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EVALUATING CREATED WETLANDS THROUGH COMPARISONS WITH NATURAL WETLANDS

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16. ABSTRACT

This report summarizes the evaluation and recommendations regarding an approach to wetland sampling and characterization developed by the Wetlands Research Program (WRP) at U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. Between trials, team members discussed at length the methodology and field protocols and modified them to reflect the conditions and difficulties encountered in sampling herbaceous wetlands in urban areas of Florida. Major emphasis is placed on the appropriateness of measured variables for determining successful wetland re-creation.

Numerous physical and biological parameters were measured and compared in the nine created and nine natural wetlands. Analysis of these data has shown some important similarities and differences between created and natural wetlands and lends insight into the complex questions surrounding wetland creation and the equivalency of created wetlands to naturally occurring wetlands. Evaluations of temporal changes in hydrology and plant successional trends within created wetlands seem most important in determining ultimate success.

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ABSTRACT

This report describes a pilot study that is part of a continuing series of wetlands studies conducted in cooperation with the Wetlands Research Program at the United States Environmental Protection Agency (USEPA) Environmental Research Laboratory, Corvallis, Oregon, (ERL-C). To date, these studies have been conducted in Connecticut, Florida, and Oregon. In the summer of 1988, field crews from the University of Florida Center For Wetlands in Gainesville spent ten days (two separate field trials with over one month between the first five day period and the second five day period) sampling 18 herbaceous wetlands (nine created and nine natural) in northern Hillsborough County, near Tampa, Florida. This report summarizes their evaluation and recommendations regarding an approach to wetland sampling and characterization developed by the Wetlands Research Program at ERL-C. Between trials, team members discussed at length the methodology and field protocols and modified them to reflect the conditions and difficulties encountered in sampling herbaceous wetlands in urban areas of Florida. Major emphasis is placed on the appropriateness of measured variables for determining successful wetland re-creation.

Numerous physical and biological parameters were measured and compared in the nine created and nine natural wetlands. Analysis of these data has shown some important similarities and differences between created and natural wetlands and lends insight into the complex questions surrounding wetland creation and the equivalency of created wetlands to naturally occurring wetlands. Evaluations of temporal changes in hydrology and plant successional trends within created wetlands seem most important in determining ultimate success.

INTRODUCTION

Under Section 404 of the Clean Water Act, it may be required that wetlands be replaced if they are degraded or destroyed. Increasingly, federal, state, and local permitting agencies have been requiring compensatory mitigation through creation of wetlands on another portion of the development site. The practice of creating a wetland to replace a natural wetland is appropriate only if the created wetland will be equivalent to, or of higher quality than, the wetland that is destroyed in terms of size, hydrology, water quality, and life support functions. Therein lies an important concern: How best to determine successful wetland creation.

In Florida, experience has shown that controversy over the potential success of wetland creation most often occurred, and resulted from concern over equivalency, during the permitting process. Frequently, especially where forested wetlands were involved, created wetlands did not resemble their naturally occurring counterparts in the initial years after creation (Clewell and Lea 1990). Even created, herbaceous wetlands, which were quicker to revegetate, often had different species than naturally occurring wetlands (Brown and Tighe 1990). Clearly, evaluative procedures are needed to measure success and to eliminate some of the uncertainty concerning the efficacy of creating wetlands as mitigation for encroachment or loss of wetlands due to development activities.

In this study, an approach for evaluating created wetlands initially developed by the U.S. EPA's Corvallis Environmental Research Laboratory (EPA ERL-C), Wetland Research Program was tested and refined (see companion document, QA Project Plan for Florida Wetlands Study). In the process of testing the methodology, numerous physical and biological parameters were measured in both created and natural wetlands. Analysis of these data has shown some important similarities and differences between created and natural wetlands and lends insight into the complex questions surrounding wetland creation and the equivalency of created wetlands to natural wetlands. Results from this and similar studies across the country can be used to help decision makers design new regulatory strategies for protecting the Nation's remaining wetlands.

PLAN OF STUDY

As part of a series of studies begun by the EPA ERL-C, the Florida tests were conducted during the summer of 1988. Early on, it was determined that comparisons of populations of created and natural wetlands offered the best potential to evaluate the success of wetland creation on a regional basis. Much emphasis, therefore, had to be given to the process of selecting natural wetlands as well as data collection.

Because of Florida's diverse climatic and geomorphologic character, the sites were chosen within a relatively small, homogeneous ecoregion. The area around Tampa, Florida, which includes Hillsborough County, was selected primarily because accurate records of species planted, year of planting, site conditions, and follow-up site visits were kept by the county's Environmental Protection Commission (EPC) on all created wetland projects required over the past six years. Detailed construction plans for the created wetlands were often omitted from the permit records, so no attempt was made to compare the current wetland condition with the proposed wetland. The northern part of the county had more created wetlands because of the outward expansion of the Tampa urban area, so it was chosen as the study region.

Created wetlands chosen for the study met criteria of: size (less than or equal to one hectare); type (herbaceous vegetation); age (at least one year); and maintenance (the less maintenance performed since creation of the site, the more desirable the site). Natural, herbaceous wetlands that were used as reference wetlands occur most often as isolated, fully vegetated communities throughout this ecoregion. Therefore, isolated, fully vegetated marshes were the most desirable created sites to make relevant comparisons between natural and created wetlands. Location of wetlands in an urbanized setting and accessibility were additional selection criteria. Although access to use the created wetlands as study sites was granted for all systems chosen, there was some reluctance on the part of landowners to grant access to natural wetlands. This resulted in the inclusion of a clause in letters requesting site access guaranteeing that landowner's names or site locations would not be used in any reports or publications. Therefore, only general maps of the study area are presented and the wetlands are referred to by number. Figure 1 shows the locations of wetlands from which the created study sites were chosen.

Several physical and biological parameters were measured in nine created and nine natural, herbaceous wetlands and comparisons were made of the characteristics of the two populations. Comparison with natural wetlands seemed the most relevant way of evaluating created wetland success for several reasons: (a) most qualitative evaluations by agencies, and the public in general, involve some comparison with an "ideal" or average wetland; (b) quantitative evaluation requires that some standard or natural characteristics be used for comparison (characteristics of natural wetlands were used because specific goals for created wetland projects were not given); and (c) permit conditions for the creation of wetlands usually

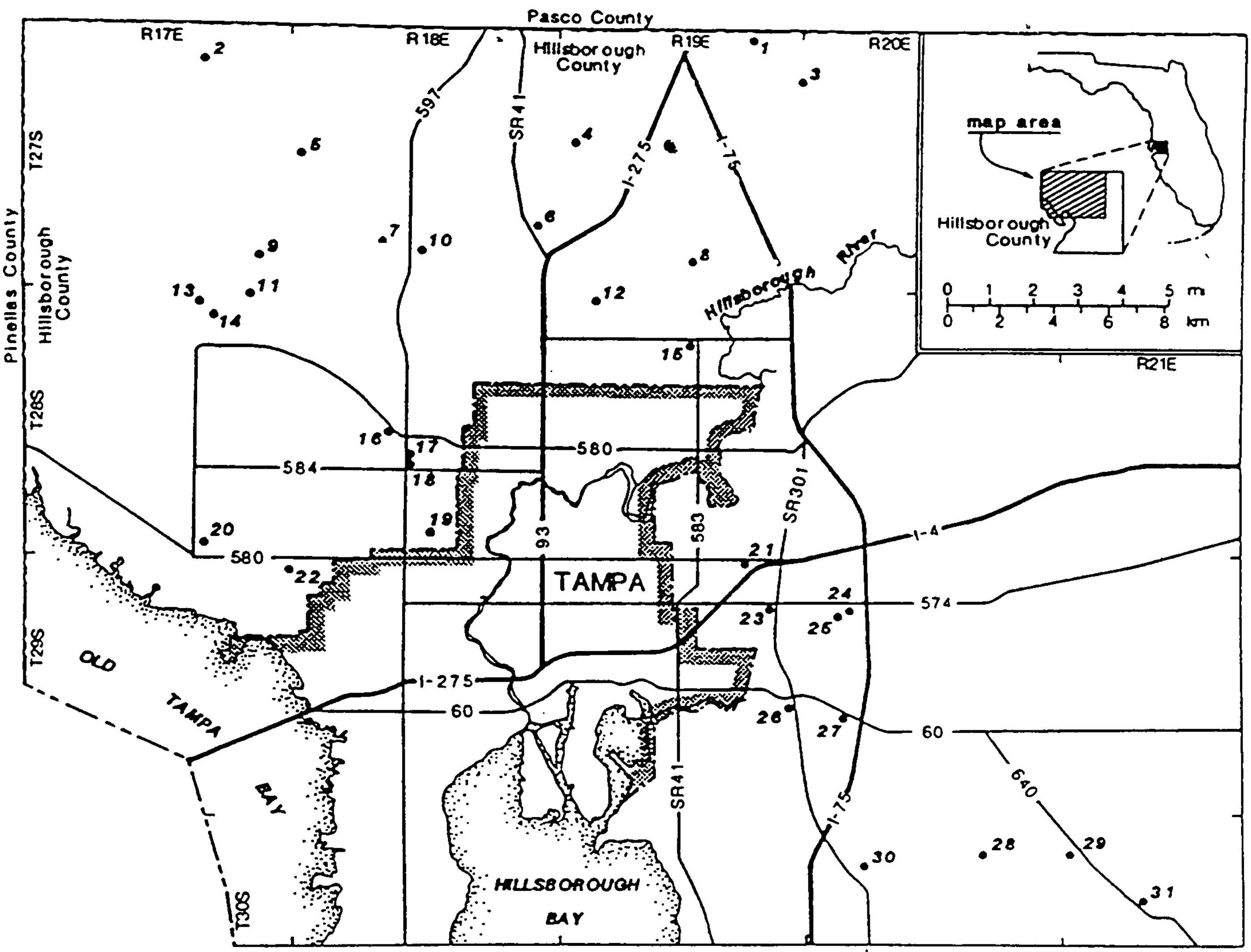

FIGURE 1. Map of Tampa and the surrounding area in Hillsborough County showing locations of created wetlands considered as study sites.

require planting of species that occur in wetlands of the type that is being replaced, and often require that created wetlands match specific wetland species composition.

