Please note.

Everglades Landscape
Vegetation Succession Model (ELVeS) Ecological and Design Document:
version 2.2.2

There have been substantial updates to ELVeS since the release of the ecological and design document for version 1.1. Most notable are:

1. Improved parameterizations including a larger number of communities. Separate parameterization files are available for both EDEN and RSM ECB as baseline conditions. The accuracy assessments presented in the current document are out of date.
2. An option is now available to model at a collection of point locations (e.g., along a transect) rather than on a continuous grid.

In process are changes to improve implementation of temporal lags in the model.

Communities used in parameterizations(as of April 2014)

ID	Name	RECOVER classes	Notes
0	Excluded	AB, CA, all exotics classes, all forest classes, HI, LEV,MFB,MFG, MFGh, MFGs, MFGz, MFH, RD, SP, OW/MFGtS, MFGtS, MFGe, CSGt, CSGP, CSO, SSa, SSy, WStS	MFG and MFH excluded as being too broad a category MFGtS (sparse cattail) is excluded to reduce class confusion Excluded for too few points: MFGe, CSGt, CSGP, CSO, SSa, SSy, WStS
1	Open Water	OW	Excludes OW/MFGtS
2	Sawgrass	MFGc	
3	Sawgrass-Short	MFGcS	
4	Sawgrass-Tall	MFGcT	
5	Open Marsh	MFO	Open water dominated freshwater marsh often with a mix of sparse graminoids, herbaceous, and/or emergent freshwater vegetation, such as Spikerush (*Eleocharis* spp.), Panicgrass (*Panicum* spp.), low stature Sawgrass (*Cladium jamaicense*) , Cattail (*Typha* spp.), Arrowhead (*Sagittaria* spp.), Pickerelweed (*Pontederia cordata*), Waterlily (*Nymphaea* spp.), Green Arum (*Peltandra virginica*), Swamp-Lily (*Crinum americanum*), Spiderlilies (*Hymenocallis* spp.), among others.
6	Cattail	MFGtD, MFGtM,	
7	Floating Emergent Marsh	MFF	Typically Nuphar or Nymphaeea. Also Lemna, Salvinia
8	Drier Marl Prairie	MFGP	Short hydroperiod marsh characterized primarily by graminoids that includes low-stature sawgrass (*Cladium jamaicense*), Muhly Grass (*Muhlenbergia capillaris var. filipes*),
9	Wetter Marl Prairie	MFGP	Short hydroperiod marsh characterized by a mix of graminoids that includes low-stature sawgrass (*Cladium jamaicense*), Little Bluestem (*Schizachyrium scoparium*), Gulfdune Paspalum (*Paspalum monostachyum*), Beakrush (*Rhynchospora* spp.), Black Sedge (S*choenus nigricans*), among others.
10	Swamp Scrub	SS, SSl, SSm	SSl = primrosewillow, SSm = wax myrtle
11	Swamp Scrub-Marsh	CSE, CSG, CSGc	Swamp scrub in a matrix composed predominately of broadleaf emergent vegetation or Freshwater Graminoid Marsh..
12	Willow Scrub/Shrub	SSs, CSsGc, CSsGt	
13	Cypress Scrub	CStD, CStG, CStGc, CStO	
14	Bayhead Shrubland	SSB	Mix of Cocoplum (Chrysobalanus icaco), Swamp Bay (Persea palustris), Red Bay (Persea borbonia), Dahoon Holly (Ilex cassine), Willow (Salix caroliniana), Wax Myrtle (Myrica cerifera), Sweetbay (Magnolia virginiana), Cypress (Taxodium spp.), Pond Apple (Annona glabra), among others.
15	Pine Rockland	WUpR	Pine Upland found on low ridges of oolitic limestone. Found on the Miami rock ridge, in the Florida Keys, EVER, and in BICY.

Everglades Landscape Vegetation Succession Model (ELVeS) Ecological and Design Document:

Freshwater Marsh & Prairie Component version 1.1

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GLOSSARY OF ACRONYMS

ANPP	Above ground net primary production
ATLSS	Across Trophic Level System Simulation
BCNP	Big Cypress National Preserve
BD	Bulk density
CERP	Comprehensive Everglades Restoration Plan
CSSS	Cape Sable seaside sparrow
EDEN	Everglades Depth Estimation Network
ELM	Everglades Landscape Model
ELVeS	Everglades Landscape Vegetation Succession model
ENP	Everglades National Park
EPA	Environmental Protection Agency
GAP	Gap Analysis Program
LOI	Loss on ignition
NSM	Natural Systems Model
RECOVER	Restoration Coordination & Verification
R-EMAP	Regional Environmental Monitoring and Assessment Program
RSM	Regional Simulation Model
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
TaRSE	Transport and Reaction Simulation Engine
TC	Total carbon
TIP	Total inorganic phosphorus
TN	Total nitrogen
TM	Total magnesium
TP	Total phosphorus
WCA	Water Conservation Area

