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EVALUATION OF CONSTRUCTED WETLANDS ON PHOSPHATE MINED LANDS IN FLORIDA
VOLUME III

Vegetation, Wildlife, & Ecosystem and Landscape Organization

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The Nature Conservancy

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Florida Institute of Phosphate Research

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EVALUATION OF CONSTRUCTED WETLANDS ON PHOSPHATE MINED LANDS IN FLORIDA

VOLUME III

VEGETATION
WILDLIFE
ECOSYSTEM AND LANDSCAPE ORGANIZATION

Edited by
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Summarizing Research Conducted
from
June, 1993 to May, 1995

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FINAL REPORT
FIPR PROJECT 92-03-103

Prepared for

Florida Institute of Phosphate Research
1855 West Main Street
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November, 1997

DISCLAIMER

PERSPECTIVE

EVALUATION OF CONSTRUCTED WETLANDS ON PHOSPHATE MINED LANDS IN FLORIDA

Construction of wetlands to replace natural wetlands damaged or destroyed by mining activities has been required by state law since 1973. The degree of success in replacing those mined wetlands has been debated for many years. In an effort to shed some light on the subject, representatives of the phosphate industry approached FIPR to conduct an evaluation of constructed wetlands. By late 1991 an *ad hoc* committee, including representatives from government, industry, environmental organizations and the scientific community, was formed to develop the project. In 1993, a multidisciplinary team of research scientists received a grant from FIPR to evaluate wetland construction on phosphate mined lands in Florida. The general approach was to assemble the data available from various reports and company or agency files and to observe as many constructed wetland sites as possible. A limited amount of descriptive data was also taken during the site visits. A Wetlands Research Advisory Committee (WRAC) was formed to provide critical review of the project, and the WRAC members' valuable input is here acknowledged.

The report is divided into three volumes. The first volume summarizes the conclusions and recommendations of the entire research team. The second volume contains the subgroup reports on Hydrology, Soils, Water Quality, and Aquatic Fauna. The third volume contains the subgroup reports on Vegetation, Wildlife, and Ecosystem and Landscape Organization.

The reader is referred to the following related projects and reports:

Brown, M.T. and R.E. Tighe (Eds.). 1991. Techniques and Guidelines for Reclamation of Phosphate Mined Lands. FIPR Publication No. 03-044-095.

Crisman, T.L., W.J. Streever, J.H. Kiefer and D.L. Evans. 1997. An Evaluation of Plant Community Structure, Fish and Benthic Meiofauna and Macrofauna as Success Criteria for Reclaimed Wetlands. Final Report FIPR Project 88-03-086.

Cowell, B.C. 1997. Meiofauna and Macrofauna in Six Headwater Streams of the Alafia River, Florida. FIPR Publication No. 03-101-130.

Richardson, S.G. and C.D. Johnson. 1998. Forested Wetland Restoration and Nuisance Plant Species Management on Phosphate Mined Lands in Florida. Proceedings of the 1998 National Meeting of the American Society for Surface Mining and Reclamation.

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TABLE OF CONTENTS

SECTION 6 - VEGETATION

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 6 - VEGETATION

EXECUTIVE SUMMARY

In this section, the vegetation component of constructed wetlands is evaluated. Site visits to over 164 reclaimed and natural wetlands in the central and northern Florida phosphate mining regions were made, data were compiled and synthesized from numerous sources, and trends in wetland plant community establishment and persistence were examined to determine present plant community structure and how it may be changing over time.

The objectives of this component of the larger project were four-fold:

1. Collect and synthesize existing information related to the vegetation characteristics of wetlands constructed on phosphate mined lands;

2. Evaluate these data to determine whether they are adequate to assess a) the present structure and composition of plant communities on constructed wetlands, b) the likelihood of plant community persistence or future changes, and c) the relationship of vegetation development to site design criteria and post mining treatments;

3. Collect, synthesize, and evaluate existing information on the vegetation characteristics of natural wetlands in the Florida phosphate-mining region; and

4. Identify vegetation indicators of wetland ecosystem functions and develop systematic quantitative methods of measuring these indicators.

CONCLUSIONS

Findings regarding the success of wetland reclamation related to development and persistence of the plant community are based on a general lack of data., incomplete data sets for the data that existed, and a lack of comparability of data from one company to the next. As a result, our conclusions are based on trends that have been extracted from monitoring reports and the research of others. The data base suffers from lack of consistency in methodologies for data acquisition and analysis. About 36% of the sites visited by the research team did not have useable data. Of the sites that had good data only a handful had time series data that could be used to evaluate trends in community development and persistence. Regardless, the following are conclusions of this preliminary analysis:

- The data set for evaluation of wetland reclamation success is inadequate to statistically test community development, effects of site design and treatments, or long term trends. While we have presented trends based on existing data from a variety of sources, it must be understood that these are only trends based on a handful ofwetlands with incomplete data sets, and for only several years.

- Percent cover in marsh wetlands increased in most wetlands for which we had data but then appeared to level within 3 - 5 years . Evaluation of mean change in percent cover industry-wide indicated that change is between 2 and 8% per year depending on method of calculation.

- Evaluation of the growth and survival of planted tree species suggests that survival is about 50% over 6 years (one site with 20 years of data [parcel B] exhibited survival of only 28% of planted wetland and mesic trees). Mortality averages between 2.5 and 4% per year after the first year.

- Industry-wide percent increase in mean forest cover in forested wetlands was between 1.5 and 2% per year for the period over which we have data.

- On the average, species richness of reclaimed marshes appears to rival the most diverse native marshes. Zonation and patch diversity within marshes was not testable with the data set, but anecdotal evidence from the site visits suggests that at least some reclaimed marshes were planted to achieve these characteristics.

- Species richness of obligate wet herbaceous species appeared to decline for those sites for which there were longer term data, decreasing on the average by about 40%. Without more detailed analysis it is unclear if this is loss of important species or just the loss of floating and rooted aquatic species as communities shift to less open water systems

- Species richness of planted trees in forested wetlands is higher than richness found in native mixed hardwood swamps. However, there is a dearth of single species dominated wetlands like bayheads and cypress domes being created.

- The number of trees planted per acre, on average (800), appears to be similar to native wetlands when all age classes are considered. Survival indicates that stand densities will be about 400 trees per acre at the end of 5 years and that continued yearly mortality of about 2-3% will continue, thus mature constructed wetlands will have between 300 and 350 trees per acre. This appears to agree with densities of mature trees in native forested wetlands.

- There are no data on long-term recruitment of herbaceous and shrub species within forested wetlands. Anecdotal evidence from site visits suggests that this may be a serious shortcoming for the development of vertical structure in forested wetlands.

- Survival of planted trees on sandtailing/overburden sites appears to be similar to survival on overburden sites. The data do not clearly demonstrate significant trends, however first year data suggest trees survive better on sandtailings than overburden. The over all trend thereafter appears to favor overburden sites, but after 6 years survival appears to be relatively similar between the two treatments.

- Mulching does appear to have positive benefits for herbaceous wetlands. Percent cover was higher in the first year and appeared to continue for 4 or 5 years. Species richness appeared to be little affected by mulching.

- There is no question that herbiciding controls nuisance species. The data show that mean percent cover of nuisance species on non-herbicided sites reached about 30% in the 6th year, while it was kept below 10% on herbicided sites. Species richness on herbicided sites appears to be lower than on non-herbicided sites (although the data are limited).

- Nuisance species control in forested wetlands appears to benefit tree survival. The data suggest that survival is better on herbicided sites, but data are too few to be sure. A controlled experiment to test the positive and negative effects of herbicides in constructed forested wetlands is strongly recommended.

- The effect of initial hydrologic regime could not be tested with the data set, but evidence from the site visits suggested that, on more than one occasion, initial water levels played a significant role in the failure of marsh plantings.

- There are no data related to micro-topographic relief; but site visits confirm that, without exception, forested wetlands were created with extremely "smooth" topographies. Micro-relief on the order of less than 1 meter would increase diversity of hydrologic regimes and in turn potentially increase survival and growth of planted species.

RECOMMENDATIONS

Recommendations are grouped into two broad categories: (1) recommendations related. to reclamation techniques and treatments, and (2) recommendations related to data collection and reporting.

Based on the summaries of data and trends observed in community development as well as observations in the field, we recommend the following:

- A trend in the decline of obligate wetland species in herbaceous wetlands, coupled with no decline in overall species richness may indicate a need for additional research that would help to illuminate the reasons for the trend.

- Urgent additional research relating to the long-term trends in invasability of herbaceous wetlands by nuisance and exotic species and the documentation of trends in effort expended for controlling them over time.

- Anecdotal evidence suggested a disturbing trend of invasion by exotics on older sites that were "released" and therefore of less concern for continued maintenance by industry. We strongly urge a detailed survey and program for control, least the reclaimed wetlands become dominated by exotics.

- A study of the effects of early dominance of nuisance species on growth and survival of tree species?

- Forested wetlands should be constructed with greater micro-topographic relief If trees are planted on hummocks, water levels could be deeper without threatening tree survival, and greater Surface storage can be accomplished.

- Provision should be made to plant shrub and herbaceous species in constructed forested wetlands once the canopy begins to close. Anecdotal evidence from older reclaimed and naturally reclaimed sites suggests that constructed systems will be lacking these strata, considerably lowering their wildlife habitat values.

- The use of Bahia grass *(Paspalum notatum)* on reclamation sites should be discontinued, instead plant annual crops for soil stabilization. Anecdotal evidence from site visits that it is extremely persistent, outcompeting native flora.

- Since survival of some tree species is low, it probably makes little sense to plant only a few individuals of any one species. Each species planted should comprise a minimum of 10% of the total trees per acre.

Based on our analysis of the quality and completeness of data, we recommend the following:

- Overall there is a need for standardization of methods of field data collection and analysis. In addition, data that would help in the interpretation of trends are not currently collected (ie. level of effort expended in nuisance control, water levels, mulch thickness, planting densities, percent mixtures of species planted, etc) but should be.

- At the very least, a minimum amount of data should be collected on all wetland reclamation sites. As it now stands there are not sufficient data to determine overall success of the industry's reclamation of wetlands. Of the total sites visited, over 60% had no data whatsoever.

- The quality of data falls off rapidly after 2 to 3 years. More attention should be given to standardization and there should be a longer term commitment to monitoring.

SECTION 6 - VEGETATION

INTRODUCTION

In this section, the vegetative component of constructed wetlands is evaluated. Site visits to over 164 reclaimed and natural wetlands in the central and north Florida phosphate mining regions were made, data were compiled and synthesized from numerous sources, and trends in wetland plant community establishment and persistence were examined to determine present plant community structure and how it may be changing over time. An important question that is often asked about constructed wetlands is: to what degree are they functional, persistent replacements for the wetland communities that were mined?

We have attempted to answer this question in relation to the plant community. Functionality was addressed by evaluating the species composition of created wetlands, its cover, density, and richness. Our assumption was that if constructed wetlands had a "reasonable assemblage" of wetland species, that appeared to be persistent, the plant community was functioning. "Reasonable" in this case meant that the plant community was composed of species that are considered wetland species. We understand that questions concerning functionality are most difficult to answer and are controversial. Comparisons of constructed wetlands on phosphate-mined lands with native Florida wetlands is suggested by some, as the only way of insuring functional replacements. Others believe that since soils and topography are so different, it is unreasonable to expect constructed wetlands to be similar to native wetlands.

Regardless of the controversy, in this study we use the characteristics of native wetland plant communities as the benchmark to which constructed wetlands are compared. By benchmark, we mean a starting point, or basis for comparison, not the end point. In previous studies of constructed marsh wetlands (Brown, 1991), both constructed and reference wetlands were surveyed. The variability in species composition between reference sites suggested that if success of a constructed wetland was based on matching composition of the reference wetlands, much would depend on the wetland chosen. If species composition data from each of the reference wetlands were pooled so as to develop an "average wetland composition," the resulting species list was so large and had such high variability, that if matched, the resulting constructed wetland would not resemble anything that could be called a naturally occurring wetland type. A benchmark, however, suggests that we look at reference wetlands for larger scale, integrative characteristics.

The question of persistence was evaluated in this study by looking for trends in the growth and survival of plant species and where sufficient data existed, we searched for evidence that shifts in species composition away from wetland species were not occurring. However, long-term monitoring data do not exist for most constructed wetlands. In fact, the preponderance of data now available is only about two to three years in length, with only a few sites having five or more years of data. For the most part, these are not sufficient lengths of time to judge persistence, especially of forested wetlands. However, in marsh wetlands, because of the speed of colonization and reproduction of marsh plants, five years may be sufficient to determine if plants are established and persisting.

Another area of investigation concerned comparison of various post-mining and post-reclamation treatments. We evaluated data for wetlands that were constructed on different soils, for wetlands that were mulched with organic soils from native wetlands, and for wetlands where herbicides were used for control of nuisance species. In all these cases, we were searching for trends in the existing plant community and in growth and survival that would provide insights related to treatment effects. Of particular interest was wetland plant community establishment on clay soils, since such a large portion of reclaimed landscapes will have these soils.

Specifically, the objectives of this component of the larger project were four-fold:

1. Collect and synthesize existing information related to the vegetative characteristics of wetlands constructed on phosphate-mined lands;
2. Evaluate these data to determine whether they are adequate to assess a) the present structure and composition of plant communities on constructed wetlands, b) the likelihood of plant community persistence or future changes, and c) the relationship of vegetative development to site design criteria and post mining treatments;
3. Collect, synthesize, and evaluate existing information on the vegetative characteristics of natural wetlands in the Florida phosphate-mining region; and
4. Identify vegetative indicators of wetland ecosystem functions and develop systematic quantitative methods of measuring these indicators.

OVERVIEW OF WETLAND VEGETATION

A general overview of wetland community types and characteristic vegetation of Florida wetlands are given first, followed by brief reviews of previous research on vegetation in constructed wetlands, mulching practices, and control of nuisance and exotic species. Finally, a review of wetland functions and values and success criteria in so far as they relate to vegetation is given.

WETLAND ECOLOGICAL COMMUNITIES

There are several types of wetlands occurring within the central and north Florida phosphate regions. Community structure of wetlands is controlled primarily by hydrologic parameters (hydroperiod and depth of inundation) and also by other factors such as nutrient availability, soils, recent fire history, and logging activities. The types of wetlands occurring within the region are as follows: Bay swamps (bayheads), cypress domes/strands/sloughs, mixed hardwood swamps, hydric hammocks, wet prairies, shallow marshes, and deepwater marshes. The classification scheme used in this section is primarily the Florida Land Use and Classification Code

(FLUCC) developed by Florida DOT (1987), adopted by most state agencies, and used throughout the state by public and private agencies. The main reason for using the FLUCC code is the fact that almost without exception, companies within the phosphate industry employ it as the principal means of classifying land cover types on reclamation sites, For purposes of cross reference, the descriptions of each wetland type that follow include the FLUCC designation.

Bay swamp communities (FLUCC-611) - Bay swamps (sometimes called bayheads) naturally occur where ground surfaces are rarely inundated to any degree for long periods of time, but saturation is quite common for most of the year. Seepage areas at the base of sandy ridges are often dominated by bay communities. Experience has shown that many bayheads are the result of community shifts from cypress wetlands in response to lowered groundwater tables and fire (Brown et al. 1990). The soils of bay swamps are often deep organic accumulations.

Bay swamps are dominated by sweet bay *(Magnolia virginiana),* loblolly bay *(Gordonia lasianthus),* and, to a lesser extent, swamp red bay *(Persea palustris).* Other species sometimes reaching canopy stature include: wax myrtle *(Myrica cerifera)* and dahoon holly *(Ilex cassine).* The understory often resembles a thicket dominated by wax myrtle *(Myrica cerifera),* fetterbush *(Lyonia lucida),* and vines like wild grape *(Vitis rotundifolia)* and catbrier *(Smilax laurifolia).*

Bay swamps are numerous throughout the north and central Florida phosphate regions. Many cypress domes and swamps throughout Florida are increasingly becoming dominated by bays, presumably resulting from lowered groundwater tables and increased occurrence of fire.

Cypress Swamps (FLUCC-621) - Cypress swamps are one of the most common forested wetland types in Florida. When circular in shape and isolated they are called cypress domes. When elongated and exhibiting sluggish surface-water flow in nondistinct channels, they are called cypress sloughs; and when surface flows are evident but still without distinct channels, they are referred to as cypress strands. Riverine cypress occupy the margins of channelways of streams and rivers. Lake border swamps are often dominated by cypress along the lake margins. Growth rates, density of trees, and basal area all seem to increase with increasing hydrologic function and access to nutrients; from cypress domes (smallest trees and lowest growth rates) to riverine cypress swamps (largest trees and highest growth rates).

Cypress domes, sloughs, and sometimes strands are dominated by pond cypress *(Taxodium ascendens) while* riverine swamps and lake border swamps are more characteristically dominated by bald cypress *(Taxodium distichum).* Other trees sharing the canopy include black gum *(Nyssa sylvatica),* pond pine *(Pinus serotina),* slash pine *(Pinus elliottii),* red maple *(Acer rubrum),* and one or more of the bay species. The understory can be relatively diverse including fetterbush *(Lyonia lucida),* wax myrtle *(Myrica cerifera),* dahoon holly (Ilex *cassine),* buttonbush *(Cephalanthus occidentalis),* Virginia *willow (Itea virginica)* and numerous other species.

Cypress domes, sloughs and strands are quite common throughout the north and to a lessor extent the central Florida phosphate regions. Many show successional trends and the effects of earlier logging to the extent that cypress now co-dominates with other tree species, some having only remnant cypress trees. When the dominance of cypress gives way to other species, especially in riverine floodplain swamps, the community is classified as a mixed hardwood swamp.

Mixed hardwood swamp (FLUCC-630) - When hydroperiods are short to moderate, inundation is moderate, fire frequency is low, and ground topography is relatively rough., the diversity of plant species that can colonize, survive and grow is richer. Mixed hardwood swamps have the highest diversity of the forested wetland communities, primarily as a result of the variation in hydrologic regimes of "micro-sites" within the wetland.

The canopy in these wetlands is a rich assemblage of hardwood species and cypress such that no single species dominates. Canopy species include: red maple *(Acer rubrum)*, water tupelo *(Nyssa aquatica)*, swamp black gum *(Nyssa sylvatica* var. *biflora)*, sweet gum *(Liquidambar styriciflua)*, bald cypress *(Taxodium distichum)*, pond cypress *(Taxodium ascendens)*, pop ash *(Fraxinus caroliniana)*, Florida elm *(Ulmus americana var. floridana)*, cabbage palm *(Sabal palmetto)*, sweet bay *(Magnolia virginiana)*, and loblolly bay *(Gordonia lasianthus)*. The understory is similar to cypress swamps.

The preponderance of mixed hardwood swamps are associated with the riverine swamps of the floodplains of streams and rivers of the regions, although there are numerous isolated wetlands that resemble cypress domes or strands but, because of hydrologic conditions, or past logging, have mixed canopies.

Hydric hammocks (FLUCC-617) - Soils in hydric hammocks are generally shallow and sandy, and limestone (either in bedrock or in nodules in the soil) is most often present (Vince et al. 1992). Hardpans (weakly cemented Bh horizons) do not occur in hydric hammocks, but clay layers that support surficial water tables occur in some hammocks (Vince et al. 1992).

Hydroperiod and flooding frequency in hydric hammocks are less than in mixed hardwood swamps. Sources of water to hydric hammocks include groundwater seepage, rainfall, stream overflows, and aquifer discharge; groundwater seepage from uplands is the major source of water for many hydric hammocks found bordering floodplain swamps. Hydric hammocks are quite diverse, with a richness that rivals mixed hardwood swamps. Common species include live oak *(Quercus virginiana)*, swamp laurel oak *(Quercus laurifolia)*, water oak *(Quercus nigra)*, sweet bay *(Magnolia virginiana)*, red maple *(Acer rubrum)*, red cedar *(Juniperus silicicola)*, cabbage palm *(Sabal palmetto)*, loblolly pine *(Pinus taeda)*, blue beech *(Carpinus caroliniana)*, sweet gum *(liquidambar styraciflua)* and Florida *elm (Ulmus americana Var. floridana).*

Wet prairies (FLUCC-643) - This community is often found surrounding forested wetlands in a transitional zone from several meters to as much as 50 meters wide, and in isolated depressions. Wet prairies are essentially treeless wetlands inundated for short periods of time, and often ravaged by fire. Wet prairies often occur on mineral soils and do not exhibit accumulations of organic matter. However, when fire is not a recurrent element, minor organic accumulations may occur. Wet prairies are maintained by high water tables, infrequent inundation, and frequent fires, as well as heavy grazing.

St. Johns wort *(Hypericum fasciculatum)* is often the only woody species present. Sometimes on the drier margins dense stands of wax myrtle *(Myrica cerifera)* may grow to heights of 4 meters or more. There is a wide variety of herbaceous species associated with wet prairies including: grassy arrowhead *(Sagittaria graminea)*, pipewort *(Eriocaulon decangulare)*, capitate beaked-rush *(Rhynchospora microcephala)*, mermaid-weed *(Proserpinaca pectinata)*, *yellow*-eyed grass *(Xyris caroliniana)*, bloodroot *(Lachnanthes caroliniana)*, red ludwigia *(Ludwigia repens)*, Virginia chain-fern *(Woodwardia virginica)*, Baldwin's *spikerush (Eleocharis baldwinii)*, maidencane *(Panicum. hemitomon)*, water smartweed *(Polygonum punctatum)*, *Pluchea rosea*, *Cyperus* spp., and water pennywort *(Hydrocotyle umbellata)*.

Shallow marshes (FLUCC-641) - Where inundation is more frequent, depths of inundation are around 0.5 meters, and fire is somewhat less frequent than on wet prairies, shallow marshes are common. These are of two main types. With deeper inundation, longer hydroperiods and accumulations of organic matter, broad-leaved marshes (sometimes called flag ponds) occur dominated by the following species: pickerelweed *(Pontederia. cordata)*, arrowhead *(Sagittaria* spp.), fire flag *(Thalia geniculata)*, and cattail *(Typha* spp.). Dominant in the grassy shallow marshes are sawgrass *(Cladium jamaicense)*, *spikerush (Eleocharis cellulosa)*, soft *rush (Juncus effusus)*, bulrush *(Scirpus* spp.), maidencane *(Panicum hemitomon)*, to name but a few.

Shallow marshes are common throughout the central Florida phosphate region, where they appear as isolated flatwoods marshes and sometimes as the headwaters of small streams.

Deepwater marshes (FLUCC-644) - Where hydroperiods are long, and depths of inundation greater than 0.5 meters to a much as 1 m., deepwater marshes prevail. Often found as deeper pools within other wetland systems (including forested wetlands) they are usually dominated by free-floating plants such as water hyacinth *(Eichhornia crasspipes)* and water lettuce *(Pistia stratiodes)*, or rooted aquatic plants such as water lily *(Nymphaea odorata)* if nutrients are high, and spatterdock *(Nuphar luteum)* in lower nutrient conditions.

REVIEW OF THE LITERATURE AND RELATED WORK

In this sub-section, a review of the literature concerning previous studies of vegetation in constructed wetlands is given. Of specific importance and treated separately was a review of "mulching" and "nuisance and exotic species." Two final sections review wetland functions and values and success criteria as they relate to constructed wetlands.

VEGETATION STUDIES ON CONSTRUCTED WETLANDS

One of the first evaluations of wetlands and reclamation was conducted by Odum et al. (1983) in a project titled "The interaction of wetlands and phosphate mining." Numerous studies of the varying landforms generated by mining, of wetlands impacted by mining, and of developing wetland communities on clay settling areas were undertaken. Later, in follow-up research, Rushton (1988) evaluated the wetland communities that develop naturally and with active reclamation on clay settling areas. Studying succession clay settling ponds, Rushton (1983,1984) noted that for the first 30 years, community structure and biomass increased over time as herbaceous vegetation was replaced by shrubs, which were replaced by trees. However, trees, seedlings, and species diversity show a decline after 30 years, indicating some factors may be retarding succession. Willow communities in older sites (60 years old) suggest arrested succession that might be caused by widely fluctuating (1-2 meters) water levels and the absence of a seed source. Since vegetation appears to represent a response to the moisture regime, inundated water levels would not be suitable for hardwood communities. In later studies, Rushton (1988) observed that during succession on clay settling areas vegetation organized itself along a moisture gradient. Also, succession showed rapid colonization by early successional species, slow invasion by wetland generalists when a seed source was nearby, and few trees of more specialized climax communities.

Clewel (1981) described vegetation restoration techniques for reclaimed lands which included techniques for wetlands reclamation and some data on "success". Robertson (1985) provided a comprehensive description of wetlands reclamation projects throughout the regions. Erwin et al (1984) presented some data on forested and marsh wetland reclamation, and later Erwin and Best (1985) evaluated development of a reclaimed marsh community.

A study of reclaimed wetlands and some controlling influences was conducted by Bersok (1986, 1990). The interaction of *Typha* with two tree species and the relationships between marsh establishment and increase in cover as they relate to *Typha* were studied. She found that there was no significant difference between seedling success, after 18 months of growth, in plots where cattail (Typha spp.) were cleared and control plots where cattail were not cleared.

Studying species interactions, Dunn (1989) evaluated species composition on several reclaimed marsh transects and the effects of mulch on percent cover. He showed that newly established seed banks contain only wind-dispersed early successional species; but that late successional marsh species can be added as an instant seed bank through mulching with wetland muck. Marsh development was monitored over 4 years and different communities developed in mulched and unmulched sites. Dunn also studied upland succession and found that weeding of plots enhanced growth of planted tree seedlings.

In a pilot project with the EPA, Brown (1991) evaluated 9 created herbaceous wetlands through comparisons with natural wetlands in northern Hillsborough county. Species richness was greater in created wetlands than natural ones and had greater variation within the sampled sites. With the exception of one site, the number of species planted in constructed wetlands was less than 10% of the total number of occurring species. The effect of mulching on species richness was evaluated, showing that wetlands with mulch had nearly 80% more wetland species than did unmulched sites.

Brown and Tighe (1991) reported on a comprehensive research project funded by FIPR that included detailed data on the vegetation and physical features of Florida ecological communities and reclaimed lands. In that report, Davis et al. (1991a) provided detailed vegetation data on native Florida wetlands of the phosphate regions including species composition, topographic characteristics, hydrology, and soils. Gross (1991) studied native floodplain vegetation of small streams developing 12 typical vegetation types (associations of tree species) using cluster analysis. Dividing small streams into headwaters, midreaches, and lower reaches, she summarized species distributions by reach using importance values. Davis et al. (1991b) evaluated growth and survival of planted tree species on eight reclamation projects: three were constructed to resemble streams, three were lake border swamps, and two were more similar to marsh fringe swamps. Tree survival and growth were related to depths of inundation and soil moisture. Ground surface profiles and soil chemistry characteristic of reclaimed wetlands were also measured.

WETLAND MULCHING

The term mulching has become the term used by the phosphate industry to describe the practice of spreading organic soils (sometimes called muck or peat) from a wetland over the substrate in a newly constructed wetland. Usually the muck is obtained from a wetland that is to be mined. The thickness of organic soils that are spread vary from site to site, as does the time between “harvesting” and application, Protracted stockpiling of organic soils probably reduces the number of viable seeds, (unpublished data, M.T. Brown).

The practice of mulching has been advocated in reclamation for a number of years (see Dudeck et al., 1970; McDonald, 1990; TVA, 1980; Schuman et a1., 1991), although most uses of mulching were in dry land reclamation to enhance soil characteristics and stabilize erodible areas.

It has been suggested that mulching enhances growth and survival of planted species, and indeed in some studies enhanced growth and survival has resulted on upland sites (USDA, 1980; Schuman et al., 1991). Brown, et al., (1985) studied use of peat (collected from a donor site) as a mulching material in wetland reclamation after phosphate mining. They found that as thickness of application increased, submerged and transitional wetland vegetation species experienced increased survival and growth, whereas upland species experienced decline in survival and growth. The highest growth was achieved when peat thickness averaged 16 cm Biomass was highest at sites where peat was spread uniformly. Diversity was greatest at sites where uneven distribution of peat occurred as a result of increased topographic variation. On the other hand, some studies have shown little or no influence on tree seedling growth and survivability between sites that were mulched and sites that were not. Rushton, in several studies, (1983, 1988 and Ruston 1991 [in Odum et al.. 1991]) found no significant difference in growth and percent survival between seedlings that received mulch treatment and those that did not. The suggestion was made that soil factors (moisture, pH, etc) may be more important in determining survival and growth. Studying mulched and unmulched marsh transects, Dunn (1989) showed that there were significant differences in establishment of Pickerelweed *(Pontederia cordata)* on mulched versus unmulched sites, and that cattail *(Typha spp.)* became well established on unmulched sites, but lagged in colonizing those areas with well established stands of pickerelweed.

Time of collection and application of mulch is probably crucial in so far as their seed bank potential is concerned. Rushton (1988) found timing to be essential in her study of mulching and wetland reclamation. Her report compared different types of mulch, including forest litter from a donor site and hay purchased from a feed store, against an unmulched control site. She stated that more desirable results may have been attained if "considerably more attention had been paid to the time of collection [of litter mulch from the donor site] and the type of donor site selected". Bersock (1986) found time of litter transfer to be correlated with germination of seedlings. This correlation was attributed to the difference in seed volume and species diversity of the seeds in the litter seed bank as affected by the seasonality.

CONTROL OF NUISANCE AND EXOTIC SPECIES

That nuisance/exotic species are colonizing reclaimed lands is evident by several recent studies. In Doherty's 1991 study of 35 reclamation sites (5 clay settling areas and 30 mining spoil mounds), 163 species were found of which 11 were listed as nuisance/ exotic (based on Florida Exotic Pest Plant Council) as follows: *Abrus precatorius, Dioscorea bulbifera, Lantana camara, Schinus terbinthifolius, Cinnamomum camphora, Melia azedarach, Imperata cylindrica, Psidium guajava, Ricinus commums, Sesbania emerus, Urena lobata.* Rushton (1988) found 5 nuisance/exotic species *(Cinnamomum camphor, Schinus terebinthifolius, Lygodium japonicum, Lantana camara, Urena lobata)* in varying densities from 1 to over 600 occurrences *(Lygodium japonicum)* per 100 meter transect. There has not been a systematic study of the occurrence of exotics on reclamation sites, something that may be an important area of future research, especially as it relates to long-term success of reclamation efforts.

Little documented evidence of the effectiveness and impacts of exotic/nuisance species control exists in the literature. A small-scale study performed by Mobil (1985) suggested that the pre-emergent herbicide Karmex at low application rates can significantly increase in seedling growth with only moderate effect on seedling survival. This study also suggests that Karmex application to an older site may have little effect on perennials, but may significantly reduce competitive growth of annuals. Studying the effect of removal of herbaceous vegetation on growth of planted tree seedings, Paulic (1991) found no discernable long-term benefits to the success of seedling establishment by removing herbaceous ground cover at the time of planting. Ground cover consisted of *Typha, willow,* and primrose willow.

Buele (1979) found the use of herbicide sprays (Amitrol T, Radapon, and Dowpon) in water depths of 2.5-30 cm to be effective at controlling *Typha latifolia. The* time of spraying is important in light of the carbohydrate storage cycle and should correspond to the period when the bulk of the food is being manufactured in the leaves and is being transported underground to form the new rhizomes.

WETLAND FUNCTIONS AND VALUES

Section 404 of the clean water act provided a generalized list of wetland functions that should be protected or restored. These are as follows [from (33CFR 320 (b)(2)]:

- Food chain production
- General habitat
- Research, education, and refuges
- Hydrologic modification
- Sediment modification
- Wave buffering and erosion control

- Flood storage
- Ground water recharge or discharge
- Water purification
- Uniqueness/scarcity

The literature on wetland functions and values is relatively consistent in naming habitat, hydrologic, and recreational uses as key functions. Reppert et al. (1979) categorized values into two broad classes: primary functions and cultural values. They further subdivided each class in several functions including 8 primary functions (food chain production, habitat values, study areas and sanctuaries, hydrologic support, shoreline protection, water storage, groundwater recharge, water purification) and 5 cultural values (commercial fisheries, agriculture, recreation, aesthetics, other special values). Lonard et al (1981) reported 5 functions, including habitat, hydrology, recreation, agriculture/silviculture, and heritage. In developing a methodology for wetland functional assessment, Adamus and Stockwell (1983) listed 10 wetland functions including: ground water recharge/ discharge, flood storage, shoreline anchoring, sediment trapping, nutrient retention, food chain support, fish habitat, wildlife habitat, active recreation, and passive recreation. Roman and Good (1983), in a study to protect wetlands of the New Jersey Pinelands, listed hydrologic values (storm water retention, ground water interactions), water quality maintenance, food web values (primary and secondary production), habitat values (fish, birds and mammals, and threatened and endangered species), and cultural values (wetland harvest and socio-cultural values). In a summary of wetland evaluation methodologies, the EPA (1984) reviewed the literature concerning evaluation techniques of others, summarizing wetland values and functions into 4 categories: habitat functions, hydrologic functions, agricultural/silvicultural functions, and recreation and heritage functions.

In a study of Seminole County, Fla., wetlands, Brown and Starnes (1983) developed a functional assessment of nine wetland parameters within two functional areas. The following is a summary of those parameters and basis for ranking of wetlands for each parameter.

<u>Physical functions.</u> Of importance in this category are the functions that wetlands perform with regards to water quality enhancement, flood protection, water storage, and potential for recharge of potable water. Following each function are ranking criteria for wetland types.

1. Water Quality Enhancement--This parameter is measured as the assimilative capacity or nutrient uptake capacity for nitrogen and phosphorus of the wetlands, expressed as potential percent reduction in nutrient concentration between input and output waters. Values are expressed as percent removal under ideal conditions. Data are given in terms of potential percent removal instead of in pounds per acre since there are many variables that may significantly effect any particular wetland's ability to immobilize nitrogen and phosphorus, the most important of which are size of wetland and loading rate. The rankings are as follows:

    90- 100% = High Value;
    60-89% = Medium Value, and

> 59% = Low Value.

2. Hydroperiod--Related to water quality enhancement, hydroperiod is the period of inundation of a wetland. Wetland communities are adapted to varying depths and periods (length of time) of inundation; some have standing water nearly the entire year, while others have standing water for only a few months during the wettest time of the year. Those wetlands that have long hydroperiods are generally more evergreen, while those adapted to shorter hydroperiods tend to have a dormant season that corresponds to dry times of the year. Communities that are adapted to long hydroperiods are more suitable as interface systems and have greater potential for year-round nutrient uptake. The rankings are as follows:

   Long hydroperiod (300-356 days) = High Value;
   Moderate hydroperiod (200-299) = Medium Value; and
   Short hydroperiod (100-199 days) = Low Value.

3. Evapotranspiration--A major attribute of most wetlands is their ability to store water and slowly recharge groundwater. Wetlands, through shading of surface waters and the blocking of evaporative breezes, reduce potential evaporation from surface water stored within. Thus wetlands that have lower evapotranspiration conserve water and allow for greater groundwater recharge. The rate of evapotranspiration directly affects the availability of surface water and thus groundwater recharge. Wetlands with high evapotranspiration leave less water available as surface water to recharge superficial groundwaters and to contribute to surface water flow within a water basin, and their value for water conservation is low. Wetlands with low evaporation rates conserve water, making it available for longer periods of time into the dry season and increasing the potential for groundwater recharge; their value for water conservation is high. The rankings (mm H_2O day^{-1}) are as follows:

   Low evapotranspiration rate (<4.0) = High Value;
   Moderate evapotranspiration rate (4.0-5.6)= Medium Value; and
   High evapotranspiration rate (5.6) = Low Value.

4. Water Storage Capacity--The capacity for surface water storage is related to two parameters of importance. The first is the normal storage capacity during the wet season when waters accumulate and are stored, providing for potential recharge and holding water tables higher. The second is stormwater storage, providing flood protection. Thus this function has two aspects.

   4a. Normal water storage capacity is the depth of normal water during average rainfall years. The rankings are as follows:

   High storage capacity (>0. 5 m depth) = High Value;
   Moderate storage capacity (0.2-0.5 m depth) = Medium Value; and
   Low storage capacity (<0.2 m depth) = Low Value.

4b. Stormwater storage. For short periods, much deeper inundation is possible for the purposes of stormwater storage for short duration. The depth and duration of stormwater storage are different for each type of wetland, depending on tolerance ofvegetation to flooding. The rankings are as follows:

High inundation potential ($\geq$ 2.0 m depth) = High Value;
Moderate inundation potential (1.0- 1.9 m) = Medium Value; and
Low inundation potential (1 m depth) = Low Value.

5. Recharge Potential--The potential for recharge of deep aquifers from wetland communities is relatively small; however, it is believed that recharge is an important function of wetlands as they store water during the wet season and slowly recharge the superficial groundwater systems during dryer periods. Thus, they conserve water and through their slow recharge functions maintain higher superficial groundwater levels than would be possible without the presence of wetland communities as an integral part of the landscape mosaic. The rankings ($m^3 m^{-2} yr^{-1}$) are as follows:

High recharge potential (>0.7) = High Value;
Moderate Recharge Potential (0.3 - 0.7) = Medium Value; and
Low recharge potential (<0.3) = Low Value.

Biological functions. Biological functions are those functions that contribute to wildlife values either directly as in the case of food chain support and habitat or indirectly as in the case of life form richness. There are three such functions or values of importance for the ranking of wetlands.

1. Wildlife Utilization--Utilization is measured as the species richness of wildlife that is characteristic of each community. It is the summation of the number of amphibian, reptile, mammal, and bird species commonly found in each wetland community. The rankings are as follows:

High species richness (>80 species) = High Value;
Moderate species richness (50-79 species) = Medium Value; and
Low species richness (<50 species) = Low Value.

2. Life Form Richness--Life form richness is the physical structure or growth habit of a plant. Height, branching pattern, and leaf shape are major features contributing to form. Five life forms and 18 subforms are recognized. The forms represent obvious divisions of vegetation: trees, shrubs, emergents, surface plants, and submergents. Many studies have shown that differences in life form are more important than differences in plant species when analyzing wildlife habitat. Each wildlife species is adapted primarily to one or a complex of life forms and, as a result, wildlife diversity in an area is closely related to life form diversity. The rankings are as follows:

High life form richness (4-5 forms) = High Value;
Moderate life form richness (3 forms) = Medium Value; and
Low life form richness (2 forms) = Low Value.

3. Gross Primary Production--The gross primary production of a community is a measure of total sunlight "fixed" as plant matter during the growing season that may become food for consumers of all types. Since gross production is the first step in the food chain, higher gross production leads to longer and more complex food chains. The rankings (grams organic matter/m^2 day^{-1}) are as follows:

   High gross production (>50.0) = High Value;
   Moderate gross production (21-49) = Medium Value; and
   Low gross production ($\leq$ 20) = Low Value.

Our survey of success criteria found general agreement concerning wetland functions that should be monitored. In the most general sense, those that are of importance to evaluating success of constructed wetlands on phosphate mined lands were hydrologic and habitat functions. These can be further subdivided into ground water recharge/discharge, water storage, water quality maintenance, food chain support (gross primary production), and habitat value (life form richness).

SUCCESS CRITERIA

Success criteria can be both quantitative and qualitative. Examples of quantitative success criteria are the attainment of certain percent cover, tree height, crown cover, species richness, etc. Qualitative criteria might be such things as whether the effects of mining are concealed, vegetation is reproducing naturally, attainment of a multi-species assemblage similar to undisturbed areas, and so forth. Our survey of the literature revealed a paucity of information on success criteria. D'Avanzo (1989) proposed six criteria for evaluation of long-term success of constructed wetlands, many of which were based on comparisons with naturally occurring wetlands (reference wetlands). They include: (1) comparison of vegetative growth characteristics, (2) habitat requirements of plants invading the created site, (3) success of planted species, (4) comparison of animal species composition and biomass, (5) comparison of chemical analysis of soils, (6) Evidence of geologic or hydrologic change. D'Avanzo summarizes by suggesting that the following points are especially important in evaluating the success of constructed wetlands:

> 1) One to two years of monitoring is too short; Evaluations over as long a period of time as possible (10-20 years) are desirable; 2) Vegetation characteristics are useful but do not necessarily indicate function; at a minimum, several parameters should be used (e.g., belowground/aboveground biomass comparisons); 3) Chemical/physical aspects of wetland soils are also useful in evaluating trends in created sites; 4) Local reference wetlands are vital for comparative purposes; and 5) Wetlands of certain types should not be created casually in that they may have failed in the past, or because we know little about such types (e.g., forested wetlands).

Erwin (1989) provided quantitative methods for evaluating various parameters of wetland ecosystems, including: hydrology, vegetation (biomass and productivity), macroinvertebrate populations, and wildlife utilization. Qualitative evaluation based on vegetation mapping, post construction monitoring, fixed point photographs, data from rain and staff gauges, observed wildlife utilization, and "qualitative sampling" of the fish and macroinvertebrates. Success criteria were presumably based on agreement between measured values in constructed wetlands and reference wetlands.

A survey of those permits and annual reports by the phosphate industry to which the research team had access has revealed a wide variety of criteria for success. Table 6-1 provides a summary of these data. The most commonly used success criteria were:

1) a community similarity of 0.6 (Morisita's index) and 75% of the species richness of a reference wetland,
2) average density of 400 trees per acre above the herbaceous stratum,
3) tree canopy cover greater than 33% of total area and of an acre or more with less than 20% canopy cover,
4) ten percent or less cover by *Typha*, *Ludwigia peruviana*, and other exotics,
5) eighty percent or more cover by non-nuisance, non-exotic, wetland species

Relatively specific quantitative success criteria for four Occidental Co. sites in the north Florida phosphate region were developed to assess success over a period of 4 years. There were two year milestones for the following parameters:

Tree density (trees/acre)
Diversity (% *Taxodium*, % *Nyssa*, % other)
Growth rate (% increase)
Ground Cover (areal extent)
Seed Production (% of *Taxodium* producing seed)
Hydrology (one site had inundation criteria)
Water quality (two sites were required to meet class III waters)
Wildlife abundance (using macroinvertebrates)
Wildlife Richness (using macroinvertebrates)
Soils (% organic matter in top 5 cm)

There continues to be considerable debate and few new answers concerning success criteria. Indeed, most of the literature, while suggesting that standard measures of success are not adequate, calls for a new method of assessing success that, in the words of Erwin (1989), " . . . . must adequately characterize and evaluate the functions of the created or reference wetland given the limitations of time, budget, type of wetland, size of wetland, context, degree of alteration from original wetland, location, and expertise of the investigator." On the contrary, what is most often used in the regulatory arena are quantitative measures of individual parameters that deal more with community development and how well the constructed wetland measures up to either a specific reference or "idealized" natural wetland. Some measures such as seed production suggest concern with persistence, yet few measures are concerned with community level persistence such as invasibility and long-term succession. Long-term trends require long-term data sets, and often there is considerable pressure on regulatory agencies to make "success" judgements too quickly.

Table 6-1. Success criteria by site and company

Company/Site #	Site Name	80% or more cover by natural veg.	Similarity of 0.6 and 75% of richness	Comparable similarity and diversity	Tree Density / Acre > 400	Tree Density / Acre > 200	Tree cover >33% and not < 20% in any area	10% or less cover by exotics	Procedures have resulted in multispecific assemblage	Vegetation is repr. naturally
AG 1P	Payne Creek	X	X		X		X	X		
AG 3	AGR-FG-84(5)		X		X		X			
AG 4	8.4 Acre 7 years			X	X				X	X
AG 5	2.3 Acre	X	X					X		
AG 6	Dragline Crossing									
AG 7	Hardee Lakes	X	X		X		X			
AG 10	Morrow Swamp									
AG 13P	Big Marsh	X	X		X		X	X		
AG 15P	Preservation Drain	X					X	X		
AG 18	Sec. 29 FT. Green									
AG 19	Sec. 29 FT. Green									
CF 5	Hickory Branch R7			X		X			X	x
CF 6	Hickory Branch R9			X		X			X	x
CF 7	Hickory Branch R10			X		X			X	x
MO 1P	Beulah Creek		X		X		X	X		
MO 2	George Allen Creek		X		X		X	X		
MO 3	Guy Branch		X		X		X	X		
MO 4	Bird Branch N and S		X		X		X	X		
MO 6	Consent Order 7984									
MO 7	Thirty-Mile Crossing				X		X	X		
MO 9	McCullough Creek		X		X		X	X		
MO 11	Gooch Creek		X		X		X	X		
MO 14	Sink Branch Recl. Area		X		X		X	X		
MO 17	Upper Myers Branch		X		X		X	X		
MO 18	Rocky Branch Upper		X		X		X	X		
MO 19	Lower Myers Branch		X		X		X	X		
MO 20	Rocky Branch Reference		X		X		X	X		
MO 21P	Peace River Dragline		X		X		X	X		
MO 25P	Section 23 Creek		X		X		X	X		
MO 27	SP4 Marsh part of FM-6									
MO 28	TF West of Plant									
MO 30	AMX-BF-82 Lake Br. Trib.		X		X		X	X		
MO 31	AMX-BF-1									
MO 32	AMX-BF-2									
MO 34	AMX-BF-6									
IMC 1	Hall Branch		X		X		X	X		
IMC 2	Jamerson Junior		X		X		X	X		
IMC 3	Wetland "G"				X		X	X		
IMC 4	Dogleg									
IMC 5	Alfalfa River Crossing "B"			X	X		X			
IMC 6	McMullen Branch Dragline									
IMC 7	Cemetery Branch		X		X		X	X		
IMC 8	Alfalfa River Crossing "A"									
IMC 9P	Section 15	X			X		X			x
IMC 10	The West of K6 Recl. Unit									
IMC 11	Sec. 1, 80 Acre Mitig. Site									
IMC 12	Horse Creek									
IMC 13	Hooker's Prairie	X			X					x
IMC 14	IMC-K-MC (2A) Unit H							X		x
IMC 15	NE Sec. 7/12 Reclaimed Stream	X	X		X		X	X		
IMC 16	Miles Grove Peanut	X	X		X		X	X		
IMC 18	Tadpole									
IMC 23	South of K6									
IMC 29	Bird Branch									
IMC 32	Section 6									
CAR 1	Hooker's Prairie	X	X		X		X	X		
CAR 2P	PR2	X	X		X		X	X		
CAR 3	SP6	X			X		X	X		
CAR 4	Bryant's Branch									
CAR 13		X		X				X		
CAR 18										
CAR 19										
CAR 23P			X		X		X	X		

P = FROM PERMIT ONLY

VEGETATION OF CREATED WETLANDS IN THE FLORIDA PHOSPHATE DISTRICT

Successful wetlands creation according to vegetative criteria is related to species composition, abundance, growth rates, reproduction, and persistence over time. During site visits it was apparent that most constructed wetlands had at least some vegetation that was characteristic of natural wetlands. During these site visits, no formal data were collected, but qualitative impressions of the vegetative community were recorded. The impressions gained were of the vegetative community for that moment in time and little if any evidence of the past was learned from the site visit. Thus data from monitoring reports conducted by industry for permit compliance, and previous studies of wetlands by a variety of scientists were compiled and analyzed to evaluate trends and long-term plant community development.

MATERIALS AND METHODS

EVALUATION OF VEGETATION DATA

To assess reclamation success of the vegetative component of wetlands created by the phosphate industry, data from two main sources were used: (1) data were extracted from monitoring reports kept by each company for individual sites, and (2) data from published reports by a variety of individuals. Obviously, these data varied in quality and quantity. Data from monitoring reports generally were not comparable between sites since very often different techniques were used to collect and evaluate it. Data were also often inconsistent from year to year on the same site, making it difficult to evaluate trends with time. To determine how useful the assembled data were, we developed a ranking system

The quality of data for each reclamation site was evaluated and ranked using a scoring system as follows:

- 0 - No data received
- 1 - Vegetation data with little useful information. Typically, data presented in these reports listed tree survival only and sometimes provided a list of herbaceous species. Data were mostly qualitative, while some quantitative data may have existed, but for only a few variables of interest (see below).
- 2 - Vegetation data with more information than category one, but with little detailed information. Data were somewhat qualitative with only minor amount of quantitative data for a few variables of interest.
- 3 - Vegetation data with some detailed information, but incomplete. Data was about 50% qualitative and 50% quantitative, covered more variables of interest, but were often incomplete, changing in completeness from one year to the next.
- 4 - Vegetation data were relatively detailed and complete, with greater than 50% quantitative. Numerical data were presented for tree species and herbaceous species (although sometimes herbaceous species were only listed).

5 - Vegetation data were detailed and complete for almost all variables of interest. Quantitative data were given for both woody and herbaceous species for at least 3 years.

In addition to monitoring reports by industry, we used data in published reports. These data were from a variety of sources and, as with the monitoring report data, they varied in quality. The intent was not to collect, data and develop a data base that could be subjected to statistical analysis, for it was well understood that the data were from such varied sources that no statistical evaluations would be possible. The intent was, however, to synthesize the available data and develop a "picture" of the vegetation within the communities and to look for trends in community development and persistence.

TRENDS IN VEGETATION

Data from the vegetation monitoring reports were used to evaluate trends in vegetation community development as they related to two main questions: 1) the present structure and composition of plant communities in constructed forested and herbaceous wetlands; 2) the relationship between vegetation development and site design and post mining treatments (effects of soil type, mulching, and control of nuisance species on vegetation growth and survival). A third question proved more difficult to address because of the paucity of long-term data: 3) the likelihood of plant communities to persist or change in the future.

Of the 164 sites visited, a total of 55 wetland sites had some data that could be used to evaluate vegetation. The data for these 55 sites were organized into a data base according to the variables of interest listed in Table 6-2. The data base was designed to evaluate the structure of plant communities within created wetlands, evaluate trends in community development, and evaluate the effects of various treatments on wetland establishment and growth. There were 40 variables for which descriptive and plant community data were sought for each site. The descriptive section of the data base consisted of 15 data categories used to record the company, permit number, and project name; etc. In addition, this section was used to categorize the wetland by type (forested, marsh, isolated, lake border, etc), the major soil components (overburden, sand tailing or clay settling areas), the total area of the site, and date monitoring began. Finally, construction and monitoring costs were included if available.

The plant community categories of the data base were designed to characterize community structure and evaluate trends in community development. Trends in herbaceous community establishment and development over time were addressed using categories ‘bare ground %", and “cover herbaceous % ” which listed percent bare ground and percent cover of herbaceous species for each year there were data. “Herbaceous species #," (number of herbaceous species) and “herbaceous species obl wet” (number of obligate wetland species) were used to evaluate species richness and the number of obligate wetland species on a given site compared to total species for each year there was data. By comparing percent cover over time of the five dominant species, “herbaceous species dom1” through “herbaceous species-dom5”, trends in community structure and species persistence were addressed, as well as dominance and persistence of exotic or

Table 6-2. Data Matrix Template

CATEGORY	CATEGORY	DATA / YEAR
DER PERMIT	BARE GROUND %	
COMPANY	COVER HERBACEOUS %	
PROJECT NAME	HERBACEOUS SPECIE OBL WET	
COUNTY	HERBACEOUS SPECIES #	
CONTACT PERSON	HERBACEOUS SPECIES DOM1%	
TELEPHONE	HERBACEOUS SPECIES DOM2%	
FAX #	HERBACEOUS SPECIES DOM3%	
WET. HERBACEOUS ACRES	HERBACEOUS SPEICIES DOM4%	
WET. FORESTED ACRES	HERBACEOUS SPECIES DOM5%	
OTHER	MARSH PLANTED SPECIES #	
WATER PROVIDED	REPRODUCTIVE STATUS	
OVERBURDEN	MULCH ADDED (SPREADING)	
SAND TAILING	MULCH DEPTH	
CLAY SET. AREA	NUISANCE SPECIES CONTROL	
TOTAL ACREAGE	METHOD OF CONTROL	
PRE CONST. MONITOR DATA	NUISANCE SPECIES #	
BASE LINE DATA COLLECTED	NUISANCE SPECIES % COVER	
TOTAL YEAR DATA	TREE ADDITIONAL SPECIES	
DATE PLANTING COMPLETED	TREE CANOPY COVER %	
MONITORING COSTS	TREE CONTAINER TYPE	
CRITERIA	TREE CROWN WIDTH CM	
ANNUAL GROW RATE	TREE HEIGHT CM	
% HERBACEOUS COVER	TREE SPECIES #	
% TREES COVER	TREES PER SITE	
DESIGN WATER LEVEL	TREE SPECIES % MIXTURE	
NUISANCE SPECIES #	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES % MIXTURE	
	TREE SPECIES SURVIVAL%	
	TREE SPECIES SURVIVAL%	
	TREE SPECIES SURVIVAL%	
	TREE SPECIES SURVIVAL%	
	TOTAL TREE SURVIVAL %	
	TOTAL TREES PER ACRE	
	MARSH WATER LEVEL CM	
	FORESTED WETLAND WATER LEVEL	

uisance species. “Planted marsh species,” a list of herbaceous species planted, was compared with natural recruitment to determine if these same species were likely to colonize and persist if not -planted.

To evaluate trends related to site treatments, several categories were used. Categories related to soil type (“overburden”, “sand tailing”, and “clay settling area”) were used to evaluate trends in vegetation establishment, growth, and persistence on different soil substrates. The category “mulch added” was used to evaluate the effect of adding mulch to created systems. And “mulch depth” was envisioned as a test to determine if mulch depth had an effect on vegetation; however, there were insufficient data on application depth. The “nuisance species #” category was used to determine the number of nuisance species and evaluate possible effects on community development and species richness of the developing vegetation community. "Nuisance species control” and “method of control” were included to evaluate the effectiveness of control and possible impacts on other herbaceous and woody vegetation when combined with percent cover of herbaceous species and tree survival and growth. Insufficient data were found to analyze method of control. “Tree container type” was used to evaluate container size effects on tree survival when combined with survival and growth rates.

Trends in forest community development were evaluated using the remaining categories. “Tree survival %” (data were listed by year) was used to determine trends in survival over time. Individual tree species survival was evaluated using the categories “Tree species > 90 % SP1 - SP5” and “Tree species < 50 % SP1 - SP5” (these categories listed trees by species that had greater and less than 50% survival during the period of record). “Tree height cm”, “Tree crown width”, “Tree canopy cover %”, “Trees per site” were used to evaluate trends in forest development over time. The category “Tree species % mixture” was used to determine what species were commonly used in wetland reclamation and the percent typically planted per site, as well as species richness.

STATISTICAL EVALUATION

In all cases, since the data set was relatively small, there was no control of data quality, and since data from a wide variety of sites were mixed, statistical evaluation was not possible. Instead data were graphed, some means were calculated, and trends were qualitatively surveyed. This is an extremely important point. In no cases were there sufficient data of consistent quality that statistical comparisons were possible. And while there were 55 sites for which we had data, there were often as few as 5 or 6 sites where sufficient data existed that trends for more than 2 or 3. years could be observed. Often, when we were graphing a variable by age classes, there were 10 to 15 sites a year old for which we had data, and decreasing numbers with age. We had only a few sites that were 5 years and older for which there were good data.

GRAPHS OF TRENDS

Graphs of data were constructed and means were calculated for a given variable using all sites for which there were data. Interpretation of means is problematic since there could be many factors affecting a given variable. None of these factors could be controlled, so it is difficult to identify the key reason for a trend over time. For example, changes in percent cover of herbaceous vegetation was determined using all herbaceous sites, but some were mulched, some were on overburden, and some may have had nuisance species controlled. None of these things were taken into account in the overall analysis, in which all sites were lumped together, but they were examined individually. In the overall analysis, we deduced a trend that might be loosely interpreted as a trend for the industry as a whole, more or less averaging conditions and treatments across all sites and all companies. While this is not rigorous statistics, we believe that it offers an overview that is a useful summary of the "state-of-the-art" of wetlands reclamation by the phosphate industry.

PERCENT CHANGE AS A WEIGHTED MEAN

As a means of understanding industry wide trends in wetlands growth and development, change over time for several parameters was calculated and graphed. The parameters included herbaceous cover, nuisance vegetative cover, herbaceous richness, herbaceous obligate richness, herbaceous cover in forested wetlands, tree survival, tree height, and tree crown cover. On each site for which there were data, the change in parameter from year to year was calculated. Three indices were calculated from these data. First, the mean change per year was calculated by averaging all changes for all sites by year. Second a weighted change was calculated by multiplying change at each site by the sites area, summing weighted changes, and then dividing by the total area of all wetlands. The third index was calculated as the second, except the largest and smallest wetlands were eliminated from the data. We called this index modified weighted change.

We chose to calculate all three indices, since a straight mean for all sites gives them equal weight whether they were 3 acres, or 3000 acres. The second index accounts for area, giving more weight to large wetland sites and less weight to the smaller ones. The third index eliminates the largest and smallest percent change, as a test of the index, to see how much the weighted factor is influenced by the largest and smallest changes. Some sites had negative change for a year; others had extremely large positive changes from one year to the next.

RESULTS AND DISCUSSION

A total of 178 sites were visited by the project team (see Figure 6-1 and Appendix 6A). About sixteen of the visited sites were natural, non-mandatory, or other lands that were not wetland reclamation sites. Data in the form of copies of permit monitoring reports and other reports were obtained from participating phosphate mining companies. The data have been surveyed, synthesized and entered into a database from which we have done evaluations of trends in ecosystem development and persistence. There were 130 reclamation sites that we could index by a DEP or DNR permit number . Of these 130 sites, we obtained vegetation data for only 55 sites or about 34% of the sites for which there was a permit.

Data that we received varied in quantity and quality. We rated the vegetation data on a scale of "0" to "5". The lowest rating ("0") meant that we have not received the data for the site. A "1" meant that we received some data, but it was vague, seriously incomplete, or qualitative. Ratings "2" through "5" represented increasing usefulness of the data received from the phosphate mining

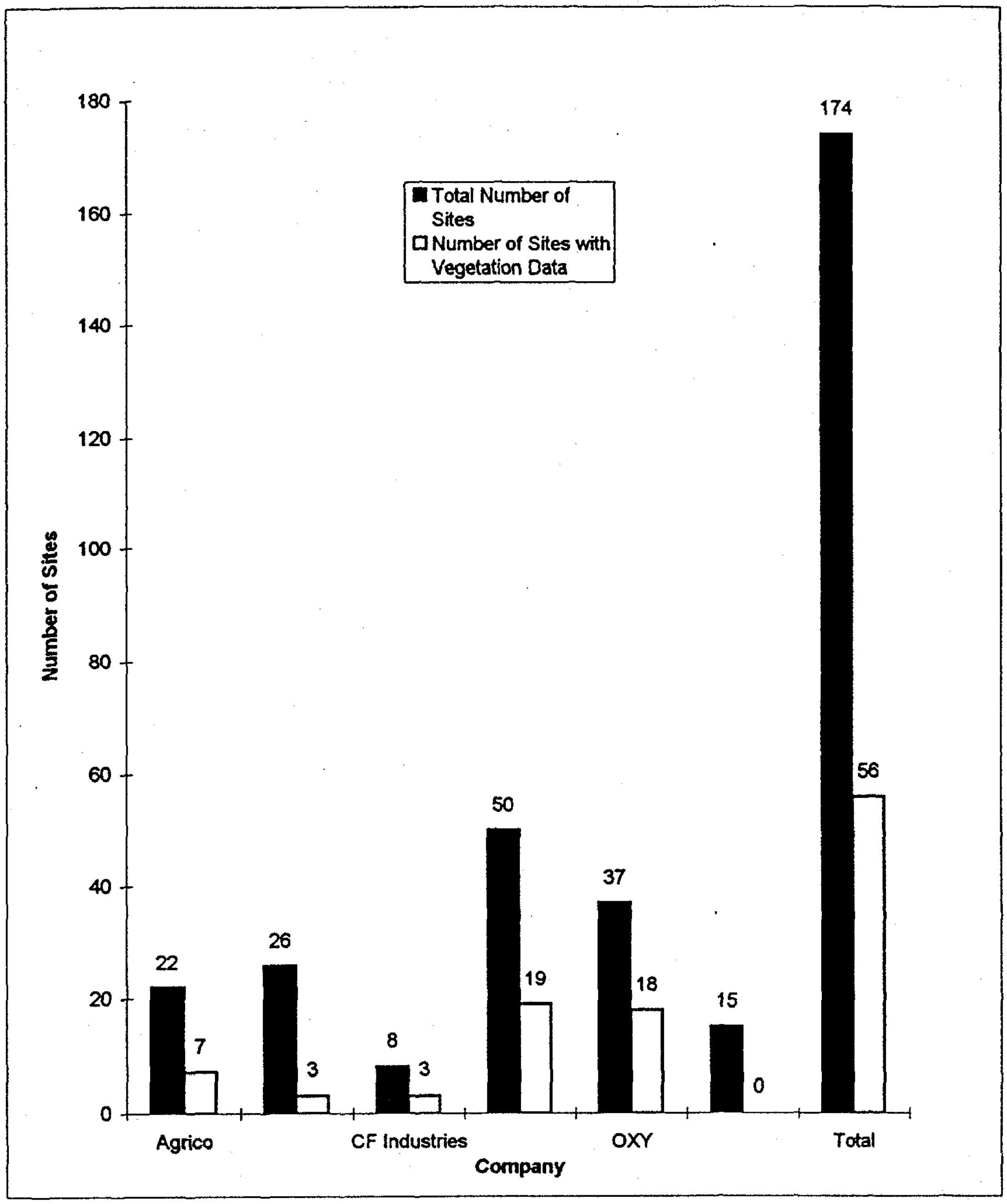


Figure 6-1. Total number of reclamation sites and number of sites with vegetation data (for the different companies).

companies. Vegetation data for 123 reclamation sites had “0” ratings because we have not received any information about them other than a name or permit number (see Figure 6-2). Some of these sites are not reclamation sites, but rather sites visited by the project team as special interest sites. Seven of the fifty-five reclamation sites for which we received data were rated as 1, “not useful.” Sixteen sites had partially useful data, sixteen sites had half useful data, twelve had mostly useful, and only four sites had data sets that were considered sufficiently detailed.

The age of sites for which we have data is somewhat problematic. Figure 6-3 shows the distribution of sites by number of years for which we have data. Thirteen sites had data for only 1 year, seven sites had 2 years of data, fourteen had 3 years, six had 4 years of data, two had 5 years, and thirteen sites had data for periods of time greater than 5 years. The longest data records were Agrico’s Morrow Swamp (10 years of data) and Mobil’s Sink Branch for which there was 9 years of data.

HERBACEOUS COMMUNITY DEVELOPMENT

Tables of data for each parameter that follows are given in Appendix 6B.

<u>Percent Cover with Time</u> - Forty--one sites were used for evaluating development of plant cover in herbaceous wetlands (see Table 6B-1). The distribution of sites by length of the data set is comparatively, very good. Six sites had data for 8 years or more, and twenty-four sites had data records of 3 years. Figure 6-4 summarizes data for percent cover of herbaceous communities. Methods of field data collection for this parameter can be grouped into two distinct approaches. On some of the sites, percent cover was evaluated using more than one stratum, and in others, only the ground stratum was used. In the first case, percent cover can be greater than 100%, while in the second, it can never be greater than 100%. Mean cover for sites using two strata increased from about 100% in the first year to a peak of about 126% in the seventh year and declined to about 113% in the eighth year. The one site having nine years of data exhibited an increase from 88% in the third year, peaking at 138% in the sixth year and then declining again to about 95% in the ninth year. Those sites using only the ground stratum (total percent cover =100%) exhibited increases in percent cover from an overall mean of about 71% in the first year to about 74% in the fifth year. Cargill’s Hookers prairie had cover of about 21% in the first year increasing to 69% in the fifth year. Three sites showed marked declines in percent cover, Occidental’s Grean area declined from 77% in the first year to 41% in the fifth year, Occidental’s McCullum Bay declined from 75% in the first year to 20% in the third year, and Occidentals Cabbage Head declined from 40% in the first year to 19% in the second year.

The longest data sets are for those sites where percent cover was collected over two strata. The trend is for herbaceous cover to hold relatively constant, although when the means for the eight years of data are compared, there is a peak in the 7th year and noticeable decline in the 8th year. The one site for which there are nine years of data exhibits a marked decline from the 6th through the 9th years. It is difficult to determine if the data for percent cover by herbaceous vegetation were collected in areas where trees were also planted. If this is the case, then the trend of declining cover may be explained by the increase in tree canopy cover. We could find nothing in the data sets to confirm or deny this assumption.

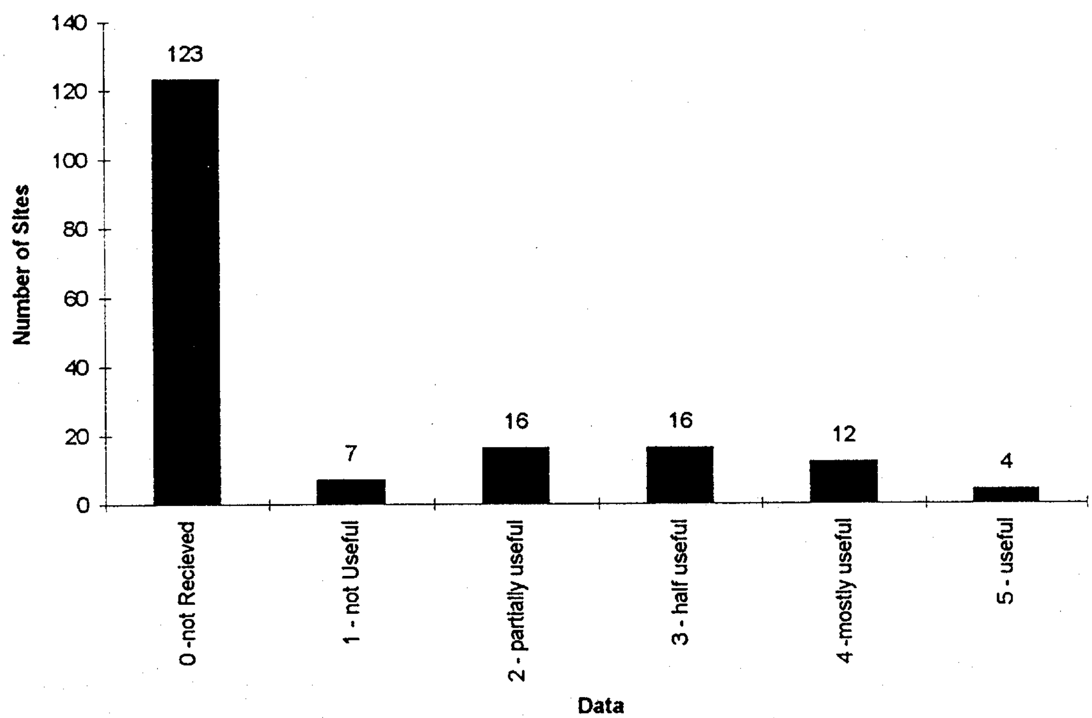


Figure 6-2. Quality of available vegetation data received from monitoring reports and company records.

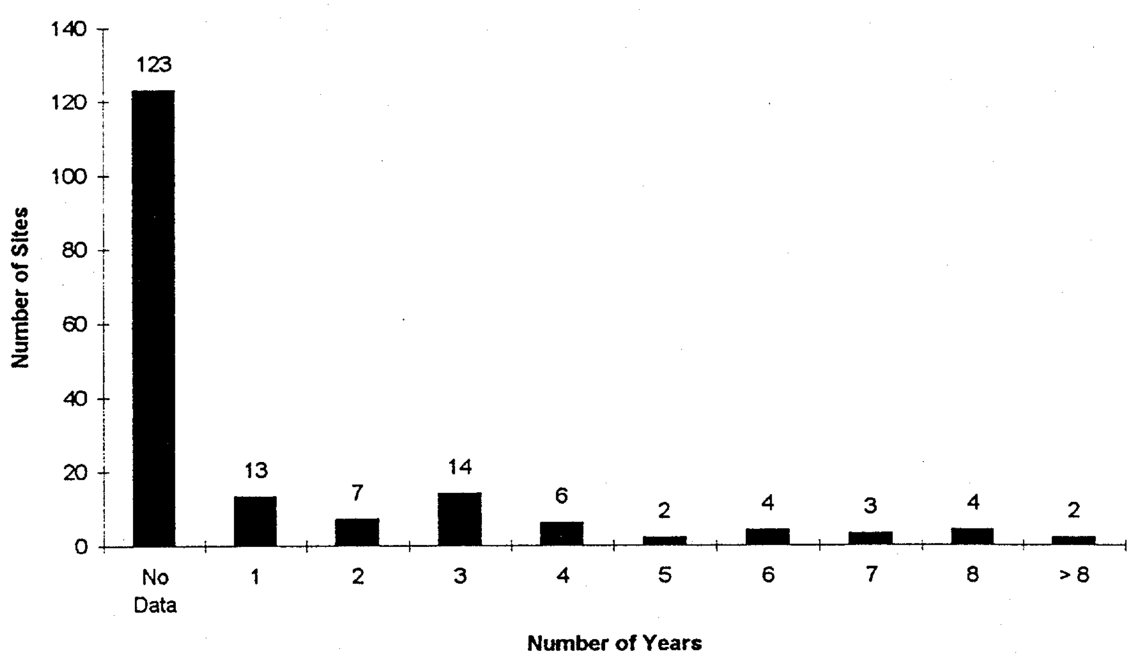
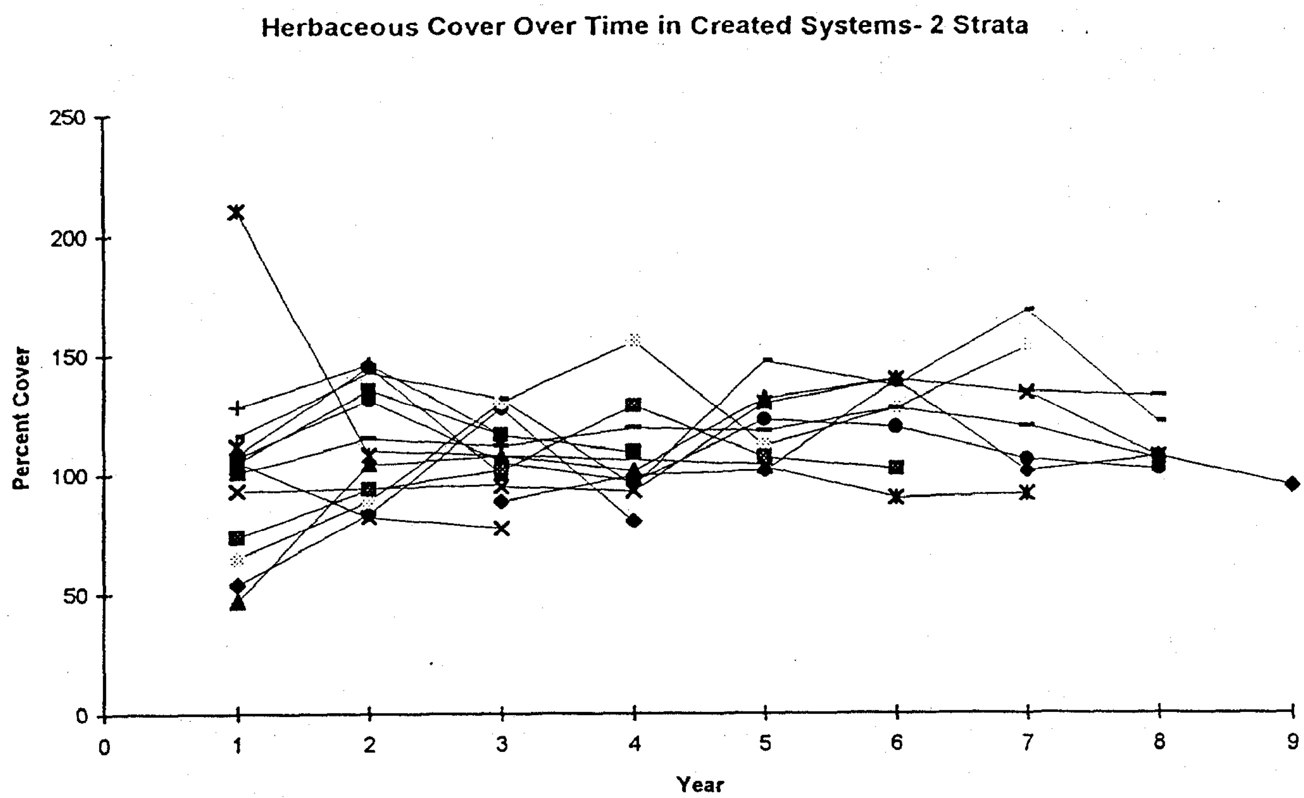


Figure 6-3. Number of sites and the length of time data has been collected



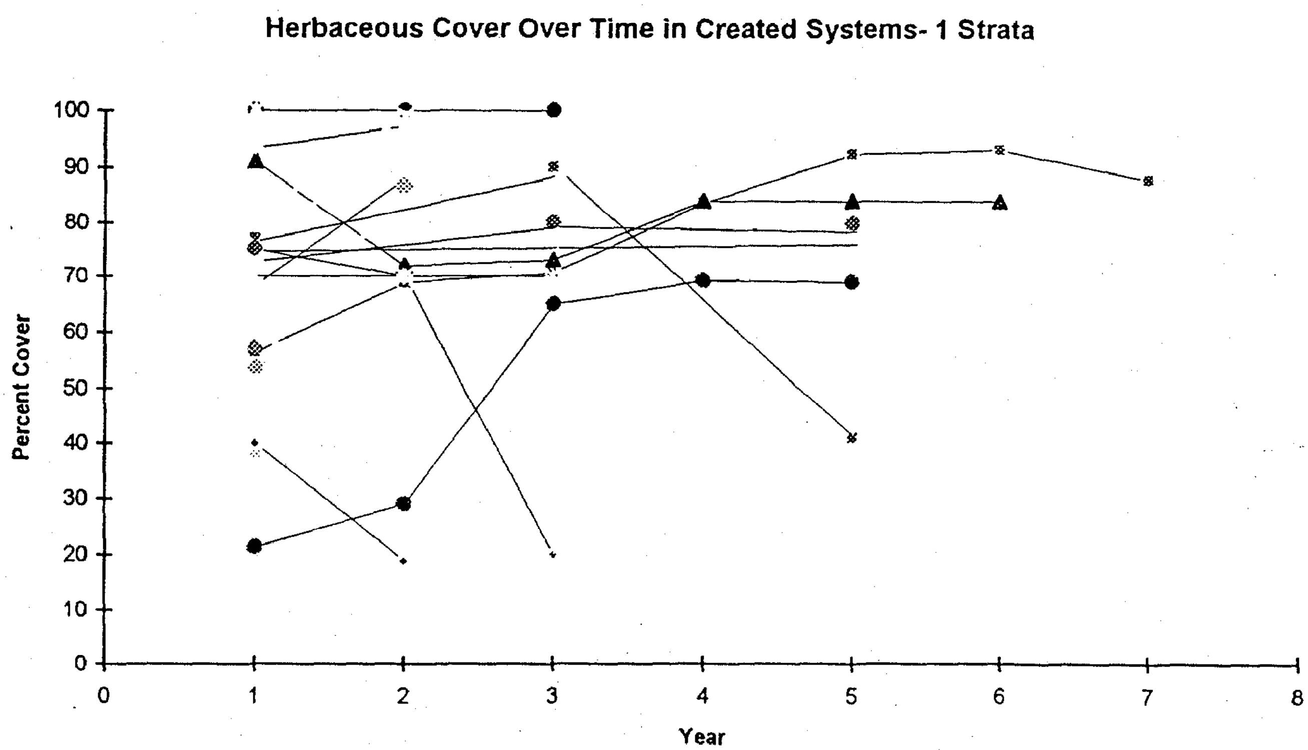


Figure 6-4. Percent cover in herbaceous wetlands over time.