In this study, comparisons were made between the two populations of wetlands (created and natural) as a means of addressing the overall success or equivalency question of wetlands creation rather than the success of an individual created wetland. It was not the intent of the study to evaluate any particular wetland, but instead, to test a methodology by which individual wetlands could be evaluated in the future, once an adequate data base on both created and natural wetlands exists. This latter point is most important if evaluation is to be meaningful, since the variation in vegetation and physical attributes between wetlands often makes one-on-one comparisons inappropriate.

The field protocol was designed with two overriding concerns. First, it had to be quick and economical. The field measurements had to be taken in a relatively short period of time, by a small number of technicians and biologists. This meant that seasonal or annual monitoring schemes were not feasible. Second, the protocol for field measurements had to minimize damage to the wetland that might result from sampling or trampling.

Identical field measurements were made in both created and natural wetlands. Both biotic and abiotic variables were measured within each wetland reflecting the importance of biological success in the short run, and physical equivalence that, in the long run, would ensure continued success of the created wetland. The variables measured were: vegetation composition, soil organic matter, water depth, water quality (basic nutrients and common metals), and site topography. In addition, qualitative assessments of the surrounding landscape were noted and a photo record of the site and surroundings was made.

A word of caution here. The evaluation of a created wetland by sampling various parameters and comparing the values obtained with those of natural wetlands is subject to two major drawbacks. First, the sampling of a created wetland "catches" the system at one point in time, often after a relatively short time interval since creation, and compares it to wetlands that have existed over a much greater period of time. Second, the timing of the "snap shot", both in relation to the season and the time since creation, has a significant impact on the utility of the data collected as an indicator of successful creation.

To overcome seasonal variation, sampling should be conducted during the mid-to-late growing season (in this case, sampling was conducted during late May and early July). To overcome variation resulting from time since creation, the evaluation of created wetlands may need to be postponed until several growing seasons have passed, reducing the likelihood of significant changes in species composition or zonation. Our experience with created wetlands in the phosphate district of central Florida suggests that a period of approximately three years (depending on site treatment and existing conditions) is sufficient to eliminate early successional variation in species composition and zonation. Balance must be achieved between the need for early evaluation and waiting for the system to develop floristic equilibrium.

With the increased use of evaluative monitoring and greater experience in creating wetlands, the appropriate time interval between creation and evaluation may be more accurately determined. It may be necessary and productive to sample at different times for different parameters. For instance, hydrology might be sampled in the first year after creation to determine early on whether the created wetland has appropriate hydrologic characteristics, while vegetation might better be sampled later.

METHODS

Eighteen herbaceous wetlands (nine created, nine natural) were chosen for comparison to test a methodology for evaluating created wetlands. Field and data analysis protocols were developed and tested earlier at EPA ERL-C (see companion document, QA Project Plan for Florida Wetlands Study). Suggestions for modification of the protocols were made prior to and after field tests and data analysis in Florida. The methods given here are those used in the Florida Pilot Study. Sample sizes were limited in this study as it was one of several pilot studies to develop methods for evaluation of created wetlands. Following further refinement and testing of the evaluation techniques, full-scale regional studies of created wetlands will be initiated by the EPA ERL-C Wetlands Research Program.

SITE SELECTION

The studies were conducted in herbaceous wetlands less than or equal to one hectare in size to coincide with previous work on the evaluation technique done in Oregon. Criteria and a method for selection of created and natural wetlands were given in a previous paper by Brown et al. as yet unpublished. Therefore, a general overview of the selection process follows:

1. Created wetlands were selected from a data bank of the Hillsborough County, Florida, Environmental Protection Commission (EPC). All candidate wetlands within the ecoregion were selected, randomly numbered, and visited in numerical order. The first nine sites visited that met the selection criteria were chosen. Since the sites were still in the active files of the EPC, permission to gain access to the sites was easily obtained from the landowners.

2. Natural wetlands were selected to represent as wide a variety of environmental settings within the same ecoregion as possible. A method of ranking the intensity of urbanization surrounding a wetland (its environmental setting) was developed and used as a primary selection criteria. The method, called the Landscape Development Intensity Index (LDI Index), scaled the intensity of development from 1 (completely natural), to 10 (completely urbanized). Permission to access natural wetlands on private lands proved to be difficult and selection ultimately favored access over environmental setting.

Permission to access sites was obtained for only two of the originally selected natural sites. The selection methodology was further refined to first select natural wetlands based on access and then to classify them according to their LDI index. The remaining seven natural wetlands were located on public lands. It was necessary to limit the candidate wetlands to those on public lands because of the limited amount of time and the lack of success in obtaining access from private landowners.

FIELD PROTOCOL

Of primary concern during the field trials was the potential for trampling of vegetation in both created and natural wetlands as a result of the number of crew members and the number of times that they were required to enter the wetland. Every step of the evaluation protocol was examined in light of this very important consideration, and whenever possible the number of trips and number of individuals entering the wetland were minimized. Many suggested changes to the field protocol resulted in decreasing the potential for trampling. For example, although the number of field crew members was increased, trampling was decreased by reducing the number of times each person entered the wetland to one.

FIELD CREW COMPOSITION

Based on review of ERL-C documentation and training, the original field protocol calling for a six member work crew divided into three teams (two vegetation teams and a survey team, each composed of two members) was modified to a seven-member work crew divided into three teams (two vegetation teams composed of a botanist and a recorder and a survey team of three members). In the Florida study, the addition of two alternates to the field crew was proposed as insurance that the field work be completed within the time allotted, and the project manager was added to observe the field team in action for later evaluations of the methodology, including the time needed to perform the tasks.

On the first day of field trials, it was found that adding one permanent member to the two member survey team expedited the completion of the tasks. One of the original alternates became the third member of the team. Based on this change to the survey team protocol, one of the team members drew the map, recorded general site information, and took photographs while the other two members collected morphological data. Soil samples were taken following completion of these tasks, by any two of the three survey team members, while the third person checked and finalized data sheets.

The remaining alternate collected water samples from several sites on a given day during the required sampling time. Since two or three sites were sampled during any given field day, and water samples were to be collected during a relatively short period at mid-day, the additional person was necessary to adhere to the quality assurance plan for water samples.

Budget constraints and travel distance to the wetland sites required that the field work be completed in two, five-day periods. Since the sites were three hours from Gainesville, the field team stayed in Hillsborough County during each field sampling period. In addition, the fieldwork had to be completed within a relatively short seasonal window to insure that seasonal changes in species composition did not bias the data.

FIELD MEASUREMENTS

Field measurements were made along transects that crossed the wetlands at right angles. Parameters measured included: plant population structure, site morphology, water depths, soil organic matter, and water quality (nutrients and metals). The vegetation teams quantitatively determined vegetation characteristics. The survey team measured site morphology and water depth, and collected soil and water samples. In addition, they characterized surrounding site conditions and obtained a complete photographic record of the site. The field data collection took place in the summer of 1988 and was organized into two separate field excursions of 5 days each separated by four weeks. After the first round of data collection, the field team evaluated the field protocol and suggested further modifications for the second round of field data collection. Wetlands 101-110 were evaluated during the first week of field sampling and numbers 201-208 were evaluated during the second week.

TRANSECT ESTABLISHMENT

All parameters were sampled along transects at regular intervals. Since many wetlands exhibit zonation that results from varying hydroperiods, transects crossing the wetland and perpendicular to each other were established to capture community level variation in measured parameters.

Figure 2 illustrates how transects were established. In general, two transects were established on each wetland at right angles to each other. Where the wetland was long and narrow (length greater than twice the width) three transects were established, one lengthwise and two crossing the long transect at right angles. Since both vegetation and basin morphology were to be measured along the same transects, transect layout was designed to capture variation in both features. As a consequence transect establishment in some instances favored locations that ensured greatest topographic variation. Under most conditions this layout also resulted in "capturing" greatest detail in vegetative zonation and variation since basin morphology determines hydroperiod and, as a consequence, spatial manifestations of plant community structure.

