-249/Plot	2	90-179/Plot	1	<90/Plot	1
Ave. Pitcher Height	>16"	2	14-16"	1	12-14"	1	<12"	1
DISTURBANCE								
Ditching	No ditches >2 ft deep within 250 yards of site boundaries	7	No ditches >2 ft deep within 100 yards of site boundaries	4	Ditches 2-4 ft deep are present within 100 yards of site boundaries	-3	Ditches ≥4 ft deep are present within 200 yards of site boundaries	-5
Timber Harvest	Ave. tree DBH ≥12"; minimal rutting	3	Ave. tree DBH 10-12"; slight-mod. rutting	2	Ave. tree DBH 8-10"; moderate rutting	1	Ave. tree DBH <8"; extensive rutting	0
UNDESIRABLE SPECIES COMPOSITION								
Presence	0-2 Species	5	3-5 Species	2	6-8 Species	-3	>8 species	-5
Abundance	<5%	5	5-10%	2	11-20%	-3	>20%	-5
LANDSCAPE CHARACTER								
Size	>50 Acres	5	11-50 Acres	3	2-10 Acres	2	<2 Acres	1
Headwaters Position	Site boundaries within 50 yards of brackish/ salt marsh, cypress-tupelodepression/drain, forested bayhead, or 1st order stream	5	Site boundaries within 100 yards of brackish/ salt marsh, cypress-tupelo depression/drain, forested bayhead, or 1st order stream	4	Site boundaries within 250 yards of brackish/ salt marsh, cypress-tupelo depression/drain, forested bayhead, or 1st order stream	3	Site boundaries > 250 yards from a brackish/ salt marsh, cypress-tupelo depression/drain, forested bayhead, or 1st order stream	2
	TOTAL		TOTAL		TOTAL		TOTAL	

APPENDIX B

DATA SHEETS FOR HGM

Appendix B.1: Data Sheet 1.

Field Data Sheet 1: Mineral Soil Wet Pine Flats of the Altlantic and Gulf Coastal Plain

Assessment Team:______________________ Date:__________

Project Name/Location:______________________

Sketch WAA below (provide north arrow, major landmarks)

Be sure to partition WAA into partial WAAs first (use key in Table A1).

Notes:

Appendix B.2: Data Sheet 2.

Sheet 2: Wet Pine Flats ($V_{LANDSCP}$, V_{INFLOW}, $V_{SURFFLOW}$, $V_{OUTFLOW}$, $V_{STORAGE}$, V_{ET})

Assessment Team: ______________________ ______________

Project Name/Location: ______________________ ______________

1. $V_{LANDSCP}$ Area of contiguous savanna (upland and wetland, including WAA) which has burned within the past 3 years: ______ (do not include fire-excluded areas or barriers to fire exclusion > 50 m wide). Also, exclude all bedded areas, even if manged with fire.
$V_{LANDSCP}$ = 0.0095 x (area in hectares) + 0.05.

1. $V_{LANDSCP}$: ☐

2. V_{INFLOW} Inflow of water from an exogenous basin (calculate from county drainage maps, aerial photos, topographic maps, and/or site reconnaissance). If no water is imported, V_{INFLOW} = 1.0. Otherwise, calculate from information below (basin areas determined from upgradient of point of water inflow).
   a. Size of total drainage basin (TB)______ minus size of total natural drainage basin (NB) ______ equals size of exogenous basin (EB) ______.
   b. Divide EB by NB, subtract from 1.0 (1.0 - EB/NB). If answer is negative, assign 0.0 to score.

2. V_{INFLOW} ☐

Variables 3-8 are obtained from partitioning the WAA .

3. $V_{SURFFLOW}$ Absence of reservoir (1.0) caused by an impediment (dam) to throughflow: [within reservoir (0.0); within reservoir shadow (0.5)] — 3. $V_{SURFFLOW}$ ☐

4. $V_{OUTFLOW}$ Within (0.0) or outside (1.0) lateral effect distance — 4. $V_{OUTFLOW}$ ☐

5. $V_{STORAGE}$ Presence (0.0) or absence (1.0) of fill or excavation — 5. $V_{STORAGE}$ ☐

6. V_{ET} Evapotranspiration potential
If site history is not known or WAA has been planted with pines for silviculture, then obtain LAI data from plots (Data Sheet 4). Otherwise, assign V_{ET} subindex from site history conditions (below). Note: Treat mowing (utility rights-of-way, etc.) the same as fire.
(a) If the WAA has not been planted with pines for silviculture and fire has occurred within past 3 years, then V_{ET} = 1.0
(b) If fire has been excluded for the past 3-10 years, record the number of ~~years~~ years since last mowing or fire (LF) ______. V_{ET} = 0.30((10 - LF)/7) + 0.70
(c) If fire has been excluded for more than 10 years, then, V_{ET} = 0.70.