INTRODUCTION

The Everglades Landscape Vegetation Succession model (ELVeS) is a spatially explicit simulation of vegetation community dynamics over time in response to changes in environmental conditions. The model uses empirically based probability functions to define the realized niche space of vegetation communities. Temporal lags in response to changing environmental conditions are accounted for in the model. ELVeS version 1.1 simulates Everglades freshwater marsh and prairie community response to hydrologic and soil properties. Subsequent versions of ELVeS are planned to include a larger suite of vegetation communities and responses to disturbances such as fire and storms. Figure 1 illustrates the Everglades spatial domain for ELVeS parameterization including the Water Conservation Areas (WCAs) and Everglades National Park (ENP).

ELVeS has been developed to provide scientists, planners, and decision makers a simulation tool for Comprehensive Everglades Restoration Project (CERP) landscape-scale analysis, planning, and decision making. The model is also intended for integration with wildlife models to provide a temporally dynamic vegetation input layer. We anticipate that ELVeS will consider a suite of vegetation communities within the CERP planning domain that span a wide suite of environmental conditions from seagrass communities, freshwater marshes, mangroves, saline prairies, and tropical and temperate hammocks to upland pine forests (Figure 1). Eleven of the communities are in the freshwater marsh and wet prairie component described in this report. Of the 11 communities, three are too broadly defined to effectively model, leaving eight freshwater marsh and wet prairie classes parameterized in this version of ELVeS (Figure 2).

ELVeS v.1.1 is the first iteration of a model design and parameterization process that relies on feedback from the knowledge and experience of the larger scientific community to continually improve the model's capabilities and performance. To encourage that process, we attempt to be explicit in discussing methods, presenting validation trials, acknowledging current limitations, and proposing potential future directions. The iterative design process is also explicitly implemented in ELVeS program coding with an open graphical user interface design that allows easy modification to the variable selected and their parameterization (ELVeS User's Guide, Supernaw et al. 2011). User and developer interaction to further ELVeS development is also encouraged by web distribution of the application and its open source code (www.SimGlades.org).

ELVeS v.1.1 treats each of the major vegetation communities and community drivers as user-accessible components of the model. In future versions, we anticipate ELVeS will integrate vegetation succession components for seagrasses, mangroves, saline prairies, freshwater marshes, hammocks, tree islands, cypress, and pine forests in a single simulation model. Incorporating the coastal system communities in a general Everglades vegetation succession model along with inland marsh and terrestrial community types represents a fundamental progression of vegetation succession modeling for this diverse ecosystem. ELVeS is designed with the capacity to integrate future modules for climate change, hurricanes, and fire scenarios, providing the opportunity to explore potential habitat modifications for estuarine, freshwater, and coastal vegetation, and their effects on wildlife communities.

Design considerations were developed following initial open discussion workshops that were conducted in 2009 and 2010 addressing four broad categories of 1) freshwater marshes, 2) coastal and estuarine communities, 3) tree islands, and 4) forest communities. Participants of these workshops represented university scientists, Restoration Coordination and Verification (RECOVER) team members, and government scientists. Discussions during these meetings considered a wide variety of topics. For example, meeting participants were asked to consider and make recommendations for a baseline Everglades vegetation map, assessment of known ecological drivers, and reasons and opportunities to develop new vegetation succession metrics. Open discussions were held to inform participants of the final selected critical ecological drivers, approaches to parameterizing drivers, and the format of the model outcomes. Additional considerations related to the availability of regional data sets limited ELVeS v.1.1 development. For example, we had to use static multivariate soil data layers even though multi-temporal data layers would be much more desirable. ELVeS has been designed to be easily modified, recognizing a need for flexibility that promotes the integration of new data layers as they become available.

This report details the progressive development of the freshwater marsh component of ELVeS and the ecological basis for the relationships and rules reflected in the model. Section I of the report provides a broad overview of the ELVeS modeling framework including the model description, data integration, data processing, and simulation solutions. Section II follows with a description of the application of the ELVeS framework to Everglades freshwater marsh communities. Methods of analyses of empirical ecological data within the modeled domain and selection of principal hydrologic and soil biogeochemical processes in the freshwater communities are described. The methods are followed by simulation results, notes on model limitations, and potential future directions of model development.