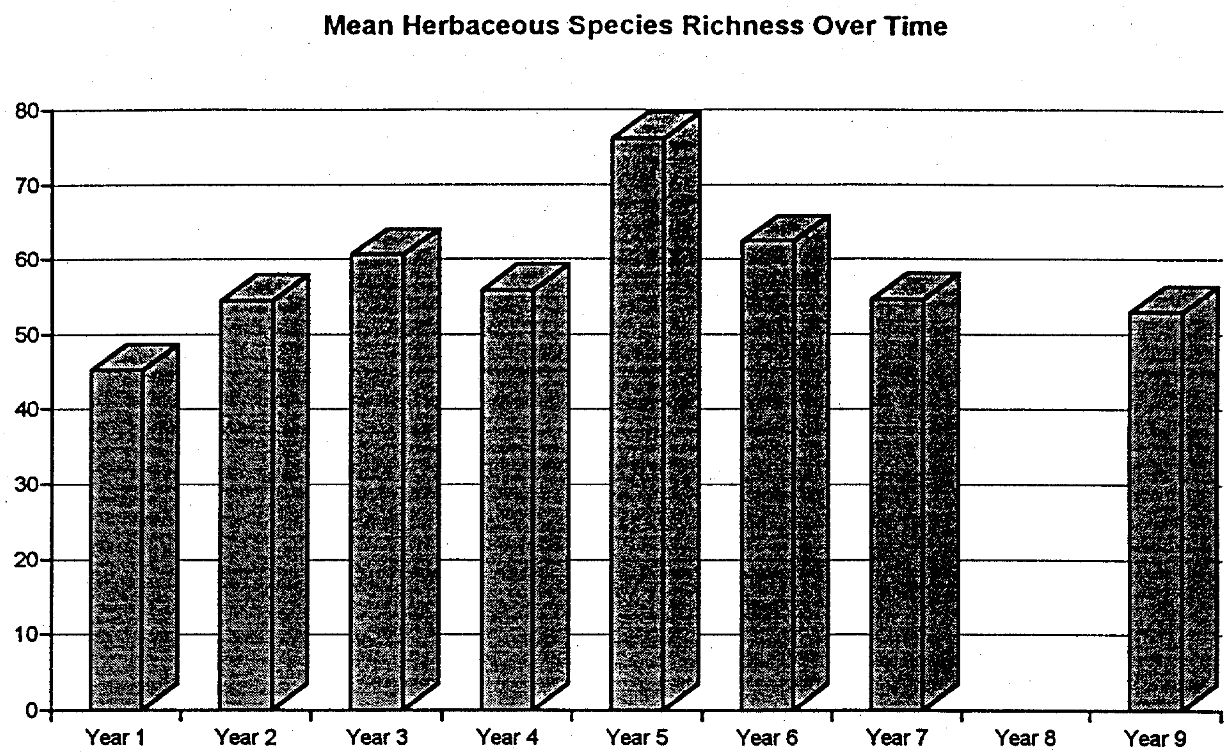
Species Richness - Overall species richness was evaluated on 34 sites. The data are given in Table 6B-2 and are summarized in Figure 6-5. Mean species richness for all sites over all years appears to be a little more than 50 species. When mean species richness for each year for all sites was graphed, there appears to be a increasing trend in richness, peaking in the 5th year and then declining (Figure 6-5, top). However, this is an artifact of the one site whose richness increased to 171 in the fifth year. When individual sites were evaluated (Figure 6-5 ,bottom), the trend is not so clear. Several sites exhibited declines, several showed impressive increases in richness, and most remained about the same. Overall, increases in species richness from year to year only slightly out-numbered sites where there were decreases. The situation suggests that these marsh communities are still in relatively early phases of community self-organization, but that long-term trends (7-9 years of data) would suggest that richness will remain at about 50 species per site.

Species Richness of Obligate Wetland Species - Figure 6-6 summarizes data for 32 sites for which data existed to determine the richness of obligate wetland species (data are given in Table 6B-3). Seven sites had only 1 year of data, six sites had 2 years of data, eight sites had 3 years of data, one had 4 years of data, two sites had 5 years of data, two sites had 6 years of data, two had 7 years and one site had 8 years of data. Overall, the mean obligate wetland species richness was about 25 species (or about half of the total species richness).

There is no strong pattern to the data when means for each year are compared. In the 3rd year 5 sites exhibited declines while 8 sites exhibited increases in obligate species richness. In the fifth year 2 sites declined while 4 sites exhibited increases. Three sites exhibited significant declines in obligate species richness beginning in the 3rd and 4th years. The mean decrease for all three sites was about 35%, while the mean for two sites where there were long-term data sets of greater than 4 years had overall declines of about 45% in the seventh year. The few sites with seven or eight years of data suggest a trend for obligate wetland species to decline over time, although one site exhibited an increase from the fourth through the seventh years (but declined from the first year by about 38%).

Species Used in Marsh Plantings - Data from 54 sites were evaluated in order to determine which species were most often used as marsh plantings. Many sites had no available information on which species were used, however 30% (16 sites) had species lists that could be compared. While some sites listed total number of species used, the species were not identified for most sites.

The relative importance of shrub species planted in marsh wetlands was minor; 10% of the marsh sites were planted in shrubs species. Figure 6-7 summarizes the most frequently used herbaceous species in marsh plantings, based on the number of sites that species were used. They were: *Pontederia cordata. and Sagittaria lancifolia.* The next most frequently used species were *Spartina bakeri* and *Juncus effusus* . It must be emphasized that these data are based on a relatively small sample size. Figure 6-8 summarize data on planted and "naturally occurring" species found in herbaceous wetlands. The most common naturally occurring species were *Panicum hemitomon, Pontederia cordata.,* and *Juncus effusus.*



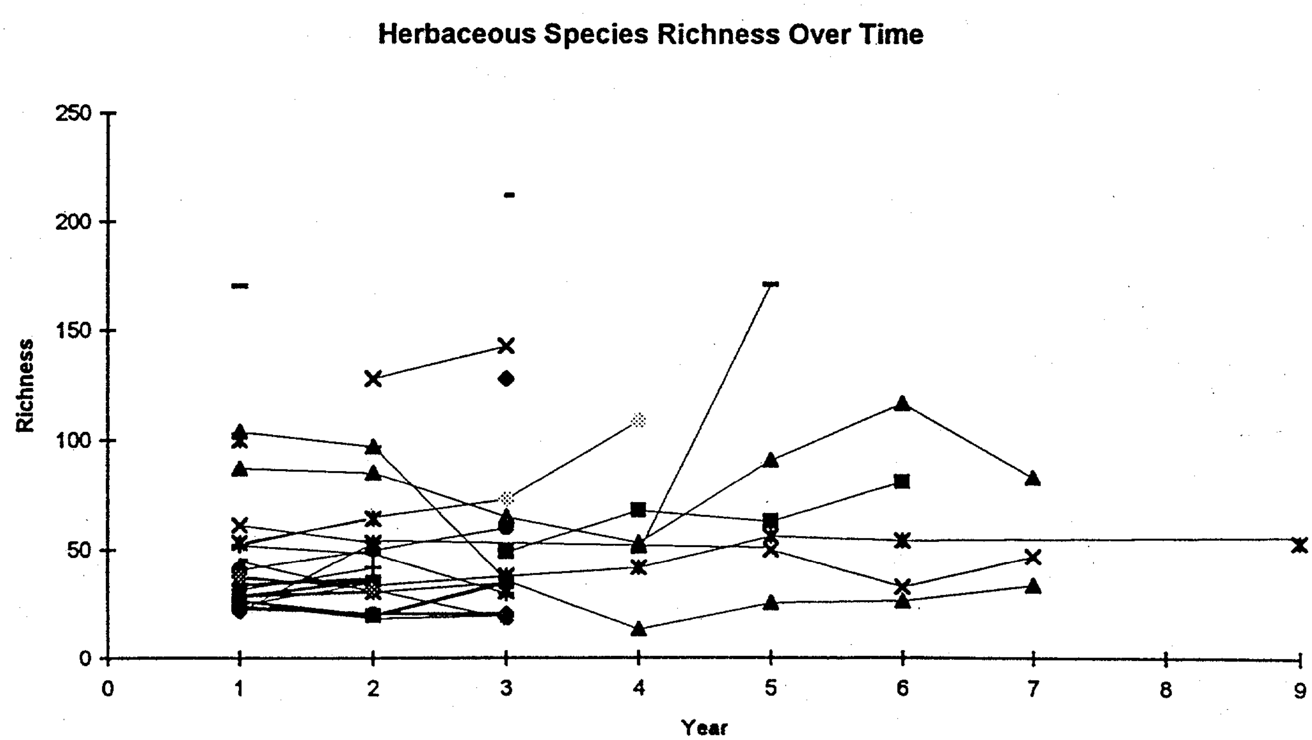


Figure 6-5. Species richness in herbaceous wetlands over time.

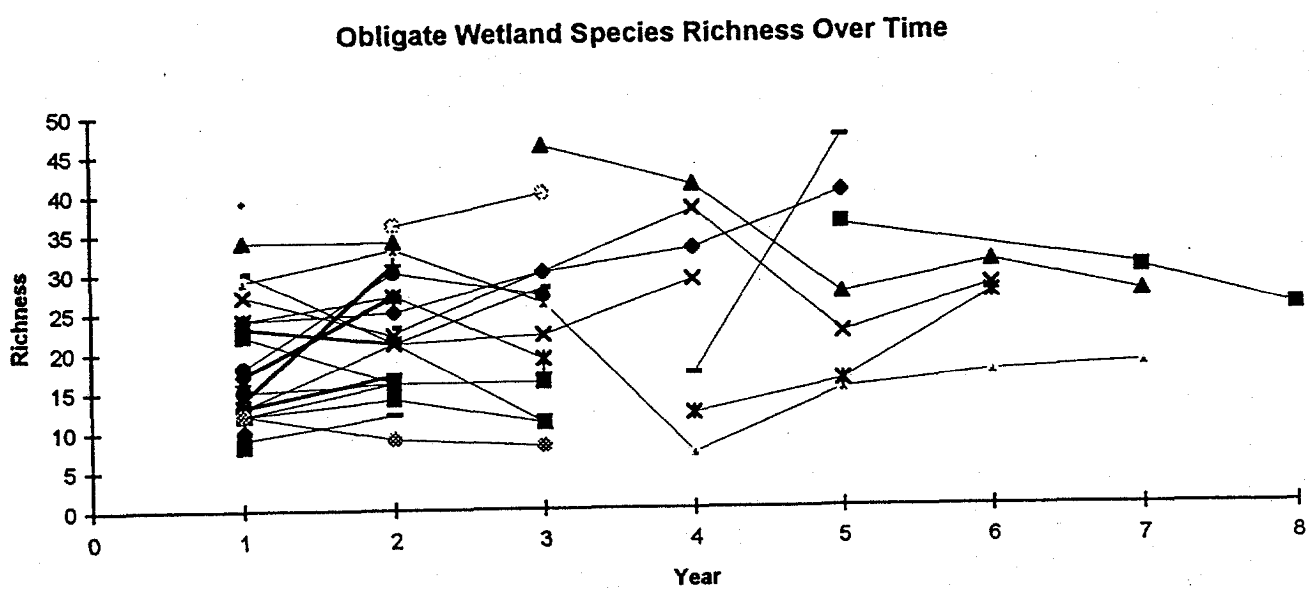


Figure 6-6. Number of obligate wetland species by site for each year of data.

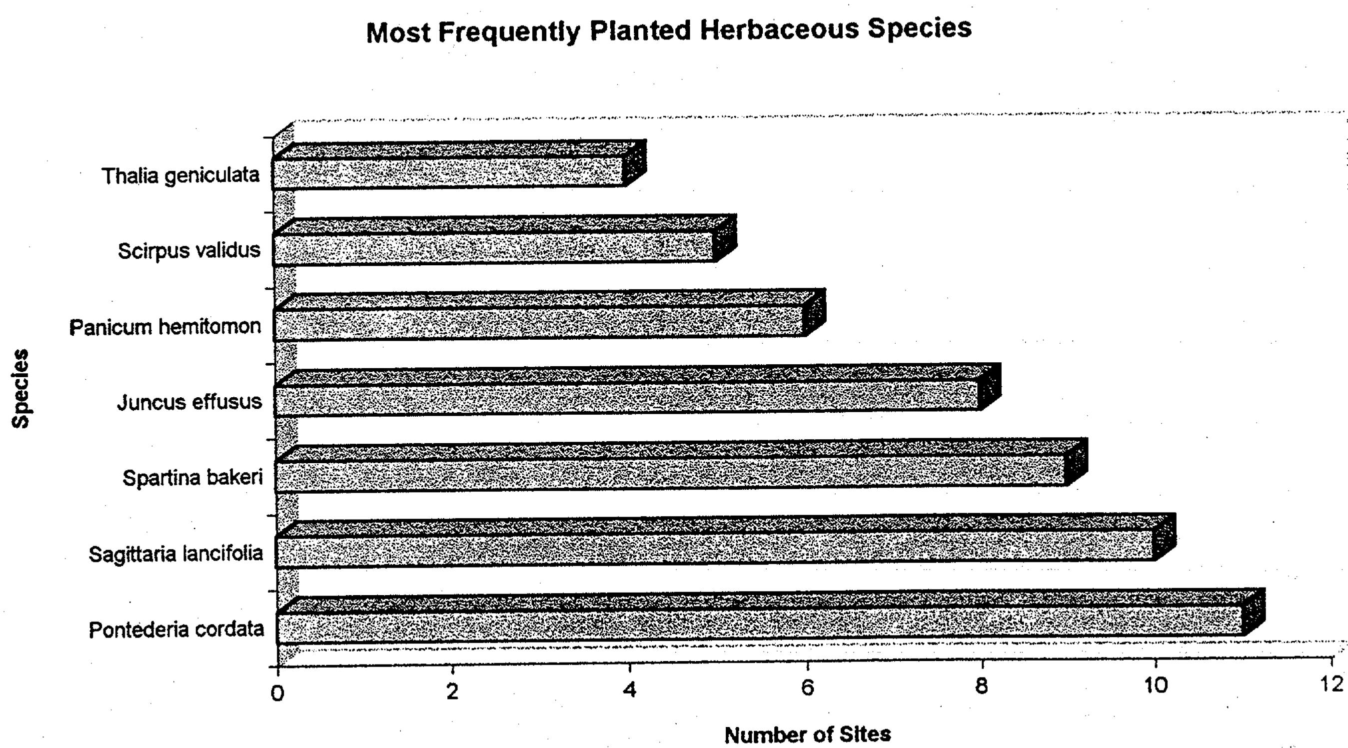


Figure 6-7. Most frequently used marsh species, and the number of sites planted.

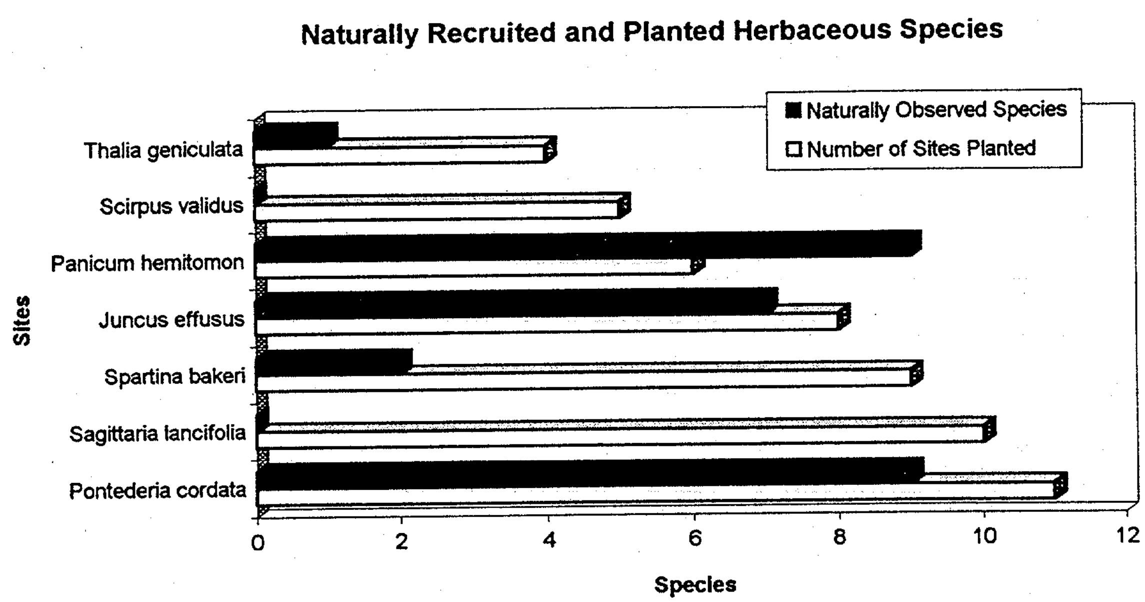


Figure 6-8. Eight most frequently planted species, frequency of planting and natural occurrence

Figure 6-9 summarizes the percent cover of the four most common herbaceous species found on wetlands reclamation sites (*Typha latifolia* is included, although not a planted species) for the first three years of data. *Pontederia cordata* appears to remain relatively constant over the three year period, although there is an increase in the second year. *Typha latifolia* exhibits a marked increase in the second year, but an equally striking decrease between the 3rd and 4th years (presumably the result of removal). *Panicum hemitomon* exhibits steady increases over the three years, while *Juncus* effusus markedly increased in the 2nd year and declined again in the third year (possibly the result of increases in other species, so that the relative percent cover is not as great as in the second year).

Development of Herbaceous Vegetation Within Forested Wetlands - The interaction of planted trees and community development in the herbaceous strata was evaluated by studying trends in percent cover and species richness in the herbaceous cover within forested wetlands. Twenty-two sites had combined herbaceous and tree data that were complete enough to evaluate the interaction of forest canopy on herbaceous community structure (see Table 6B-4). While data were reported as if these were combined plantings of herbaceous and tree species, it is not entirely clear if, in fact, this was the case. Figure 6-10 plots percent canopy cover, percent herbaceous cover, and herbaceous species richness over time. Canopy cover begins to exhibit noticeable increases in the fourth or fifth year, and for the three sites for which we have eight years of data, average percent canopy cover is about 8%.

Beginning in the sixth year, there appears to be a slight decline in herbaceous cover as the forest canopy developed. The decline in herbaceous cover is not striking, and when comparison with the marsh cover in Figure 6-4 (many of the sites are included in both data sets) there is no difference in overall cover. Likewise, there are no trends in richness over time that would suggest canopy interactions in shading, or nutrient limitations. Since the overall canopy closure is relatively minor (only about 8%), light limitations probably are not of consequence.

FORESTED WETLAND DEVELOPMENT

Tree Survival and Growth - The number of trees planted per acre is summarized for 50 sites in Figure 6-11 and Table 6B-5. Number of trees planted per acre in the first year varied from over 1500 (Agrico's Fort Green site), to a low of about 300 (this represents several sites). Mean number of trees planted in the first year was about 566 trees per acre. Since some sites were re-planted we summarized re-planting data in Figure 6-12 and Table 6B-6, Four sites were replanted in the second year (mean = 652 trees per acre), three in the third year (mean = 133 trees per acre), four in the fourth year (mean = 343 trees per acre), two sites in the fifth year (mean = 119 trees per acre), two in the sixth year (mean = 207 trees per acre) and one in the seventh year (179 trees per acre).

Tree survival was evaluated using percent survival for 41 sites with data ranging from 1 to 9 years in length (see Table 6B-7). While we had seven sites with 8 years of data, there were thirteen sites with 5 years of data, five additional sites had 4 years of data, four more sites had 3 years of data, and five additional sites had 2 years of data. Eight sites had only one year of data. Trends in tree crown growth were analyzed using 15 sites (Table 6B-8), while there were 41 sites with tree

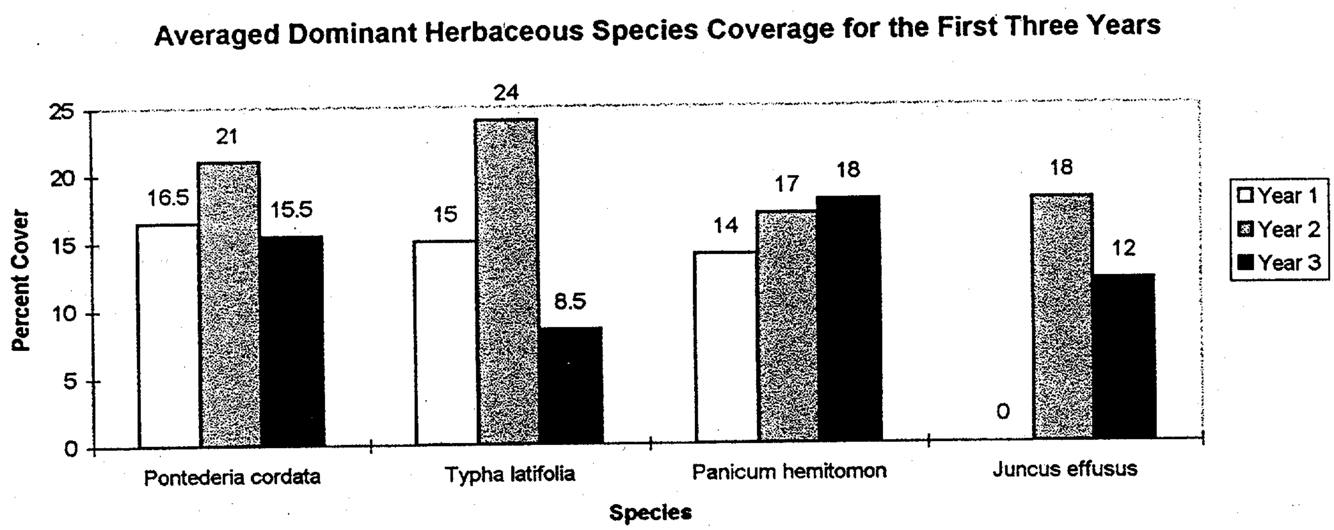


Figure 6-9. Average dominant herbaceous species cover for the first three years

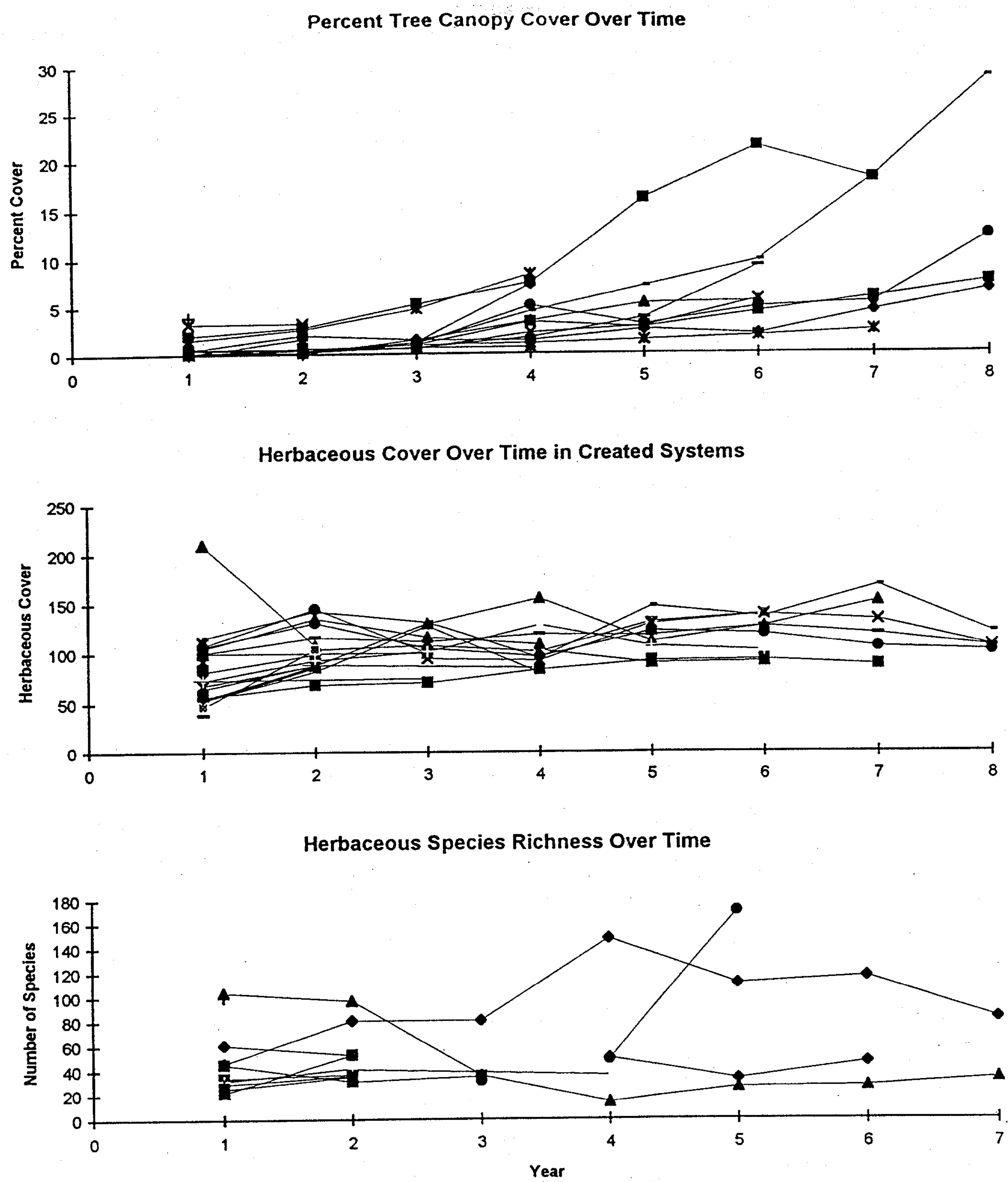


Figure 6-10. Interaction of tree canopy with herbaceous vegetation.

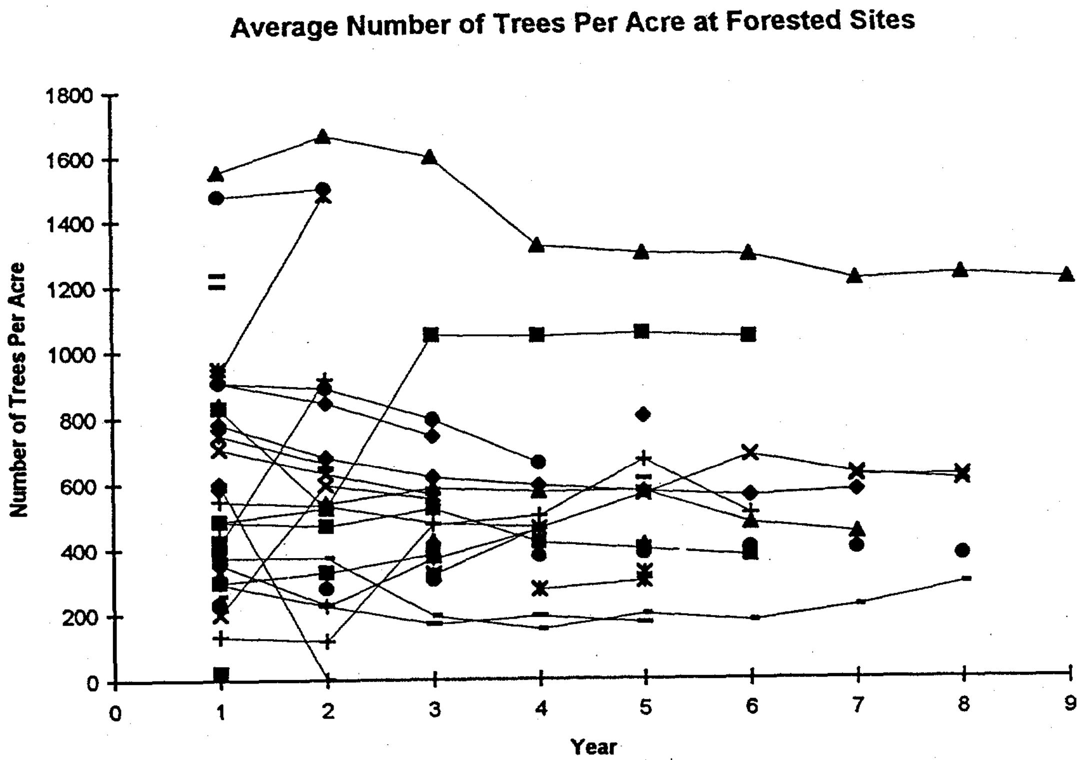


Figure 6-11. Average number of trees per acre at forested sites

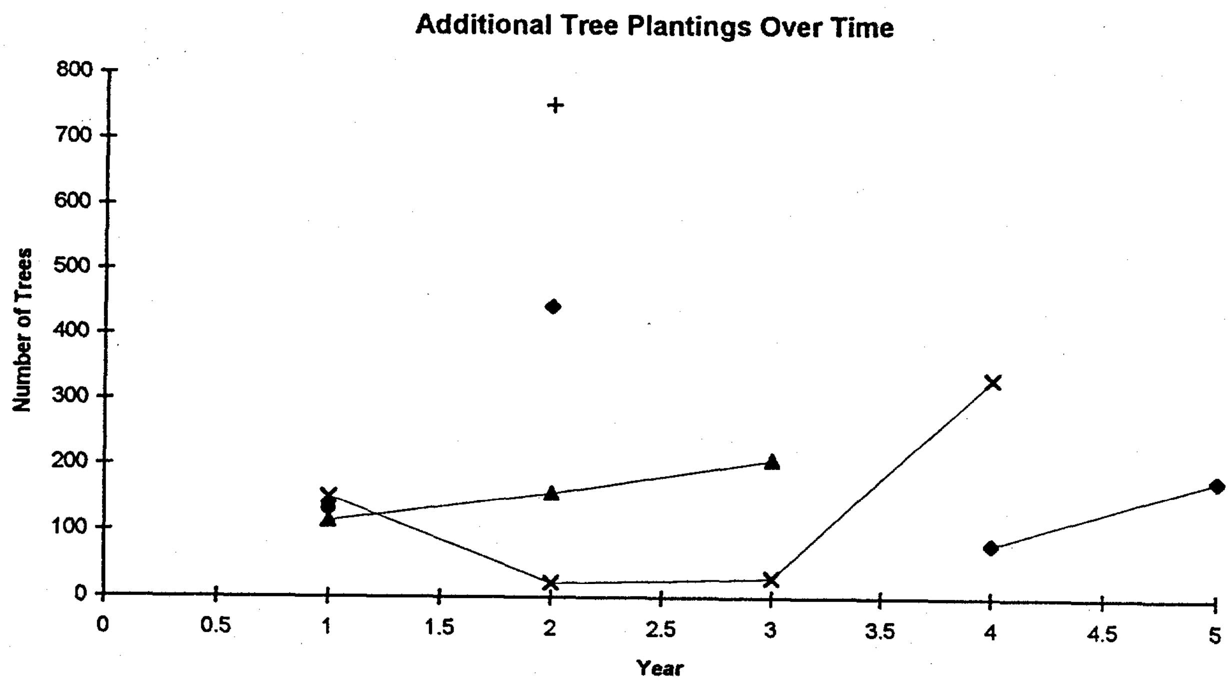


Figure 6-12. Additional tree plantings over time

height data (Table 6B-9). In all, the data when averaged over all sites and species provided some indication of the trend in tree establishment.

Figure 6-13 summarizes data for tree survival, tree crown width and tree height. Average survival in the first year was about 72%, in the second year it was about 62%, and continued to decline to about 43% in the eighth year. Sites where there was replanting of trees show increase in percent survival. When these sites are omitted, average overall survival is about 49%. Individual sites were not significantly different than the average. Ten sites (out of 21) had better than 50% survival in the fourth year. Of the seven sites for which there were 8 years of data, average overall survival was about 43%, with two sites having about 20% survival, two with about 45%, and two with 60 and 69% survival. In earlier work, Davis et al. (1991) found tree survival for 14 species declining to as low as 60% over a three year period on 8 sites, and to about 20% for 4 species for which there were 7 years of data. They also showed survival for 6 common wetland species *(Taxodium distichum, Acer rubrum, Ilex cassine, Liquidambar styraciflua, Nyssa sylvatica, Gordonia lasianthus)* ranging from 65% to as low as 5% over a three year period.

Growth of the canopy in surviving trees is shown in the middle graph of Figure 6-13. Fifteen sites had data for evaluation of the change in width of the tree crown. Tree crown width for surviving trees increased almost 146% in five years. For the site with 7 years of data, crown width increased nearly 310%.

The bottom graph is Figure 6-13 shows that tree height increased by about 172% in 7 years and for the 5 sites with 8 years of data, height increased about 210%. It is interesting to note the difference in slope of the Fort Green site (nine years of data) with those of the other longer term data sets. Survival rates at this site are not significantly different than the average of all sites, but tree growth is obviously slower, This may be the result of planting in less than ideal conditions, but cannot be determined because of the paucity of hydrological data on all sites.

Species-specific survival rates were evaluated and are given in Figure 6-14 and Tables 6B-10 and 6B-11. Species with highest survival rates (using those species with seven years as the time frame; thus only three sites are included in the data base: Agrico 8.4 acre, Agrico FG-84, and Agrico Ft. Green) were *Ulmus americana* (85%) *Fraxinus caroliniana* (80%), and *Taxodium distichum* (72%). When survival over four years was considered (for which the database included 6 sites) species with highest *survival* were: *Quercus virginiana* (100%), *Fraxinus caroliniana and Magnolia virginiana* (90%), and *Taxodium disticum, T. ascendens, Ulmas americanas*, and *U. floridanus* (85%). Davis et al. (1991) evaluated survival of 22 tree species and found *Taxodium ascendens* and *T. distichum* to have the highest survival rates, while *Acer rubrum, Fraxinus caroliniana,* and *Liquidambar styraciflua* had among the lowest survival rates. This suggests that the database is difficult, at best, to evaluate. Long-term data sets are few and thus long-term species specific survival rates reflect only the survival on a small number of sites (not necessarily random), rather than an industry average.

<u>Tree Species Richness</u> - Species richness of constructed forested wetlands was evaluated using the data from 50 sites, however only 23 had data for more than 1 year, twenty-two had data for 3

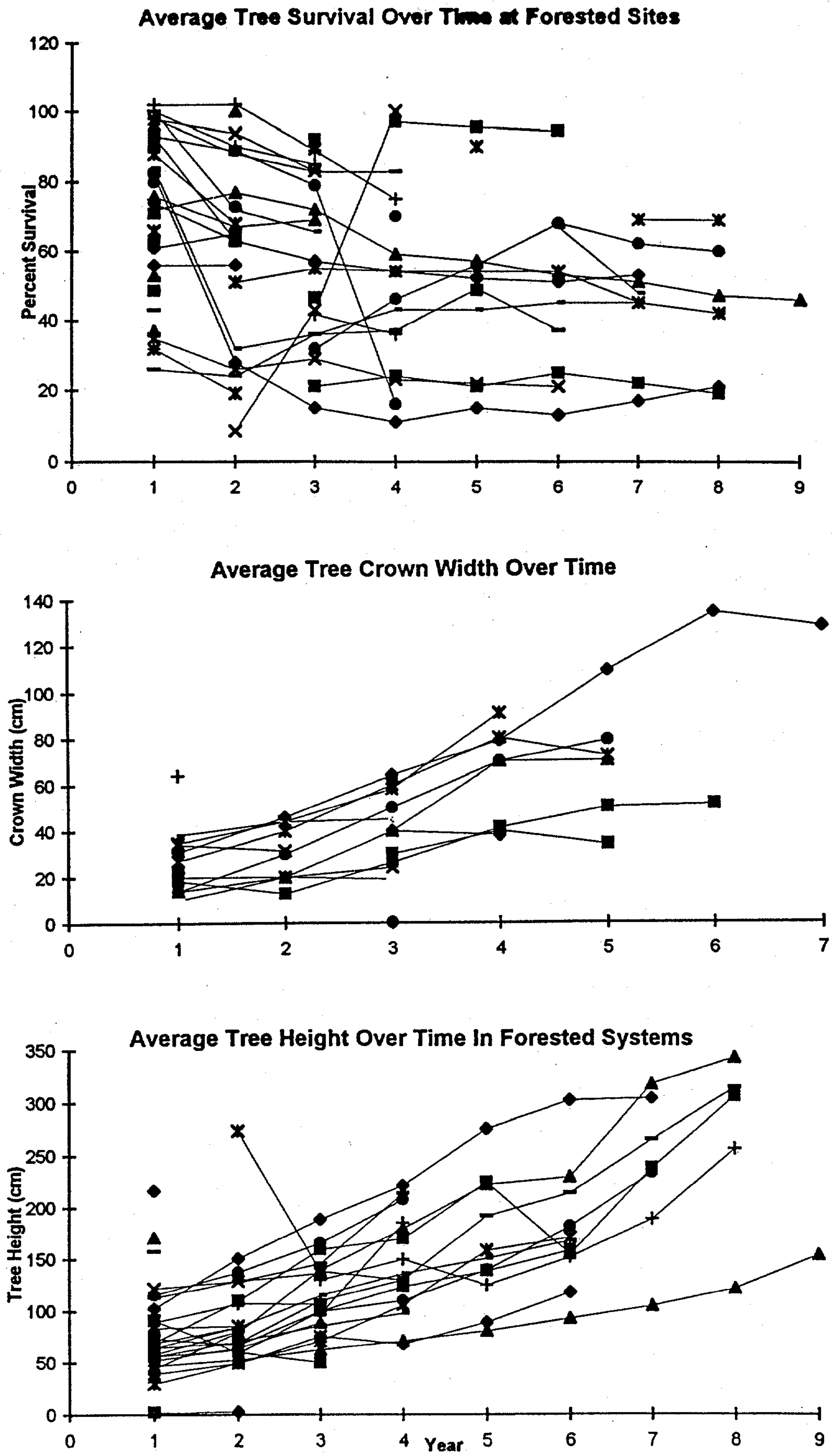
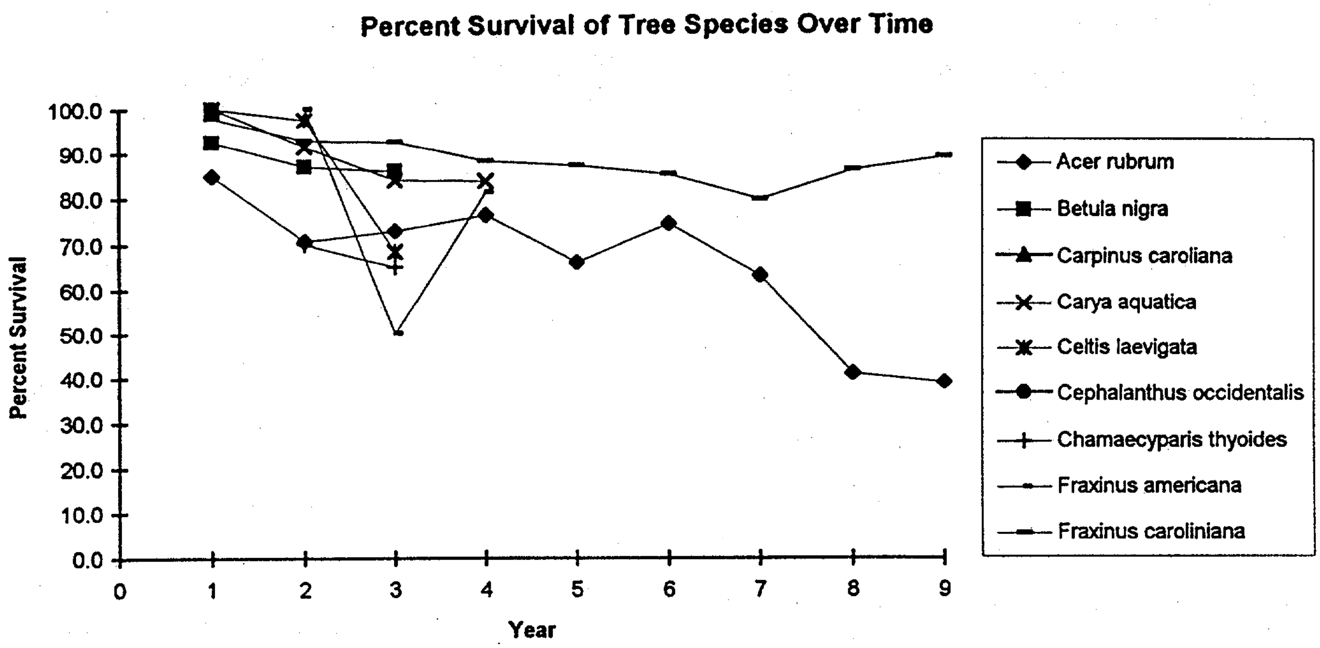


Figure 6-13. Planted tree survival (top), crown width (middle) and tree height (bottom) in forested sites.

Percent Survival of Tree Species Over Time



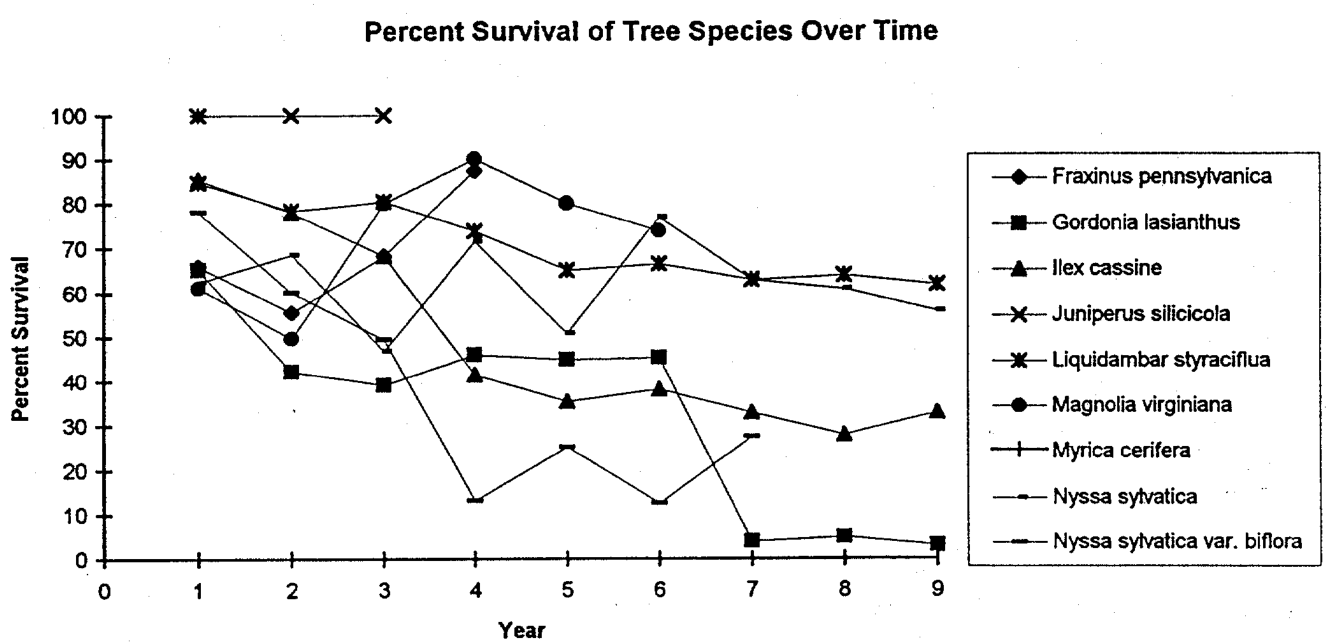
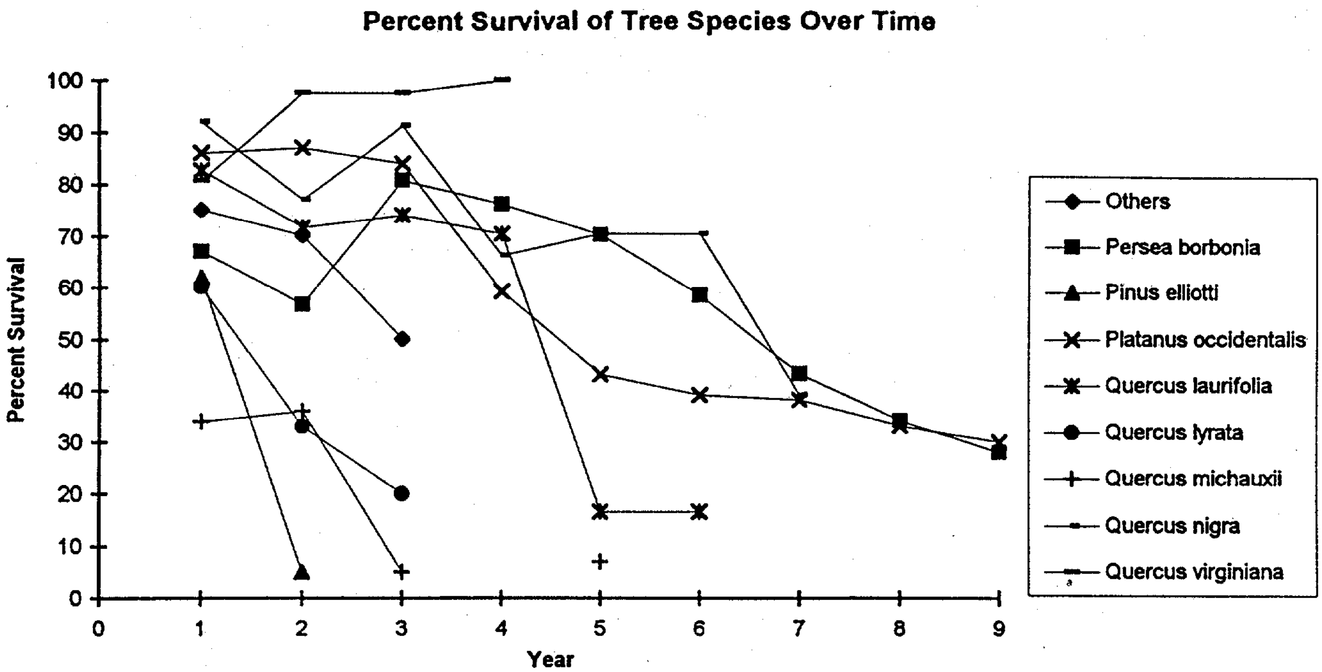


Figure 6-14. Percent survival of major tree species over time. Data are from all sites where species specific data were available.



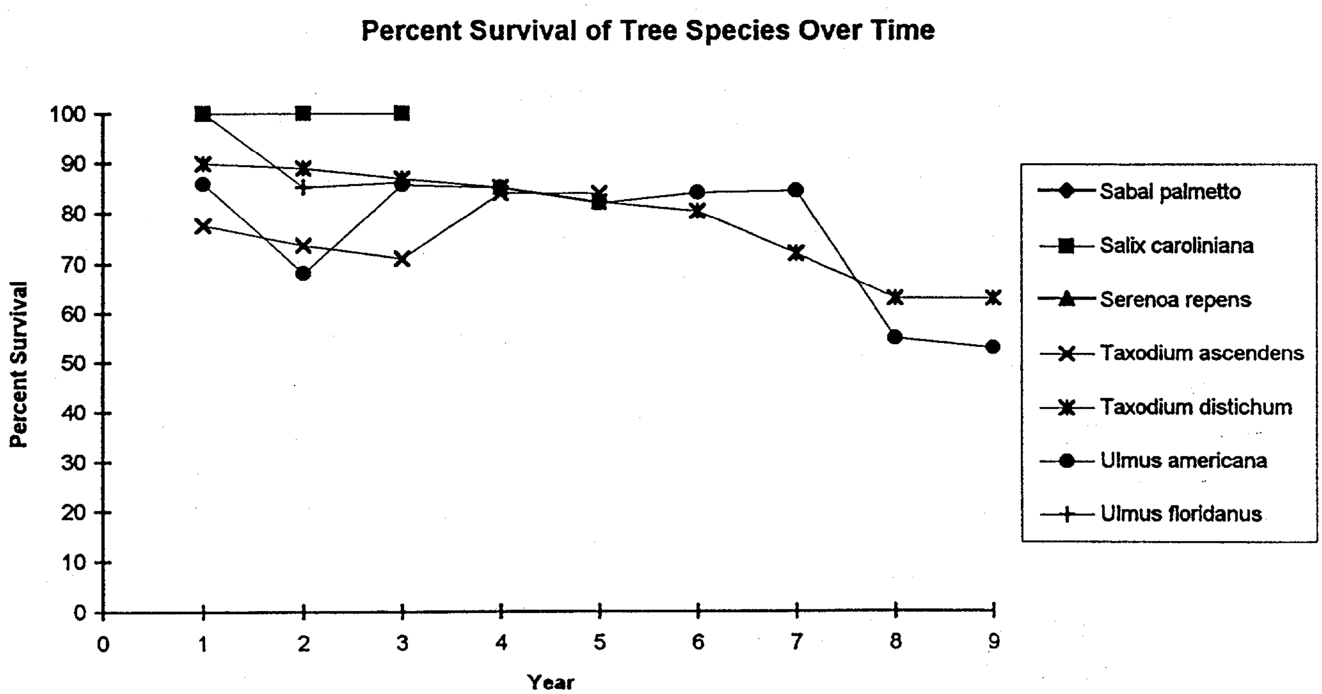


Figure 6-14 (continued) Percent survival of major tree species years, ten had data for 4 years, eleven had data for 5 years, four for 6 years, two for 7 years, and 1 site had data for 9 years (Table 6B-12). Figure 6-15 summarizes data for species richness over time. Average planted richness (1st year) was about 10 tree species per wetland, varying from a high of 24 (IMC's Dogleg), to a low of 3 (Occidental's SR-8) species. There is no apparent change of species richness over time (Figure 6-15, top). In the bottom graph, site richness is graphed showing the number of sites grouped into several richness categories. The largest number of sites have richness of between 8 and 11 species per site (17 sites) and 4-7 species per site (15 sites).

Measures of diversity may be a better way of determining long-term trends in species composition, since using richness masks changes in composition unless all individuals of a species were to die. Yet to measure diversity, both species and the numbers of each species must be determined. For the most part, these data are not collected nor reported for constructed wetlands sites.

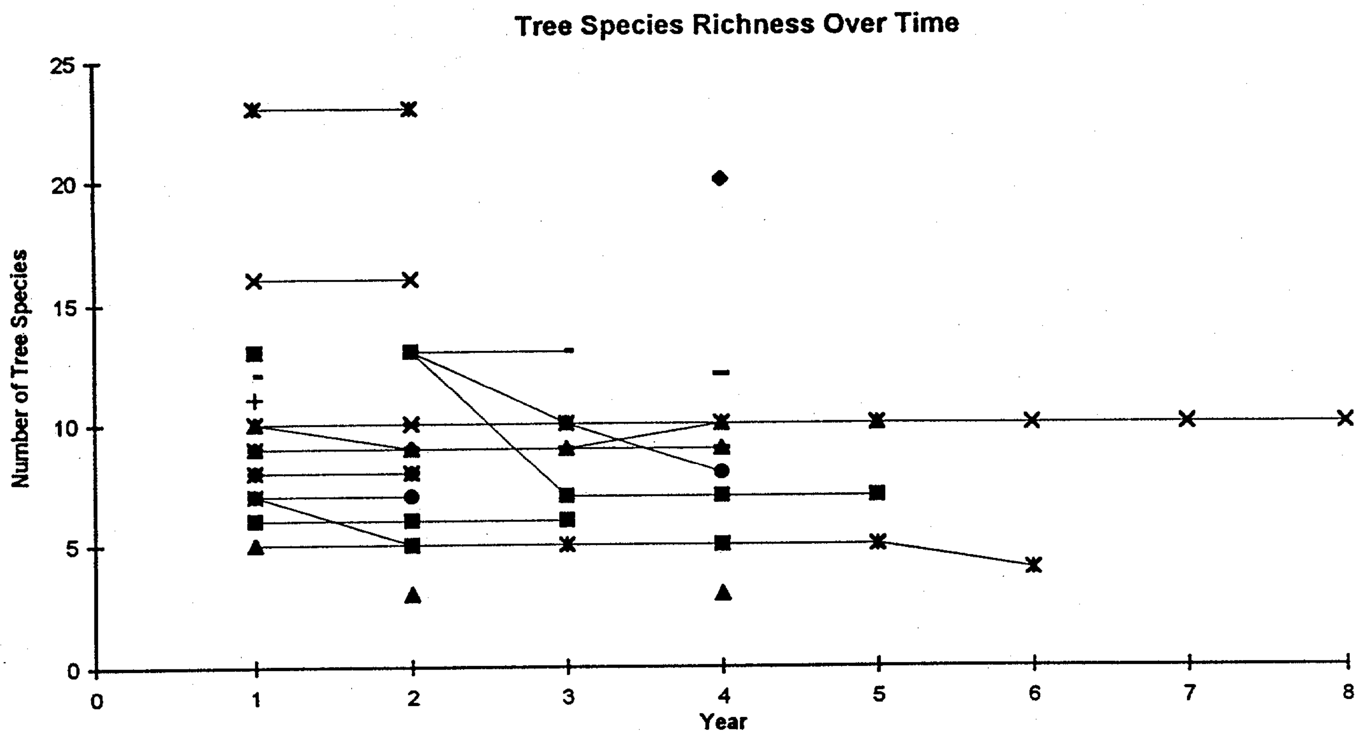
Tree Species and Planting: Mixtures - Data from 22 sites were evaluated to determine which tree species were planted most frequently. Figure 6-16 and Table 6B-13 summarizes frequency of planting for 19 species. These data were for all sites that reported species planted whether percent mixture was specified or not, thus frequency as used here is the number of sites where a species was planted. In terms of frequency of planting, Acer *rubum* was used the most (about 37 sites), and *Liquidambar styraciflua* was next most common (32 sites). Other species used frequently were *Taxodium distichum* (29 sites), *Fraxinus caroliniana* (23 sites), *Ilex casine* (22 sites) Nyssa *biflora* and *Quercus laurifolia* (20 sites each)

Nineteen sites had data on the percent of the total trees planted by species. Mean percent mixtures were calculated for each species based on the average of its make up of site mixtures. These data are summarized in Figure 6-17. For *these* eleven sites, *Taxodium disticum* had the highest average percent mixture on 11 sites (about 28%). *Nyssa sylvatica* made up about 20% of the tree mixture on sites were it was planted (6 sites). *Fraxinus caroliniana* and *Quercus laurifoli*, planted on 8 sites, made up about 17% and 15%, respectively, of the tree mixtures.

EVALUATION OF SITE TREATMENTS

Tree Survival and Herbaceous Cover vs. Soil Types - Soil type effect upon tree survival was analyzed for a total of 31 sites (Table 6B-14, 6B-15). There were not enough sites to perform an analysis for sites with clay soils or pure sand tailings. Twenty-four of the sites had overburden as the soil component, while seven had a soil mixture of sand tailings and overburden.

Figure 6-18 summarizes data for tree survival on overburden and sand/overburden mix sites. Survival in the first year appears to be greater on sand tailings/overburden sites (mean = 85%) than on sites created with just overburden material (mean = 65%). Overall, when survival for all sites is compared, trees planted on sand/overburden appear to have declining survival over time, while the overburden sites exhibit relatively constant survival after the first year. By the 6th year, tree survival between the two treatments is relatively similar (mean survival about 43% for sand/overburden sites and 47.5 % for overburden sites).



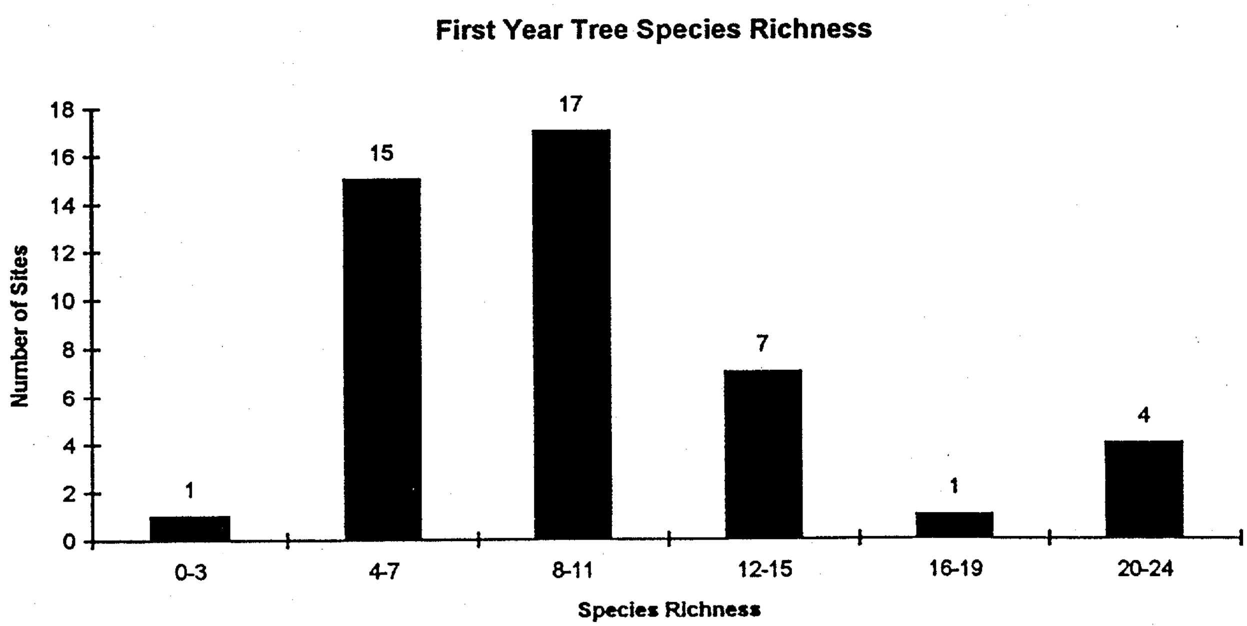


Figure 6-15. Species richness of constructed forested wetlands.

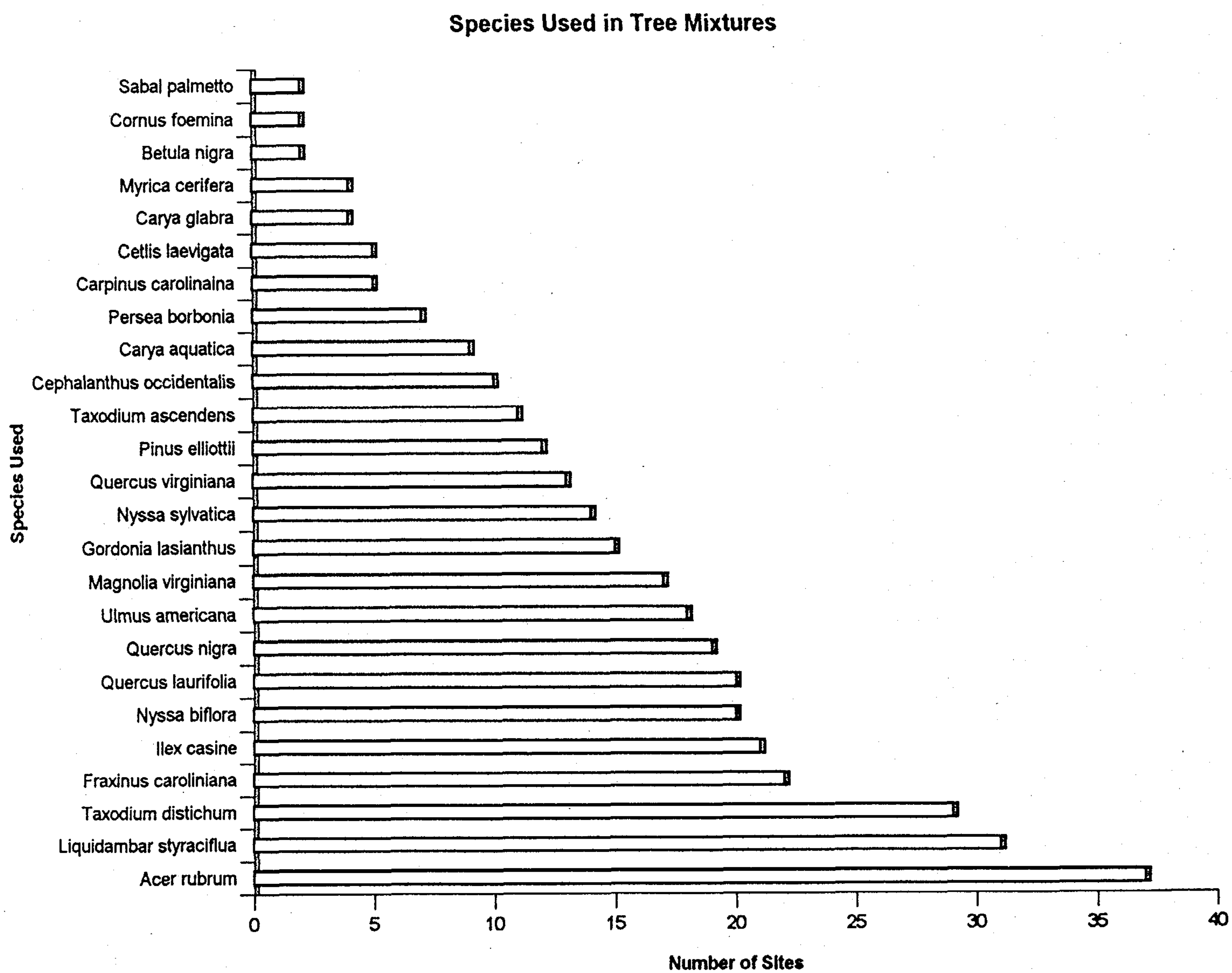


Figure 6-16. Number of sites (frequency) trees were planted.

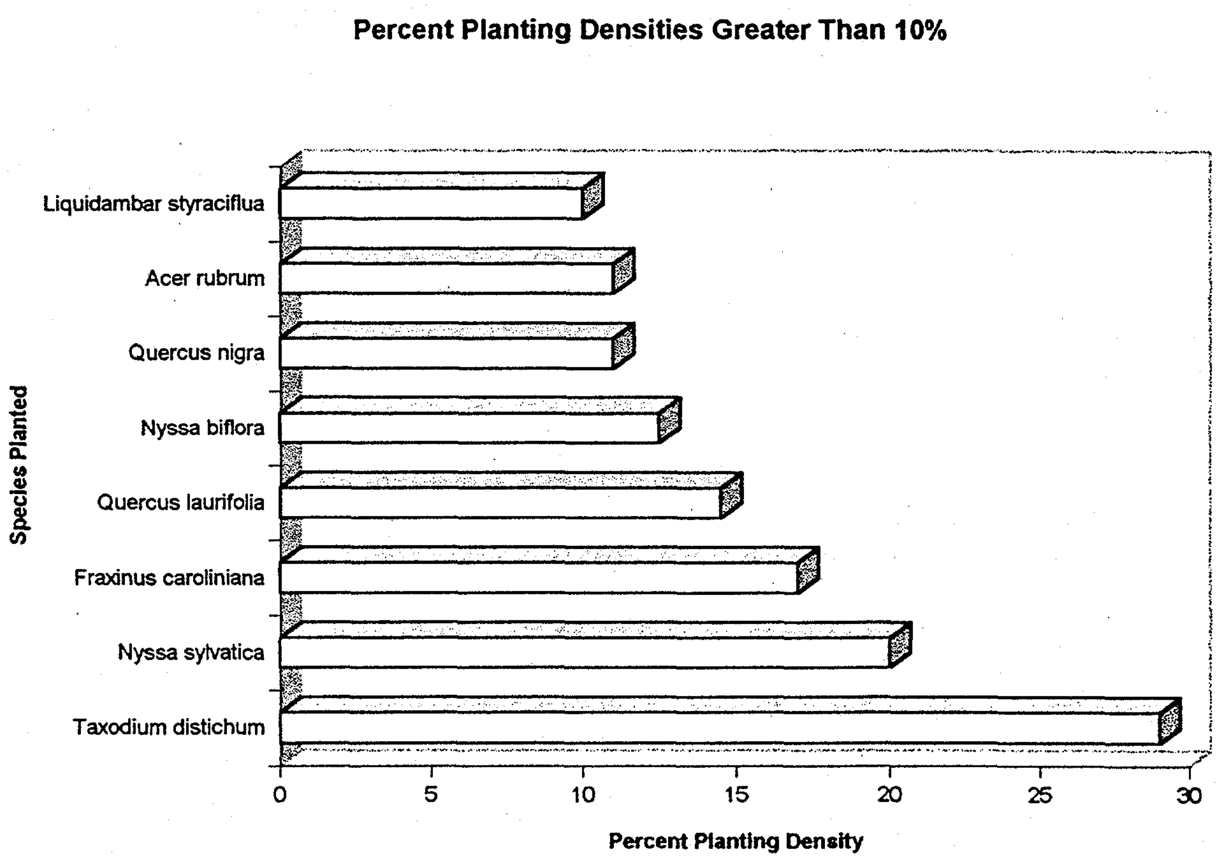
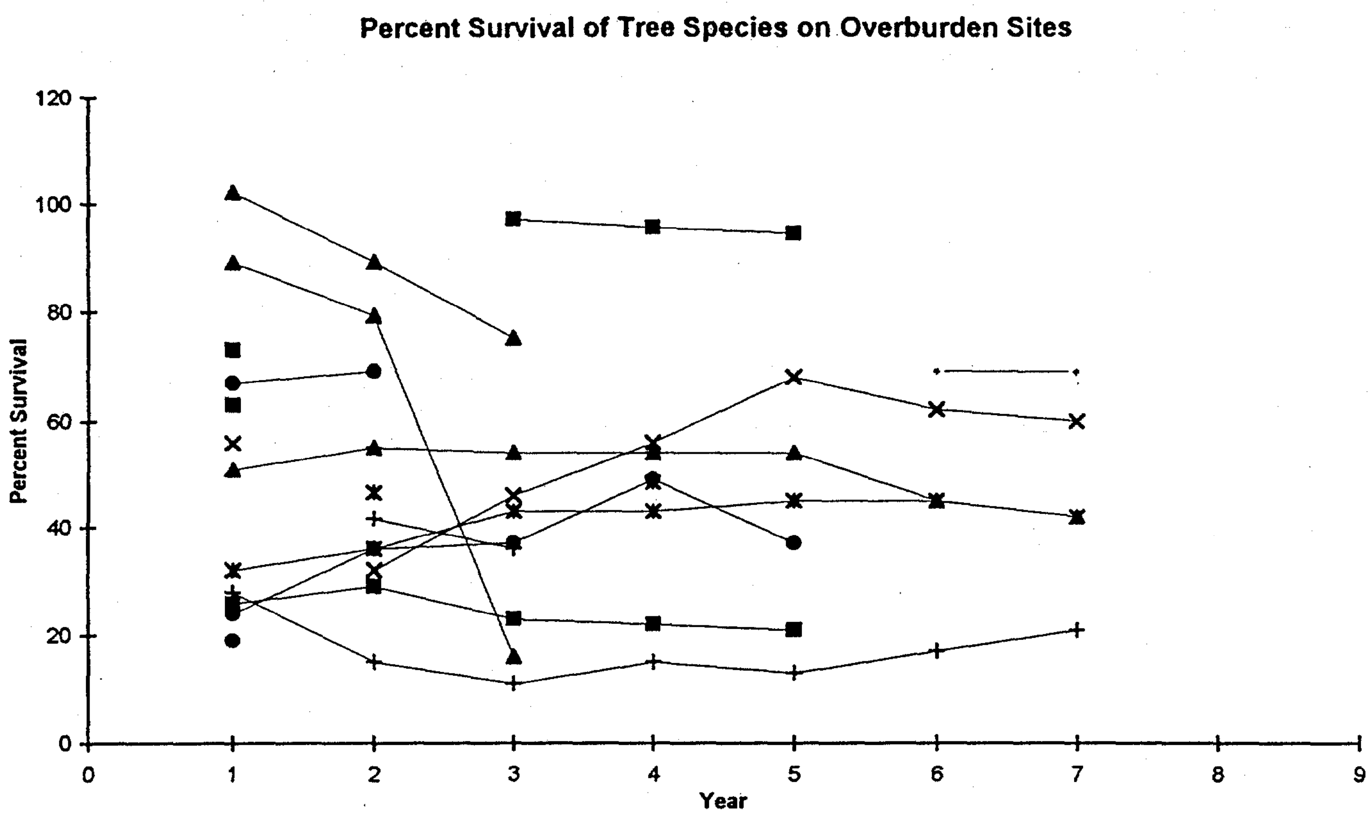


Figure 6-17. Mean percent of planting mixture for 14 most common species.



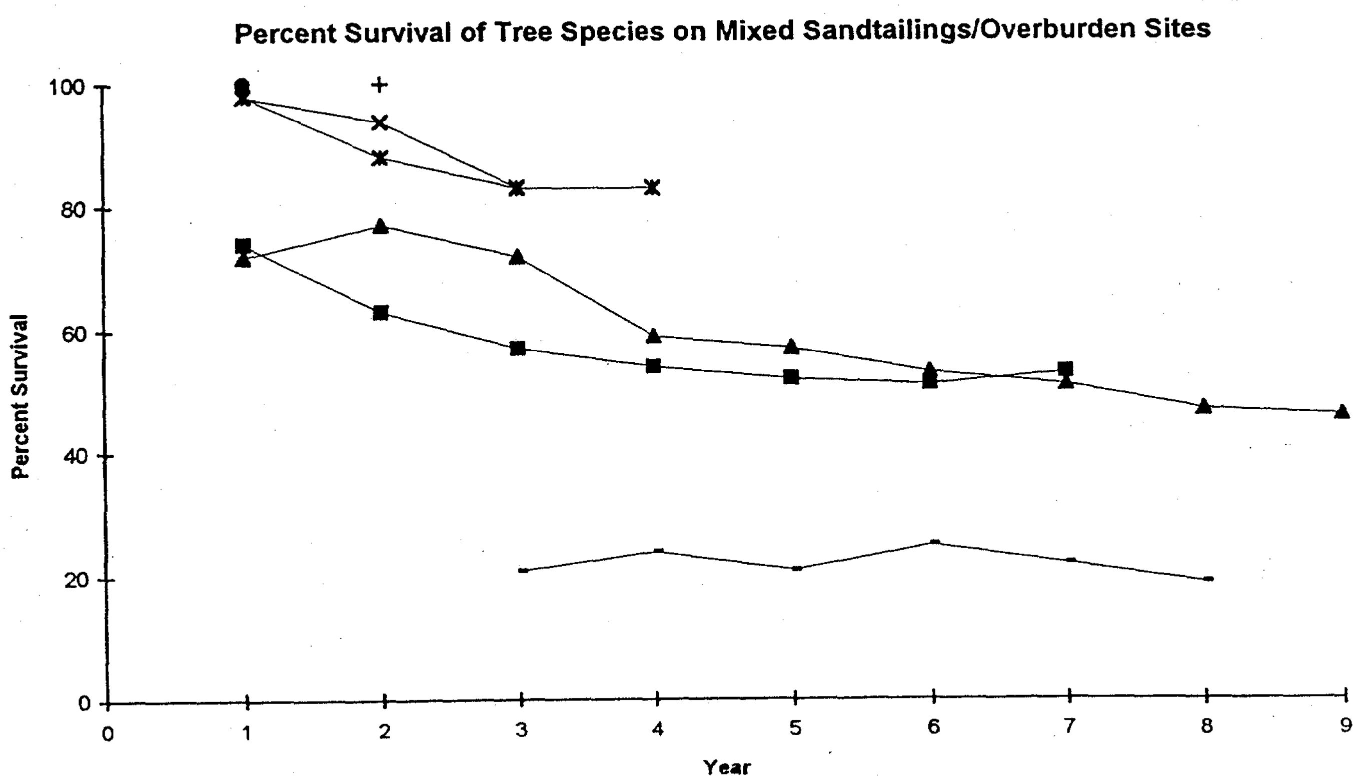


Figure 6-18. Tree survival on overburden (top) and sand/overburden mix (bottom) sites.

Herbaceous Community Development on Mulched and Non-Mulched Sites - A total of 41 sites was examined to evaluate the effects of mulching. Twenty-five sites had data indicating they were mulched and fourteen sites were not mulched (Table 6B-16). Some of the non-mulched sites may have been mulched, in whole or in part. However, if there was no mention of mulching in the reports we consulted, we assumed the site was not mulched. It is important to keep in mind that the data include both sites in which two strata were used and sites where only one stratum was used to determine percent cover.

Average percent cover for mulched and unmulched sites are summarized in Figure 6-19. There is wider variation in cover in the first year on non-mulched sites when compared to mulched sites, and mean cover for all sites is lower in the first year for non-mulched sites (Table 6B-15) Overall, the trends suggest that mulched sites had greater mean percent cover than did unmulched sites, and that this was probably driven by establishment and survival in the first year since mean cover was greater after one year on the mulched sites. The total increase in mean percent cover for mulched sites was 35% in five years, while unmulched sites essentially had no increase in cover in the same time period. Since the examples in the database include a mixture of methodologies (two strata versus one stratum) for determining percent cover, it is difficult to see trends in terms of total percent cover, but the change in cover suggests that mulching has a positive effect on community establishment.

Species richness on mulched and unmulched sites was evaluated for 35 sites for which there were data (Table 6B-17). There were more mulched sites (22) than non-mulched sites (13), probably reflecting the widespread use of mulching by the industry. While the data are somewhat limited, the trends in Figure 6-20 are relatively clear that there is no discernable difference in species richness between mulched and non-mulched sites. Again, it should be mentioned that sites were classified as non-mulched if there was no mention of mulching in reports reviewed by the project team Some of the non-mulched sites may have been mulched but not recorded.

Only five sites had data on mulch application thickness. Of these sites, four had depths of from 5 to 10 cm and the remaining site had depths ranging from 10 to 45 cm

Nuisance Species, Herbicide, and Community Development - The data from a total of thirty-eight sites were used to evaluate herbicide treatment. Ten sites had records indicating that herbicides had been used to treat “nuisance” species, while 28 sites had no records indicating herbicide treatment (Table 6B-18). There is no doubt that control of “nuisance” species is effective as shown in Figure 6-21. Percent cover on non-herbicided sites increased steadily beginning in year one to year seven. Mean percent cover of nuisance species was about 27% in year five on uncontrolled sites while only about 4% in year five on sites where there had been herbicide treatment. Several sites in the untreated population exhibited marked declines of percent cover of nuisance species, while others maintained coverages below 10%, suggesting that while there were no records of treatment, they in fact, may have been treated.

To evaluate the effect of herbicides on non-target species, data on species richness were compared between herbicided and non-herbicided sites. Species richness of the herbaceous

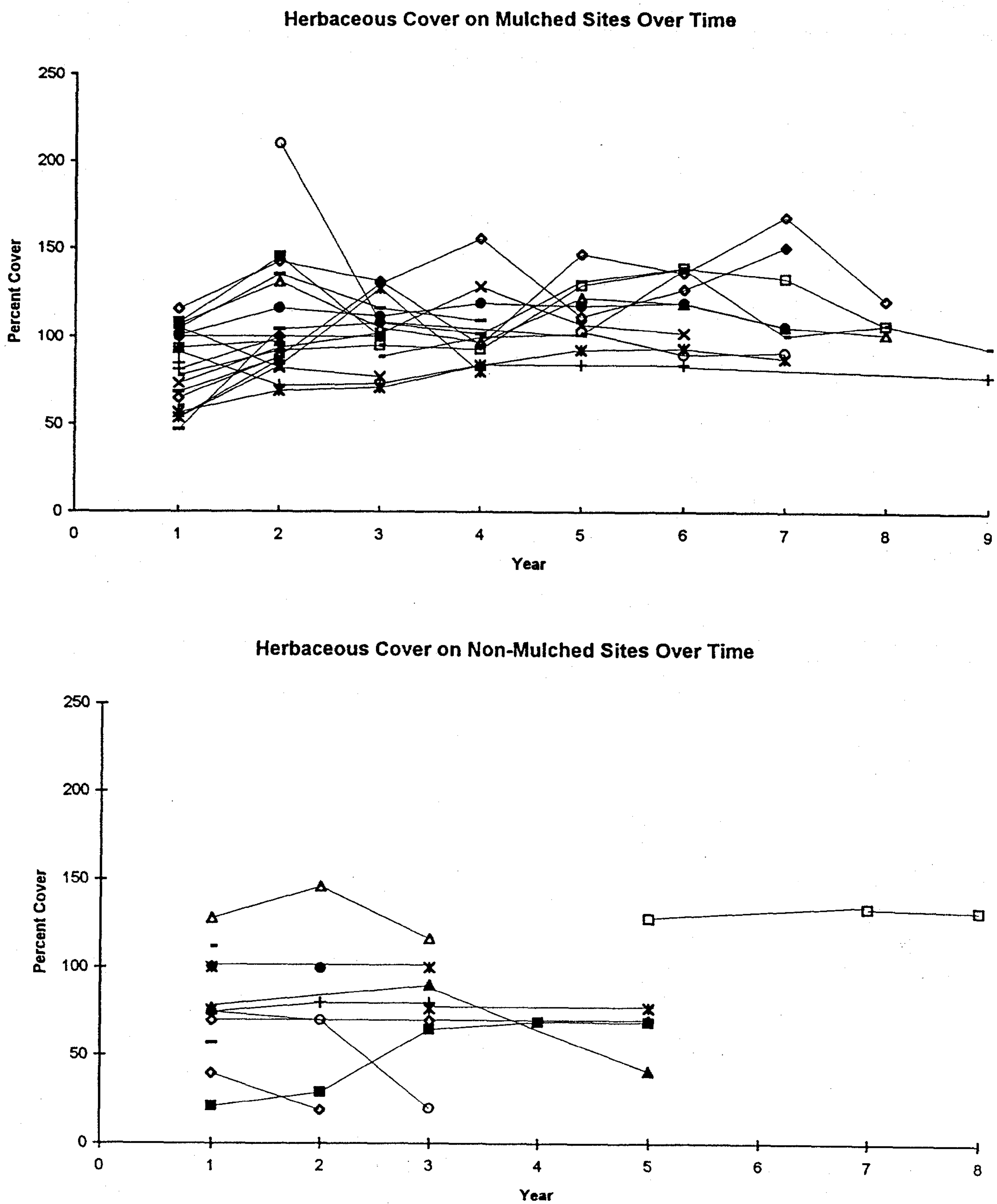


Figure 6-19. Percent cover of herbaceous vegetation on mulched (top) and unmulched (bottom) sites.