6. V_{ET} ☐

Appendix B.3: Data Sheet 3.

Sheet 3: Wet Pine Flats (V_{HERB})

Assessment Team:

Project Name/Location:

Date: __________

WAA: __________

Measure only in Bunchgrass/Pine Savannas and Cypress/Pine Savannas (least wet end of wetness gradient).

(a) For each indicator species/genus that occurs in the 1-m^2 nested plot, record "1.0".

(b) For each indicator plant that occurs in the 2-m-radius plot, but does not occur in the 1-m^2 nested plot, record "0.5".

Herb Indicator Species	Plot 1	Plot 2	Plot 3
Aletris spp. (*A. farinosa, A. aurea*)			
Aristida spp. (*A. stricta, A. beyrichiana), Sporobolus* spp.			
Balduina spp.			
Bigelowia nudata			
Carphephorus spp.			
Chaptalia tomentosa			
Coreopsis spp.			
Ctenium aromaticum			
Dichromena spp.			
Erigeron vernus			
Eriocaulon spp.			
Eryngium integrifolium			
Eupatorium leucolepis			
Helianthus spp.			
Lycopodium spp. (especially *L. alopecuroides*)			
Muhlenbergia expansa			
Rhexia spp.			
Sarracenia spp.			
Schizachyrium scoparium			
Xyris spp.			
Total Indicator Score for each plot			
Mean for all plots			

(c) To determine the mean score, total all scores and divide by the number of 1-m^2 plots (at least 3).

(d) Divide the mean by 8.0 for Bunchgrass/Pine Savanna or by 7.0 for Cypress/Pine Savanna. If score > 1.0, reduce score to 1.0.

Bunchgrass/Pine Savanna score (divide Mean by 8.0)	8. V_{HERB}:	
Cypress/Pine Savanna score (divide Mean by 7.0)	9. V_{HERB}:	

Appendix B.4: Data Sheet 4.

Sheet 4: Wet Pine Flats (V_{SUBC})

Assessment Team:
Project Name/Location:

Date: __________
WAA: __________

Measure only in wet Cypress/ Pine Savannas and in Switchcane/Pine Savannas

Plot size: 50 m^2. V_{SUBC} (subcanopy density): woody stems > 1 m tall and < 7.5 cm dbh rooted within plots. Count all stems (not limbs) at 1 m height.

Species	Subcanopy stem count			Total	Mean
	Plot 1	Plot 2	Plot 3		
Total					
Total Subcanopy Density for Site (mean x 200)					
				11. V_{SUBC}[1]:	

[1]If site has been mechanically cleared, then V_{SUBC} = 0.0; otherwise, if subcanopy density < 6,500 stems/ha, then V_{SUBC} = 1.0. If subcanopy density is between 6,500 and 19,500 stems/ha, then V_{SUBC} = (19,500 - density)/13,000. If subcanopy density is > 19,500 stems/ha, then V_{SUBC} = 0.0.

Appendix B.5: Data Sheet 5.

Sheet 5: Wet Pine Flats (V_{MICRO}, V_{PORE})

Assessment Team:

Project Name/Location:

Date: ____________

WAA: ____________

Do not measure if Hydrologic submodels 1-4 (i.e., $V_{SURF\ FLOW}$, $V_{OUTFLOW}$, V_{INFLOW}, or $V_{STORAGE}$ = 0.0).

Type of alteration to microtopography	Cover 1 (midpoint) of 50-m² plots			Mean Cover	Microtopo Alteration Value	Score (Mean cover x Value)
	Plot 1	Plot 2	Plot 3			
None, natural [2] (unaltered)					1.0	
Lightly grazed, rutted					0.8	
Intensively grazed, rutted					0.6	
Light artillery divots					0.4	
Fire breaks or deep ruts (> 20 cm from rut to ridge)					0.3	
Tilled cropland					0.3	
Recent feral hog rooting					0.2	
Bedded for silviculture					0.2	
Ruts from off-road vehicles (< 20 cm deep)					0.1	
Gasline ROW					0.1	
Impervious					0.0	
SUM	1.000	1.000	1.000			
Total microtopographic alteration score (sum last column)					9. V_{MICRO} =	

Type of alteration to soil porosity	Cover 1 (midpoint) of 50-m² plots			Mean Cover	Soil Alteration Value	Score (Mean cover x Value)
	Plot 1	Plot 2	Plot 3			
None, natural [2] (unaltered)					1.0	
Recent feral hog rooting					0.9	
Ruts from off-road vehicles (< 20 cm deep)					0.6	
Fire breaks or deep ruts (> 20 cm from rut to ridge)					0.4	
Bedding for silviculture					0.4	
Light artillery					0.3	
Compacted by grazing cattle					0.2	
Graded or excavated for pipeline					0.1	
Tilled cropland					0.1	
Impervious					0.0	
SUM	1.000	1.000	1.000			
Total soil alteration score (sum last column)					10. V_{PORE} =	

Note: At least three 50 m^2 plots (150 m^2) should be sampled per WAA. This variable is only measured if the site is otherwise hydrologically unaltered.