SECTION I - ELVES MODEL FRAMEWORK

ELVeS is a spatially explicit cell-based probability model designed to predict the likelihood of specific vegetation communities given a set of specific environmental conditions. The underlying structure of the model is the geographic spatial domain represented by a regular grid of cells. Ecological driver state conditions are calculated for each cell in order to calculate characteristics of multi-dimensional niche space at each location. Estimated probabilities of vegetation communities occupying the derived realized niche space are then calculated using a conditional probability based method.

Other spatially explicit vegetation and wildlife models have been formulated following several alternate methodological procedures similar to ELVeS including gradient percolation and gradient contact process models (Gastner et al. 2009), agent based models (Topping et al. 2003), transition-matrix probability models (Perry and Enright 2007), linear regression models (Li et al. 2003), stochastic individual species models (Mladenoff 2004), and rule-based models including the Across Trophic Level System Simulation (ATLSS) vegetation succession model for the Everglades (Duke-Sylvester 2006). All of these models rely on a variation of probability theory or conditional rule sets as an underlying modeling approach for assigning niche space conditions and outcomes.

The ATLSS vegetation succession model (Duke-Sylvester 2006) was a pioneering and innovative approach to the challenge of modeling Everglades freshwater vegetation succession based on an extensive literature review of vegetation community hydroperiod estimates and fire disturbance nutrient estimates compiled by Wetzel (2001, 2003) for the ATLSS project (DeAngelis et al. 2000). Although it was our initial plan to build on and update the existing ATLSS model, we concluded that was not practical or efficient because the existing code is difficult to modify and was not built with the modular structure we seek to allow rapid adaptation to other models and rapid modifications as desired in future iterations. Although the procedures are conceptually well presented in Scott Duke-Sylvester's dissertation (Duke-Sylvester 2006), the code itself is undocumented. Specifically, we sought model modifications because:

1. There is a considerable amount of new information published after Wetzel's (2001) report and development of the ATLSS model. Some of that information is synthesized by the literature review in this report and by other authors such as Richards and Gann (2008).
2. Using modern, object-oriented programming techniques, standardized methods, and standard file formats (a) increases model flexibility to future changes, (b) enhances opportunities for collaborative development, and (c) allows us to more efficiently couple vegetation routines with specific hydrology models and wildlife/habitat response models.
3. We sought the capacity to model vegetation response to several factors differently, including hydroperiod, nutrients, and fire. The ATLSS model does not replace vegetation communities if hydroperiod is within range for that community. ELVeS uses response distributions to consider the probability for new communities to outcompete existing community when hydrologic or other parameters are within range, but not optimal for the existing community. Nutrients are a critical driver, but phosphorus is only considered in the ATLSS model if there is a fire in the current year. ELVeS treats nutrients in the same way as other parameters defining the niche space of the community. Dynamic phosphorus modeling is not available in ELVeS v.1.1, but is planned for future versions in coordination with fire modeling. Fire calibration in the ATLSS

model is dependent on historic patterns and proportions of hot and cold fires. Historic trends have been found not to correlate with current fire activity (Rick Anderson, pers. comm., ENP 2008). Particularly with climate change, we need to consider temperature and precipitation relationships to those patterns and allow a dynamic change in fire patterns. Fire is not modeled in ELVeS v.1.1, but it is planned for future versions.
4. To address sea level rise and climate change response in future vegetation succession modeling, coastal and near-shore coastal vegetation communities need to be incorporated as well as salinity and climate tolerance responses.
5. A goal in ELVeS design was to provide a model that adapts readily to iterative experimentation and change. In addition to open source code distribution and the already mentioned object oriented design, the ELVeS interface permits rapid variable modification without requiring code changes (ELVeS User's Guide, Supernaw et al. 2011).

Figure 3 illustrates ELVeS data pre-processing and simulation occurring within five stages: 1) Data inputs to the model, 2) Pre-processing of input data, 3) Probability calculations, 4) Temporal lag controls on community succession and 5) Model output. The stages are described below.

MODEL INPUT AND PREPROCESSING

Planned model inputs originate from one of five primary data domains:

1. hydrology
2. soil biogeochemistry
3. salinity
4. fire
5. storms

HYDROLOGIC PARAMETERS

Hydrologic input data may come from a variety of data sources and modeling output that provide spatially continuous water depths (e.g., Everglades Depth Estimation Network (EDEN), South Florida Water Management Model (SFWMM), Natural System Model (NSM), Regional Simulation Model (RSM), and other hydrologic models). These data are pre-processed to extract a suite of hydrologic metrics (Appendix A) that were evaluated for use in the classification engine. The utility to extract hydrologic metrics was created in-house, and details of its use are provided in the HydroMetrics program User's Guide (SFNRC 2011a).