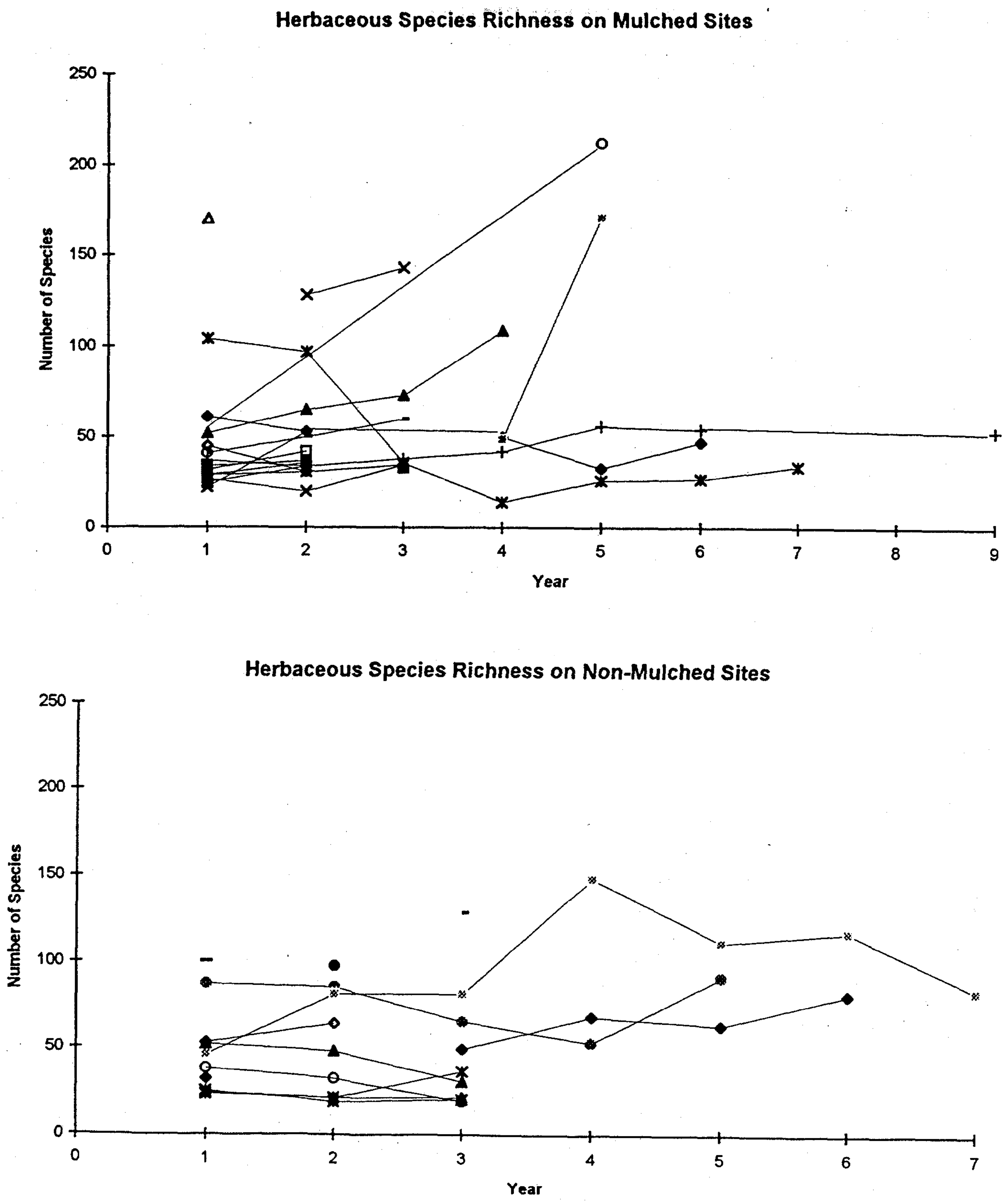
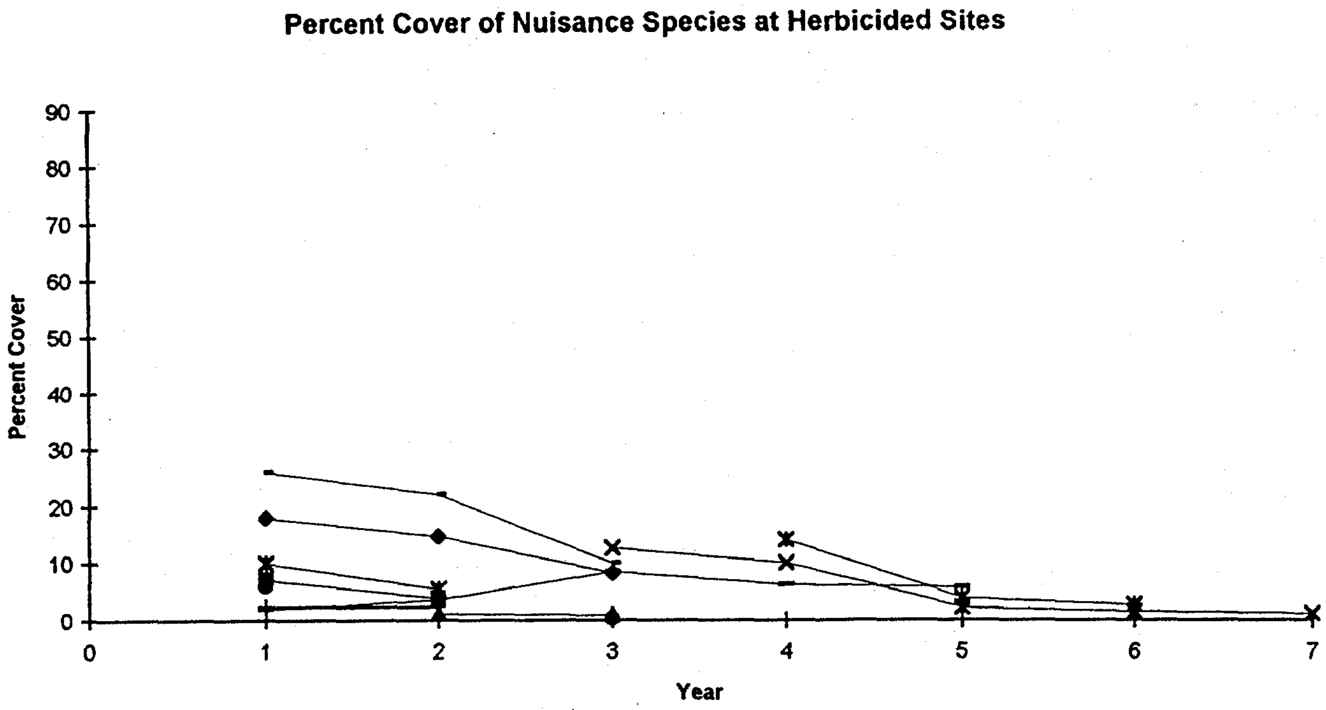


Figure 6-20. Species richness on mulched (top) and unmulched (bottom) sites.



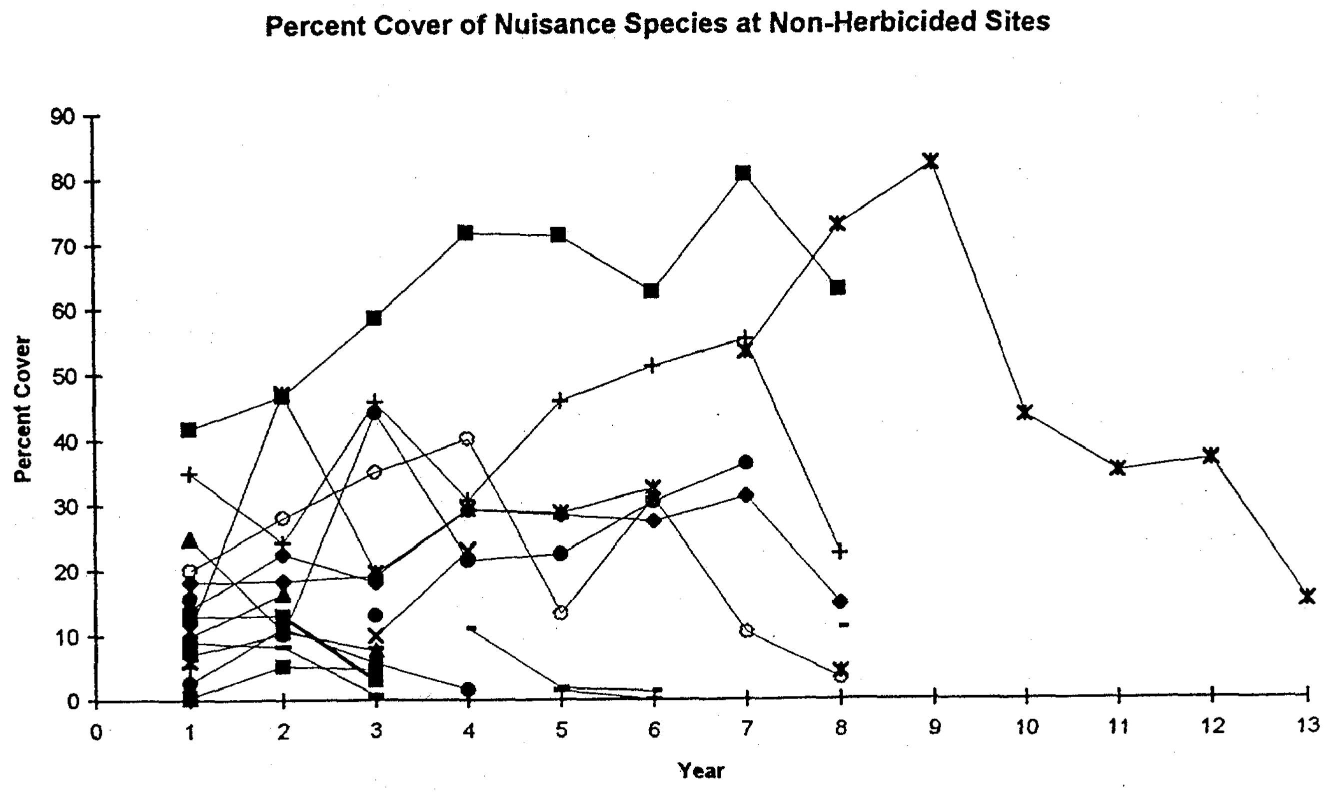


Figure 6-21. Percent cover of nuisance species on herbicided (top) and non-herbicided (bottom) sites.

community on herbicided and non-herbicided sites is summarized in Figure 6-22 and Table 6B-18. There appears to be no significant difference in species richness between herbicided and non-herbicided sites. However, when sites that are suspected to have been herbicided (because cover of “nuisance” species is comparatively quite low), are omitted from the analysis, mean species richness from year to year is higher on sites without herbicide treatment.

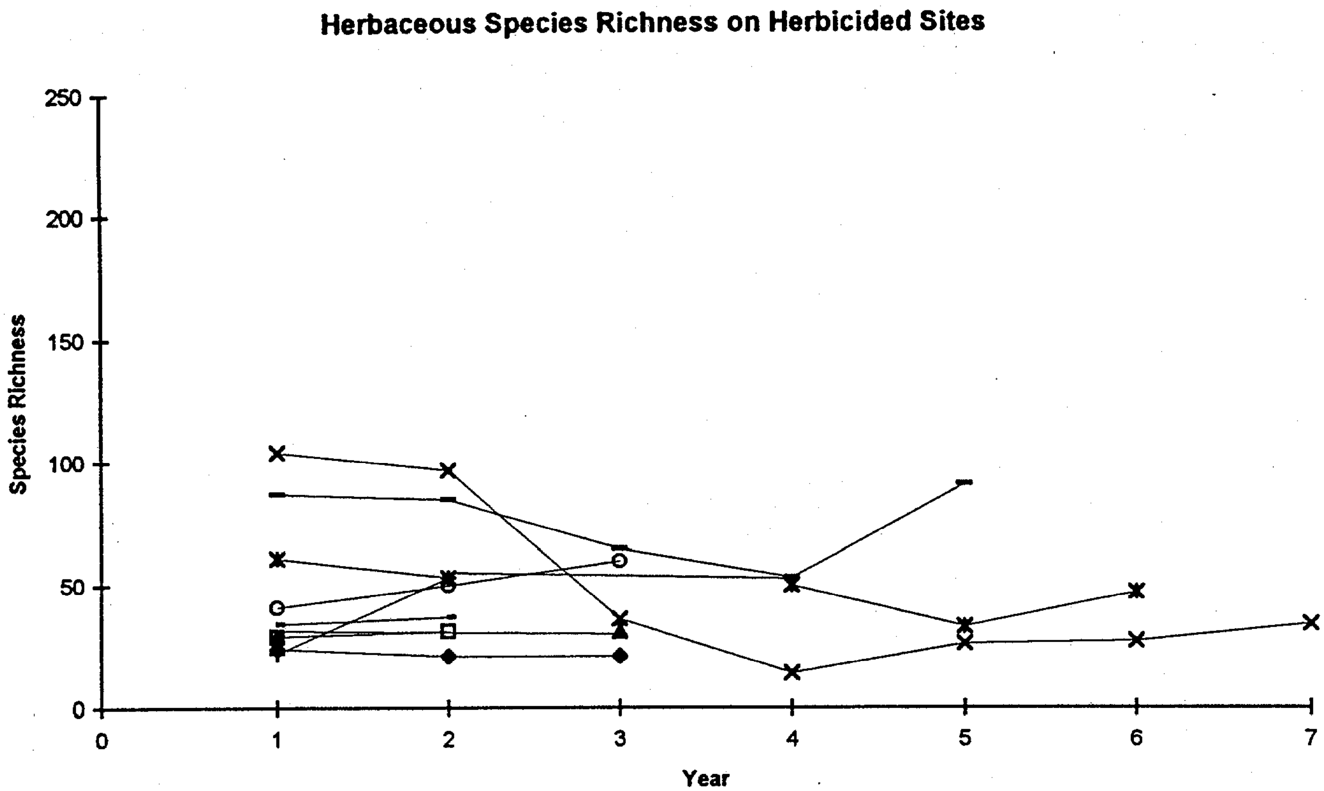
Tree survival on six herbicided sites and 32 non-herbicided sites is summarized in Figure 6-23 and tabular data are given in Table 6B-19. Trends suggest that survival is better on herbicided sites. Mean survival in the first year appears to be similar, but decreases faster on untreated sites than on herbicided sites. Extreme caution must be used in evaluating the significance of these results, because the trends are based on such a small sample of herbicided sites (6 sites), only one more than four years old.

Whether herbicide application affected richness and percent cover of herbaceous species and on tree survival is still problematic. The data sets are obviously flawed, since it appears that some sites were herbicided but the treatments were not recorded in those project reports and permit records to which the project team had access. Some sites had species richness of greater than 170 species. These probably included both upland and wetland species counts in the same data set. This is a most important question in that the widespread use of herbicides to control nuisance and exotic species is not without other environmental consequences. On the other hand, we believe that there is a serious potential for exotic species to invade older reclamation sites and without herbicide treatments their control may not be possible. There is little doubt that herbicides control nuisance species, but whether forested sites should be cleared of nuisance species remains unclear. We strongly urge the industry and FIPR to study this question in greater detail. We believe that whenever we can reduce release of toxic exotic chemical compounds in the environment we are better off. When herbicides need not be used, or their application can be greatly reduced, this should be done, yet without detailed study, we may never know when and where their use is really warranted.

COMPARISONS WITH NATIVE FLORIDA WETLANDS

Given in Table 6-3 is a summary of literature-derived values for tree species richness and density in native Florida forested wetlands. Of the data surveyed, forested wetland richness varied from 6.8 to 13.5 tree species/hectare. Density varied from a high of 2336 stems/hectare (945 stems/acre) to a low of 1183 stems/hectare (478 stems/acre). When compared to constructed wetlands on reclaimed sites, constructed forested wetlands were planted with greater species richness than native wetlands.

Planting densities of trees on constructed wetlands appear to be about 800 trees per acre, declining to about 566 trees/acre in the first year and to about 400 trees/acre by the fifth year. While four hundred trees/acre is less than 50% of the total stems in most natural wetlands, it should be remembered that “total stems” includes all size classes. When only mature trees are considered, density in native wetlands is more on the order of 300-350 trees/acre. The planting of trees at higher densities may, in fact, inhibit growth, through competition for light, nutrients, and



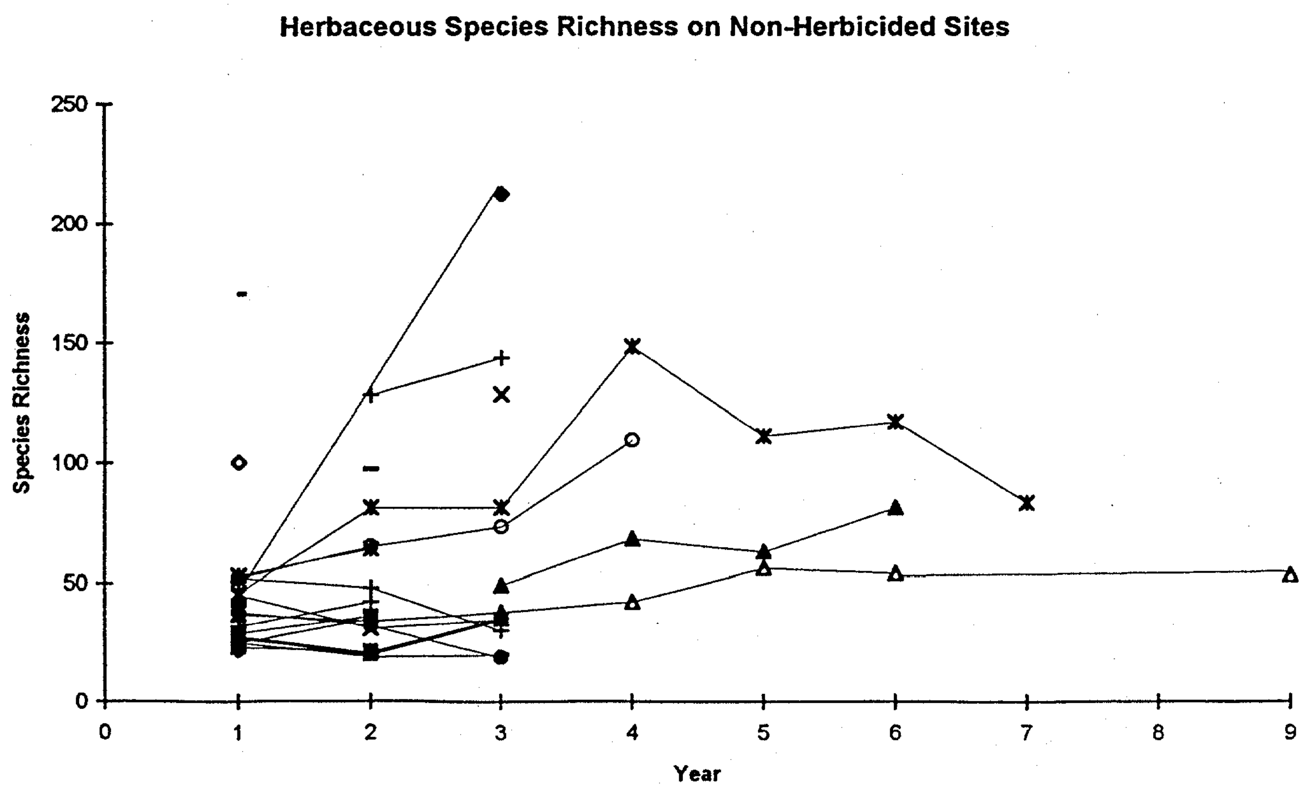
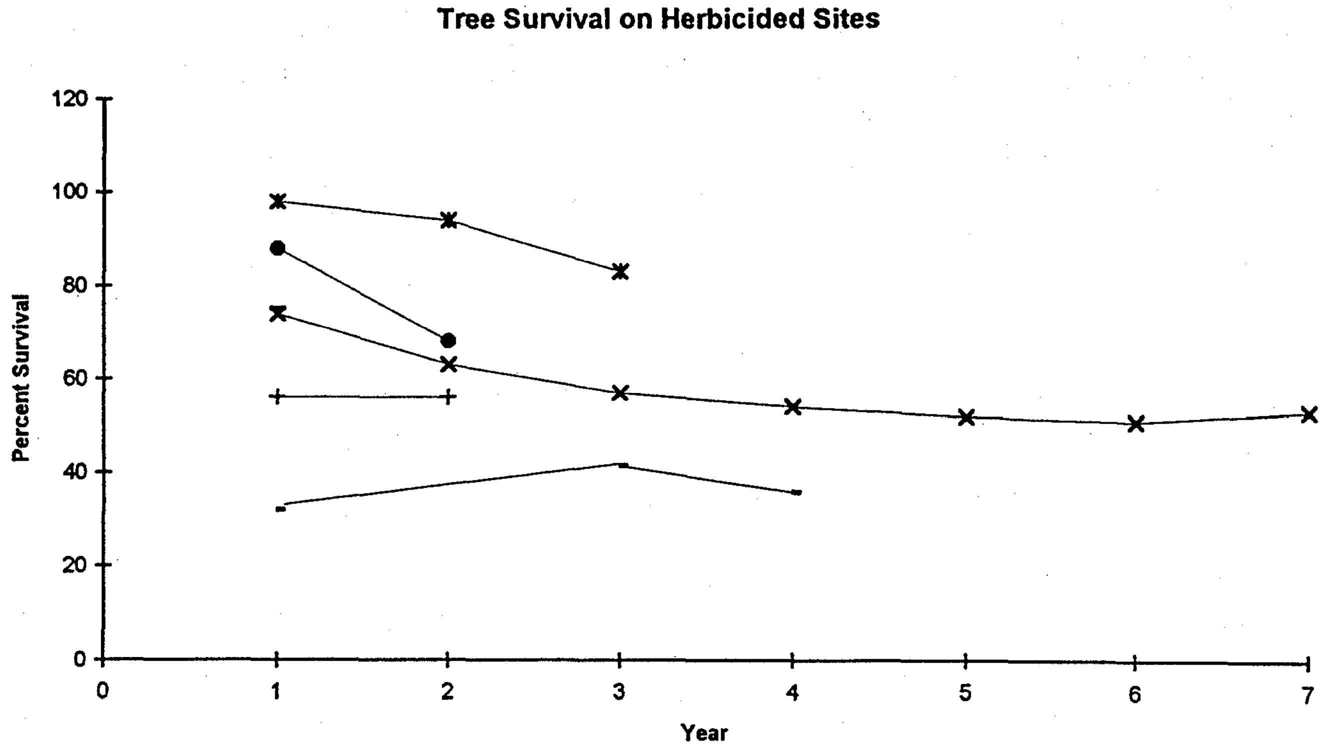


Figure 6-22. Species richness of herbaceous vegetation on herbicided (top) and non-herbicided (bottom) sites.



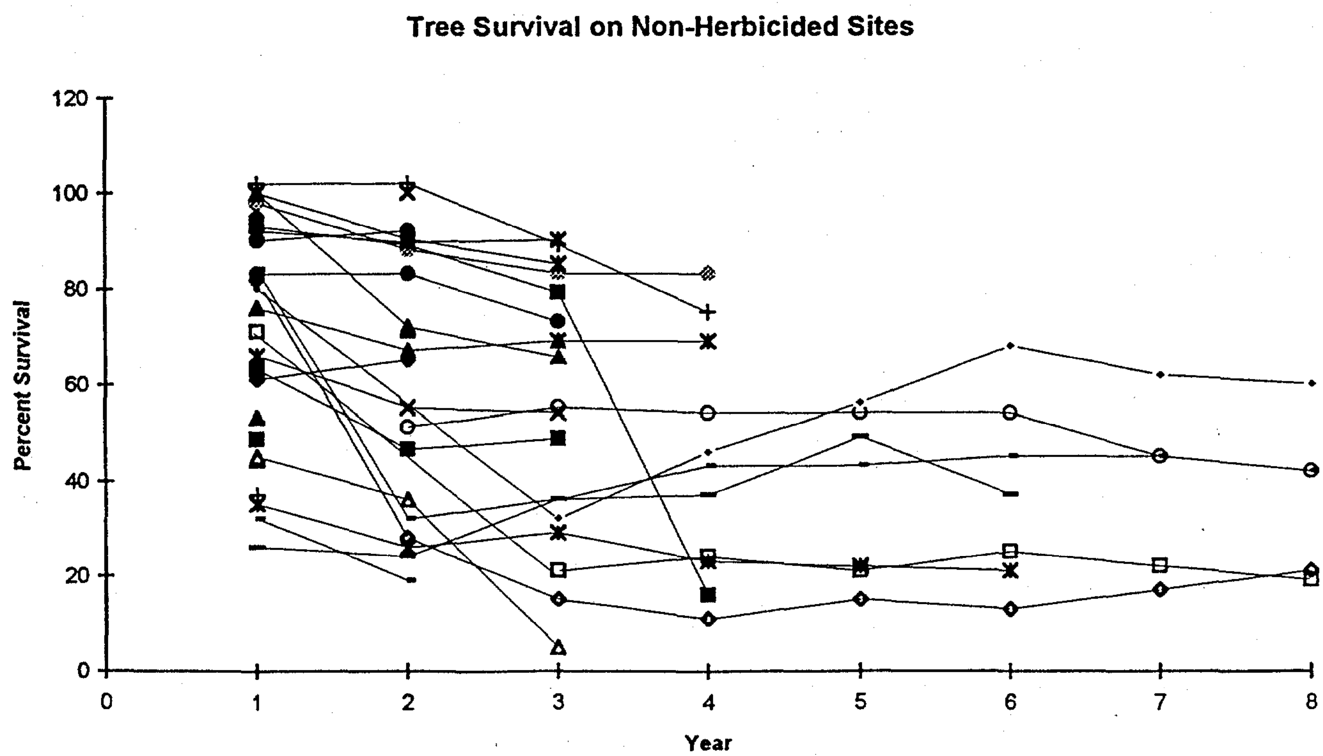


Figure 6-23. Tree survival on herbicided (top) and non-herbicided (bottom) sites.

Table 6-3 . Comparative data for native Florida forested wetlands

Note	Site Description	Species Richness (# species)	Density (stems/hectare)	Citation
1	Lake border swamp	8.5	1239.4	Davis et al. 1991
2	Cypress dome	7.2	1809.2	Davis et al. 1991
2b		6.5	NA	Davis, 1990
2c		8	NA	Monk, 1968
2d		12.3	2336.7	Brown, 1978
2e		14	NA	Bailey, 1994
3	Bayhead	6.8	1183.2	Davis et al. 1991
3b		6.6	NA	Davis, 1990
3c		10	NA	Monk, 1968
3d		12	NA	Best et al., 1987.
3e		20	525	Clewell et al., 1982
4	Mixed hardwood swamp	13.5	1290.3	Davis et al. 1991
4b		14	NA	Monk, 1968
5	Floodplain swamp	16	1644	Brown, 1978
5b		15	NA	Bailey, 1994
5c		19	444	Clewell et al., 1982
5d		47	1540	Leitman et al., 1983

Notes

1 Based on mean of 2 lake border swamps. Data reported as number of stems > 5cm DBH/ha and species richness was based on 1000 m2 belted transects

2 Based on mean of 6 cypress swamps. Data reported as number of stems > 5cm DBH/ha and species richness was based on 1000 m2 belted transects

2b Based on the average of two cypress domes. Data reported as number of stems > 5cm DBH.

2c Based on 15 cypress domes located in North Central Florida

2d Average of 7 domes in Alachua County. Data reported as number of stems > 2.5 cm.

2e Based on 5 cypress domes within the Upper Hillsborough River Flood Detention Area.

3 Based on mean of 4 bay swamps. Data reported as number of stems > 5cm DBH/ha and species richness was based on 1000 m2 belted transects

3b Based on three bayhead communities in floodplain forests along the Oklawaha River.

3c Based on 9 Bayhead Commuities in North Central Florida

3d Based on a natural bayhead swamp in North-Central Florida

3e Based on riverine forests along the south prong of the Alafia River System

4 Based on mean of 11 mixed hardwood swamps. Data reported as number of stems > 5cm DBH/ha and species richness was based on 1000 m2 belted transects

4b Based on 24 mixed hardwood swamps in North-Central Florida

5 Data reported as stems greater than 2.5 cm DBH

5b Based on 5, 100 meter transects within the Upper Hillsborough River Detention Area.

5c Based on 129, 625 square foot transects along the South Prong of the Alafia River.

5d Based on riverine cruise point sampling along the Apalachicola River floodplain.

space. Trends in survival, growth in height, and development of crown closure suggest that constructed forested wetlands are surviving and the tree component is persisting.

Using data from Davis et al.. (1991) the most common tree species in native wetland types, as indicated by importance value, were as follows:

	Species	Mean Importance Value
Bay swamps -		
	Gordonia lasianthus	43.0
	Pinus elliottii	30.0
	Taxodium ascendens	19.7
Cypress domes-		
	Taxodium ascendens	72.8
	Magnolia virginica	21.4
	Pinus elliottii	13.5
Lake border swamp -		
	Nyssa sylvatica var *biflora*	32.3
	Taxodium distichum	27.7
	Quercus laurifolia	16.1
Mixed hardwood swamp -		
	Acer rubrum	17.2
	Taxodium ascendens	15.5
	Taxodium distichum	10.8

The most common species planted in constructed forested wetlands in order of frequency of planting were: *Acer rubrum, Liquidambar styraciflua, Taxodium distichum, Fraxinus caroliniana, Ilex casine, Nyssa sylvatica* var. *biflora* , and *Quercus laurifolia. When* expressed as a percentage of species mixture planted, *the* most common tree species were *Taxodium distichum* (28%), *Nyssa sylvatica var. biflora* (20%), *Fraxinus caroliniana* (17%), *Quercus laurifolia.* (14%). Most common species planted in constructed wetlands are also commonly found in native wetlands.

Species richness and percent open water in native Florida marshes are given in Table 6-4. Richness varied considerably from *Juncus/Pontedaria* marshes with only 3 species to a freshwater marsh with over 35 species. Species richness of constructed wetlands is considerably higher than that found in native systems. Several sites had over 175 species, and it was not uncommon for sites to have more than 100 species. Presumably these sites included both upland and wetland species. The mean richness for all constructed sites was about 50 species -- still higher than that found in the most diverse native wetlands.

Table 6-4. Comparative data for native Florida herbaceous wetlands

Note	Site Description	Species Richness (# species)	% open water	Citation
1	Shallow marshes	35.4	1.88	Brown, 1991
2	Freshwater marsh	85	-	Evans, 1989
3	Freshwater marsh	34	-	Evans, 1989
4	Lake Kanapaha marsh	18.5	-	Dunn, 1989
5	Juncus/Pontedaria marsh	3	-	Dunn, 1989
6	Juncus/Pontedaria marsh	4	-	Dunn, 1989
7	CSS freshwater marsh	16	15	Carlson, 1982
8	Reference marsh/Pontederia	7	48	Erwin, 1988
9	Reference marsh/Eleocharis	5	42	Erwin, 1988
10	Reference marsh/Mixed	22	-	Erwin, 1988

Notes
1 Based on mean of 9 shallow marshes.
2 97 acre natural marsh
3 104 acre natural marsh
4 Average of 4 zones
5 At four corners mine area
6 Pasture marsh near four corners
7 Species total of 6 biomass samples
8 Reference marsh rm-29a, pontederia community
9 Reference marsh RM-29a, eleocharis community
10 Reference marshes RM-19d & RM-20B, mixed marsh communities

INDUSTRY-WIDE MEANS AS A MEASURE OF SUCCESS

The change in several vegetation parameters were calculated for the mining area as a whole by averaging change over all sites for each year. The parameters included: herbaceous cover, nuisance cover, forested cover, tree survival, tree height, tree crown cover. The mean change in each parameter from year to year was calculated, as was a weighted mean (weighting based on site area). In this way we developed several graphs of the average change in wetland development for the phosphate industry as a whole. We calculated the change in three ways: mean change, weighted mean change, and weighted mean change with largest and smallest change eliminated. While the graphs give a picture of the change in the industry as a whole, they also might be used to compare an individual site's progress over time with the mean of all sites. For comparative purposes, the weighted mean change may be more appropriate.

The graphs in Figures 6-24 through 6-29 show the three ways of presenting each parameter. The mean for all sites by year is given in the top graph, weighted mean by year is given in the middle graph, and the weighted mean with smallest and largest change in each year eliminated is given in the bottom graph of each figure.

Change in herbaceous cover over time is given in Figure 6-24. In the top graph, mean change for all sites between years 1 and 2 was about 8% and between years 2 and 3 there was a negative change of about 4.5%. Between years 3 and 4 there was another negative change of about 2.7%. Thereafter the mean change was positive, ending with a total of about 14% increase in the final year. In the middle graph, weighted mean change is given. The most striking difference is the much larger percent change that is driven by several large increases in cover on relatively large sites. Total percent change using the weighted factor method is almost 45% by the final year. The weighted change in percent cover when the highest and lowest values in each year are eliminated from the data is given in the bottom graph in Figure 6-24 is. Overall, the weighted mean percent cover increased about 4% per year over the six time periods. The change in percent cover, industry-wide, using the three methods suggests a yearly increase of between 2 and 8 percent.

Mean change in percent cover of nuisance species is given in Figure 6-25. There are significant differences between the three methods of calculating industry-wide percent change. The mean changes show yearly increase of about 1% per year for three time periods and then a sharp decline of about 7% between years 4 and 5, and then an increase of about 1% per time period thereafter. The weighted mean percent change shows an increase of about 1 and 2 % in the first two time periods and then decreases of about 2 and 1% in the next two time periods, followed by an increase of 3% and finally a decrease of about 6%. In the bottom graph when the highest and lowest weighted means are eliminated, the percent change remains relatively constant, near zero until the third time period when it declines about 10% and remains relatively constant thereafter. The radical changes in the mean percent cover of nuisance species reflects the use of control at various times on various sites, large and small. It appears that there is a trend for industry to aggressively treat nuisance species in the third and fourth years.

The graphs in Figure 6-26 show mean percent change in forested cover. The mean change and weighted mean change in forested cover, industry-wide, shows increases of about 2 percent per

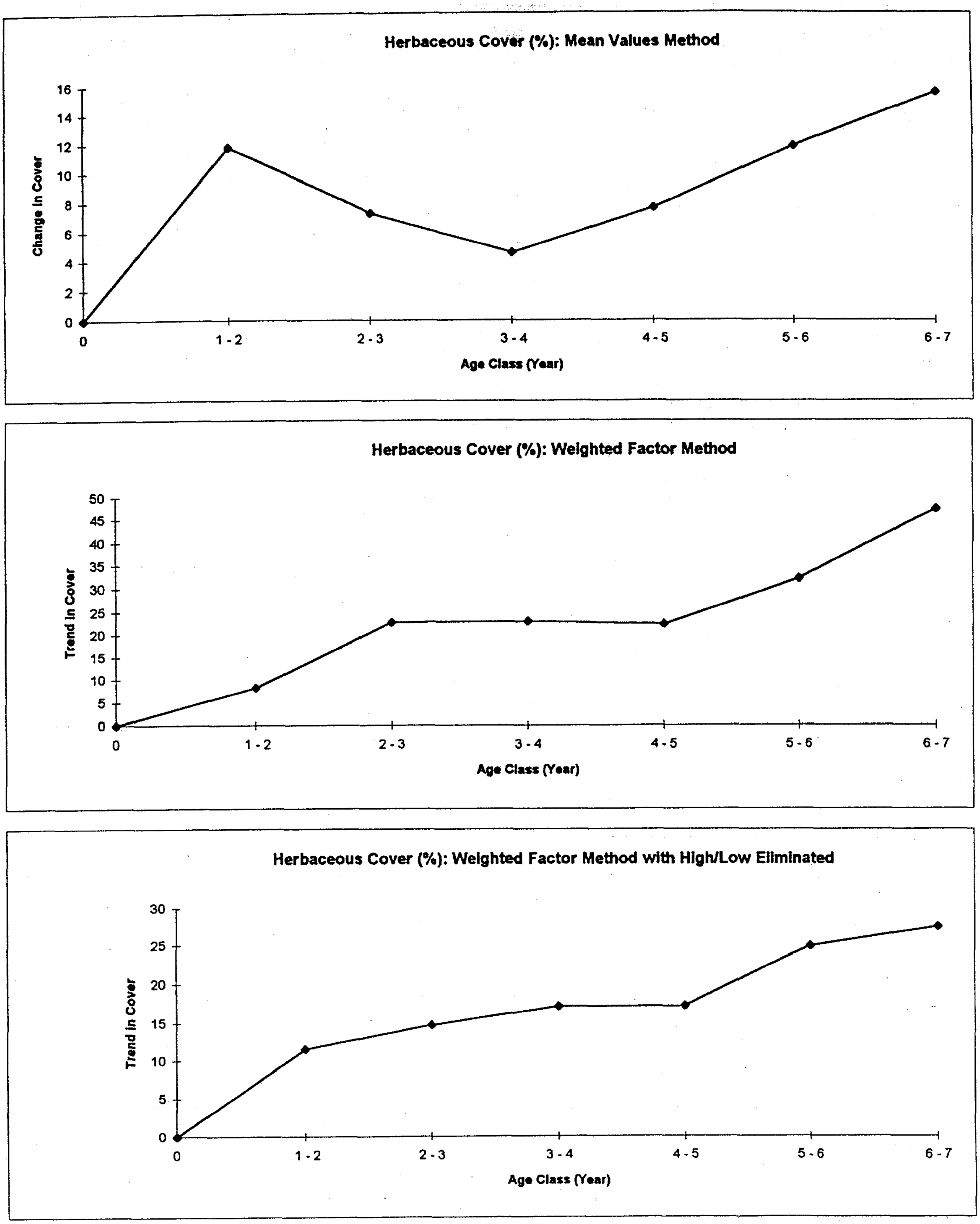


Figure 6-24. Industry-wide mean change in percent cover of herbaceous vegetation

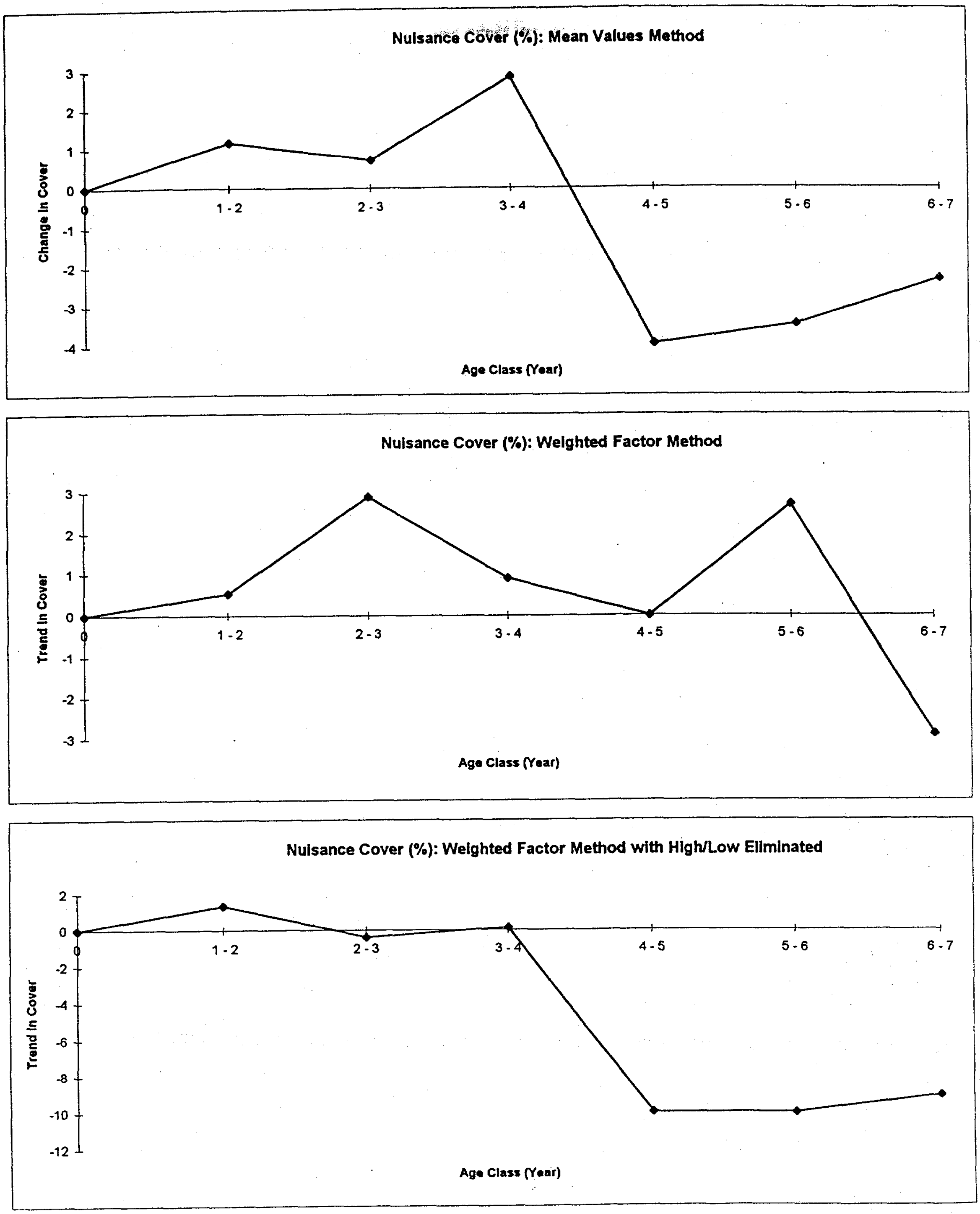


Figure 6-25. Industry-wide mean change in percent cover of nuisance species

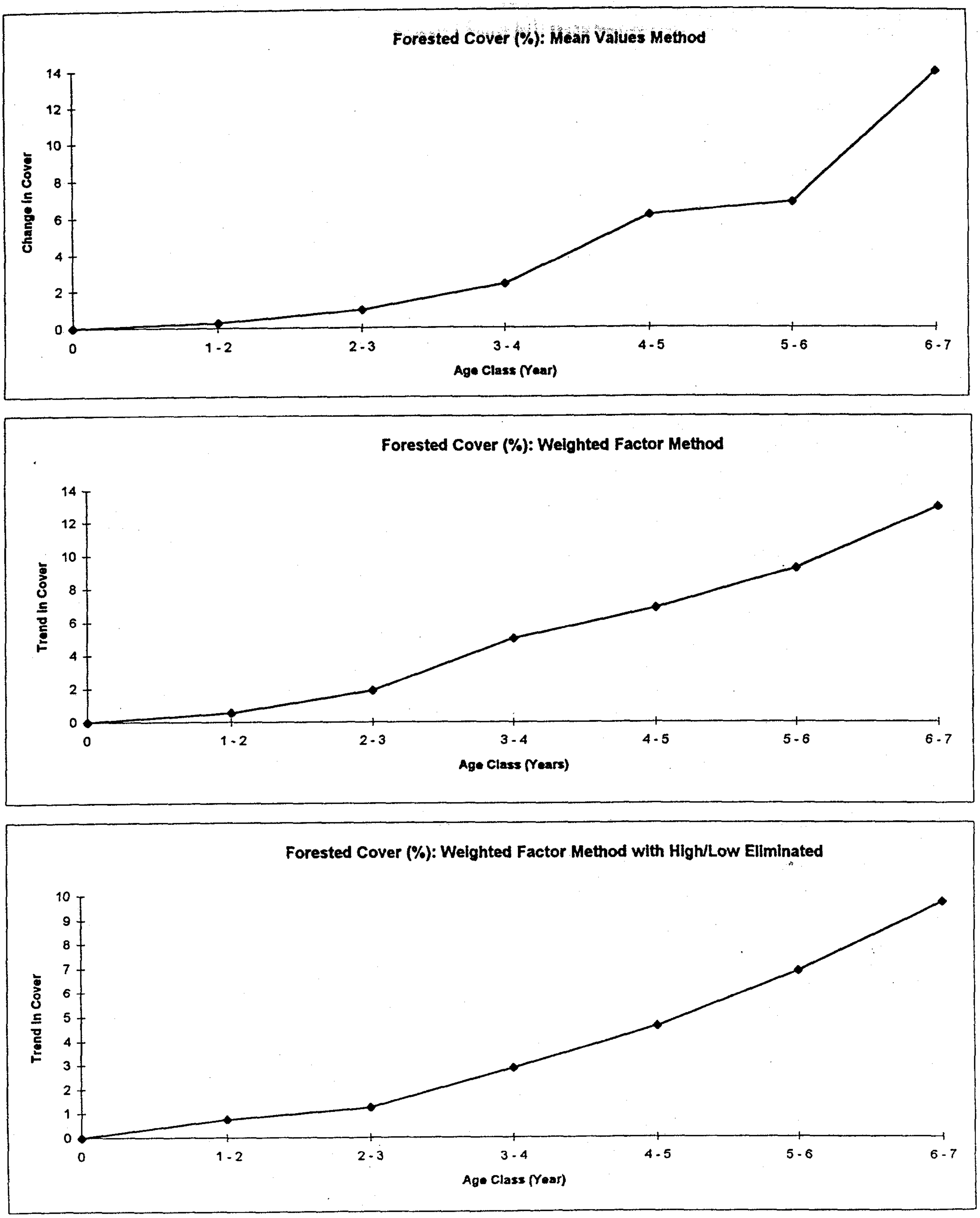


Figure 6-26. Industry-wide mean change in percent cover of forested vegetation

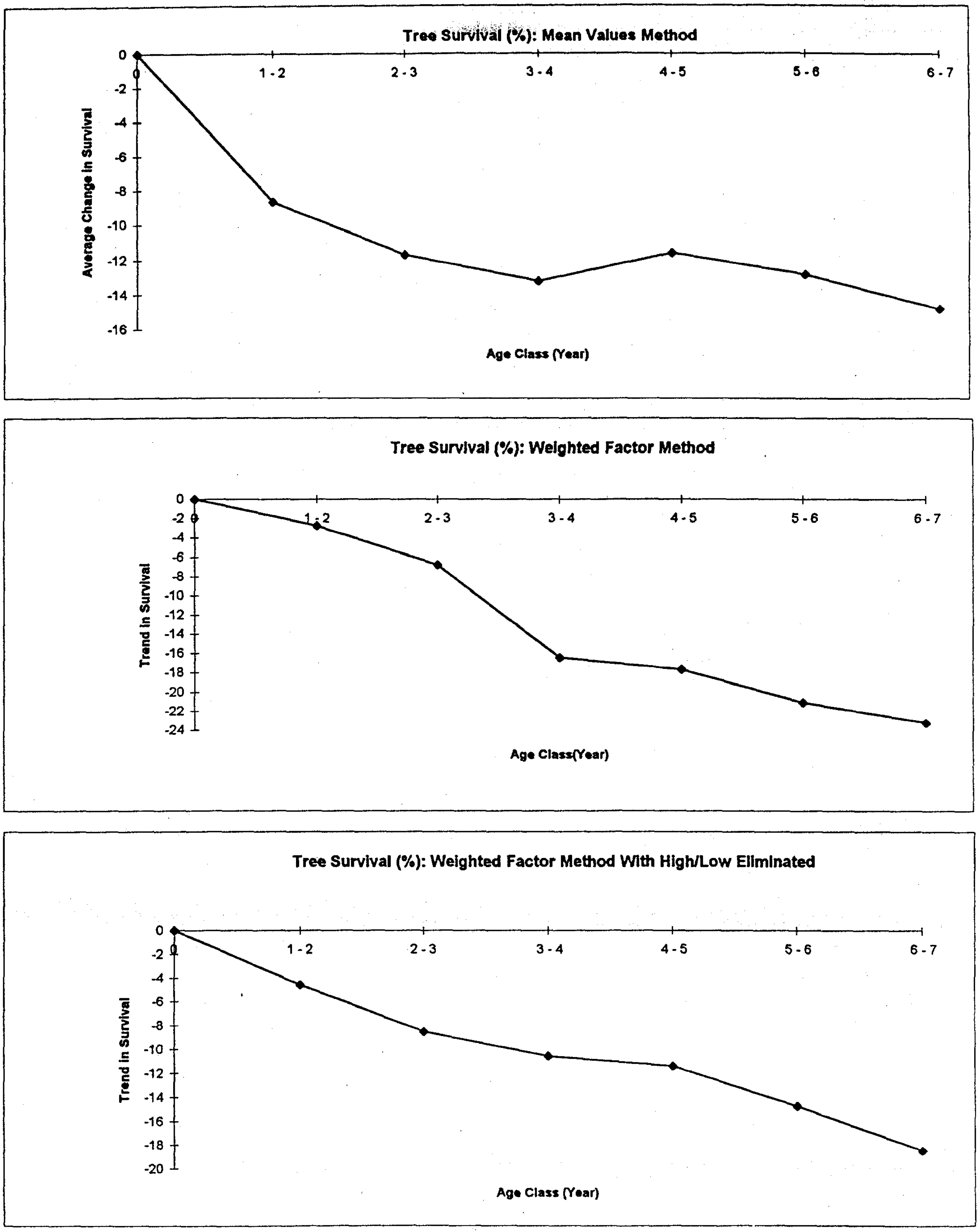


Figure 6-27. Industry-wide mean change in tree species survival

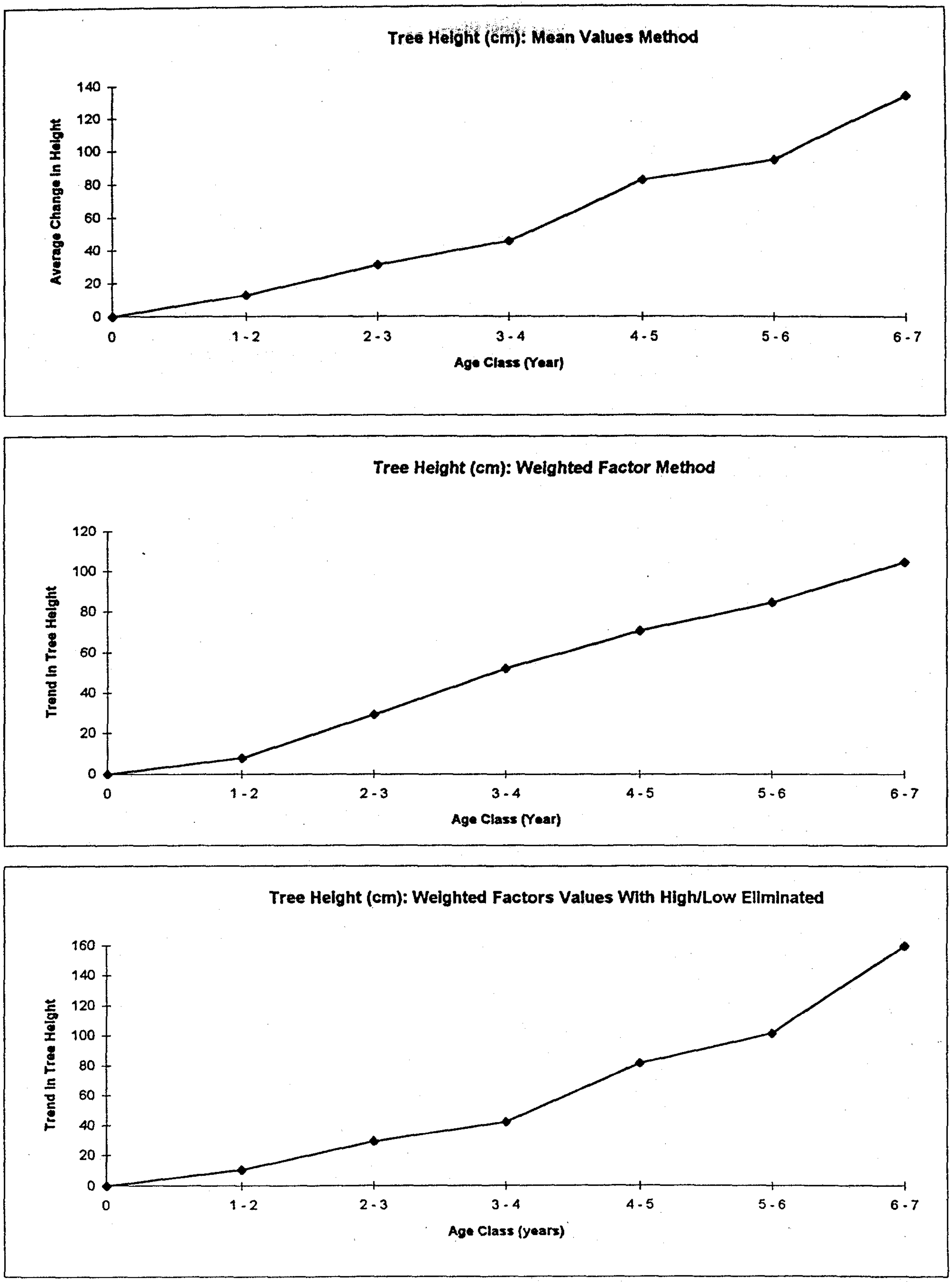


Figure 6-28. Industry-wide mean change in tree height

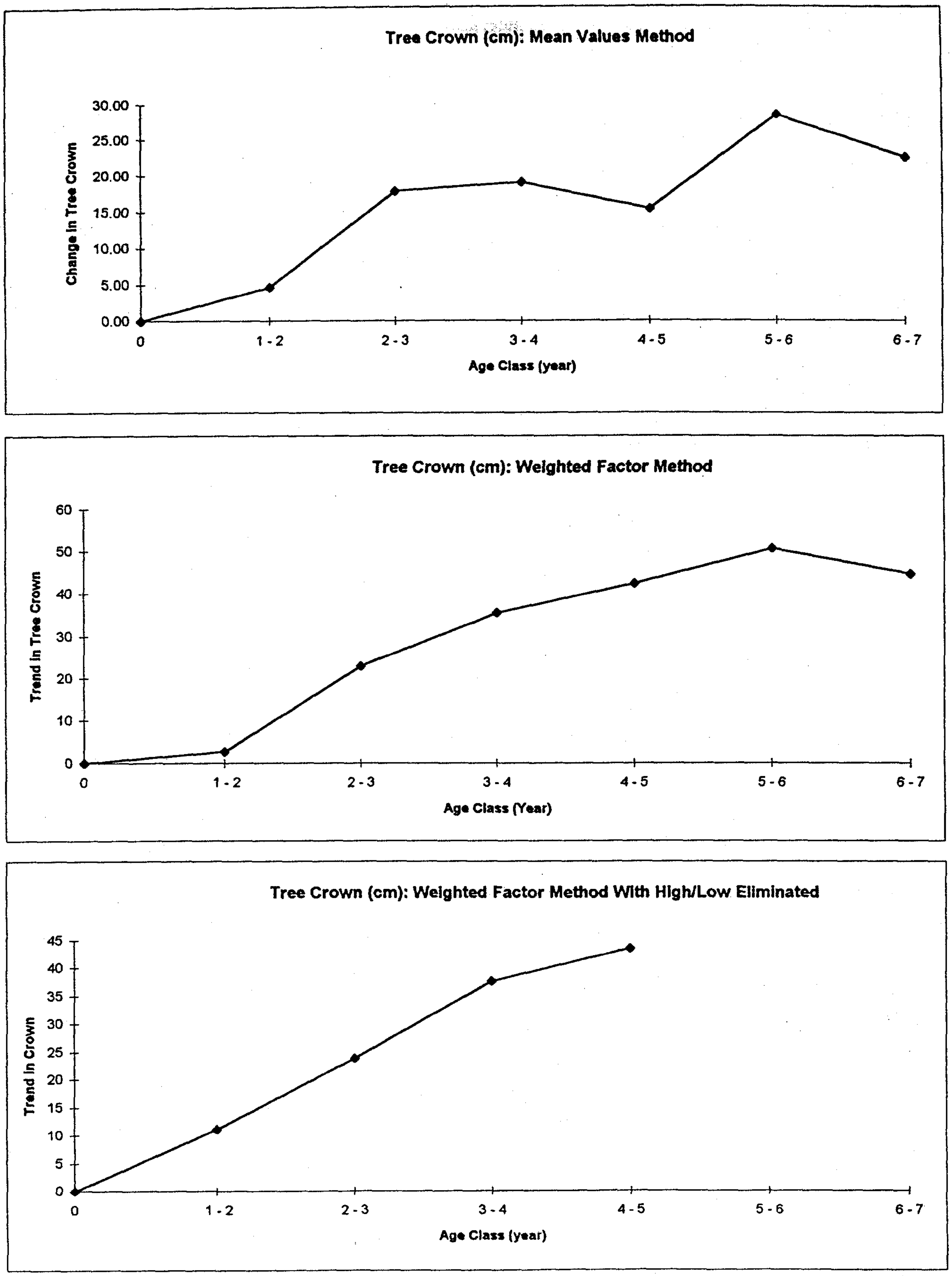


Figure 6-29. Industry-wide mean change in width of tree crown

year. The weighted mean with high and low values eliminated shows mean percent changes of about 1.5% per year.

Industry-wide, mean change in survival of planted trees, tree height, and crown width are shown in Figures 6-27, 6-28 and 6-29. Overall mortality is between 2.5 and 4% per year when calculated as a mean for the entire industry. Mortality calculated this way does not consider the significant losses in the first year, where survival appears to average about 70%. Figure 6-28 shows graphs of industry-wide mean change per year in tree height. Mean change is between 20 and 26 cm per year. Figure 6-29 shows mean changes in tree crown width per year. Industry-wide mean change in tree crown width was between 6 and 10 cm per year.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Findings regarding the success of wetland reclamation related to development and persistence of the plant community are hampered by a severe shortage of data, incomplete data sets for the data that existed, and a lack of comparability of data from one company to the next. As a result, our conclusions are based on trends that have been extracted from monitoring reports and the research of others. The data base suffers from lack of consistency in methodologies for data acquisition and analysis. About 36% of the sites visited by the research team did not have useable data. Of the sites that had good data only a handful had time series data that could be used to evaluate trends in community development and persistence. Regardless, the following are conclusions of this preliminary analysis:

- The data set for evaluation of wetland reclamation success is inadequate to statistically test community development, effects of site design and treatments, or long-term trends. While we have presented trends based on existing data from a variety of sources, it must be understood that these are only trends based on a handful of wetlands with incomplete data sets, and for only several years.

- Percent cover in marsh wetlands increased in most wetlands for which we had data but then appeared to level within 3 - 5 years. Evaluation of mean change in percent cover industry-wide indicated that change is between 2 and 8% per year, depending on method of calculation.

- Evaluation of the growth and survival of planted tree species suggests that survival is about 50% over 6 years (one site with 20 years of data [parcel B] exhibited survival of only 28% of planted wetland and mesic trees). Mortality averages between 2.5 and 4% per year after the first year.

- Industry-wide percent increase in mean forest cover in forested wetlands was between 1.5 and 2% per year for the period over which data were available.

- On the average, species richness of reclaimed marshes appears to rival the most diverse native marshes. Zonation and patch diversity within marshes was not testable with the data set, but anecdotal evidence from the site visits suggests that at least some reclaimed marshes were planted to achieve these characteristics.

- Species richness of obligate wet herbaceous species appeared to decline for those sites for which there were longer term data, decreasing on the average by about 40%. Without more detailed analysis it is unclear if this is loss of important species or just the loss of floating and rooted aquatic species as communities shift to less open water systems

- Species richness of planted trees in forested wetlands is higher than richness found in native mixed hardwood swamps. However, few wetlands with a single dominant species, like bayheads and cypress domes, are being created.

- The number of trees planted per acre, on average (800), appears to be similar to the density of native wetlands when all age classes are considered. Survival indicates that stand densities will be about 400 trees per acre at the end of 5 years and that continued yearly mortality of about 2-3% will continue, thus mature constructed wetlands will have between 300 and 350 trees per acre. This appears to agree with densities of mature trees in native forested wetlands.

- There are no data on long-term recruitment of herbaceous and shrub species within forested wetlands. Anecdotal evidence from site visits suggests that this may be a serious shortcoming for the development of vertical structure in forested wetlands.

  Survival of planted trees on sandtailing/overburden sites appears to be similar to survival on overburden sites. The data do not clearly demonstrate significant trends, however first-year data suggest trees survive better on sandtailings than overburden. The overall trend thereafter appears to favor overburden sites, but after 6 years survival appears to be relatively similar between the two treatments.

- Mulching does appear to have positive benefits for herbaceous wetlands. Percent cover was higher in the first year and appeared to continue for 4 or 5 years. Species richness appeared to be little affected by mulching.

- There is no question that herbiciding controls nuisance species. The data show that mean percent cover of nuisance species on non herbicided sites reached about 30% in the 6th year, while it was kept below 10% on herbicided sites. Species richness on herbicided sites appears to be lower than on non-herbicided sites (although the data are limited).

- "Nuisance" species control in forested wetlands appears to benefit tree survival. The data suggest, but do not confirm, that survival is better on herbicided sites, but the database is somewhat limited. A controlled experiment to test the positive and negative effects of herbicides in constructed forested wetlands is strongly recommended.

- The effect of initial hydrologic regime could not be tested with the available database, but from the site visits suggested that, on more than one occasion, initial water levels played a significant role in the failure of marsh plantings.

- There are no data related to micro-topographic relief but site visits confirm that, without exception, forested wetlands are created with extremely "smooth" topographies. Micro-relief on the order of less than 1 meter would increase diversity of hydrologic regimes and in turn potentially increase survival and growth of planted species.

RECOMMENDATIONS

Preliminary recommendations are grouped into two broad categories: (1) recommendations related to reclamation techniques and treatments, and (2) recommendations related to data collection and reporting.

Based on the summaries of data and trends observed in community development, as well as observations during field visits, we recommend the following:

- A trend in the decline of obligate wetland species in herbaceous wetlands, coupled with no decline in overall species richness may indicate a need for additional research that would help to illuminate the reasons for the trend.

- Additional research is urgently needed on the long-term trends in invasability of herbaceous wetlands by nuisance and exotic species and the documentation of success of efforts expended for controlling them over time.

- We subjectively noted a disturbing degree of invasion by exotics on older sites that were "released" and therefore of low priority for continued maintenance by industry. We strongly urge a detailed survey and program for control, lest the reclaimed phosphate district become dominated by exotics.

- The effects of early dominance of nuisance species on growth 'and survival of tree species need further investigation.

- Forested wetlands should be constructed with greater micro-topographic relief. If trees are planted on hummocks, water levels could be deeper without threatening tree survival, and greater surface storage can be accomplished.

- Provision should be made to plant shrub and herbaceous species in constructed forested wetlands once the canopy begins to close. Anecdotal evidence from older reclaimed and naturally reclaimed sites suggests that constructed systems will be lacking these strata, considerably lowering their wildlife habitat values.

- The use of Bahia grass *(Paspalum notatum)* on reclamation sites should be discontinued and replaced by annual crops for soil stabilization. Our impression was that *Paspalum* was extremely persistent in the sites visited, outcompeting native flora.

- Since survival of some tree species is low, total loss may occur if only a few individuals of any one species are planted. No planted species should constitute less than 10% of the trees planted in a given area.

Based on our analysis of the quality and completeness of data, we recommend the following:

- Overall there is a need for standardization of methods of field data collection and analysis. In addition, data that would help in the interpretation of trends are not collected (ie. level of effort expended in nuisance control, water levels, mulch thickness, planting densities, percent mixtures of species planted, etc.) are not currently corrected, but should be.

- At the very least, basic data should be collected on all wetland reclamation sites. As present there are insufficient data to determine overall success of the industry’s reclamation of wetlands. Data were completely unavailable for over 60% of the total sites visited.

- The quality of data falls declines rapidly after 2 to 3 years. More attention should be given to standardization, and a longer term commitment made to monitoring.

A PROPOSED SITE MONlTORING AND EVALUATION PLAN

The purpose of this proposed monitoring and evaluation plan is to detail methods for long-term monitoring of constructed wetlands to evaluate success of reclamation efforts, consistent with objectives of the various governmental agencies who oversee reclamation, and capable of providing information necessary for evaluating success of the reclamation effort.

The time necessary for development of a mature wetland ecosystem may be lengthy, especially for development of a mature forested wetland. However, determining success of creating a wetland does not require evaluation of the climax community itself but rather, it requires demonstrations that various community development milestones are being achieved and passed on schedule. Inasmuch as the functions that an ecosystem performs depend, in significant part, on the vegetation within that ecosystem most of the proposed monitoring effort will be directed toward documenting the rate at which the plant community is developing coupled with measuring the environmental factors affecting ecosystem development.

The ultimate test of success requires that the constructed wetland emulate a natural wetland in both function and structure. In addition, the community should be persistent; that is, the community should be capable of self-replication and be resistant to invasion. To the degree to which emulation of structural features and functional properties of natural wetlands has been achieved may be difficult to measure. Certainly structural features can be evaluated, but measuring functional equivalency requires indicators of functions. In this proposed monitoring and evaluation plan we use vegetation as a means of evaluating functional equivalency for habitat values and food chain support. We propose monitoring of surface and ground water hydrology to evaluate functional equivalency for recharge/discharge and water storage. Finally we propose measuring water quality to evaluate functional equivalency for water quality enhancement. We believe that if there is reasonable survival and growth of vegetation, if there is reasonable hydrology, and if water quality is not declining, then one might predict the potential for success in ultimately establishing a functional, self-maintaining and persistent wetland.

PLANT COMMUNITY MONITORING

Purpose: The primary purpose of plant community monitoring is to collect information on development of plant community structure necessary for determining type, nature and function of constructed wetlands. Data should be collected using techniques to allow for evaluating rate of plant community development useful for assessing the trajectory of the developing ecosystem and ultimately the success of reclamation.

Scope: In order to evaluate the developing ecosystem it is necessary to document the plant community as well as the rate at which the community is developing. Data should be collected systematically and allow for determination of the following:

TREES

- species composition, richness, diversity, density
- survival, condition, height, crown diameter, seed phenology
- recruitment status: planted, basal or root sprout, volunteer seedling

GROUND COVER

- herbs/forbs: species composition, richness, diversity, cover
- shrubs: species composition, richness, diversity, cover, seed phenology

Field Sampling Methods: TREES: A modification of the “line strip” quadrat (as per Woodin & Lindsey 1954, Lindsey 1955) sampling method is ideal for monitoring vegetation on reclaimed lands (see Best et al. 1983, Best & Erwin 1984, Erwin & Best 1985). The method consists of permanently establishing an elongated quadrat (generally, measuring 10 x 100 m) within which individual planted trees can be located, mapped and measured; then subsequently resampled to determine survival, condition, reproductive status and growth (height and crown increases). Since planted individuals are located/mapped during initial sampling, the technique allows for identifying “new” individuals recruiting into the plot and following their development.

Permanent, elongated quadrats (10 x 100 m) should be established in each wetland being created. To permanently establish the quadrats, a PVC-covered metal rebar is placed at the beginning, at 25-m intervals and at the end of the elongated (100 m) portion of each quadrat. During sampling, a centerline measuring tape is attached to beginning and end sampling points to establish the center of the 10-m portion of the quadrat. During initial sampling(s) tree seedlings occurring within 5 m of either side of the centerline are noted for distance along the centerline plus the distance (within 5 m) right/left of the centerline to establish location coordinates for each individual. In addition to location coordinates, further information relevant to each individual at each location is collected (species, height, condition, crown size, reproductive status, water depth, etc.). Through subsequent sampling, this method not only permits relocating each individual tree, but also allows for assessing change in condition of each individual as well as determining recruitment and mortality of tree seedlings, and relating these parameters to location and water level.

Trees should be sampled on an annual basis for the first several years then bi-annually thereafter.

Field Sampling Methods: MARSHES: Within marsh communities, a modified line-strip transect should be set up along topographic gradients and sampled at regular intervals using one-meter square sampling quadrats to determine species composition, percent cover, frequency, phenology, and average water depth (Phillips 1959, Smith 1980). In addition to vegetative ground cover, data should recorded on open-water areas and non-vegetated ground (such as bare ground, leaf-litter).

HYDROLOGY MONITORING

Purpose: The hydrology of an area is one of the most critical environmental factors affecting the type, nature and function of wetlands developing in the area. The purpose of this task is to collect data on frequency, duration and depth of flooding and/or soil saturation.

Scope: At least one stage level recorder should be installed in each hydrologically isolated wetland to determine water level fluctuation at the surface and shallow-subsurface levels of the area. Stage level data should be correlated to landscape elevations to determine depth and duration (hydroperiod) of water levels throughout the wetlands.

Data generated should be synthesized to provide information on hydroperiod, average depth and duration of flooding, frequency of flooding, depth (if within one m of surface) to subsurface groundwater, i.e. soil saturation, etc. These data can be compared to published information for similar types of wetlands.

WATER QUALITY MONITORING

Purpose: Initial conditions of water quality parameters in constructed wetlands will show little resemblance to typical water quality of natural wetlands. However, as the ecosystems mature, water quality should begin to approach some set of target conditions. The purpose of this task is to measure select water quality parameters and evaluate changes in these parameters as the ecosystems mature.

Scope: The following water quality parameters are recommended for surface water sampling: pH, suspended solids, turbidity, TKN and TP

Field Sampling Methods; Surface water should be sampled at inflow and outflow Points of wetlands at regular intervals depending on the hydrology . For constant flowing waters, samples should be taken weekly as well as during or immediately following rainfall events. After several months sampling can decrease to biweekly and then to monthly after 6 months. After two years sampling can be conducted on a quarterly basis. In still water wetlands (those not hydrologically connected), sampling should be conducted weekly during initial phases, decreasing to biweekly after several months, then to monthly. After two years water samples can be collected quarterly

INFORMATION GAPS AND RESEARCH NEEDS

A crucial and fundamental deficiency is that sufficient long-term data do not exist to evaluate long-term viability of constructed wetlands. We received vegetation data for 15 wetland sites five years of age or older, and of these, only about 50% had useful information. To these data we added information from several sites from research reports and published papers. The trends we have discovered, using the data available, suggest that species richness remained about the same while obligate wetland species richness declined, and percent cover increased on herbaceous wetlands. In forested wetlands, survival of planted trees was less than 50% after four or five years, species richness was lower than at time of planting, height of surviving trees was increasing, and crown width was increasing. As a result, the trends are not conclusive. The picture that emerges is one of wetland systems going through the very early stages of succession, self-organizing around the suite of conditions and driving energies characteristic of reclaimed lands. However, the data do not project a clear image of success. or identify the factors responsible for the more rapid and diverse revegetation of some sites and not others.

Zonation in wetlands, while used on several sites (ie. mixtures of vegetation were tailored to differing moisture regimes) was not monitored in a format (continuous transects) that would allow evaluations of species composition or growth and survival along gradients of moisture or soils.

The presence of exotic species was noted during the site visits. Brazilian pepper *(Schinus terebinthifolius)* was seen on several of the older sites, in a zone that corresponds roughly with that occupied by wax myrtle *(Myrica cerifera).* This is a disturbing trend, but because most of these sites have been “released”, the invasion was not documented. Discussion with industry personnel at the time of the site visits indicated that some control was being attempted, but this was sporadic.

Herbaceous and shrub understories in forested wetlands are an important component, and are composed of different species depending on ecosystem and maturity. Native forested wetlands have understories that are composed of species not normally planted during reclamation. It is impossible to evaluate recruitment and long-term trends in the development of the shrub and herbaceous layers in forested reclamation sites, because data were not collected.

While hydrology is discussed in another section of this report, we mention it here as it relates to vegetation growth and survival. With very few exceptions, there are no data relating hydroperiod or depth of inundation to growth and survival of planted species or zonation.

In summary, with very few exceptions, there are no long-term data sets that would allow a more complete characterization of community development, community trajectories, zonation, development of vertical structure, regeneration by dominant species, invasibility, or effects of hydrological regime. We were able to evaluate trends in community structure, specifically: growth and survival of planted vegetation, and species richness. In addition, there were some data on the effects of post mining treatments related to growth and survival, however our analysis suffers from a lack of consistent methodologies and reporting format for monitoring data. There is a strong need for development and adoption of industry-wide field measurement techniques, methods for summary and synthesis of collected data, and format for reporting monitoring data.