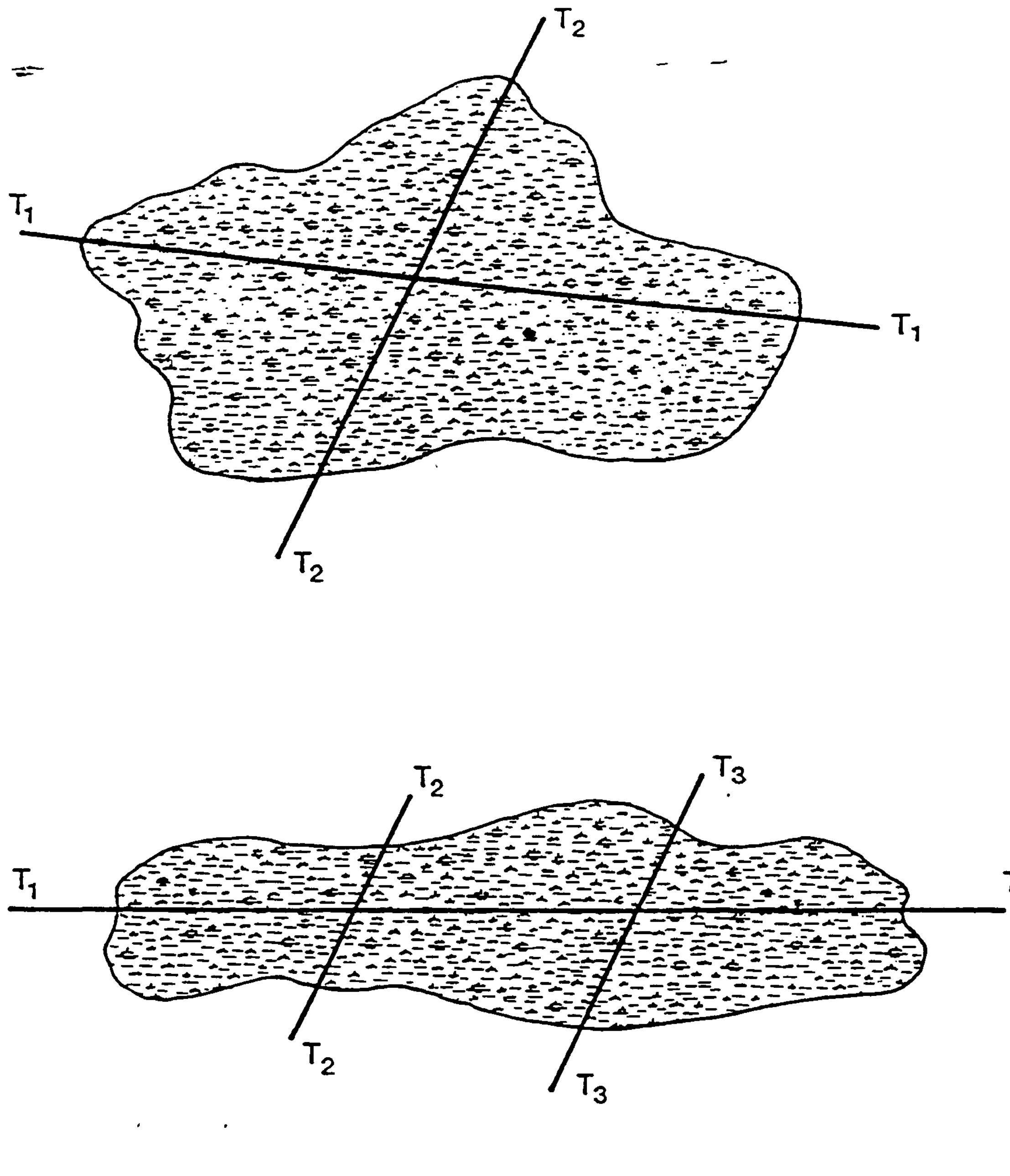

FIGURE 2. General layout of transects in natural and created wetlands. Both morphology and vegetation data were collected from a total of 40 quadrats spaced equally along the transects.

Natural, isolated wetlands in the Florida landscape are generally regular in shape, and are usually circular, or very nearly so. Our experience indicates that created wetlands are also generally regular in shape, although several shapes are common, ranging from circular to square or rectangular. Both systems tend to have relatively regular morphology. From these considerations, and the above discussion, it was concluded that most small, isolated wetland systems in Florida--both natural and manmade--can be adequately described using only two transects, these being measured for both morphology and vegetation. However, special or unusual circumstances may require additional transects.

As stated earlier, trampling of vegetation was of paramount concern. Transect establishment and subsequent measurement of variables was designed to minimize the number of people and trips through each wetland. Once the transect locations were determined, the ends of each transect were located 10 meters upland of the wetland edge and marked with three-meter PVC poles and an appropriate number of flags to denote transect number. The length of each transect was estimated and spacing of sample plots calculated so that there were at least 40 plots per site spaced equally along the transects beginning at the wetland edge. Based on the vegetation present and the State of Florida Wetland Plant List[1], the botanists established the wetland edge by common agreement.

To minimize the number of wetland crossings by field personnel, measuring tapes were laid along the length of the transect as the plots were located and vegetation measurements were made. The tapes were left in place for all subsequent measurements, and removed by the last team through the wetland after all the data had been collected.

VEGETATION MEASUREMENTS

The composition of the vegetation team remained the same in the Florida study as recommended by ERL-C: two teams with a botanist and a recorder on each team. Some changes were made in the field methodology, however. Vegetation sampling basically consisted of three parts: identification and collection of species, use of a modified Pielou Technique (Pielou 1986), and estimation of cover. The Pielou Technique called for vegetation sampling to be based on "k" number of species, "k" being the number of species to be sampled in a plot. It was to be determined before field work began and was to be constant for all study sites. This value was to be based on a pre-sampling study in wetlands similar to those to be sampled in the actual study with the value of R large enough to sample the common species on sites. The protocol was changed by eliminating the use of "k" number of species in favor of determining commonness based on specified time intervals as discussed below. The reason for this being, herbaceous wetlands in Florida vary from those dominated by only one or two species to those with dozens of different species. We felt that commonness was not related to a pre-determined

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[1]Fla. Admin. Code. Ch. 17-312 (July 1989).

number of species, but rather to the number of species that could be readily observed within a specified interval.

Nondestructive sampling was used to characterize the vegetative community structure. Rectangular sampling frames (1-m^2 quadrat frames), made of PVC pipe, were used to estimate percent cover and "commonness" by species. A total of 40 1-m^2 sample plots (quadrats) were established at equally spaced intervals along the transects. Spacing between quadrats varied from two meters on the smallest sites, to five meters on the larger sites.

Estimating Commonness

Relative commonness or rarity of the vegetation species at each site was determined using the modified Pielou method. In the modified technique, the botanist identified species that were seen within given time intervals, and the recorder assigned a numeric value to each time interval. Specifically, species observed in the first 15 seconds were most common and given a value of 3. Those observed in the next 15 seconds (15 - 30 seconds) were less common, and given a value of 2. Those observed in the next 30 seconds (30 - 60 seconds) were uncommon and given a value of 1. Finally, those species that were not observed in the first minute, were rare, and given a value of 0.

Estimating Percent Cover

Cover was estimated using grid marks along the edges of the quadrat frame. The botanist estimated the percent of the quadrat that was covered by all vegetative structures of each identified species. Because of stratification of species perpendicular to the ground surface, total percent cover estimates often were greater than 100% within a given quadrat.

We suggest that estimation of percent cover be done for differing vegetation strata, starting with ground cover. Strata might be as follows: 0 to 5 cm above ground, 6 cm to 50 cm, and greater than 50 cm. In this way some additional information is gained with the data set, and one avoids the problem of having greater than 100% cover on any single plot. However, during these field trials we did not alter the protocol to deal with percent cover in this manner.

VEGETATION CHARACTERISTICS

Using a technique suggested by Wentworth et al. (1988), a wetland weighted average score (hereafter referred to as WA score) was calculated for each wetland. The technique uses the NWI species categories (Reed, 1988), and assigns an ecological index from 1 to 5 as follows: obligate wetland = 1, facultative wetland = 2, facultative = 3, facultative upland = 4, and obligate upland = 5. Wetland weighted average scores were calculated with the following formula:

$$\text{Wetland WA Score} = \frac{\sum_0^s (C_i \times E_i)}{\sum C_i}$$

Where: C_i = Percent Cover of Species i
E_i = Ecological index of species i
s = Number of species in the wetland

Calculated wetland WAs range from 1 (extreme wetland, 100% obligate wetland plants) to 5 (extreme upland, 100% obligate upland species).

SOIL SAMPLES

Two soil samples (5-cm and 30-cm depths) were taken from every fourth quadrat using an 8.25-cm (3.25-inch) open-sided bucket soil auger. Munsell color was recorded and odor subjectively determined at the vehicle and in the field, respectively. Samples were iced for later determination of organic matter content by ignition.

The determination of soil organic matter in a variety of created wetlands over a wide range of conditions is a valuable data set for comparative purposes. As the data on created wetlands builds, comparisons can be made between newly sampled wetlands and the data from all created wetlands. The value of soil organic matter data may lie more with the ability to compare between created wetlands of various ages, rather than between created and natural wetlands.

WATER QUALITY SAMPLES

Sample collection for measurement of water quality was generally undertaken as prescribed by ERL-C methodology. Two minor changes resulted from previous experience. First, sample bottles were prefixed at the laboratory selected to do the water quality analysis, and second, samples were collected from several wetlands by an alternate field crew member during the required time period each day.

Where there was surface water, water samples were collected at each wetland in prefixed 250-ml sample containers and iced for laboratory analysis. Two water samples, one each at the inlet and outlet were collected in wetlands with flowing water. In isolated or "stagnant" wetlands with no flowing water, one sample was collected. Laboratory analysis using standard procedures was performed for the following constituents: Total Suspended Solids (TSS), Total Phosphorous (TP), Total Kjeldahl Nitrogen (TKN), Total Organic Carbon (TOC), Lead (Pb), Cadmium (Cd), and Aluminum (Al).

The collection of a grab sample does not allow for much inference related to long-term water chemistry, but may give some indication of gross abnormality. Comparison of water quality between a created wetland and other wetlands (both created and natural) that indicates serious departure from normal ranges may be important information that would suggest a need for closer monitoring, resampling, or reevaluation at a later date.

SITE MORPHOLOGY AND WATER DEPTHS

Site morphology was determined by measuring topographic relief across each wetland along the transects. Topography was measured using a contractor's level and stadia rod to determine ground elevations in each vegetation quadrat. Where relief warranted (i.e., where slope changed abruptly), more frequent measurements of ground surface elevation were made to adequately capture topographic relief.

At each wetland, a benchmark was established and all elevations were recorded relative to the benchmark. Later, elevations were converted and expressed relative to the wetland edge.

When surface water was encountered, elevation was measured and surface water depth was calculated for each quadrat by subtracting ground surface elevation from the water surface elevation. On sites with no surface water, depth to groundwater was measured in each of the holes augered for soil samples.

The "snap shot" of water levels obtained on sampling day, when combined with basin morphology, begins to give some approximations of potential water depths. While it cannot be used effectively to predict long-term hydrology, the one-time measurement does serve to characterize the physical environment of the wetland on sampling day. It is relatively easy to acquire water level measurements during the sampling effort and, based on the importance of adequately characterizing the wetland, water levels should be measured.

Depths of water and periods of inundation are probably the most critical factors in determining wetland creation success. However, for hydrologic data to be of use in determination of hydroperiods, it must be measured over long periods of time. A minimum of one year is necessary, and preferably, measurements over a drought-flood cycle should be obtained. Recently, in some parts of Florida there has been a move toward requiring creation of mitigation sites prior to destruction of the original wetlands. Under these circumstances, it seems quite appropriate to require continuous hydrologic monitoring to determine if proper hydroperiods have been established.

DATA ANALYSIS

Data analysis was performed using the Statistical Analysis System (SAS) on data sets created using dBase III. Data were double entered and anomalies between sets rectified until both data sets agreed. Numerous indices were calculated for each wetland and means compared between created and natural wetlands.

Comparisons were made between the population of created wetlands and the population of natural wetlands rather than on a wetland-by-wetland basis, since the objectives of this study were not to determine whether any individual wetland was successful, but rather to suggest and test various measures and indices of wetland structure and organization using indices of similarity and to determine the range of possibilities for successful wetland creation projects based on natural variability. In actual practice, once a sufficient data base on both created and natural wetlands exists, evaluations on a wetland-by-wetland basis could be conducted using indices of similarity.