[1] Record midpoint of cover classes (in parentheses): 0% (0), 0-5% (0.025), 5-25% (.015), 25-50% (0.375), 50% (0.50), 50-75% (0.625), 75-95% (0.85), 95-100% (0.975), 100% (1.0).

[2] First determine cover for all other categories (alterations), sum, and subtract sum from 1.0 to obtain area unaltered (row 1).

Appendix B.6: Data Sheet 6.

Sheet 6. Wet Pine Flats (V_{NBG}, V_{SEDGES}, V_{ET})

Assessment Team: ______________________ Date: ________

Project Name/Location: ______________________ WAA: ____________

	Percent cover (living plants in 2-m radius)[1]					
	Plot 1	Plot 2	Plot 3	Cover		
Native bunchgrasses [2]					12. V_{NBG}[4]:	
Sedges[3]					13. V_{SEDGES}[5]:	

	Cover of living plants (2-m radius)								
	Plot 1			Plot 2			Plot 3		
Stratum [6]	Cover [1]	LAI	Composite LAI score[8]	Cover [1]	LAI	Composite LAI score[8]	Cover [1]	LAI	Composite LAI score[7]
Groundcover		1			1			1	
Low Shrub		2			2			2	
Subcanopy		3			3			3	
Midcanopy		4			4			4	
Canopy		5			5			5	
Total LAI score									
Mean LAI score (total/ number of plots)									
			Bunchgrass/Pine Savanna					14. V_{ET}[8]:	
			Cypress/Pine and Switchcane/Pine Savanna					15. V_{ET}[9]:	

Note: Cover is midpoint of cover categories from Table 4.

[1] Record midpoint of cover classes: 0% (0), 0-5% (0.025), 5-25% (0.15), 25-50% (0.375), 50% (0.50), 50-75% (0.625), 75-95% (0.85), 95-100% (0.975), 100% (1.0).

[2] Includes *Ctenium aromaticum* (toothache grass), *Muhlenbergia expansa* (Muhly grass), *Aristida stricta* (northern wiregrass), *Aristida beyrichiana (southern* wiregrass), *Schizachyrium scoparium* (little bluestem), *Sporobolus* spp. (dropseed), and wiry native *Rhyncospora* spp. (if west of the Mississippi River).

[3] Includes *Carex, Scleria,* and non-wiry *Rhynchospora* spp. (Measure only in Cypress/Pine Savannas)

[4] V_{NBG} (if mean cover > 0.50, then V_{NBG} = 1.0; if mean cover < 0.50, then V_{NBG} = mean cover/0.50).

[5] V_{SEDGES} (if mean cover > 0.50, then V_{SEDGES} = 1.0; if mean cover < 0.50, then V_{SEDGES} = mean cover/0.50).

[6] Living vegetation: Groundcover = herbaceous stratum); Low Shrub = woody plants < 1m tall, Subcanopy = woody plants > 1 m tall and < 7.5 cm dbh; Midcanopy = stems 7.5-15 cm dbh; Canopy= trees > 15 cm dbh.

[7] Composite LAI = Cover X LAI

[8] V_{ET} for Bunchgrass/Pine Savanna, if Site LAI < 2.0, then V_{ET} = 1.0, if the Site LAI is between 2.0 and 3.0, then V_{ET} = 1.0 – [0.3 (LAI – 2.0)], if Site LAI > 3.0, then V_{ET} = 0.7)..

[9] V_{ET} for Cypress/Pine and Switchcane/Pine Savannas, if Site LAI < 3.5, then V_{ET} = 1.0, if Site LAI is between 3.5 and 5.0, then V_{ET} = 1.0 – [0.2 (LAI – 3.5)], if Site LAI > 5.0, then V_{ET} = 0.7

Appendix B.7: Data Sheet 7.

Sheet 7: Wet Pine Flats ($V_{CYPRESS}$)

Assessment Team: ____________________

Project Name/Location: ____________________ Date: ____________________

Measure only *Taxodium ascendens* (pond ~~pine~~ CYPRESS) in Cypress/Pine Savannas.

	Distance (m)[4]			Mean		
	Plot #1	Plot #2	Plot #3	Distance	Density[5]	Physiognomy[6]
Sapling[1]						
Midcanopy[2]						
Canopy[3]						
Mean					16. $V_{CYPRESS}$[7]:	

[1] Stems > 1 m tall, but < 7.5 cm dbh
[2] Stems 7.5-15 cm dbh
[3] Stems > 15 cm dbh
[4] Measure distance in meters to nearest individual in each size class
[5] Density = 10,000/[2 X (Mean Distance)^2]
[6] Sapling Physiognomy = Density/450, if > 1.0, reduce to 1.0
Midcanopy Physiognomy = Density/50, if > 1.0, reduce to 1.0
Canopy Physiognomy = Density/100, if > 1.0, reduce to 1.0
[7] $V_{CYPRESS}$ is the mean of all three Physiognomy scores

Appendix B.8: Data Sheet 8.