Numerous hydrologic metrics have been used by investigators working in the Everglades. One result from this large body of work is a plethora of reports identifying similar hydrologic metrics such as hydroperiod that are useful in describing vegetation response (Appendix B). The decision to examine and develop a larger set of derivative hydrologic metrics than those described in the literature followed from the spring 2010 workshop. It was clear to the workshop participants that limiting ELVeS parameterizations to the previously developed parameters would not provide the sufficient analytical information required to enhance performance of the model. Additional hydrologic metrics, representing different temporal periodicities and estimates of parameter variability were expected to better quantify ecological relationships between vegetation communities and hydrologic drivers. This was undertaken following recommendations that several new metrics in addition to seasonally based wet and dry periods, and mean annual water depth estimates would enhance examination of critical relationships between vegetation and the hydrologic environment. Forty-nine hydrologic metrics were identified (Appendix A) in response to this suggestion. As of this report, water depth simulations from EDEN (releases as of July 2010) and SFWMM ECB3 v.6.0 daily data records have been used to calculate annual estimates for each of the 49 metrics. EDEN is an interpolated water-depth data layer from a water level monitoring network (Liu et al. 2009). This report uses the daily median water-depth data layers for the period from 2000 to 2010. SFWMM ECB3 is the existing conditions baseline alternative of the SFWMM covering the period from 1965 to 2000. Pearson correlations were calculated for the EDEN hydrologic metric set to aid in reducing the metric set used in modeling by determining degrees of independence among the metrics (Table 1). The majority of the metrics were determined to be both highly positively and negatively correlated with one another as expected. Selection of hydrologic metrics for use in ELVeS was governed by two criteria; 1) maximizing separability and 2) reducing correlation of vegetation community classes. Selection of parameters based on low correlation scores reduces the multi-dimensional niche space to the fewest number of independent metrics, thereby making the model more efficient in defining a niche space. However, some correlated metrics still aided in achieving maximum separation of communities. The vegetation community relationships with the metrics are modeled simplifications of multidimensional environmental gradients. Community composition is often overlapping in these modeled niche spaces.

SOIL – NUTRIENT PARAMETERS

Newman and Osborne (Reddy et al. 2005) collected soil samples throughout the Everglades region in 2003 (Figure 4). This survey included samples from WCA1 (A.R.M. Loxahatchee National Wildlife Refuge) at the northern extreme to - just north of Florida Bay in the south. The soil survey includes records for 1,410 points distributed throughout the system. A subset consisting of 1,292 sites includes descriptive records of the vegetation and soil characteristics at each surveyed site. Soil physical property attributes included in this survey are: total phosphorus (TP), total inorganic phosphorus (TIP), Loss on Ignition (LOI), bulk density (BD), total nitrogen (TN), total carbon (TC), total magnesium (TM), and water depth recorded at the time of the survey. Vegetation data were collected in a nested sampling design, one reflecting a 10-m landscape scale and the second one at a 3-m radius of the sample location reflecting site-level species coverage estimates.

The Regional Environmental Monitoring and Assessment Program (R-EMAP) soil survey sponsored by the Environmental Protection Agency (EPA) (Scheidt and Kalla 2007) references 344 sites throughout the WCAs and ENP (Figure 4). R-EMAP was designed to address broader issues related to water quality, eutrophication, mercury contamination, soils, and habitat than the Newman and Osborne survey data (Reddy et al. 2005) and therefore includes metrics for substantially more environmental variables. Vegetation characterization of the survey samples is also more detailed in the R-EMAP survey than in the Newman and Osborne survey data. Plant species diversity inventoried by Newman and Osborne totaled 20 whereas R-EMAP totaled 178 species.

Table 2 compares the frequency of soil survey sample locations as they occur in cells classified according to the RECOVER-Gap Analysis Program (GAP) vegetation map (see Methods for details of the RECOVER-GAP combined vegetation classification). This comparison suggests that the major vegetation types depicted in the RECOVER-GAP vegetation map are approximately equally represented by each of the independent soil surveys. R-EMAP includes 21 categories represented by no samples or by samples representing less than 1% of the total number of samples. The Newman and Osborne (Reddy et al. 2005) survey sample locations occur within a larger number of vegetation types, but 15% of these survey sites are represented by less than 1% of the complete survey. The major types represented by both surveys include Sawgrass Marsh (56.10% and 43.46% by R-EMAP and Newman and Osborne, respectively), Open Marsh (19.19% and 12.22%, by R-EMAP and Newman and Osborne, respectively), and *Muhlenbergia* Wet Prairie (8.72% and 6.19% by R-EMAP and Newman and Osborne, respectively).