PHYSICAL CHARACTERISTICS

The physical characteristics of natural and created wetlands that were compared included: surrounding landscape condition, wetland basin topography (depth, slope and roughness), water depths, percent open water, and soil organic matter.

Surrounding Landscape Condition

An index of Landscape Development Intensity (LDI) was calculated for each wetland to evaluate environmental setting. In brief, the index was calculated using the percent cover by urban, agricultural, and natural lands in an area of 0.68 km^2 surrounding each wetland. Aerial photographs were used to estimate percent cover of each land use type. In addition, ground-based, qualitative observations of the "condition" of the surrounding lands were noted during the field data collection.

Basin Topography

Figure 3 illustrates a typical wetland basin cross section divided into three segments: two edge slopes and a bottom basin. The boundary between edge slope and bottom basin was determined visually using cross sections of each wetland. Average slope of the edge slope area was calculated using the difference in elevation between the wetland edge and the elevation of the edge slope/bottom basin boundary divided by the distance between these two points and expressed as a percent.

Average wetland depth was calculated as the average of elevation readings of the bottom basin on each transect relative to the wetland edge.

Roughness was determined using only the elevations of the bottom basin and was calculated as the variance about the mean elevation of the bottom basin.

Water Depth

Average water depth was calculated from the depths measured on the day of sampling. Field measurements were conducted during the wet season and while observed water levels were not an indication of long-term levels or seasonal fluctuation, they did provide a comparative indication of hydrology. In addition to average water depth calculated as the average of only those stations that had standing water, a weighted water depth was calculated by multiplying average water depth by the percent area of the wetland that was inundated.

Percent Open Water

Percent open water was determined by subtracting vegetation percent cover from 100% within each quadrat of the wetland, summing the total and dividing by the number of quadrats.

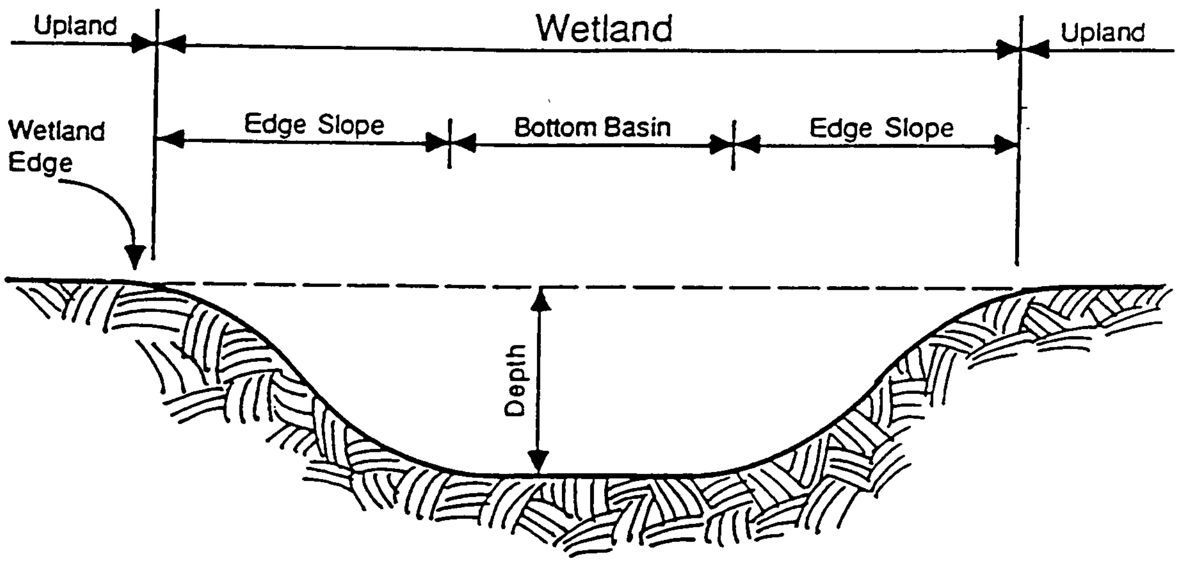

FIGURE 3. Typical cross section of a wetland illustrating the boundaries between upland and wetland edge, and edge slope and bottom basin.

Soil Organic Matter

Soil samples collected at 5-cm and 30-cm depths at every fourth vegetation plot were oven dried to 0% moisture content, weighed and then fired at 550° F for 30 minutes. Organic matter content as percent of total was calculated as the difference between weights before and after ignition divided by the pre-ignition weight and multiplied by 100.

FIELD DATA COLLECTION

Field data were collected by a seven-member work crew divided into three teams as described in the section on field crew composition. The vegetation team established transects, quadrat spacing and collected both percent cover and plant species commonness data. The survey team measured topography, assessed surrounding environmental conditions, took photographs, collected soil and water samples, and mapped the wetland.

The length of time spent at each site was recorded by task and is summarized in Figure 4. In the top portion of Figure 4, a flow diagram for each of the field teams is given. The length of time given for each task in the bottom diagram of Figure 4 is somewhat generalized and is based on the average time spent at each task. Field data collection in created wetlands was more time consuming than in the natural sites. The average total length of time at created sites was 3.8 hours, while the time spent at natural sites was about 2.6 hours. Total person hours averaged 26.6 and 18.2 at each site for created and natural wetlands, respectively.

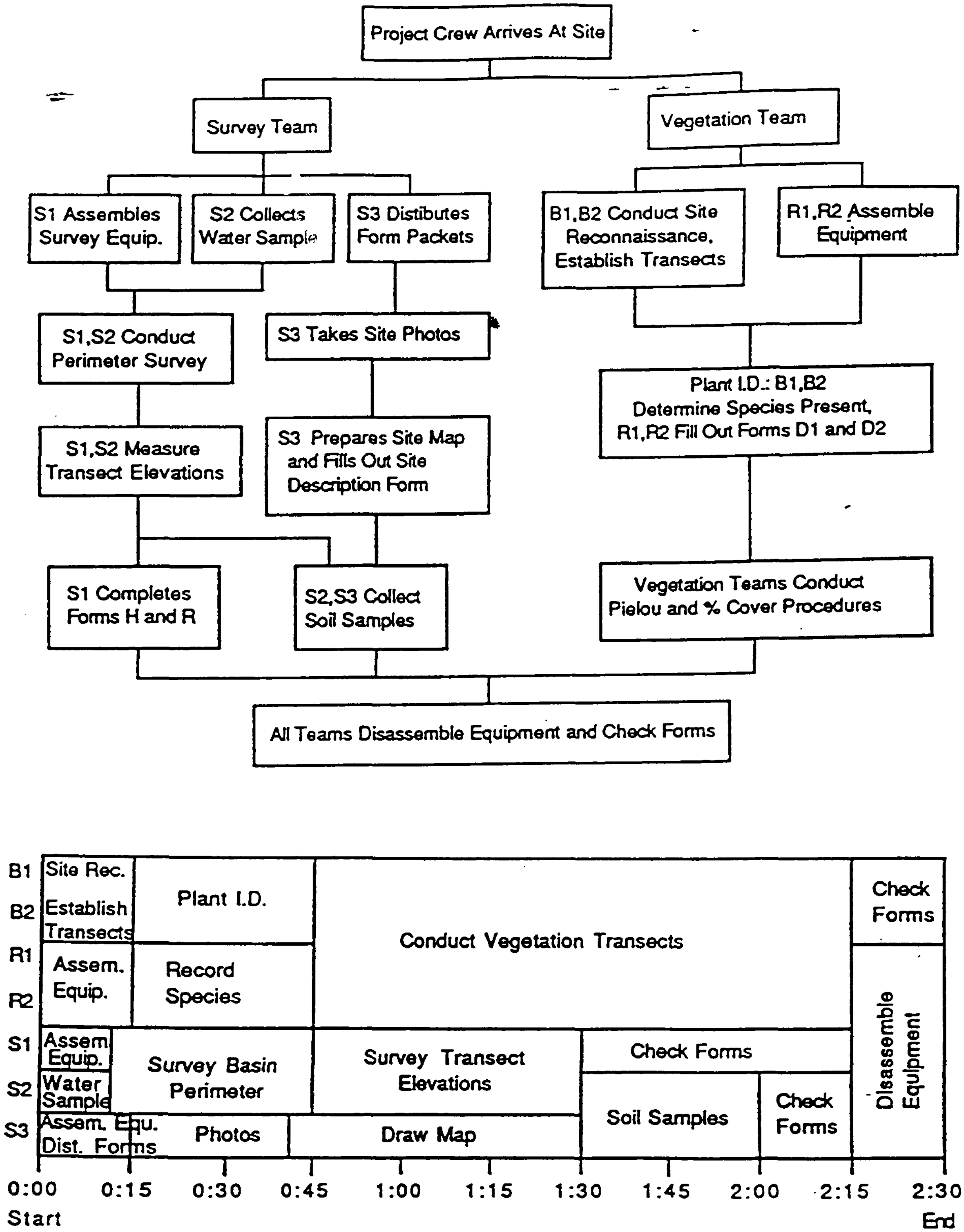

FIGURE 4. Major work tasks of field crew (top) and average time spent on each task (bottom) during the field data collection in natural and created wetlands.

RESULTS

PHYSICAL CHARACTERISTICS

Created wetlands ranged in age from 1 to 8 years with the majority 3 years of age (Table 1). Age was taken from permit records and corresponds to the number of growing seasons since site construction was completed.

Several characteristics that are related to basin morphology as well as percent open water and organic matter in soils of natural and created wetlands are given in Table 1. Maximum depth (the deepest point measured from the wetland/upland edge) in natural wetlands ranged from 0.46 to 1.58 m and mean depths ranged from 0.13 to 1.10 m. Created wetlands, on the whole, had a similar range of maximum depths (0.33 to 1.66 m) but a larger portion of the created wetlands exceeded 1 m in depth. Created wetlands also had greater mean depths, ranging from 0.36 to 1.33 m.

Roughness and edge slope are measures of basin morphology that may have a large influence on long-term vegetative community structure. Roughness, a measure of micro-topographic relief was defined as the variance of the measurements of ground surface elevation around the mean ground surface elevation of the bottom basin. Roughness varied in natural wetlands from a low of 0.069 to a high of 0.723, and from 0.152 to 0.897 in created wetlands. Edge slopes were greater in created wetlands (varying from 3.31% to 17.70%) than in natural sites (from 1.41% to 5.92%).