Sheet 8: Wet Pine Flats (V_{LONGL}, V_{PINES})

Assessment Team:

Project Name/Location:

Date: ________

WAA: ________

Measure only in Switchcane/Pine Savannas.

Plot size = 10-m radius. V_{PINES} (pine tree density): trees > 15 cm dbh

Species	Pine tree count			Total	Mean
	Plot 1	Plot 2	Plot 3		
Pinus palustris					
Pinus serotina					
Pinus taeda					
Pinus elliottii					
Total Density of all Pine species (mean x 31.8)					
Total Density of Longleaf and Pond Pines (mean x 31.8)					
			17. V_{LONGL}[1]:		
			18. V_{PINES}[2]:		

[1] V_{LONGL} (If longleaf and pond pine density is 75-300 stems/ha, then V_{LONGL} = 1.0; if longleaf and pond pine density < 75 stems/ha, then V_{LONGL} = density/75; if longleaf and pond pine density > 300 stems/ha, then V_{LONGL} = 1.0 - ((longleaf and pond pine density - 300)/300); if longleaf and pond pine density > 600 stems/ha, then V_{LONGL} = 0.0.

[2] V_{PINES} (If pine density 75-300 stems/ha, then V_{PINES} = 1.0; if pine density < 75 stems/ha, then V_{PINES} = density/75; if pine density > 300 stems/ha, then V_{PINES} = 1.0 - ((pine tree density - 300)/300); if pine density > 600 stems/ha, then V_{PINES} = 0.0.

Appendix B.9: Data Sheet 9.

Summary Workheet for Mineral Soil Wet Pine Flats

Assessment Team: ____________________

Project Name/Location: ____________________

Date: __________

WAA: __________

Note: All scores must be between 0.0 and 1.0

2. V_{INFLOW}	Inflow of water from an exogenous basin	☐
3. $V_{SURFFLOW}$	Surface flow (inhibited by a dam)	☐
4. $V_{OUTFLOW}$	Outflow (via drainage conveyance)	☐
5. $V_{STORAGE}$	Added (fill) or Excavated Material	☐
6. V_{ET}	Evapotranspiration Potential (from site history)	☐
14. V_{ET} BPS	Evapotranspiration Potential (from LAI)	☐
15. V_{ET} CPS	Evapotranspiration Potential (from LAI)	☐
9. V_{MICRO}	Microtopographic Alterations	☐
10. V_{PORE}	Soil Alterations	☐
7. V_{HERB}	Herbaceous Indicator Score (Bunchgrass/PS)	☐
8. V_{HERB}	Herbaceous Indicator Score (Cypress/PS)	☐
12. V_{NBG}	Cover of Selected Native Bunchgrasses	☐
13. V_{SEDGES}	Cover of *Carex, Scleria, Rhynchospora* spp.	☐
18. V_{PINES}	Pine Density	☐
11. V_{SUBC}	Subcanopy Density	☐
16. $V_{CYPRESS}$	Physiognomic Structure of pond cypress	☐
17. V_{LONGL}	Physiognomic Structure of longleaf and pond pine	☐
1. $V_{LANDSCP}$	Area of contiguous fire-maintained landscape	☐

F1: Maintain Characteristic Water Level Regime

$FCI_{HYDROLOGY}$ = The lowest score of the following 5 submodels (note: submodel # 5 need not be calculated if any indice for submodels 1-4 = 0.0) ☐

1. V_{INFLOW} ☐
2. $V_{SURFFLOW}$ ☐
3. $V_{OUTFLOW}$ ☐
4. $V_{STORAGE}$ ☐
5. $(V_{ET} \times ((V_{MICRO} + V_{PORE})/2))^{1/2}$ ☐

[Use either V_{ET} (# 6) or V_{ET} (# 14 or 15) in above equation]

F2: Maintain Characteristic Plant Community ☐

For Bunchgrass/Pine Savanna, FCI_{PLANTS} = the highest score of:

1. V_{HERB} (# 9) and ☐
2. V_{NBG} (# 11) ☐

For Cypress/Pine Savanna, FCI_{PLANTS} = the highest score of:

3. V_{HERB} (# 10) and ☐
4. V_{NBG} and ☐
5. $[V_{CYPRESS} \times ((V_{SEDGES} + V_{SUBC})/2)]^{1/2}$ ☐

For Switchcane/Pine Savanna, FCI_{PLANTS} =

6. $[V_{LONGL} \times ((V_{PINES} + V_{SUBC})/2)]^{1/2}$ ☐

F3: Maintain Characteristic Animal Community

$FCI_{ANIMALS} = [FCI_{PLANTS} \times V_{LANDSCP}]^{1/2}$ = ☐

F4: Maintain Characteristic Biogeochemical Processes

$FCI_{BIOGEOCHEM} = [FCI_{PLANTS} \times FCI_{HYDROLOGY}]^{1/2}$ = ☐

APPENDIX C

DATA SHEETS FOR WRAP

Appendix C.1: Data Sheet 1.