Kriging surfaces for TP and LOI were created directly from the Newman and Osborne survey data (Reddy et al. 2005), using ArcGIS (Version 9.3.1). Calibration of these surfaces was guided by other kriged surfaces for these parameters in the Everglades WCAs (Bruland et al. 2006, Corstanje et al. 2006, Rivero et al. 2007). Data used by these authors are the same data used to produce the surfaces for ELVeS. In each of these investigations, each WCA was kriged independently. The surfaces developed for ELVeS used data from the complete survey, including ENP, but, in this first iteration of the model, disregarded canals, roads, and other infrastructure that divide the Everglades into unique water impoundment areas. Parameterization values for the kriged surfaces developed for ELVeS are reported in Table 3.

FIRE AND STORM PARAMETERS

Fires and storms are not yet incorporated in this model. Because these disturbance regimes are important in Everglades ecology we anticipate they will be included in future versions of the model.

SALINITY PARAMETERS

Although the saline community modeling component is also not presented in this report, it is useful to note that Antlfinger and Dunn (1979) developed a classification scheme integrating frequency of flooding and interstitial salinity to discriminate saline prairie vegetation. ELVeS will examine these classifications and a broader literature base for use in the mangrove and saline prairie/hardwood zonation areas. Their classification integrates frequency of flooding and interstitial salinity to discriminate five communities (Rushes (*Juncus)* – Sea Oxeyes *(Borrichia)*, Glassworts *(Salicornina)* – Saltworts (*Batis)*, Salt Flats, Cord Grasses (*Spartina)*, and tidal creeks) along a saline to freshwater gradient. Two modeling efforts Teh et al. (2008) and Wang et al. (2007) address vegetation dynamics associated with saline water intrusion and salinity diffusion in coastal Florida environments. These models may provide a framework for our modeling design consideration and sea level rise assessments for coastal regions of the Everglades. Sea level rise is potentially the most important global change factor that will influence the distribution of the mangrove – saline prairie and the mangrove – hardwood ecotone boundary. Flooding by increasing sea level and changes in the soil salinity concentrations will be directly influenced.

SPATIAL DOMAIN AND RESOLUTION

Parameters for each of the input data layers are maintained in NetCDF files as spatially explicit, geo-referenced information. ELVeS classifies vegetation distribution patterns within each of the WCAs, and ENP (Figure 2). Inclusion of Big Cypress National Preserve (BCNP) is anticipated in future releases as forested communities are included in the model and as better continuous data layers become available for the preserve. Templates or geographic masks can be defined in a pre-processing step or as post-processing to focus the model output on a smaller isolated zone such as Taylor Slough in ENP, or a single model cell.

The modeling resolution of ELVeS is unrestricted and dependent only on the resolution of input data sources. For example, EDEN hydrologic data are geo-referenced in a 400 x 400-m resolution regular grid and output will match the EDEN grid when EDEN is used as the input hydrologic layer. The model is flexible and can accept input data from any CF-compliant NetCDF format regular grids, including CERP-compliant NetCDF, such as the SFWMM (with either 2 x 2-mile or 500 x 500-m resolution) or potentially even grids with finer resolutions for local modeling. The ability to accept variable resolution mesh input data such as the RSM is anticipated in the near future.

MODEL CALCULATIONS

ELVeS operates as a raster at 400-m resolution when using the EDEN grid and hydrology. When the SFWMM is used for hydrologic input, the Delaney triangulation method was used to interpolate the SFWMM grid and hydrology to a 500-m resolution. Every grid cell processes the hydrologic, soils, and nutrient information on a yearly time step to define an ecological niche for each year of the simulation. Each of the input data files is stored independently as a NetCDF file that is accessed during the data pre-processing stage. Model output is developed for every modeled cell. When other hydrologic models are used, the spatial domain (number of cells and spatial resolution) changes relative to the selected hydrologic model.

Every cell in the raster is parameterized to characterize a multi-dimensional environmental gradient space. Instantaneous probability scores for the vegetation types are calculated by examining the ecological drivers on a cell-by-cell basis. That is, for each environmental variable (or driver), a distribution function has been established for the estimated probability of occurrence for each of the vegetation communities. The model uses the joint probability distribution functions to classify the likelihood for each vegetation community within individual cells during a model run. Vegetation types with the highest-ranking instantaneous probability score are evaluated against the current community and temporal lags in community transition to produce a final vegetation map. Instantaneous probabilities refer to the probability of a vegetation type occurring in a cell, given the environmental conditions in the current year. Temporal lags control how quickly an existing community will be replaced when a different community has a higher probability of being at the location. The equations of these procedures are presented in more detail below for the freshwater marsh component. Because ELVeS is typically expected to operate at resolutions of 400 to 500 m, the influence of spatial neighbors on community succession was assumed to be minimal and was not modeled.