Percent open water was evaluated to determine differences in overall percent cover for natural and created wetlands. The variation in percent open water for natural and created wetlands was 0.00% to 2.5% and 0.51% to 3.03%, respectively, suggesting little difference between the two populations.

The last two columns in Table 1 give the mean percent organic matter in soil samples obtained at 5-cm and 30-cm depths for each wetland. The 5-cm sample from natural wetlands had percent organic matter content that was significantly higher than the deeper samples at the same sites, and from the samples taken at created sites. With the exception of three sites (103, 105 and 106, all created sites), results indicated normal wetland conditions, as all had lower percent organic matter in the deeper samples (30 cm) than in the surface samples.

TABLE 1. Physical Characteristics of Natural and Created Wetlands.

Wetland Number	Age	Maximum Depth	Mean Depth	Roughness[1]	Edge Slope[2]	% Open Water	% O.M. (5 cm)	% O.M. (30 cm)
Natural								
107		1.19	0.70	.553	2.02	1.23	42.0	40.5
108		0.67	0.13	.069	1.9	0.00	12.7	4.5
109		0.46	0.22	.088	1.8	1.05	11.7	3.8
110		0.76	0.33	.190	3.35	2.50	37.3	12.9
201		1.58	1.10	.723	5.92	2.22	3.6	2.1
202		0.51	0.22	.066	1.41	2.50	10.3	4.5
203		0.56	0.27	.154	2.13	2.50	3.1	8.7
206		1.04	0.58	.310	2.56	2.50	16.7	6.3
207		0.83	0.37	.173	2.28	2.38	2.22	10.9
Created								
101	3	1.17	0.67	.383	21.69	3.03	8.6	3.4
102	1	0.33	0.40	.152	16.82	2.38	6.3	3.7
103	4	1.05	0.57	.191	3.71	1.89	5.3	5.4
104	8	1.66	0.78	.450	3.31	2.50	7.9	3.5
105	3	1.43	1.08	.588	17.70	2.50	3.1	4.2
106	3	1.48	0.93	.323	11.03	2.50	3.6	5.5
204	3	1.62	1.33	.897	9.69	2.50	3.9	3.3
205	2	0.53	0.36	.188	8.78	0.51	1.8	0.7
208	3	1.18	0.67	.488	9.69	2.50	13.8	4.9

[1] Roughness is calcuated as the variance about the mean depth of the bottom basin.

[2] Edge slope is calculated as the difference in elevation between the wetland/upland edge and the edge/bottom basin boundary divided by the horizontal distance.

Figure 5 summarizes the physical differences between natural wetlands and created wetlands using typical cross sections of each. Natural wetlands were shallower (0.47 m mean depth) compared to created wetlands (0.79 m mean depth) and were smoother (mean roughness equal to 0.258 and 0.407 for natural and created wetlands respectively). Created wetlands had greater maximum depths (1.16 m) than did natural wetlands (0.84 m) and steeper edge slopes (11.4% in created versus 2.6% in natural wetlands).

WATER QUALITY

Table 2 summarizes water quality data for the natural and created wetlands. Water was present in seven of the nine natural wetlands and in all nine of the created sites. Water levels in all wetlands sampled presumably were lower than normal since the region had been experiencing a relatively serious drought prior to and during field data collection.

In several wetlands more than one sample was taken either as part of the quality assurance (QA) program, or because there was flowing water. Wetlands 103, 108, and 207 had two samples taken as part of the QA program as detailed in the ERL-C work plan. The results from the two samples taken from sites 103 and 207 reflect similar trends in concentrations of nutrients and metals, but site 108 had significant differences between the two samples, probably the result of inadvertently collecting suspended organic matter during sampling.

Wetland 204 was part of a flowing water system where two water samples were taken, one at the inflow directly from a lake (sample 204) and the second sample at the outflow from the created wetland (sample 204a). The higher total suspended solids and total phosphorus in the inflow than in the outflow may be indicative of the filtering action of the created wetland.

Water quality differed somewhat between the natural sites and the created sites. Generally the natural sites exhibited higher concentrations of nutrients and metals than the created sites. Since most of the natural wetlands were experiencing unseasonable dry-down, the result of low rainfall, the higher concentrations may be a function of oxidation of organic substrate and the concentrating influence of the dry-down.

Since only one sample was taken from most wetlands and the three duplicates show considerable variation, these results should be viewed cautiously.

VEGETATION CHARACTERISTICS

Table 3 summarizes the species planted for the nine created wetlands. In addition, six of the nine sites were mulched with organic matter from a "donor wetland." By far the most prevalent species planted were **Pontederia cordata** and **Sagittaria lancifolia**, two rather showy

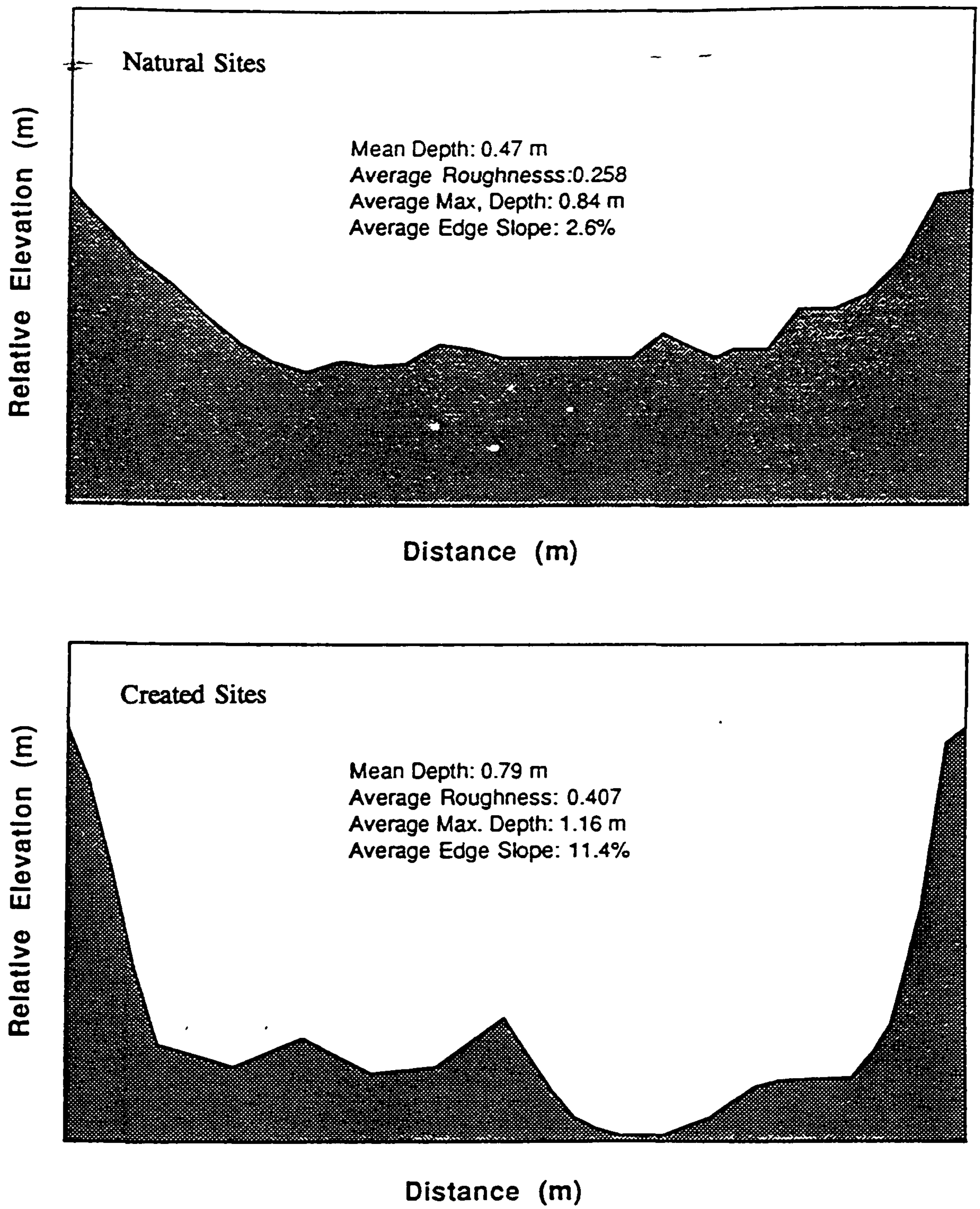

FIGURE 5. Typical cross sections of a natural (top) and created wetland (bottom) showing physical characteristics.

TABLE 2. Water Quality in Natural and Created Wetlands.

Wetlands #	TSS	Tot P	TKN	TOC	Pb	Cd	Al
Natural Wetlands							
107	11.0	0.05	2.20	26	0.010	0.003	0.50
108	800.0	1.50	15.00	37	0.010	0.003	1.30
108a	4.0	0.05	2.20	28	0.010	0.003	0.50
110	66.0	0.11	2.50	54	0.010	0.003	0.50
201	5.0	0.05	1.90	18	0.010	0.003	0.50
206	3.0	2.10	6.40	41	0.010	0.003	0.50
207	270.0	6.10	10.00	43	0.010	0.003	1.40
207a	280.0	8.70	13.00	37	0.010	0.003	1.30
Created Wetlands							
101	21.0	0.42	1.40	18	0.010	0.003	3.70
102	13.0	0.13	1.30	30	0.010	0.003	0.50
103a	13.0	0.05	0.65	17	0.010	0.003	0.50
103	10.0	0.06	1.30	9	0.010	0.003	0.50
104	1.0	0.05	1.20	12	0.010	0.003	0.50
105	24.0	0.19	2.40	21	0.010	0.003	0.50
106	20.0	0.18	1.10	14	0.010	0.003	0.50
204	43.0	0.44	3.90	26	0.010	0.003	0.50
204a	4.0	0.05	7.50	19	0.010	0.003	0.50
205	50.0	0.05	1.20	27	0.010	0.003	0.50
208	59.0	0.05	6.60	20	0.010	0.003	0.72

species that tend to flower much of the growing season and are relatively easy to propagate and transplant. An average of five species were planted at each created site. Site 104 had no species planted, while site 204 had 11 species planted. Comparisons between the species planted and species occurring on each created site are given in Figure 6. With the exception of site 204, the number of species planted at each site was less than 10% of the total number of occurring species.