Wetland Rapid Assessment Procedure

(WRAP)

Check one: ☐ Existing Conditions ☑ ☐ Proposed Conditions

Application Number	Project Name	Date	Evaluator	Wetland Type

Land Use	FLUCCS Code	Description:	Wetland Acreage

Wildlife Utilization (WU)	Wetland Canopy (O/S)	Wetland Ground Cover (GC)

Field Hydrology (HYD)	WQ Input & Treatment (WQ)*

* The value of WQ is obtained by adding the TOTAL scores of Land use Category and Pretreatment category then dividing by 2

Habitat Support / Buffer

Buffer type	(Score) X	(% of area)	=Sub Totals
			TOTAL

Land use Category (LU)

Land use Category	(Score) X	(% of area)	=Sub Totals
		(LU) TOTAL	

Pretreatment Category (PT)

Pretreatment Category	(Score) X	(% of area)	=Sub Totals
		(PT) TOTAL	

WRAP Score

Field Notes:

Wildlife Utilization (WU)

Wetland Canopy (O/S)

Wetland Ground Cover (GC)

Habitat Support / Buffer

Field Hydrology (HYD)

WQ Input & Treatment (WQ)

Appendix C.2: Data Sheet 2.

Pine Savanna Habitat Assessment Variables

Wildlife Utilization

		Score
Existing Pine Savanna Exhibits No Evidence Of Target Wildlife		**0**
•	No evidence of utilization by target wildlife	
X	Existing wetland is heavily impacted	
X	No habitat for target wetland wildlife species	
Existing Pine Savanna Exhibits Minimal Evidence of Target Wildlife		**1**
X	Minimal evidence of utilization by target wildlife	
X	Wetland may be located in a residential, industrial, or commercial development with frequent human disturbance	
X	Sparse or limited adjacent upland food sources	
X	Little habitat for target wetland wildlife species	
Existing Pine Savanna Exhibits Moderate Evidence of Target Wildlife		**2**
X	Moderate evidence of utilization by target wetland wildlife	
X	Evidence of aquatic macroinvertebrates and/or amphibians	
X	Minimal evidence of human disturbance	
X	Adequate adjacent upland food sources	
X	Adequate protective cover (habitat) for target wetland wildlife species	
Existing Pine Savanna Exhibits Strong Evidence of Target Wildlife		**3**
X	Strong evidence of utilization by target wetland wildlife	
X	Abundant aquatic macroinvertebrates and/or amphibians present	
X	Negligible evidence of human disturbance	
X	Abundant adjacent upland food sources	
X	Excellent protective cover (habitat) for target wetland wildlife species	

The wildlife utilization variable is a measure of observations and signs (i.e. scat, tracks etc.) of target wildlife, primarily wetland dependent species. A list of target wildlife species is provided as Attachment A. This list may be expanded in the future as more information becomes available.

Appendix C.3: Data Sheet 3.

Pine Savanna Overstory/Shrub Canopy Strata

		Score
Closed Overstory/Shrub Canopy Strata		0
X	Percent areal cover of either tree/shrub stratum 75% or greater	
X	Heavy encroachment of upland/transitional tree/shrub species	
Moderate Closure Of The Overstory/Shrub Canopy Strata		1
X	Percent areal cover of either tree/shrub stratum 50% or greater but less than 75%	
X	Moderate natural recruitment of overstory tree/shrub species	
Minimal Closure Of The Overstory/Shrub Canopy Strata		2
X	Percent areal cover of both tree/shrub stratum 20% or greater but less than 50%	
X	Some natural recruitment of overstory tree/shrub species	
Open Overstory/Shrub Canopy Strata		3
X	Percent areal cover of both tree/shrub stratum between 0% and 20%	
X	Negligible natural recruitment of overstory tree/shrub species	

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Appendix C.4: Data Sheet 4.