The vegetation community with the highest joint probability is defined as the dominant type within specific cells. Dominance in the current version of the ELVeS model doesn't address the issue of assigning a "winning" vegetation type when its probability, for example is 27% and the second highest ranking type has a 26% probability, an insignificant difference. However, probability estimates for each vegetation community are stored regardless of whether it is the highest-ranking probability, allowing users to assess possible ecotonal conditions or for post-processing applications.

The final vegetation community predicted to occur in each cell is the probability of occurrence when considering temporal lags. This result is a stochastic simulation that assigns an increasing probability that the community will be replaced when there is an increasing number of years with low instantaneous probability that the current vegetation community should be dominant.

MODEL OUTPUT

The ELVeS model creates several layers of projected, spatially explicit mapped output that allow the user to examine the individual probabilities that result in the final mapped classification. Those layers are:

1. Conditional probabilities of occurrence for each of the vegetation communities, given each input variable independently

e.g., for each grid cell: $P(i| j)$

where i = each of the vegetation communities and j = each of the input variables

2. Joint instantaneous probabilities of occurrence of each of the vegetation communities when the input variable results are combined as a geometric mean

e.g., for each grid cell: $P(i) = (P(i| j1) \times P(i| j2) \times P(i| j3) \ldots \times P(i| jn))^{1/n}$

3. The dominant instantaneous probability predicted vegetation community

e.g., for each grid cell: for the set of community instantaneous probabilities (P(i)) select the community with the highest probability.

4. The secondary instantaneous probability predicted vegetation community

e.g., for each grid cell: for the set of community instantaneous probabilities (P(i)) select the community with the second highest probability.

5. Temporal lagged vegetation community response.

e.g., the dominant vegetation community after simulation of temporal lags.

Because the intermediate model outputs for conditional probabilities and joint instantaneous probabilities are retained, the investigator can reconstruct the communities at each grid cell in increasing detail as desired. The distribution of probabilities for each community in the grid cell is available as well as the contribution that each metric contributes to that probability. Temporal lags associated with community change are integrated in the modeling and predicted community probabilities reflect this dynamic.

SECTION II - FRESHWATER MARSH COMPONENT OF ELVES

This report focuses on the freshwater marsh component of ELVeS v.1.1. Forest communities and coastal saline wetland communities are planned for incorporation into ELVeS in future versions. Background information for the freshwater marsh component of ELVeS comes from a variety of sources including published literature in ecological journals, professional technical reports, and decisions based on the series of species expert workshops that were conducted to design the model. A February 2009 workshop led to the initial parameterization of ELVeS. Results based on this initial development work were presented to freshwater marsh workshop participants in March 2010. The outcome of these reviews and discussions was recognition of the need for additional parameters and further analyses to improve model performance. Parameters used to model the freshwater marsh had to come from available, spatially continuous data layers or from data layers that could be readily constructed. Two criteria for parameter selection are reducing correlation and maximizing separability of the marsh communities. This documentation examines the probability of occurrence for 11 freshwater marsh communities (Spikerush, Graminoid Marsh, Willow, Cattail, Open Marsh, Floating Emergent Marsh, *Muhlenbergia* Wet Prairie, Mixed Marl Wet Prairie, Sawgrass, Herbaceous Marsh, and Open Water) matching community descriptions from the RECOVER classification scheme (Rutchey et al. 2006)). Of the 11 classes investigated, eight are modeled in this version of ELVeS as discussed below.

FRESHWATER MARSH & WET PRAIRIE LITERATURE REVIEW

We conducted a literature review to identify specific environmental drivers that affect vegetation succession in the Everglades. Broad ecotonal overlap among communities can result in investigators reporting different environmental responses to similarly labeled vegetation classes. The problem of possibly comparing unlike communities is exacerbated by inconsistencies in nomenclature such as in references to “wet prairie.” Conclusions drawn between the freshwater communities modeled on the RECOVER classification scheme and information identified in the literature should be based on firm knowledge of the methods and nomenclature used by the referenced investigator.

This literature review, in concert with workshops and discussions with local investigators, set the stage for modeling Everglades graminoid communities and was central in guiding our approach to developing metrics for vegetation response. The Methods section of this report details when relationships identified in the literature review were used directly in the ELVeS model. Perhaps most importantly, however, the literature served to inform our understanding of how and why species and communities segregate on the landscape. Ultimately, this background provided a basis for developing a multivariate statistical assessment of the metrics used to parameterize the model.