Figure 7 graphs the importance values of the 10 most dominant species in natural sites (top graph) and created sites (bottom graph) as determined by relative density, relative dominance and relative frequency of occurrence. For comparative purposes, the importance values for the same species in the other population of wetlands is given for each. The two most dominant species in natural wetlands were **Panicum hemitomon** and **Pontederia cordata.** **Pontederia cordata** was also important in created sites. Four species in the top ten were shared by both populations: **Panicum hemitomon, Pontederia cordata, Juncus effusus,** and **Hydrocotyle umbellata**. Of these species only **Panicum hemitomon** and **Pontederia cordata** were planted in created wetlands.

Table 4 summarizes the characteristics of plant communities of natural and created wetlands. In the first three columns, details of species composition are given. The total number of species found in natural and created wetlands was comparable, although, created wetlands tended to have greater numbers of species and greater variation in number (13 to 93) than did natural wetlands (23 to 48). When species were categorized using the NWI ecological groups (Reed 1988) where obligate, facultative wetland, and facultative were considered wetland species, while facultative upland and upland were considered upland species, the numbers of wetland and upland species in the second and third columns resulted. While the general trend was for greater numbers of upland species in created wetlands representing a greater proportion of the total number of species, the trend was not significant.

The fifth column in Table 5 lists the WA score for each of the wetlands. Figure 8 graphically depicts the range of WA scores for natural wetlands (above the scale line) and created wetlands (below the scale line). The WA scores ranged from 1.06 to 1.84 for created wetlands; from .08 to 2.5 for natural wetlands. There was no significant difference between WA scores for the populations of natural and created wetlands. With the exception of natural wetland 107, all wetlands scored below 2.0, with the majority of sites scoring below 1.5. Six of the nine natural wetlands scored below 1.5, while five of the created wetlands were below 1.5. The lowest score was that of site 105, an 8 year old mulched, created site. The highest score, site 107 was a wetland in a residential setting that was described by its owners as becoming increasingly dryer over the past several years, presumably the result of changes in groundwater conditions.

The last two columns in Table 4 give indices of plant species diversity. Comparisons between the two populations of wetlands revealed no significant differences.

TABLE 3. Species Planted and Use of Mulching at Created Wetlands.

Treatment	Sites								
	101	102	103	104	105	106	204	205	208
Mulch		X	X	X			X	X	X
Species Planted:									
Bacopa caroliniana							X		X
Blechnum serrulatum							X		X
Canna flaccida		X			X	X	X		
Hypericum fasciculatum		X							
Iris spp.							X		
Iris virginica		X			X	X			
Juncus effusus			X				X	X	X
Ludwigia spp.							X		
Nymphaea odorata					X	X		X	
Osmunda regalis							X		
Peltandra virginica		X							
Pontedaria cordata	X	X	X		X	X	X	X	X
Sagittaria lancifolia	X	X	X		X	X	X	X	
Saururus cernuus		X							
Spartina bakeri		X	X		X	X	X		X
Thalia geniculata							X		X

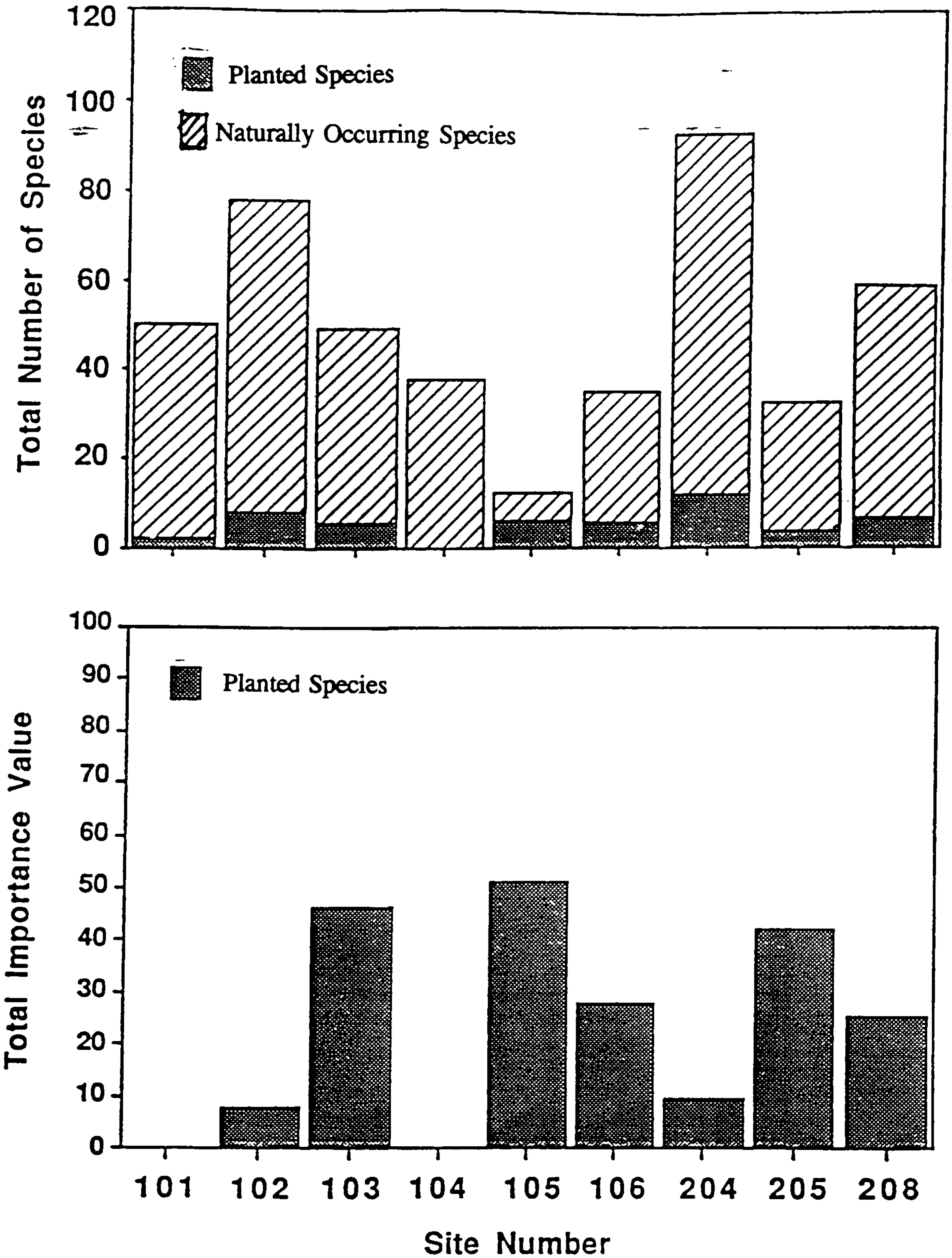

FIGURE 6. The proportion of total number of species in created wetlands that resulted from planted species (top graph), and their importance values as determined by relative density, relative dominance, and relative frequency of occurrence (bottom graph).

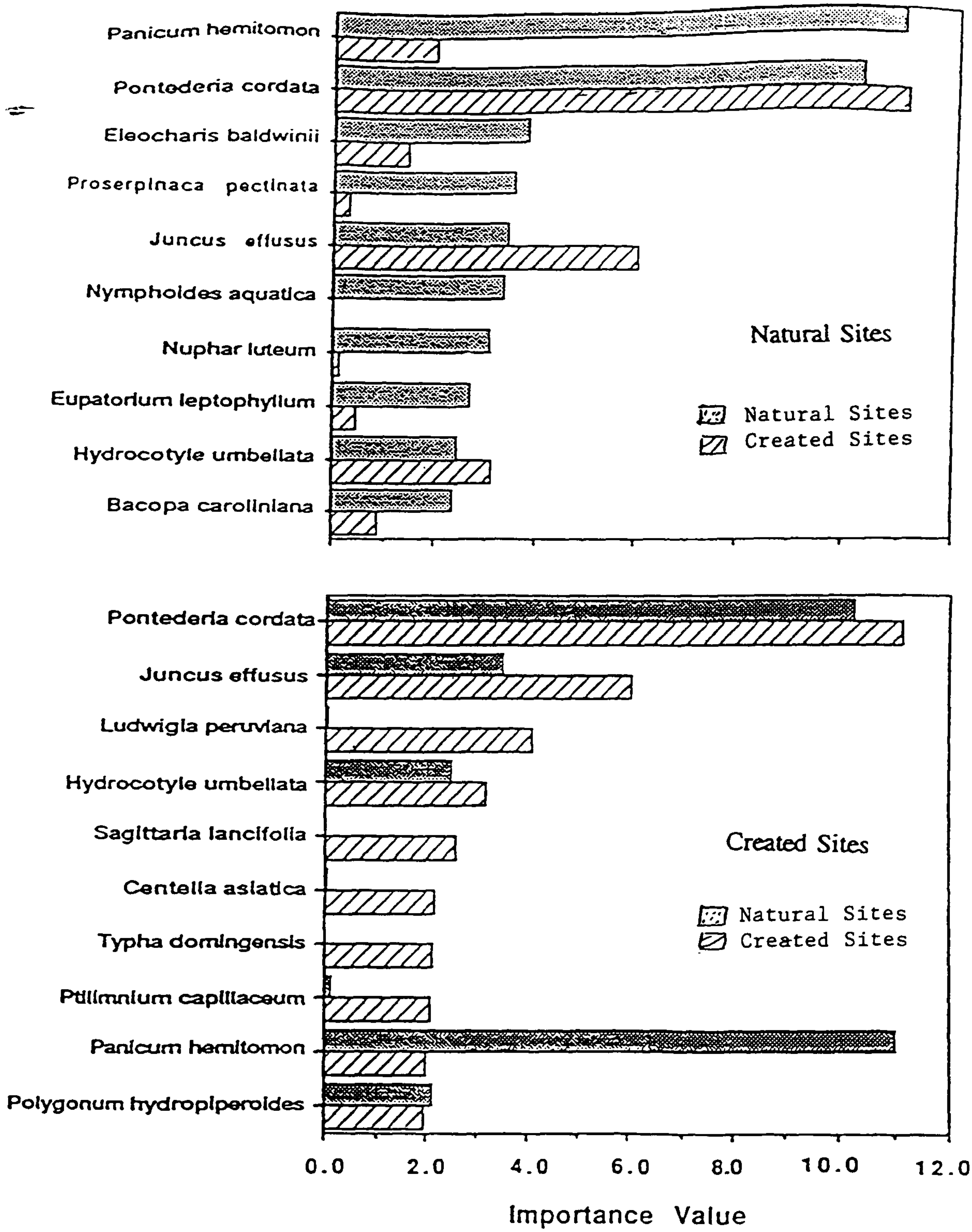

FIGURE 7. The ten most important species in natural (top) and created wetlands (bottom) as determined by relative densities, relative dominance, and relative frequency of occurrence. For comparison, importance values are shown for both natural and created wetlands in each graph.