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APPENDIX 6A

List of projects and quality of data

Project	PROJECT NAME	DEP	DNR	Site Age	# Years of Data	Vetetation Data
Agrico						
AG1	Payne Creek Recl. Project	250872429		3	3	4
AG3	22-Acre (AGR-FG-84(5))	250852409		7	6	4
AG4	8.4 Acre	530644009		9	7	3
AG5	2.3 Acre	530919539		6	3	2
AG6	Payne Cr. Dragline Crossing	532028413		NA	2	5
AG7	Hardee lakes, AGR-FG-PC-1	251378469		4	0	0
AG10	Morrow Swamp, FT. Greene, FG-13			13	10	4
AG11	FG-SP-8 Clay Settling Area			0	0	0
AG12	FG-SP-9 Clay Settling Area			0	0	0
AG13	Big Marsh, FG-GSB-3	251642849		0	0	0
AG14	Trio Marsh, FG-84(6), FG-84(7)	531201979		0	0	0
AG15	Preservation Drain	531478399		0	0	0
AG16	PC-PC-1	251224079		NA	3	5
AG17	PC-PC-2	531120329		0	0	0
AG18	Section 28 FT. Green			0	0	0
AG19	Section 29 FT. Green			0	0	0
AG20	PC-17			0	0	0
AG22	FG-HC-1			0	0	0
AG23	Natural Area Marsh, Section 20			0	0	0
AG24	Natural Area Bayhead S.			0	0	0
AG25	Natural Area, Marsh Near Bayhead	1201979		0	0	0
AG26	Ag-East East	1201979		0	0	0
CF Industries				0	0	0
CF 1	SP1 Clay Settling Area			0	0	0
CF2	SP5 Sand-clay mix disposal area			0	0	0
CF3	R6 Sand-clay mix disposal site			0	0	0
CF4	R8 Active sand clay mix disposal			0	0	0
CF5	Hickey Branch R7			10	7	2
CF6	R9	250627469		8	4	2
CF7	R10	250627469		6	3	3
CF8	R12			0	0	0
Mobil				0	0	0
MO1	Beulah Creek	531008789	MCC-N-85(1)	0	0	0
MO2	George Allen Creek	530695759	MCC-N-SP(6)	11	8	4
MO3	Guy Branch	530419373	MCC-N-SP(1)	11	8	4
MO4	Bird Branch N and S	530523779	MCC-N-82(1)	10	6	3
MO5	Consent Order 7984			NA	7	3
MO6	Upfront Mitigation Area			0	0	0
MO7	30-Mile Crossing			4	1	1
MO8	Lake			NA	2	1
MO9	Mc Cullough Creek	530286939	MCC-FM-SP (8)	NA	8	5
MO10	FM6 Land and Lake			0	0	0
MO11	Gooch Wetland	531380689	MCC-FM-87 (4)	4	1	1
MO12	FM-1 Clay settling area		MCC-FM--09	NA	1	1
MO13	Sink Branch Natural Reveg.			0	0	0
MO14	Sink Branch	530275443		NA	9	3
MO15	VARN CSA. Lower Rocky Branch	530952859	MCC-FM-05	8	1	1
MO16	Candie's Marsh			0	0	0
MO17	Upper Myers Branch	530711649	MCC-FM-83(3)	NA	4	2
MO18	Upper Roc ky Branch	530952859	MCC-FM-87(1)	4	1	1
MO19	Lower Myers Branch		MCC-FM-22a	11	8	4
MO20	Rocky Reference Wetland			0	0	0
MO21	Peace Dragline Crossing	531656559		0	0	0
MO22	3w Cut, naturally recl.			0	0	0
MO23	Homeland			0	0	0
MO24	Minor Jones Lakes and Swale			0	0	0
MO25	Section 23 Creek (in land and lakes program)	531664409	MCC-FM-PR(1)	3	1	1
MO27	SP(4) Marsh		MCC-FM-SP(4)	0	0	0
MO28	TF West of Plant			0	0	0
MO29	SFM-1 Marsh	53-47545	MCC-SFM-PB(1)	0	0	0
MO30	Lake Br. Tributary	290558139		NA	6	3
MO31	BF-1			NA	1	2
MO32	BF-2			0	0	0
MO33	BF-4			0	0	0
MO34	BF-5			NA	1	2
MO35	BF-SP (8)			0	0	0

Project	PROJECT NAME	DEP	DNR	Site Age	# Years of Data	Vetetation Data
MO36	BF-SP(9D) phase 1			0	0	0
MO37	Pembroke 2/m-s CSA			0	0	0
MO38	BFSP (9)-2		AMX-BFSP (9D)	0	0	0
Occidental						
OX1	SP-1		OCC-SR-SP(1)A	0	0	0
OX2	Mc Callum Bay: Natural Area			0	0	0
OX3	Mc Callum Bay		OCC-SR-82(3)A	6	3	3
OX5	SP-4		OCC-SR-SP(4)	11	3	4
OX6	SR-8 Purvis Lake		OCC-SR-8	13	3	3
OX7	Cabbage Head	241341589	OCC-SR8715	4	4	2
OX8	SR 8816		OCC-SR-8816	0	0	0
OX9	Green Area	241341609	OCC-SR-83(2)	8	3	3
OX10	82-(2)		OCC-SR-82-2(2)	0	0	0
OX11	Roaring Creek- Reconstruction Channel	241089309	OCC-SR-83(2)	0	0	0
OX12	SA-1			6	3	4
OX13	Rosebud Branch		OCC-SC-85(2)	0	0	0
OX14	SC-85-(2)		SC-85(2)	0	0	0
OX15	Lang Lake		OCC-SC-86(1)	0	0	0
OXY 16	85(6)	241341569	OCC-SC-85(6)	0	0	0
OXY 17	SR-4, SA #10 Demonstration		OCC-SC 85(5)	0	0	0
IMC						
IMC1	Cemetery Branch	291202919	BP-L 85(6)	7	3	2
IMC2	Lizard Branch	291791699	BP-L-SPA(1)	0	0	0
IMC3	McMullen Branch	290951739		9	2	3
IMC4	Jamerson Jr.	290747149	BP-L-84(1)	7	2	2
IMC5	Hall Branch	290491529	BP-L-SP(2A)	10	5	3
IMC6	Miles Grove	290201851	IMC-L-LMR (1A)	0	0	0
IMC7	Dogleg Branch	290463229	BP-L-SP (12A)	12	4	2
IMC8	E. Lake Branch		IMC-H-LB (2)	0	0	0
IMC9	Tadpole	530876049		3	1	2
IMC10	E. Old Fort Green Road		IMC-H-PR(1)	0	0	0
IMC11	N of CR630		IMC-H-SPA(7)	0	0	0
IMC12	S of CR630		IMC-H-87(3A)	0	0	0
IMC13	W of SR 37		IMC-H-SPA(3A)	0	0	0
IMC14	FCO Sec 15	291638103		5	1	5
IMC15	FCO Sec 1		IMC-FC-HC(1)	NA	2	2
IMC16	Horse Creek		IMC-FC-SP(1A)	10	6	2
IMC17	South of K6		IMC-K-SP(1)	0	0	0
IMC18	Lake Branch			0	0	0
IMC19	West of K6		IMC-K-10	5	1	3
IMC20	South Mizelle Creek		IMC-KC-MC(3)	0	0	0
IMC21	Unit H		IMC-K-MC(2A)	5	2	2
IMC22	Achan 5/6		IMC-K-BB(1A)	0	0	0
IMC23	Achan		IMC-K-BB(2A)	7	1	1
IMC24	Bird Branch	530781759	IMC-K-BB(2)	10	3	4
IMC25	Myers Lake		IMC-K-SP(4)	0	0	0
IMC26	South Pebbledale Instant Wetland		IMC-NP-HP(1)	0	0	0
IMC27	Section 12 Hal Scott		IMC-NP-HP(1A)	5	4	3
IMC28	Section 7/12	530651609		5	3	3
IMC29	Section 6 South Pebbledale		IMC-PD-HP(1)	0	0	0
IMC30	Southwest Phosphoria		IMC-NP-HP(4)	0	0	0
IMC31	East Farmland Cateye		IMC-NP-SMC(1A)	0	0	0
IMC32	N-2 Area		IMC-NP-SMC(3A)	0	0	0
IMC33	Sweetwater Branch		IMC-NP-SWB(1C)	0	0	0
IMC34	Self-reclaimed			0	0	0
IMC35	South Tiger Bay		IMC-NP-SP(1)	0	0	0
IMC36	H-9 Clay Settling Area		IMC-CS-074	0	0	0
IMC37	North of Parcel B		IMC-CS-PR(5)	0	0	0
IMC38	W of CS-11		IMC-CS-PR(2)	0	0	0
IMC39	Parcel B		IMC-CS-063	0	0	0
IMC40	W of CS-11 floodplain1		IMC-CS-82(1)	0	0	0
IMC41	W of CS-11 floodplain2		IMC-CS-SP(1)	0	0	0
IMC42	N. of 640		IMC-CS-19	0	0	0
IMC43	E of CS-11		IMC-CS-PR(4A)	0	0	0
IMC44	Sand and Mud Lake		IMC-CS-SL(1A)	0	0	0
IMC45	Fortner		IMC-CS-1A	0	0	0
IMC46	SW of CS8 floodplain		IMC-CS-85(2)	0	0	0
IMC47	Section 6 Nor/Phos		IMC-NP-HP(2)	8	1	4

Project	PROJECT NAME	DEP	DNR	Site Age	# Years of Data	Vetetation Data
IMC48	Hooker's Prairie	530862379		6	3	3
IMC49	Alafia River Crossing	291001019		10	4	2
IMC50	60 Acre Mitigation Site			3	2	2
Cargill						
CA 1	HP4-1	530391099	108-76-01	0	0	0
CA 2	HP4-2		GAR-FM-PR2	0	0	0
CA.3	HP6-1		HP6-1	0	0	0
CA.4	HP1	531427729		5	5	3
CA.5	HP5-1	530967689		0	0	0
CA.6	HP5-2a	530650029		6	3	2
CA.7	HP5-2b		HP 5-2B	0	0	0
CA.8	HP5-3		HP5-3	0	0	0
CA 9	HP3-4		HP 3-4	0	0	0
CA 10	HP3-5		HP-3-5	0	0	0
CA 11	HP3-7 naturally recl.		HP-3-7	0	0	0
CA 12	HPSP(2)A		HPSP (2)A	0	0	0
CA 13	FMWC1 OH Wright		FM WK1	0	0	0
CA 14	FMOLD nat. recl.		FM OLD	0	0	0
CA 15	FMPR1		FM PR 1	0	0	0
CA 16	FMPR2		FM PR 2	0	0	0
CA 17	FMSP10		FM SP10	0	0	0
CA 18	FMSP11		FM SP11	0	0	0
CA 19	FMSP12 Bryants Branch		FM SP12	5	3	4
CA 20	FMLP1		FM LP1	0	0	0
CA 21	FMLP1REF		FM LP1 REF	0	0	0
CA 22	FMLP4		FM LP4	0	0	0
CA 23	FMLP2		FM LP2	0	0	0
CA 24	FMSP02		HP4-2	0	0	0
CA 25	FMSP04		FM SP4	0	0	0
CA 26	FMSP06		FM SP 6	0	0	0
US Agrachem				0	0	0
USAG 1	SP(2A), (N. CENT, S. CELLS)		SP (2A)	0	0	0
USAG 2	SP(5A)		SP (5A)	0	0	0
USAG 3	SP(4)		SP (4)	0	0	0
USAG 4	84(1A)		84 (1A)	0	0	0
USAG 5	84(2B)		84(2B)	0	0	0
USAG 6	Dragline Crossing			0	0	0
USAG 7	85(2B)		85 (2B)	0	0	0
USAG 8	85(4B)		86 (4B)	0	0	0
USAG 9	SP6A		SP-6A	0	0	0
USAG 10	SP8		SP-8	0	0	0
USAC 11	SP(11)B			0	0	0
USAC12	84-3A Walker Lk.			0	0	0
USAC 13	R-3, non-mand.			0	0	0
USAC14	S1			0	0	0
USAC 15	87-4			0	0	0

APPENDIX 6B

Table 6B-1 Herbaceous Cover Over Time In Created Systems For One and Two Strata

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Two Strata										
Agrico	2.3 Acre Wetland	105.00	82.00	77.00						
Agrico	FG-84 (5)	210.00	108.00			103.00	89.70	91.50		
Cargill	Bryant's Branch	108.00	145.00	100.00						
Cargill	Section 9 Marsh	128.00	145.90	116.20						
IMC	Bird Branch (IMC 24)	100.00		103.00						
IMC	Horse Creek (IMC 16)					127.50		133.73	132.00	
IMC	Section 12 (N Hookers Prairie)	53.70	83.20	127.32	80.00					
Mobil	Bird Branch North	47.00	104.20	107.80	101.50	131.40	139.10			
Mobil	Bird Branch South	64.80	88.60	129.90	155.40	111.50	127.00	152.50		
Mobil	George Allen Creek	92.90		94.80	92.80	129.30	138.90	133.30	107.00	
Mobil	Gooch	111.70								
Mobil	Guy Branch	107.00	131.00	105.00	96.80	122.20	119.00	106.00	101.90	
Mobil	Lake Branch Tributary	73.20	93.50	101.70	128.30	107.10	102.00			
Mobil	Lower Myers Branch	115.80	142.50	131.20	95.30	146.90	136.20	168.20	121.00	
Mobil	McCullough Creek	100.80	115.00	111.60	119.00	117.70	126.80	119.20	106.30	
Mobil	Sink Branch			88.40	99.50	101.40	138.40	101.00	107.20	94.70
Mobil	Upper Myers Branch	105.00	135.10	116.20	109.10					
Mobil	Varn	100.60								
	mean	101.47	114.50	107.87	110.24	119.80	124.12	125.68	125.68	94.70
One Strata										
Agrico	Agrico 8.4 Acre	56.60	68.90	70.60	83.70	92.40	93.20	87.90		
Agrico	Fort Green (Agrico Swamp)	91.00	72.00	73.00	84.00	84.00	84.00			
Agrico	Hardee Lakes	77.90	91.90	94.80						
Agrico	Payne Creek Dragline	68.30	88.00							
Agrico	Payne Creek Swam East	100.00	100.00	100.00						
Cargill	Hookers Prairie	21.40	29.00	65.00	69.30	69.10				
IMC	60 Acre Mitigation Site	93.40	97.20							
IMC	Cemetery Branch		99.40							
IMC	Hookers Prairie	53.70	86.60							
IMC	Section 15	38.20								
IMC	Section 6 (IMC 47)	100.00								
IMC	Section 7/12 (IMC 28)	81.30	99.00							
IMC	West of K6 (IMC 19)	60.00								
Mobil	Peace River Crossing	57.20								
Mobil	Section 23	84.70								
Mobil	Upper Rocky Branch	100.00								
Occidental	Cabbage Head	40.00	19.00							
Occidental	Green Area, Ga, OXY 9	77.00		90.00		41.00				
Occidental	McCallum Bay	75.00	70.00	20.00						
Occidental	SP-4, OXY 5	76.00		76.79		77.00				
Occidental	SR-8, OXY 6	70.00	70.00	70.00						
Occidental	Swift Creek Reclamation, SA-1	75.00		80.00		80.00				
	mean	71.27	76.23	74.02	79.00	73.92	88.60	87.90		

Table 6B-2 Herbaceous Species Richness Over Time

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	2.3 Acre Wetland	27.00	20.00	35.00						
Agrico	Agrico 8.4 Acre	104.00	97.00	36.00	14.00	26.00	27.00	34.00		
Agrico	FG-84 (5)	61.00	53.00			50.00	33.00	47.00		
Agrico	Fort Green (Agrico Swamp)	37.00	34.00	38.00	42.00	56.00	54.00			53.00
Agrico	Hardee Lakes	41.00	50.00	60.00						
Agrico	Payne Creek Dragline	22.00	53.00							
Agrico	Payne Creek Swamp East	45.00	31.00	35.00						
Cargil	Bryant's Branch	34.00	37.00							
Cargil	Section 9 Marsh	24.00	21.00	21.00						
Cargil	Hookers Prairie	87.00	85.00	65.00	53.00	91.00	117.00	83.00		
CF Industries	R9	52.00	65.00	73.00	109.00					
CF Industries	R10		128.00	143.00						
IMC	60 Acre Mitigation Site	29.00	31.00							
IMC	Bird Branch	23.00	21.00	35.00						
IMC	Cemetery Branch		97.00							
IMC	Dog Leg	41.00		212.00						
IMC	Hall Branch				49.00	171.00				
IMC	Hookers Prairie	29.00	36.00							
IMC	Horse Creek			49.00	68.00	63.00	81.00			
IMC	McCullen Ranch Dragline Crossing			128.00						
IMC	Section 12 (N Hookers Prairie)	29.00		31.00						
IMC	Section 15	100.00								
IMC	Section 6	25.00								
IMC	Section 7/12	32.00	42.00							
IMC	Tadpole	32.00								
IMC	West of K6	170.00								
Mobil	George Allen Creek	22.00								
Mobil	Guy Branch	25.00	35.00							
Mobil	Lower Myers Branch	26.00								
Mobil	McCullough Creek	29.00								
Occidental	Cabbage Head	53.00	64.00							
Occidental	Green Area, Ga, OXY 9	38.00	32.00	19.00						
Occidental	SP-OXY 5	52.00	48.00	30.00						
Occidental	Swift Creek Reclamation, SA-1	25.00	19.00	20.00						
	mean	45.31	49.95	60.59	55.83	76.17	62.40	54.67		53.00

Table 6B-3. Obligate Wetland Species Richness Over Time

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Agrico	2.3 Acre Wetland	22.00	16.00	16.00					
Agrico	Agrico 8.4 Acre	29.00	33.00	26.00	7.00	15.00	17.00	18.00	
Agrico	FG-84	27.00	22.00		38.00	22.00	28.00		
Agrico	Fort Green (Agrico Swamp)				12.00	16.00	27.00		
Agrico	Hardee Lakes	18.00	30.00	27.00					
Agrico	Payne Creek Dragline	14.00	31.00						
Agrico	Payne Creek Swamp East	30.00	21.00	28.00					
Cargil	Bryant's Branch	13.00	17.00						
Cargil	Hookers Prairie	24.00	25.00	30.00	33.00	40.00			
Cargil	Section 9 Marsh	12.00	14.00	11.00					
CF Industries	R7			46.00	41.00	27.00	31.00	27.00	
CF Industries	R9	13.00	21.00	22.00	29.00				
CF Industries	R10		36.00	40.00					
IMC	60 Acre Mitigation Site	15.00	16.00						
IMC	Bird Branch (IMC 24)	16.00		17.00					
IMC	Cemetery Branch		23.00						
IMC	Hall Branch				17.00	47.00			
IMC	Hookers Prairie	17.00	27.00						
IMC	Horse Creek (IMC 16)					36.00		30.00	25.00
IMC	Section 12 (N Hookers Prairie)	16.00							
IMC	Section 6 (IMC 47)	9.00							
IMC	Section 7/12 (IMC 28)	12.00	16.00						
IMC	Tadpole (IMC 9)	12.00							
IMC	West of K6 (IMC 19)	39.00							
Mobil	George Allen Creek	9.00							
Mobil	Guy Branch	9.00	12.00						
Mobil	Lower Myers Branch	10.00							
Mobil	McCullough Creek	8.00							
Occidental	Cabbage Head	34.00	34.00						
Occidental	Green Area, Ga, OXY 9	23.00	21.00	11.00					
Occidental	SP-4, OXY 5	24.00	27.00	19.00					
Occidental	Swift Creek Reclamation, SA-1	12.00	9.00	8.00					
	mean	17.96	22.55	23.15	25.29	29.00	25.75	25.00	25.00

Table 6B-4

Percent Tree Canopy cover Over Time in Created Systems

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Agrico	Agrico 8.4 Acre	2.00	2.80	5.20	7.40	16.00	21.40	18.10	
Agrico	FG-84(5)	0.15	0.18	1.50	3.40	5.20	5.40		
Agrico	Payne Creek Dragline	3.20	3.20						
Agrico	Payne Creek Swamp East	1.57	2.62	4.71	8.31				
Cargil	Bryant's Branch	0.50	0.50						
CF Industries	R7				1.00				
IMC	Hookers Prairie	0.10	1.60						
IMC	Section 12 (N Hookers Prairie)	0.15		1.29	7.20				
IMC	Section 15	0.30							
IMC	Section 7/12 (IMC 28)		1.28						
Mobil	Bird Branch North	0.10	0.70	0.60	2.20	2.80	5.60		
Mobil	Bird Branch South		0.60	1.00	1.10	1.40	1.82	2.34	
Mobil	George Allen Creek	0.40		1.10	5.00	3.00	4.80	5.30	12.30
Mobil	Gooch	0.40							
Mobil	Guy Branch		0.40	1.20	4.40	7.00	9.70	18.20	29.00
Mobil	Lake Branch Tributary	0.10	0.20	0.70	1.70	3.70	9.10		
Mobil	Lower Myers Branch	0.54	2.00	1.50	1.40	2.50	2.00	4.40	6.60
Mobil	McCullough Creek	0.12	0.40	1.00	3.30	2.70	4.30	5.80	7.50
Mobil	Peace River Crossing	0.20							
Mobil	Section 23	0.40							
Mobil	Upper Myers Branch	0.20	0.40	0.70	0.70				
Mobil	Upper Rocky Branch	0.20							
Mobil	Varn	3.90							
	mean	0.76	1.21	1.71	3.62	4.92	7.12	9.02	13.85

Herbaceous Cover Over Time in Created Systems

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Agrico	Agrico 8.4 Acre	56.60	68.90	70.60	83.70	92.40	93.20	87.90	
Agrico	FG-84 (5)	210.00	108.00		103.00	89.70	91.50		
Agrico	Payne Creek Dragline	68.30	88.00						
Agrico	Payne Creek Swamp East	100.00	100.00	100.00					
Cargil	Bryant's Branch	108.00	145.00	100.00					
IMC	Hookers Prairie	53.70	86.60						
IMC	Section 12 (N Hookers Prairie)	53.70	82.00	127.32	80.00				
IMC	Section 15	38.20							
IMC	Section 7/12 (IMC 28)	81.30	99.00						
Mobil	Bird Branch North	47.00	104.20	107.80	101.50	131.40	139.10		
Mobil	Bird Branch South	64.80	88.60	129.90	155.40	111.50	127.00	152.50	
Mobil	George Allen Creek	92.90		94.80	92.80	129.30	138.90	133.30	107.00
Mobil	Gooch	111.70							
Mobil	Guy Branch	107.00	131.00	105.00	96.80	122.20	119.00	106.00	101.90
Mobil	Lake Branch Tributary	73.20	93.50	101.70	128.30	107.10	102.00		
Mobil	Lower Myers Branch	115.80	142.50	131.20	95.30	146.90	136.20	168.20	121.10
Mobil	McCullough Creek	100.80	116.00	111.60	119.00	117.70	126.80	119.20	106.30
Mobil	Peace River Crossing	57.20							
Mobil	Section 23	84.70							
Mobil	Upper Myers Branch	105.00	135.10	116.20	109.10				
Mobil	Upper Rocky Branch	100.00							
Mobil	Varn	100.60							
	mean	87.75	105.89	108.01	105.90	116.47	119.30	127.85	109.08

Table 6B-4 Continued

Herbaceous Species Richness Over Time in Created Systems

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Cargil	Bryant's Branch	34.00	37.00					
CF Industries	R7	46.00	81.00	81.00	148.00	111.00	117.00	83.00
IMC	Hall Branch				49.00	171.00		
IMC	Hookers Prairie	29.00	36.00					
IMC	Section 12 (N Hookers Prairie)	29.00		31.00				
IMC	Section 15	100.00						
IMC	Section 7/12 (IMC 28)	32.00	42.00					
Agrico	Agrico 8.4 Acre	104.00	97.00	36.00	14.00	26.00	27.00	34.00
Agrico	FG-84 (5)	61.00	53.00		50.00	33.00	47.00	
Agrico	Payne Creek Dragline	22.00	53.00					
Agrico	Payne Creek Swamp East	45.00	31.00	35.00				
Mobil	George Allen Creek	22.00						
Mobil	Guy Branch	25.00	35.00					
Mobil	Lower Myers Branch	26.00						
Mobil	McCullough Creek	29.00						
	mean	43.14	51.67	45.75	65.25	85.25	63.67	58.50

Table 6B-5 Average Number of Trees Per Acre at Forested Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	Agrico 8.4 Acre	782	679	619	593	573	560	575		
Agrico	FG-84 (5)	828	527	1048	1044	1052	1040			
Agrico	Fort Green (Agrico Swamp)	1552	1664	1598	1321	1298	1293	1217	1232	1214
Agrico	Hardee Lakes	706	632	565						
Agrico	Hooker's Prairie				275	300				
Agrico	Payne Creek Dragline	1475	1500							
Agrico	Payne Creek Swamp East	547	533	479	465					
BF Ind., IMC	Alafia River Crossing "B" Pipeline					613				
BF Ind., IMC	Alafia River Crossing "B" TECO					613				
Cargil	Bryant's Branch	298	328	382						
Cargil	Bryant's Branch	298	328	382						
IMC	60 Acre Mitigation Site	486	526							
IMC	Bird Branch (IMC 24)	200	597	553						
IMC	Cemetery Branch	930	1480							
IMC	Dogleg	372		306						
IMC	Hall Branch		226	369	460					
IMC	Hooker's Prairie	600	815*							
IMC	McMullen Branch Dragline Crossing	1202		1034						
IMC	Sec. 12 (N. Hooker's Pr.)	600		418						
IMC	Sec. 6 Noralyn/Phosphoria (IMC 47)	412								
IMC	Sec. 7/12 (IMC 28)	320		376						
IMC	Section 15	384								
IMC	Section 6	412								
IMC	Tadpole (IMC 9)	233								
IMC	Unit H (IMC 21)	417	915							
IMC	West of K6 (IMC 19)	214								
IMC	Wetland 'G'	1237								
Mobil	Thirty Mile Creek, Stream Crossing,	906	844	744						
Mobil	Bird Branch North	485	472	523	419	397	377			
Mobil	Bird Branch South		541	586	573	575	478	447		
Mobil	George Allen Creek	423		321	464	565	683	625	607	
Mobil	Gooch	948								
Mobil	Guy Branch	380	281	319	377	384	401	397	377	
Mobil	Lake Br. Tributary	133	120	475	501	670	506			
Mobil	Lower Meyer's Branch	372	372	195	152	198	177	222	290	
Mobil	McCullough Creek	293	226	170	194	171				
Mobil	Peace River Crossing	586								
Mobil	Program AMX-BF-1	389								
Mobil	Section 23	839								
Mobil	Sink Branch							619	619	
Mobil	Stream Crossing, Thirty Mile Creek	747	663							
Mobil	Upper Meyer's Branch	905	889	794	660					
Mobil	Upper Rocky Branch	442								
Mobil	VARN	256								
OXY	Cabbage Head	353.6	230							
OXY	Green Area, Ga, OXY 9	828		791		802				
OXY	McCallum Bay	21.7								
OXY	SP-4, OXY 5	425		425		412				
OXY	SR-8, OXY 6	331		325		325				
OXY	SR-8, OXY 6	331				325				
	Mean	565.9	633.6	551.9	535.6	545.5	612.8	586	625	1214

Table 6B-6 Additional Tree Plantings Per Acre Over Time

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Agrico	Agrico 8.4 Acre						81.1	178.6
Agrico	FG-84 (5)		215					
BF Ind. IMC	Alafia River Crossing "B" Pipeline		208.3	114.6	156.3	208.3		
BF Ind. IMC	Alafia River Crossing "B" TECO		120.8	151.1	22.7	30.2	332.3	
IMC	Alafia River crossing "B"	13.6						
IMC	Cemetery Branch	50		133.3				
IMC	Hall Branch				750.3			
IMC	Jamerson Junior		2062.5					
IMC	McMullen Branch Dragline Crossing	796						
IMC	Sec. 12 (N. Hooker's Pr.)				442.5			
IMC	Wetland 'G'	1518.6						
	Mean	594.6	651.7	133	343.0	119.3	206.7	178.6

Table 6B-7 Average Tree Survival Over Time at Forested Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	Agrico 8.4 Acre	74	63	57	54	52	51	53		
Agrico	FG-84 (5)	93.2	63		97	95.5	94.4			
Agrico	Fort Green (Agrico Swamp)	72	77	72	59	57	53	51	47	46
Agrico	Hardee Lakes	97.9	93.8	83.1						
Agrico	Payne Creek Dragline	88	68							
Agrico	Payne Creek Swamp East	93	89	79	16					
CFI	R10	100	90.3	85						
CFI	R7	100	72	65.5			66.8	47.6		
CFI	R9	98	88	83	83					
IMC	60 Acre Mitigation Site	56	56							
IMC	Bird Branch (IMC 24)	90		92						
IMC	Cemetery Branch	37								
IMC	Hall Branch		8.5	43	100					
IMC	Hooker's Prairie	32	19							
IMC	Horse Creek (IMC 16)				70					
IMC	Sec. 12 (N. Hooker's Pr.)	32		41.6	36					
IMC	Sec. 6 Noralyn/Phosphoria (IMC 47)	48.5								
IMC	Sec. 7/12 (IMC 28)	100								
IMC	Section 15	95								
IMC	Section 6	48.5								
IMC	Unit H (IMC 21)		100							
Mobil	Bird Branch North	35	26	29	23	22	21			
Mobil	Bird Branch South		51	55	54	54	54	45	42	
Mobil	George Allen Creek	80		32	46	56	68	62	60	
Mobil	Gooch	75								
Mobil	Guy Branch	84	32	36	43	43	45	45	42	
Mobil	Lake Br. Tributary	26	24	36	37	49	37			
Mobil	Lower Meyer's Branch	82	28	15	11	15	13	17	21	
Mobil	McCullough Creek	71		21	24	21	25	22	19	
Mobil	Peace River Crossing	53								
Mobil	Section 23	91								
Mobil	Sink Branch	66						69	69	
Mobil	Stream Crossing, Thirty Mile Creek	83	73							
Mobil	Upper Meyer's Branch	102	102	89	75					
Mobil	Upper Rocky Branch	52								
Mobil	VARN	43								
OXY	Cabbage Head	61	65							
OXY	Green Area, Ga, OXY 9	63		46.5		48.5				
OXY	McCallum Bay	76	67	69						
OXY	SP-4, OXY 5	66		55		54				
OXY	SR-8, OXY 6	92		89.5		90				
	Mean	71.8	61.6	57.92	51.8	50.5	48.0	45.7	42.9	46

Table 6B-8 Average Tree Crown Width Over Time at Forested Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Agrico	Agrico 8.4 Acre	31	46	64	79	109	134	128
Agrico	FG-84 (5)	18.3	12.8	26.5	41.3	50	51.2	
Agrico	Hardee Lakes	38.3	44	45				
Agrico	Payne Creek Dragline	34.1	31.4					
Agrico	Payne Creek Swamp East	35	44	58	91			
IMC	Bird Branch (IMC 24)			0.2				
IMC	Sec. 7/12 (IMC 28)	64		26				
IMC	West of K6 (IMC 19)	38						
Mobil	Bird Branch North	10	20	19				
Mobil	Bird Branch South		20	40	38			
Mobil	George Allen Creek	22		30	40	34		
Mobil	Guy Branch	14	20	40	70	70		
Mobil	Lake Br. Tributary	20	20	24				
Mobil	Lower Meyer's Branch	27	40	60	80	72		
Mobil	McCullough Creek	14	30	50	70	79		
	Mean	28.1	29.8	37.1	63.7	69	92.6	128

Table 6B-9 Average Tree Height Over Time in Forested Systems

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	Agrico 8.4 Acre	103	151	189	222	276	303	305		
Agrico	FG-84 (5)	74	67.8	100.5	123.5	138.7	159			
Agrico	Fort Green (Agrico Swamp)	47.9	53.4	63	71	81	93	105	122	155
Agrico	Hardee Lakes	122	129	137						
Agrico	Payne Creek Dragline	84	86.1							
Agrico	Payne Creek Swamp East	116	138	166	208					
CFI	R10	89.7	107.5	107						
CFI	R7	65	85	115.4	136.2	151.2	168			
CFI	R9	113	129	146	214					
IMC	60 Acre Mitigation Site	2.55	2.85							
IMC	Bird Branch (IMC 24)	91	61	50						
IMC	Cemetery Branch	61								
IMC	Dogleg	335		640						
IMC	Hall Branch		274	139	129.5					
IMC	Hooker's Prairie	59	81							
IMC	Sec. 12 (N. Hooker's Pr.)	97		97.2	185.3					
IMC	Sec. 6 Noralyn/Phosphoria (IMC 47)	77.5								
IMC	Sec. 7/12 (IMC 28)	158		97						
IMC	Section 15	55								
IMC	Section 6	2.6								
IMC	West of K6 (IMC 19)	171								
Mobil	Thirty Mile Creek, Stream Crossing, 2			76						
Mobil	Bird Branch North	30	50	71	106	159	171			
Mobil	Bird Branch South		60	100	110	140	182	234		
Mobil	George Allen Creek	62		130	150	125	152	189	257	
Mobil	Gooch	40								
Mobil	Guy Branch	65	70	110	130	192	214	266	315	
Mobil	Lake Br. Tributary	40	50	76	68	89	118			
Mobil	Lower Meyer's Branch	70	110	160	170	225	155	239	307	
Mobil	McCullough Creek	45	80	140	180	223	230	318	344	
Mobil	Peace River Crossing	37								
Mobil	Section 23	47								
Mobil	Sink Branch	80								
Mobil	Stream Crossing, Thirty Mile Creek	69.8	85.3							
Mobil	Upper Meyer's Branch	57	71	86	98					
Mobil	Upper Rocky Branch	59								
Mobil	VARN	217								
OXY	Cabbage Head	57	63							
OXY	McCallum Bay	52.8	65	89						
OXY	SR-8, OXY 6	300				470				
OXY	Swift Creek Reclamation, SA-1	57								
	Mean	87.1	90	134.1	143.8	189.2	176.8	236.6	269	155

Table 6B-10 **Percent Survival of Tree Species Over Time at Forested Sites**

Company	Site	Species	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Mean
Agrico	Agrico 8.4 Acre	Acer rubrum				82.6	79.8	80.7	80			80.78
	Agrico 8.4 Acre	Fraxinus caroliniana				77.5	72.1	68.9	69.2			71.93
	Agrico 8.4 Acre	Liquidambar styraciflua				62.3	61.2	61.9	59			61.1
	Agrico 8.4 Acre	Quercus nigra				42.1	40.5	40.5	38.9			40.5
	Agrico 8.4 Acre	Quercus laurifolia				16.7	16.7	16.7				16.7
	Agrico 8.4 Acre	Nyssa sylvatica var. biflora				13.3	13.3	12.7	27.5			16.7
	Agrico 8.4 Acre	Ilex cassine				10	6.7	6.7				7.8
	Agrico 8.4 Acre	Carya aquatica				0	0	0				0
	Agrico 8.4 Acre	Ulmus americana							100			100
	Agrico 8.4 Acre	Taxodium distichum							80			80
Agrico	FG-84 (5)	Carya aquatica	100	88.9								94.45
	FG-84 (5)	Ilex cassine	100	80		75	67	67				77.8
	FG-84 (5)	Taxodium distichum	97.3	85		96	96	96				94.06
	FG-84 (5)	Fraxinus caroliniana	96.6	87.3		98	95	95.7				94.52
	FG-84 (5)	Ulmus americana	95.8	84		100	99	99.3				95.62
	FG-84 (5)	Acer rubrum	95.6	70.8		96	95	93.5				90.18
	FG-84 (5)	Gordonia lasianthus	88.9	51.4		86	85	85.7				79.4
	FG-84 (5)	Magnolia virginiana	83.6	56.5		90	80	74				76.82
	FG-84 (5)	Persea borbonia	71.4	52.6			85	71.4				70.1
	FG-84 (5)	Nyssa sylvatica		90		95	96	95				94
	FG-84 (5)	Quercus nigra					100	100				100
Agrico	Fort Green (Agrico Swamp)	Fraxinus caroliniana	98	98	99	90	94	91	90	86	89	92.78
	Fort Green (Agrico Swamp)	Nyssa sylvatica	90	79	90	66	54	59	63	61	56	68.67
	Fort Green (Agrico Swamp)	Platanus occidentalis	86	87	84	59	43	39	38	33	30	55.44
	Fort Green (Agrico Swamp)	Liquidambar styraciflua	84	81	81	70	67	71	67	64	62	71.89
	Fort Green (Agrico Swamp)	Ulmus americana	84	77	78	70	65	69	69	55	53	68.89
	Fort Green (Agrico Swamp)	Acer rubrum	80	80	78	46	46	49	46	41	39	56.11
	Fort Green (Agrico Swamp)	Persea borbonia	79	79	79	76	55	45	43	34	28	57.56
	Fort Green (Agrico Swamp)	Taxodium distichum	73	71	74	66	64	65	64	63	63	67
	Fort Green (Agrico Swamp)	Ilex cassine	53	53	41	38	33	41	33	28	33	39.22
	Fort Green (Agrico Swamp)	Gordonia lasianthus	29	37	23	6	5	5	4	5	3	13
Agrico	Hardee Lakes	Taxodium distichum	100	96	88							94.67
	Hardee Lakes	Acer rubrum	100		80							90
	Hardee Lakes	Quercus nigra	100									100
	Hardee Lakes	Persea borbonia	100	100	83.3							94.43
	Hardee Lakes	Carya aquatica	100	95	85.7							93.57
	Hardee Lakes	Fraxinus caroliniana	100	94	94.1							96.03
	Hardee Lakes	Ilex cassine	100	97	95.4							97.47
	Hardee Lakes	Ulmus americana	100	98	93.5							97.17
	Hardee Lakes	Quercus laurifolia	100	95								97.5
	Hardee Lakes	Nyssa sylvatica var. biflora		95	89.6							92.3
	Hardee Lakes	Liquidambar styraciflua		100	85.7							92.85
	Hardee Lakes	Others	75	70	50							65
Agrico	Payne Creek Dragline	Ulmus americana	93.3	81.6								87.45
	Payne Creek Dragline	Nyssa sylvatica var. biflora	90	68.5								79.25
	Payne Creek Dragline	Fraxinus caroliniana	94.7	82.5								88.6
	Payne Creek Dragline	Acer rubrum	89.2	59.7								74.45
	Payne Creek Dragline	Quercus laurifolia	78.1	17.2								47.65
	Payne Creek Dragline	Quercus nigra	86.3	42.9								64.6
Agrico	Payne Creek Swamp East	Fraxinus americana		100	50	81.3						77.1
	Payne Creek Swamp East	Quercus laurifolia		100	100	100						100
	Payne Creek Swamp East	Fraxinus pennsylvanica		98.9	97.4	87.3						94.53
	Payne Creek Swamp East	Taxodium distichum		95.6	95.2	93.7						94.83
	Payne Creek Swamp East	Fraxinus caroliniana		94.1	84.1	81.3						86.5
	Payne Creek Swamp East	Quercus nigra		93.5	91.3	89.8						91.53
	Payne Creek Swamp East	Nyssa sylvatica		84.1	66.2	60.9						70.4
	Payne Creek Swamp East	Ilex cassine		81.9	68.1	42.9						64.3
	Payne Creek Swamp East	Liquidambar styraciflua		80	80	80						80
	Payne Creek Swamp East	Carya aquatica		90.6	82.4	83.8						85.6
CFI	R9	Fraxinus caroliniana	97	97	94	94						95.5
	R9	Taxodium ascendens	100	89	84	84						89.25
	R9	Nyssa sylvatica	97	71	62	64						73.5

	R9	Acer rubrum	94	88	81	81	86
	R9	Quercus laurifolia	100	98	94	94	96.5
	R9	Quercus virginiana	100	100	100	100	100
	R9	Liquidambar styraciflua	97	86	86	83	88
CFI	R10	Nyssa sylvatica var. biflora	100	77	50		75.67
	R10	Carpinus caroliana	100				100
	R10	Cephalanthus occidentalis	100				100
	R10	Taxodium distichum	100	98.6	98.6		99.07
	R10	Ilex cassine	100	100	84.6		94.87
	R10	Ulmus floridanus	100	85.2	86.2		90.47
	R10	Celtis laevigata	100	97.4	68.4		88.6
	R10	Quercus laurifolia	100	100	93.1		97.7
	R10	Quercus virginiana	100	94.7	94.7		96.47
	R10	Gordonia lasianthus	100	75	62.5		79.17
	R10	Fraxinus caroliniana	100	96.9	91.7		96.2
	R10	Acer rubrum	100	94.4	86.5		93.63
	R10	Juniperus silicicola	100	100	100		100
	R10	Sabal palmetto	100				100
	R10	Serenoa repens	100				100
	R10	Salix caroliniana	100	100	100		100
	R10	Magnolia virginiana	100	92.9	80		90.97
	R10	Liquidambar styraciflua	100	97.7	90.6		96.1
	R10	Quercus nigra	100	94.7	91.2		95.3
	R10	Myrica cerifera	100				100
	R10	Persea borbonia		40	80		60
IMC	Section 15	Acer rubrum	98				98
	Section 15	Cephalanthus occidentalis	100				100
	Section 15	Liquidambar styraciflua	97				97
	Section 15	Nyssa sylvatica var. biflora	96				96
	Section 15	Quercus laurifolia	62				62
	Section 15	Quercus nigra	88				88
	Section 15	Ulmus americana	100				100
Mobil	Guy Branch	Acer rubrum	82				82
	Guy Branch	Liquidambar styraciflua	86				86
	Guy Branch	Nyssa sylvatica	57				57
	Guy Branch	Pinus elliotti	71				71
	Guy Branch	Quercus nigra	100				100
	Guy Branch	Quercus virginiana	33				33
	Guy Branch	Quercus laurifolia	85				85
	Guy Branch	Taxodium distichum	93				93
	Guy Branch	Taxodium ascendens	50				50
Mobil	Lower Meyer's Branch	Acer rubrum	80				80
	Lower Meyer's Branch	Liquidambar styraciflua	76				76
	Lower Meyer's Branch	Nyssa sylvatica	82				82
	Lower Meyer's Branch	Pinus elliotti	83				83
	Lower Meyer's Branch	Quercus virginiana	88				88
	Lower Meyer's Branch	Taxodium distichum	86				86
Mobil	McCullough Creek	Acer rubrum	61				61
	McCullough Creek	Liquidambar styraciflua	71				71
	McCullough Creek	Nyssa sylvatica	70				70
	McCullough Creek	Pinus elliotti	69				69
	McCullough Creek	Quercus laurifolia	82				82
	McCullough Creek	Quercus nigra	77				77
	McCullough Creek	Quercus virginiana	82				82
	McCullough Creek	Taxodium distichum	80				80
	McCullough Creek	Taxodium ascendens	98				98
OXY	Cabbage Head	Acer rubrum	60	38			49
	Cabbage Head	Betula nigra	89	85			87
	Cabbage Head	Fraxinus pennsylvanica	66	34			50
	Cabbage Head	Gordonia lasianthus	39	8			23.5
	Cabbage Head	Liquidambar styraciflua	72	44			58
	Cabbage Head	Magnolia virginiana	0	0			0
	Cabbage Head	Nyssa sylvatica var. biflora	83	71			77
	Cabbage Head	Nyssa sylvatica	46	25			35.5
	Cabbage Head	Persea borbonia	17	11			14
	Cabbage Head	Pinus elliotti	24	5			14.5

	Cabbage Head	Quercus laurifolia	78	52								65
	Cabbage Head	Taxodium ascendens	92	93								92.5
	Cabbage Head	Taxodium distichum	94	95								94.5
	Cabbage Head	Ulmus americana	42	0								21
OXY	Green Area, Ga, OXY 9	Taxodium distichum	90		82		83					85
	Green Area, Ga, OXY 9	Nyssa sylvatica var. biflora	64		32		37					44.33
	Green Area, Ga, OXY 9	Quercus michauxii	23		5		7					11.67
	Green Area, Ga, OXY 9	Liquidambar styraciflua	75		67		67					69.67
OXY	McCallum Bay	Acer rubrum	82	64	74							73.33
	McCallum Bay	Betula nigra	96	89	86							90.33
	McCallum Bay	Chamaecyparis thyoides		70	65							67.5
	McCallum Bay	Fraxinus pennsylvanica	66	34	39							46.33
	McCallum Bay	Gordonia lasianthus	69	40	32							47
	McCallum Bay	Ilex cassine	74	56	52							60.67
	McCallum Bay	Liquidambar styraciflua	89	61	73							74.33
	McCallum Bay	Nyssa sylvatica var. biflora	83	40	31							51.33
	McCallum Bay	Taxodium distichum	87	82	83							84
OXY	SP-4, OXY 5	Acer rubrum	81		38		43					54
	SP-4, OXY 5	Taxodium distichum	88		87		86					87
	SP-4, OXY 5	Taxodium ascendens	90		90		84					88
	SP-4, OXY 5	Nyssa sylvatica	5		5		3					4.333
OXY	Swift Creek Reclamation, SA-1	Taxodium ascendens	35	39	39							37.67
	Swift Creek Reclamation, SA-1	Nyssa sylvatica	52	62	11							41.67
	Swift Creek Reclamation, SA-1	Nyssa sylvatica var. biflora	31	9	45							28.33
	Swift Creek Reclamation, SA-1	Quercus laurifolia	58	39	9							35.33
	Swift Creek Reclamation, SA-1	Quercus lyrata	60	33	20							37.67
	Swift Creek Reclamation, SA-1	Quercus michauxii	45	36	5							28.67
		Mean	81.43	72.33	71.26	70.43	59.01	60.7	57.15	47	45.6	62.77

Table 6B-11 *Percent Survival of Tree Species Over Time*

Species	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Mean
Acer rubrum	84.8	70.7	72.9	76.4	66.0	74.4	63	41	39	76.3
Betula nigra	92.5	87	86							88.7
Carpinus caroliana	100									100
Carya aquatica	100	91.5	84.1	83.8						91.2
Celtis laevigata	100	97.4	68.4							88.6
Cephalanthus occidentalis	100									100
Chamaecyparis thyoides		70	65							67.5
Fraxinus americana		100	50	81.3						77.1
Fraxinus caroliniana	97.7	92.8	92.6	88.2	87.0	85.2	79.6	86	89	90.3
Fraxinus pennsylvanica	66	55.6	68.2	87.3						63.6
Gordonia lasianthus	65.2	42.3	39.2	46	45	45.4	4	5	3	48.4
Ilex cassine	85.4	78.0	68.2	41.5	35.6	38.2	33	28	33	63.2
Juniperus silicicola	100	100	100							100
Liquidambar styraciflua	84.7	78.5	80.5	73.8	65.1	66.5	63	64	62	78.6
Magnolia virginiana	61.2	49.8	80	90	80	74				55.9
Myrica cerifera	100									100
Nyssa sylvatica	62.4	68.5	46.8	71.5	51	77	63	61	56	59.7
Nyssa sylvatica var. biflora	78.1	60.1	49.5	13.3	25.2	12.7	27.5			62.3
Others	75	70	50							65
Persea borbonia	66.9	56.5	80.8	76	70	58.2	43	34	28	59.2
Pinus elliotti	61.8	5								59.4
Platanus occidentalis	86	87	84	59	43	39	38	33	30	55.4
Quercus laurifolia	82.6	71.6	74.0	70.2	16.7	16.7				73.3
Quercus lyrata	60	33	20							37.7
Quercus michauxii	34	36	5		7					20.2
Quercus nigra	91.9	77.0	91.3	66.0	70.3	70.3	38.9			84.1
Quercus virginiana	80.6	97.4	97.4	100						79.9
Sabal palmetto	100									100
Salix caroliniana	100	100	100							100
Serenoa repens	100									100
Taxodium ascendens	77.5	73.7	71	84	84					75.9
Taxodium distichum	89.8	89.0	86.8	85.2	82.3	80.5	72	63	63	87.6
Ulmus americana	85.9	68.1	85.8	85	82	84.2	84.5	55	53	81.4
Ulmus floridanus	100	85.2	86.2							90.5
Mean	83.4	72.1	70.8	72.6	56.9	58.7	50.8	47.0	45.6	75.9

Table 6B-12 Tree Species Richness Over Time at Forested Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	Agrico 8.4 Acre	13	13	13	7	7	7			
Agrico	FG-84 (5)	10	10	9	9	10	10			
Agrico	Fort Green (Agrico Swamp)	10	10	10	10	10	10	10	10	10
Agrico	Hardee Lakes	23	23	23						
Agrico	Hooker's Prairie				10	8				
Agrico	Payne Creek Dragline	6	6							
Agrico	Payne Creek Swamp East		13	13	13					
BF Industries, IMC	Alafia River Crossing "B" Pipeline					12				
BF Industries, IMC	Alafia River Crossing "B" TECO					20				
Cargil	Bryant's Branch	10								
Cargil	Bryant's Branch	10								
CFI	R10	20	16	16						
CFI	R7	11	7	5	5	5	5	4		
CFI	R9	7	7	7						
IMC	60 Acre Mitigation Site	11	11							
IMC	Achan (IMC 23)	8								
IMC	Bird Branch (IMC 24)	8		10						
IMC	Cemetery Branch	6								
IMC	Dogleg	24								
IMC	Hall Branch	5	5	5						
IMC	Hooker's Prairie	13	13							
IMC	McMullen Branch Dragline Crossing	9								
IMC	Sec. 12 (N. Hooker's Pr.)	12		13	10					
IMC	Sec. 6 Noralyn/Phosphoria (IMC 47)	5								
IMC	Sec. 7/12 (IMC 28)	8		8						
IMC	Section 15	7								
IMC	Section 6	5								
IMC	Tadpole	7								
IMC	Unit H (IMC 21)	13								
IMC	West of K6 (IMC 19)	21								
IMC	Wetland 'G'	9								
Mobil	Bird Branch North	13	13	13						
Mobil	Bird Branch South	13	13							
Mobil	George Allen Creek	6		6						
Mobil	Guy Branch	9	9	9	9	9				
Mobil	Lake Br. Tributary	8	8	8						
Mobil	Lower Meyer's Branch	6	6	6	6					
Mobil	McCullough Creek	9	9	9	9	9				
Mobil	Program AMX-BF-1	10								
Mobil	Sink Branch	9	9							
Mobil	Stream Crossing, Thirty Mile Creek	7	7							
Mobil	Upper Meyer's Branch	16								
OXY	Cabbage Head	13	12							
OXY	Green Area, Ga, OXY 9	4								
OXY	McCallum Bay	9	9	9						
OXY	SP-4, OXY 5	5		5		5				
OXY	SR-8, OXY 6	3		3		3				
OXY	SR-8, OXY 6	5								
OXY	Swift Creek Reclamation, SA-1	6	8	8						
	Mean	9.8	10.3	9.5	8.8	8.9	8	7	10	10

Table 6B-13 Sites on Which Tree Species Were Planted and Average Percent Mixtures

Species	Number of Sites	Average Percent Mixture*
Acer rubrum	11	11
Betula nigra	2	7.7
Carya aquatica	4	4.5
Cetlis laevigata	3	6.7
Fraxinus caroliniana	8	17
Gordonia lasianthus	6	7
Ilex casine	9	6.3
Liquidambar styraciflua	9	10
Magnolia virginiana	6	5.3
Nyssa biflora	8	12.5
Nyssa sylvatica	6	20
Persea borbonia	3	7
Pinus elliottii	2	9
Quercus laurifolia	8	14.5
Quercus nigra	5	11
Quercus virginiana	5	7.7
Taxodium ascendens	2	7
Taxodium distichum	11	29
Ulmus americana	6	8

* For species with data from greater than one site

Table 6B-14 Percent Tree Survival on Overburden Soil

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Agrico	FG-84 (5)	93.2	63		97	95.5	94.4		
Agrico	Payne Creek Swamp East	93	89	79	16				
IMC	60 Acre Mitigation Site	56	56						
IMC	Cemetery Branch	37							
IMC	Hooker's Prairie	32	19						
IMC	Sec. 12 (N. Hooker's Pr.)	32		41.6	36				
IMC	Sec. 6 Noralyn/Phosphoria (IMC 47)	48.5							
IMC	Section 15	95							
IMC	Section 6	48.5							
Mobil	Bird Branch North	35	26	29	23	22	21		
Mobil	Bird Branch South		51	55	54	54	54	45	42
Mobil	George Allen Creek	80		32	46	56	68	62	60
Mobil	Guy Branch	84	32	36	43	43	45	45	42
Mobil	Lake Br. Tributary	26	24	36	37	49	37		
Mobil	Lower Meyer's Branch	82	28	15	11	15	13	17	21
Mobil	Peace River Crossing	53							
Mobil	Section 23	91							
Mobil	Sink Branch	66						69	69
Mobil	Stream Crossing, Thirty Mile Creek	83	73						
Mobil	Upper Meyer's Branch	102	102	89	75				
Mobil	Upper Rocky Branch	52							
OXY	Green Area, Ga, OXY 9	63		46.5		48.5			
OXY	McCallum Bay	76	67	69					
OXY	SP-4, OXY 5	66		55		54			
	Mean	65.0	52.5	48.6	43.8	48.6	47.5	47.6	46.8

Table 6B-15 Percent Tree Survival on Sand Tailings/Overburden Soil Mix

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Agrico	Agrico 8.4 Acre	74	63	57	54	52	51	53		
Agrico	Fort Green (Agrico Swamp)	72	77	72	59	57	53	51	47	46
Agrico	Hardee Lakes	97.9	93.8	83.1						
CFI	R9	98	88	83	83					
IMC	Sec. 7/12 (IMC 28)	100								
IMC	Unit H (IMC 21)		100							
Mobil	McCullough Creek	71		21	24	21	25	22	19	
	Mean	85.5	84.4	63.22	55	43.3	43	42	33	46

Table 6B-16 Herbaceous Cover on Mulched and Non-Mulched Sites Over Time in Created Systems

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Cover on Mulched Sites										
Agrico	2.3 Acre Wetland	105.00	82.00	77.00						
Agrico	Agrico 8.4 Acre	56.60	68.90	70.60	83.70	92.40	93.20	87.90		
Agrico	FG-84		210.00	108.00		103.00	89.70	91.50		
Agrico	Fort Green (Agrico Swamp)	91.00	72.00	73.00	84.00	84.00	84.00			78.00
Agrico	Hardee Lakes	77.90	91.90	94.80						
Agrico	Payne Creek Dragline	68.30	88.00							
Agrico	Payne Creek Swamp East	100.00	100.00	100.00						
Cargil	Bryant's Branch	108.00	145.00	100.00						
IMC	60 Acre Mitigation Site	93.40	97.20							
IMC	Hookers Prairie	53.70	86.60							
IMC	Section 12 (N Hookers Prairie)	53.70	83.20	127.32	80.00					
IMC	Section 6 (IMC 47)	100.00								
IMC	Section 7/12 (IMC 28)	81.30	99.00							
IMC	West of K6 (IMC 19)	60.00								
Mobil	Bird Branch North	47.00	104.20	107.80	101.50	131.40	139.10			
Mobil	Bird Branch South	64.80	88.60	129.90	155.40	111.50	127.00	151.00		
Mobil	George Allen Creek	92.90		94.80	92.80	129.30	138.90	133.30	107.00	
Mobil	Guy Branch	107.00	131.00	105.00	96.80	122.20	119.00	106.00	101.90	
Mobil	Lake Branch Tributary	73.20	93.50	101.70	128.30	107.10	102.00			
Mobil	Lower Myers Branch	115.80	142.50	131.20	95.30	146.90	136.20	168.20	121.10	
Mobil	McCullough Creek	100.80	116.00	111.60	119.00	117.70	119.20	106.30		
Mobil	Section 23	84.70								
Mobil	Sink Branch			88.40	99.50	101.40	138.40	101.00	107.20	94.70
Mobil	Upper Myers Branch	105.00	135.10	116.20	109.10					
Mobil	Upper Rocky Branch	100.00								
	mean	84.35	107.09	102.20	103.78	113.35	116.97	118.15	109.30	86.35
Cover on Non-Mulched Sites										
Cargil	Hookers Prairie	21.40	29.00	65.00	69.30	69.10				
Cargil	Section 9 Marsh	128.00	145.90	116.20						
IMC	Bird Branch	100.00		100.00						
IMC	Cemetery Branch		99.40							
IMC	Horse Creek (IMC 16)					127.75		133.73	132.00	
IMC	Gooch	111.70								
IMC	Peace River Crossing	57.20								
IMC	Varn	100.60								
Occidental	Cabbage Head	40.00	19.00							
Occidental	Green Area, Ga, OXY 9	77.00		90.00		41.00				
Occidental	McCallum Bay	75.00	70.00	20.00						
Occidental	SP-4, OXY 5	76.00		76.79		77.00				
Occidental	SR-8, OXY 6	70.00		70.00		70.00				
Occidental	Swift Creek Reclamation, SA-1	75.00	80.00	80.00						
	mean	77.66	73.88	77.25	69.30	76.97		133.73	132.00	

Table 6B-17 . Herbaceous Species Richness on Mulched and Non-Mulched Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Richness on Mulched Sites										
Agrico	2.3 Acre Wetland	27.00	20.00	35.00						
Agrico	Agrico 8.4 Acre	104.00	97.00	36.00	14.00	26.00	27.00	34.00		
Agrico	FG-84 (5)	61.00	53.00		50.00	33.00	47.00			
Agrico	Fort Green (Agrico Swamp)	37.00	34.00	38.00	42.00	56.00	54.00			53.00
Agrico	Hardee Lakes	41.00	50.00	60.00						
Agrico	Payne Creek Dragline	22.00	53.00							
Agrico	Payne Creek Swamp East	45.00	31.00	35.00						
Cargil	Bryant's Branch	34.00	37.00							
CF Industries	R9	52.00	65.00	73.00	109.00					
CF Industries	R10		128.00	143.00						
IMC	60 Acre Mitigation Site	29.00	31.00							
IMC	Dogleg	41.00				212.00				
IMC	Hall Branch				49.00	171.00				
IMC	Hookers Prairie	29.00	36.00							
IMC	Section 12 (N Hookers Prairie)	29.00		31.00						
IMC	Section 6 (IMC 47)									
IMC	Section 7/12 (IMC 28)	32.00	42.00							
IMC	West of K6 (IMC 19)	170.00								
Mobil	George Allen Creek	22.00								
Mobil	Guy Branch	25.00	34.00							
Mobil	Lower Myers Branch	26.00								
Mobil	McCullough Creek	29.00								
	mean	45.00	50.79	56.38	52.80	99.60	42.67	34.00		53.00
Richness on Non-Mulched Sites										
Cargil	Hookers Prairie	87.00	85.00	65.00	53.00	91.00				
Cargil	Section 9 Marsh	24.00	21.00	21.00						
CF Industries	R7	46.00	81.00	81.00	148.00	111.00	117.00	83.00		
IMC	Bird Branch (IMC 24)	23.00	21.00	36.00						
IMC	Cemetery Branch		97.00							
IMC	Horse Creek (IMC 16)			49.00	68.00	63.00	81.00			
IMC	McCullen Branch Dragline Crossing			128.00						
IMC	Section 15	100.00								
IMC	Tadpole	32.00								
Occidental	Cabbage Head	53.00	64.00							
Occidental	Green Area, Ga, OXY 9	38.00	32.00	19.00						
Occidental	SP-4, OXY 5	52.00	48.00	30.00						
Occidental	Seift Creek Reclamation, SA-1	25.00	19.00	20.00						
	mean	48.00	52.00	49.89	89.67	88.33	99.00	83.00		

Table 6B-12 Percent Cover of Nuisance Species at Herbicide and Non-Herbicide Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13
Cover on Herbicided Sites														
Agrico	Agrico 8.4 Acre			12.6	10.0	2.2	1.5	1.2						
Agrico	FG-84 (5)	10.0	5.5		14.0	3.8	2.7							
Agrico	Hardee Lakes	5.9		0.4										
Agrico	Payne Creek Dragline	2.3	2.4											
Cargil	Bryant's Branch	26.0	22.0	10.0										
Cargil	Hookers Prairie	1.9	3.6	8.5	6.2	5.7								
Cargil	Section 9 Marsh	18.0	14.7	8.2										
IMC	60 Acre Mitigation Site	7.1	3.8											
IMC	Section 12 (N Hookers Prairie)		1.2	0.9										
Mobil	Gooch	7.4												
	mean	9.8	7.6	6.8	10.1	3.9	2.1	1.2						
Cover on Non-Herbicided Sites														
Agrico	2.3 Acre Wetland	13.0	13.0	3.0										
Agrico	Payne Creek Swamp East	24.8	10.6	7.7										
CF Industries	R9			10.0	23.0									
IMC	Alafia River Crossing "B" Pipeline								4.3					
IMC	Bird Branch	15.8		13.1										
IMC	Cemetary Branch		35.0											
IMC	Horse Creek (IMC 16)				11.1	1.9	1.4		11.1					
IMC	McMullen Branch Dragline Crossing			8.0										
IMC	Section 15	0.3												
IMC	Section 6 (IMC 47)	7.6												
IMC	Section 7/12 (IMC 28)	10.0	16.4											
IMC	West of K6 (IMC 19)	6.0												
Mobil	Bird Branch North	10.9	47.1	19.6	29.2	28.7	32.4							
Mobil	Bird Branch South	7.1	10.2	44.1	21.5	22.4	30.4	36.1						
Mobil	George Allen Creek	34.9	24.1	45.8	30.6	45.8	51.2	55.1	22.5					
Mobil	Guy Branch	20.0	28.0	35.0	40.0	13.3	31.0	10.4	3.3					
Mobil	Lake Branch Tributary	9.1	8.2	0.7		1.4	0.1							
Mobil	Lower Myers Branch	18.2	18.3	19.1	29.1	28.3	27.4	31.1	14.8					
Mobil	McCullough Creek	41.7	46.7	58.5	71.6	71.2	62.4	80.5	62.7					
Mobil	Peace River Crossing	0.3												
Mobil	Section 23	1.8												
Mobil	Sink Branch							53.3	72.8	82.2	43.6	35.0	36.7	15.3
Mobil	Upper Myers Branch	2.6	11.2	5.7	1.6									
Mobil	Varn	5.2												
Occidental	Cabbage Head	6.3												
Occidental	Green Area, Ga, OXY 9	12.3												
Occidental	SP-4, OXY 5	14.2	22.5	18.1										
Occidental	Swift Creek Reclamation, SA-1	0.5	5.2	4.8										
	mean	11.9	21.2	19.6	28.6	26.6	29.5	44.4	27.4	82.2	43.6	35.0	36.7	15.3

Table 6B-19 Tree Survival on Herbicide and Non-Herbicide Sites

Company	Site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Survival on Herbicided Sites									
Agrico	Agrico 8.4 Acre	74.00	63.00	57.00	54.00	52.00	51.00	53.00	
Agrico	Hardee Lakes	97.90	93.80	83.10					
Agrico	Payne Creek Dragline	88.00	68.00						
IMC	60 Acre Mitigation Site	56.00	56.00						
IMC	Section 12 (N Hookers Prairie)	32.00		41.60	36.00				
Mobil	Gooch	75.00							
	mean	70.48	70.20	60.57	45.00	52.00	51.00		
Survival on Non-Herbicided Sites									
Agrico	Payne Creek Swamp East	93.00	89.00	79.00	16.00				
CF Industries	R7	100.00	72.00	65.50					
CF Industries	R9	98.00	88.00	83.00	83.00				
CF Industries	R10	100.00	90.25	85.00					
IMC	Bird Branch (IMC 24)	90.00	92.00						
IMC	Cemetery Branch	37.00							
IMC	Hookers Prairie	32.00	19.00						
IMC	Horse Creek (IMC 16)		70.00						
IMC	Section 15	95.00							
IMC	Section 6 (IMC 47)	48.50							
IMC	Section 7/12 (IMC 28)	100.00							
IMC	Unit H (IMC 21)		100.00						
Mobil	Bird Branch North	35.00	26.00	29.00	23.00	22.00	21.00		
Mobil	Bird Branch South		51.00	55.00	54.00	54.00	54.00	45.00	42.00
Mobil	George Allen Creek	80.00		32.00	46.00	56.00	68.00	62.00	60.00
Mobil	Guy Branch	84.00	32.00	36.00	43.00	43.00	45.00	45.00	42.00
Mobil	Lake Branch Tributary	26.00	24.00	36.00	37.00	49.00	37.00		
Mobil	Lower Myers Branch	82.00	28.00	15.00	11.00	15.00	13.00	17.00	21.00
Mobil	McCullough Creek	71.00		21.00	24.00	21.00	25.00	22.00	19.00
Mobil	Peace River Crossing	53.00							
Mobil	Section 23	91.00							
Mobil	Sink Branch	66.00		69.00	69.00				
Mobil	Stream Crossing, Thirty Mile Creek	83.00	83.00	73.00					
Mobil	Upper Myers Branch	102.00	102.00	89.00	75.00				
Mobil	Upper Rocky Branch	52.00							
Mobil	Varn	43.00							
Occidental	Cabbage Head	61.00	65.00						
Occidental	Green Area, Ga, OXY 9	63.00	46.50	48.50					
Occidental	McCallum Bay	76.00	67.00	69.00					
Occidental	SP-4, OXY 5	66.00	55.00	54.00					
Occidental	SR-8, OXY 6	92.00	89.50	90.00					
Occidental	Swift Creek Reclamation, SA-1	45.00	36.00	5.00					
	mean	71.19	63.11	54.42	43.73	37.14	37.57	38.20	36.80

SECTION 7 - WILDLIFE

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TABLE OF CONTENTS

SECTION 7 - WILDLIFE

EXECUTIVE SUMMARY

Vertebrate wildlife (mammals, birds, reptiles, and amphibians) is an integral component of most wetlands, both natural and man-made. Nevertheless, wildlife has been ignored in the development of “success” criteria for constructed wetlands on phosphate-mined lands, based on the apparent assumption that if a diverse plant community is successfully established, wildlife will automatically appear and inhabit a site. This has indeed occurred wherever wetlands have been created. However, the mere presence of some fauna does not necessarily prove that a fully successful or optimal wetland has been created. Many wildlife species inhabit a wide variety of environments, both uplands and wetlands, and their presence is not necessarily diagnostic of a wetland. Nevertheless, in Florida four species of mammals, numerous bird species, several reptiles, and many amphibians are wetland-dependent and sufficiently abundant and widespread to serve as “indicator” species for wetland habitats.

Wildlife diversity is highest in wetlands that include open bodies of water intermixed with herbaceous marsh. Wetlands that are not permanently flooded, or that lack bodies of open water, contain fewer species and numbers of animals. But, isolated wetlands that are flooded only periodically are extremely valuable because they provide important and vital breeding habitat for many species of amphibians that cannot successfully breed in permanent bodies of water because of the presence of predatory fish.

For constructed wetland projects designed as “forested wetlands”, it takes many years to develop a mature wetland forest, even when many of the trees are planted by hand or machine. The oldest of these to date--about 15 years--are still essentially in the seral shrub/forest ecotone stage of development and are inhabited by wildlife species typical of this habitat.

Because the surrounding uplands play a crucial role in the functions and ecological “health” of a wetland, and a greater diversity of wildlife usually occurs in wetlands in close proximity to shrub/forested uplands, efforts should be made to include an upland buffer zone or preserve adjacent to a constructed wetland.

The rate of population or repopulation of a constructed wetland by animals is influenced by the mobility of the species, proximity to already populated habitats, and pathways or corridors for movement from one place to another. Many animals are restricted to particular ecosystem types and rarely venture into alien habitat.

Baseline studies inventorying the species present on a wetland site should be conducted prior to mining if the site is to be reconstructed as a similar type wetland.

Criteria should be developed utilizing a suite of selected species of wildlife as indicators of successful wetland creation--herbaceous wetlands with, (or without) bodies of water, isolated wetlands, forested wetlands, etc. Once a wetland community has become established, seasonal qualitative monitoring and sampling of the mammals, birds, and herpetofauna using the site would help in determining whether or not that particular wetland development is on track towards an appropriate climax configuration. The development of these criteria is beyond the scope of this preliminary investigation. But it is a task that should be undertaken and one that should result in a clear set of criteria.

SECTION 7 - WILDLIFE

INTRODUCTION

Legal criteria under the rules of the Florida Department of Environmental Protection for the determination of successful completion of a constructed wetland project are based upon monitoring of vegetation survival and growth and water quality for a period of time after construction. In comparison with absolute biomass productivity of other natural communities, wetlands tend to be considerably more productive. Higher numbers and biomass of plants and animals is a result of a number of factors, including the presence of plentiful water, nutrients, and increased mobility of nutrients in water; higher import and export rates; higher turnover rates; and wider variety of micro habitats. It is not surprising, therefore, that the variety and numbers of wildlife species are also greater in wetlands.

Because of the variety and abundance of natural habitats still extant in much of the phosphate mining areas of Florida, wildlife tends to locate and colonize newly created habitats without too much difficulty or delay. All that is usually necessary for a wetland to develop and mature is for the physiography and hydrology to be in place. Mother Nature does the rest--at her own pace, of course.

When it comes to wetland creation/restoration in mined lands, we want recovery/restoration to occur more rapidly and in a planned direction, so planting of selected/desirable species is required. Yet, because we know that wildlife is mobile, we have not yet reached the stage where we deem it necessary for animals to be introduced into a newly created wetland. Indeed, if we locate and design our wetlands in a region properly, we may never have to "seed" wildlife on a site. This is the current attitude of most biologists and regulators, Legal criteria under the rules of the Florida Department of Environmental Protection for the determination of successful completion of a constructed wetland project are based upon monitoring of vegetation survival and growth and water quality for a period of time after construction is completed, so no wildlife standards dealing with kinds of species, numbers, or biomass have been established and required for wetland construction/reclamation. As a result, few data are available for review and evaluation of wildlife usage of constructed wetlands. This is not necessarily a criticism of regulators or industry standards, merely a statement of fact.

In some instances, monitoring reports have included some incidental wildlife observations (Atkins 1991, Atkins & Sacco 1986a,b,c,d, Anon. 1991, Erwin 1985, 1989, 1990a,b, 1991, 1992, Env. Serv. & Permitting 1991), and several special studies focusing on wildlife on phosphate-mined lands have been reported and/or published (Edelson & Collopy 1990, Layne et al. 1977, Frohlich & Marion 1984, Kale 1992, King et al. 1980, Maehr 1981, 1984, Maehr and Marion 1984, and Schnoes & Humphrey 1987.) In addition, lists of wildlife (but most often only bird species) have been reported by Audubon Society visitors to selected sites.

Experience gained over many years of wildlife observations in Florida, supplemented by the observations and studies mentioned above, and anecdotal observations by nonbiologist workers on phosphate mine lands, have enabled us to compile lists of wildlife fauna that should and/or do occur in natural and constructed wetland habitats.

Tables in this report present a list of most of the wildlife species that are present in the phosphate mining areas, and a list of those species most closely associated with wetlands. Wetlands do not exist out of context with their immediately surrounding uplands, and this is especially true of their wildlife component. Both of these communities, and the structural features that they may contain, influence the species that are present in one or the other habitat.

Wetlands exist in many forms: herbaceous wetlands fringing large bodies of water, herbaceous wetlands with no associated water bodies, forested wetlands lining streams or lakes, seepage wetlands and isolated wetlands. Some wetlands remain permanently inundated with water, others go dry for varying periods of their annual cycle. The kind of wetland often dictates the species of wildlife present on a site on a seasonal or permanent basis.

Goals for constructed wetlands vary. Some are designed to maximize production of waterfowl, wading birds, fish, etc. Some are designed simply to replace a feature or function destroyed during mining. Should a constructed wetland be deemed completed/successful when a minimum vegetation standard is reached, or should it be so deemed when a faunal occupancy standard is also reached? Will the constructed wetland remain in perpetuity? When phosphate mining is completed in a region, what are Society's goals for that region?

The objectives of the wildlife component of this study are to elucidate both the desirability and the feasibility of incorporating wildlife considerations into the criteria for "success" in the artificial creation of wetlands. In order to accomplish this, we examine the wildlife species that might be expected to occur on created wetlands in the phosphate mining areas of Florida, establish criteria for the selection of indicator or "desirable" species, as opposed to ubiquitous, dominant, or exotic species, and examine the methodologies by which wildlife species in wetlands may be sampled, both qualitatively and quantitatively.

OVERVIEW OF WETLAND WILDLIFE

The geography of Florida--a peninsula extending into the subtropical zone, surrounded by water, extremely flat, and with a relatively high annual rainfall--results in a large number of wetlands--herbaceous marshes, hydric forests, riparian marshes and forests, and various combinations of these where they interrelate. The relative flatness inhibits runoff and allows greater water retention and infiltration into underground aquifers. An abundant supply of water, permanent in some places, cyclic in others, fosters a wide variety and biomass of plant and animal species. The greater the variety of land, water, and plant features, the greater the range of ecological niches, and thus the potential for zoological diversity.

A healthy wetland ecosystem performs the following vital ecological functions in addition to the retention and storage of water:

(a) Plant biomass production for (1) structure (cover, perching and nesting sites), (2) food for invertebrate and vertebrate wildlife, (3) seed sources, (4) peat/organic deposition, and (5) uptake ofnutrients and metallic ions from the water.

(b) Animal biomass production for food for predatory invertebrates and vertebrates.

(c) Refugia for plants and animals.

(d) Wildlife nodes and corridors for genetic continuity of plants and movement of animals within and between regions.

All animals are ultimately dependent upon plants for food and structure. Animals eat plant material directly by ingesting leaves, tubers, fruits, seeds, etc., or indirectly by eating animals that themselves feed directly or indirectly on plants. Vegetation structure also helps to modify microclimate and soil and water conditions, enabling additional species of plants and animals to exist on a site. Increasing complexity of plants and plant communities often allows a greater diversity of animals to inhabit a site. Specialized, evolving, or early-succession habitats often favor certain animal species. For example, in the early stages of wetland development on construction sites or on clay settling ponds, shorebirds have feeding advantages on the exposed or sparsely vegetated mud flats.

The greatest wetland faunal diversity in Florida occurs in herbaceous wetlands associated with open bodies of water. The open water of lakes and ponds enable aquatic predators to capture prey by diving on them from above, or by swimming on or below the water surface. Animals that consume submergent plants and invertebrates obtain these by Surface feeding or diving. Along the edges of lakes and within herbaceous vegetation, animals can walk and feed in shallow water, and move through and over the emergent vegetation. In addition, upland terrestrial species also frequent wetland habitats and open water, even if only on a temporary or periodic basis.

Wetlands, because they include both aquatic and terrestrial substrates, are among the most productive habitats in the world, and this is reflected in the diversity, density, and biomass of birds, mammals, and reptiles and amphibians that occur in or near them In shallow water habitats, especially where the water is reasonably clear and open to sunlight penetration, plant food can be produced at all levels in the water column--surface, midwater, and bottom This affords a much deeper zone of primary productivity and a greater diversity of food forms than are produced in an equivalent terrestrial system

Numerous studies and observations have noted the great variety of birdlife associated with wetlands, although few of these have been conducted on wetlands in phosphate mining areas. (Kale, 1992; Ogden, 1994; Edelson and Collopy, 1990). Those that have all confirm the high avian biodiversity of wetland sites, especially where open water is present.

Many kinds of amphibians (frogs, toads, and salamanders) are terrestrial, but almost all Florida species require wetlands for at least a part of their life cycle. Most species of turtles are aquatic and inhabit wetlands for food and cover, but all Florida species lay their eggs in terrestrial sites. Although few mammals are as dependent on wetlands as are amphibians, their populations tend to be higher in wetland areas because of the higher abundance and diversity of food and habitat (Hammer 1992).

Because of extensive drainage of wetlands for agriculture and urban developments in Florida, and over pumping of water from aquifers, the number and area of wetlands have declined greatly since the early years of this century (Tiner 1984). As a result, wetland dependent species, especially waterfowl and wading birds, have also greatly declined--in some cases, by as much as 90% in the past 30 or 40 years (Frederick and Spalding 1994, Ogden 1994). Even in areas “protected” from agriculture or development, such as Everglades National Park, the decline of wading birds as a result of alteration of biological cycles has been catastrophic.

The construction of wetlands to replace those destroyed by mining or to enhance wetlands adversely impacted by nearby mining operations should be designed to restore their basic productivity and diversity, and thus benefit wildlife species dependent on these habitats. Depending on the design and the variety of habitat features built into a constructed wetland, the presence (or absence) of certain species of wildlife may serve as an indicator of success (or failure) of a wetland construction project. The kinds and possibly the numbers of organisms utilizing a constructed wetland are the criteria of the appropriateness of the physical, chemical, and hydrological engineered parameters of the site, with the presence of either sensitive, specialized “indicator” species, or high trophic level taxa, being the ultimate test.

METHODS

(1) Site inspections of virtually all permitted and non-permitted reclamation sites were conducted at Agrico Chemical Company (June 29-July 1, 1993) CF Industries (August 11-12,1993), Occidental Chemical Company (September 8-10, 1993), Mobil Mining and Minerals Company (October 11-12, 1993) Cargill Fertilizer, Inc. (January 19-20, 1994) U.S. Agri-Chemicals, Inc. (January 21, 1994), and IMC-Agrico Co., (February 8-10, 1994). At each site, visited field notes were made on all wildlife seen or heard, and on presence of wildlife signs (scat, tracks, burrows, etc.). Visits at each site were a collaborative effort by the team of research investigators and company representatives, and ranged in time from several minutes to a halfhour or longer per site, so the amount and variety of field data collected on wildlife varied considerably from site to site. No effort was made to conduct a complete survey of each site during these visits.

(2) The literature--both published and unpublished (the latter including monitoring reports of consultants, results of surveys, and field trips by Audubon Society members, etc.)--was searched for references and observations on wildlife reported to be in or near phosphate mining areas.

(3) Techniques for surveying herpetofauna, birds, and mammals were reviewed in an effort to develop the most practicable and least expensive or disruptive methods for detecting and monitoring wildlife populations on constructed wetlands.

RESULTS

Tables 7-1 through 7-4 list the species (common name and scientific name) of mammals (excluding bats), birds, and herpetofauna (reptiles and amphibians), respectively, that are known to occur on wetland habitats or uplands closely associated with wetlands, on phosphate-mined lands in Florida. These lists were compiled from observations made during site visits to wetlands of the seven major phosphate mining companies in Florida and from the literature. Species recorded during the site visits mentioned above are presented in Appendix 7-1. We must emphasize that because of the brief non-repeated nature of our inspection visits these data must be considered preliminary only.

Table 7-1. Mammals (excluding bats) known to occur on wetland habitats on phosphate-mined lands in Florida

Order
  Family
    Species : Common name (scientific name)

Marsupiala
  Didelphiidae
    Opposum *(Didelphis marsupialis)*
Insectivora
  Soricidae
    Least Shrew *(Cryptotis parva)*
    Shorttail Shrew *(Blarina brevicauda)*
Carnivora
  Procyonidae
    Raccoon *(Procyon lotor)*

  Mustelidae
    Mink *(Mustela vison)*
    River Otter *(Lutra canadensis)*

  Canidae
    Coyote *(Canis latrans)*
    Red Fox *(Vulpes fulva)*
    Gray Fox *(Urocyon cinereoargenteus)*

Table 7-1 continued.

Felidae
- Panther (*Felis concolor*)
- Bobcat (*Lynx rufus*)

Rodentia

Sciuridae
- Eastern Gray Squirrel (*Sciurus carolinensis*)

Cricetidae
- Oldfield Mouse (*Peromyscus polionotus*)
- Cotton Mouse (*Peromyscus gossypinus*)
- Eastern Woodrat (*Neotoma floridana*)
- Rice Rat (*Oryzomys palustris*)
- Cotton Rat (*Sigmodon hispidus*)
- Florida Water Rat (*Neofiber alleni*)
- House Mouse (*Mus musculus*)

Lagamorpha

Leporidae
- Eastern Cottontail (*Sylvilagus floridanus*)
- Marsh Rabbit (*Sylvilagus palustris*)

Artiodactyla

Suidae
- Feral Pig (Swine) (*Sus scrofa*)

Cervidae
- White-tailed Deer (*Odocoileus virginianus*)

Xenarthra

Dasypodidae
- Nine-banded Armadillo (*Dasypus novemcinctus*)

Table 7-2. Birds known to occur in wetland habitats on phosphate-mined lands in Florida.

Order / Family / Species: Common name (Scientific name)	Status
Gaviformes	
Gaviidae	
Common Loon (*Gavia immer*)	Winter
Podicipediformes	
Podicipedidae	
Pied-billed Grebe (*Podilymbus podiceps*)	PR*
Horned Grebe (*Podiceps auritus*)	
Eared Grebe (*Podiceps nigricollis*)	Winter
Pelecaniformes	
Pelecanidae	
American White Pelican (*Pelecanus erythrorhyncos*)	Winter
Brown Pelican (*Pelecanus occidentalis*)	PR*
Phalacrocoracidae	
Double-crested Cormorant (*Phalacrocorax auritus*)	PR*
Anhingidae	
Anhinga (*Anhinga anhinga*)	PR
Ciconiiformes	
Ardeidae	
American Bittern (*Botaurus lentiginosus*)	Winter
Least Bittern (*Ixobrychus exilis*)	PR*
Great Blue Heron (*Ardea herodius*)	PR*
Great Egret (*Casmerodius albus*)	PR*
Snowy Egret (*Egretta thula*)	PR*
Little Blue Heron (*Egretta caerulea*)	PR*
Tricolored Heron (*Egretta tricolor*)	PR*
Cattle Egret (*Bubulcus ibis*)	PR*
Green Heron (*Butorides virescens*)	PR*
Black-crowned Night-Heron (*Nycticorax nycticorax*)	PR*
Yellow-crowned Night-Heron (*Nyctinassa violacea*)	PR*

Table 7-2 continued.