Vegetative Ground Cover of Pine Savanna Species

		Score
Negligible Target Ground Cover Vegetation Present		**0**
X	Percent areal cover of target vegetation ≤10%	
X	Prominent woody vine stratum	
X	Target pine savanna herbaceous species rarely occurring	
X	Extreme natural recruitment of undesirable species	
Minimal ***Target Ground Cover Vegetation Present***		**1**
X	Percent areal cover of target vegetation <50% but greater than 10%	
X	Prominent woody vine stratum between 10% and 20%	
X	Minimal number of target herbaceous pine savanna species present	
Moderate Target Ground Cover Vegetation Present		**2**
X	Percent areal cover of target vegetation 50% or greater but <70%	
X	Prominent woody vine stratum ≤10%	
X	Moderate number of target herbaceous pine savanna species present	
Abundant Target Cover Vegetation Present		**3**
X	Percent areal cover of target vegetation 75% or greater	
X	No woody vine stratum	
X	Abundant number of target herbaceous pine savanna species present	

The vegetative ground cover variable is a measure of the presence, abundance, appropriateness and condition of ground cover vegetation within the wetland. A list of target herbaceous pine savanna species is provided as Attachment B. This list may be expanded in the future as more information becomes available.

Appendix C.5: Data Sheet 5.

Adjacent Upland/Wetland Buffer

Score

No Adjacent Upland/Wetland Buffer **0**

X Buffer is non-existent (i.e. development)

Adjacent Buffer Averages 30 Feet or Less, Containing Undesirable Plant Community **1**

X Less than 30 feet average width
X Provides some cover, food source, roosting
X Not connected to wildlife corridors
X Greater than 300 feet but has greater than 75% invasive or nuisance plant species

Adjacent Buffer Averages >30 Feet But <300 Feet, With a Predominantly Desirable Plant Community **2**

X >30 feet average width
X Contains desirable plant community provides cover, food source, & roosting
X Portions connected to contiguous offsite wildlife corridors
X Greater than 300 feet but has less than 75% nuisance/undesirable plant species

Adjacent Buffer Averages >300 Feet, With a Predominantly Desirable Plant Community **3**

X >300 feet wide average width
X Contains predominately desirable plant species that provide cover, food source, & roosting
X Connected to contiguous offsite wildlife corridors

Appendix C.6: Data Sheet 6.

Wetland Hydrology

Score

Hydrologic Regime Severely Altered **0**

X	Wetland hydrology severely altered
X	Hydroperiod inadequate to support wetland plant species for the target community
X	Strong evidence that upland plants are encroaching into the historical wetland area
	Significant die-off of target plant species due to an increased or decreased hydroperiod
X	In organic soils, there is substantial soil subsidence

Hydrologic Regime Inadequate to Maintain a Viable Wetland System **1**

X	Site hydroperiod inadequate to maintain the target wetland plant community
X	Succession of wetland plant species to transitional/upland plant species. Target vegetation stressed or dying from too much or too little water.
X	In organic soils, there is evidence of soil subsidence

***Hydrologic Regime Adequate to Maintain a Viable Wetland System*-External Features May Affect Wetland Hydrology** **2**

X	Wetland hydroperiod adequate, although conditions present which possibly interfere with or influence the hydroperiod (i.e. canals, ditches, swales, berms, etc...)
X	Target community healthy, although there may be some signs of improper hydrology.
X	In organic soils, there is little evidence of soil subsidence

Hydrologic Regime Adequate to Maintain a Viable Wetland System **3**

X	Target vegetation healthy, and exhibit no stress from an improper hydroperiod
X	Wetland not adjacent to external feature which could affect the hydroperiod
X	Wetland exhibits a natural hydroperiod
X	In organic soils, there is no evidence of soil subsidence

APPENDIX D

TABLES AND GRAPHS OF SITE INFORMATION

Appendix D.1: Characteristics Site Statistics for Reference Sites used in study.

Site Id	Area (Hectares)	Private	Government
1	24.2		✓
2	223.9		✓
3	53.5		✓
Total		0	3
Mean	100.5		
Min-Max	24.2-223.9		

Appendix D.2: Characteristic Site Statistics for Mitigation Sites used in study.

Site Id	Area (Hectares)	Age	Private	Government
4	4.9	6		✓
5	12	6		✓
6	0.6	5		✓
7	3.1	2	✓	
8	2.6	2	✓	
9	1.5	2	✓	
10	5.8	7	✓	
11	2.9	8		✓
12	2.2	8		✓
13	4.5	8		✓
14	24.1	8		✓
15	3.5	8		✓
16	4.2	8		✓
17	6.6	2	✓	
18	11.3	5		✓
19	9.9	5		✓
Total			5	11
Mean	6.2	5.6		
Min-max	0.6-24.1	2-8		

Appendix D.3: HGM Function and Composite Scores for Reference and Mitigation Sites Used in Study.