TABLE 4. Vegetation Characteristics of Natural and Created Wetlands.

Wetland Number	Total Species	Wetland Species	Upland Species	WA Score	Shannon Diversity	Simpsons Diversity
Natural						
107	27	25	2	2.57	4.14	0.923
108	39	36	3	1.11	4.63	0.944
109	48	42	6	1.38	4.91	0.951
110	23	22	1	1.08	3.50	0.874
201	41	38	3	1.43	4.58	0.939
202	32	31	1	1.49	4.30	0.929
203	28	26	2	1.55	3.99	0.894
206	34	31	3	1.55	4.51	0.937
207	47	45	2	1.25	4.79	0.941
Created						
101	50	42	8	1.84	4.87	0.952
102	78	69	9	1.78	5.55	0.971
103	49	46	3	1.29	4.95	0.942
104	38	37	1	1.54	4.82	0.957
105	13	13	0	1.06	3.00	0.834
106	35	32	3	1.24	4.44	0.932
204	93	83	10	1.82	5.92	0.977
205	33	28	5	1.31	4.05	0.897
208	59	56	3	1.35	4.92	0.952

TABLE 5. Summary of the Means of the Variables Measured for Natural and Created Wetlands.

Parameter	Natural	Created
Mean Depth	0.47	0.79
Maximum Depth	0.844	1.16
Roughness	0.258	0.407
Edge Slopes*	2.58	11.4
% Open Water	1.88	2.26
% O. M.*	13.8	4.86
LDI*	2.79	5.32
Shannon Diversity	4.37	4.73
Simpsons Diversity	0.926	0.935
WA Scores	1.49	1.47
Species Richness	35.4	49.8

*indicates significant difference @ .05 confidence level determined by an analysis of variance.

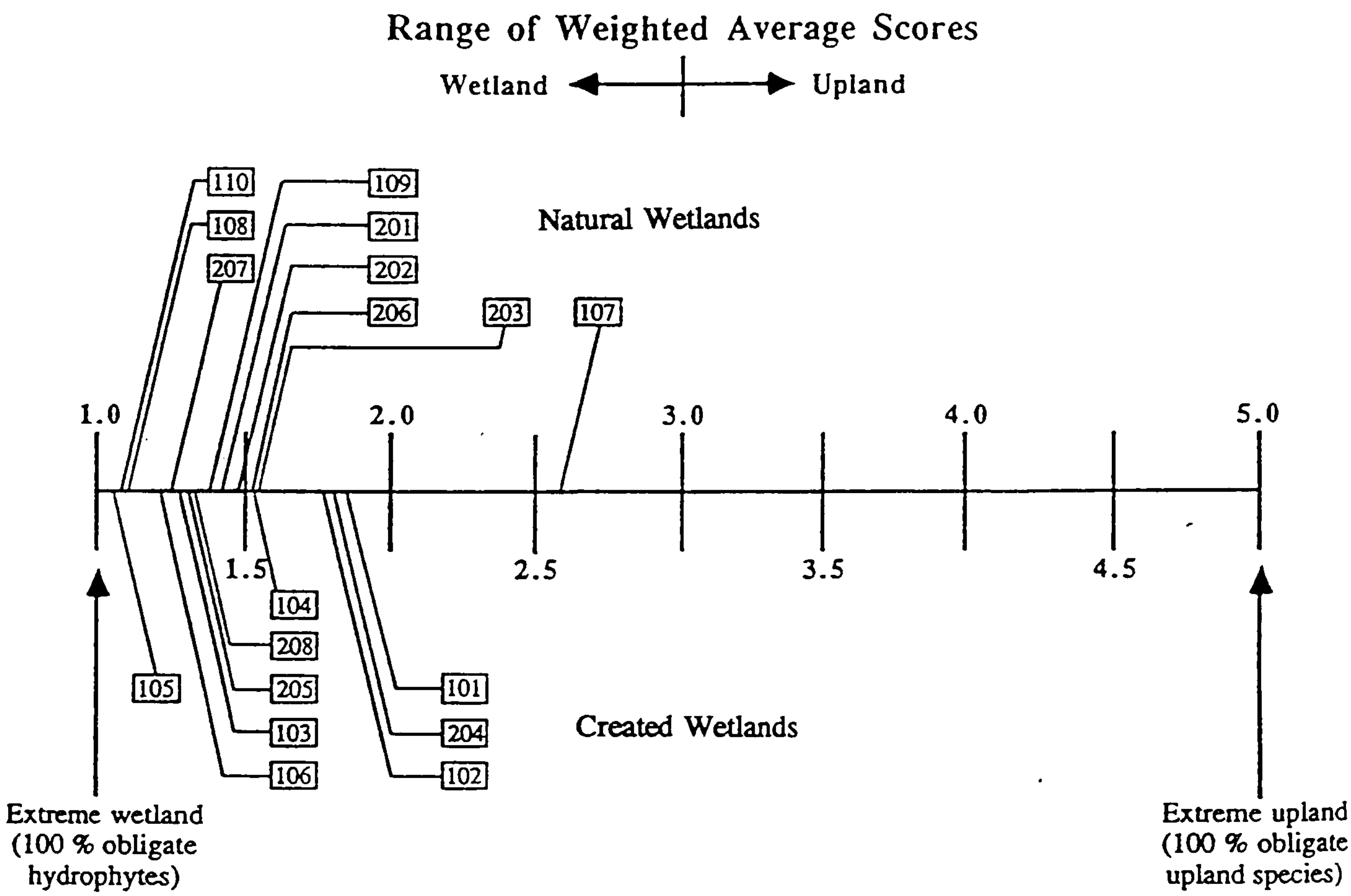

FIGURE 8. Range of weighted average (WA) scores for natural and created wetlands using NWI (Reed 1988) classification of species.

DISCUSSION

COMPARISON OF NATURAL AND CREATED WETLANDS

Table 5 summarizes the results of analysis of the data for the populations of natural and created wetlands. Several parameters were significantly different at the .05 confidence level (determined by an analysis of variance) between the two populations, they included: edge slope, percent organic matter in both the 5-cm and 30-cm soil samples, and the Landscape Development Intensity (LDI) index. Other parameters, while showing differences in the means for each sample were not significantly different at the .05 confidence interval, owing in part to the small sample size and variability within each population.

Differences in edge slope between the created and natural wetlands were observed during field data collection. The unnaturally steep slopes in the created wetlands most probably resulted from a combination of inadequate design and economic realities associated with the value of real estate. All the created wetlands were built in residential or commercial developments, often "tucked" into corners, beside roadways or were associated with stormwater systems. The lack of space and possible unwillingness of the landowner to commit larger land areas to wetland creation (resulting from the high development value of land) may have contributed to the designer and contractor minimizing the "footprint" of the wetland by increasing the slope of the wetland edge. Gentle slopes require greater area to achieve adequate depth and result in larger transitional area surrounding each wetland. While no attempt was made in this study to evaluate the widths of transitional areas between uplands and wetlands, observations suggested that transitional areas were smaller in the created sites, often completely absent. Most small herbaceous natural wetlands in Florida exhibit zonation of plant species as a result of differing hydroperiods along the moisture gradient extending from upland edge to the topographic low point of the wetland. Analysis of the edge slopes showed that created wetlands had steeper edge slopes and thus less potential for development of transitional areas and zonation.

The low soil organic matter in created wetlands was expected since most of these wetlands were less than 4 years old. Created wetlands that were mulched had higher organic matter than those that were not mulched, although because of the small sample size (six of the nine sites were mulched) the difference was not statistically significant.

Mulch increases organic matter content of the surface soil horizon, but can easily oxidize under dry conditions, or wash away under flowing water conditions. Previous studies of the use of mulch in wetland reclamation on phosphate mined lands (Brown et al. 1985) estimated the costs of digging, transporting and spreading of the mulch to be between $237 and $408 per acre/inch per mile of round trip travel distance. In light of these costs, inundation soon after application of mulch material and control of water velocity as well as tillage in flowing water wetlands may help to lower loss of the added organic matter.

The LDI index was significantly higher for created wetlands than for natural wetlands since most created sites were within residential and commercial developments, within regions of Hillsborough County, Florida that were under considerable development pressure. Every effort was made during natural site selection to choose natural wetlands that had the full range of LDI indices, yet difficulties in obtaining permission to access sites in urbanizing locations ultimately shifted site selection to more remote locations. The long-term consequences of the differences in landscape setting as indicated by the LDI index on the structural and functional aspects of created wetlands are yet to be understood, but observations (Brown 1986) of wetlands within urban settings would suggest decreasing wetland function with increasing level of urbanization in the surrounding landscape.

SIGNIFICANCE OF MULCHING ON COMMUNITY STRUCTURE

The lack of significant differences between created and natural wetlands related to species diversity, and the nearly identical WA scores suggested that created sites were well stocked with wetland species. Since six of the nine created sites were mulched with organic matter from donor wetlands and only 16 species were planted in all the sites, the relatively high number of species (mean = 49.8) probably resulted from introduction of species with mulch material. Mean number of species for the three created wetlands that were not mulched was 32.6, while the mean for the six mulched wetlands was 58.3 (Table 6). Planted species in mulched created sites varied from 11 (site 204) to none (site 104). While planting helped to increase the number of species, mulching alone had a greater effect (site 104, where no species were planted, had 32.6 species sampled).