Threskiornithidae	
White Ibis (*Eudocimus albus*)	PR*
Glossy Ibis (*Plegadis falcinellus*)	PR
Roseate Spoonbill (*Ajaia ajaja*)	PR
Ciconiidae	
Wood Stork (*Mycteria americana*)	PR*
Anseriformes	
Anatidae	
Wood Duck (*Aix sponsa*)	PR
Green-winged Teal (*Anas crecca*)	Winter
American Black Duck (*Anas rubripes*)	Winter
Mottled Duck (*Anas fulvigula*)	PR
Mallard (*Anas platyrhynchos*)	Winter
Northern Pintail (*Anas acuta*)	Winter
Blue-winged Teal (*Anas discors*)	Winter
Cinnamon Teal (*Anas cyanoptera*)	Winter
Northern Shoveler (*Anas clypeata*)	Winter
Gadwall (*Anas strepera*)	Winter
American Wigeon (*Anas penelope*)	Winter
Canvasback (*Aythya valisineria*)	Winter
Redhead (*Aythya americana*)	Winter
Ring-necked Duck (*Aythya collaris*)	Winter
Lesser Scaup (*Aythya affinis*)	Winter
Oldsquaw (*Clangula hyemalis*)	Winter
Common Goldeneye (*Bucephala clangula*)	Winter
Bufflehead (*Bucephala albeola*)	Winter
Hooded Merganser (*Lophodytes cucullatus*)	Winter
Red-breasted Merganser (*Mergus serrator*)	Winter
Ruddy Duck (*Oxyura jamaicensus*)	Winter
Falconiformes	
Cathartidae	
Black Vulture (*Coragyps atratus*)	PR*
Turkey Vulture (*Cathartes aura*)	PR*
Accipitridae	
Osprey (*Pandion haliaetus*)	PR*

Table 7-2 continued.

Snail Kite (*Rostrhamus sociabilis*)	PR-Rare
Bald Eagle (*Haliaeetus leucocephalus*)	PR
Northern Harrier (*Circus cyaneus*)	Winter
Sharp-shinned Hawk (*Accipiter striatus*)	Winter
Cooper's Hawk (*Accipiter cooperi*)	PR-Rare
Red-shouldered Hawk (*Buteo lineatus*)	PR
Broad-winged Hawk (*Buteo platyperus*)	Winter-Rare
Red-tailed Hawk (*Buteo jamaicensis*)	PR*
Falconidae	
American Kestrel (*Falco sparverius*)	PR*
Merlin (*Falco columbarius*)	Winter-Trans
Peregrine Falcon (*Falco peregrinus*)	Winter-Trans
Galliformes	
Phasianidae	
Northern Bobwhite (*Colinus virginianus*)	PR
Wild Turkey (*Meleagris gallopavo*)	PR
Gruiformes	
Rallidae	
King Rail (*Rallus elegans*)	PR*
Virginia Rail (*Rallus limicola*)	Winter
Sora (*Porzana carolina*)	Winter
Purple Gallinule (*Porphyrula martinica*)	Summer-PR
Common Moorhen (*Gallinula chloropus*)	PR
American Coot (*Fulica americana*)	Winter-PR
Aramidae	
Limpkin (*Aramus guarauna*)	PR-Rare
Gruidae	
Sandhill Crane (*Grus canadensis*)	PR*
Charadriiformes	
Charadriidae	
Black-bellied Plover (*Pluvialis squatarola*)	Winter
Semipalmated Plover (*Charadrius semipalmatus*)	Winter
Killdeer (*Charadrius vociferus*)	PR*

Table 7-2. Continued.

Recurvirostridae	
Black-necked Stilt (*Himantopus mexicanus*)	Summer
American Avocet (*Recurvirostra americana*)	Transient
Scolopacidae	
Greater Yellowlegs (*Tringa melanoleuca*)	Winter
Lesser Yellowlegs (*Tringa flavipes*)	Winter
Solitary Sandpiper (*Tringa solitaria*)	Transient
Spotted Sandpiper (*Actitis macularia*)	Winter
Ruddy Turnstone (*Arenaria interpres*)	Winter
Sanderling (*Calidris alba*)	Winter
Semipalmated Sandpiper (*Calidris pusilla*)	Transient
Western Sandpiper (*Calidris mauri*)	Winter
Least Sandpiper (*Calidris minutilla*)	Winter
White-rumped Sandpiper (*Calidris fuscicollis*)	Transient
Pectoral Sandpiper (*Calidris melanotos*)	Transient
Dunlin (*Calidris alpina*)	Winter
Stilt Sandpiper (*Calidris himantopus*)	Transient
Short-billed Dowitcher (*Limnodromus griseus*)	Winter
Long-billed Dowitcher (*Limnodromus scolopaceous*)	Winter
Common Snipe (*Gallinago gallinago*)	Winter
American Woodcock (*Scolopax minor*)	Winter-PR
Wilson's Phalarope (*Phalaropus tricolor*)	Transient
Laridae	
Laughing Gull (*Larus atricilla*)	PR*
Bonaparte's Gull (*Larus philadelphia*)	Winter
Ring-billed Gull (*Larus delawarensis*)	Winter
Herring Gull (*Larus argentatus*)	Winter-rare
Gull-billed Tern (*Sterna nilotica*)	PR-rare
Caspian Tern (*Sterna caspia*)	PR*
Royal Tern (*Sterna maxima*)	PR*
Sandwich Tern (*Sterna sandvicensis*)	PR-rare
Forster's Tern (*Sterna forsteri*)	Winter
Least Tern (*Sterna antillarum*)	Summer
Black Skimmer (*Rynchops niger*)	PR*
Columbiformes	
Columbidae	
Rock Dove (*Columba livia*)	PR

Table 7-2 continued.

Mourning Dove (*Zenaida macroura*)	PR*
Common Ground-Dove (*Columbina passerina*)	PR
Cuculiformes	
Cuculidae	
Yellow-billed Cuckoo (*Coccyzus americanus*)	Transient-PR
Strigiformes	
Tytonidae	
Barn Owl (*Tyto alba*)	PR-rare
Strigidae	
Eastern Screech-Owl (*Otus asio*)	PR
Great Horned Owl (*Bubo virginianus*)	PR
Barred Owl (*Strix varia*)	PR
Caprimulgiformes	
Caprimulgidae	
Common Nighthawk (*Chordeiles minor*)	Summer
Chuck-will's-widow (*Caprimulgus carolinensis*)	Summer
Whip-poor-will (*Caprimulgus vociferus*)	Transient
Apodiformes	
Apodidae	
Chimney Swift (*Chaetura pelagica*)	Summer
Trochilidae	
Ruby-throated Hummingbird (*Archilochus colubris*)	Summer
Coraciiformes	
Alcedinidae	
Belted Kingfisher (*Ceryle alcyon*)	Winter-PR
Piciformes	
Picidae	
Red-bellied Woodpecker (*Melanerpes carolinus*)	PR
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	Winter
Downy Woodpecker (*Picoides pubescens*)	PR
Northern Flicker (*Colaptes auratus*)	PR
Pileated Woodpecker (*Dryocopus pileatus*)	PR

Table 7-2 continued.

Passeriformes	
Tyrannidae	
Eastern Wood-Pewee (*Contopus virens*)	Transient-PR
Acadian Flycatcher (*Empidonax virescens*)	Transient-PR
Eastern Phoebe (*Sayornis phoebe*)	Winter
Great Crested Flycatcher (*Myiarchus crinitus*)	Summer
Eastern Kingbird (*Tyrannus tyrannus*)	Summer
Hirundinidae	
Purple Martin (*Progne subis*)	Summer
Tree Swallow (*Tachycineta bicolor*)	Winter
No. Rough-winged Swallow (*Stelgidopteryx serripennis*)	PR-Tran
Bank Swallow (*Riparia riparia*)	Transient
Barn Swallow (*Hirundo rustica*)	PR-Tran
Corvidae	
Blue Jay (*Cyanocitta cristata*)	PR
American Crow (*Corvus brachrhynchos*)	PR
Fish Crow (*Corvus ossifragus*)	PR
Paridae	
Tufted Titmouse (*Parus bicolor*)	PR
Troglodytidae	
Carolina Wren (*Thryothorus ludovicianus*)	PR
House Wren (*Troglodytes aedon*)	Winter
Sedge Wren (*Cistothorus platensis*)	Winter
Marsh Wren (*Cistothorus palustris*)	Winter
Muscicapidae	
Ruby-crowned Kinglet (*Regulus calendula*)	Winter
Blue-gray Gnatcatcher (*Polioptila caerulea*)	PR
Eastern Bluebird (*Sialia sialis*)	PR*
Hermit Thrush (*Catharus guttatus*)	Winter
American Robin (*Turdus migratorius*)	Winter
Mimidae	
Gray Catbird (*Dumatella carolinensis*)	Winter-PR
Northern Mockingbird (*Mimus polyglottus*)	PR
Brown Thrasher (*Toxostoma rufum*)	PR

Table 7-2 continued.

Motacillidae	
American Pipit (*Anthus rubescens*)	Winter
Bombycillidae	
Cedar Waxwing (*Bombycilla cedrorum*)	Winter
Laniidae	
Loggerhead Shrike (*Lanius ludovicianus*)	PR
Sturnidae	
European Starling (*Sturnus vulgaris*)	PR
Vireonidae	
White-eyed Vireo (*Vireo griseus*)	PR
Solitary Vireo (*Vireo solitarius*)	Winter
Red-eyed Vireo (*Vireo olivaceus*)	Summer
Emberizidae	
Blue-winged Warbler (*Vermivora pinus*)	Transient
Tennessee Warbler (*Vermivora peregrina*)	Transient
Orange-crowned Warbler (*Vermivora celata*)	Winter
Northern Parula (*Parula americana*)	Summer-Tran
Yellow Warbler (*Dendroica petchia*)	Transient
Magnolia Warbler (*Dendroica magnolia*)	Transient
Cape May Warbler (*Dendroica tigrina*)	Transient
Black-throated Blue Warbler (*Dendroica caerulescens*)	Transient
Yellow-rumped Warbler (*Dendroica coronata*)	Winter
Blackburnian Warbler (*Dendroica fusca*)	Transient
Yellow-throated Warbler (*Dendroica dominica*)	PR-Tran
Pine Warbler (*Dendroica pinus*)	PR
Prairie Warbler (*Dendroica discolor*)	Tran-PR
Palm Warbler (*Dendroica palmarum*)	Winter
Bay-breasted Warbler (*Dendroica castanea*)	Transient
Black-and-white Warbler (*Mniotilta varia*)	Winter
American Redstart (*Setophaga ruticilla*)	Transient
Prothonotary Warbler (*Protonotaria citrea*)	Summer
Worm-eating Warbler (*Helmitheros vermivorus*)	Transient
Ovenbird (*Seiurus aurocapillus*)	Transient
Northern Waterthrush (*Seiurus noveboracencis*)	Transient
Louisiana Waterthrush (*Seiurus motacilla*)	Transient

Table 7-2 continued.

Mourning Warbler (*Oporornis philadelphia*)	Transient
Common Yellowthroat (*Geothlypis trichas*)	PR*
Hooded Warbler (*Wilsonia pusilla*)	Summer
Summer Tanager (*Piranga rubra*)	Summer
Northern Cardinal (*Cardinalis cardinalis*)	PR
Indigo Bunting (*Passerina cyanea*)	Tran-Summer
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	PR
Bachman's Sparrow (*Aimophila aestivalis*)	PR
Chipping Sparrow (*Spizella passerina*)	Winter
Field Sparrow (*Spizella pusilla*)	Winter-PR
Savannah Sparrow (*Passerculus savannarum*)	Winter
Song Sparrow (*Melospiza melodia*)	Summer
Swamp Sparrow (*Melospiza georgiana*)	Winter
White-throated Sparrow (*Zonotrichia albicollis*)	Winter
Bobolink (*Dolichonyx oryzivorus*)	Transient
Red-winged Blackbird (*Agelaius phoeniceus*)	PR*
Eastern Meadowlark (*Sturnella magna*)	PR
Rusty Blackbird (*Euphagus carolinus*)	Winter-rare
Boat-tailed Grackle (*Quscalus major*)	PR
Common Grackle (*Quiscalus quiscula*)	PR
Brown-headed Cowbird (*Molothrus ater*)	PR
Orchard Oriole (*Icterus spurius*)	Summer-Tran
Northern Oriole (*Icterus galbula*)	Tran-winter
Fringillidae	
American Goldfinch (*Carduelis tristis*)	Winter

Table 7-3. Reptiles and Amphibians known to occur in wetland habitats on phosphate-mined lands in Florida

Order Family Species: Common name (Scientific name)	Status
A. Reptiles	
Crocodylia	
Alligatoridae	
American Alligator (*Alligator mississippiensis*)	PR-Ponds
Testudines	
Chelydridae	
Snapping Turtle (*Chelydra serpentina*)	PR-Ponds
Kinosternidae	
Common Musk Turtle (*Sternotherus odoratus*)	PR-Ponds
Florida Mud Turtle (*Kinosternon subrubrum steindachneri*)	PR-Ponds
Striped Mud Turtle (*Kinosternon bauri*)	PR-Ponds
Emydidae	
Florida Box Turtle (*Terrapene carolina bauri*)	Terrestrial
Peninsular Cooter (*Pseudemys floridana peninsularis*)	PR-Ponds
Trionychidae	
Florida Softshell (*Trionyx ferox*)	PR-Ponds
Squamata	
Lacertilia	
Polychridae	
Green Anole (*Anolis carolinensis*)	Terrestrial
Scincidae	
Ground Skink (*Scincella lateralis*)	Terrestrial
Serpentes	
Colubridae	
Florida Green Water Snake (*Nerodia cyclopion floridana*)	Ponds,marsh
Brown Water Snake (*Nerodia taxispilota*)	Ponds,marsh
Florida Water Snake (*Nerodia fasciata pictiventris*)	Ponds,marsh

Table 7-3 continued.

Striped Crayfish Snake (*Regina alleni*)	Ponds,marsh
South Florida Swamp Snake (*Seminatrix pygaea cyclas*)	Ponds,marsh
Florida Brown Snake (*Storeria dekayi victa*)	Terrestrial
Eastern Garter Snake (*Thamnophis sirtalis sirtalis*)	Terrestrial
Peninsula Ribbon Snake (*Thamnophis sauritus sackeni*)	Terrestrial
Eastern Mud Snake (*Farancia abacura abacura*)	Terrestrial
Southern Black Racer (*Coluber constrictor priapus*)	Terrestrial
Rough Green Snake (*Opheodrys aestivus*)	Terrestrial
Eastern Indigo Snake (*Drymarchon corais cooperi*)	Terrestrial
Corn Snake (*Elaphe guttata guttata)*	Terrestrial
Yellow Rat Snake (*Elaphe obsoleta guardrivittata*)	Terrestrial
Florida Kingsnake (*Lampropeltis getula floridana*)	Terrestrial
Scarlet Kingsnake (*Lampropeltis triangulum elapsoides*)	Terrestrial
Elapidae	
Eastern Coral Snake (*Micrurus fulvius fulvius*)	Terrestrial
Viperidae	
Florida Cottonmouth (*Agkistrodon piscivorus conanti*)	Ponds,marsh
B . Amphibians	
Caudata	
Amphiumidae	
Two-toed Amphiuma (*Amphiuma means*)	PR-Ponds
Sirenidae	
Greater Siren (*Siren lacertina*)	PR-Ponds
Lesser Siren (*Siren intermedia*)	PR-Ponds
Narrow-striped Dwarf Siren (*Pseudobranchus striatus axanthus*)	PR-Ponds
Salamandridae	
Peninsula Newt (*Notophthalmus viridescens piaropicola*)	PR-Ponds
Plethodontidae	
Spotted Dusky Salamander (*Desmognathus fuscus conanti*)	Ravines
Southern Dusky Salamander (*Desmognathus auriculatus*)	Swamps

Table 7-3 continued.

Slimy Salamander (*Plethodon glutinosus*)	Wet hammocks
Dwarf Salamander (*Eurycea quadridigitata*)	Wet hammocks
Anura	
Pelobatidae	
Eastern Spadefoot (*Scaphiopus holbrookii holbrookii*)	Terr-Ponds
Bufonidae	
Southern Toad (*Bufo terrestris*)	Terr-Ponds
Oak Toad (*Bufo quercicus*)	Terr-Ponds
Hylidae	
Florida Cricket Frog (*Acris gryllus gryllus*)	Ponds
Green Treefrog (*Hyla cinerea*)	Terr-Ponds
Barking TreeFrog (*Hyla gratiosa*)	Terr-Ponds
Pine Woods Treefrog (*Hyla femoralis*)	Terr-Ponds
Squirrel Treefrog (*Hyla squirella*)	Terr-Ponds
Florida Chorus Frog (*Pseudacris nigrita verrucosa*)	Ponds
Little Grass Frog (*Pseudacris ocularis*)	Ponds
Microhylidae	
Eastern Narrowmouth Toad (*Gastrophryne carolinensis*)	Ponds
Ranidae	
Bullfrog (*Rana catesbeiana*)	Ponds
River Frog (*Rana heckscheri*)	Ponds
Pig Frog (*Rana grylio*)	Ponds
Florida Leopard Frog (*Rana utricularia sphenocephala*)	Ponds
Florida Gopher Frog (*Rana capito aesopus*)	Terr-Ponds

Table 7-4. Additional species of amphibians occurring in wetlands of north Florida only.

Order Family Species: Common name (Scientific name)	Status
Testudines	
Kinosternidae	
Loggerhead Musk Turtle (*Sternotherus m. minor*)	PR-Ponds
Eastern Mud Turtle (*Kinosternon s. subrubum*)	PR-Ponds
Emydidae	
Eastern Box Turtle (*Terrapene c. carolina*)	Terrestrial
Yellowbelly Slider (*Trachemys s. scripta*)	PR-Ponds
Florida Cooter (*Pseudemys f. floridana*)	PR-Ponds
Eastern Chicken Turtle (*Deirochelys reticularia*)	PR-Ponds
Caudata	
Sirenidae	
Slender Dwarf Siren (*Pseudobranchus striatus sphenicus*)	PR-Ponds
Salamandridae	
Striped Newt (*Notophthalamus perstriatus*)	Ponds
Central Newt (*Notophthalamus viridescens louisianensis*)	Ponds
Plethodontidae	
Marbled Salamander (*Ambystoma opacum*)	Terr-Ponds
Mole Salamander (*Ambystoma talpoideum*)	Terr-Ponds
Eastern Tiger Salamander (*Ambystoma t. tigrinum*)	Terr-Ponds
Southern Two-lined Salamander (*Eurycea bislineata cirrigera*)	Creek,swamps
Rusty Mud Salamander (*Pseudotriton montanus floridanus*)	Seepage
Southern Red Salamander (*Pseudotriton ruber vioscai*)	Streams
Anura	
Hylidae	
Southern Spring Peeper (*Hyla crucifer bartramiana*)	Ponds
Gray Treefrog (*Hyla chrysoscelis*)	Terr-Ponds
Ornate Chorus Frog (*Pseudacris ornata*)	Terr-Ponds
Ranidae	
Bronze Frog (*Rana clamitans clamitans*)	Wet-hammock

Inasmuch as many bird species are migratory, with some being present in one season and not another, we have indicated the status of each species in Table 7-2. Permanent residents are species that occur year-round in Florida, summer residents only in summer, and winter residents only in winter. Transients occur only during spring and fall migration when they pass through Florida en route to their summer breeding grounds to the north or wintering areas south of Florida. The populations of some of the permanent resident species are augmented in winter by visitors from the north (indicated with an asterisk on Table 7-2). Some of the wintering and summering species also have components that pass through Florida during migration, thus augmenting their numbers during spring and fall. Because Florida serves as the wintering ground for many northern species of birds, higher numbers of both species and individuals are present in wetlands in the winter than in the summer.

Much overlap occurs in the timing of bird movements, so no single date or month can delineate seasonal boundaries. For example, shorebirds begin fall migration and move through Florida in July and August (sometimes from late June) en route to wintering areas in South America, with many individuals of some species remaining to winter in Florida. Most waterfowl species do not arrive in the state until November or December, although Blue-winged Teal begin arriving in July. Early southbound passerine migrants reach Florida by mid-July, but the majority of transient species pass through in September or October. In the Spring, some northbound species reach Florida in March, but the majority of them pass through in April and May.

Table 7-4 is a list of species of amphibians that occur only in north Florida near the southern edge of their ranges and which could also be present in wetland habitats on phosphate-mined lands in north Florida. Almost all of the herpetofauna listed in Table 7-3 also occur in the north Florida phosphate areas.

Herpetofauna occur year-round in or near wetlands and are considered to be permanent residents, although some species may be present in the water itself for only a brief period during their breeding season. The status of each species is indicated on Tables 7-3 and 7-4. Species that are permanent residents within aquatic habitats are indicated as "PR-Ponds", and species that are primarily terrestrial are indicated as such, but it should be noted that many of these also may occur along the edges of wetlands or on vegetation in the wetlands. Species that are terrestrial, but require aquatic habitat during a stage of their breeding cycle are shown as “Terr-Pond”.

Mammals, for the most part, are also considered to be permanent residents, although some of the wider ranging species may occur only sporadically in a particular site as they move from place to place within their territories or home ranges. A Florida Panther was observed for several minutes on October 10, 1993 as we were traveling from one wetland site to another on Mobil Mining and Minerals Company property. The average home range of a male panther in Florida is over 500 sq. km (Maehr et al, 1991) and few panthers now occur outside of south Florida, except for vagrant males. Another relatively wide-ranging mammal is the Coyote *(Canis lutrans),* which has been extending its range into Florida in recent years (Brady and Campbell 1983). While visiting an Agrico site on the Polk-Hardee County line in June 1993, we stopped near a saw-palmetto patch that housed an active coyote den.

Several additional species of mammals inhabiting uplands occasionally occur in or near wetlands. These are the Eastern Mole *(Scolopus aquaticus),* Long-tailed Weasel *(Mustela frenata),* Spotted Skunk *(Spilogale putorius),* Striped Skunk *(Mephitis mephitis),* Eastern Harvest Mouse *(Reithrodontomys humulis),* Golden Mouse *(Peromyscus nuttali),* Florida Mouse *(Podomys floridanus),* and Black Rat *(Rattus rattus).* The Wood Rat, House Mouse, and Old-field Mouse have been reported on spoil piles in old unreclaimed mines (Schnoes and Humphrey 1987).

During our site visits, the mounded grassy lodges of the Florida Water Rat, also known as the Round-tailed Muskrat, were noted only on natural undisturbed isolated herbaceous marshes. It is one of the last mammals to move into newly created habitat, which may be a function of its occurrence in isolated wetlands. Nevertheless, phosphate industry personnel have routinely observed Florida Water Rat feeding platforms in reclaimed marshes, indicating that their use of reclaimed marshes is common.

Fall shorebird (plovers and sandpipers) migration brings considerable numbers of these birds to active clay settling ponds beginning in July and continuing through the winter months. Shorebirds also appear at constructed wetland sites when in their initial stages of construction. Although the majority of these shorebirds migrate into Central and South America, many individuals also remain to winter in Florida.

Table 7-5 presents a list of those species or groups of species that are wetland-dependent, i.e., those species that occur only in wetland habitats and nowhere else. Many of these species (those marked with an asterisk) require open bodies of water--a lake or pond, or a stream--associated with the wetland for feeding, resting, and breeding. Without this feature they will be absent, or, if present, will be so in greatly reduced numbers and frequency. Most waterfowl--pelicans, ducks, etc., require expanses of open water.

Table 7-5. Wetland-dependent wildlife species. Species marked with an asterisk(*) require open bodies of water (lake,pond, or stream) associated with the wetland system.

Mammals:
- Mink
- River Otter*
- Rice rat
- Florida Water Rat

Birds:
- Common Loon*
- Pied-billed Grebe*
- American White Pelican*
- Brown Pelican*
- Double-crested Cormorant*

Table 7-5 continued.

Anhinga*
bitterns, herons, egrets, ibises
Wood Stork
geese* and ducks*
Osprey*

Bald Eagle*
rails
Purple Gallinule*
Common Moorhen*
American Coot*
Limpkin*
shorebirds*, gulls*, terns*
Belted Kingfisher*
Sedge Wren
Marsh Wren
Swamp Sparrow

Reptiles:
American Alligator*
Snapping Turtle*
Common Musk Turtle*
Florida Mud Turtle*
Striped Mud Turtle*
Peninsula Cooter*
Florida Softshell*
Florida Green Water Snake
Brown Water Snake
Florida Water Snake
Striped Crayfish Snake
South Florida Swamp Snake
Eastern Mud Snake
Florida Cottonmouth

Amphibians:
Amphiuma, sirens, salamanders, toads, frogs

Table 7-6 is a list of wildlife species that could serve as indicators of suitable habitat on constructed wetlands. Species marked with an asterisk require open bodies of water associated with the wetland. Some of the species listed, for example, the Common Yellowthroat, Red-winged Blackbird, and Boat-tailed Grackle are present in most Florida wetlands, but they are not wetland-dependent in that they also occur in a wide variety of terrestrial habitats. Hence, such species, alone, should not be used as "indicators" of successful wetland creation. On the other hand, their absence from a wetland habitat would be cause to raise questions about suitability of the site for wildlife.

Table 7-6. Wildlife species that serve as indicators of suitable habitat on constructed wetlands. Species marked with an asterisk(*) require open bodies of water (lake, pond, or stream) associated with the wetland system.

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1. Herbaceous marshes (including early stages of forested wetlands)

Mammals:

Mink
Raccoon
River Otter*
Rice Rat
Florida Water Rat
Marsh Rabbit

Birds:

Pied-billed Grebe*
American White Pelican*
Brown Pelican*
Double-crested Cormorant*
Anhinga*
bitterns, herons, egrets, ibises
Wood Stork*
ducks*, geese*
Osprey*
rails
Purple Gallinule*
Common Moorhen*
American Coot*
Limpkin*
shorebirds*, gulls*, terns*
Belted Kingfisher*
Sedge Wren
Marsh Wren

Table 7-6 continued.

Common Yellowthroat
Swamp Sparrow
Red-winged Blackbird
Boat-tailed Grackle

Reptiles:
American Alligator*
Snapping Turtle*
Common Musk Turtle*
Florida Mud Turtle*
Striped Mud Turtle*
Florida Yellowbelly Slider
Peninsular Cooter*
Florida Softshell*
Florida Green Watersnake
Brown Water Snake
Florida Water Snake
Striped Crayfish Snake
South Florida Swamp Snake
Eastern Mud Snake
Florida Cottonmouth

Amphibians:
Amphiuma, sirens, newts, salamanders, toads, frogs

2. Forested Wetlands (Shrub through mature stages)

Mammals:
Mink
Raccoon
River Otter*
Bobcat
Eastern Gray Squirrel
Cotton Mouse
Rice Rat
Marsh Rabbit

Birds:
Red-shouldered Hawk
American Woodcock

Table 7-6. Continued

Yellow-billed Cuckoo
Eastern Screech-Owl
Barred Owl
Chuck-will's-widow
Whip-poor-will
All woodpeckers
Eastern Wood-Pewee
Acadian Flycatcher
Eastern Phoebe
Great Crested Flycatcher
Blue Jay
Tufted Titmouse
Carolina Wren
Blue-gray Gnatcatcher
White-eyed Vireo
Red-eyed Vireo
Northern Parula
Yellow-rumped Warbler
Palm Warbler
American Redstart
Prothonotary Warbler
Ovenbird
Northern Waterthrush
Common Yellowthroat
Red-winged Blackbird

REVIEW OF VERTEBRATE SURVEY AND CENSUSING METHODOLOGY

Considerable effort has been expended in recent decades to develop techniques for making accurate estimates of animal populations (Bibby et al. 1992, Burnham et al. 1980, Conner and Dickson 1980, Eberhardt 1978, Heyer et al. 1994, Ralph and Scott 1981, Seber 1982, Verner 1985). Verner (1985) discusses the levels of detail in sample data (lists, counts, censuses), their associated scales of measurements, and the sorts of biological questions appropriately addressed by each. He concluded that researchers tend to seek more detailed information than needed in most cases.

To ascertain whether or not a site provides suitable or adequate habitat for wildlife one needs to observe and list the wildlife present on the site over a period of time, (ideally monthly, but at least once or twice each season). A list of avian species can be acquired relatively easily by a knowledgeable observer visiting a site periodically and walking transects that traverse the site, and using various aids that encourage birds to respond (recordings of songs, owl calls, firecrackers, etc.). Because many avian species are migratory and seasonal in occurrence, it is important to sample bird populations during each season of the year. For large mammals and herps, a careful search for signs (scat, burrows, kills, etc.), in addition to visual or aural detection is required. For small mammals and herps more effort is needed involving various trap arrays. Small rodents can be sampled with the use of trapline transects that traverse the habitat under study, with one or two live traps per station every 10 meters. Usually 3-5 nights of trapping once each season should suffice to reveal which species are present. Special modifications of the live traps enhances capture of smaller insectivores (shrews).

Because a goal of wetland construction is to provide habitat for wildlife, and it may take considerable time before some species become established, we do not recommend trapping methods that are lethal (snap-traps, or flooded pitfalls, for example) to the animals being sampled. For qualitative sampling of a site to detect listed species, the Florida Game & Fresh Water Fish Commission has published *"Wildlife Survey Methodology Guidelines"* (Allen 1988) which would be suitable for qualitative sampling in wetlands.

SAMPLING METHODOLOGIES FOR REPTILES AND AMPHIBIANS

In an initial survey of a given wetland area, it is desirable to generate the most complete possible list of the amphibian and reptile species present. This will require that all efforts be made to locate those microhabitats where amphibians and reptiles are most likely to concentrate and to capture as many of the species present as possible.

For aquatic, basking turtles, ideal circumstances to promote conspicuous basking will be conditions of bright sunshine and relatively low (but not excessively low) water temperature, i.e., sunny, spring days. There may be cases where a shortage of appropriate basking sites (ideally, stable logs, emergent from the water at a shallow angle, and of sufficient diameter to allow a large turtle to perch without danger of toppling) is evident. It is acceptable, in such cases, to set up artificial basking logs or platforms, which may be placed in areas convenient for long-distance viewing (e.g., by binocular or tripod-mounted telescope). Alligators, when present, are more often seen while floating than while basking, and the characteristic profile of emergent snout-tip, eyes, and the highest point of the back soon becomes easily recognizable, and, with a little experience, allows also for reasonably accurate estimation of size. But under appropriate conditions, alligators of all sizes may also engage in fully terrestrial basking.

Softshell turtles are also quite easily seen while floating at the surface of open water, and are less likely to be observed while walking on land or while basking. The snapping turtle and the mud and musk turtles tend to be bottom-walkers and are relatively inconspicuous even when present in numbers, except when water is very clear. They may be sampled by means of baited traps, especially hoop-traps, fashioned from chicken wire or steel hoops encased in nylon netting, fixed in position in shallow water with stakes or other means, and with about 25 percent of the enclosed volume above water, to prevent drowning. Various baits have been utilized successfully; the best are those that allow ready permeation of odiferous exudate into the water, but are not readily consumed completely or removed. Perforated cans of sardines, or chunks of raw chicken (including bones), dangled in the central part of the trap by means of strong string or cord, have been used very successfully.

In shallow, well-vegetated water, hatchling and small juvenile turtles may be present. They may be caught with improvised small seines and dredges, by which means a substantial volume of vegetation may be brought ashore, and picked through at leisure.

Carcasses of larger turtles may be quite persistent. Adult female turtles are sometimes killed by predators while away from water in the course of their nesting excursions. A careful circumambulation through the woods, thickets, or open land surrounding a wetland may well reveal shells or skeletons of turtles that died in this way. These can be collected as vouchers. On the other hand, the large-scale collection and preservation of voucher specimens of live turtles from constructed wetlands is discouraged, being substantially unnecessary in that the species diversity of turtles in such situations is low enough that field identification of species is adequate. In addition, turtles, having much slower growth and reproductive potential than most amphibians, for example, are susceptible to lasting population impact when subject to substantial levels of scientific collection. This is especially the case with limited isolated populations such as occur in a small constructed wetland. As mentioned above in the case of small mammals, one does not want to remove animals from recently constructed wetlands when one of the goals is to encourage them to inhabit the site.

Amphibian species present in a wetland area may be sampled by a variety of techniques. At appropriate seasons, large numbers of larvae (tadpoles) may be visible in shallow open or vegetated water situations. These may easily be sampled by means of a small dipnet and may be identified by microscopic examination and comparison with illustrations or specimens of the anuran species known to be in the area. It is important to identify and record the presence of tadpoles, even of species for which the presence of adults has already been established, because it constitutes *prima facie* evidence of reproduction.

Adult amphibians are best sought at night, especially following an early spring rain, at which time they may be quite conspicuous and may either be spotted with a headlamp or identified by the mating calls of the males, The latter are highly species-specific, and, in view of the relatively limited species inventory to be expected within the phosphate-mining areas of Florida, it is not a difficult task for the observer to learn all of the potential calls for the area. Cassette tapes of Florida species are available commercially and from the Florida Game & Fresh Water Fish Commission’s Wildlife Research Laboratory in Gainesville.

Both amphibians and many reptiles may also be found by a technique known as patch sampling. This requires a knowledge of the preferred terrestrial microhabitat of the species in question. Microhabitats may be augmented or established artificially, and allowed to mature in place to give the desired species time to colonize. Most commonly, such microhabitats take the form of large, flat objects such as heavy wooden boards, placed upon the surface of the ground in appropriate (at least partially shaded) situations. These provide retreats where humidity is high, temperature extremes somewhat moderated, and protection from predation is excellent. They may be visited regularly, picked up or turned over, and the amphibian and reptile specimens thus exposed inventoried.

It may be a long time before an herpetological inventory list for even a small area can be considered complete. But, once the more common or conspicuous species have been identified, and the area deemed appropriate for quantitative evaluation, it is appropriate to embark upon various techniques for population survey and estimation. This does not mean that qualitative techniques or development of faunal inventories end at that point. Rather, a phase is initiated during which both qualitative and quantitative approaches run concurrently. Indeed, rare or elusive species may not even be found until the last days of a quantitative survey (if at all).

QUANTITATIVE TECHNIQUES

i) Catch per unit effort.

The first step towards quantification of the survey/capture techniques outlined above is to introduce the element of time. Searches may continue by whatever means have been found to be productive, but can now be quantified in terms of catch (or observation) per hour of search time. This does not give a direct estimate of overall population size -- for elusive species, only a minimal percentage of individuals present may actually be located -- but it, theoretically, allows for comparisons between different sites, or between different times or successional stages (or seasons) of the same site.

Search-per-unit-effort techniques have many shortcomings. The element of chance -- whether a given individual will be spotted or not by a given observer -- may be so overwhelming as to negate quantitative findings unless conducted over an unrealistically long interval. Seasonal or weather factors may influence success in locating individuals to an extreme degree -- with amphibians, for example, literally none may be encountered during very cold or dry episodes, whereas hundreds may be seen after spring rains.

In addition, short-lived, R-selected species (species that produce large numbers of progeny with little or no parental investment) may show natural seasonal peaks and troughs in real abundance, as opposed to mere conspicuousness. For example, the number of individuals of a given frog species presumably reaches its seasonal minimum value just before breeding time (even though this may correspond to a time of elevated conspicuousness), while the population may include very large numbers of young frogs shortly after metamorphosis is complete in a year of favorable rainfall. To correct for this, it is important that the samples used for comparison should either be seasonally comparable or should consider adult individuals only.

Comparisons of abundance between species are particularly susceptible to error, in that different species may have behavioral patterns that make them unequally accessible to an observer even when they are present in an environment in comparable numbers. Frogs, for example, include species that are conspicuous and species that are highly cryptic; or species that have a loud call and species that have a very soft call.

ii) Mark-recapture.

Various modifications of the basic Lincoln Index technique are applicable to reptiles and amphibians. The procedure requires that a marking technique be identified that, if not truly permanent, be at least likely to leave detectable identification marks for the duration of the project. Traditionally, such techniques as shell notching in turtles, toe clipping in anurans and lizards, and ventral scale removal in snakes, have been used. Technological alternatives, including the use of subdermal or coelomic PIT tags, that respond with a unique numerical code when a detection instrument is placed against the marked organism are also invaluable, although not necessarily perfect.

The basic principle of the Lincoln Index technique states that, if the number of individuals that have been marked is known and, on a second sampling, the ratio between captured marked and unmarked individuals is also known, then the absolute population size may be estimated by multiplying the total number of marked individuals by the proportion of marked individuals in the overall population, as determined by the second sampling.

However, many circumstances may bias the results. These include: a) Post-marking trauma decreasing the survival of marked individuals. b) Natural mortality reducing the percentage of marked individuals between the initial and the subsequent sampling episodes. c) Imperfect mixing of marked and unmarked individuals, or differential "catchability" of individual organisms, so that there is a tendency for the same individuals to be captured repeatedly. d) Edge effects, or effects of outmigration, where the sampled population is not constrained within finite boundaries, and where marked animals may leave the study area, and unmarked ones move in.

iii) Drift fences.

Drift faces are utilized for those species, such as amphibians or aquatic turtles, where reproductive journeys to or from a body of water constrain at least the breeding females (sometimes both sexes) to move towards or away from wetland areas. By encircling a restricted wetland habitat with a closed fence, the organisms encountering the fence will tend to move laterally along the obstruction, until they encounter a pitfall trap. The fences can also be placed in linear fashion across parts of non-isolated wetland habitats. An aquatic equivalent of this technique is the deployment of a continuous curtain of seine net across a body of water, with a standard funnel-entrance turtle trap at each end.

Drift fences are usually made from continuous rather than open-web material. Strips of aluminum roof flashing have been used successfully, these being held in place with small posts, and with the lower edge extending into the substrate for a few centimeters.

These techniques have many merits, and have been utilized extensively for amphibians and reptiles, as well as for small mammals. Nonetheless, drift fence techniques also have shortcomings, including: a) checking of traps needs to be very frequent, to prevent predatory interactions between trapped organisms. Moreover, small mammals may drown in "wet" traps or those that have been exposed to rain, whereas amphibians may dehydrate in "dry" traps. b) Certain amphibians can cross drift fences (Dodd, 1991). For example, both juvenile and adult frogs can circumvent drift fences either by jumping over them or crawling up them Amphibians capable of burrowing, especially toads *(Bufo*, *Scaphiopus)* may dig under drift fences, especially in sandy or soft soil. Striped newts may use tunnels to go under fences under field conditions.

Data acquired in this manner (and assuming that the habitat meets the requirements of most wildlife) provide biogeographical information (what species are in what habitats), species richness (number of species), and frequency of occurrence (how often is the species recorded present).

Counts of animals involve more time and effort. For some species, such as a flock of birds on a pond, or number of singing males in the marsh, counts are easily made. For small mammals or herps hidden in the vegetation, considerable trapping efforts must be undertaken. But, if a goal is to determine the relative abundance of a species, or changes in abundance, then such counts are necessary.

DISCUSSION

For the most part, the constructed wetlands we inspected are relatively young and still in the process of development and succession, the pace and direction of which is dependent upon a reliable source ofwater--most often local rainfall either on-site or upstream In some cases, because of a lack of a reliable water source, or the possibility of episodes of consecutive rain-deficient years, or because neighboring land is yet to be mined, which may change hydrological patterns, or some other event that may interfere with water flows, we are unable to predict the long-term persistence of a constructed wetland system So long as an adequate supply of water is able to maintain wetland plant species and associated invertebrate fauna, a wildlife community will be present. Wildlife use of an area is greatly influenced by the productivity of the food base--the greater the habitat diversity and quantity of food, the greater the diversity and numbers of wildlife that will frequent the site. Vegetation structure--density, height, cover and nest/perch sites--and the variety of micro-habitat also play roles in determining the variety and numbers of wildlife species on a site.

When the long-term goal of a restored site is a forested wetland, then many years must pass before a final determination of persistence or “success” can be made. However, the successional trend toward this mature stage should be apparent within relatively few years of restoration.

When wetlands are constructed from barren mined lands many factors control the degree and speed of development or succession--hydrology (location, elevation, water sources, depths, flows), substrate (sand, clay, overburden, organic mucks), initial vegetation sources (seeds, cuttings, transplantings), distance from natural seed sources, etc. Likewise, the degree and speed of occupation of a constructed wetland by animal species--both invertebrates and vertebrates--is dependent upon a number of factors: vegetation and structure, food and cover, inoculation of life forms (plants and invertebrates in muck soils, for example), distance from a source, motility abilities, water depths and hydroperiods.

Wetlands associated with bodies of open water that include a littoral zone of submergents and emergents, hydrologic connection to a natural drainage system and a surrounding upland of fields or shrubs usually possess the greatest variety and numbers of wildlife. Lakes and ponds are a prerequisite for a large number of species--fish, many turtle species, alligator, grebes, cormorant, anhimga, pelicans, herons, storks, ibises, ducks, osprey, eagles, coots, moorhens, gulls and terns and their aquatic foods. The high production of plants, invertebrates, and fishes in these water bodies supports large numbers of individuals of these species, which in turn provide food for a suite of terrestrial and wetland predators, including bobcat, raccoon, otter, fox, coyote, various raptors, snakes, etc. King (1989) states "The siting of upland habitats adjacent to contrasting wetland habitats...provides valuable edge and ecotone communities.. known to enhance wildlife density and diversity. The upland forest edge provides cover, nesting, denning and roosting sites for much of the wildlife that forages in wetland and lake settings." Kale (1991) showed that almost half of the 160 species of birds recorded at six reclaimed and unreclaimed (spoil piles and pits) wetlands owned by IMC Fertilizer Company (now IMC/Agrico) were associated with the upland components of the sites. A buffer of vegetated upland habitat adjacent to constructed wetlands should be incorporated into the design and protection of wetland sites.

Many birds (pelicans, cormorants, ducks) require an extensive open water surface for feeding. If this is absent, these birds w-ill be absent, even though appropriate food species may be present. Other species, such as herons, rails, and some passerines, can also inhabit wetlands that lack bodies of open water. Some species of birds that may be common and abundant in herbaceous wetlands, are not wetland-dependent and commonly occur in upland habitats as well. For example, the Common Yellowthroat and Red-winged Blackbird are two species that are widespread in marshes, but also inhabit upland edge and old field habitats.

Marsh systems that do not include patches of open water contain fewer species and fewer individuals than do wetlands associated with water bodies. In some cases, it may not be practicable or feasible to include a pond or lake in a constructed wetland system but if wildlife considerations are an important goal then an effort should be made to include a body of water in the design.

Active clay settling ponds contain the highest diversity and densities of avian species in Florida (matched only by temporarily flooded muckland farms near Lakes Apopka and Okeechobee). They are many hundreds of acres in size and vary in water depth from several inches to several feet. Invertebrate and fish populations are high and many species of waterfowl and wading birds frequent them in high numbers. Ring et al. (1980) studied 12 clay settling ponds and recorded 19 species of herptiles, 8 species of mammals, and 99 species of birds inhabiting them During migration thousands of shorebirds stop to rest and feed in them Waterfowl (grebes, American White Pelican, Double-crested Cormorants, ducks, mergansers), and herons and egrets from the north and locally w-inter in these impoundments.

If an inactive settling pond is not dried out and reclaimed for other uses, it gradually consolidates and succeeds to a shrub/thicket stage and then to a forest. Unless some means can be found to perpetuate their continuation as an open body of water into the distant future, they will all disappear with the termination of phosphate mining when the ore bodies have been exhausted in the next 30-50 years. Edelson and Collopy (1990) have recommended reclaiming some clay settling ponds as both temporary and permanent wetlands for use by wildlife, especially colonial wading birds. The potential use of these impoundments for tertiary wastewater, energy plant cooling waters, or other potential uses that will allow concurrent and safe utilization by wildlife should be investigated.

Mature forested wetlands provide habitat for a different suite of birds from those found in herbaceous and open water wetlands. Mammalian predators occur in all three wetland types, but in lower numbers in the wetland forest. Water depths and hydroperiods play a large role in determining which species are present. Mature wetland forests are highly important habitats for seasonally appearing species, such as neotropical migratory birds during spring and fall migrations (flycatchers, thrushes, warblers, tanagers, grosbeaks, etc.), and for wintering birds from northern regions (kinglets, catbirds, vireos, warblers). Forested wetlands also provide important nesting habitat for forest and edge species, such as Northern Cardinal, Carolina Wren, Tufted Titmouse, Great Crested Flycatcher, Red-eyed Vireo, Northern Parula, and several species of woodpeckers. None of these widely distributed species are wetland dependent; their occurrence is a result of the presence of the tree canopy and shrub layer. But, indirectly, their presence is indicative of a healthy functioning forest ecosystem. Higher moisture and humidity in these wetland forests probably results in higher productivity of insects and other invertebrates.

Another characteristic of mature wetland forests is the number of dead trees or snags present, These are important feeding and nesting sites for woodpeckers, and those species of animals that utilize woodpecker holes for nesting and roosting. The “planting” of snags in a constructed forested wetland assists in the repopulation of the habitat and in the reseeding of tree and shrub species by fruit and seed-eating wildlife (Wolfe 1990, McClanahan and Wolfe 1991). In the early seral stages of forested wetlands (which comprised most of the forested wetland we examined) abundant stands of herbaceous vegetation are interspersed among the growing trees and a number of vertebrate taxa are associated with these stages: frogs, turtles, Rice Rats, Marsh Rabbits, White-eyed Vireos, Common Yellowthroats, Red-winged Blackbirds, and the predatory birds and mammals that feed on these.

Because large extensive wetlands appear to be more viable and persistent than small isolated wetlands, and because it may be less costly in the long run to create one large wetland rather than several smaller isolated wetlands, the tendency in reclamation is not to replace these smaller wetlands, but to “mitigate” for their loss by combining their acreages and constructing a larger wetland connected to a stream or lake system In nature isolated wetlands are unconnected to permanent bodies of waters and because they often dry-up completely they contain few, if any, predatory fish species. The absence of large predator populations enables amphibians to reproduce and complete their larval stages once water levels have been restored. Hence, the loss of these isolated wetlands can have a severe, adverse impact on populations of toads, frogs, and salamanders dependent upon them for reproduction.

It is incumbent upon reclamation planners to insure that the number and distribution of isolated wetlands on phosphate mined lands are not altered to the point of adversely impacting the amphibian populations of a basin or region.

The size of a wetland, its vegetative composition, and the requirements of an animal species determines whether a wetland can provide all or some of a species' requirements. Marple (1992) lists 26 site selection and site design features that can enhance wetland dependent wildlife diversity in constructed wetlands. Different features can be emphasized depending on whether the principal function of a wetland is to enhance breeding habitat, migration habitat, wintering habitat, or a combination of these. According to Marple (1992) "Principal factors that require consideration include size, cover, food, specialized habitat needs, and the geometric and seasonal qualities of cover and food requirements", and the most critical site selection and site design concept for this wetland function is the diversity of habitat conditions within the wetland as well as in the region. A variety ofhabitat conditions is critical in enhancing species diversity. Interspersion of vegetation and water and shoreline length correlate directly with bird species diversity, for example.

Because the planning and design of practically all of the constructed wetlands we observed were done at the company level, based on land ownership boundaries and future mining considerations, and not (in too many instances) from a regional watershed or basin perspective, some of these constructed wetlands may not become as successful or persistent as desired. Because it is difficult, if not impossible, for one mining company alone to plan and design systems that extend beyond its boundaries, it is vital for the industry and regulatory agencies to cooperate in the planning, design, and implementation of region-wide and basin-wide reclamation and wetland construction. The integrity of drainages, both preserved and reconstructed, their natural or rearranged watersheds designed to approach closely their natural regimes and configurations, and the proper location of preserved or constructed wetlands, along with intact dispersed uplands, all play a vital role in the continued well-being of wildlife and their habitat in the region. King (1989) urged reclamation planners and regulators to look at landscape patterns in both premining and post-reclamation settings and to base their actions on maintaining hydrological system integrity, including basin (or subbasin) drainage, headwaters, and stream segments. Erwin (1990b) has also emphasized the importance of a complete evaluation of proposed wetland construction/restoration from a watershed and regional perspective. Anyone concerned about the functioning and persistence of constructed wetlands into the distant future must consider this perspective.

Because forested wetlands are more productive of invertebrate fauna than are upland forests (which are primarily pine forests in central Florida), they provide important habitat for migratory birds, especially neotropical migrants en route to and from their wintering grounds in Central and South America. Thus, a habitat that may be relatively depauperate of avian fauna during the summer and winter months, becomes a vitally important way-station during spring and fall migration.

A number of old unreclaimed (but naturally revegetated) pit and spoil pile mines still exist in the phosphate mining area. These are now forested and have become rich in wildlife values, providing habitat for wetland and terrestrial species alike (Schnoes and Humphrey 1987). Saddlecreek Park, a Polk County park near Lakeland, mined in the 1940s and left as pits and spoil piles, has become a naturally reclaimed forested wetland and is one of the best-known stopovers for fall migrating birds in central Florida. The majority of the remaining old unreclaimed mines, especially those dating back to the 1930s through the 1960s, should be left unreclaimed because their wildlife value is now considerable, and would be set back rather than enhanced by retroactive reclamation.

Wetlands can be designed to provide habitat for a range of wildlife species. Their strategic location may be critical for the interchange of animals among watersheds and regions, and to provide breeding sites for upland terrestrial species (frogs, toads).

VERTEBRATE INDICATORS

Several species of wildlife whose lifestyles are associated with wetland habitats can be used as indicator species, i.e., their presence is indicative of a "suitable" wetland habitat, For example, the following bird species are found in emergent wetlands associated with patches of open water in central Florida:

Pied-billed Grebe, Double-crested Cormorant, Anhinga, Least Bittern, American Bittern, Great Blue Heron, Great Egret, Snowy Egret, Little Blue Heron, Tricolored Heron, Green Heron, White Ibis, Wood Stork, Blue-winged Teal, American Wigeon, Ring-necked Duck, Common Moorhen, American Coot, King Rail, Sora, Osprey, Belted Kingfisher, Marsh Wren, and Swamp Sparrow.

Among the mammals, the River Otter, Rice Rat, and Florida Water Rat are good indicator species for this type of wetland because they are relatively abundant and widely distributed. The Mink is also indicative of wetlands, although it is considerably less abundant than the latter three mammals and more difficult to detect. The Raccoon is an abundant mammal in wetlands, but is also widespread in upland habitats. In conjunction with the presence of the wetland-dependent species its presence is indicative of good habitat conditions.

Among the herpetofauna, the American Alligator, various species of turtles (including the Florida Softshell Turtle, Peninsular Cooter, and in north Florida, the Yellowbelly Turtle) and frogs (including the Southern Leopard Frog, Cricket Frog, and Chorus Frog) are good indicator species for wetlands with open bodies of water.

A number of the species listed above, (less the grebe, cormorant, anhinga, the ducks, coot, kingfisher, River Otter, and alligator), also inhabit herbaceous wetlands that are not associated with an open body of water, so they serve as good indicators of suitable habitat in herbaceous marshes and isolated wetlands.

Mature forested wetlands, i.e., closed canopy forest with periodically flooded substrate, host a suite of birds also present in upland forests, but not in herbaceous wetlands. For example, in central Florida several species of woodpeckers, Tufted Titmouse, Carolina Wren, Red-eyed Vireo, and Northern Parula breed in forest habitats, including forested wetlands. These species may also be present in developing forested wetlands as soon as trees reach heights approaching canopy state. During early "shrub" stages of development, when herbaceous marsh is interspersed with growing trees, both herbaceous and forested wetland birds may occur together. Several additional species commonly winter in forest/edge habitats in Florida: Yellow-bellied Sapsucker, Blue-gray Gnatcatcher, Ruby-crowned Ringlet, and Yellow-rumped Warbler.

Wildlife Communities in Natural Wetlands of the Region

Few studies of wildlife on natural wetlands in the phosphate mining region have been conducted. Layne et al (1977) compiled a list of species, including habitat types and relative abundances for each species known to occur in the seven county phosphate area of central Florida, but did not present any quantitative data on site-specific studies. Perrin et al. (1982) conducted extensive surveys of selected ciconiiform (herons, ibis) and gruiform (cranes, gallinules) birds within the Kissimmee River Basin immediately east of the phosphate mining region, and found greater numbers of species, density, and diversity of wading birds in the lake marshes of the survey area than in the river and C-38 canal system itself

Some of the constructed wetlands that we visited were close to “reference” wetlands. Presumably, if the constructed wetland at some point in time closely resembles the reference wetland a criteria of success would be demonstrated. For forested sites, Clewell and Lea (1990) “advise against the adoption of success criteria that require direct comparisons with one specific natural “reference” wetland...” and instead recommend “a comparison of species composition at a project site with its generalized forest ecosystem as it naturally occurs in that locality.“ Erwin (1990b) reinforces this view, believing that “the concept should be used only for evaluating the structural and functional attributes of a particular habitat or system”

SHOULD THE PRESENCE OF WILDLIFE BE A CRlTERION FOR “SUCCESS”?

The selection of vegetative and water quality criteria as indicators of success in wetland construction makes sense in that both of these criteria allow for straightforward monitoring, with easy replication of data and determination of trends in the parameters measured. Whether it be the mean diameter of young cypress trees or the amount of dissolved oxygen in the water, the data can be gathered in a finite and relatively brief span of time, and changes found in the parameters in question on a subsequent site visit are likely to be real.

On the other hand, the presence of wildlife on a site cannot be determined in a rigidly quantified and replicable way. Wildlife survives, in general, by being elusive. Amphibians have to protect themselves, not only from predation, but also from desiccating conditions, and may be difficult or impossible to find during a dry period even though they may still be present. Some reptiles, especially cooter turtles and alligators, may make themselves conspicuous by diurnal basking, but others, such as kinosternid turtles and most snakes, will be difficult to see and may easily be overlooked. Birds may visit a site in large numbers, seasonally or during migration, but at other times will be absent. Small mammals may have to be trapped in order to be seen and the larger mammals--Raccoon, Bear, Bobcat, Panther--may be detectable only by the presence of scat or spoor. Their use of wetland environments is for the most part not obligatory, and thus their occasional presence within the wetlands would not necessarily constitute an obvious criterion of “success.” On the other hand, the habitual presence on a given site of an aquatic mammal such as the River Otter may be taken as a valid criterion of wetland success.

Nevertheless, collectively, and despite the obvious shortcomings and difficulties, it is important to demonstrate whether or not a constructed wetland attracts or supports a significant fauna. Techniques are available for the quantitative sampling of small fauna, especially mammals and amphibians, by means of trapping or intensive collecting along limited transects or in very small areas. Birds and larger mammals will come and go, and their numbers will certainly fluctuate. But, for avifauna, as well as for amphibians, species diversity is as valid a criterion of success as is sheer numbers of individuals or absolute biomass, and we recommend that a biodiversity index for such fauna, couched essentially in terms of number of species, either consistently present or occasionally encountered, may be the best to use.

Demonstration of the ability of a species to colonize and survive within a given environment is at least as important as determining the carrying capacity or resident population size of such species. Moreover, since many wetland species may be able to survive in almost any wetland situation, the true criterion of success in the artificial replication of a natural wetland may be best expressed in terms of the ability not only of ubiquitous, but also of highly specialized species to live there. Thus, a biodiversity inventory will include both a "lowest common denominator" component of species with wide environmental tolerance, and a variable subset of more sensitive or specialized species that are only found in wetlands that best approach the condition of a mature, natural ecosystem

Such an index should not be applied uncritically. Not all local faunal or floral species will exist within a fully matured, undisturbed ecosystem Moreover, it is possible (but certainly not recommended!) to increase a species inventory by artificially manipulating the environment to promote invasion by weedy, opportunistic species (both native and exotic). So, a criterion of "desirability" of species, favoring those that are slow-maturing, specialized, easily destroyed or disturbed, and known characteristic components of the natural ecosystems upon which the constructed wetlands are modelled, would be appropriate. This is already the case in the Florida DEP criteria for vegetative species in constructed wetlands, and it would be appropriate for fauna1 criteria as well.

As wetlands mature, there is a tendency, in most cases, for open water areas to be reduced. As discussed above, the elimination of open water also eliminates habitat for a number of avian species whose presence is considered desirable. Alligators and the larger turtle species, especially the Florida Softshell and the Peninsular Cooter, are desirable residents of clay settling ponds on active phosphate mining sites, and the elimination of all such open water in the course of reclamation, favoring instead the development of forested or seasonal wetlands, should, we feel, not be accepted without question.

Biodiversity, and especially faunal diversity, may be maximized by the promotion of wetlands incorporating a mosaic of subsystems that will include marshes and seasonal wetlands, open permanent water, and islands elevated above inundation during times of high water. Such islands, although they may be very small, will generally be free of direct disturbance by both man and predatory mammals, and may constitute crucial nesting and roosting habitats for wading and other colonial birds, as well as basking and nesting sites for alligators and turtles.

Reintroduction of Fauna

Erwin (1990b) correctly states that "If the goals of [a] marsh creation project are met, namely satisfactory site location, an adequate hydroperiod, and a successful revegetation., introduction of desired fauna should not be necessary", except in some cases where the stocking of fish and herps may be desirable in isolated marsh systems. Birds, having the mobility of flight, have no difficulties in reaching suitable habitats. Large wide-ranging mammals also need little or no assistance to reach new habitats although their movements can benefit from the existence of habitat corridors and specially constructed underpasses on highways with high vehicle traffic. Where wetlands are connected by drainages and/or close proximity, amphibians and reptiles can also reach new suitable habitat, although the time scale may be longer. If there is a reason for speeding up the immigration of a particular species, or suite of species, especially in an constructed isolated wetland, then a trapping and relocation effort may be feasible.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Wildlife is a major component of every wetland system. As such, it should be a major concern in the construction of wetlands designed to replace natural wetlands destroyed during the mining of phosphate ore. Measurements of successful restoration of wetlands should include standards for wildlife replacement/restoration within a reasonable period of time consistent with the maturation of the vegetative components.

RECOMMENDATIONS

The cost of wildlife monitoring is high and to require mining companies to monitor for presence of wildlife would greatly add to reclamation costs. However, the Florida Institute of Phosphate Research, in cooperation with the phosphate mining industry, should support research directed towards the development of habitat design and performance standards that result in restoration of wildlife in constructed wetlands within a reasonable time period. Simple techniques for monitoring of selected groups of wildlife species near the end of a wetland construction project should be devised during the course of wetland development. An essential component of this research would be the simultaneous study of natural undisturbed wetland habitats in the region, for which there are currently few data.

MAJOR GAPS AND RESEARCH NEEDS

A major gap exists in our knowledge of the hinds of wildlife inhabiting (1) most of the constructed wetlands on phosphate mined lands, and (2) natural wetlands in the region. Adequate information is available in the case of birds and large mammals, but data on small mammals, reptiles, and amphibians are sparse.

Studies need to be conducted on several undisturbed natural wetlands--both herbaceous and forested, and on selected samples of each of the various types of constructed wetlands--herbaceous marsh with water bodies and those without, forested wetlands with streams and those without, and isolated wetlands, both natural and constructed.

SPECIES-SPECIFIC STUDIES

Although we inspected a wide diversity ofwetlands and open-water habitats in the course of our site visits, we found actual evidence of only a very limited variety of species of freshwater turtles. These were primarily the Peninsular Cooter *(Pseudemys Floridana peninsularis)* and the Florida softshell *(ApaZone ferox).* On the other hand, aquatic habitats of Central Florida would be expected to include many other species, including the Florida snapping turtle *(Chelydra serpentina osceola);* the Florida chicken turtle *(Deirochelys reticularia chrysea);* the three-striped mud turtle *(Kinosternon bauri);* the Florida mud turtle *(Kinosternon subrubrum steindachneri);* the common musk turtle *(Sternotherus odoratus);* the Florida red-bellied turtle *(Pseudemys nelsoni);* and possibly the southern musk turtle *(Sternotherus minor).* Freshwater turtles are in general durable and ecologically flexible species, with considerable tolerance to pollution or poor water quality, although their ability to reach and colonize newly-created isolated wetlands may be quite modest. The apparent absence of many expected species in created wetlands of the Bone Valley area is noteworthy.

We recommend that a study be initiated to document, in considerably more detail than has been possible to date, the species, distribution, and abundance of freshwater turtle species in both man-made and natural aquatic habitats in phosphate mining regions and in mineralized, unmined lands of the Bone Valley.

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APPENDIX 7-1.

VERTEBRATES RECORDED DURING SITE VISITS TO RECONSTRUCTED WETLANDS

1. Agrico Sites

Fort Green Morrow Swamp AG13 (Swamp West) FG-13 -- June 29, 1993
11 yrs old, 366 acres (150 ac forested)

Birds:

- Anhinga
- Great Egret
- Osprey
- Common Moorhen
- Yellow-billed Cuckoo
- Blue Jay
- Common Yellowthroat
- Rufous-sided Towhee
- Red-winged Blackbird
- Boat-tailed Grackle

Mammals:

- Bobcat

Herps:

- Alligator

Payne Creek AG1 Swamp East PC-SP-1 -- June 29, 1993
7 yrs old, 104 acres (102 forested)

Birds:

- Double-crested Cormorant
- Anhinga
- Great Egret
- Snowy Egret
- Tricolored Heron
- Green Heron
- White Ibis
- Osprey (+ nest)
- Red-shouldered Hawk
- Common Moorhen
- Common Nighthawk
- Mourning Dove
- Great Crested Flycatcher
- Purple Martin
- Fish Crow
- Carolina Wren
- White-eyed Vireo
- Common Yellowthroat
- Red-winged Blackbird
- Boat-tailed Grackle

Mammal:

- Feral Pig

Payne Creek AG3 FG-84(5) - June 29, 1993
6 yrs old, 22 ac (20 ac forested, 2 ac herbaceous)

Birds:

- Double-crested Cormorant
- Common Moorhen

- Great Blue Heron
- Turkey Vulture
- Osprey
- Northern Bobwhite
- White-eyed Vireo
- Common Yellowthroat
- Red-winged Blackbird

Payne Creek AG4 FG-93(1) -- June 29, 1993
8 yrs old, 8.4 ac forested

Birds:
- White-eyed Vireo
- Red-winged Blackbird

Herps:
- Cricket Frog

AG5 FG84(1) -- June 29, 1993
5 yrs old, 2.3 ac herbaceous marsh

Birds:
- Black Vulture
- Common Moorhen
- Great Crested Flycatcher
- White-eyed Vireo
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee
- Red-winged Blackbird
- Eastern Meadowlark

Hardy Lakes AG7 AGR-FG-PC-1 -- June 29, 1993
2 yrs old, 102 ac forested, 256 open water

Birds:
- Double-crested Cormorant
- Anhinga
- Great Egret
- Wood Stork
- Turkey Vulture
- Red-shouldered Hawk
- Northern Bobwhite
- Common Moorhen
- Blue Jay
- Carolina Wren
- Northern Parula
- Red-winged Blackbird
- Boat-tailed Grackle
- Common Grackle

Mammals:
- Cotton Rat
- Nine-banded Armadillo

Herps:
- So. Leopard Frog
- Black Racer

Clay Settling Areas AG11 FG-SP-8

Birds:

- Northern Flicker
- Northern Mockingbird
- Common Yellowthroat
- Rufous-sided Towhee
- Red-winged Blackbird

Reptiles:

- Diamondback Rattlesnake

AG12 FG-SP-9 -- 12 yrs old

Birds:

- Cattle Egret
- Common Moorhen
- Northern Flicker
- Northern Mockingbird
- Common Yellowthroat
- Rufous-sided Towhee
- Red-winged Blackbird
- Common Grackle

Herps:

- Peninsular Cooter

Big Marsh AG13 FG-GSB-3 Phase 1 -- June 30, 1993
184 ac marsh, 45 forest

Birds:

- Great Egret
- Snowy Egret
- Cattle Egret
- White Ibis
- Mottled Duck
- Common Moorhen
- Killdeer
- Black-necked Stilt
- Mourning Dove
- Red-winged Blackbird
- Boat-tailed Grackle

Trio Marshes AG14 FG-84 (6) (7) -- June 30, 1993
1 yr old, 110 ac marsh Middle Marsh

Birds:

- Common Moorhen
- Killdeer
- Black-necked Stilt
- Red-winged Blackbird

Mammals:

- Eastern Cottontail
- Coyote (+den with pups)

East Marsh

Birds:

- Least Bittern
- Great Blue Heron
- Great Egret
- Tricolored Heron
- Glossy Ibis
- Common Moorhen
- Black-necked Stilt
- Boat-tailed Grackle

Mammals:

- Raccoon
- White-tailed Deer
- Nine-banded Armadillo

Ag East AG17 PCPC2 -- June 30, 1993

Birds:

- Anhinga
- Least Bittern
- Snowy Egret
- Little Blue Heron
- White Ibis
- Glossy Ibis
- Wood Stork
- Killdeer
- Black-necked Stilt
- Eastern Meadowlark

Herps:

- Black Racer
- Softshell Turtle

Ag East-East AG26 P.C-SP-14 -- July 1, 1993

Birds:

- Double-crested Cormorant
- Great Egret
- Glossy Ibis
- Black-necked Stilt
- Least Tern

Preservation Drain AG15 Sec. 18 & 19 (The Creek) -- July 1, 1993
1.4 ac forest

Birds:

- Green Heron
- Osprey
- Blue Jay
- Carolina Wren

Barred Owl
Red-bellied Woodpecker
Northern Parula

Section 29 (Fort Green) AG19 -- June 30, 1993

Birds:

Anhinga
Great Blue Heron
Great Egret
Common Moorhen
Northern Mockingbird
Red-winged Blackbird
Eastern Meadowlark
Boat-tailed Grackle

Preservation Area-Cypress Head FGPC-2 -- July 1, 1993

Birds:

Downy Woodpecker
Great Crested Flycatcher
Tufted Titmouse
Carolina Wren
White-eyed Vireo
Northern Parula
Northern Cardinal
Red-winged Blackbird
Common Grackle

Herps:

Squirrel Tree Frog

AG22 FG-HC-1 -- July 1, 1993
2.5 acres

Birds:

Little Blue Heron
Glossy Ibis
Northern Bobwhite
Rufous-sided Towhee
Red-winged Blackbird

2. Cargill

Hookers Prairie Mine, Phase 1 (CARS) HP5-1 -- January 19, 1993
4 yrs old, 78 ac herbaceous, 61 forest, 7 ac open water

Birds:

Osprey
Red- shouldered Hawk
Red-tailed Hawk
Ring-billed Gull
Belted Kingfisher
Tree Swallow
Yellow-rumped Warbler
Boat-tailed Grackle

Hookers Prairie, Phase 2A (CAR6) HP5-2A -- January 19, 1994
4 yrs old, 103 ac herbaceous, 17 ac forest, 3 ac open water

Birds:

- Double-crested Cormorant
- Great Blue Heron
- Great Egret
- Wood Stork
- Red-tailed Hawk
- Common Snipe
- Common Yellowthroat
- Swamp Sparrow
- Boat-tailed Grackle

Hookers Prairie, Phase 2B (CAR7) HP5-2B -- January 19, 1994
4 yrs old, 140 ac herbaceous, 35 ac forest, 14 ac open water

Birds:

- Osprey
- Turkey Vulture
- Sora
- Killdeer

Hookers Prairie, Phase 4 (CAR9) HP3-4 and Phase 5 (CAR10) HP3-5
4 yrs old, 95 ac herbaceous, 38 forest

Birds:

- American White Pelican
- Double-crested Cormorant
- Great Blue Heron(+nests)
- White Ibis
- Glossy Ibis
- Wood Stork
- Mottled Duck
- Blue-winged Teal
- Turkey Vulture
- Northern Harrier
- Red-shouldered Hawk
- Red-tailed Hawk
- King Rail
- Common Moorhen
- Killdeer
- Greater Yellowlegs
- Lesser Yellowlegs
- Least Sandpiper
- Royal Tern
- Forster's Tern
- Tree Swallow
- Fish Crow
- Boat-tailed Grackle
- American Goldfinch

Unreclaimed Mine, Phase 7 (CAR11) HP3-7 -- January 20, 1994
80 yrs old, 209 ac

Birds:

- Turkey Vulture
- Tree Swallow
- White-eyed Vireo
- Yellow-rumped Warbler

Carolina Wren
Ruby-crowned Kinglet
Blue-gray Gnatcatcher
Gray Catbird
Northern Cardinal
Swamp Sparrow
Red-winged Blackbird
American Goldfinch

Mammals:

Nine-banded Armadillo
Bobcat

Fort Meade (CAR13) FMWC1 -- January 20, 1994
5 yrs old, 8.6 ac herbaceous, 13 ac open water

<u>Parcel A</u>

Birds:

Great Blue Heron
Great Egret
Tricolored Heron
Turkey Vulture
Ring-billed Gull
Forster's Tern
Carolina Wren
Marsh Wren
Common Yellowthroat
Red-winged Blackbird

Mammals:

River Otter

<u>Parcel B</u>

Birds:

Pied-billed Grebe
Double-crested Cormorant
Ring-necked Duck
Turkey Vulture
Osprey
Red-tailed Hawk
Common Moorhen
American Coot
Ring-billed Gull
Palm Warbler
Common Yellowthroat
Swamp sparrow
Red-winged Blackbird

Mammals:

Marsh Rabbit
Raccoon

Herps:

Peninsular Cooter

Fort Meade, mixed wetlands, lake (CAR15) FMPR1 -- January 20, 1994
4 yrs old, 22 ac herbaceous,9 ac forest, 66 ac open water

Birds:

American White Pelican-375
Double-crested cormorant-50
Anhinga-6
Great Blue Heron- 1
Great Egret-5
Tricolored Heron-3
Wood Stork-25
Turkey Vulture- 10
Sharp-shinned Hawk- 1
Red-shouldered Hawk- 1
Common Moorhen- 10
Killdeer-2
Ring-billed Gull-35
Forster's Tern- 10
Northern Flicker- 1
Pileated Woodpecker- 1
Tree Swallow-75
Blue Jay-5
Carolina Wren-2
White-eyed Vireo-1
Palm Warbler-2
Red-winged Blackbird-75
Boat-tailed Grackle-10
Common Grackle-30

Fort Meade, mixed wetlands, lakes (CAR16) FMPR2 -- January 20, 1994
6 yrs old, 28 ac herbaceous, 38 ac forest. 41 ac open water

Birds:

Double-crested Cormorants-20
Anhinga-6
Great Blue Heron-2
Great Egret-55
White Ibis- 10
Glossy Ibis-6
Wood Stork-6
Ring-necked Duck- 100
Canvasback-2
Common Moorhen-20
American Coot-40
Ring-billed Gull-5
Forster's Tern-2
Tree Swallow- 150
Carolina Wren- 1
Ruby-crowned Ringlet- 1
Blue-gray Gnatcatcher- 1
Yellow-rumped Warbler-30
Palm Warbler- 18
Common Yellowthroat-3
Red-winged Blackbird-20

Fort Meade (CAR18) FMSP11 -- January 20, 1994
9 yrs old, 3 ac herbaceous, 5 ac forest, 13 ac open water

Birds:

Blue-winged Teal-20
Canvasback-2
Ring-necked Duck- 10
Common Moorhen-20
Blue Jay-2
American Robin- 1
Yellow-rumped Warbler-6
Common Yellowthroat-2

American Coot-50

Bryant's Branch (CAR19) FMSP12 -- January 20, 1994
8 yrs old-8 ac herbaceous, 4 yrs old-29 ac forest and 5600 ft of stream.