The term “wet prairies” can refer to short-term or longer-term hydroperiod locations in the Everglades. Unfortunately, this term is used indiscriminately throughout Everglades science literature obfuscating discussion of two unique communities: deeper-water marsh communities underlain by peat common in the central and northern portions of the system and southern Everglades marl communities that occur on calcitic pinnacle rock (Lodge 2010). Long-term hydroperiod wet prairies are dominated by spikerush (*Eleocharis* spp.) and occupy three times as much area as do the short-term hydroperiod prairies (Rutchey et al. 2006). Short-term hydroperiod wet prairies occur in ENP and in the adjacent BCNP on marl substrates and are dominated by Gulf muhly (*Muhlenbergia capillaris* var. *Filipes*) or mixed graminoids. Vegetation composition and structural patterns in wet prairie settings varies responding to a combination of hydropattern characteristics (Armentano et al. 2006, Childers et al. 2006), but also to substrate (peat vs. marl) and phosphorus distribution (Doren et al. 1997, Childers et al. 2006). Hydropattern in the Everglades has been considered as a principal factor in virtually all ecological dynamics for wet prairies, marsh, and slough communities (Appendix B). Each of these components has a significant bearing on vegetation dynamics. Hydroperiod is often cited as a primary driver responsible for vegetation distribution patterns. As will be illustrated in this report, hydroperiod is only one of several hydrologic drivers that should be considered when modeling vegetation dynamics and distribution patterns. In fact, the analysis conducted in support of the model development demonstrates that discontinuous hydroperiod does not provide sufficient ecological separability among vegetation communities in comparison to other hydrologic metrics (See Methods and Appendix C). Ross et al. (2003a), Richards and Gann (2008), and Gann and Richards (2009), for example, identified water depth, length of draw-down periods, and variability of mean annual water depth among the critical drivers of vegetation dynamics.

Different authors have used a variety of terms to identify marl wet prairie vegetation (U.S. Fish and Wildlife Service 1999). Synonyms include Marl Prairie, Short Sawgrass Prairie, *Muhlenbergia* Prairie, Mixed Grass/Sedge Prairie, and Rocky Glades Prairie (Olmsted et al. 1980, Kushlan 1990, Olmsted and Armentano 1997, Davis et al. 2005, Bernhardt and Willard 2006, Sah et al. 2006). Dominant species include Gulf muhly and sawgrass (*Cladium jamaicense)*. Subdominant species include black sedge (*Schoenus nigricans),* arrowfeather threeawn (*Aristida purpurascens),* Florida little bluestem *(Schizachyrium rhizomatum),* and love grass (*Eragrostis elliottii)*. Marl prairies are situated in slightly higher (30 cm or less) elevated positions east and west of Shark River Slough, ENP. Historically, these areas experienced inundation periods lasting from 2 to 9 months and supported different dominant vegetation. Following the development of the Central and Southern Florida Project, this pattern reversed with dry downs lasting an average of 9 months (Van Lent et al. 1993, Fennema et al. 1994). Armentano et al. (2006) suggested inundation periods of 2 to 4 months with occasional periods of 6 months in the southern coastal wet prairies. History seldom documents complete biological records and such is the case of the role of Gulf muhly in the southern Everglades marshes. Armentano et al. (2006) raises concern that the substantial presence of Gulf muhly in marl prairies is potentially an artifact of recent hydrologic mismanagement and fire incidence. Lower water depths and short hydroperiods are conducive to development of Gulf muhly dominance. Greater water depths and longer inundation periods will alternatively favor other species, such as sawgrass and or spikerush (in the absence of elevated phosphorus). Marl prairie is the primary habitat for the Cape Sable seaside sparrow (CSSS) (*Ammodramus maritimus mirabilis*). Field surveys of nest site occupancy have demonstrated different preferences for marl plant communities exhibiting slightly drier conditions and shorter hydroperiods as highlighted in Table 4.

Nott et al. (1998) investigated water management histories in the marl prairies adjacent to Shark River and Taylor Slough to improve understanding of CSSS population dynamics. Their assessment identified an association between the management of water as a principal agent responsible for major population declines in this endangered species. Marl prairies west of Shark River Slough were determined to be “too wet” during critical breeding seasons and prairies east of Taylor Slough were both “too wet and too dry” (Nott et al. 1998). Gulf muhly, a dominant species in the short-hydroperiod marl communities, lost its competitive advantage to sawgrass when the hydroperiod was extended. Perhaps as a secondary factor, community trajectory is also influenced by periphyton dynamics and its spread in sloughs. Above ground net primary production (ANPP) estimates of periphyton in the Everglades were examined by