The three graphs in Figure 9 show the number of wetland and upland species in plots along one transect of an unmulched site (top), a mulched site (middle), and for comparison, a natural site (bottom). The unmulched site exhibited lower overall numbers of species per plot and no upland species occurred. The mulched site (middle graph) had higher overall numbers of species per plot, exhibited zonation with decreasing numbers of species from the upland edge toward the center of the wetland, and had several upland species along the wetland edge. This graph illustrates that although the potential for introducing undesireable upland or exotic species is increased with mulching, the zonation and species richness of the mulched site tends to mimic the conditions found in natural sites (bottom graph).

The potential for introduction of noxious or exotic species is increased with mulching. In Florida, *Typha* spp. (cattails) are considered an undesirable species in created wetlands. Since they are rather ubiquitous within wetland systems, especially those that have some level of disturbance, the possibility of transferring cattails and the long term consequences related to maintenance should be considered when selecting "donor" wetlands. None of the mulched

TABLE 6. Species Characteristics of Mulched and Unmulched Created Wetlands.

Parameter	Mulched	Unmulched
Richness	58.3	32.6
Shannon Diversity	5.04	4.1
Simpson Diversity	0.949	0.906
WA Score	1.52	1.38
Upland Species	5.2	3.67

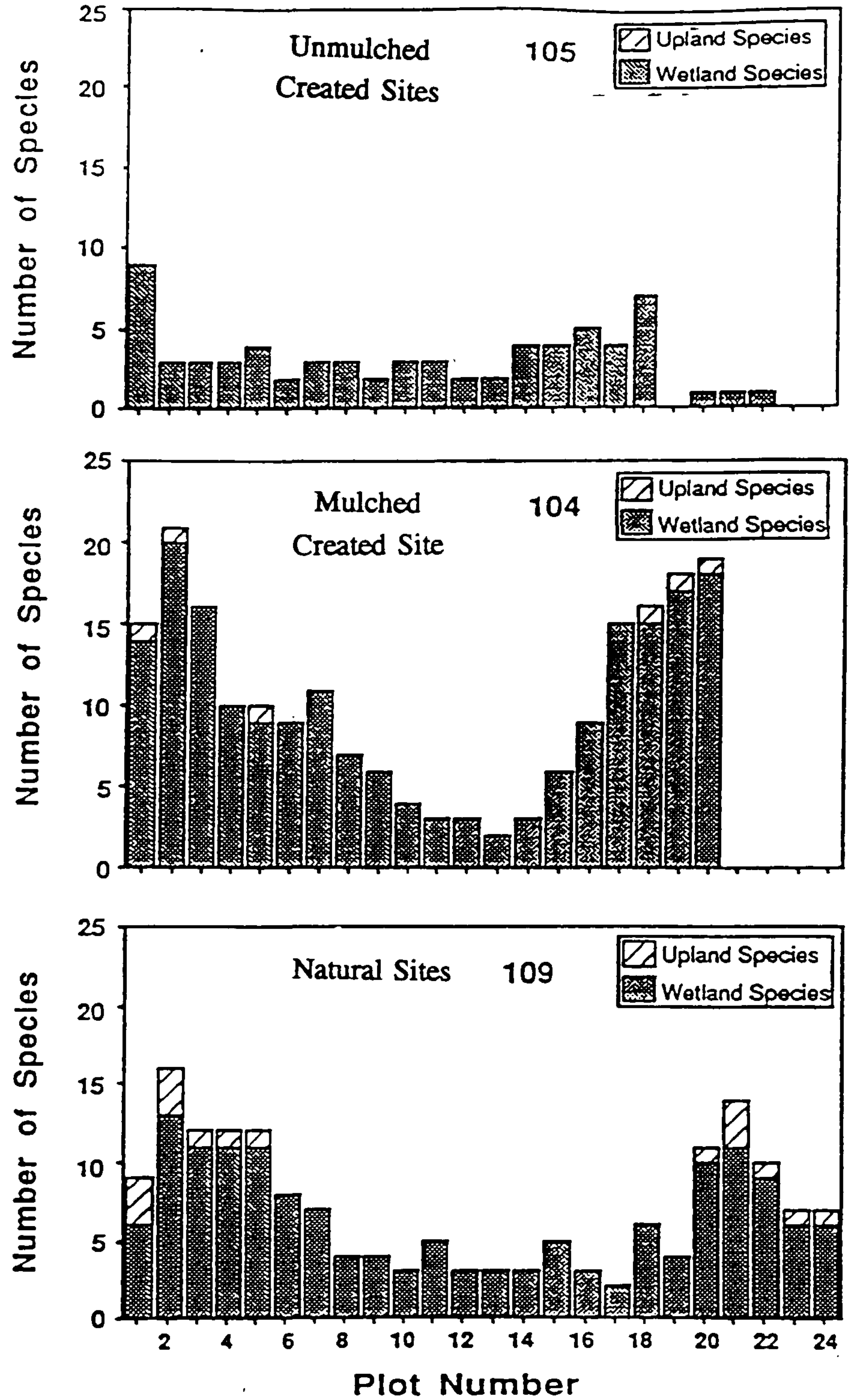

FIGURE 9. Number of species and proportion of upland species along transects of an unmulched created wetland (top), and a mulched created wetland (middle), and a natural wetland (bottom).

wetlands in this study exhibited problems with undesirable or exotic species invasions, nor did the permit records indicate that problems had occurred in the past.

UTILITY OF THE EVALUATION APPROACH

The evaluation approach tested in this study was designed to minimize impacts to wetlands and to be relatively quick, yet yield sufficient data to evaluate the created wetland. The average time spent at each site was about 16 person hours. The field crew left relatively few visible traces of their presence. Therefore, using these criteria the approach was successful.

Evaluation of created wetlands should take into account not only short-term structural similarity to naturally occurring wetlands but long-term functional equivalency as well. Long-term functions are more difficult to evaluate since they require long-term monitoring, or at the least, several site visits and data gathered over a period of years. The evaluation technique used in this study did not address the long term, but could form the basis for data collection and comparative analysis over a period of years to measure temporal trends and long-term success.

Seven of the nine created wetlands evaluated in this study were less than four years old (one site was eight years old), and while experience has shown that four years is sufficient time for the establishment of herbaceous wetlands, successional trends after a period of years could result in a community with few wetland characteristics. Long-term stability, and therefore the long-term success of the creation of wetlands, is impossible to determine with only one synoptic field event. Yet, the measured parameters, including vegetation and soil organic matter, if monitored on a yearly basis for several years could provide sufficient trends data to extrapolate long-term success. For instance, trends in vegetative community structure and spatial distributions of species could indicate whether the created wetland was shifting from domination by wetland vegetation to domination by more upland vegetation. Changes in organic matter content of soils could provide inference of hydrologic condition. If soil organic matter decreased over time, it might be inferred that the wetland had low water levels and dry periods sufficient for oxidation, and thus, no net accumulation of soil organics. If corroborated with vegetation data, the inference could be strengthened without the necessity to monitor long-term water levels.

Probably the most important class of functions that was not evaluated in this study was related to wetland hydrology. Synoptic water levels were taken but proved little, other than water was or was not present on the day of measurement. A better approach, of course, would involve measuring water levels over a complete hydrologic cycle. Hydroperiod (period and frequency of inundation) and water depth are key factors that control vegetation and most chemical and biologic processes. Without some evaluation of hydrologic characteristics over a sufficient period of time, it is difficult to ascertain equivalency in this most important category of wetland functions. The use of iron rods implanted in created wetlands and left for a sufficient period of time may help to evaluate minimum and maximum water levels (Harenda, et al. 1991).

In closing, evaluations of temporal changes in hydrology and plant successional trends within created wetlands, seem most important to determine ultimate success. The costs associated with several site visits may be justified until sufficient data and experience have been gained that one site visit after an appropriate number of growing seasons will yield enough information to accurately estimate the success of the created wetlands.

LITERATURE CITED

Brown, M.T. 1986. Cumulative impacts in landscapes dominated by humanity. *In* Estevez, E.D., Miller, J., and Hamman, R. (eds.), Managing Cumulative Effects in Florida Wetlands: Conference Proceedings. pp. 33-50. Sarasota, Florida: New College Environmental Studies Program, Publication No. 37.

Brown, M.T., H.T. Odum, F. Gross, J. Higman, M. Miller, and C. Diamond. 1985. **Studies of a Method of Wetland Reconstruction Following Phosphate Mining.** Final Report to the Florida Institute of Phosphate Research, Bartow, FL. Gainesville, FL: Center for Wetlands, University of Florida. 76 pp. (CFW-85-05)

Brown, M.T. and R.E. Tighe (eds.). 1990. **Techniques and Guidelines for Reclamation of Phosphate Mined Lands**. Final Research Report to the Florida Institute of Phosphate Research. Gainesville, Florida: Center for Wetlands, University of Florida.

Clewell, A.F. and R. Lea. 1990. Creation and restoration of forested wetland vegetation in the southeastern United States. **Wetland Creation and Restoration: The Status of Science. pp. 195-232**. Kusler, J.A. and M.E. Kentula (eds.) Island Press, Washington, D.C.

Harenda, M.G., M.E. Kentula, J.C. Sifneos, and J. Honea. Evaluating the "Rusty Rod" Technique for Use in Monitoring Subsurface Water levels in Wetlands. In Press **Wetlands Ecology and Management.**

Pielou, E.C. 1986. Assessing the diversity and composition of restored vegetation. **Can. J. Bot.** 64: 1344-1348.

Reed, P. B., Jr. 1988. **National List of Plant Species That Occur in Wetlands: 1988 Florida**. Biological Report NERC-88/18.09. National Wetlands Inventory, U.S. Fish and Wildlife Service. St. Petersburg, Florida.

Sherman, A.D., S.E. Gwin, and M.E. Kentula, in conjunction with M. Brown. 1991. Quality Assurance Project Plan: Florida Wetlands Study. Companion document, Environmental Research Laboratory-Corvallis, Oregon.

Wentworth, T.R., G.P. Johnson, and R.L. Kologiski. 1988. Designation of wetlands by weighted averages of vegetation data: A preliminary evaluation. **Water Resources Bulletin**, 24(2): 389-396.