Site Id	Hydro	Plant	Animal	BioGeo	Composite
1	0.89	1	0.53	0.92	0.845
2	1	1	1	1	1
3	1	1	0.75	0.72	0.87
7	0.4	1	0.26	0.4	0.52
8	0	0.88	0.25	0	0.28
9	0.96	1	0.24	0.98	0.80
18	0	0.55	0.31	0	0.22
19	0	0.29	0.21	0	0.13
17	0.31	0.5	0.2	0.27	0.32
11	0	0.21	0.13	0	0.09
12	0	0	0	0	0
13	0	0.22	0.14	0	0.09
14	0.63	0.82	0.41	0.81	0.67
15	0	0.5	0.2	0	0.18
16	0	0.5	0.21	0	0.18
4	0	0.77	0.28	0	0.26
5	0	1	0.24	0	0.31
10	0	0.6	0.26	0	0.22
6	0.9	0.45	0.27	0.5	0.53

Hydro = Hydrology
Biogeo = Biogeochemical

Appendix D.4: WRAP data before being normalized for comparative analysis.

Site Id	WU	OS/SC	GC	Buff	Hydro	WQ	Overall
1	2.50	2.00	3.00	3.00	2.50	2.06	0.84
2	3.00	3.00	3.00	3.00	3.00	1.70	0.93
3	3.00	3.00	3.00	3.00	2.00	2.55	0.92
7	1.00	2.50	3.00	1.50	2.50	1.34	0.66
8	1.00	2.50	2.00	1.00	2.00	1.25	0.54
9	1.50	2.00	2.50	1.00	2.00	1.25	0.57
18	1.50	1.00	1.50	2.00	2.00	1.79	0.54
19	1.50	1.00	1.50	2.50	1.50	2.61	0.59
17	2.00	2.50	1.50	2.00	2.00	2.32	0.68
11	2.00	2.00	2.00	2.50	2.50	2.82	0.77
12	2.00	1.50	1.00	1.50	1.50	2.86	0.58
13	1.00	1.00	0.50	0.00	0.50	1.68	0.26
14	2.00	2.00	1.50	1.00	1.50	1.18	0.51
15	1.00	0.00	0.00	1.00	0.00	1.65	0.20
16	1.50	2.00	1.00	1.00	1.00	1.70	0.46
4	1.50	1.00	2.50	1.50	2.00	1.86	0.58
5	2.00	3.00	2.50	1.50	2.00	2.55	0.75
10	1.50	1.50	1.50	1.50	1.50	2.35	0.55
6	2.50	3.00	2.00	3.00	2.50	3.00	0.89

WU = Wildlife Utilization
OS/SC = Overstory and Shrub Coverage
GC = Ground Cover
Buff = Buffer
Hydro = Hydrology
WQ = Water Quality

Appendix D.5: WES Overall Scores for Reference and Mitigation Sites Used in Study.

Site Id	**WES Overall Scores**
1	0.57
2	0.64
3	0.86
7	0.81
8	0.62
9	0.73
18	0.30
19	0.21
17	0.5
11	0.52
12	0.45
13	0.52
14	0.61
15	0.34
16	0.48
4	0.55
5	0.63
10	0.49
6	0.70

Appendix D.6: HGM Data for repeatability.

Site Id	Hydro		Plant		Animal		Biogeo	
	T1	T2	T1	T2	T1	T2	T1	T2
1	1	0.89	1	1	0.62	0.53	1	0.92
2	1	1	1	1	1	1	1	1
3	1	1	1	1	0.75	0.75	1	0.72
8	0	0	0.94	0.88	0.26	0.25	0	0
18	0	0	0.63	0.55	0.32	0.31	0	0
19	0	0	0.50	0.29	0.27	0.21	0	0

T1 = Function Score for first visit
T2 = Function Score for second visit

Appendix D.7: WRAP Data for testing repeatability.

Site Id	WU		OS/SC		GC		Buff		Hydro	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
1	1	0.83	1	0.67	1	1	1	1	1	0.83
2	1	1	1	1	1	1	0.67	1	1	1
3	1	1	0.83	1	1	1	1	1	1	0.67
7	0.50	0.33	1	0.83	1	1	0	0.50	0.67	0.833
8	0.50	0.33	1	0.83	1	0.67	0	0.33	0.67	0.67
9	0.50	0.50	0.83	0.67	0.67	0.83	0.50	0.33	0.67	0.67
18	0.67	0.50	0.67	0.33	0.50	0.50	0.67	0.67	0.67	0.67
19	0.50	0.50	0.67	0.33	0.33	0.50	0.67	0.83	0.33	0.50

T1 = Function Score for first visit
T2 = Function Score for second visit

Appendix D.8: WES Data for testing repeatability.

Site Id	Overall	
	T1	T2
3	0.85	0.86
7	0.58	0.81
8	0.64	0.62
9	0.72	0.73
18	0.33	0.30
19	0.25	0.21

T1 = Function Score for first visit
T2 = Function Score for second visit

Appendix D.9: Summary of Statistical data for repeatability comparisons.