Birds:

Turkey Vulture-20
Bald Eagle- 1
Northern Harrier- 1
American Kestrel- 1
Ring-billed Gull-20
Caspian Tern-2
Palm Warbler- 1
Red-winged Blackbird-20
Boat-tailed Grackle

Reptile:

Gopher Tortoise

Ft. Meade, Sec. 32 (CAR20) FMLP1 -- January 20, 1994
< l yr old, 5 ac herbaceous, 43 ac forest, 18 open water

Birds:

Downy Woodpecker-l
Eastern Phoebe-1
Yellow-rumped Warbler-5
Palm Warbler-20
Savannah Sparrow- 10

Ft. Meade, mixed, lake with wetland fringe (CARR22) FMLP4
3 yrs old, 38 ac herbaceous, 118 ac lake

Birds:

American White Pelican-2
Hooded Merganser-3 5
Greater Yellowlegs- 1
Laughing Gull-25
Ring-billed Gull-60
Forster's Tern-60
Tree Swallow- 100
Palm Warbler-4
Common Yellowthroat-2
Red-winged Blackbird-55

Mammals:

Marsh Rabbit
Coyote
Feral Pig
Nine-banded Armadillo
Rice Rat
River Otter

Mark Brown's Wetland (CAR26) FMSP06
10 yrs old, 9 ac forest, 1.2 open water

Birds:

Little Blue Heron- 1
Turkey Vulture- 1
Osprey-2
Pileated Woodpecker-l
Carolina Wren- 1
Gray Catbird- 1
Yellow-rumped Warbler-8
Palm Warbler- 1
Common Yellowthroat-2
Northern Cardinal- 1

Mammal:

Marsh Rabbit

3. CF Industries

Hickey Branch (CF5) R7
8 yrs old, 2.1 ac herbaceous; 6 yrs old, 13.1 ac forest

Birds:

Great Egret
Green Heron
Common Moorhen
Red-winged Blackbird

Hickey Branch (CF6) R9
7 yrs old, 4.1 ac herbaceous, 16.5 forest

Birds:

Red-bellied Woodpecker

Hickey Branch (CF7) R1O
4 yrs old, 25 ac herbaceous, 29 ac forest, 9.8 open water

Birds:

King Rail
Red-winged Blackbird
Boat-tailed Grackle

Mammals:

Raccoon
Nine-banded Armadillo

Clay Settling Area (CF1) SP1

Birds:
- Common Moorhen
- Carolina Wren
- Common Grackle

Mammals:
- Bobcat

Reptiles:
- Watersnake *(Nerodia sp.)*

Clay Settling Area (CF1) SP1-West

Birds:
- Common Moorhen
- Barn Owl
- Red-winged Blackbird

Mammals:
- Nine-banded Armadillo

Clay Settling Area (CF?) SP-5

Birds:
- Double-crested Cormorant
- Anhinga
- Great Blue Heron
- Black-necked Stilt
- Snowy Egret
- Little Blue Heron
- White Ibis
- Osprey
- Red-winged Blackbird
- Greater Yellowlegs
- Western Sandpiper
- Stilt Sandpiper
- Dowitcher sp.
- Great Egret
- Eastern Meadowlark

Reptiles:
- American Alligator

4. IMC Mines

Lonesome Mine, Cemetery Branch (IMC1) -- February 8, 1994
5 yrs old, 0.86ac

Birds:
- Anhinga- 1
- Turkey Vulture-3
- Black Vulture- 1
- White-eyed Vireo- 1
- Palm Warbler- 1
- Northern Cardinal- 1

Downy Woodpecker- 1
Eastern Meadowlark- 1

Mammals:
Feral Pig
Nine-banded Armadillo

Dogleg Branch (IMC7) -- February 8, 1994
5.71 ac preserved, 19.75 ac forest

Birds:
Turkey Vulture- 10
Black Vulture- 1
Bald Eagle- 1
Red-tailed Hawk- 1
Killdeer- 10
Lesser Yellowlegs- 1
Least Sandpiper-30
Common Snipe-20
Palm Warbler- 1

Mammals:
White-tailed Deer
Raccoon

Lizard Branch (IMC2) -- February 8, 1994
11 yrs old, 5.2 ac forest

Birds:
Common Moorhen- 1
Northern Flicker- 1
Yellow-rumped Warbler-20
Palm Warbler- 1

Mammals:
Feral Pig
Bobcat

McMullen Branch, Dragline crossing (lMC3) - February 8, 1994
9 yrs old, 1.51 ac forest

Mammals:
Nine-banded Armadillo
Bobcat

Jamerson Jr. (lMC4) -- February 8, 1994
1 yr old, 3.2 ac forest

Birds:
Red-shouldered Hawk- 1
Yellow-rumped Warbler- 1

Tree Swallow- 150

Palm Warbler- 1

Mammals:

Nine-banded Armadillo

Raccoon

Reptiles:

Peninsular Cooter

Hall Branch (IMC5) - February 8, 1994
9 yrs old, 2.25 ac herbaceous, 1.55 ac forest

Birds:

White-eyed Vireo

Yellow-rumped Warbler

Rufous-sided Towhee

Red-winged Blackbird

Miles Grove, Parts A and B (IMC6) -- February 8, 1994
2 yrs old, 12 ac herbaceous, 30 ac forest, 22 ac open water

Part A

Birds:

Doublecrested Cormorant- 13

Great Egret-2

Snowy Egret- 10

Blue-winged Teal-6

Yellowlegs sp- 1

Tree Swallow- 15 0

Loggerhead Shrike-1

Palm Warbler- 1

Savannah Sparrow- 1

Eastern Meadowlark- 1

Boat-tailed Grackle-30

Mammals

Nine-banded Armadillo

Bobcat

Part B

Birds:

Pied-billed Grebe- 1

Double-crested Cormorant-36

Great Blue Heron- 5

Great Egret-2

Tricolored Heron-2

Green Heron- 1

Black-crowned Night-Heron- 1

Hooded Merganser-20

Killdeer-5

Common Snipe- 1

Tree Swallow- 100

Savannah Sparrow-3

Red-winged Blackbird-50

Boat-tailed Grackle-20

Haynsworth Mines, East Lake Branch (IMC8) -- February 8, 1994
1 yr old, 26 ac herbaceous, 178 ac forest

Birds:

Double-crested Cormorant-5
Anhinga- 1
Great Blue Heron- 1
Ring-necked Duck- 113
Common Moorhen-6

Tadpole-Haynesworth Extension (IMC9) -- February 8, 1994
2 yrs old, 5.8 ac herbaceous, 3,9 ac forest

Birds:

Palm Warbler
Red-winged Blackbird

Mammals:

Nine-banded Armadillo

East of Old Fort Green Road (IMC10) - February 8, 1994
1 yr old, 26 ac forest, 15 ac open water

Birds:

American White Pelican- 150
Snowy Egret- 10
White Ibis-2
Glossy Ibis-2
Mottled Duck-2
Blue-winged Teal-50
Ring-necked Duck-25
Hooded Merganser-20
Osprey- 1
Common Moorhen- 1
American Coot- l
Lesser Yellowlegs- 1
Laughing Gull-2
Northern Mockingbird- 1

North of County Road 630 (lMC11) -- February 8, 1994
1 yr old, 15 ac herbaceous around old pit lakes

Birds:

American Bittern- 1
Great Blue Heron- 1
Blue-winged Teal-2
Common Moorhen- 1
Common Yellowthroat- 1

South of County Road 630 (IMC12) -- February 8, 1994
2 yrs old, 65 ac herbaceous, 10 ac forest, 57 ac open water

Birds:

- Pied-billed Grebe- 1
- Double-crested Cormorant- 1
- Anhinga-2
- Little Blue Heron- 1
- Duck spp-3
- Hooded Merganser-2
- Common Moorhen-6

West of State Road 37 (IMCl3) -- February 8, 1994
2 yrs old, 10 ac forest

Birds:

- Pied-billed Grebe- 1
- Double-crested Cormorant-50
- Snowy Egret- 1
- Ring-necked Duck-50
- Hooded Merganser-50
- Osprey (on nest)- 1
- Ring-billed Gull-8
- Northern Mockingbird- 1
- Loggerhead Shrike- 1
- Palm Warbler- 1
- Savannah Sparrow- 1
- Boat-tailed Grackle- 1

Four Corners Mine, FCO Sec 15 (IMC14) -- February 8, 1994
4 yrs old, 1.5 ac herbaceous, 1.5 ac forest

Birds:

- Common Snipe
- Palm Warbler
- Common Yellowthroat
- Swamp Sparrow

Mammals:

- Nine-banded Armadillo

Reptiles:

- Florida Mud Turtle

Four Corners Mine, FCO Sec 1 (lMC15) -- February 9, 1994
1 yr old, 40 ac herbaceous, 20 ac forest

Birds:

- Great Egret-2
- Northern Harrier- 1
- Northern Flicker- 1
- American Crow-2
- Blue Jay-2
- Carolina Wren- 1
- Sedge Wren- 1
- Loggerhead Shrike- 1
- Common Yellowthroat- 1
- Northern Cardinal- 1
- Swamp Sparrow- 1
- Red-winged Blackbird-5

Mammals:

- Feral Pig
- Nine-banded Armadillo

Horse Creek (IMC16) -- February 9, 1994
9 yrs old, 49 ac herbaceous

Birds:

- Mourning Dove-2
- Downy Woodpecker- 1
- House Wren- 1
- Northern Mockingbird-1
- Yellow-rumped Warbler-5
- Common Yellowthroat- 1
- Northern Cardinal- 1
- Rufous-sided Towhee-1
- Savannah Sparrow- 1

North Hookers Prairie Sec 12 (Hal Scott Wetlands) (lMC27)
4 yrs old, 82 ac herbaceous, 64 ac forest, 101 ac open water

Birds:

- American White Pelican-15
- Double-crested Cormorant-75
- Great Blue Heron-5
- Great Egret-10
- Green Heron- 1
- White Ibis-20
- Glossy Ibis- 10
- Wood Stork-2
- Mottled Duck-5
- Ring-necked Duck-800+
- King Rail- 10
- Sora- 1
- Common Moorhen-20
- American Coot-20
- Lesser Yellowlegs-3
- Common Snipe-1
- Laughing Gull-1
- Caspian Tern-2
- Belted Kingfisher- 1
- Tree Swallow-250
- Blue Jay-1
- Fish Crow-2
- Loggerhead Shrike-2
- White-eyed Vireo- 1
- Common Yellowthroat- 1
- Savannah Sparrow-5
- Red-winged Blackbird-40
- Eastern Meadowlark- 1
- Boat-tailed Grackle-50

Mammals:

- River Otter

Hookers Prairie, Section 7/12 (lMC28) -- February 9, 1994
4 yrs old, 65 ac herbaceous, 50 ac forest, 1800 ft reclaimed stream

Birds:

- Double-crested Cormorant- 1
- Song Sparrow- 1

Anhinga- 1
Cattle Egret-2
Red-winged Blackbird-5

Mammals:
Marsh Rabbit
Raccoon

Reptiles:
Peninsular Cooter

South Pebbledale, Sec. 6 .(lMC29) -- February 9, 1994
1 yr old, 7.5 ac herbaceous, 7.5 ac forest

Birds:
Blue-winged Teal-50+
Northern Shoveler-4
Osprey- 1
Northern Harrier- 1
Common Moorhen-25
American Coot-50+
Tree Swallow-20
Palm Warbler-2
Savannah Sparrow- 10

Mammals:
Bobcat

Phosphoria, Sec 6 (lMC47) (IMC-NP-HP(2) -- February 9, 1994
6 yrs old, 14.7 ac herbaceous, 13.3 ac forest (to be rebuilt)

Birds:
American White Pelican- 150
Double-crested Cormorant-150
White Ibis- 10
Wood Stork-6
Ring-necked Duck-6
Osprey (+nest)
Common Moorhen- 5
American Coot- 100+
Eastern Phoebe- 1
Palm Warbler- 1
Red-winged Blackbird-75
Boat-tailed Grackle-20

East Farmland-Cateye (IMC31) -- February 9, 1994
7 yr old, 2 ac herbaceous, 2 ac forest, 10 ac open water

Birds:
Anhinga
Great Egret
Loggerhead Shrike
Blue-gray Gnatcatcher

Mammals:
Marsh Rabbit
Nine-banded Armadillo
Bobcat

Reptiles:
Peninsular Cooter

N-2 Area (IMC32) -- February 9, 1994
<l yr old, 5 ac herbaceous, 3 ac forested

Birds:

- Pied-billed Grebe-2
- American White Pelican-20
- Double-crested Cormorant-30
- Anhinga-5
- Great Blue Heron-5
- Great Egret- 10
- Snowy Egret-30
- Black-crowned Night-Heron-2
- Wood Stork-2
- Bald Eagle- 1
- Common Moorhen-20
- American Coot-30
- Ring-billed Gull-5
- Mourning Dove- 1
- Palm Warbler-10
- Common Yellowthroat-2
- Northern Cardinal- 1
- Savannah Sparrow-6
- Red-winged Blackbird-20
- Boat-tailed Grackle- 10

Sweetwater Branch (lMC33) -- February 9, 1994
9 yrs old, 20 ac herbaceous, 13 forest, 29 open water

Birds:

- Double-crested Cormorant-10
- Little Blue Heron- 1
- Northern Harrier- 1
- Cooper’s Hawk- 1
- Belted Kingfisher
- Eastern Phoebe- 1
- Yellow-rumped Warbler-1
- Common Yellowthroat- 1
- Red-winged Blackbird-5

Land and Lakes (Self reclaimed area) (IMC34) February 9, 1994
(We visited only a small part of this large acreage)

Birds:

- Double-crested Cormorant
- Great Blue Heron
- Tricolored Heron
- Cooper’s Hawk
- Belted Kingfisher
- Carolina Wren

South Tiger Bay (IMC35) -- February 9, 1994
10 yrs old, 51 ac herbaceous, 95 ac forest, 174 open water

Birds:

- Double-crested Cormorant
- Great Blue Heron
- Glossy Ibis
- Blue-winged Teal
- Common Moorhen
- Greater Yellowlegs
- Laughing Gull
- Sandwich Tern
- Tree Swallow
- Yellow-rumped Warbler
- Common Yellowthroat

Old Clay Settling Area H-9 (IMC36) -- February 9, 1994
>25 yrs old, 23 ac forest

Birds:

- Osprey
- Blue Jay
- American Robin
- White-eyed Vireo
- Yellow-rumped Warbler
- Palm Warbler
- Northern Cardinal

Mammals:

- Marsh Rabbit
- Feral Pig

North of Parcel B (lMC37a) -- February 10, 1994
3 yrs old, 10 ac herbaceous, 20 ac forest, 17 ac open water

Birds:

- Anhinga
- Common Moorhen
- Blue-gray Gnatcatcher
- White-eyed Vireo
- Common Yellowthroat
- Northern Cardinal
- Red-winged Blackbird
- American Goldfinch

Reptiles:

- Peninsular Cooter(8)

Still North of Parcel B (IMC37b) -- February 10, 1994

Birds:

- Red-shouldered Hawk
- Carolina Wren
- White-eyed Vireo
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee
- Red-winged Blackbird

Parcel B (IMC38a) -- February 10, 1994
16 yrs old, 20 acres forest

Birds:

- Mourning Dove
- Tufted Titmouse
- Blue Jay
- Carolina Wren

Mammals:

- Feral Hog
- Nine-banded Armadillo
- Marsh Rabbit

Southwest Corner of Parcel B (IMC38b) -- February 10, 1994

Birds:

- Great Blue Heron
- Glossy Ibis
- Blue-winged Teal
- Northern Shoveler
- American Wigeon
- Osprey (on nest)
- Common Moorhen
- Eastern Phoebe
- American Robin
- White-eyed Vireo
- Yellow-rumped Warbler
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee
- Red-winged Blackbird

Southwest of CS 8 Floodplain (IMC46) -- February 10, 1994
3 yrs old, 3 ac herbaceous, 2 ac forest, 3ac open water

Birds:

- Turkey Vulture
- Osprey
- Carolina Wren
- Blue-gray Gnatcatcher
- American Robin
- Loggerhead Shrike
- White-eyed Vireo
- Common Yellowthroat
- Northern Cardinal

Mammals:

- Bobcat

West of CS-11 Floodplain (IMC 40) IMC-CS-82(l) -- February 10, 1994
6 yrs old, 34 ac herbaceous, 38 ac forest, 25 ac open water

Birds:

- Anhinga
- Glossy Ibis
- Sandbhill Crane
- Common Moorhen
- Palm Warbler
- Common Yellowthroat
- Red-winged Blackbird

Mammals:

- Cotton Rat
- Marsh Rabbit

West of CS11 Floodplain (IMC41) IMC-CS-SP1 -- February 10, 1994
7 yrs old, 8 ac herbaceous, 8 ac forest, 6 ac open water

Birds:

Common Moorhen
White-eyed Vireo
Yellow-rumped Warbler
Palm Warbler
Red-winged Blackbird
Boat-tailed Crackle

Reptiles:

Peninsular Cooter

West End of South End of CS11 (IMC#?) -- February 10, 1994

Birds:

Wood Stork
Turkey Vulture
Red-shouldered Hawk
Blue-gray Gnatcatcher
Gray Catbird
White-eyed Vireo
Yellow-rumped Warbler
Common Yellowthroat

Mammals:

Coyote

Kingsford Mines, Bird Branch (lMC24) -- February 10, 1994
8 yrs old, 3.7 ac forest

Birds:

Eastern Phoebe
House Wren
Common Yellowthroat
Northern Cardinal
Rufous-sided Towhee
Red-winged Blackbird

Unit H (lMC21) -- February 10, 1994
5 yrs old, 41 ac herbaceous; 34 ac forest

Birds:

Double-crested Cormorant
Blue-winged Teal
Common Yellowthroat
Savannah Sparrow
Red-winged Blackbird
Boat-tailed Crackle

South Mizzell Creek MC(3) (IMC20) -- February 10, 1994
7 yrs old, 4 ac herbaceous; 4 yrs old, 7 ac forest, 2 ac open water

Birds:

Common Moorhen
Palm Warbler
Yellow-rumped Warbler

West of K-6 (lMC19) -- February 10,1994
10 yrs old, 9 ac herbaceous, 23 ac forest, 6 ac open water

Birds:

Black-crowned Night-Heron
Carolina Wren
Yellow-rumped Warbler
Red-winged Blackbird

Mammals:

Nine-banded Armadillo

Reptiles:

Gopher Tortoise

PCPC-2 Phase 2 (Newly mucked site AG17) -- February 10,1994

Birds:

Little Blue Heron
Killdeer
Lesser Yellowlegs
Semipalmated Sandpiper-10
Western Sandpiper-60
Least Sandpiper-50
Stilt Sandpiper-65
Short-billed Dowitcher- 14
Common Snipe
Red-winged Blackbird

5. Mobil Mining & Minerals Company

Beulah Creek N85(1) (MO1) -- October 11, 1993
<1 yr old, 12 ac forest

Birds:

Northern Mockingbird
Indigo Bunting

Mammals:

Nine-banded Armadillo

Reptiles:

Black Racer

George Allen Creek NSP(6) (MO2) -- October 11, 1993
9 yrs old, 3 ac forest, 1 ac herbaceous, 2 ac open water

Birds:

- House Wren
- Blue-gray Gnatcatcher
- Gray Catbird
- Common Yellowthroat
- Boat-tailed Grackle

Mammals:

- Nine-banded Armadillo

Reptiles:

- Florida Redbellied Turtle

Guy Branch NSP(1) (MO3) -- October 11, 1993
9 yrs old, 10 ac forest

Birds:

- Blue-gray Gnatcatcher
- Northern Mockingbird
- Black-and-white Warbler
- Ovenbird
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee
- Red-winged Blackbird

Bird Branch N82(1) (MO4) -- October 11, 1993
8 yrs old, 23 ac herbaceous, 50 ac forest,
5280 ft reclaimed stream

Birds:

- Red-shouldered Hawk
- Blue Jay
- House Wren
- Marsh Wren

Consent Order #7984 (MO5)94 -- October 11, 1993
0.5 yrs old, 2.5 ac forest

Birds:

- Great Egret-2
- Cattle Egret-60
- Glossy Ibis-30
- Mottled Duck-75
- Blue-winged Teal-68
- Red-shouldered Hawk- 1
- Greater Yellowlegs-
- Blue-gray Gnatcatcher- 1
- Boat-tailed Grackle- 15

Upfront Mitigation Area (MO6) -- October 10, 1993
2 yrs old, 1.6 ac forest

Birds:

- Blue Jay
- Blue-gray Gnatcatcher

Tufted Titmouse
Carolina Wren
White-eyed Vireo

McCullough Creek FMSP8 (MO9) -- October 11, 1993
7yrs old, 2 ac herbaceous; 9 yrs old, 21 ac forest,
2600 ft. reclaimed stream

Birds:

Double-crested Cormorant
White Ibis
Osprey
Blue Jay
Carolina Wren
House Wren
Ruby-crowned Ringlet
Gray Catbird
White-eyed Vireo
Palm Warbler
Mourning Warbler
Common Yellowthroat
Northern Cardinal
Rufous-sided Towhee
Red-winged Blackbird
Boat-tailed Grackle

FM1 Clay Settling Area (FM-09) (MO12) -- October 12, 1993
1 yr old, forested wetland

Birds:

Wood Stork
Northern Harrier
Northern Bobwhite
Common Ground-Dove
House Wren
Blue-gray Gnatcatcher
Gray Catbird
Loggerhead Shrike
Palm Warbler
Common Yellowthroat

Mammal:

Marsh Rabbit

Sink Branch (MO14) -- October 12, 1993
13 yrs old, 1 ac forest, l000ft reclaimed stream

Birds:

Blue Jay
Tufted Titmouse
Carolina Wren

Naturally Reclaimed Site (mined in 1940s) (MO13) -- October 12, 1993

Birds:

Red-bellied Woodpecker
Downy Woodpecker
Ruby-crowned Ringlet
Blue-gray Gnatcatcher

- Eastern Phoebe
- Blue Jay
- Tufted Titmouse
- Carolina Wren
- White-eyed Vireo
- Northern Parula
- American Redstart

Land and Lakes FM-6 (MO10) -- October 12, 1993
3 yrs old, 34 ac forest, 101 ac open water

Birds:

- Double-crested Cormorant
- Anhinga
- Great Blue Heron
- Great Egret
- Little Blue Heron
- Tricolored Heron
- Blue-winged Teal
- Turkey Vulture
- Killdeer
- Greater Yellowlegs
- Ring-billed Gull
- Forster's Tern
- Red-winged Blackbird
- Boat-tailed Grackle

Mammals:

- Bobcat

Reptiles:

- American Alligator

Gooch Creek FM87(4) (MO11) -- October 12, 1993
1 yr old, 25 ac forest, and a reclaimed stream

Birds:

- Red-tailed Hawk
- Eastern Phoebe
- Blue Jay
- Gray Catbird
- Palm Warbler
- Common Yellowthroat
- Indigo Bunting
- Red-winged Blackbird

Amphibian:

- Leopard Frog

Candy's Marsh FM83(3) (MO17) -- October 12, 1993
5 yrs old, 7 ac herbaceous, 12 ac forest

Birds:

- Pied-billed Grebe
- Anhinga
- Snowy Egret
- Little Blue Heron-80
- White Ibis
- Common Moorhen
- Greater Yellowlegs
- Common Snipe
- Red-winged Blackbird
- Boat-tailed Grackle(nest building)

Upper Rocky Branch FM87(1) (MO18) -- October 12, 1993
2 yrs old, 18 ac forest

Mammals:
- Raccoon
- River Otter
- White-tailed Deer

Rocky Branch Reference Wetland (undisturbed segment downstream)

Birds:
- Blue Jay
- Black-and-white Warbler
- Common Yellowthroat

Amphibian:
- River Frog

Lower Myers Branch FM 22A (MO19) -- October 12, 1993
9 yrs old, 19 ac forest

Birds:
- House Wren
- Common Yellowthroat
- Rufous-sided Towhee
- Red-winged Blackbird
- Common Grackle

Lake Branch Tributary AMX-BF-82(1B) (MO30) -- October 13, 1993
7 yrs old, 6 ac forest

Birds:
- Killdeer
- Red-bellied Woodpecker
- Carolina Wren
- House Wren
- Blue-gray Gnatcatcher
- Northern Mockingbird
- White-eyed Vireo
- Palm Warbler
- Common Yellowthroat
- Red-winged Blackbird

Mammals:
- White-tailed Deer
- Raccoon

BF1 AMX-BF1 (MO31) -- October 13, 1993
12 yrs old, 31 ac forest

Birds:
- Barn Owl
- Barred Owl
- Gray Catbird
- White-eyed Vireo

Blue Jay
Carolina Wren
House Wren

Common Yellowthroat
Rufous-sided Towhee
Red-winged Blackbird

Mammals:
Nine-banded Armadillo

BF-5 AMX-BF5 (MO34) -- October 13, 1993
12 yrs old, 21 ac forest

Birds:
Blue Jay
Fish Crow
House Wren
White-eyed Vireo

Common Yellowthroat
Rufous-sided Towhee
Red-winged Blackbird

Mammals:
White-tailed Deer
Nine-banded Armadillo

Reptiles:
Gopher Tortoise

BF-SP9 AMX-BFSP(9)-1 (MO36) -- October 13, 1993
7 yrs old, 80 ac herbaceous

Birds:
Great Egret
Northern Harrier
Red-shouldered Hawk

Mourning Dove
Common Yellowthroat
Red-winged Blackbird

Mammals:
Nine-banded Armadillo
Raccoon

Herps:
Peninsular Cooter
River Frog

6. Occidental Chemical Corporation

SRSP(1)A (OX1) -- September 8, 1993
2 yrs old, 138 ac forest

Birds:
Carolina Wren
Northern Mockingbird

Mammals:
Marsh Rabbit
White-tailed Deer

McCallum Bay Natural Area (OX2) -- September 8, 1993
unmined, forested

Birds:
- Carolina Wren
- White-eyed Vireo

McCallum Bay SR-82(3)A (OC3) -- September 8, 1993
3 yrs old, 167 ac forest

Mammals:
- Bobcat
- Cotton Rat

SA-10, Impoundment 10 (OX17) -- September 8, 1993
188 ac clay settling area

Birds:
- Great Blue Heron-3
- Great Egret-2
- Blue-winged Teal-150
- Barn Swallow-25

Mammals:
- Marsh Rabbitt

Reptiles:
- Mud Turtle(Sp. unk.)
- Brown Water Snake

SRSP(4) (OX5) -- September 8, 1993
7 yrs old, 15 ac herbaceous, 85 ac forest

Birds:

Forest site:
- Carolina Wren
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee
- Red-winged Blackbird

Marsh site:
- White Ibis
- Mottled Duck
- Spotted Sandpiper
- Common Yellowthroat
- Northern Cardinal
- Rufous-sided Towhee

Land & Lakes SR-8 (OX6) -- September 8, 1993
11 yrs old, 52 ac forest, 131 ac open water

Birds:
- Northern Waterthrush-3
- Common Yellowthroat-2
- Northern Cardinal-2

Cabbage Head SR-8715 (OX7) -- September 9, 1993
2 yrs old, 213 ac forest

Birds:
- Anhinga
- Great Blue Heron
- Great Egret
- Red-winged Blackbird- 150
- Boat-tailed Grackle-75

Nearby wooded site:
- Pileated Woodpecker
- Acadian Flycatcher
- Carolina Wren
- Northern Parula
- Pine Warbler
- Northern Cardinal

West of **Cabbage Head SR-8816 (OX8) -- September 9, 1993**
1 yr old, 95 ac forest, 50 ac open water

Birds:
- Pied-billed Grebe
- Double-crested Cormorant
- Canada Goose-50+
- Mottled Duck
- Northern Harrier
- American Crow

Mammals:
- White-tailed Deer
- Marsh Rabbit
- Bobcat
- Coyote
- Raccoon

Green Area SR93(2) and 86(2) (OX9) -- September 9, 1993
6 yrs old. 248 ac forest, 39 ac open water

Birds:
- Great Egret
- Common Moorhen
- Northern Bobwhite
- American Crow

Muck Area:
- Double-crested Cormorant
- White Ibis

Anhinga
Great Blue Heron
Great Egret
Snowy Egret
Little Blue Heron
Black-crowned Night-Heron
Wood Stork
King Rail
Common Moorhen
Red-winged Blackbird
Boat-tailed Grackle

Reptiles:

Pig Frog
Mud Turtle

Rosebud Branch SC85(5) (OC13) -- September 9, 1993
1 yr old, 88 ac forest

Birds:

Snowy Egret- 100+
Killdeer
Red-winged Blackbird- 100
Boat-tailed Grackle

Mammals:

Raccoon
Bobcat

Reptiles:

Florida Softshell Turtle

DNR Program, Swift Creek, SC85(2) (OX14) -- September 9, 1993
4 yrs old, 45 ac forest

Birds:

Great Egret
Red-bellied Woodpecker
White-eyed Vireo
Common Yellowthroat
Northern Cardinal (+ fledgling)

Lake & Marsh Site (Lang Lake) (OX-15) -- September 9, 1993

Birds:

Pied-billed Grebe
Double-crested Cormorant
Anhinga
Great Blue Heron
Great Egret
Snowy Egret
Green Heron
Common Moorhen
American Coot
Mourning Dove
Blue Jay

SR 82(2) (OX10) -- September 9, 1993
4 yrs old, 22 ac forest, 37 ac open water

Birds:

Great Egret-75
White Ibis
Wood Stork
Red-winged Blackbird

Herps:

Cricket Frog

Roaring Creek Reconstructed Channel (OC11) -- September 9, 1993

Birds:

Carolina Wren
White-eyed Vireo

Mammals:

Raccoon
Beaver

7. U.S. AgriChemicals Corp.

SP(2A) Dike between SP6A & 2A (USAC1)
<1 yr old, 78 ac herbaceous, 4 ac forest, 15 ac open water

Birds:

American White Pelican-50
Double-crested Cormorant-500
Anhinga-50
Great Blue Heron-3
Snowy Egret- 1
Little Blue Heron-2
Tricolored Heron-2
Black-crowned Night-Heron- I
Wood Stork- 12
Mottled Duck-20
Blue-winged Teal-150
Northern Shoveler-2
American Wigeon- 12
Canvasback- 1
Ring-necked Duck- 1000
Osprey- 1
Northern Harrier- 1
Red-tailed Hawk-2
Common Moorhen-50
American Coot-5000
common Snipe-2
Forster's Tern-75
Eastern Phoebe- 1
Tree Swallow-300
Blue-gray Gnatcatcher-2
Marsh Wren- 1
Gray Catbird- 1
White-eyed Vireo-4
Palm Warbler-20
Common Yellowthroat-2
Northern Cardinal-4
Rufous-sided Towhee-2
Savannah Sparrow-2
Swamp Sparrow-6
Red-winged Blackbird-50
Eastern Meadowlark-2

Mammals:

- Marsh Rabbit
- Bobcat
- Raccoon

SP(5A) (USAC2)

<1 yr

Birds:

- Great Egret- 1
- Glossy Ibis- 10
- Blue-winged Teal- 10
- Northern Shoveler-4
- Ring-necked Duck-50
- Turkey Vulture- 1
- Sora- 1
- Common Moorhen-50
- Greater Yellowlegs- 1
- Lesser Yellowlegs- 1
- Eastern Phoebe- 1
- Tree Swallow- 100
- Marsh Wren- 1
- Palm Warbler-12
- Common Yellowthroat-2
- Savannah Sparrow- 10
- Red-winged Blackbird-60
- Boat-tailed Grackle-100

SPP-4 (USAC3)

<1 yr old,

Birds:

- Turkey Vulture
- Forster's Tern
- Yellow-rumped Warbler
- Palm Warbler
- Red-winged Blackbird
- Boat-tailed Grackle

Mammals:

- Raccoon

84(1A) (USAC4)

1 yr old, 16 ac forest, 33 ac open water

Birds:

- Pied-billed Grebe- 1
- Double-crested Cormorant- 1
- Anhinga- 1
- Great Blue Heron-3
- Great Egret- 1
- Snowy Egret- 1
- Little Blue Heron- 1
- Green Heron- 1
- Hooded Merganser-2
- Forster's Tern-6
- Belted Kingfisher-2
- Eastern Phoebe- 1
- Carolina Wren- 1
- House Wren- 1
- Marsh Wren-2
- Loggerhead Shrike- 1
- Yellow-rumped Warbler-3
- Palm Warbler- 5

Turkey Vulture- 10
Black Vulture- 10
Osprey-4
Red-tailed Hawk- 1
Common Moorhen-6
Common Yellowthroat-5
Swamp Sparrow-2
Red-winged Blackbird-20
Boat-tailed Grackle-12

Mammals:

Raccoon

85-2B, 86-4B (USAC7,8)
6yrs-1 ac forest; 5 yrs-1 ac herbaceous, 1 ac forest

Birds:

Pied-billed Grebe-1
Double-crested Cormorant- 10
Anhinga-3
Snowy Egret-2
Ring-necked Duck-9
Osprey-2
Common Moorhen-10
American Coot- 10
Lesser Yellowlegs-6
Barn Owl
Eastern Phoebe- 1
Tree Swallow- 100
House Wren- 1
Blue-gray Gnatcatcher-2
White-eyed Vireo- 1
Palm Warbler- 10

Reptile:

Carolina Anole

Sec. 32 (Old mined lands)
30 yrs old

Birds:

Double-crested Cormorant-2
Anhinga- 1
Black-crowned Night-Heron-5
Turkey Vulture- 1
Carolina Wren- 1
Common Yellowthroat-2
Northern Cardinal-2

SECTION 8 - ECOSYSTEM & LANDSCAPE ORGANIZATION

By
Mark T. Brown, Principal Investigator

With
John Craig, Ted Weber, Tina Bower, Matt Shaps, Gina Tillis, and Tonya Howington

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 8 - ECOSYSTEM & LANDSCAPE ORGANIZATION

EXECUTIVE SUMMARY

STATEMENT OF THE PROBLEM

Wetlands reclamation on phosphate-mined lands needs to develop a lasting and functional assemblage of wetland flora and fauna, as well as an ecological community that is integrated into its landscape setting. This setting determines functionality and, ultimately, how successful reclamation from an inter-community perspective will be. The intra-community perspective seeks to evaluate how the created wetland relates to surrounding areas and how it affects and is affected by these areas.

In this section overall project goals were three-fold:

1. To integrate the component parts of the research effort (soils, hydrology, vegetation, wildlife, etc) into an overview describing processes and interactions that result in emergent ecosystem properties;
2. To evaluate large scale exterior influences (i.e. landscape position) on ecosystem succession, processes, and persistence; and.
3. To develop a GIS data base of wetland reclamation sites that includes land cover, topography, and quantitative data on vegetation, soils and hydrology.

To accomplish these goals the research was organized into two parts: Systems Ecology and Landscape Ecology.

SYSTEMS ECOLOGY

Plan of Study - A computer model was developed to simulate vegetative competition and succession in central Florida wetlands. For given initial conditions, the model simulates the change of floral composition over time, and the biomass and diversity of the final tree, shrub, and herbaceous communities. It helps to predict trends and test theories of long-term consequences of various natural and human-managed revegetation patterns.

CONCLUSIONS: SYSTEMS ECOLOGY

The model of wetland ecosystem succession was simulated to test several questions regarding reclamation.

- What are the effects of planting seedlings on long-term organization of reclaimed, forested wetlands?

- What are the effects of hydroperiod on long-term organization?

- Do shrub and herbaceous species out-compete trees and "hold" forested wetlands in lower successional stages?

To answer these questions, the model was simulated first, for conditions that might be found on a cleared wetland site where seed inputs are readily available. Secondly, the model was simulated using conditions found on phosphate-mined lands and using initial conditions characteristic of wetland reclamation.

The simulation results generated the following conclusions:

- There is a significant effect of hydroperiod control on seed germination and thus on long-term diversity of wetland ecosystems.

- The lack of signifcant negative response of forested wetlands to early domination by nuisance species makes their long-term control in forested wetlands questionable.

- There is a need for the introduction of shrub and herbaceous species which may require more micro-topographic relief in created wetlands.

RECOMMENDATIONS: SYSTEMS ECOLOGY

With the above conclusions in mind we recommend the following:

- The control of nuisance species in the early years of establishment of forested wetland communities, and the removal of canopies of shrub species (primarily willow) may not be necessary since simulation results suggest that tree species compete well and soon overtop these early colonizers.

- Simulation results confirm the need for more "micro-topographic relief" in created forested wetlands. The smooth topography that is characteristic of most created wetlands favors lower diversity of tree, shrub and herbaceous species in the mature communities.

- Simulation results suggest that there is a strong need for the introduction of shrub and herbaceous species within created forested wetlands, although the lack of micro-topographic relief and high light levels in the early years make their survival problematic. Introduction of these species during a later phase of succession might be warranted.

LANDSCAPE ECOLOGY

Plan of Study - The primary objectives of this study were two fold: 1) to develop a GIS data base for wetlands reclamation projects, and 2) to investigate and describe the general characteristics of wetland reclamation sites, and analyze their landscape "fitness" at a landscape scale as opposed to success at the scale of individual ecosystem components such as floral composition. Evaluation of landscape fit is a relatively new and as yet, evolving area of inquiry. While the evaluation of community structure is relatively straightforward using such techniques as indices of community organization and persistence, evaluation of wetland success at a landscape scale is not so common. Indices of landscape organization are not well defined nor is the theoretical basis for appropriate organization well developed.

In this evaluation we have selected three measures of landscape scale fitness. These measures are based on our review of the literature, and previous studies of the organization of Florida landscapes.

They are:

1. "Ecological connectedness" of the sites, determined by observing the percentage of the site's perimeter that is adjacent to preexisting natural communities,

2. "Hydrologic connectedness", which indicates whether a site has a surface water connection to natural drainageways or communities,

3. An evaluation of the relationship of the vegetation communities within sites as well as to those of the surrounding area and landscape position, termed "community fitness."

CONCLUSIONS: LANDSCAPE ECOLOGY

Findings regarding the success of wetland reclamation at the landscape scale are based on incomplete data sets, lack of comparability of data from one company to the next, and a general lack of data. As a result, our conclusions are based on trends that have been extracted from a GIS data base constructed as part of this project. The data base suffers from incompleteness and lack of consistency.

Conclusions are organized by three main landscape scale subject areas: (1) Ecological Connectedness, (2) Hydrological Connectedness, and (3) Community Fitness.

Ecological Connectedness

- About 50% of surveyed wetland reclamation projects are connected directly to natural forested lands, but an average of only about 16% the perimeter of these sites abuts the natural area. Thus the connection is often weak between existing forests and individual wetlands on a site.

- Forty-eight percent of projects are connected to relatively mature reclaimed lands. The average length of border that is shared between wetland reclamation projects and adjoining reclaimed areas is about 46% of the sites perimeter. The majority of reclamation sites that share borders with other reclamation sites are not ecologically connected, or integrated.

- Twenty-four percent of wetland reclamation projects are integrated into a regional habitat system by having forested connections to core habitat reserves. Since the reclaimed landscape is often a patchwork of reclamation projects in various stages of design, implementation, and successional regrowth, it continues to be a real challenge to link reclamation projects and their natural ecological communities together in a cohesive regional habitat network.

Hvdrological Connectedness

- About 50% of wetland reclamation projects are within 1st order (smallest) drainage basins, yet most 1st order basins have direct hydrologic connections to the regional drainage network. The fact that they are connected may result in serious long-term hydrological problems associated with the maintenance of sufficient storage, groundwater recharge, and maintenance of stream base flow during the dry season.

- About 16% of reclamation projects are constructed in second order drainage basins (second smallest), and 10% are constructed in third order basins. About 23% are constructed with no apparent hydrologic connection. Of those wetland reclamation projects in 2nd and 3rd order basins about equal percentages are hydrologically directly connected to the drainage network and hydrologically isolated.

- About 43% of all wetlands reclamation projects are in the upper 1/3 of drainage basins (roughly equivalent to the headwaters of the drainage basin), while about 40% are within the middle 1/3, and 17% are within the lower 1/3. Thus about 20% of all wetlands reclamation projects (50% of the 43% of projects that are hydrologically isolated) depend on rainfall and groundwater levels for maintenance of hydrology, with little or no surface water inputs.

Communitv Fitness

- The most common land cover type in wetlands reclamation projects is agriculture (primarily pastureland). Between 25 and 35% of the land area of reclamation projects is devoted to agriculture, and agriculture has the highest number of polygons on reclamation projects. While agriculture can be a compatible land cover with wetlands, often management practices and animal foraging can be detrimental to wetland habitat.

- Landscape heterogeneity (the number of polygons, and number of unique polygons) of wetlands reclamation projects is relatively low, when compared to the native Florida landscape.

- Average upland/wetland ratios for wetland reclamation projects appears to be somewhat lower than those found for native Florida landscapes, especially in the larger reclamation projects (this in essence means a larger percentage of the Landscape is covered by wetlands). When lakes are included as a wetland type, the percent of reclamation projects that is “wet” (both wetlands and lakes) is even higher, between 30% and 50%. This may translate into wetlands and lakes that are more dominated by rainfall events and less driven by groundwater inflows. Under these conditions, hydroperiods may be shorter, with more frequent cycles of inundation and drying, thus making creation of wetland ecosystems that require long sustained hydroperiods difficult to establish and maintain. Succession to dryer types of wetlands (shrub, and tree dominated) may result if sufficient seed sources are available.

- Low Upland/wetland ratios combined with the relatively small amount of uplands that are planted in forests (on average about 20%) translates into lowered overall carrying capacity for fauna1 species that require a mix of upland and wetland habitats for life support functions. While it is true that larger wetland areas can mean larger populations of wetland dependent species, many species require good quality upland forests for portions of their life cycles, or portions of their life support functions.

- Lake boarders, on the average are planted with herbaceous wetlands far more frequently than any other cover type (about 40% of all created lakes are dominated by herbaceous wetland margins). This is probably a good juxtaposition of land cover types. However, often these wetland lake margins are planted as thin bands around the edges, lowering their habitat value because of high edge to interior ratios.

Overall, our analysis has found:

- there is little standardization in the way site plans are produced, annotated, and documented, making comparisons between projects difficult and the job of organizing coherent landscapes a hit and miss proposition;

- there appears to be no larger scale (beyond the scale of the individual reclamation project) organizational principles driving the reclamation of phosphate mined lands,

- wetland reclamation projects are constructed close to existing native forested communities about 1/3 of the time, but ecological connectedness is often not maximized because of the minimal area of planted upland forests;

- upland forested corridors connecting individual created wetlands on reclamation sites were found on 89% of the reclamation sites;

- hydrology of constructed wetlands may be problematic, while many constructed wetlands are hydrologically connected, upland/wetland ratios suggest that hydroperiods may be shorter in duration but more frequent than those characteristic of native Florida landscapes;

- patch sizes of constructed wetlands and upland forests may be too small for larger animals and minimum viable populations.

RECOMMENDATIONS: LANDSCAPE ECOLOGY

With these conclusions in mind we recommend the following:

- Standardize submittal requirements for reclamation plans that would include standardized format for plans and topography maps, site plans that show off-site ecosystems and drainage patterns, planting lists giving species and planting densities for each community type, cross-sections of site topography showing predicted ground and surface water elevations and indicating zones of each community type

- Make reclamation planning units dependent on fauna1 habitat requirements, hydrologic basins, logical landscape scale habitat units, etc, instead of on mining units.

- Increase the required area of upland forested communities so that constructed wetlands can achieve better off-site ecological connectedness.

- To increase the likelihood of achieving appropriate wetland hydrology, reclaim on a drainage basin basis beginning with headwaters areas and proceeding down slope to the basin's mouth.

- Develop region wide reclamation schemes that maximize opportunities for creating an integrated approach to habitat restoration similar to that proposed by King and Cates (1994).

In all, it will be important to establish new criteria, but rather than making the reclamation process harder by adding more restrictions, explore ways that better reclamation can be achieved through cooperation and incentives rather than through stricter controls.

SECTION 8 - ECOSYSTEM & LANDSCAPE ORGANIZATION

INTRODUCTION

Wetlands reclamation is not only a question of developing a lasting and functional assembledge of wetland flora and fauna, but an ecological community that is integrated into a larger context, sometimes referred to as a landscape setting. The landscape setting of a created wetland community determines functionality, not from both an inter-community perspective and an intra-community one. The inter-community perspective looks to evaluate how the parts (i.e., vegetation, fauna, hydrology, soils, and interior processes like nutrient cycling, productivity, and development of food chains) interact and develop to provide the “required” functions that distinguish a successful wetland from an unsuccessful one. The intra-community perspective is concerned with how the wetland community "fits" within the landscape, ecologically and hydrologically. It seeks to evaluate how the created wetland relates to surrounding areas...how it affects and is affected by these areas.

In this section overall project goals were three-fold:

1. To integrate the component parts of the research effort (soils, hydrology, vegetation, wildlife, etc) into an overview describing processes and interactions that result in emergent ecosystem properties;
2. To evaluate large scale exterior influences (i.e., landscape position) on ecosystem succession, processes, and persistence; and.
3. Develop a GIS data base of wetland reclamation sites that included land cover, topography, and quantitative data on vegetation, soils and hydrology.

To accomplish these goals the research was organized into two parts: Systems Ecology and Landscape Ecology. In Part I: Systems Ecology, inter-community structure and processes were overviewed. In Part II: Landscape Ecology, a GIS data base was generated and evaluated seeking answers to the question ofwetlands success at the landscape scale.

OVERVIEW OF ECOSYSTEM AND LANDSCAPE ORGANIZATION

SYSTEMS ECOLOGY

This section addresses the organizational structure of wetland ecosystems and expected changes of biomass, diversity, productivity, and cycling of materials and energy over time with emphasis on forested wetland restoration in central Florida. Natural reclamation of gaps is compared to human-directed reclamation. Key questions are the persistence of ecological systems, and the effects of undesired exotic and “weedy” species.

Reclamation of phosphate-mined wetlands involves the creation of ecosystems having an array of components organized into functional wholes and having predictable structural organization and successional trajectories. One indicator of successful reclamation is the ecosystem's floral composition. The plant community both reflects and contributes to the other ecosystem elements, like hydrology, soil composition, and fauna; while the interaction of the various components of the newly created wetland ecosystem generates changes in nutrient cycling, productivity, and hydrodynamics, as well as faunal species composition. Understanding how the parts interact and change with successional stages may make prediction of long-term success possible.

SYSTEMS DIAGRAM OF A WETLANDS ECOSYSTEM

Figure 8-1 is a systems diagram of a generalized wetland ecosystem showing main compartments of vegetation, soils, and fauna, and the flows of energy and materials between them The diagram includes all vegetation components and thus can serve to summarize interactions in forested wetlands as well as herbaceous wetlands. In herbaceous wetlands, the canopy vegetation would, obviously, be absent.

The main driving energies are sunlight, wind (carrying CO2 and water vapor), rain (carrying nutrients), runoff from uplands (carrying nutrients, sediments, organic matter and toxins), seeds, and the migration of animals. Inputs of outside energies in the form of drainage can increase water outflows carrying nutrients, sediments, organic matter and toxins. An economic use of harvested wood is shown.

Vegetation compartments compete for sunlight, with each higher compartment intercepting light from the one's below. Seeds and organic matter add to the storage of litter and peat on the wetland-soil interface. Decomposition recycles nutrients for uptake by plants as well as releasing some nutrients to the water column. The fauna1 food chain begins with plant matter consumed by insects and, to a lesser degree, fish. The higher animals include herpeto-fauna, birds and mammals.

REVIEW OF THE LITERATURE

Theories of Succession -Succession is defined as the orderly process by which community structure changes through time as one suite of species is replaced with succeeding suites of species. Succession begins with a pioneer community, and ends with a climax community determined by external physical forces such as climate, hydrology, and soil type. In classical theories of succession, pioneer communities are opportunistic r-strategists: fast-growing, short-lived, and highly fecund, but without elaborate structure for storage or defense. They are adapted to take over bare or disturbed sites rapidly, but not for sustained competition with K-strategists. The latter, which will invade from surrounding undisturbed areas, will form the climax community (Colinvaux, 1986).

Another theory of succession is a three-strategy model. Ruderals, like r-strategists, are plants adapted to colonize bare or disturbed areas, but not for competition. They devote most of their resources to fecundity and dispersal. Ruderals are displaced by competitors, which, like K-

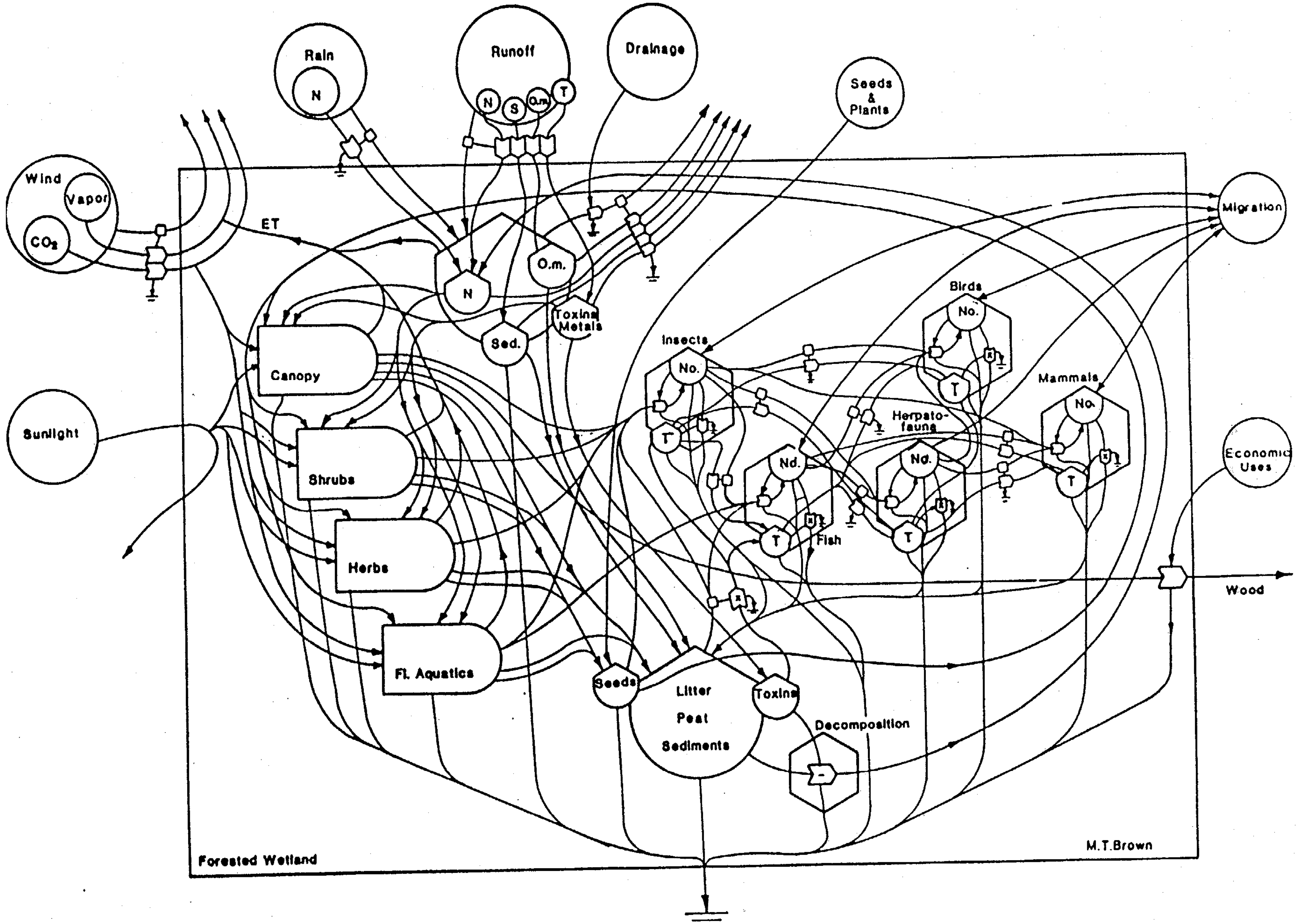


Figure 8-1. Systems diagram of wetland ecological system showing main compartments of vegetation, soils, and fauna, and the flows of energy and materials between them.

strategists, are adapted for low disturbance and low stress. They devote most of their resources to competition, and form dense equilibrium populations. Stress tolerators are plants adapted for low disturbance with high stress. They divide their resources between stress resistance and competition, and displace competitors at the climax (Colinvaux, 1986).

Sprugel (1985) listed four stages in post-disturbance succession in North American forests. The first stage is stand reinitiation. Herbs and shrubs typically dominate the site for 1-10 years, slowly displaced by tree or shrub seedlings. Second is the stem exclusion stage. Woody species monopolize limiting resources (light, water, and/or nutrients) and prevent further invasion by seedlings. Herbs and grasses are scarce, so total diversity is low. Third is the understory reinitiation stage. An understory of shade-tolerant herbs and sometimes shade-tolerant woody seedlings develops. Fourth is an old-growth stage. Without disturbance, first-generation trees senesce and die, and are replaced by other species.

Biomass usually follows a sigmoid curve in the above successional sequence. It accumulates slowly at first, then more rapidly after woody species predominate, then slows as stand biomass approaches a maximum during the understory reinitiation stage (Sprugel, 1985).

Succession can be autogenic, allogenic, or a combination of the two. Autogenic succession is directed by the community: the biota alters the physical habitat by soil building, nutrient collecting, etc., and this promotes succeeding suites of species. Allogenic succession is driven by forces outside the ecosystem: species composition shifts in response to habitat changes like changing hydrology, climate, etc. (Colinvaux, 1986).

Succession is often arrested by disturbances like fires or heavy grazing. If these disturbances are frequent, a subclimax community persists that is different from the climax that would develop in their absence (Colinvaux, 1986; Pickett and White, 1985). For example, periodic fires maintain pine flatwoods in Florida, preventing invasion by hardwoods. Without introduction of tree and herbaceous species during reclamation, most phosphate mined lands would remain in stages of arrested succession because of a lack of seed sources.

E. P. Odum (1969) summarized characteristics of pioneer and climax communities, in essence suggesting that succession leads to higher diversity, slower turnover times, internal nutrient cycling, and higher productivity, among others. H. T. Odum (1983) defines succession as “the self-organizational process by which ecosystems develop structure and processes from available energies.” Changes in structure allow the system to capture more energy. Each stage (or sere) in succession develops storages of structure that are available as energy and material resources for following stages. Succession is often part of a pulse in an oscillating system; retrogression or local-scale catastrophes comprise the rest (H. T. Odum, 1983).

H. A. Gleason proposed an individualistic approach to succession. Successional change was defined as “any change in the relative abundance of species in the plant cover of an area or in its floristic composition with time.” Bather than directed succession to a climax, changes in the local environment, biological interactions, and invasions from surrounding areas caused a continuous change in vegetative composition (van der Valk, 1981).

A. G. van der Valk (1981) created a qualitative model of succession in freshwater wetlands based on Gleason's individualistic approach to vegetative dynamics. Succession is based on the lifespan (annual, perennial, or vegetative propagating), propagule longevity (long-lived seed bank or dispersal dependent), and propagule establishment requirements (presence or absence of standing water, shade tolerant or intolerant) of individual species. Different combinations produce 12 life history types. Depending on whether the wetland area is drawn down or flooded, species of a given life history type are present in a persistent seed bank, mature adults, or locally extinct (van der Valk, 1981). The model does not include biotic alteration of the environment or interaction between floral species, fauna, or microbes.

Monk (1965) proposed an ordered succession from wetland to upland community types in north-central Florida landscapes with suggestions that drainage and fire were key elements in either allowing communities to proceed to terrestrial communities (increased drainage and absence of fire) or remain as wetland assembledges (in the absence of increased drainage and or fire). Brown (1989) suggested a modified dynamic model based on the variability of flood and drought and occurrence of fire that maintains wetlands and reverses successional trajectories during alternating flood and drought cycles.

Theories of Diversity - In the classical view, diversity is proportional to the stability of the environment. The fewer the large energy pulses, the more stable the environment, and the greater the diversity. Connell and Orias (1964) linked diversity to stability such that more stable environment meant less energy required for maintenance, and more energy for production of larger populations, or greater genetic diversity. Stress from larger scales (e.g. humans, hurricanes) decreases diversity, often at a greater rate than decreasing biomass, by eliminating sensitive species.

Connell and Orias included feedbacks from diversity. In early stages of speciation, greater diversity increased the cycling of nutrients, releasing more energy for production, which in turn further increased diversity. Further, greater diversity increased community stability and damped climactic fluctuations, which also released more energy for production and increased diversity. In later stages of evolution, species overspecialized and decreased in population, decreasing community stability (Odum, 1983).

Colinvaux (1986) asserted that the feedback from diversity to stability "has now been shown to be untrue". However, species would not diversify if there was no benefit. Odum models diversity as "a state variable developed as a second priority after production, consumption, and recycle are developed." It increases autocatalytically with biomass, but a quadratic maintenance drain (the organizational energy required increases as the square of the number of species) produces logistic growth. Diversity feeds back to capture additional energy to increase populations and further increase diversity, until limited by the organizational energy drain and by the energy sources

(Odum, 1983).

Seemingly contrary to the classical view, high productivity (e.g., from high nutrient loads) can allow high densities of selected species (often r-strategists), and decrease diversity. Conversely, environmental stress, as long as it does not favor selected species, can increase diversity by reducing populations and thus reducing competition and allowing other species to invade. For example, predators that don't overgraze increase local diversity. Predators, at the appropriate grazing efficiency, keep populations from growing large enough for density-dependent competition.

Diversity and succession are linked. According to E. P. Odum (1969), diversity is low at first (early successional weedy species), and high at climax. On a landscape scale, plants invade forest gaps; this increases diversity. An increase in gaps increases diversity, viewed on the appropriate scale. Gaps from tree falls are frequent in forests. Larger natural gaps decrease in frequency as a function of gap size: for example, large patches opened by wildfire are much rarer than tree fall gaps. Landscape scale diversity often increases with the presence of humans at low population and technological levels, but declines with higher population densities and technological development. Species richness is thus greatest in communities subject to intermediate frequencies and intensities of disturbance (Pickett and White, 1985). The disturbance does not necessarily have to be exogenous (driven by external factors such as fire or clearing by humans); it can be endogenous (driven by the community, e.g., predation), or a combination of both (e.g. wind blowing down dead trees) (White and Pickett, 1985).

With the serial stages characteristic of succession come increase in diversity and community composition dominated by different species. A major question surrounding reclamation of phosphate mined lands concerns how to introduce seed and genetic material of later serial stages of ecosystem development in a newly reclaimed community.

<u>Previous Studies of Ecosystems Related to Phosphate Mining</u> - Clewell et al. (1982) described five floodplain communities in west central Florida riverine forests. These communities were classified by topographic and moisture conditions. Two hydric communities described were river swamp or hydric deciduous forests consisting of obligate hydrotrophs (*Carya aquatica*, *Nyssa biflora*, *Salix caroliniana*, etc.) and bay swamp or hydric evergreen forests consisting of hydric evergreen hardwoods (*Ilex cassine*, *Magnolia virginiana* and *Persea palustris*). The three mesic communities consisted of moist mesic (mixed tree species of mesic habitat), wet mesic (hydrophytes and hydric evergreen hardwoods) and dry mesic (obligate mesophytes). Field data collected included soil analysis, depth to water table and inventory of vascular plants.

In a study of physical and vegetative characteristics of small stream floodplain ecosystems typical of the phosphate districts, Gross (1991) identified trends in community organization that related to physical parameters. She found that physical characteristics of stream channels vary along the length of streams from headwaters to mouth, tending to be broad and flat with braided channels and highly organic soils in the headwaters areas and deeply incised with low accumulations of organic matter in the lower reaches. Vegetation tended to change in response to position and presumably in response to flooding depths and duration.

A manual for Florida wetlands provided excellent descriptions of vegetational and physical parameters for wetland types (Wharton et al. 1977). While not specifically concerned with phosphate mining and ecological reorganization after mining, the authors provided much information concerning organizational properties, functions and values of Florida wetlands from an ecosystem perspective.

LANDSCAPE ECOLOGY

Wetlands are not isolated ecological systems, but are always found in a matrix of upland ecosystems, exchanging material, energy and wildlife. An analysis of ecosystem and landscape ecology of constructed wetlands should be mindful of these interconnections and the upland mosaic of ecosystems within which these wetlands are embedded. The following discussion provides details of landscape organization of wetlands and uplands generalized into what have been termed "landscape associations" to provide background related to organizational parameters and driving energies of wetlands.

The term "landscape" is both a concept and a concrete entity. Its dimensions are smaller than a region and larger than a community and, like all systems, a landscape is composed of interacting and interdependent components. Noss (1983) suggests that a landscape is an "ecological unit with a distinguishable structure" that interacts with and responds to changes in its physiographic surroundings. Forman et al. (1986) offer yet another definition of landscape, defining it as a geographic cluster of similar and repeating ecosystem types [components]. These structural components of pattern within the landscape interact to organize the available flows of energy.

To provide a means of classifying landscapes into familiar units, Brown (in Brown and Best 1985; Brown, Schaefer and Brandt 1989) proposed using the term "landscape association"; based on characteristics of ecological organization with topographical and hydrological gradients.

LANDSCAPE ASSOCIATIONS

In previous studies (Brown and Best, 1985; Brown, Schaefer and Brandt, 1989; and Davis et al. 1991) a technique of landscape scale classification was developed that generalizes somewhat, characteristics of ecological organization with topographical and hydrological gradients. Called landscape associations, they are an assemblage of ecological communities classified on the basis of similarity of topographic, geologic, and hydrologic conditions as well as landscape position.

The landscape associations consisted of two ecological community types that were typically found together. For the most part, an association consisted of a background (or matrix) covering the majority of the landscape, with "patches" within having dissimilar community structure from that of the matrix. The most common matrix in the Florida landscape is the pine flatwood. Generally, this community is characterized by very low topographic relief and very minor surface drainage features. As a result, overland flow during the wet season or during significant storm events is quite common. During normal years, water tables are at or near the ground Surface for about six months of the year.

Pine flatwoods are so named because of the flat topography on which they are typically found. The lack of gradient results in frequent flooding during the summer rainy season (Brown 1980). Often underlain by a "hardpan" of organic materials, clays or accreted oxides, that retard downward migration of groundwaters, flatwood soils are often poorly drained and flood easily. Many grassy scrub areas and palmetto prairies were probably once pine flatwoods that have been converted to grassy scrub by tree harvest, increased drainage, and/or greater fire frequency (Brown 1980)

The central and northern Florida phosphate districts are composed of 6 landscape associations. The associations are composed of land cover types used in the Florida Land Use, Cover and Forms Classification System (FLUCFCS) developed by Florida Department of Transportation (FDOT, 1985). General descriptions of the associations are given below. The FLUCFCS code for each of the components of each association is given below:

- <u>Pine flatwoods/Lake fringe swamp</u> -- [FLUCFCS 411/(615 or 621)]. Where topography gently slopes to permanent water bodies the pine flatwoods/lake fringe swamp association often occurs. Due to gentle topographic relief groundwater moves by seepage or subsurface flow to low points. Soils associated with the wetland community are nearly level, very poorly drained, and dark in color. They are either organic or have coarse- to medium-textured surfaces underlain by finer textured material (Brown and Starnes 1983).

  Lake fringe swamps border permanent, open water. The period of time trees are inundated ranges from infrequent, seasonal flooding at the upper reaches of the lake edge, to permanently flooded at the waterward edge of the swamp. Species composition depends upon flooding of the adjacent lake and is similar to the mixed hardwood swamp. The most common species are red maple *(Acer rubrum)*, water tupelo *(Nyssa aquatica)*, swamp black gum *(Nyssa sylvatica* var. *biflora)*, sweet gum *(Liquidambar styriciflua)*, bald cypress *(Taxodium distichum)*, ash *(Fraxinus* spp), Florida elm *(Ulmus floridana)*, and cabbage palm *(Sabal palmetto)* (Brown 1980). Shrub and herbaceous species increase in abundance with decreasing hydroperiod.

- <u>Pine flatwoods/Marsh</u> -- [FLUCFCS 411/641]. Interspersed throughout pine flatwoods are topographic low areas, which are occupied by patches of wetlands of various types. Wetlands are typically circular in shape and vary from quite small (less than one-half acre) to large (tens of acres). Depth of standing water in isolated wetlands during the rainy season is typically 45 to 55 centimeters. Occasionally deep freshwater marshes (Brown 1980) are found. although they most often are associated with areas of higher relief and greater surface water drainage. The wetlands in this association are relatively oligotrophic whose main source of nutrients is rainfall and a minor surface drainage from small surrounding watersheds.

Where topography of the pine flatwoods is depressional, and depressions have long hydroperiods (periods of inundation), marshes are common. They often appear as circular in shape and sometimes support tree species only along their fringes. Grading down from flatwoods into a marsh, the vegetation associations often go from flatwoods either through a fringe of mesic oaks (e.g., laurel oak, *Quercus laurifolia;* live oak, *Quercus virginiana;* and water oak, *Quercus nigra)* to pond cypress, *Taxodium ascendens,* and black gum, *Nyssa sylvatica)* into the marsh vegetation, or directly from the flatwoods into the marsh bordered by shrubs typical of a cypress dome ecotone. Shallow marshes are common where inundation is frequent and depths of inundation are less than 0.5 meters. Marsh vegetation consists of a diverse mix species (between regions and from marsh to marsh). However, dominant in the grassy shallow marshes are several species which consistently occur and are often dominant: maidencane *(Panicum hemitomon),* St. John's Wort *(Hypericum fasiculatum),* yellow-eyed grass *(Xyris* spp), marsh fleabane *(Pluchea* spp), and pickerel-weed *(Pontederia cordata).* Also occurring are sawgrass *(Cladium jamaicense),* spikerush *(Eleocharis cellulosa),* and soft rush *(Juncus effusus),* and, maidencane *(Panicum hemitomon),* to name but a few. With deeper inundation, longer hydroperiods and accumulations of organic matter, broad-leaved marshes occur (sometimes called flag ponds) dominated by the following species: pickerelweed *(Pontederia cordata),* arrowhead *(Sagittaria* spp.), fire flag *(Thalia geniculata),* bulrush *(Scirpus* spp.), and cattail *(Typha,* spp.).

Deepwater marshes occur where depths of inundation are a meter or more and rarely if ever dry down. Deepwater marshes are usually dominated by free-floating plants such as water hyacinth *(Eichhornia crassipes)* and water lettuce *(Pistia stratiodes)* or rooted aquatic plants such as water lily *(Nymphaea odorata)* and spatterdock *(Nuphar luteum).* Around their margins deepwater marshes often have shallow marsh species.

- <u>Pine flatwood/Cypress dome</u>-- [FLUCFCS 411/621]. Like the pine flatwoods/marsh association, the flatwoods/cypress dome association is very poorly drained and floods during the summer rainy season. Where the flatwoods exhibit extremely low relief depressional areas that are not as deep as marshes often support stands of cypress commonly called cypress domes because of their domed shape when viewed from the side. Standing water can occur in cypress domes from 50%-90% of the time. Pond cypress *(Taxodium ascendens)* is often the only canopy species, but can be mixed with black gum *(Nyssa sylvatica),* pond pine *(Prunus serotina),* slash pine *(Pinus elliottii),* red maple *(her rubrum),* and one or more of the bay species, red bay *(Persea borbonia),* sweet bay *(Magnolia virginiana),* loblolly bay *(Gordonia lasianthus).* The understory can be relatively *diverse* having fetterbush *(Lyonia lucida),* wax myrtle *(Myrica cerifera),* dahoon holly *(Ilex cassine),* buttonbush *(Cephalanthus occidentalis),* Virginia *willow (Itea virginica)* and numerous others, depending on the hydroperiod. Vegetation at ground level is often sparse, depending on the duration of inundation. The most frequent herbaceous species are: lemon bacopa *(Bacopa caroliana),* chain fern *(Woodwardia virginiana), coinwort (Centella asiatica),* maidencane *(Panicum hemitomon).*

The ecotone consists of species of both communities, including shrubs (e.g., wax myrtle, *Myrica cerifera;* stagger-bush, *Lyonia ferruginea;* gallberry, *Ilex glabra;* fetterbush, *Lyonia lucida)* and vines (e.g., greenbriar, *Smilax bona-nox;* blackberry, *Rubus artibufolious;* muscadine grape, *Vitus rotundifolia;* and yellow jessamine, *Gelsemium semprevirens).*

- Pine flatwoods/Bayhead-- [FLUCFCS 41l/611]. A similar association in structure to the pine flatwoods/Cypress dome, the bayhead occurs where water levels are shallower than the cypress dome. Many bayheads have little or no standing water, but remain saturated throughout the year.

  Dominant tree species in bayheads include swamp bay *(Persea palustris),* sweet bay *(Magnolia virginiana),* loblolly bay *(Gordonia lasianthus),* black gum *(Nyssa sylvatica),* and red maple *(Acer rubrum).* Pond pine *(Pinus serotina),* and slash pine *(Pinus elliottii)* are often present depending on topographic relief within the community and frequency and duration of inundation. The understory is often dominated by wax myrtle *(Myrica cerifera),* fetterbush *(Lyonia lucida),* dahoon holly *(Ilex cassine)* and vines like wild grape *(Vitisis rotundifolia)* and catbrier *(Smilax laurifolia).*

- Pine flatwoods/Mixed hardwood swamps-- [FLUCFCS 411/615]. Unlike the previous wetland associations which are isolated hydrologically, mixed hardwood swamps are associated with larger scale drainage systems. Drainage can be sheetflow (strands) small, braided channels (sloughs) or channelized (floodplain swamp). Having somewhat greater relief the flatwoods of this association have Surface drainage features dominated by wetland vegetation. Both surface and groundwaters contribute water flows to the wetland drainage features. Sloughs or strands are elongated wetlands with no open water channels; however, water flows imperceptibly slowly as sheet flow during the wet season and through small, braided channels during drier times. Seasonal flooding that is characteristic of flowing water wetlands provides the nutrients needed for plant growth. Water levels can fluctuate about .75 meters between the wet and dry season in an average year. The normal depths of inundation are about 55 to 75 centimeters. Often deeper pools in a slough may be as deep as 1.5 meters (Brown and Starnes 1983). Flooding is also important for seed distribution, seed scarification, and elimination of upland plant species (Brandt and Ewe1 1989). The soils in this category are poorly drained and have higher percentages of clay and organic matter than do those of the flatwoods/isolated wetland associations.

Flowing water wetlands include both bald cypress *(Taxodium distichum)* forests and southern mixed hardwood forests growing throughout sloughs and strands. Common hardwood species in the mixed hardwood community include red maple *(Acer rubrum),* water tupelo *(Nyssa aquatica),* swamp black gum *(Nyssa sylvatica* var. *biflora),* sweet gum *(Liquidambar styraciflua),* ash *(Fraxinus spp.),* Florida *elm (Ulmus floridana),* and cabbage palm *(Sabal palmetto)* (Brown 1980). Where drainage occurs in sloughs, pond cypress *(Taxodium ascendens)* may be dominant. Midstory and ground cover species are similar to those in bayhead communities. Shrub and herbaceous vegetation is often localized to raised hummocks which are abundant in this association.

- Mesic hardwoods/Mixed hardwood swamps-- [FLUCFCS 438/615]. More moderate to moderately well drained sandy soils and level to sloping topography characterize the uplands of this association. This association is often characterized by well developed drainage networks. Between the upland communities of mesic hammocks and the lower zone communities of hardwood swamps along drainage features, hydric hammocks often occur where moisture conditions maintain soils in constant saturation but rarely, if ever, flood.

The excellent growing conditions and good soils of the uplands foster the development of quite diverse and robust pine flatwoods, but if fire is excluded, the mesic hammocks that follow are the most diverse of the upland communities in the north. and central Florida regions containing between 8 and 35 tree species. Overstory species in mesic hammocks include Southern magnolia *(Magnolia grandiflora),* laurel oak *(Quercus laurifolia),* red bay *(Persea borbonia),* sweetgum *(Liquidambar styraciflua),* pignut *(Carya glabra),* American holly *(Ilex opaca),* water oak *(Quercus nigra),* black cherry *(Prunus serotina),* and live oak *(Quercus virginiana).* The canopy is so dense that little sunlight reaches the forest floor. Soils are moderately well drained to somewhat poorly drained. Rainfall is the major water source for mesic hammocks, although seepage and runoff may provide water to some stands (Brown 1980).

Soils in hydric hammocks are generally shallow and sandy, and limestone (either in bedrock or in nodules in the soil) is most often present (Vince et al. 1991). Hardpans (weakly cemented Bh horizons) do not occur, but clay layers that support surficial water tables occur in some hammocks (Vince et al. 1991). Where high water tables are characteristic, hydric hammock soils are saturated most of the year (Brown and Schaefer 1987). Hydric hammocks have the most diverse flora of any wetland in central Florida. Species include pop ash *(Fraxinus caroliniana),* live oak *(Quercus virginiana),* laurel oak *(Quercus laurifolia),* water oak *(Quercus nigra),* Southern magnolia *(Magnolia grandiflora),* red bay *(Persea borbonia),* sweet bay *(Magnolia virginiana),* tulip poplar *(Liriodendron tulipifera),* red maple *(Acer rubrum),* red cedar *(Juniperus silicicola),* cabbage palm *(Sabal palmetto),* slash pine *(Pinus elliottii),* and blue beech *(Carpinus caroliniana)* (Brown and Starnes 1983).

Vegetation of the mixed hardwood swamps of this association is similar to that of the previous association.

REVIEW OF THE LITERATURE

<u>Landscape Defined</u> - The science of landscape ecology has developed considerably during the last decade. It is the study of the structure, function and change of the assemblage of biotic and abiotic elements which occupy a given area of land. Landscape elements may be natural or human in origin. They range from about 10 meters to 1 km in width and are usually identifiable in aerial photography (Forman and Godron, 1986). Ecological commmunities are important landscape elements and are usually defined by the dominant species within them in terms of land cover. Abiotic landscape elements may be natural, such as open water, rock outcroppings or sand dunes, or cultural features such as roads, buildings, dams, etc. Agricultural fields, pastures and tree plantations form important biotic elements of cultural origin.

In landscape ecology the term matrix is used to identify the most extensive and most connected element type (Forman and Godron, 1986). There are three main criteria for determining which element of a given landscape is the matrix. They are the relative area which the element covers, the degree of connectivity it has within its area of coverage, and the control that element has over the dynamics of the landscape as a whole. To determine which element type is the matrix of the landscape Forman and Godron suggest, first, that relative areas be calculated and if one element type clearly predominates it is the matrix. If no element type predominates then the one which has the highest degree of connectivity may be considered the matrix. If the designation of the matrix is still uncertain after calculating relative area and connectivity, then research must be done on the history of the landscape and the dynamics of the species which compose its elements to determine which one is exerting a greater control over the landscape and its changes (Forman and Godron, 1986).

Elements within a landscape of a type different than the matrix are known as patches or corridors. Patches are areas of varying shape, but whose width and length are comparable. Corridors are elements which are very narrow compared to their length, such as rivers, roads, hedge rows, power line corridors, etc. They are either line or strip corridors. Line corridors are so narrow that any vegetation they contain is homogeneous. A strip corridor is wide enough that there may be an appreciable difference between the vegetation at its edge and that in its interior. Stream corridors border streams and rivers. They may be of varying width, depending on the width of the stream and the local topography. The ecological significance of the shape of a patch or corridor can be attributed to a large extent to the edge effect, where the species composition at the edge of a patch is often different from that in its interior. This boundary area is also known as an ecotone. E.P. Odum (1971) defined an ecotone as a transition between two or more diverse communities. Ecotonal communities may contain many of the species of each community together with some which are found only in the ecotone. Many species, however, including some of the most endangered ones, are restricted to the interior of their respective habitats, and where patches of a sufficient size do not exist in the region, these species cannot be supported (Meffe and Carroll, 1993). Since biotic and abiotic components must move across the boundariesbetween landscape elements, ecotones may have an important controlling function on the dynamics of the system (Holland and Risser, 1991).

Corridors may function not only as habitat for certain species, but as conduits for migration, or barriers to migration, depending on the type of corridor and the organisms involved (Meffe and Carroll, 1993). The connectivity of a corridor, or number of breaks per unit length, may affect the degree to which it serves as a conduit or barrier to migration. Corridors may gradually vary in species composition along their length in response to local environmental factors such as hydrology, colonization-extinction patterns, or as a result of disturbance. This variance is known as a gradient (Forman and Godron, 1986). A node is a patch attached to a corridor of the same element type, or an intersection of corridors, which may act as a source or sink for a flow of objects or organisms along the corridor.

In the case of open water patches such as lakes, shape determines the length of shoreline present. This is of interest because shoreline processes affect the productivity and organisms present in the lake as a whole (Forman and Godron, 1986).

The Role of Disturbance - Disturbance can act to increase spatial diversity and cycling of material and energy within the landscape. The open space created changes the availability of resources--sunlight, soil nutrients, wind, and water flow--altering the site's successional stage and creating niches for other individuals to become established. Perturbation may act as a pulsing mechanism that increases the recycling of information and materials back into the system Varying degrees of natural disturbance and the associated patterns of succession which follow, become a source of spatial heterogeneity constantly reorganizing and reinforcing the landscape mosaic.

Cultural land use practices, such as surface mining, impact landscapes differently than do natural processes and disturbance regimes. Urban et al. (1987) note that many changes in land use cover large areas but are frequent and often chronic, contrary to the large/slow or small/fast rule of natural processes. The authors refer to the impacts of cultural land use practices as "anthropogenic rescaling" of natural processes and patterns in time and space. The specific actions of rescaling are to change the set of constraints (including disturbance frequencies) governing lower-level biotic processes and to alter the exchange of information between patches within the landscape. Natural boundaries are often altered, imposing new edges which may act as barriers to dispersal of genetic information between patches.

Cultural-dominated landscapes also change according to non-ecological factors such as market price, zoning, and transfers of land ownership. The successional capabilities of the landscape are ultimately determined by this rescaling of natural process and pattern. These actions are readily apparent in phosphate-mined landscapes, where the disturbance regimes are so large and so closely spaced that the seed refugia become isolated, and the intervening landscape can no longer effectively respond to the levels of disturbance.

Previous Studies of Landscape Related to Phosphate Mining - Doherty (1990) studied naturally reclaimed lands using the supposition that space and time were linked. There were three scales to the analysis: the regional landscape (thousands of km^2), the landscape (tens of km), and the community (hundreds of m^2). Time was analyzed through selection of a variety of sites of differing ages. In Doherty's study of the role of landscape organization in the recovery of disturbed areas by natural succession, the central Florida region was found to be dominated by phosphate mining and agriculture. Forested land was found to be fragmented, occurring generally in patches of less than 16 ha surrounded by agriculture and mining. Using an interaction potential index (IP), which relates the influence of natural vegetation "seed islands" to the inverse square of the distance to abandoned agricultural and phosphate mine sites of varying ages he showed a moderate to strong correlation of the IP to such parameters as species richness and tree stocking densities in abandoned agricultural sites, for which the average distance to a seed island was 700 meters. For the abandoned phosphate mines in the study, the mean distance to remnant patches of natural vegetation was 1,900 meters and the correlation of the existence of seed islands to community scale parameters was not as clear.

In conjunction with the Southwest Florida Water Management District (SWFWMD), successional patterns on abandoned agricultural lands (Newman et al. 1988) were measured on 45 sites within Southwest and central Florida. Then successional patterns on 35 mined sites of various ages and landforms were evaluated. Comparisons between undisturbed ecological communities, abandoned agricultural lands, and abandoned mined lands were made. Time and distance were related to successional stage and community organization.

Studying the areal organization of drainage basins, Sullivan (1990) and Sullivan and Brown (1991) developed indices relating basin order, size and slope to wetland type, wetland area, and size class distributions. They found that the ratio of upland area to wetland area was constant over the hierarchy of drainage basin orders 1 through 4, although with increasing basin size, upland wetland ratios decreased. Distributions of wetland type were explained by position within the drainage basin. Isolated wetlands were more common in headwaters areas, while riparian wetlands dominated channel-ways. Basins with lower slopes and wide floodplains contained more riverine type wetlands

King and Cates (1994) have proposed a three-part regional habitat mitigation plan for the southern phosphate district which consists of a riverine-based core habitat reserve. Taking a landscape ecology approach, they propose using the unmined segments of the five major river systems that drain the phosphate area - the Peace, Alafia, Little Manatee, Manatee, and Myakka, as the core habitat reserve. Their two part design goal for the area is to reconnect the unmined segments of these rivers, linking them together with corridors and then to extend them into otherwise isolated reclamation tracts. The three parts, then, are the core area, surrounding complementary habitat (reclaimed lands), and connections to other habitats outside the phosphate district.

ECOSYSTEM AND LANDSCAPE ORGANIZATION OF CREATED WETLANDS IN THE FLORIDA PHOSPHATE DISTRICTS

METHODS

SYSTEMS ECOLOGY

Plan of Study - A computer model was developed to simulate vegetative competition and succession in central Florida wetlands. For given initial conditions, the model simulates the change of floral composition over time, and the biomass and diversity of the final tree, shrub, and herbaceous communities. It attempts to predict trends and long-term results of various natural and human-managed revegetation patterns.

Two sets of initial conditions were considered. The first represented colonization of a bare site by nearby plants in climax forested, shrub, and marsh wetlands. In contrast, the second represented human reclamation of a phosphate-mined site. The model can be expanded to include hydrology, nutrient cycling, animal communities, and disturbances like fire, human management, and cattle and hog grazing.

Model Description - The wetland succession model (Figures 8-2 and 8-3 and program given in Appendix 8-1) places three producer units: trees, shrubs, and herbaceous plants, in competition for sunlight. Water and nutrients are not considered as limiting factors here. Trees receive sunlight first, then, shrubs receive sunlight not absorbed or reflected by trees, and finally, herbaceous plants receive sunlight not absorbed or reflected by trees or shrubs. This simplification ignores initial shading of tree seedlings by shrubs and herbs, but the relative tolerance of most tree seedlings to shading makes this omission minor.

The three producer units (trees, shrubs, and herbs) are internally similar. Seeds arrive from outside, and supplement seeds fallen from local sources. About twenty percent of tree and shrub seeds are viable, meaning they germinate and survive to the end of the first growing season, and 25% of herbaceous seeds are viable (Dunn, 1989). This seedflow adds to the local viable seedbanks. Non-viable seeds decay and add to local organic detritus. Viable seed diversity is also represented by a storage. Diversity of seeds from outside is combined with diversity of seeds from local sources, and weighted by relative seed flow volume.

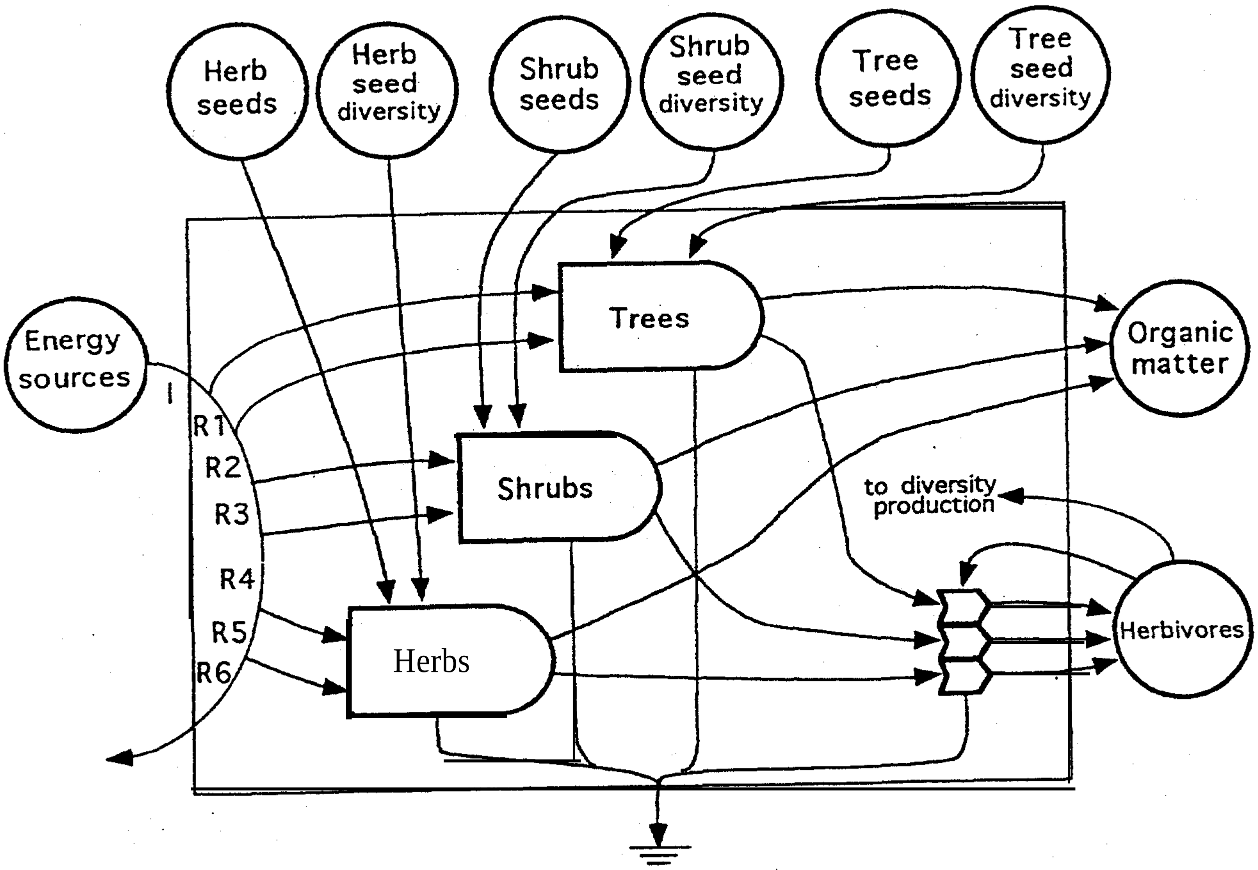


Figure 8-2. Systems diagram of the simulation model of succession in central Florida wetlands.

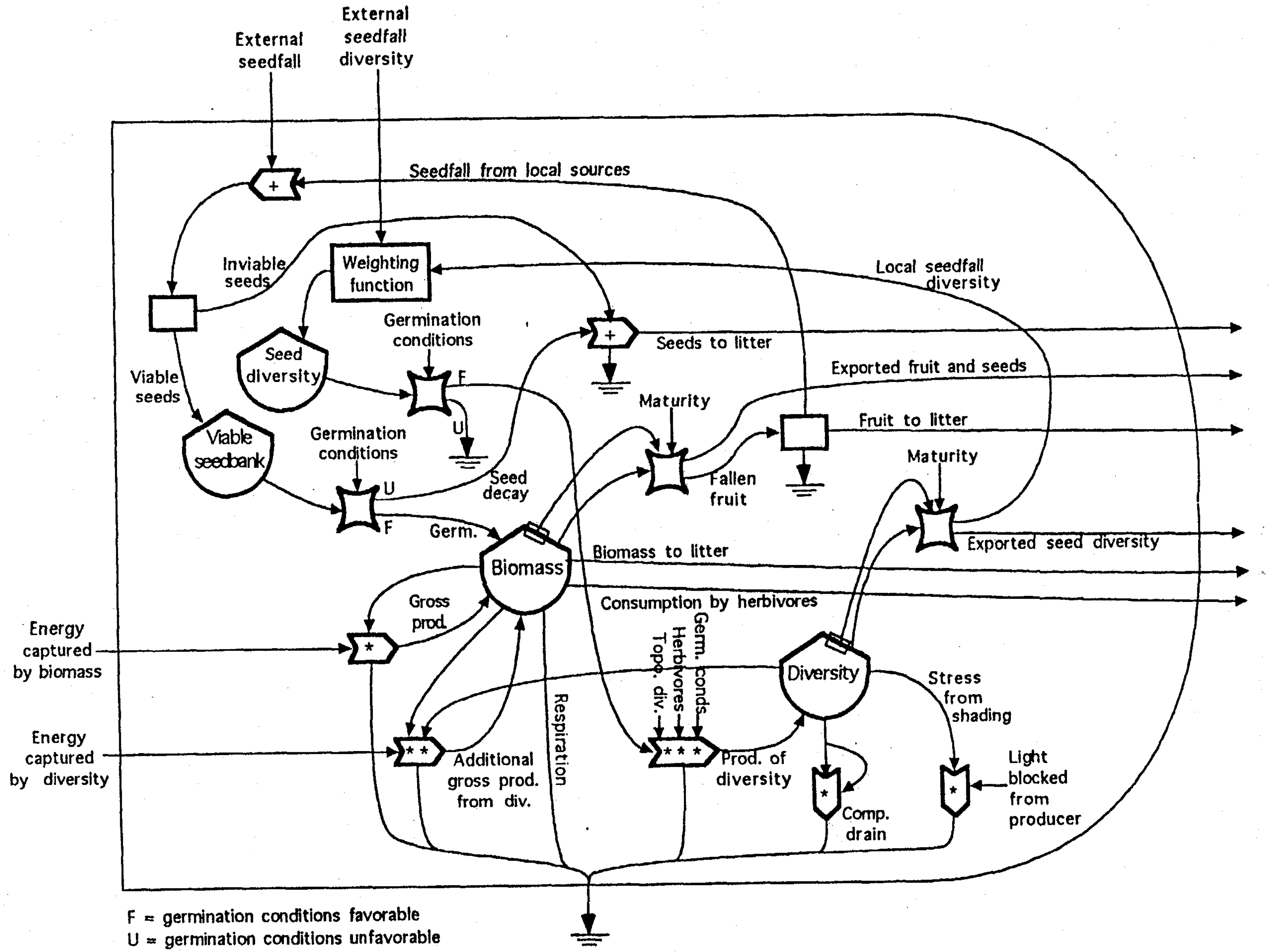


Figure 8-3. Systems diagram of interior details of a producer unit in the simulation model in Figure 8-2.

Germination conditions (water drawdown, temperature, etc.) are aggregated into a digital switch. For example, tree seeds require oxygen for germination (no standing water). Cypress seeds and seedlings require very moist, but not flooded, soil for germination and survival (Mitsch and Gosselink, 1986). When conditions are right for germination, the masses of seeds in the viable seedbanks add to tree, shrub, and herb biomasses. The seedbanks are then empty until more viable seeds are added. Similarly, the diversity of seeds in the viable seedbanks contribute to tree, shrub, and herb diversities. When conditions are not right for germination, some of the viable seeds decay (90%/year for trees and shrubs, and 50%/year for herbs; [McClanahan, 1984]), and add to local organic detritus. Viable seedbank diversity decreases faster as short-lived seeds are lost. This loss is estimated as 20%/month for trees and shrubs, and l0%/month for herbs.

Trees, shrubs, and herbs receive sunlight as a flow-limited source: the larger they grow, the less additional sunlight is available, until they reach their maximum biomass. As mentioned earlier, shrubs will shade out herbs, and trees will shade out shrubs and herbs, although some undergrowth will always remain. Because herbs grow faster than shrubs, and shrubs grow faster than trees, if the local site is cleared of all vegetation, herbs will grow first, then be replaced by shrubs, and finally the site will be dominated by trees.

Gross production is a function of available sunlight and existing biomass (the greater the biomass, the more production is possible), and adds to biomass. Nutrient availability, water availability, etc. could be added here if desired. Respiration is subtracted from biomass, although a more complex model could subtract this from gross production before net biomass production. Herbivore consumption and litter fall are also subtracted from biomass.

When trees and shrubs reach reproductive maturity (2400 g/m^2 for trees, 1000 g/m^2 for shrubs, and, for simplicity and because of their rapid growth, no requirement for herbs), they produce fruit from their biomass. Some of this is exported (6% for trees and shrubs Wolfe, 1987] and 10% for herbs), and the rest falls locally. Locally fallen seeds (20% of fruit for trees and 25% of fruit for shrubs) add to the local seedbank; the balance of the fruit becomes detritus.

Diversity production is a function of seed diversity, topographic diversity, biomass of herbivores (a function of herbivore biomass and diversity is preferable), and germination conditions. If seeds of new or unrepresented species arrive but cannot germinate, diversity does not increase. On a small scale, plant diversity is proportional to topographic diversity: $H' = 4.94s + 1.66$ (approx.), where H' is the Shannon Index of plant diversity, and s is the standard deviation of onsite elevations in meters (Davis et al, 1991). Diversity is limited by a quadratic extinction rate, or information cost. Shading of shrubs and herbs causes a stress that decreases their diversity, as shade-intolerant species are eliminated. Diversity acts to increase biomass production by capturing additional energy. This is modeled by the capture of additional sunlight by a more diverse canopy, and corresponding additional gross production. A diversity of less than one is considered to be a monoculture of one species.

Pathways and storages in the model are given in Appendix 8-2. Pathway coefficients for each producer unit are calculated using the steady-state storage values with that unit considered alone, without competition from the other two. The initial tree species is cypress; the initial shrub species is willow.

Time is incremented in days. The program user is prompted for the number of years to simulate. Tree, shrub, and herbaceous biomass and diversity are plotted on the screen, or written to a comma-delimited data file. The data file can be imported to a spreadsheet and graphed.

Model Calibration and Validation - As in all models, the Central Florida Wetlands Succession Model represented an abstraction of the real world. Complexity of the world was aggregated into several state variables and a like number of processes. The assumption was that if the aggregation is correct, the results will "track" real-world occurrences. Validation was accomplished by determining how well the model "predicted" real-world occurrences, by comparing the models output to measured data. In addition, we validated the behavior of the model when simulating succession of phosphate-mined lands by first simulating succession on "natural" Florida lands. Once satisfied that the model's simulation output approached expected results, we reset initial conditions and calibrated the model for conditions found in the phosphate region, and simulated succession under these conditions.

The Central Florida Wetlands Succession Model was calibrated using data from both reclaimed and natural communities of central Florida. Many research reports were consulted, and data on productivity, standing biomass, diversity, seed banks, and seed sources were extracted from them (these references and the values used can be found in Appendix 8-2). The second step in calibration required numerous simulation runs where state variables, driving energies, initial conditions, and pathway coefficients were varied over reasonable ranges (reasonable was defined by ranges of values found in the literature). The simulation output for each variable was compared with literature values, to determine if output "tracked" real-world data in both magnitude and the temporal domain. This is sometimes called a sensitivity analysis. The object was to determine which variables were most sensitive to which changes by comparing simulation results with known data. If simulation results indicated that a variable was either too large, or too small (when compared with values in the literature) recalibration was conducted, after checking to insure that equational structure was not at fault. Calibration was an iterative process, where data were checked and rechecked, until simulation results were within expected ranges for systems that were being simulated.

Validation of the model was accomplished through an iterative process as well. In fact, validation and calibration are parts of the same process. The process of validation and calibration is somewhat transparent since it is part of the model building exercise. When simulation results during sensitivity analysis were outside the realm of possibility, as dictated by observed real-world values, a re-evaluation of model structure and/or initial values was warranted. Earlier versions of the model had different structure, and were changed as sensitivity analysis revealed that they did not produce values (or behavior) that was consistent with those found in real-world systems.

Finally a model structure evolved co-dependently with calibrated values for state variables and rate equations that resulted in simulated behavior that "fit" real world data. Further validation was accomplished by first simulating the model for conditions found in "native" Florida ecosystems (where more data exist on long-term successional trends) and then applying the model to conditions found in the reclaimed landscape.

LANDSCAPE ECOLOGY

Plan of Study - The primary objectives of this study were twofold: 1) to develop a GIS data base for wetlands reclamation projects, and 2) to investigate and describe the general characteristics of wetland reclamation sites, and analyze their landscape "fitness" at a landscape scale as opposed to success at the scale of individual ecosystem components such as floral composition. Evaluation of landscape fit is a relatively new and as yet, evolving area of inquiry. While the evaluation of community structure is relatively straight forward using such techniques as indices of community organization and persistence. Evaluation of wetland success at a landscape scale is not so common. Indices of landscape organization are not well defined nor is the theoretical basis for appropriate organization well developed.

In this evaluation we have settled on three measures of landscape scale fitness. These measures are based on our review of the literature, and previous studies of the organization of Florida landscapes.

The three main characteristics considered and evaluated were:

1. "Ecological connectedness" of the sites, determined by observing the percentage of the site's perimeter that is adjacent to preexisting natural communities,

2. "Hydrologic connectedness", which indicates whether a site has a surface water connection to natural drainageways or communities, and

3. An evaluation of the relationship of the vegetation communities within sites as well as to those of the surrounding area and landscape position, termed "community fitness."

Evaluation of landscape fit is based on comparisons with the "native Florida Landscape." There is much controversy surrounding whether or not it is appropriate to use reference areas for comparative purposes when judging success, especially when evaluating inter-community organization. While it may or may not be appropriate to use reference areas, without a doubt, it does make sense to establish a base line from which departures can be determined. In judging success at the landscape scale we tried to measure how well the reclaimed wetland fit within its landscape by first using principles of landscape ecology concerning heterogeneity, connectivity, and spatial distributions and secondly by comparative analysis using wetlands embedded in native (undisturbed) landscapes. In essence, we judged fitness based on how closely they matched fitness criteria derived from landscape principles and undisturbed landscapes. In all cases, we were searching for trends. Are the landscapes of created wetlands and uplands heterogeneous, connected landscape wholes? Do the constructed wetlands exhibit intra-community fitness based on position and appropriate mixes of community types?

Source and Quality of Data - Topographic and vegetation maps of each reclamation site were taken from permit records, monitoring reports, and were requested from companies where permit records were incomplete or non-existent. Map quality was evaluated using the following categories:

- Good - map had clearly defined lines and boundaries, was recent and/or updated, had labels that were clearly indicated, and contained information pertaining to the position of the site in relation to township and range sections.
- Fair - Map was not recent or was hand drawn, but had clearly indicated labels and provided township and range information.
- Bad - Map provided some indication of plan for the reclamation area, but had no clearly defined map boundaries, lines, or labels, and had no township and range designations.
- None - No maps were found in permit application or monitoring reports, and supplemental information was not provided upon request.

The base maps used for land use and cover of the areas surrounding each reclamation site in the Central Florida Phosphate District were obtained in ARC/INFO digital format from the Southwest Florida Water Management District. These were digitized from 1:24,000 scale infrared aerial photos taken between December, 1989 and January 1991. All maps obtained from the SWFWMD use the UT coordinate system zone 17, datum NAD27, with all units given in meters. The resolution or minimum mapping unit used is approximately 0.5 acres, or 0.23 hectares. Land use classification is according to levels 2 and 3 of the Florida Land Use, Cover and Forms Classification System published by the Florida Department of Transportation (1985). Similar maps were obtained from the Suwannee River Water Management District for the northern phosphate district. These were digitized from infrared aerial photos taken in 1988.

The dates on which the base map aerial photography was done provided a time reference for the surrounding landscape. Therefore, the year 1990 is the time reference for the base maps in the Central Florida Phosphate District, and 1988 is the time reference for the Occidental Chemical sites in Hamilton County.

In addition to the land use and cover maps, a map of the drainage basin boundaries as well as the roads and Township/ Range grid was obtained from SWFWMD. SRWMD provided topographic contours for the area. Additionally, a map of river and stream channels for the central Florida region was obtained from the Florida Department of Environmental Protection.

Maps of the individual reclamation sites were obtained from various sources, generally from the phosphate mining company responsible for the site. Some were obtained in AutoCAD drawing format and converted to ARC/INFO format and their coordinates converted to UT meters.

Others were digitized from maps obtained from DER permits or monitoring reports, and these varied greatly in quality. The positioning of the sites in relation to the base maps was done by referencing the site to the comers of the Township and Range Section in which it is located. For maps where Township and Range references were not clearly provided, the maps were positioned in relation to known geographic features such as streams.

Once the site map was correctly positioned, an 800 meter buffer of the landscape surrounding the site was "cut" from the land use/land cover base map using ARC/INFO. This provided the surrounding land cover used for much of the analysis of landscape fit.

Land Use Classification System - The classification system used throughout this report to identify land cover types is the Florida Land Use, Cover and Forms Classification System (FLUCFCS) published by the Florida Department of Transportation (1985). The system is hierarchical, with the first classification level indicated by the first digit of the number, as follows:

1000	Urban and Built-up
2000	Agricultural
3000	Rangeland
4000	Upland Forest
5000	Water
6000	Wetlands
7000	Barren Land
8000	Transportation
9000	Special Classifications

These are subdivided into second, third and fourth level classifications indicated by the second, third and fourth digits of the codes, respectively. For example, 6400 represents vegetated, non-forested wetlands, 6410 represents freshwater marshes and 6411 indicates sawgrass marshes. The data used in this study generally specified second or third level classifications of the land cover types.

The six wetland landscape associations identified by Davis et al, (1991) outlined above were identified by land use codes as follows:

1. Pine flatwood/lake fringe swamp is indicated by a lake (code 520) surrounded by a fringe of forested-mixed wetland (630) which borders a pine flatwood land cover type (411).

2. Pine flatwoods/marsh. The land cover signature used to identify this association would feature a freshwater marsh (641) surrounded by either pine flatwoods (411) or forested-mixed wetland (630) and pine flatwoods.

3. Pine flatwoods/cypress dome. This association is identified by a cypress dome

(621) surrounded by pine flatwoods (411).

4. Pine flatwoods/bayhead. Land covers indicative of this association are bay swamp (611) surrounded by pine flatwoods (411).

5. Pine flatwoods/mixed hardwood swamp. Land cover signatures used to indicate the presence of this association are stream and lake swamp (615) adjacent to pine flatwoods (411).

6. Mesic hardwoods/mixed hardwood swamp. Indicative land covers of this association are mixed hardwood swamp (615) adjacent to mixed hardwood forest (438), temperate hardwood forest (425) or live oak (427).

Analysis of "Ecological Connectedness" - The effect of a site that is not reclaimed upon an adjacent site, through exchange of seeds or wildlife, for example, may be negligible compared to the effect a mature natural or reclaimed ecosystem may have. For this reason, barren, active mine land, and newly reclaimed lands were labeled as mined land. Reclaimed lands that were sufficiently mature to have been identified by their current land cover signatures were classified accordingly.

To evaluate ecological connectedness, a visual analysis of the site maps and surrounding land cover was performed using printed copies of the maps and interactively, using the GIS database. The percentage of the perimeter of the sites that were adjacent to natural or reclaimed land cover types was estimated by visual inspection.

Analysis of "Hydrological Connectedness" - The system of ordering drainage basins and sub-basins was based on concepts originated by Horton (1945) and later modified by Strahler (1952,1957) and applied to the extended Hydrologic Unit Code system which is used to identify drainage basins and sub-basins in the GIS database supplied by the Southwest Florida Water Management District.

The process of ordering stream networks begins at the uppermost reaches of stream networks, where unbranched tributaries are assigned the order 1. The junction of two first order streams creates a stream of order 2, and any number of first order streams may subsequently join the stream without changing the order. This process continues to the mouth of the network. Only when two 2nd order streams join, is the result assigned an order of 3, and so forth.

The hydrologic connectivity of reclamation sites was inferred from the available data by visually referencing drainage basin boundaries, land cover types on the site and surrounding area, and stream channels, where these were visible. The drainage basin boundary map, provided by SWFWMD, was overlayed on each site map and drainage basin order taken from the data base.

While this technique can be quite useful and reliable in areas which have retained their natural hydrological characteristics and topography, post mining drainage basin boundaries can be difficult to determine and often impermanent. Areas which may have previously been drained by streams are sometimes left without channelized drainage, and other areas that were drained strictly by sheet flow may become channelized. Many of the sites in the study area are within drainage basins indicated on the map as mined land with no visible stream connection to another higher order basin. Under these circumstances, drainage from one basin to another is indicated by the fact that connected basins have differing basin order numbers and not because there is a visible stream connection.

The location (position) of each site within its drainage basin was estimated by visually determining the outflow point and dividing the basin in thirds with the outflow point at the lowest extreme of the lower third.

Analysis of "Community Fitness" - Industry wide averages for land use of phosphate mining reclamation sites in Florida were examined by comparing attributes of each site with the 800 meter buffer surrounding each site. Comparisons included measuring mean area used for reclamation, mean richness of land use cover, and complexity of land use heterogeneity.

AU comparisons, including mean areas, were determined for each FLUCFCS at the 100 level (level 2), because not all maps received from each phosphate mining company used the same level of land use definition.

The reclamation sites were grouped in many of the analyses according to their sizes as follows:

Size Class A	0 - 1.3 E6 m2
Size Class B	1.4 E6 - 2.7 E6 m2
Size Class C	>2.8 E6 m2

A number of indices were used to summarize and compile the data. They are listed below:

- Richness of land use/cover types - Richness is composed of several indices: Percent occurrence, number of polygons, and number of unique polygons. Percent occurrence of land cover types on reclaimed sites provided a signature of how frequently different land cover types were found. Percent occurrence was calculated by dividing the number of polygons of each type by total number of polygons.

- Site complexity - The perimeter/area ratio was obtained by adding the total perimeter lengths on each site and dividing by the total area (all FLUCFCS designations). A perimeter is defined as the "edge" of a particular land use type. An example would be the edge of a forest along a field, or the line that marks the transition between hydric and mesic forests. The ratio of perimeter length to area gives a measure of structural and habitat diversity of a particular site. As the ratio increases, one may assume the structural complexity of a site increases.

- Percent cover of land use/cover types - Percent cover of each land use type was calculated by summing area of types and dividing by total area in reclaimed sites.

- Upland/Wetland area ratio - This ratio was computed by adding areas of all upland communities (pasture, rangeland, forests, etc.) then dividing by the combined areas of all wetlands (forested, and nonforested). Lakes and other deepwater areas were not included in this calculation as wetlands.

- Lake/Wetland area ratio - This ratio was obtained by dividing the total lake area on site by the total wetland area. All wetlands (forested and nonforested) were grouped for this comparison. In addition to lake/wetland ratio, visual estimates of the dominant land cover types surrounding lakes were determined. The dominant community type planted around lake margins was visually estimated using the GIS site maps. Only the community that shared the greatest perimeter length with a lake was included in this analysis.

Comparisons with the Native Florida Landscape - One hundred and eighty-five monitored cypress domes in Hillsborough and Pasco counties and six monitored cypress domes in the Green Swamp were chosen as centers for circular coverages in unmined Florida landscapes. In addition, 30 center points were randomly selected in Florida quads HILLCOAT, LIVE OAK, and Q2916. Ten points were randomly generated within each of the three quads, also being constrained to lie greater than 1197 meters from the quad boundaries so that sample areas centered on each point would fall completely within the quad.

Around each point centered on a cypress dome or generated randomly, three circular areas were clipped from Southwest Florida Water Management District land use coverages. The three different areas chosen were the midpoint value of each phosphate mine reclamation site size class: 65 ha, 200 ha, and 450 ha. Areas that contained urban or industrial land uses, or mined land, were removed from consideration.

A frequency analysis was done for land cover types (FLUCFCS designations) on each circular area in ARC/INFO. The analysis results were combined and summed for each geographic area, for natural (no agriculture) landscapes only, and for all sites together. Indices of landscape organization were calculated for comparison with landscape indices of reclamation sites.

RESULTS AND DISCUSSION

SYSTEMS ECOLOGY

Simulation Results of the Standard Model - Figures 8-4, 8-5, and 8-6 are the results of simulation of the central Florida wetlands succession model when initial conditions are for a cleared wetland with natural reseeding from nearby climax forests and marshes. Figure 8-4 simulates regrowth for 5 years, Figure 8-5 for 50 years, and Figure 8-6 for 500 years. Three different scenarios were

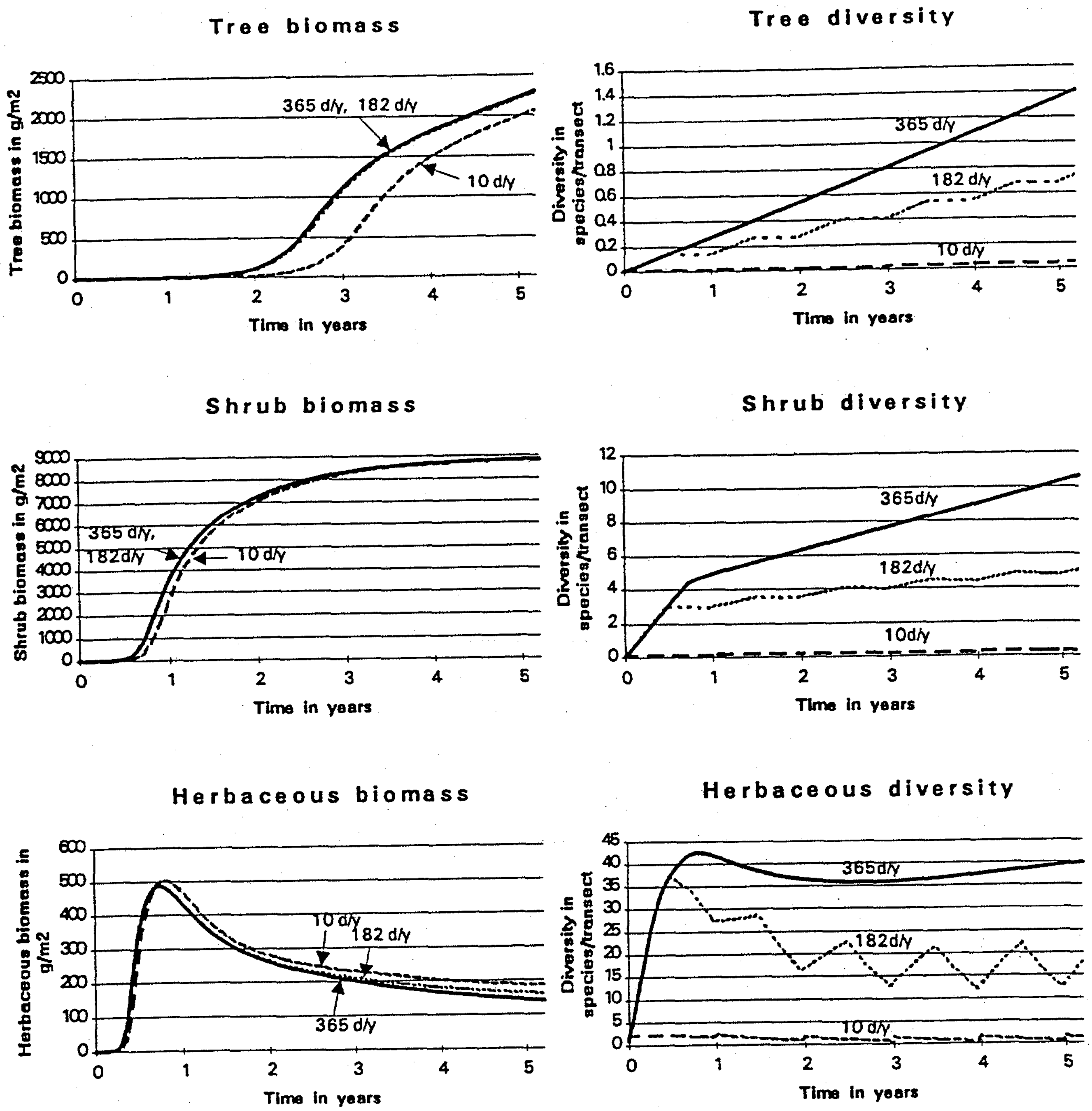


Figure 8-4. Five year simulation results of the central Florida wetlands succession model.

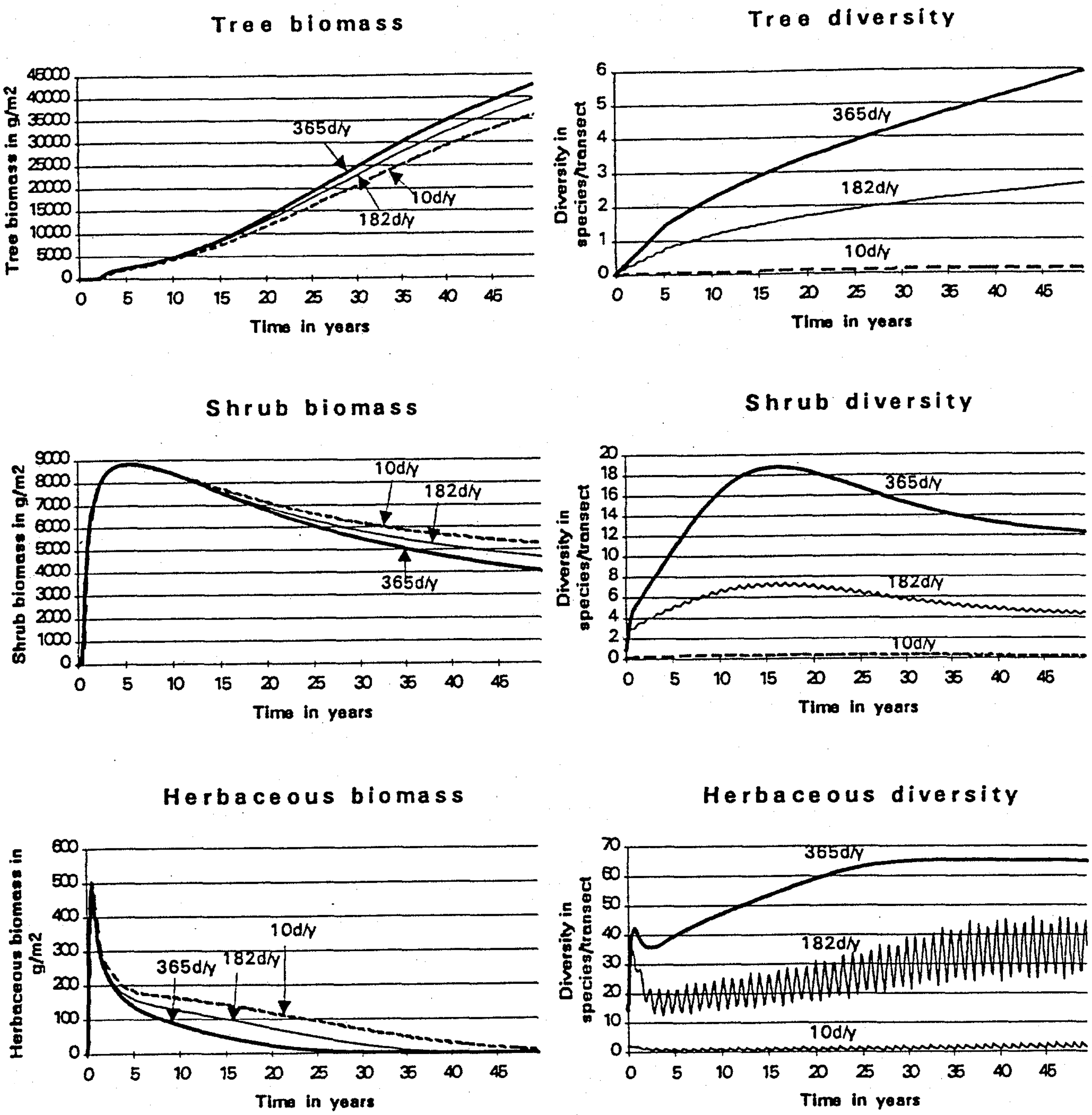


Figure 8-5. Fifty year simulation results of the central Florida wetlands succession model.

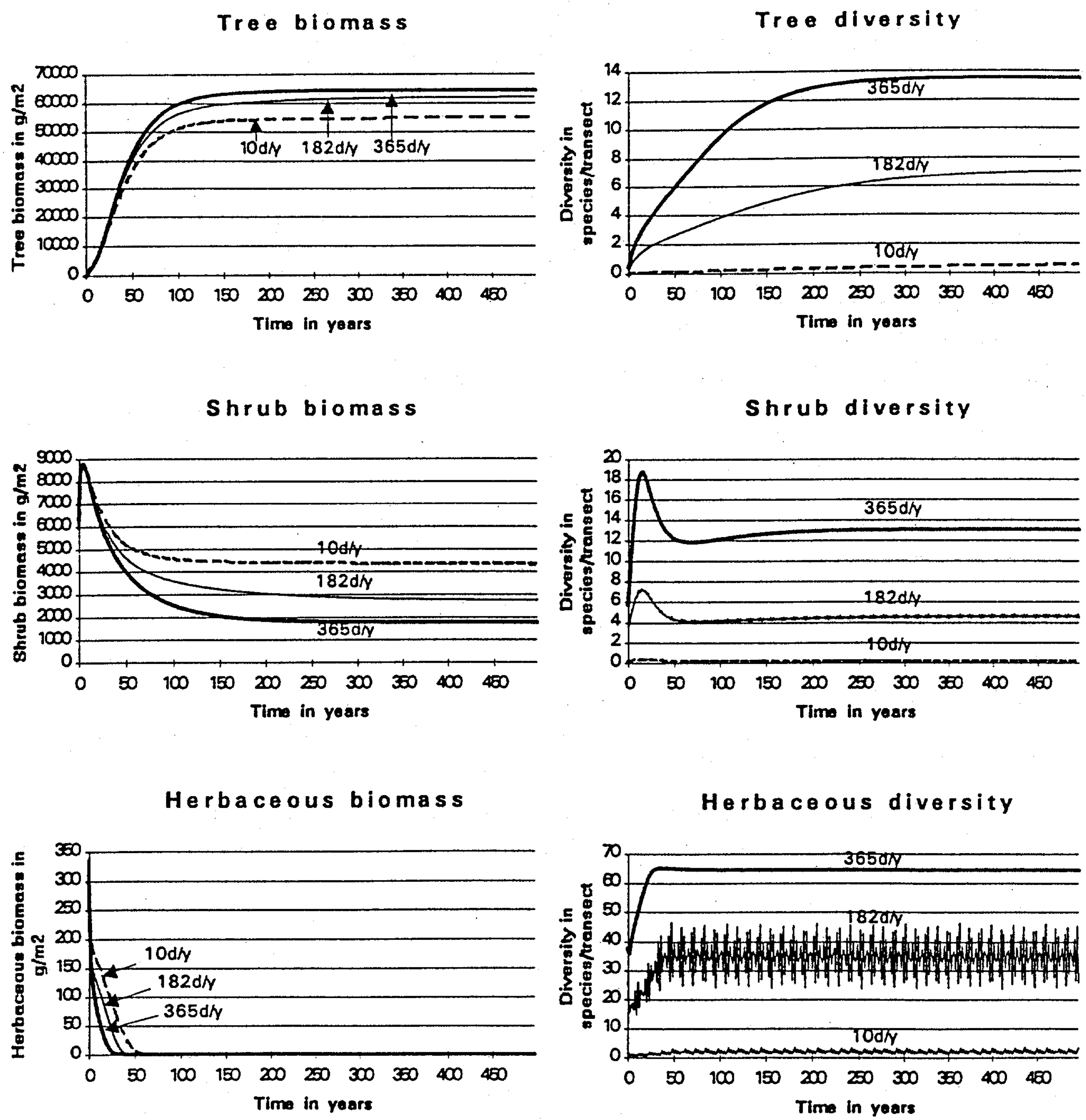


Figure 8-6. Five hundred year simulation results of the central Florida wetlands succession model.

plotted: (1) conditions right for seed germination all the time, (2) for half the year, and (3) for 10 days/year

In Figure 8-4, the simulation results show herbaceous biomass peaking after the first year at about 500 g/m^2 (60% of calibration value), and then decreasing. The peak was slightly higher and slightly later when germination conditions were favorable 10 days/year than when favorable more often. Biomass, after the first year, decreased more gradually as the timespan of favorable germination conditions was shorter. In Figure 8-5, when conditions were right year-round, herbaceous biomass minimized in 25-30 years, when right half the year, in 35-40 years, and when right 10 days/year, in 50 years.

When germination conditions were favorable all year, the simulation results (Figure 8-4) show herbaceous diversity peaking after about a year at 43 species/transect (30% of calibration value). Diversity then declined for a year to 36 species/transect, stayed at this level for a year, and then climbed for 25 years (Figure 8-5) to a steady state of 65 species/transect (40% of calibration value). When germination conditions were favorable only half the year, herbaceous diversity peaked after half a year at 37 species/transect. Diversity then declined, oscillating with the frequency of germination (decreasing half the year when conditions were unfavorable, and increasing half the year when conditions were favorable), to a mean of 17 species/transect. A mean steady state diversity of 35 species/transect (20% of calibration value) was achieved after about 30 years. The oscillation amplitude varied from 10 species/transect (± 30% from the mean) to 20 species/transect (also ± 30% from the mean). When germination conditions were favorable only 10 days/year, herbaceous diversity remained at a very low level, oscillating between one and two species/transect.

Figure 8-4 shows simulation results for shrub biomass peaking after 4 years, to 9 kg/m^2 (90% of calibration value). After about 7 years, it began declining (Figure 8-5). When germination conditions were always right, shrub biomass declined to a steady-state value of 1.9 kg/m^2 (20% of calibration value), 150-200 years after the simulation began (Figure 8-6). When germination conditions were right half the year, biomass reduced to a steady-state value of 2.4 kg/m^2 (25% of calibration value), also by 150-200 years. When germination conditions were right only 10 days/year, biomass reduced to a steady-state value of 4.2 kg/m^2 (40% of calibration value), about 100 years after the simulation began.

Simulation results for shrub diversity show diversity climbing for about 15 years to 18 species/transect (60% of calibration value), when germination conditions were favorable all year. It then declined for about 50 years to 12 species/transect; and then increased again very slowly for about 100 years to a steady state of 13 species/transect (40% of calibration value). When conditions were favorable only half the year, shrub diversity followed the same ‘pattern as above, but climbed to only 7 species/transect, declined to 4 species/transect, and then climbed to a steady state of 5 species/transect (20% of calibration value). Like herbaceous diversity, shrub diversity oscillated with the frequency of germination, varying at most by 1 species/transect semiannually. When germination conditions were favorable only 10 days/year, shrub diversity remained at only one species/transect (a monoculture).

Tree biomass followed a sigmoid curve, reaching a steady-state maximum after 150 years (Figure 8-6). When germination conditions were favorable all year, biomass reached 65 kg/m^2 (100% of calibration value). When germination conditions were favorable half the year, biomass reached only 62 kg/m^2 (95% of calibration value), and only about 55 kg^2/m (85% of calibration value) when germination conditions were favorable only 10 days/year.

Tree diversity reached a steady-state maximum of 13.5 species/transect (100% of calibration value), by 250 years when germination conditions were favorable all year (Figure 8-6). The simulation results show tree diversity reaching a steady-state of only 7 species/transect (50% of calibration value) in 350-400 years, when conditions were favorable half the year. When conditions were favorable only 10 days/year, tree diversity remained minimal (a monoculture).

Simulation of Wetlands Reclamation - Figures 8-7, 8-8, and 8-9 show simulation results for succession on a forested wetland reclamation site. Initial conditions simulated 10 tree species planted on a bare site (based on a range of 7-13 in tree-planting data). No shrubs or herbs were planted. Initial tree biomass was (100 g/tree)(1000 trees/acre)(1 acre/43,560 ft^2)(1 dt2/0.0929 m^2) = 25 g/m. Outside seed sources comprised one tree species (elm, *Ulmus* spp.), one shrub species (willow; *Salix* spp.), and 2 herbaceous species *(Typha sp.* and *Ludwigia sp.).* Figure 8-7 simulates regrowth for 5 years, Figure 8-8 for 50 years, and Figure 8-9 for 500 years. Two different scenarios were plotted: (1) conditions right for seed germination all the time, and (2) conditions right for half the year.

The simulation results in Figures 8-8 and 8-9, show tree biomass reaching a steady-state biomass of 64 kg/m^2 (100% of calibration value) when germination conditions were favorable all year. Tree diversity declined slightly during the first 10 years, to 9.4 species/transect, and then began to rise, reaching the initial value of 10 species/transect by year 35. When conditions were favorable half the year, tree biomass reached a steady-state of 61 kg/m^2 (95% of calibration value) and tree diversity declined continually for 350 years, reaching a steady-state of 6.3 species/transect.

The simulation results show, when germination conditions were favorable all year, shrub biomass climbing for 4 years to 8 kg/m^2 (80% of calibration value), then declining, reaching steady-state by year 100. The final biomass was 2.2 kg/m^2 (20% of calibration value). When conditions were favorable only half the year, the final biomass was somewhat higher: 3 kg/m^2 (30% of calibration value). Shrub diversity remained at one species/transect or lower.

For both germination period cases, herbaceous biomass peaked in less than a year, climbing to about 480 g/m^2 (55% of calibration value), and then declined. The decline was rapid at first, and then slowed. Herbaceous vegetation was mostly gone by year 25. Herbaceous diversity remained at one species/transect or lower.

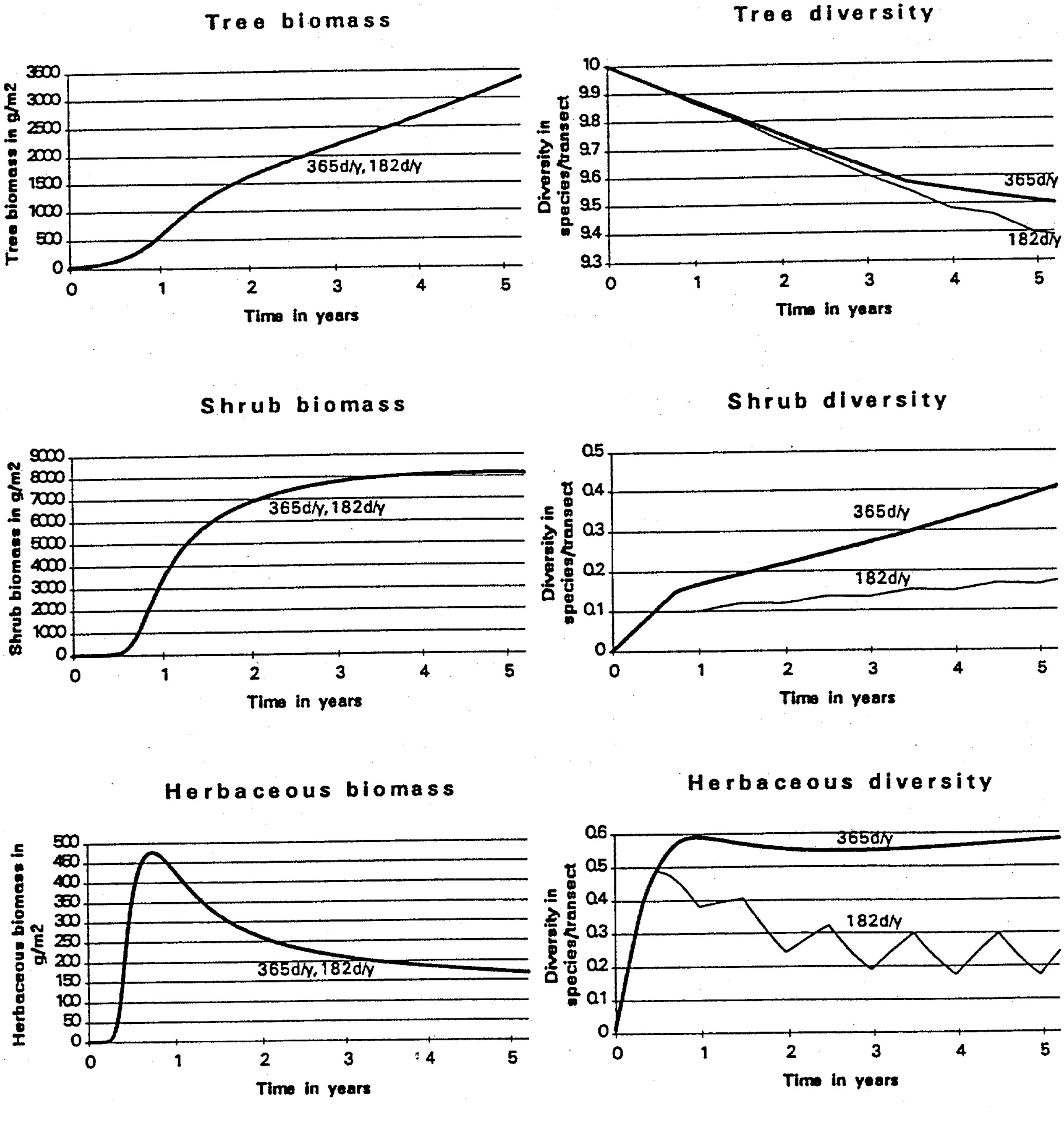


Figure 8-7. Five year simulation results of the central Florida wetlands succession model with conditions set for phosphate reclamation.

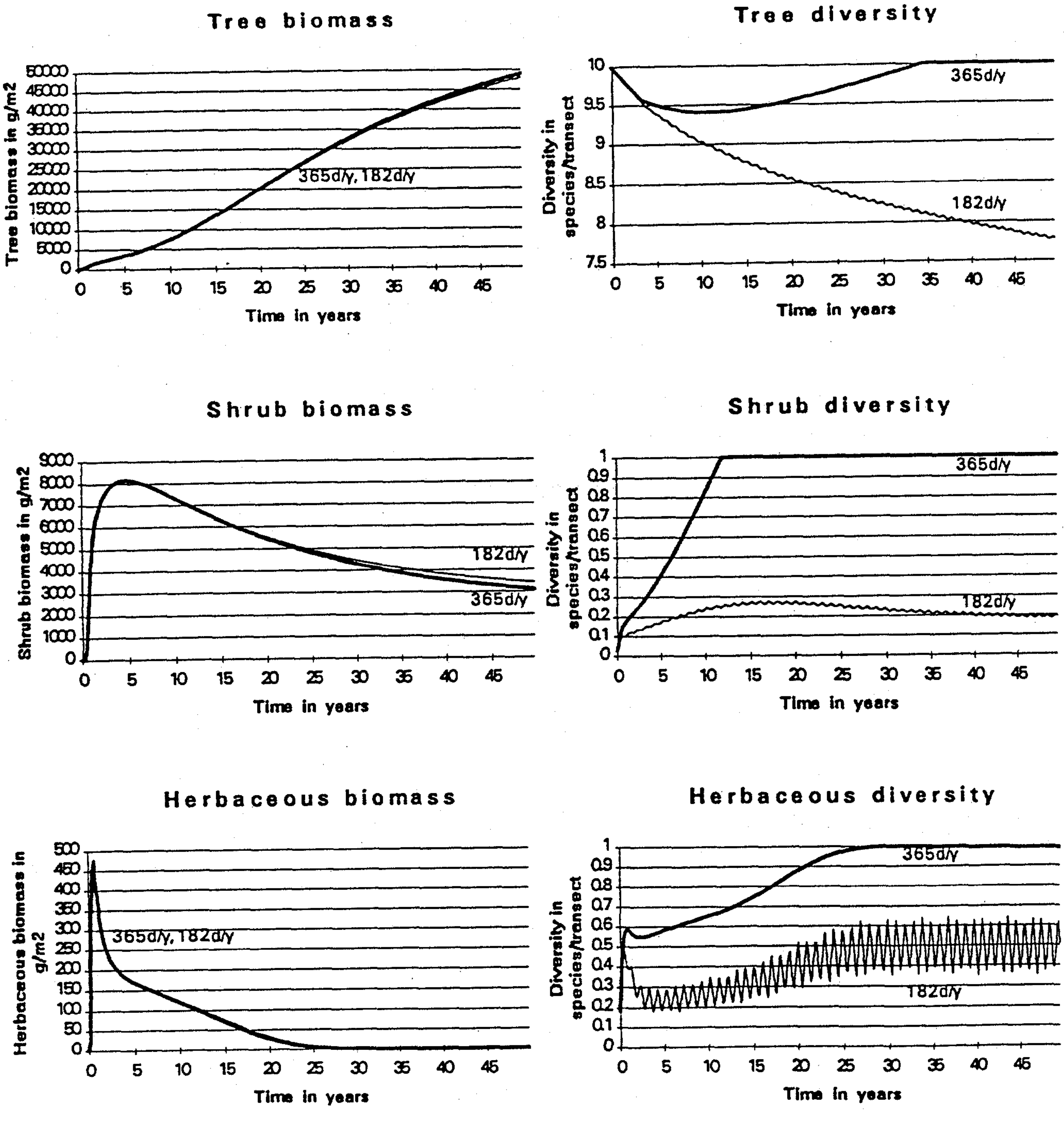


Figure 8-8. Fifty year simulation results of the central Florida wetlands succession model with conditions set for phosphate reclamation.

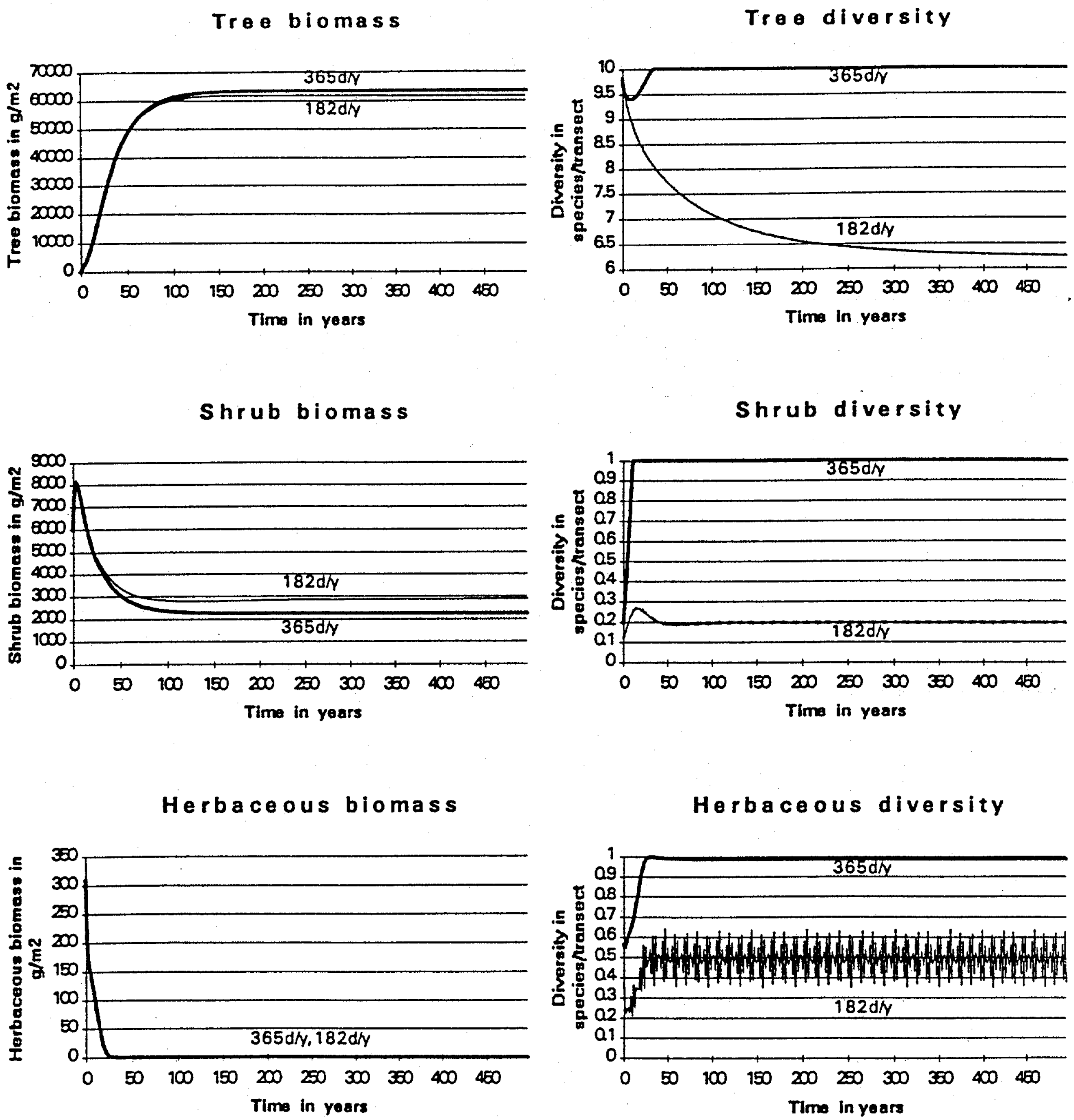


Figure 8-9. Five hundred year simulation results of the central Florida wetlands succession model for conditions set for phosphate reclamation.

Discussion - The natural reseeding simulation (Figures 8-4, 8-5 and 8-6) showed herbaceous biomass and diversity growing rapidly to cover the bare site, and then, after the first year, decreasing as shrubs outgrew and shaded them Shrub invasion prevented herb biomass and diversity from reaching their maximum values, as in a marsh climax where woody species cannot establish. After shading, herbaceous biomass decreased less rapidly as germination conditions were less often favorable. This was because shrub diversity increased more slowly as conditions for germination were right less frequently. Initial and/or more competitive species dominated longer with less introduction of outside species, and short-lived seeds decayed instead of germinating. With a less diverse shrub canopy, more light was available for herbaceous growth.

In contrast to herbaceous biomass, the simulation results suggested that if germination conditions were right less frequently, lower herbaceous diversity resulted. As with shrubs and trees, diversity did not increase when seeds could not establish, and initial species dominated longer. Some species also outcompete others (the quadratic drain from the diversity storage); in the absence of reseeding, this decreased diversity. Diversity oscillated with germination conditions, increasing when conditions were right, and decreasing when they were not. The amplitude of this oscillation was inversely proportional to the diversity turnover time: herbs, which establish and grow rapidly, varied much more in diversity than shrubs, which were slower to establish and grow. The oscillation of tree diversity was almost insignificant. Although shade-intolerant species were eliminated, after 3 years, herbaceous diversity increased again, eventually reaching 40% of marsh climax value when conditions for germination were always right.

Shrub biomass peaked in the simulation after 4 years, at about 90% of its maximum value in the absence of competition. Trees began to shade shrubs out after about 7 years. When germination conditions were always right, shrub biomass was reduced to a steady-state value of 20% of maximum. Like herbaceous plants, shrub biomass decreased less rapidly as germination conditions were favorable less often, and tree diversity was less. With a less diverse tree canopy, more light was available for shrub growth.

Shrub diversity peaked between 15 and 20 years, at about 60% of its maximum value in the absence of competition. Shading by trees subsequently eliminated many species. Similar to herbaceous diversity, shrub diversity was proportional to the timespan of favorable germination conditions, and oscillated slightly.

The model maximized tree biomass after 150 years (Figure 8-6). Diversity climaxes after 250 years, representing the replacement of cypress by mixed hardwoods. Biomass and diversity were both proportional to the timespan of favorable germination conditions. Biomass was proportional to diversity because diversity captures additional energy. The simulation showed three different endpoints of wetland succession in the absence of disturbances like fire or logging. When conditions were always, or nearly always, favorable for tree seed germination, the final endpoint was a mixed hardwood forest. When conditions were right about half the year, the final endpoint was a mixed hardwood-cypress forest, or a hardwood forest of lower diversity. When germination conditions were rarely favorable (for example, almost continuous inundation), the final endpoint was a cypress forest. This model assumed that cypress seeds were available from nearby sources. If the seed inflow is different from that modeled, the resultant floral community may be different: for example, if red maple *(Acer rubrum)* is the only available seed donor, a red maple monoculture will obviously be the successional endpoint in all three germination cases,

In the simulation of the forested wetland reclamation site (Figures 8-7, 8-8, and 8-9), initial planting sped the growth of tree biomass slightly as compared to natural reseeding. However, in the case of phosphate mined areas, nearby seed sources may not be available. When germination conditions were always favorable, tree diversity declined slightly initially, as elms invaded the site and displaced other species. However, as planted trees reached maturity and produced seeds, diversity climbed back to its initial value. When germination conditions were favorable only half the year, tree diversity continued to decline, reaching a steady-state value of 60% of planted diversity.

Shrubs (willows) quickly dominated the modeled reclamation site at first, reaching a density of 8 kg/m^2 after 3 years. After about 5 years, trees began to displace willows, surpassing them in biomass after about 10 years. Willow biomass declined to a steady-state value of 2-3 kg/m^2 (depending on germination conditions); a willow under-story persisted indefinitely.

Typha and *Ludwigia* also invaded the site at first, but after the first year, were reduced by willow shading. However, they were persistent for up to 25 years, until the tree canopy was sufficiently dense.

In this simulation, neither willow nor herbaceous invasion affected the long-term survivability, growth, or natural propagation of planted trees. However, without introduction of a diverse array of shrubs or herbs, the resultant monoculture under-story and ground cover would not support much of the wildlife found in natural forested wetlands. Decline of tree diversity over time was proportional to the absence of natural reseeding opportunities; the less often conditions were favorable, the worse the repropagation of less competitive species.

LANDSCAPE ECOLOGY

ARCInfo Data Base - The creation of the ARCInfo data base has been a long and arduous task. We have sifted through available permit and monitoring information and have requested maps from each of the companies for the reclamation sites that were visited by the team

Figures 8-10 and 8-11 summarize the availability of map data for all sites visited. The “no data” category should be clarified somewhat, for there were numerous sites visited (reference areas, some active disposal sites, etc) for which map data would not be expected. We estimate that about 1/3 of the sites with no data are naturally reclaimed, references sites, clay settling areas, active disposal areas, etc. Eighty-tie reclamation sites had good quality vegetation maps while only 62 sites had good quality topographic information. In all, we have some type of vegetation map for 133 sites and 92 sites with topographic information.

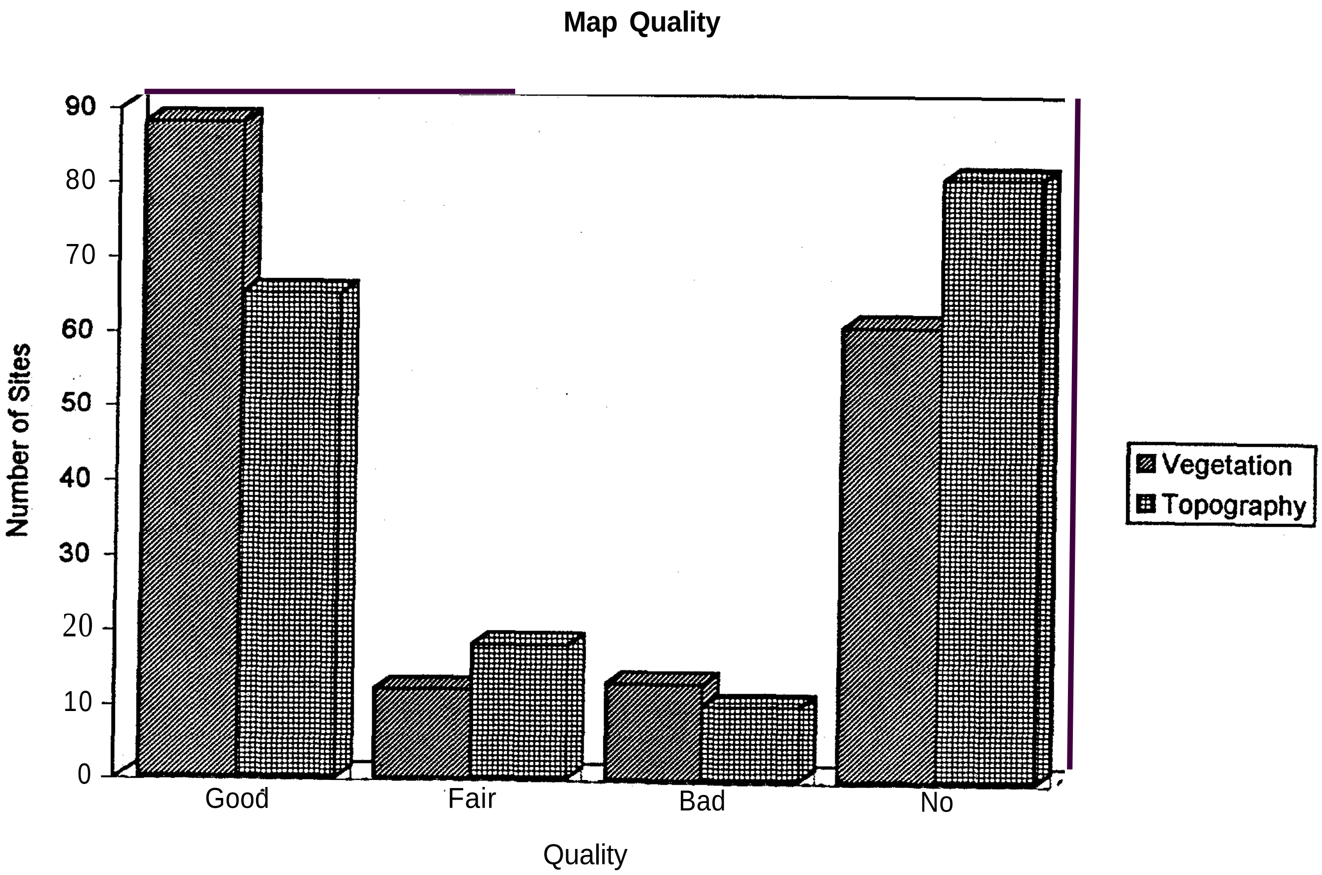
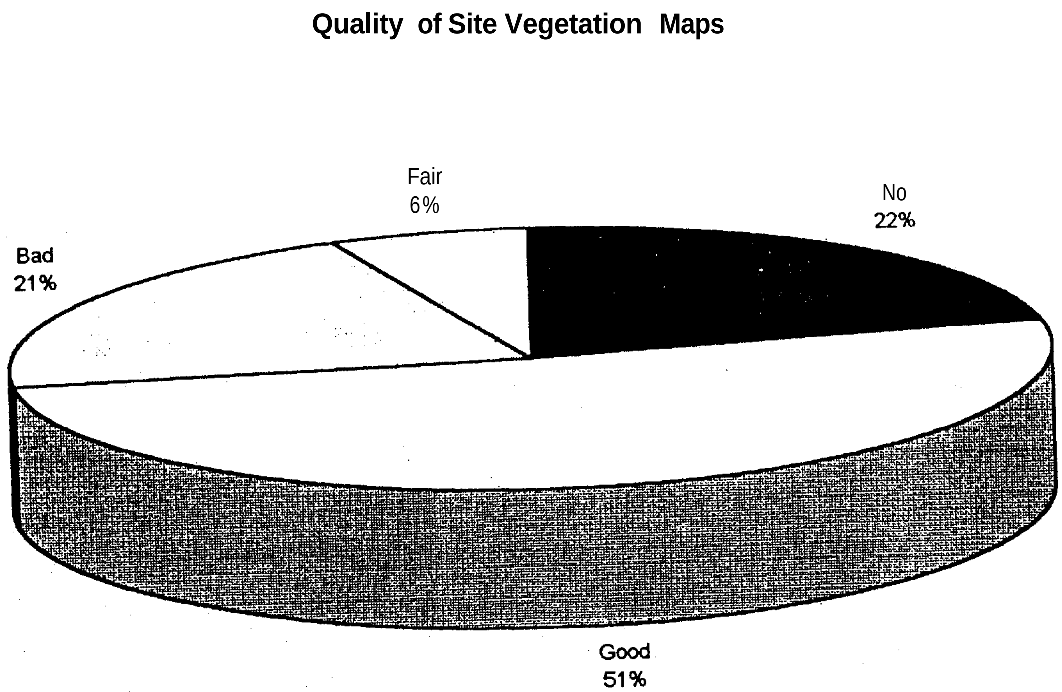


Figure 8-10. Graph of map quality showing the number of sites and the quality of vegetation and topographic maps



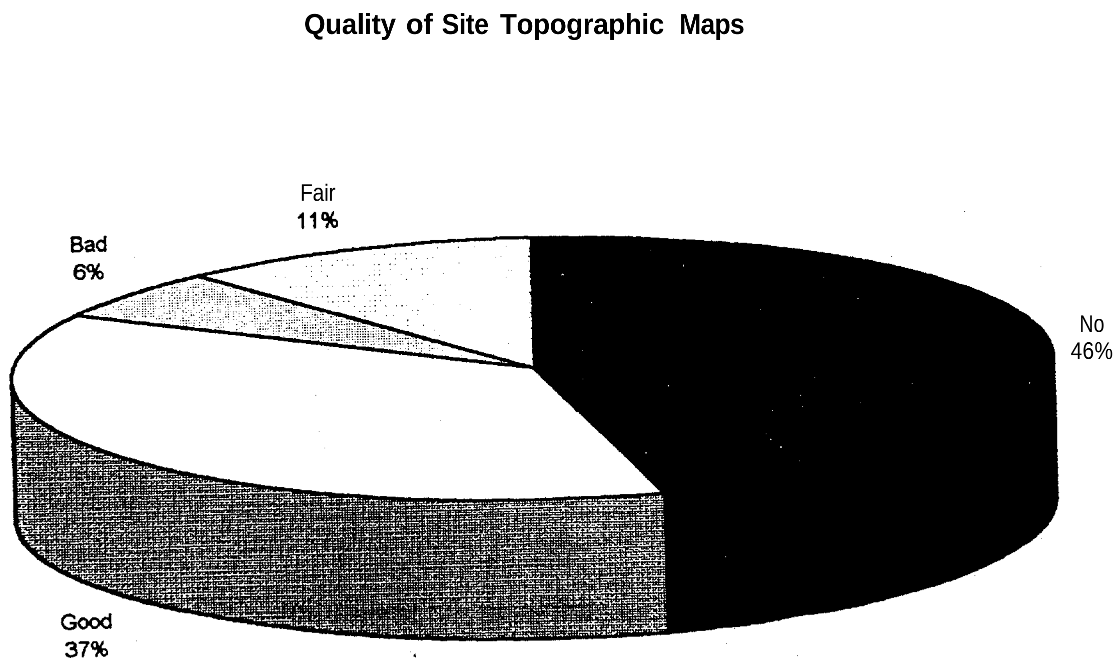


Figure 8-11. Charts showing the quality of vegetation maps (top) and topographic maps (bottom)

Given in Maps 1, 2, and 3 are example land use/land cover maps for three reclamation sites showing the site and surrounding 800 meter buffer. The 800 meter buffer was used in many of the connectedness and fitness evaluations of the wetland sites. While these maps are included as examples, they were chosen to illustrate three common landscape conditions: connection to a natural forested area, connection to a reclaimed area, and isolated (surrounded by mined land).

Analysis of "Ecolotical Connectedness" - Figure 8-12 summarizes the analysis of ecological connectedness for sites which have been integrated into the GIS database. The top figure shows the percentage of site boundaries that are shared with natural land, agricultural and range land, and mined land. A significant majority of project boundaries were shared with mined land (71%) while only 16% of project boundaries were in common with natural lands, and 13% of boundaries were shared with agricultural lands.

Another way to express connectedness is shown in the bottom two diagrams in Figure 8-12. These diagrams show the percentage of sites that are connected. When the criteria for connection is at least 25% of project boundary, about 40% of projects are connected to natural lands. When the criteria are relaxed so that any size connection is considered a connection with natural lands, about 50% of sites are ecologically connected. Thus, depending on definition, between 50% and 60% of reclamation sites are being constructed completely isolated from existing natural areas. Many of these probably will eventually be connected together with other reclaimed ecosystems, but at present they are isolated.

We visually evaluated site connectedness to "core habitat reserves" (as proposed by King and Cates, 1994) and found that of the sites for which we have data, 24% were connected to core habitat reserves or stream corridors that were connected to core habitats.

The presence or absence of corridors connecting wetland cover types within reclamation sites was analyzed visually from the GIS data base. Corridors were defined in this study as any type of forested community that linked wetland areas on a particular site. Corridors were found to exist on 89% of all the reclamation sites.

Analysis of "Hydrological Connectivity" - The top diagram in Figure 8-13 summarizes data for hydrological connectivity. Of the sites integrated in the database, 51% were located in first order drainage basins, 16% were located in second order drainage basins, 10% in third order drainage basins, and 23% were either in non-connected drainage status, or their drainage could not be determined.

Position (upper third, middle third, or lower third; more or less corresponding to headwaters, mid-reach, and lower reach as classified by Gross [1991] and Sullivan, [1991]) was visually estimated to evaluate trends in within basin position. Shown in the bottom diagram in Figure 8-13, about 43% of the reclamation sites were located in the upper third of their respective drainage basins (a majority of which were in 1st order basins), 40% are in the middle zone of the basin and 17% are in the lower third.

Figure Percent of Project Boundaries by Landscape Uses

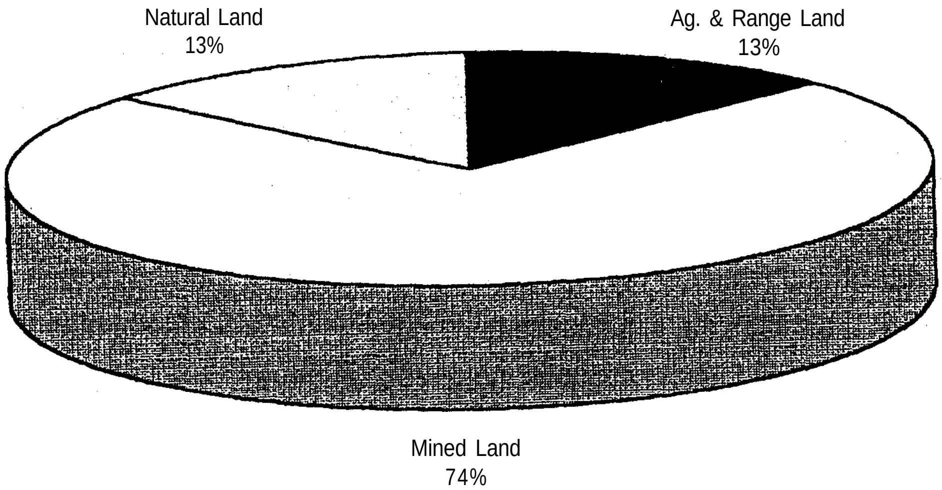


Figure Percentage of Ecologically Connected Sites (1)

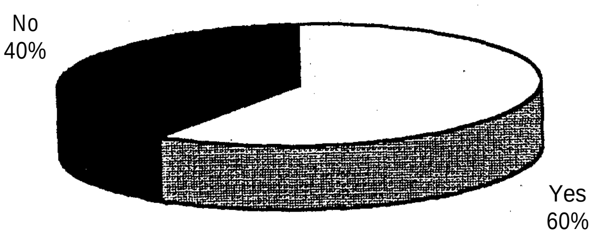


Figure Percentage of Ecologically Connected Sites (2)

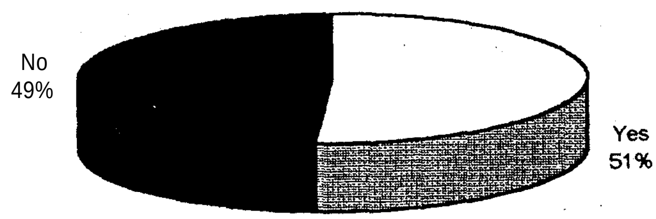
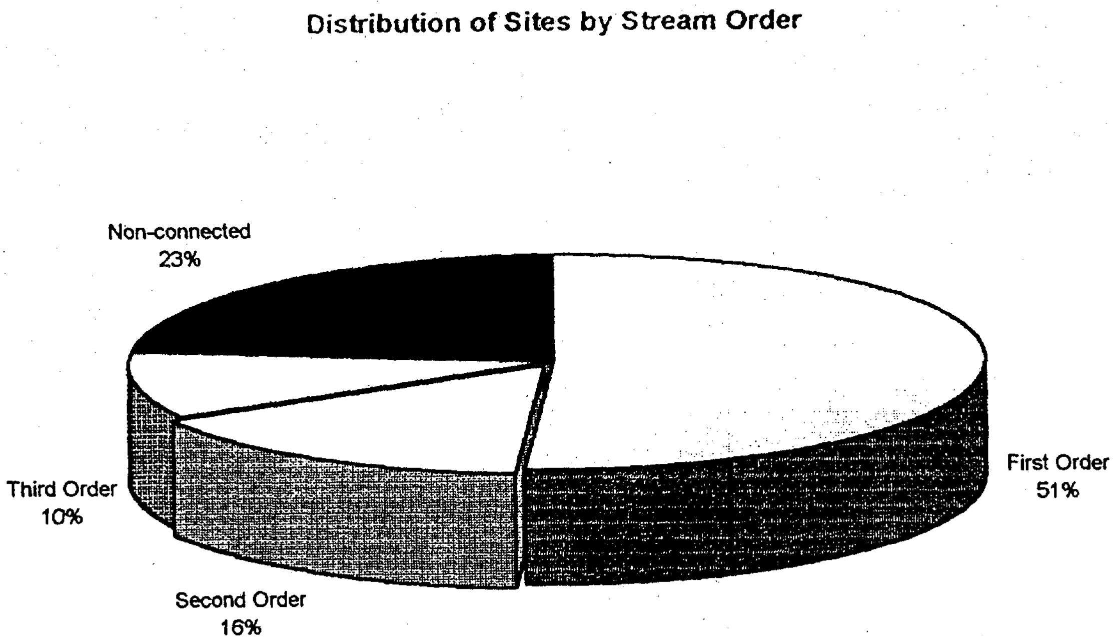


Figure 8-12. Summary of reclamation site ecological connectedness. Top diagram summarizes percent of boundaries shared with mined, natural, and agricultural lands. Bottom diagrams summarize two different definitions of connectedness.



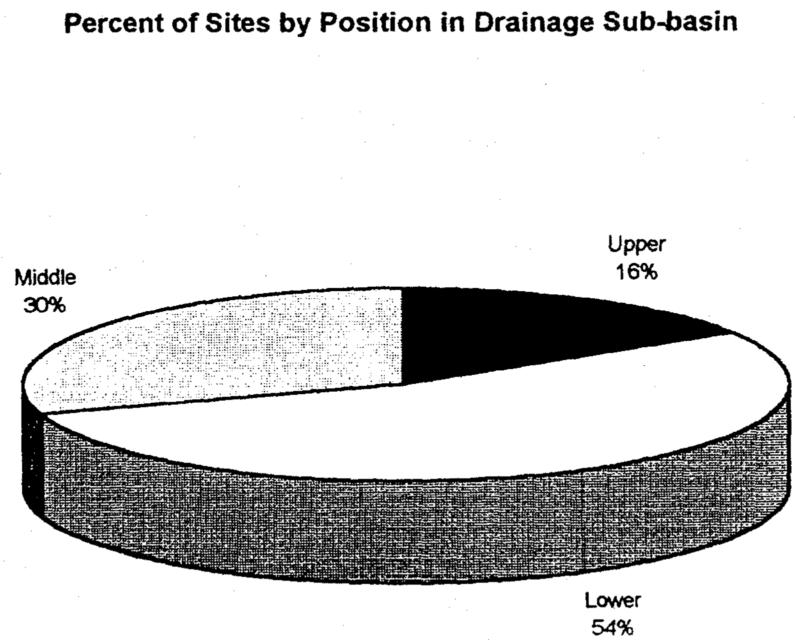


Figure 8-13. Summary of reclamation site hydrologic connectedness showing the percentage of reclamation sites in first, second third and fourth order drainage basins (top), and the percentage of reclamation sites in the upper third, middle third, and lower third of their drainage basins.