HGM Functions	Spearman	
	Rs	**p_s**
Hydro	0.95	0.004
Animal	0.94	0.005
Plant	1.0	
Biogeo	0.93	0.007
WRAP Functions	**Rs**	**p_s**
Wildlife Utilization	0.88	0.004
Overstory/Shrub	0.63	0.092
Ground Cover	0.83	0.010
Buffer	0.87	0.005
Hydrology	0.63	0.093
WES	**Rs**	**p_s**
Overall	0.83	0.042

Rs = Spearman Correlation Coefficient
p_s = confidence level

Appendix D.10: Summary of statistical tests in the Comparison of HGM and WRAP and WES with paired tests.

HGM/WRAP Functions	Spearman	
	Rs	**p_s**
Hydro	0.56	0.013
Animal	0.42	0.072
Plant	0.77	0.000
Overall	0.64	0.003
HGM/WES Overall	**Rs**	**p_s**
HGM/WES	0.80	0.000
WES/WRAP Overall	**Rs**	**p_s**
WES/WRAP	0.51	0.027

Appendix D.11: Characteristic statistics for the comparison data for functions and overall scores.

Method/Function	Mean	Median	Mode	Std. Deviation	Variance	Range
HGM/Hydro	0.32	0.00	0.00	0.42	0.18	1.0
HGM/Plant	0.65	0.60	1.00	0.32	0.10	1.0
HGM/Animal	0.31	0.25	0.20*	0.23	0.05	1.0
HGM/Overall	0.54	0.53	0.47	0.22	0.05	0.79
WRAP/Hydro	0.61	0.67	0.67	0.24	0.06	1.00
WRAP/Plant	0.62	0.67	0.50	0.29	0.09	1.00
WRAP/Animal	0.60	0.50	0.50	0.21	0.04	0.67
WRAP/Overall	0.62	0.58	0.58	0.20	0.04	0.73
WES/Overall	0.55	0.55	0.52	0.16	0.03	0.65

*indicates that more than one mode existed and the lowest is shown

Appendix D.12: Normality and homogeneity of variance for repeatability statistics.

Method	Type pf Value	Normality (K-S Test) Asymp Sig. (2-tailed)		Homogeneity of Variance (Levene's Test)
		Test 1	Test2	
WES-Overall	Normal	0.200*	0.200*	0.564
	Transformed	0.200*	0.200*	0.545
WRAP-WU	Normal	0.033	0.037	0.670
	Transformed	0.030	0.067	0.545
WRAP-OS	Normal	0.029	0.200*	0.157
	Transformed	0.032	0.200*	0.121
WRAP-GC	Normal	0.001	0.036	0.424
	Transformed	0.002	0.042	0.407
WRAP-Buffer	Normal	0.200*	0.200*	0.600
	Transformed	0.111	0.200*	0.337
WRAP-Hydro	Normal	0.120	0.066	0.218
	Transformed	0.104	0.092	0.269
WRAP-Overall	Normal	0.046	0.176	0.904
	Transformed	0.062	0.189	0.961
HGM-Hydro	Normal	0.056	0.057	0.290
	Transformed	0.056	0.056	0.290
HGM-Plant	Normal	0.037	0.128	0.395
	Transformed	0.029	0.088	0.330
HGM-Anml	Normal	0.200*	0.200*	0.984
	Transformed	0.200*	0.200*	0.981
HGM-Biogeo	Normal	0.056	0.063	0.138
	Transformed	0.056	0.060	0.144
HGM-Overall	Normal	0.133	0.200*	0.882
	Transformed	0.117	0.171	0.915

* This is the lower bound of true significance.

Appendix D.13: Normality for comparison statistics.

Method	Type of Value	Normality (K-S Test) Asymp Sig. (2-tailed)
WES-Overall	Normal Transformed	0.200* 0.200*
WRAP-WU (Animal)	Normal Transformed	0.040 0.077
WRAP-GC (Plant)	Normal Transformed	0.200* 0.197
WRAP-Hydro	Normal Transformed	0.007 0.002
WRAP-Overall	Normal Transformed	0.200* 0.200*
HGM-Hydro	Normal Transformed	0.000 0.000
HGM-Plant	Normal Transformed	0.113 0.200*
HGM-Animal	Normal Transformed	0.000 0.001
HGM-Overall	Normal Transformed	0.200* 0.200*

* This is the lower bound of true significance.

Appendix D.14: Homogeneity of variance for comparison statistics.

Category	Type of Test	Homogeneity of Variance (Levene's Test)*
Hydrology**	Normal Transformed	0.001 0.000
Plant**	Normal Transformed	0.437 0.565
Animal**	Normal Transformed	0.665 0.950
Overall***	Normal	0.514
	Transformed	0.559

* Significances are based on Levene's test to compare means
** Hydrology, Plant, and Animal are based on comparisons between WRAP and HGM.
***Overall is based on comparisons between WRAP, HGM, and WES.