Based on the finding of Sullivan (1991) related to native Florida hydrologic basins, a higher percentage of wetlands in the upper zone should be of isolated types (cypress domes, isolated marshes, and bayheads) and the landscape association should be dominated by pine flatwoods with isolated wetlands. In the upper zones, there were 43% of constructed wetlands that had no apparent hydrological connection to downstream channelways and 57% that did have a connection,

Wetlands generally make up a higher percentage of the surface area of the headwaters and upper regions of drainage basins than in the lower reaches (Sullivan, 1991). The trend for a larger number of sites located in the upper areas of the drainage basin tends to agree with her analysis of native Florida drainage basins.

Analysis of "Community Fitness" - Community fitness results from the interplay of land covers within a reclamation as well as the interplay of the site with surrounding lands. Several separate indices were calculated, that taken as a whole address how well reclamation sites and their associated land covers fit within the larger landscape mosaic.

Land Use/Cover Richness - The mean area for the reclaimed sites under study was 172.86 ha. Fifty-four percent of sites were between 0 and 130 hectares, 37.7% were between 140 and 270 hectares, 8.2% were greater than 280 hectares.

Figure 8-14 summarizes the occurrence of each type of land cover within all reclamation sites. The most common single land cover types in order of occurrence were identified as agricultural land (27%), marshes (14%) and, tree plantations (12.5%), forested-mixed wetlands and lakes (11% each). Combining land cover types into level 1 classifications the following percent occurrences result: Agriculture, 30%; forests, 27%; water, 12%; wetlands about 31%.

Figure 8-15 summarizes percent cover of land cover types grouped according to reclamation site size class. The FLUCSID codes on the horizontal axis of the graphs in Figure 8-16 illustrate a gradient that may be loosely interpreted as drier, upland sites on the left side of the axis, proceeding to wetland areas on the right. The one exception, of course, is deep water areas, classified as (5200).

In all 3 size classes, the dominant land cover type identified was cropland and pasture land (2100); occupying about 35% of size class A, about 23% of size class B and about 32% of the largest sites. Upland forests (4200 thru 4400) accounted for about 20% of size class A area, about 21% of size class B, and about 20% of size class C. Lakes (5200) were about 19% of Size class A, about 13% of size class B, and about 10% of size class C. Wetlands (6100 thru 6400) accounted for about 24% of size class A area, about 23% of size class B, and about 34% of size class C. Pineland communities (4100) account for only about 2% of size class A, about 5% of size class B , and about 1% of size class C. The dominant forest type in both B and C size classes was tree plantations (4400), accounting for about 75% of all forests in both classes. Tree plantations accounted for about 40% of all forests planted in size class A. Pine forests and tree

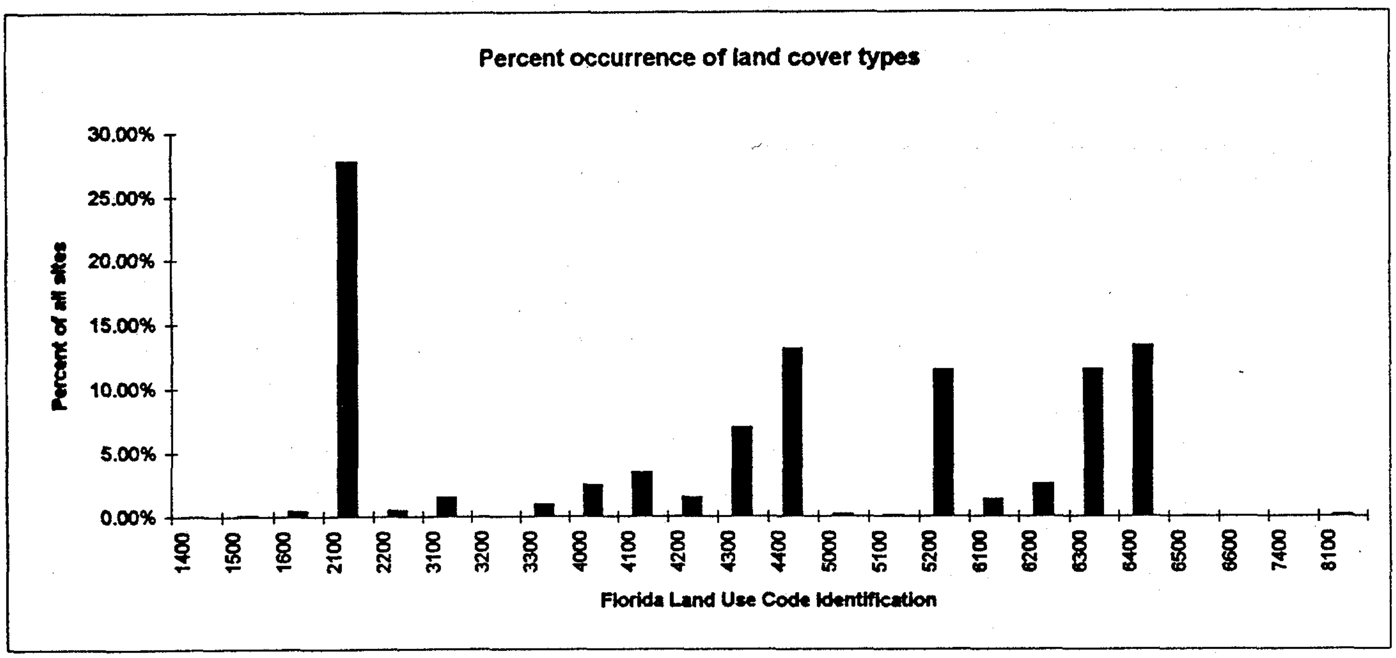


Figure 8-14. Summary of the percent occurrence of land use/land cover types on all reclamation sites.

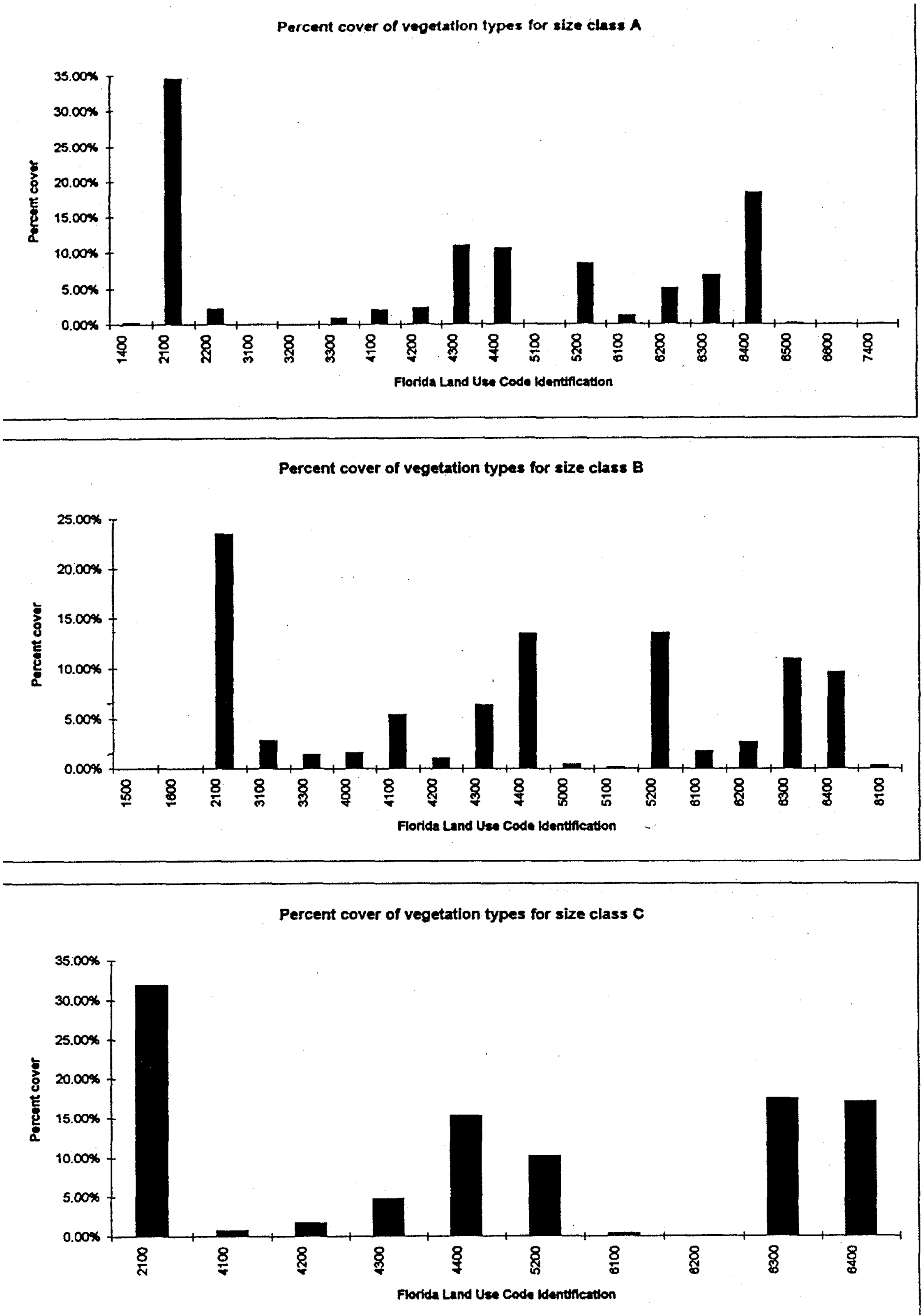


Figure 8-15. Summary of percent cover of vegetation types on reclamation sites. The top graph shows percent cover of vegetation types for size class A, middle is for size class B, and bottom is for size class C

plantations combined, account for about 16% of size classes A and B and about 20% of size class C.

It appears that reclamation sites are dominated by agricultural and range land. Marshes are the dominant wetland community type constructed on the smaller sites, forested wetlands comprise about 65% of the wetland communities on size class B sites, and there are equal percentages of marshes and forested wetlands constructed on the largest sites.

Site Complexity - Figure 8-16 illustrates the average number of polygons per site according to reclamation site size class. In the top graph of Figure 8-15, average number of polygons are between 11 and 30 per site and, as one might expect, the larger sites generally contained more polygons than the smaller sites. When viewed as unique polygons (that is unique land cover types), size class A averaged about 4.5 unique land covers per site and size classes B and C averaged about 5 unique polygons per site (Middle graph Figure 8-16).

Perimeter/area ratios were used to calculate relative complexity of the reclamation sites. The results from this analysis are given in the bottom graph in Figure 8-16. There is a general trend for complexity to decrease as the size of the reclamation site increases, falling by more than 50% between the smallest reclamation sites and the largest. It is difficult to determine if this trend results from the fact that more details are drawn on small site plans than on large ones, or as a result of the industry actually creating less complex landscapes on larger sites. Site visits seem to confirm the latter, where the largest sites had the largest areas associated with each land cover type.

Upland/Wetland Area Ratios - The average upland to wetland area ratio for reclamation site size classes is given in the top graph of Figure 8-17. In this graph, all wetland community types (forested, non forested) were grouped, as were all upland community types (pasture, forest, etc), and open water areas were not included. The values range from approximately 1/1 for size class C, to about 2.25/1 for size class B. The smallest sites had upland/wetland ratios of about 1.75 /1. Sullivan (1991) found that mean upland/wetland area ratios decreased significantly as basin size increased from 13/1 for basins smaller than 100 hectares, to only 3/1 for the largest basins (greater than 10,000 hectares). The reclamation site size classes fall within Sullivan's basin classes that averaged between 8 and 13 upland acres for each wetland acre. The ratios for reclaimed sites are considerably lower than those found by Sullivan.

Percent Cover of Site by Wetlands - The middle graph in Figure 8-17 illustrates the average percent cover of wetland areas (including open water areas) for reclamation site size classes. When lakes are included, the percent wetlands is about 37% in size class A, about 30% in size class B and about 50% in size class C.

Lake/Wetland Area Ratios - Summary data for lakes and wetland areas are given in the bottom graph of Figure 8-17. The average lake to wetland area ratios for each size class were significantly different between size classes. For the smallest site sizes, the ratio was 0.7/1, or

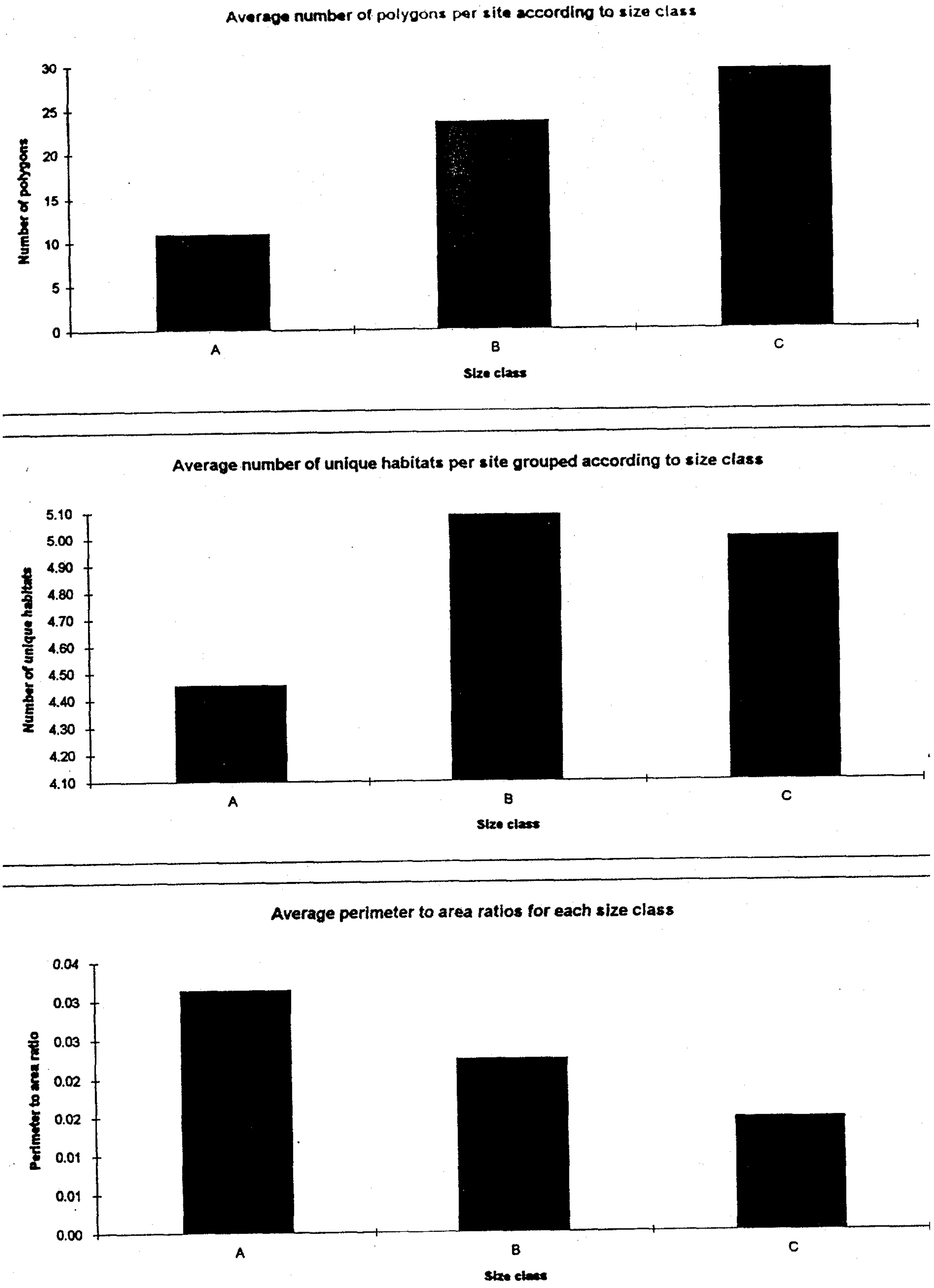


Figure 8-16. Summary of reclamation site richness and complexity, showing the average number of polygons per site (top), number of unique polygons per site (middle), and perimeter/area ratio (bottom).

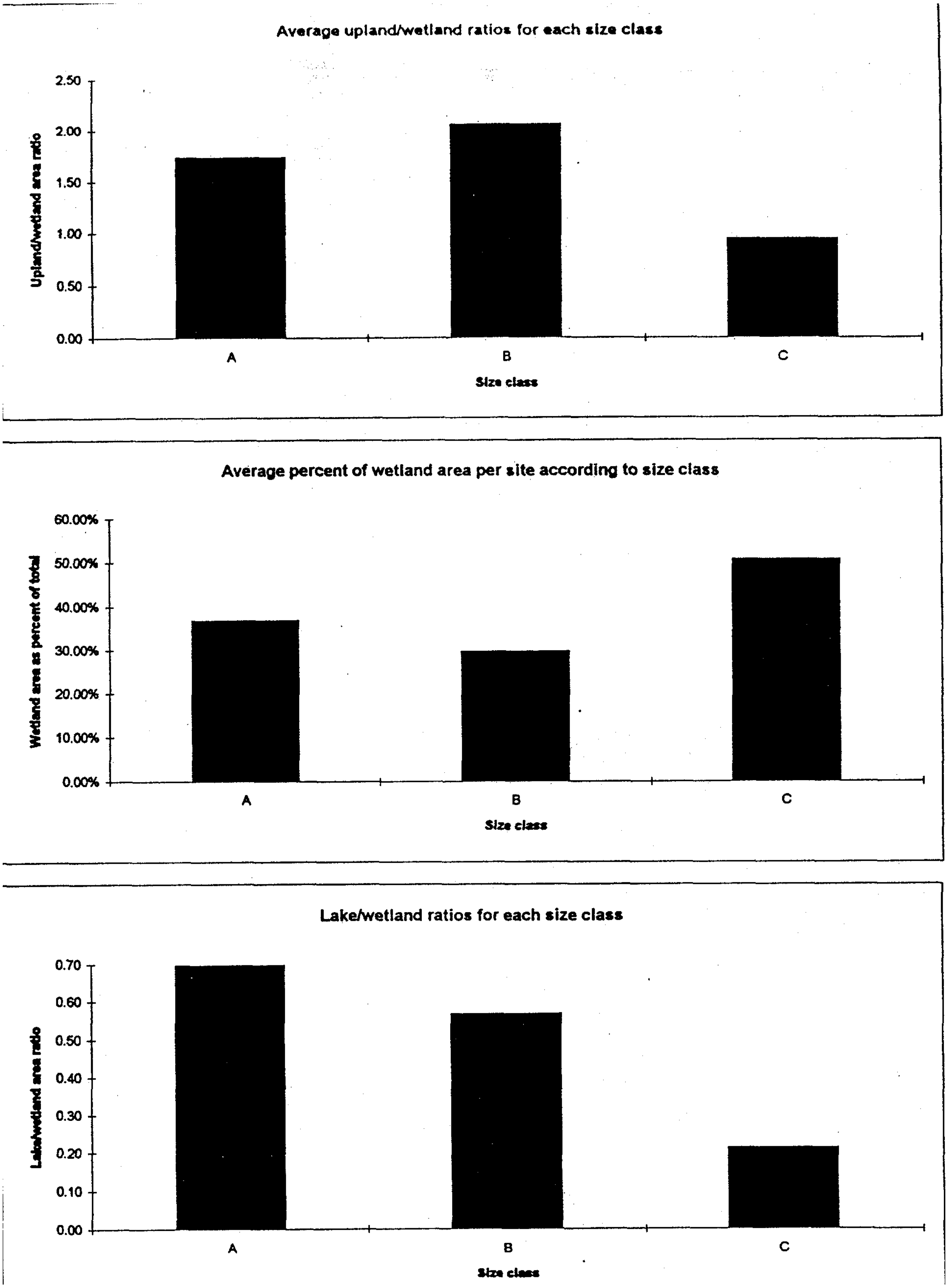


Figure 8-17. Summary of upland/wetland ratios for reclamation sites by size class (top), percent wetland area per site (middle) and lake/wetland area ratio (bottom).

about 1.4 acres of wetland for each acre of lake. The ratio was about 0.58/1 for size class B sites, or about 1.65 acres of wetland for each acre of lake. Size class C had a lake/wetland ratio of about 0.2/1 or about 5 acres of wetland for each acre of lake.

The most common community types that were associated with lakes (ie. planted around their margins) are summarized in Figure 8-18. This graph illustrates community types as a percent of all lakes margin. The vast majority of land cover types surrounding lakes were marshes (6400) comprising about 40% of all lake margins. The next most common community was mixed wetland forests (6300) planted on the average around 22% of lake margins. Pine plantation (4400) were planted on about 15% of lake margins, while cypress forests were planted on about 10% of lakes. Upland hardwood forests (4200) were planted on about 5% of lake margins.

COMPARISONS WITH NATIVE FLORIDA LANDSCAPES

Seven different Florida landscapes were evaluated for land cover richness, percent cover, site complexity, upland/wetland ratios, percent wetland, and lake/wetland ratios. Five of the landscapes were mixes of natural lands, agricultural uses and transportation corridors, and two were dominated by natural communities only. GIS coverages of each landscape were sampled using three different circular sampling frames: 65 hectares, 200 hectares, and 450 hectares. Land covers were summarized in tabular form and graphs for comparison with data from mined lands.

Figures 8-19 and 8-20 are representative graphs of land cover richness by each size class of sampling frame. Figure 8-19 shows the land cover richness for a landscape dominated by natural and agricultural uses in northern Hillsborough and southern Pasco counties. Dominated by wetlands, between 50 and 70% of all polygons in all three size classes were composed of wetland hardwood forests (10-20%) and herbaceous wetlands (about 30 to 50%). Agricultural uses and upland forests each comprised between 10 and 15% of all the polygons in each of the size classes. Figure 8-20 shows the land cover richness by size class for a landscape dominated only by natural lands located in the Green Swamp, northeast of Tampa, Florida. The percent occurrence of wetlands is quite similar to that in Figure 8-19, in which between 65 and 75% of the polygons are wetland, primarily cypress swamps and marshes. Upland forests comprise about 10 to 12% of the polygons and dry prairies (3200) make up about 5% of the polygons. Figures 8-21 and 8-22 show graphs of the percent cover of the various land covers for the same landscapes. The Hillsborough/Pasco county landscape (Figure 8-21) is dominated by agricultural uses (between 30 and 40%) in each size class. Percent cover of wetlands is between 15 and 25% of the landscape. Upland forests cover about 15%, and dry prairies between 10 and 15% of the landscape. The Green Swamp landscape (Figure 8-22) is dominated by upland coniferous forests (4100) and dry prairies (3200) totaling about 75% cover of the landscape. Percent cover of wetlands in the landscape is between 20 and 30%.

Table 8-1 summarizes indices of native and reclaimed landscapes. The indices for native landscapes are given as ranges based on the 7 landscapes analyzed. Comparison of indices shows some differences and similarities between reclaimed and native landscapes. Reclaimed landscapes have fewer polygons per unit area in all three size classes. The divergence increases as the size

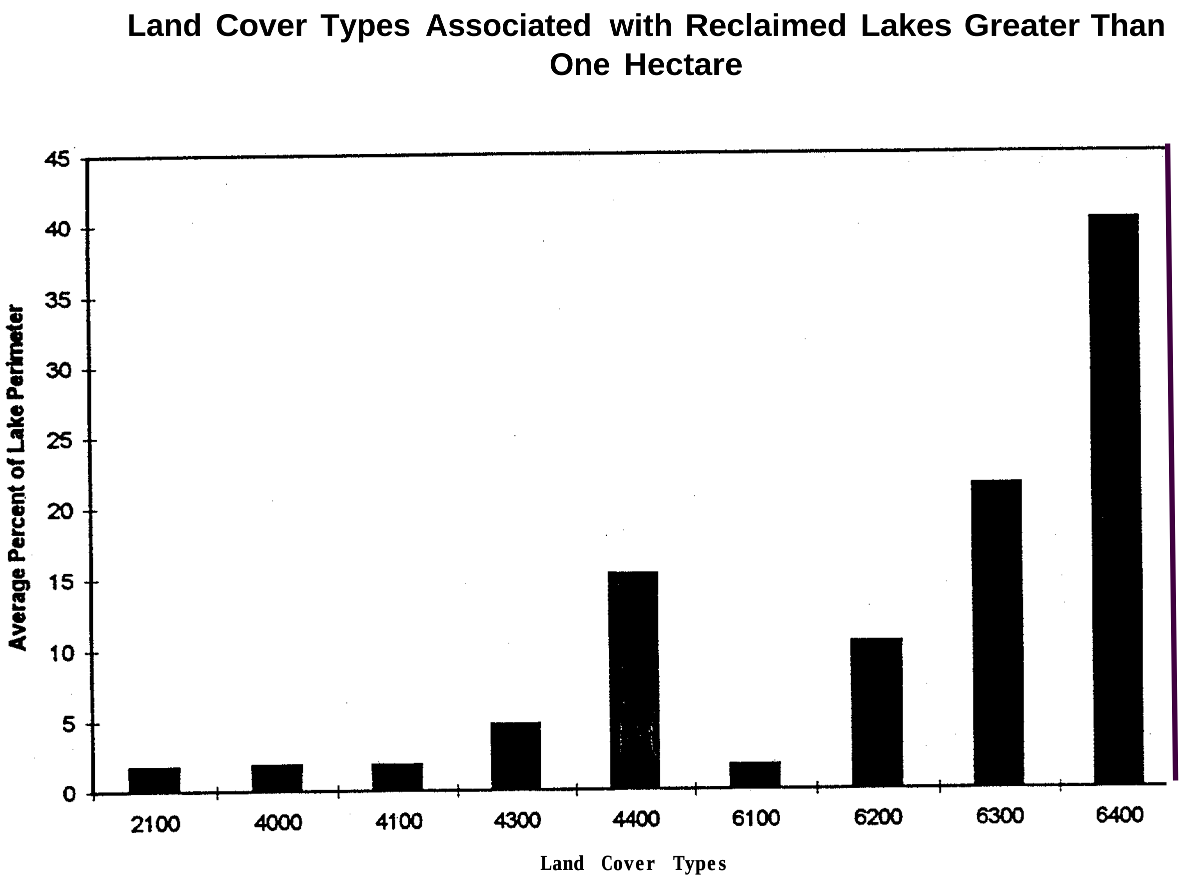
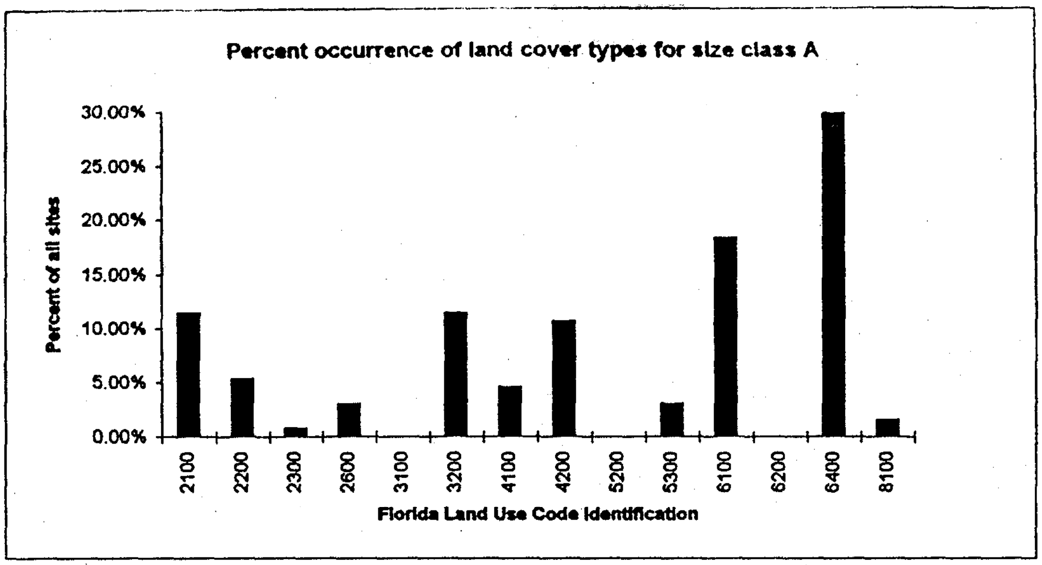
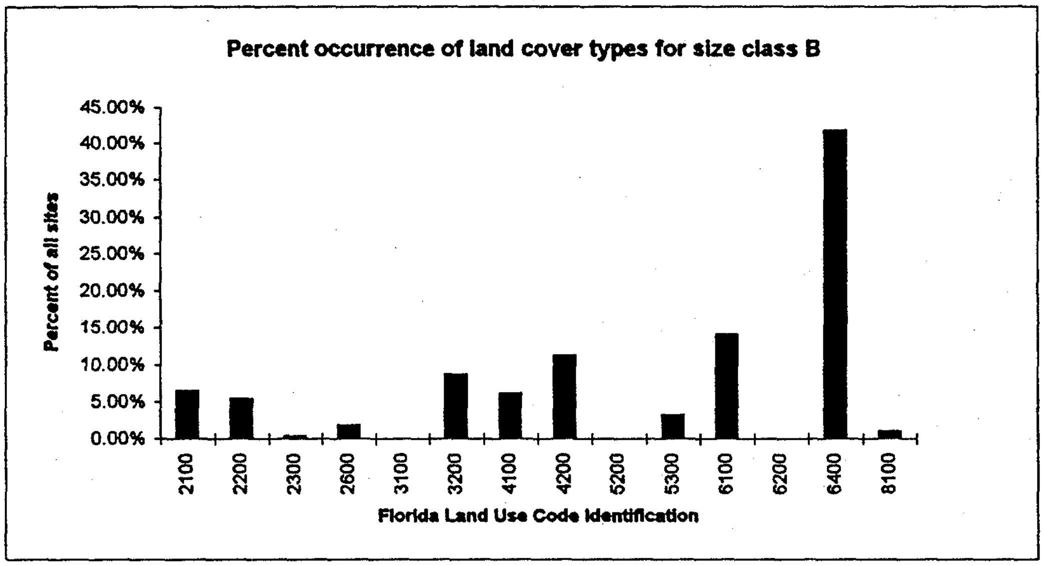


Figure 8-18. The most common community types associated with lakes (i.e. planted around their margins), illustrating community types as a percent of all lake margins.





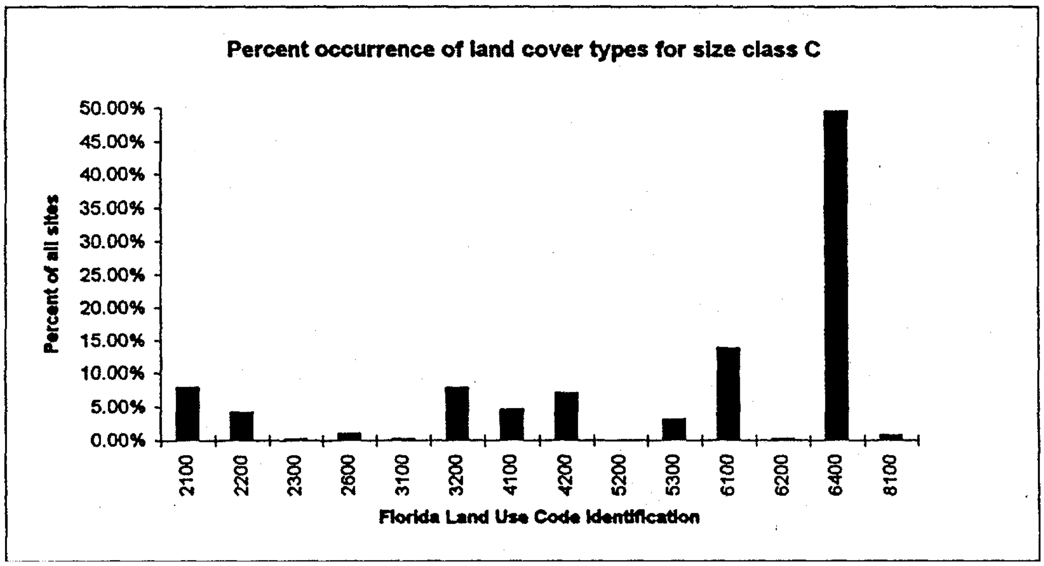


Figure 8-19. Land cover richness of a landscape dominated by natural and agricultural lands and transportation corridors. Landscape was sampled using three sample frames equal to the average size of reclamation size classes: Class A=65 hectares; Class B= 200 hectares; Class C= 450 hectares

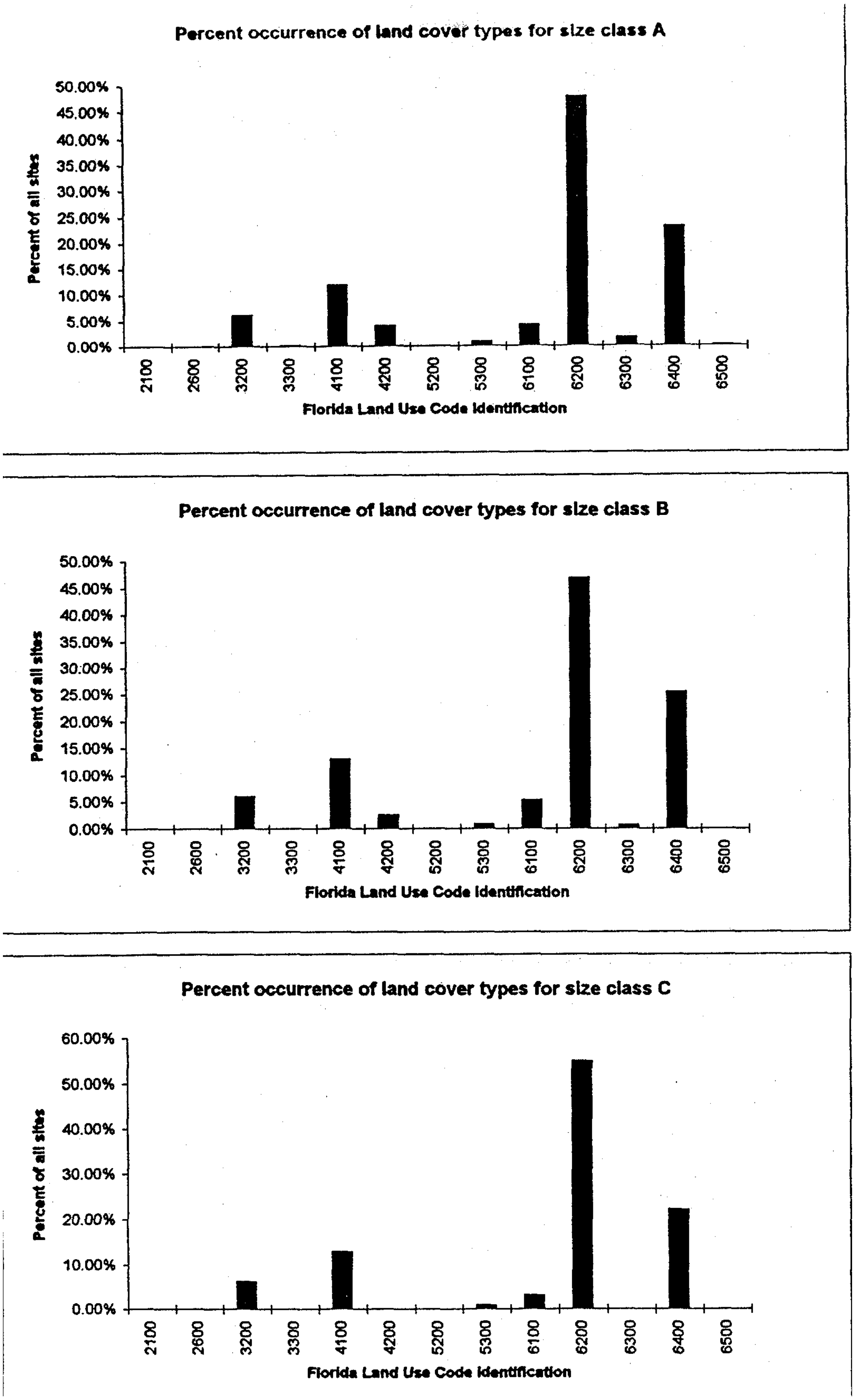


Figure 8-20. Land cover richness of a landscape dominated by natural lands. Landscape was sampled using three sample frames equal to the average size of reclamation size classes: Class A=65 hectares; Class R= 200 hectares; Class C= 450 hectares

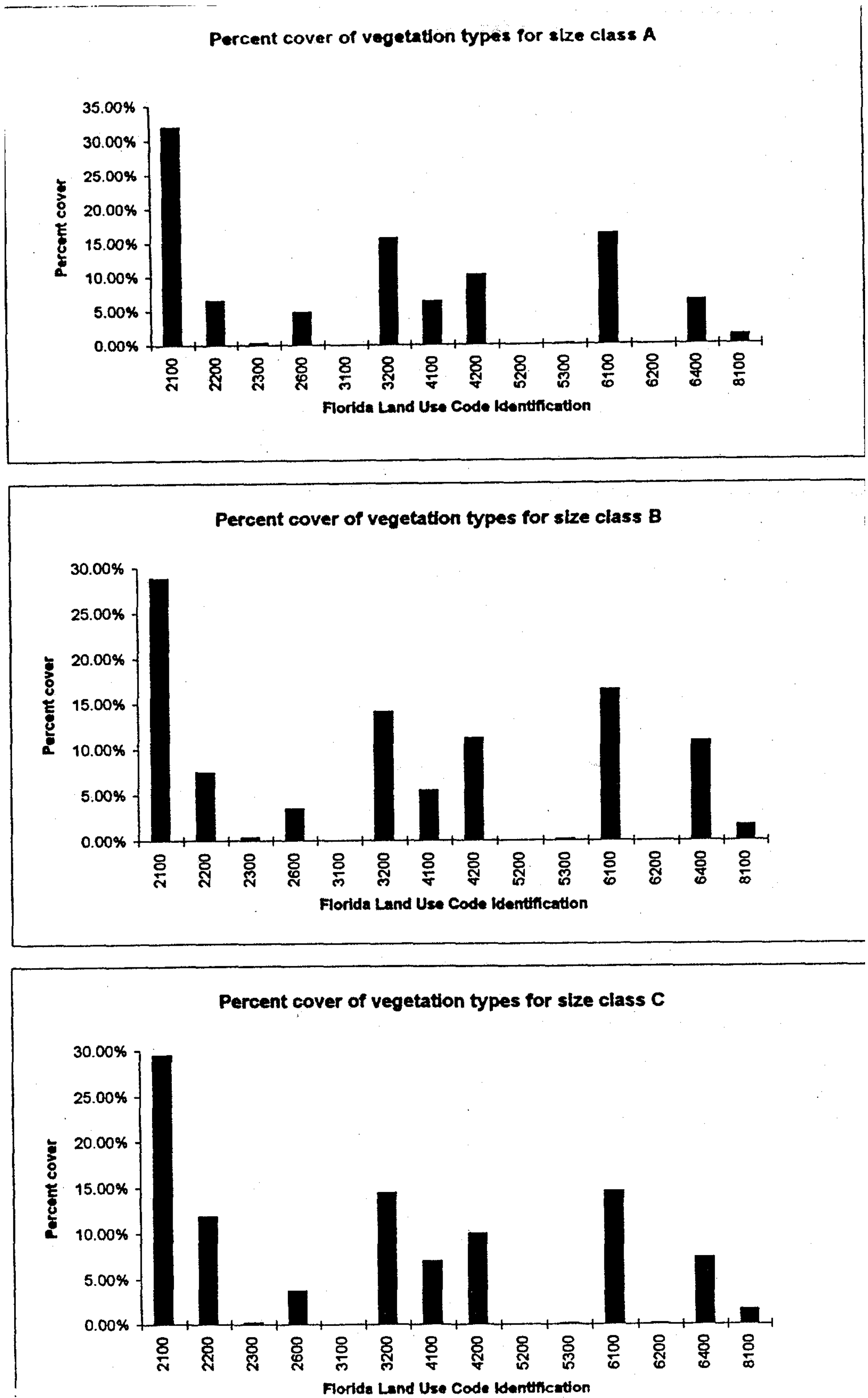


Figure 8-21. Percent cover of land cover types in a landscape dominated by natural and agricultural lands and transportation corridors. Landscape was sampled using three sample frames equal to the average size of reclamation size classes: Class A = 65 hectares; Class B = 200 hectares; Class C = 450 hectares.

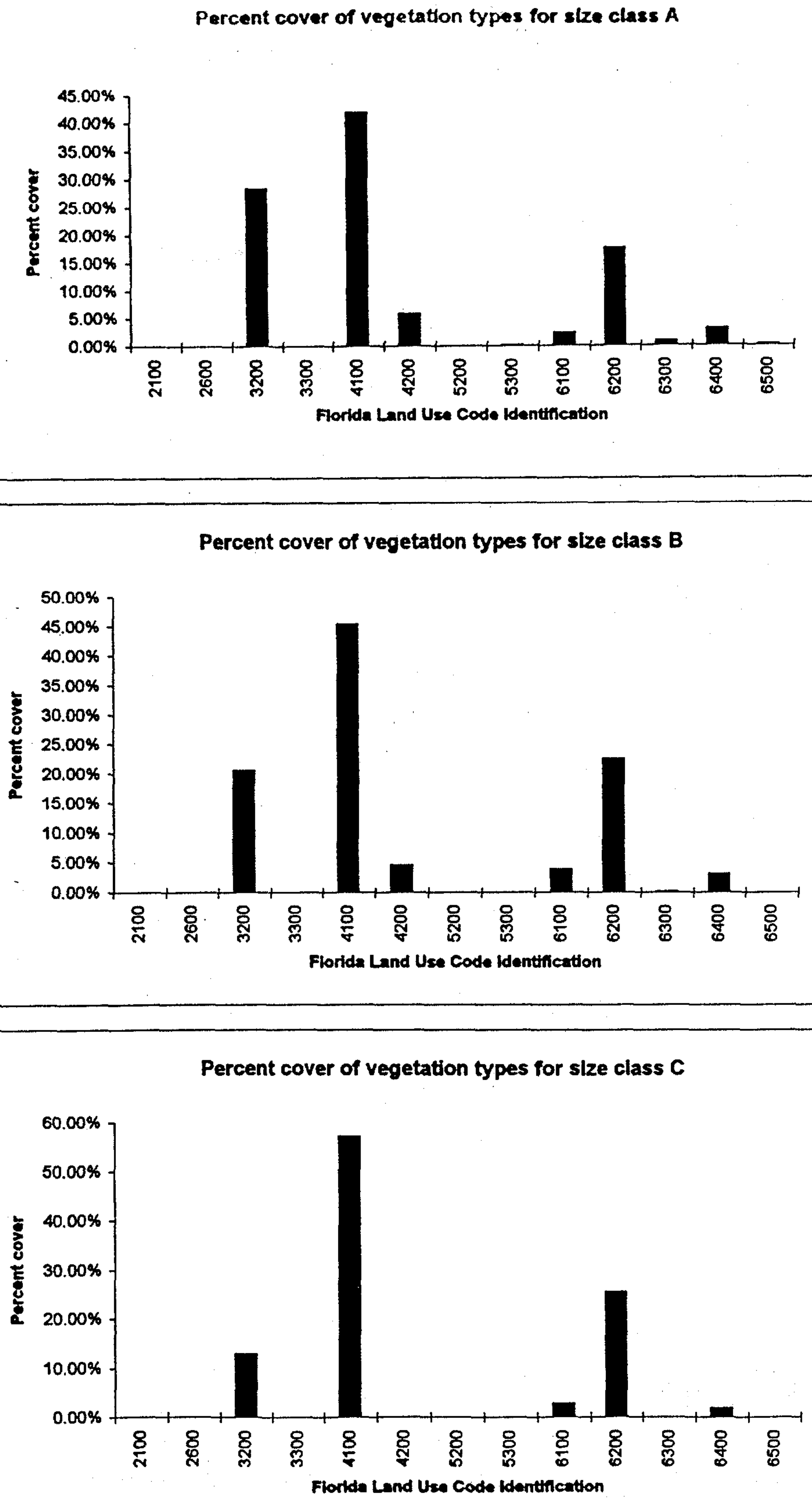


Figure 8-22. Percent cover of land cover types in a landscape dominated by natural lands. Landscape was sampled using three sample frames equal to the average size of reclamation size classes: Class A = 65 hectares; Class B = 200 hectares; Class C = 450 hectares.

class increases. Land cover richness (the number of unique polygons per unit area) is lower in reclaimed landscape; again the divergence increases as the size classes increase. Perimeter/area ratios are similar between reclaimed and native landscapes. Upland/wetland ratios appear to be somewhat lower in reclaimed landscapes, especially in the largest size class. Reclaimed landscapes appear to have similar percent wetlands, although the spread in native landscapes is relatively large. Agricultural landscapes have lower percent wetlands than do natural landscapes. The reclaimed landscapes appear to resemble the percent wetlands of native landscapes more than agricultural landscapes. As might be suspected, reclaimed landscapes have higher lake/wetland ratios than native landscapes.

In all, reclaimed landscapes appear to be less complex (as indicated by number of polygons and land cover richness) than native landscaped, but have similar upland/wetland ratios. But the ratios lower than that of landscapes dominated by agricultural uses, and the lake/wetland ratios are much higher.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

SYSTEMS ECOLOGY

The model of wetland ecosystem succession was simulated to test several questions regarding reclamation. These were: What are the effects of planting seedlings on long-term organization of reclaimed, forested wetlands? What are the effects of hydroperiod on long-term organization? Do shrub and herbaceous species out-compete trees and "hold" forested wetlands in lower successional stages?

To answer these questions, the model was simulated first, for conditions that might be found on a cleared wetland site where seed inputs are readily available. These simulations were a means of sensitivity analysis and model verification. The results indicated that the forested wetland system required nearly 150 years to reach a steady-state pattern of maturity. Shrub and herbaceous vegetation peaked and declined as the overstory vegetation out-competed these lower layers for sunlight. Ultimate levels of biomass and diversity depend upon available seed inputs and conditions for germination.

When the model was simulated using conditions found on phosphate mined lands and using initial conditions characteristic of wetland reclamation, forest regeneration to a steady-state pattern was achieved about 30 years earlier (about 20% less time) than in the "natural" regeneration, as a result of the initial input of tree seedlings. While total biomass was no different from the naturally regenerated forest, diversity was lower because of a lack of additional seed inputs from outside. In other words, the diversity of material that is planted during reclamation directly effects long-term diversity of the forest, but has little effect on long-term total biomass.

The germination of seeds has long-term implications on the structural organization of wetland ecosystems. Since most seeds cannot germinate underwater, favorable conditions are possible only when soil surfaces are exposed. The model tested the sensitivity of long-term community productivity and diversity to differing germination conditions. Obviously, with most favorable conditions, the highest community levels were obtained and with less favorable conditions for germination, ultimate levels of community organization were lower. While relatively intuitive, the important thing is that without favorable conditions for germination for some time, regeneration and replacement of planted species is not possible. The developing ecosystem has lower overall diversity of tree, shrub, and herbaceous species because of a lack of internal regeneration. Hydroperiod and depths of inundation are very important variables and have large consequences on long-term community organization.

The question of overly competitive shrub and herbaceous vegetation "holding" a developing community at a lower stage of successional development was addressed indirectly though comparison of rates of growth of shrub and herbaceous vegetation between natural regeneration and the reclamation models. In the short run, shrub biomass and diversity in the reclaimed wetland are lower than in the natural regeneration condition, while herbaceous biomass and diversity are higher in the reclaimed wetland. These conditions prevail because of the higher initial tree biomass that results from the planting of tree seedlings. In other words, with high tree densities, shrub biomass is kept lower through competition for available space and sunlight, and herbaceous biomass is higher because of a lack of shading from the shrub layer. In the long run, however, herbaceous biomass declines as trees reach canopy status and shade the lower herbaceous layer.

In all, the key to regeneration of forested systems is the introduction of seedlings and/or seeds followed by their successful germination and/or regeneration. Hydroperiod plays a major role in long-term community organization. Without favorable conditions for germination of tree species, wetlands can become dominated by single species of shrubs and herbs. The creation and long-term survival of non-forested wetlands depends on exclusion of tree seed sources, and maintaining conditions unfavorable for tree seed germination (in the short run tree seed sources will normally be unavailable, but some shrub species are wind blown and can become established if hydroperiods favor germination).

LANDSCAPE ECOLOGY

Conclusions regarding the success of wetland reclamation at the landscape scale suffer from incomplete data sets, lack of comparability of data from one company to the next, and an overall dearth of quantitative data. As a result, our conclusions are based upon trends that have been extracted from a GIS data base constructed as part of this project. The data base suffers from incompleteness and lack of consistency. About 25% of the sites visited by the research team lack mappable data. About 50% of the sites with good mappable data still lacked consistency regarding designations of land cover, resulting in some companies only specifying land cover to FLUCCS Level 1, while others specified to Level 3. In all, our analysis of the spatial data base suggests that greater attention need be given to the landscape scale perspective in both the design and implementation ofreclamation projects, and in the generation, collection, and storage of data.

Conclusions are organized by three main landscape scale subject areas: (1) Ecological Connectedness, (2) Hydrological Connectedness, and (3) Community Fitness. Separately each of these subject areas describes characteristics and trends in reclamation design and implementation. Taken together they suggest trends in successful landscape scale reclamation.

Ecological Connectedness - There are two levels of connectedness. The first is site connections to surrounding land cover that provides wildlife access and potential for seed transfer from mature systems. The second is a purposefully integrated and designed connection of forested land cover that serves as wildlife corridors to and from what King and Cates (1994) have termed Core Habitat Reserves.

- About 50% of surveyed wetland reclamation projects are connected directly to natural forested lands, but only about 16% of the perimeter of these sites abuts the natural area. Thus the connection between existing forests and individual wetlands on a site is often tenuous and, as often as not, totally lacking.

- Forty-eight percent of projects are connected to relatively mature reclaimed lands. The average length of border that is shared between wetland reclamation projects and adjoining reclaimed areas is about 46% of the site perimeter. The majority of reclamation sites that share borders with other reclamation sites are not ecologically connected nor integrated.

- Twenty-four percent of wetland reclamation projects are integrated into a regional habitat system by having forested connections to core habitat reserves. Since the reclaimed landscape is often a patchwork of reclamation projects in various stages of design, implementation, and successional regrowth, it continues to be a real challenge to link reclamation projects and their natural ecological communities together in a cohesive regional habitat network.

Hydrological Connectedness - Hydrological connections are important to insure that the landscape functions as a hydrological unit, so that storm flows and base flows in downstream surface waters are accommodated and maintained. The drainage basins of the pre-mining landscape for the most part already had been altered. Using a system of ordering drainage basins that gives lowest number to the smallest basin and increasingly larger numbers to larger ones, it is apparent that while there have been minor alterations to the largest basin drainage divides, there is increasingly severe shifts of drainage divides and thus changes in area of basin as the order decreases. For the most part, the post mining hydrologic organization is more a function of ditches, canals, mine pits, and roads than it is a function of natural topography. It will be a real challenge to reestablish a “natural” drainage network in the post mining landscape.

- About 50% of wetland reclamation projects are within 1st order (smallest) drainage basins, yet most 1st order basins have direct hydrologic connections to the regional drainage network. The fact that they are connected may result in serious long-term hydrological problems associated with the maintenance of sufficient storage, groundwater recharge, and maintenance of stream base flow during the dry season.

- About 16% of reclamation projects are constructed in second order drainage basins (second smallest), and 10% are constructed in third order basins. About 23% are constructed with no apparent hydrologic connection. Of those wetland reclamation projects in 2nd and 3rd order basins about equal percentages are hydrologically directly connected to the drainage network and hydrologically isolated.

- About 43% of all wetlands reclamation projects are in the upper 1/3 of drainage basins (roughly equivalent to the headwaters of the drainage basin), while about 40% are within the middle 1/3, and 17% are within the lower 1/3. Thus about 20% of all wetlands reclamation projects (50% of the 43% of projects that are hydrologically isolated) depend upon rainfall and groundwater levels for maintenance of hydrology, with little or no surface water inputs.

Community Fitness - Community fitness results from the interplay of land covers within a reclamation site as well as the interplay of the site with surrounding lands. Several separate indices of community organization and interaction were calculated, that taken as a whole, address how well reclamation sites and their associated land covers fit within the larger landscape mosaic.

- The most common land cover type in wetlands reclamation projects is agriculture (primarily pastureland). Between 25 and 35% of the land area of reclamation projects is devoted to agriculture, and agriculture has the highest number of polygons on reclamation projects. While agriculture can be a compatible land cover with wetlands, management practices and animal foraging can often be detrimental to wetland habitat.

- Landscape heterogeneity (the number of polygons, and number of unique polygons) of wetlands reclamation projects is relatively low, when compared to the native Florida landscape.

- Average upland/wetland ratios for wetland reclamation projects appears to be somewhat lower than those found for native Florida landscapes, especially in the larger reclamation projects (this in essence means a larger percentage of the landscape is covered by wetlands). When lakes are included as a wetland type, the percent of reclamation projects that is “wet” (both wetlands and lakes) is even higher, between 30% and 50%. This may translate into wetlands and lakes that are more dominated by rainfall events and less driven by groundwater inflows. Under these conditions, hydroperiods may be shorter, with more frequent cycles of inundation and drying, thus making creation of wetland ecosystems that require long sustained hydroperiods difficult to establish and maintain. Succession to dryer types of wetlands (shrub, and tree dominated) may result if sufficient seed sources are available.

- Low Upland/wetland ratios combined with the relatively small amount of uplands that are planted in forests (on average about 20%) translates into lowered overall carrying capacity for faunal species that require a mix of upland and wetland habitats for life support functions. While it is true that larger wetland areas can mean larger populations of wetland dependent species, many species require good quality upland forests for portions of their life cycles, or portions of their life support functions.

- Lake borders, on the average, are planted with herbaceous wetlands far more frequently than any other cover type (about 40% of all created lakes are dominated by herbaceous wetland margins). This is probably a good juxtaposition of land cover types. However, often these wetland lake margins are planted as thin bands around the edges, lowering their habitat value because of high edge to interior ratios.

RECOMMENDATIONS

SYSTEMS ECOLOGY

Recommendations are based on results of the simulation of a model of wetland succession. The model generated insights related to: (1) the effect of hydroperiod control on seed germination and thus on long-term diversity of wetland ecosystems; (2) lack of significant negative response of forested wetlands to early domination by nuisance species; and (3) The need for the introduction of shrub and herbaceous species which may require more micro-topographic relief in created wetlands.

With these insights in mind we recommend the following:

- The control of nuisance species in the early years of establishment of forested wetland communities, and the removal of canopies of shrub species (primarily willow) may not be necessary in that simulation results suggest that tree species compete well and soon overtop these early colonizers. Real-world data to confirm this, however, are still needed.

- Simulation results confirm the need for more "micro-topographic relief" in created forested wetlands. The smooth topography that is characteristic of most created wetlands favors lower diversity of tree, shrub and herbaceous species in the mature communities.

- Simulation results suggest that there is a strong need for the introduction of shrub and herbaceous species within created forested wetlands, although the lack of micro-topographic relief and high light levels in the early years make their survival uncertain. Introduction of these species during a later phase of succession might be warranted.

LANDSCAPE ECOLOGY

Overall, our analysis has found: (1) there is little standardization in the way site plans are produced, annotated, and documented, making comparisons between projects difficult and the job of organizing coherent landscapes an unpredictable proposition; (2) there appears to be no larger scale organizational principles (beyond the scale of the individual reclamation project) driving the reclamation of phosphate mined lands, (3) wetland reclamation projects are constructed close to existing native forested communities about 1/3 of the time, but ecological connectedness is often not maximized because of the minimal area of planted upland forests; (4) upland forested corridors connecting individual created wetlands on reclamation sites were found on 89% of the reclamation sites; (5) landscapes that are created on individual reclamation projects tend to maximize heterogeneity but at the expense of patch size; (6) hydrology of constructed wetlands may be problematic, while many constructed wetlands are hydrologically connected, upland/wetland ratios suggest that hydroperiods may be shorter in duration but more frequent than those characteristic of native Florida landscapes; and (7) patch sizes of constructed wetlands and upland forests may be too small for larger animals and minimum viable populations.

The following recommendations are aimed at improving ecological and hydrological connectedness and community fit of created wetlands:

- Standardize submittal requirements for reclamation plans that would include i) standardized format for plans and topography maps, ii) site plans that show off-site ecosystems and drainage patterns, iii) planting lists giving species and planting densities for each community type, and iv) cross-sections of site topography showing predicted ground and surface water elevations and indicating zones of each community type.

- Make reclamation planning units correspond to fauna1 habitat requirements, hydrologic basins, and logical landscape scale habitat units, rather than to mining units.

- Increase the required area of upland forested communities so that constructed wetlands can achieve better off-site ecological connectedness.

- To increase the likelihood of achieving appropriate wetland hydrology, reclaim on a drainage basin basis beginning with headwaters areas and proceeding down slope to the basin’s mouth.

- Develop region wide reclamation schemes that maximize opportunities for creating an integrated approach to habitat restoration similar to that proposed by King and Cates (1994).

In all, it will be important to establish new criteria, but rather than making the reclamation process harder by adding more restrictions, we need to explore ways that better reclamation can be achieved through cooperation and incentives rather than through tighter regulation.

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APPENDICES

APPENDIX 8-1. BASIC Program Listing of the Central Florida Wetlands Succession Model

```
REM DIVERSE3.BAS
REM Competition in reclaimed phosphate-mined lands in central Florida

20 REM set time scale
25 CLS : INPUT "How many years to simulate"; Y
30 D = INT(Y * 365 / 320 + 1)
50 REM set up screen
60 CLS
70 SCREEN 1, 0: COLOR 0, 1
80 LINE (0, 0)-(319, 180), 3, B
90 LINE (0, 60)-(320, 60), 3
92 LINE (0, 120)-(320, 120), 3
95 REM OPEN "a:\phosphat\d3y500.dat" FOR OUTPUT AS #1
99  REM data save version

100 REM initial conditions
110 t = 1
120 dt = 1: REM increment by days
130 I = 1: REM insolation normalized
140 H = 1: REM herbivores normalized (kept as constant for simplicity)
145 s = 1: REM micro-scale topographic variation, normalized (1=very diverse)
TB = 0: REM initial tree biomass in g/m2
KT = 1000000!: REM Tab. net prod. decay constant = 1E7
TD = 0: TD0 = TD: REM tree diversity in species/3000 m2
TS = 0: REM tree seed bank in g/m2
TDS = 0: REM tree seed bank diversity in species/3000 m2
TSO = .0078: REM seed flow from outside
TDO = 13.5: REM diversity of seed flow from outside in species/3000 m2
SB = 0: REM initial shrub biomass in g/m2
KS = 2E+07: REM Cec. net prod. decay constant = 2E7
SD = 0: SD0 = SD: REM shrub diversity in species/3000 m2
SS = 0: REM shrub seed bank in g/m2
SDS = 0: REM shrub seed bank diversity in species/3000 m2
SSO = .015: REM seed flow from outside
SDO = 30: REM diversity of seed flow from outside in species/3000 m2
HB = 0: REM initial herb biomass in g/m2
KH = 100000: REM Tab. net prod. decay constant = 1E7
HD = 0: HD0 = HD: REM herb diversity in species/3000 m2
HS = 0: REM herb seed bank in g/m2
HDS = 0: REM herb seed bank diversity in species/3000 m2
HSO = .00446: REM seed flow from outside
HDO = 157: REM diversity of seed flow from outside in species/3000 m2
```

APPENDIX 8-1

200 REM constants - see Lotus worksheet
TCF = 6: REM correction factor to multiply tree diversity pathways by;
REM tree diversity should reach steady-state at 300 years
k0 = .0000684
k1 = .000592
k2 = .0000912
k3 = .0000101
k4 = .0000221
k5 = 3.29E-06
k6 = .0000019
k9 = .00247
k11 = .00667
k12 = 2.34E-06
k13 = .0000202
k14 = 2.33E-11 * TCF
k16 = 9.13E-06 * TCF
k17 = 6.7E-07 * TCF
k20 = .000687
k21 = .00719
k22 = .000633
k23 = .0001
k24 = .0002
k25 = .0000457
k26 = .0000235
k29 = .00247
k31 = .00667
k32 = .0000028
k33 = .0000293
k34 = 1.32E-09 * TCF
k35 = .015 / 30 / (1 - .061)
k36 = .0000913 * TCF
k37 = 3.01E-06 * TCF
k40 = .00249
K41 = .013
k42 = .00275
k43 = .000051
k44 = .0016
k45 = .000411
k46 = .0000459
k49 = .00137
k51 = .00333
k52 = 4.19E-06
k53 = .000022
k54 = 1.57E-08 * TCF
k55 = .5 / 157 / (1 - .069)

```
k56 = .000274 * TCF
k57 = 1.73E-06 * TCF

400 REM scaling factors
420 T0 = 1500: REM tree biomass
430 S0 = 300: REM shrub biomass
435 H0 = 20: REM herbaceous biomass
440 D0 = .3: REM diversity

460 REM plotting
461 IF t / 365 = INT(t / 365) THEN PSET (t / D, 180), 2: REM year marker
462 IF t / D > INT(t / D) THEN GOTO 500: REM plot every D days
465 REM colors: 1,blue; 2,purple; 3,white
PSET (t / D, 60 - TB / T0), 1
PSET (t / D, 60 - TD / .3), 2
PSET (t / D, 60 - CO * 50), 3
PSET (t / D, 60 - TDS / .4), 3
PSET (t / D, 120 - SB / S0), 1
PSET (t / D, 120 - SD / .6), 2
PSET (t / D, 180 - HB / H0), 1
PSET (t / D, 180 - HD / 3), 2
495 REM WRITE #1, INT(t / 365), TB, TD, SB, SD, HB, HD
REM write time and biomasses and diversities to file

500 REM computations
502 R1 = I / (1 + k0 * TB)
504 R2 = R1 / (1 + k12 * TD * TB)
510 R3 = R2 / (1 + k20 * SB)
515 R4 = R3 / (1 + k32 * SD * SB)
520 R5 = R4 / (1 + k40 * HB)
522 R6 = R5 / (1 + k52 * HD * HB)

IF (t - INT(t / 365) * 365) < 382 THEN
  CO = 1: REM conditions right for seed germination
ELSE
  CO = 0: REM else conditions not right
END IF

525 REM tree growth
TSL = 0: REM reset local seedfall to 0
ratio = (15 - 1) * EXP(-TB * TB / KT) + 1: REM Pg/R ratio change
REM 1.83 for Tabonuco forest; find cypress number from literature or Dr. Best
c1 = ratio * k1
dTB = c1 * R1 * TB + k13 * R2 * TD * TB - k2 * TB - k4 * TB - k5 * TB * H
REM biomass change = gross primary production + diversity contribution to
REM production - respiration - litterfall - loss to herbivores
```

APPENDIX 8-1

```
IF TB > 2400 THEN dTB = dTB - k3 * TB:  TSL = k6 * TB

REM seed production at maturity
IF CO > 0 THEN
  dTB = dTB + TS
  dTS = .2 * (TSO + TSL) - TS
  dTDS = (TDO * TSO + TD * TSL) / (TSO + TSL) - TDS
  REM some seeds germinating
ELSE
  dTS = .2 * (TSO + TSL) - k9 * TS
  dTDS = (TDO * TSO + TD * TSL) / (TSO + TSL) - k11 * TDS
  REM some seeds decaying
END IF
dTD = k16 * TDS * s * H * CO - k14 * TD * TB * R2 - k17 * TD * TD
REM diversity change = diversity production - feedback to production
REM - information cost
TB = TB + dTB * dt: REM biomass increase
TS = TS + dTS * dt:  REM seed bank increase
TD = TD + dTD * dt: REM diversity increase
TDS = TDS + dTDS * dt: REM seed bank diversity increase
IF TDS > TDO AND TDS > TD THEN
REM if TDS exceeds TDO and TD (i.e., too big),
REM then set TDS to the max between TDO & TD
  IF TDO > TD THEN
    TDS = TDO
  ELSE TDS = TD
  END IF
END IF
IF TD > TDS AND TD > TD0 THEN
REM if TD exceeds TDS and TD0 (i.e., too big),
REM then set TD to the max between TDS & TD0
  IF TDS > TD0 THEN
    TD = TDS
  ELSE TD = TD0
  END IF
END IF

550 REM shrub growth
SSL = 0: REM reset local seedfall to 0
ratio = (5.53 - 1) * EXP(-SB * SB / KS) + 1: REM Pg/R ratio change
c21 = ratio * k21
dSB = c21 * R3 * SB + k33 * R4 * SD * SB - k22 * SB - k24 * SB - k25 * SB * H
REM biomass change = gross primary production + diversity contribution to
REM production - respiration - litterfall - loss to herbivores
IF SB > 1000 THEN dSB = dSB - k23 * SB:  SSL = k26 * SB
```

APPENDIX 8-1

```
REM seed production at maturity
IF CO > 0 THEN
  dSB = dSB + SS
  dSS = .2 * (SSO + SSL) - SS
  dSDS = (SDO * SSO + SD * SSL) / (SSO + SSL) - SDS
  REM some seeds germinating
ELSE
  dSS = .2 * (SSO + SSL) - k29 * SS
  dSDS = (SDO * SSO + SD * SSL) / (SSO + SSL) - k31 * SDS
  REM some seeds decaying
END IF
dSD = k36 * SDS * s * H * CO - k34 * SD * SB * R4 - k37 * SD * SD - k35 * SD * (1 - R2)
REM diversity change = diversity production - feedback to production
REM - information cost - stress from shading
SB = SB + dSB * dt: REM biomass increase
SS = SS + dSS * dt:  REM seed bank increase
SD = SD + dSD * dt: REM diversity increase
SDS = SDS + dSDS * dt: REM seed bank diversity increase
IF SDS > SDO AND SDS > SD THEN
REM if SDS exceeds SDO and SD (i.e., too big),
REM then set SDS to the max between SDO & SD
  IF SDO > SD THEN
    SDS = SDO
  ELSE SDS = SD
  END IF
END IF
IF SD > SDS AND SD > SD0 THEN
REM if SD exceeds SDS and SD0 (i.e., too big),
REM then set SD to the max between SDS & SD0
  IF SDS > SD0 THEN
    SD = SDS
  ELSE SD = SD0
  END IF
END IF

600 REM herbaceous growth
HSL = 0: REM reset local seedfall to 0
ratio = (5.53 - 1) * EXP(-HB * HB / KH) + 1: REM Pg/R ratio change
c41 = ratio * K41
dHB = c41 * R5 * HB + k53 * R6 * HD * HB - k42 * HB - k44 * HB - k45 * HB * H
REM biomass change = gross primary production + diversity contribution to
REM production - respiration - litterfall - loss to herbivores
dHB = dHB - k43 * HB:  HSL = k46 * HB: REM seed production
```

APPENDIX 8-1

```
IF CO > 0 THEN
  dHB = dHB + HS
  dHS = .25 * (HSO + HSL) - HS
  dHDS = (HDO * HSO + HD * HSL) / (HSO + HSL) - HDS
  REM some seeds germinating
ELSE
  dHS = .25 * (HSO + HSL) - k49 * HS
  dHDS = (HDO * HSO + HD * HSL) / (HSO + HSL) - k31 * HDS
  REM some seeds decaying
END IF
dHD = k56 * HDS * s * H * CO - k54 * HD * HB * R6 - k57 * HD * HD - k55 * HD * (1 - R4)
REM diversity change = diversity production - feedback to production
REM - information cost - stress from shading
HB = HB + dHB * dt: REM biomass increase
HS = HS + dHS * dt:  REM seed bank increase
HD = HD + dHD * dt: REM diversity increase
HDS = HDS + dHDS * dt: REM seed bank diversity increase
IF HDS > HDO AND HDS > HD THEN
REM if HDS exceeds HDO and HD (i.e., too big),
REM then set HDS to the max between HDO & HD
  IF HDO > HD THEN
    HDS = HDO
  ELSE HDS = HD
  END IF
END IF
IF HD > HDS AND HD > HD0 THEN
REM if HD exceeds HDS and HD0 (i.e., too big),
REM then set HD to the max between HDS & HD0
  IF HDS > HD0 THEN
    HD = HDS
  ELSE HD = HD0
  END IF
END IF

700 t = t + dt: REM to next day

800 IF t / D < 320 GOTO 460: REM else end program
PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT : PRINT
810 PRINT "TB = "; TB; " TD = "; TD: PRINT "SB = "; SB; " SD = "; SD
PRINT "HB = "; HB; " HD = "; HD
850 REM CLOSE #1
900 INPUT a: REM pause
1000 END
```

APPENDIX 8-2. Description and evaluation of energy flows and storages for model of succession in central Florida wetlands

Description of item	Expression and Value	Reference
Storages and flows used for tree steady-state calibration:		
Tree biomass	TB = 64,373 g/m2	Duever et al, 1984
Tree viable seed bank	TS = 78 g/m2	1300 seeds/m2 (Titus, 1987) * 0.06 g/seed (mean measured weight for *Liquidambar styraciflua* and *Taxodium distichum* seeds)
Tree diversity	TD = 13.5 species/ 300m*10m transect	Davis et al, 1991 (for mixed hardwood swamp)
Sunlight through cypress	R1 = 0.185	Glasser (for cypress)
Sunlight through mixed hardwoods	R2 = 0.061	Mean measured sunlight remainder for Lake Alice mixed hardwood swamp
Storages and flows used for shrub steady-state calibration:		
Shrub biomass	SB = 10,000 g/m2 (for willow)	Approximation: Rushton and Odum, 1990
Shrub viable seed bank	SS = 0.9 g/m2	500 seeds/m2 (Titus, 1987) * 0.00175 g/seed (mean measured weight for *Lyonia lucida* seeds)
Shrub diversity	SD = 30 species/ 300m*10m transect	Davis et al, 1991 (for mixed hardwood swamp)
Sunlight through early successional shrubs	R3 = 0.127	Glasser (for old, primary successional shrubs)
Sunlight through 2nd successional shrubs	R4 = 0.069	Glasser (for old, secondary successional shrubs)
Storages and flows used for herbaceous steady-state calibration:		
Herbaceous biomass	HB = 874 g/m2	Bersok, 1990 (for marsh aboveground biomass)

APPENDIX 8-2.

Description of item	Expression and Value	Reference
Herbaceous viable seed bank	HS = 40 g/m2	72,502 seeds/m2 (Dunn, 1989, for *Juncus effusus*, which dominate natural marsh seedbanks studied in central Florida) * 0.0005 g/seed (mean measured weight for *Juncus effusus* seeds)
Herbaceous diversity	HD = 157 species/ 300m*10m transect	Davis et al, 1991 (for marsh)
Sunlight through monoculture	R5 = 0.315	Glasser (for grass-sedge)
Sunlight through mixed marsh	R6 = 0.2	Mean measured sunlight remainder for Paynes Prairie grass-Pontedaria marsh
Sources used for all steady-state calibrations:		
Insolation (normalized)	I = 1	
Herbivores (normalized)	H = 1	
Topographic standard deviation (normalized)	s = 1	
Coefficient calculations:		
Trees at steady-state:		
Sun used by trees (fraction)	k0*R1*TB = 0.815 k0 = 6.84E-05	I - R1
Gross production	k1*R1*TB = 7.054 g/m2/d k1 = 5.92E-04	based on turnover time of 25 years
Respiration	k2*TB = 5.872 g/m2/day k2 = 9.12E-05	remainder of pathways from biomass
Fruit production	k3*TB = 0.65 g/m2/day 5 * k3 = 1.01E-05	seed production from Bersok, 1990; estimated 20% of fruit is seeds

APPENDIX 8-2

Description of item	Expression and Value	Reference
Loss to litter	k4*TB = 1.42 g/m2/day k4 = 2.21E-05	Mitsch and Gosselink, 1993 (for cypress dome)
Herbivore consumption	k5*TB*H = 0.212 g/m2/day k5 = 3.29E-06	estimated 3% of gross production
Local seedfall	k6*TB = 0.122 g/m2/day k6 = 1.90E-06	6% of seeds exported >= 30m from forest edge (Wolfe, 1987)
Seeds decaying from predation & decomposition	k9*TS = 0.192 g/m2/day k9 = 2.47E-03	90%/year (McClanahan, 1984)
Seed species lost	k11*TDS = 0.09 species/day k11 = 6.67E-03	estimated 20% species lost/month
Sun captured by diversity	k12*R2*TD*TB = 0.124 R1 - R2 k12 = 2.34E-06	
Additional production from diversity	k13*R2*TD*TB = 1.073 g/m2/day k13 = 2.02E-05	Gross production * (sunlight captured by mixed hardwood forest / sunlight captured by cypress monoculture)
Diversity feedback to production	k14*R2*TD*TB = 1.2E-06 species/day k14 = 2.33E-11	estimated 1% of diversity production
Production of diversity	k16*TDS*s*H = 1.2E-04 species/day k16 = 9.13E-06	300 years for cypress to succeed to mixed hardwood (Duever et al, 1976)
Diversity information drain	k17*TD*TD = 1.2E-04 species/day k17 = 6.70E-07	estimated 99% of diversity production
Shrubs at steady-state in full sunlight:		
Sun used by shrubs	k20*R3*SB = 0.873 k20 = 6.87E-04	I - R3
Gross production	k21*R3*SB = 9.132 g/m2/day k21 = 7.19E-03	based on turnover time of 3 years

APPENDIX 8-2

Description of item	Expression and Value	Reference
Respiration	k22*SB = 6.333 g/m2/day k22 = 6.33E-04	remainder of pathways from biomass
Fruit production	k23*SB = 1 g/m2/day k23 = 1.00E-04	Estimated. Also, estimated 25% of shrub fruit mass is seed mass.
Loss to litter	k24*SB = 2 g/m2/day k24 = 2.00E-04	from Rushton and Odum, 1990 (for willow)
Herbivore consumption	k25*SB*H = 0.457 g/m2/day k25 = 4.57E-05	estimated 5% of gross production
Local seedfall	k26*SB = 0.235 g/m2/day k26 = 2.35E-05	6% of seeds exported >= 30m from forest edge (Wolfe, 1987)
Seeds decaying from predation & decomposition	k29*SS = 0.00221 g/m2/day k29 = 2.47E-03	90%/year (McClanahan, 1984)
Seed species lost	k31*SDS = 0.2 species/day k31 = 6.67E-03	estimated 20% species lost/month
Sun captured by diversity	k32*R4*SD*SB = 0.058 R3 - R4 k32 = 2.80E-06	
Additional production from diversity	k33*R4*SD*SB = 0.607 g/m2/day k33 = 2.93E-05	Gross production * (sunlight captured by secondary successional shrubs / sunlight captured by early successional shrubs)
Diversity feedback to production	k34*R4*SD*SB = 2.7E-05 species/day k34 = 1.32E-09	estimated 1% of diversity production
Production of diversity	k36*SDS*s*H = 0.00273 species/day k36 = 9.13E-05	30 years for succession from primary to secondary shrubs (Glasser)
Diversity information drain	k37*SD*SD = 0.00271 species/day k37 = 3.01E-06	estimated 99% of diversity production

APPENDIX 8-2

Description of item	Expression and Value	Reference
Herbaceous (marsh) at steady-state in full sunlight:		
Sun used by herbaceous plants	k40*R5*HB = 0.685 k40 = 2.49E-03	I - R5
Gross production	k41*R5*HB = 3.592 g/m2/day k41 = 1.30E-02	based on turnover time of 8 months
Respiration	k42*HB = 2.402 g/m2/day k42 = 2.75E-03	remainder of pathways from biomass
Seed production	k43*HB = 0.0446 g/m2/day k43 = 5.10E-05	Bersok, 1990
Loss to litter	k44*HB = 1.4 g/m2/day k44 = 1.60E-03	Bersok, 1990
Herbivore consumption	k45*HB*H = 0.359 g/m2/day k45 = 4.11E-04	estimated 10% of gross production
Local seedfall	k46*HB = 0.0401 g/m2/day k46 = 4.59E-05	estimated 10% of seeds exported
Seeds decaying from predation & decomposition	k49*HS = 0.0548 g/m2/day k49 = 1.37E-03	50%/year (McClanahan, 1984)
Seed species lost	k51*HDS = 0.523 species/day k51 = 3.33E-03	estimated 10% species lost/month
Sun captured by diversity	k52*R6*HD*HB = 0.115 R5 - R6 k52 = 4.19E-06	
Additional production from diversity	k53*R6*HD*HB = 0.603 g/m2/day k53 = 2.20E-05	Gross prod. * (sunlight captured by mixed marsh / sunlight captured by early successional species)
Diversity feedback to production	k54*R6*HD*HB = 0.00043 species/day k54 = 1.57E-08	estimated 1% of diversity production

APPENDIX 8-2

Description of item	Expression and Value	Reference
Production of diversity	k56*HDS*s*H = 0.0430 species/day k56 = 2.74E-04	10 years for succession from initial to marsh climax species
Diversity information drain	k57*HD*HD = 0.0426 species/day k57 = 1.73E-06	estimated 99% of diversity production