Ewe et al. (2006). Estimates of periphyton productivity reported by these investigators were demonstrated to be influenced by water levels and residence times. Overall, periphyton ANPP estimates in Taylor Slough and Shark River Slough represent some of the highest and most variable in the world (Ewe et al. 2006). Long-hydroperiod (greater than 210 days) and short-hydroperiod (60-210 days) periphyton mats differ in a number of critical ecological characteristics including biodiversity and magnitude of dry and ash-free weight. Development of biomass is greater in short-hydroperiod marshes compared to long-hydroperiod deeper marshes. These lower trophic order ecological characteristics are important for higher order ecosystem processes in nutrient biogeochemistry exchange and macrophyte productivity. Nott et al. (1998) proposed a conceptual model that describes an interaction between hydroperiods, periphyton, Gulf muhly, and sawgrass. They suggest that longer hydroperiods in the marl prairies will initiate greater periphyton productivity resulting in larger, thicker mats that can dislodge and float. Shading of the submerged macrophytes may reduce the ability of the submerged plant species to survive inundation. Sawgrass culms can penetrate these mats while Gulf muhly culms cannot. As the hydroperiod decreases, Gulf muhly would normally become reestablished as the dominant species. These authors further suggest that these mats may be large and occupy large patches. If this mechanism is correct, local scale patch dynamics and local-scale successional trajectories could be mediated by these interactions. The primary trajectories of marl prairies, discussed in the literature, revolve around the hydrologic factors. Other factors are also critical. An unambiguous characterization of the hydroperiod in this system is seldom agreed upon in the literature. Some authors as indicated above suggest a 2- to 9-month (Davis et al. 2005) hydroperiod while others suggest 3 – 7 months (Nott et al. 1998). Deriving a strict definition for all practical purposes is not feasible because representative species have narrower or wide tolerances and many of the species are also present in long-hydroperiod marsh settings. Lower water tables and shorter hydroperiods may increase the likelihood of conversion to a more woody vegetation type. For example, invasion by the natives, wax myrtle (*Myrica cerifera*) and willow (*Salix caroliniana*), and exotic tree and shrub species such as melaleuca and Brazilian pepper-tree (*Melaleuca quinquenervia* and *Schinus terebinthifolius*, respectively) could represent a potential for change in this subsystem.

Change in short-hydroperiod marsh vegetation was documented by Ross et al. (2003a) and Armentano et al. (2006). Water management delivery to the Taylor Slough elevated marl marshes changed over a 30+ year time span as new infrastructure was constructed or removed. Vegetation response patterns were directly associated with the hydrologic dynamics that these changes caused. Sites that initially supported Gulf muhly became wetter and transitioned between sawgrass and spikerush communities. Similarly, sites that became drier trended from spikerush to sawgrass and from sawgrass to Gulf muhly. Although uniform change was not observed, the overall direction of change was from drier to wetter conditions. In addition to the three dominant marl species, 26 subordinate species were identified along the five transects during the survey period. Wetter conditions reduced species richness on transects (Ross et al.

2003a, Armentano et al. 2006). Change in species abundance may occur rather quickly, within 3- to 4-year time periods trending toward either longer- or shorter-hydroperiod species given increasing or decreasing hydroperiod trends. One of the major findings from Ross (2003a, 2003b), however, was that changes in community composition could not easily be associated with a discernible temporal lag period. Hotaling et al. (2009) and Zwieg and Kitchens (2008, 2009) suggest lag periods as long as 4 years may be critical determinants of vegetation community response in the wet prairies of WCA3A. Armentano et al. (2006) reported that changes in species dominance (Gulf muhly to sawgrass and sawgrass to spikerush) in Taylor Slough was detectable within 3 to 4 years and continued for an additional 3 years following changes linked to the S332 and S332D water management structures at the head of Taylor Slough. Childers et al. (2003) resurveyed transects, first reported by Doren et al. (1997) in WCA1, WCA2, and WCA3, finding significant changes in composition and species richness and linked these changes to nutrient concentrations. Given that observed changes in Taylor Slough were inconsistent and occurred across fine topographic scales, and that various authors report different estimated temporal lags, extrapolating change dynamic behavior reported from one area of the system to a broader geographic domain of the Everglades remains a difficult process.

Hydroperiod alone only partially explains how vegetation communities are distributed in wet prairies and sloughs. A generalized realization of the community distribution pattern positions bayhead swamps and tall sawgrass communities in shorter hydroperiod zones near sparse sawgrass with slightly longer hydroperiods followed ultimately by spikerush communities in the longest marsh hydroperiod settings (Ross et al. 2003a). Spikerush and sparse sawgrass communities according to this gradient occupy sites with average annual water depths of 25 cm lasting for approximately 9 months. Tall sawgrass sites may be inundated for 6 – 10 months, and bayhead swamps for 2 – 6 months (Ross et al. 2003a). Earlier investigations (Olmsted and Armentano 1997, Busch et al. 2004) that examined relationships between water depths and hydroperiod also reported significant relationships between vegetation distribution patterns and the interaction between hydroperiod length and water depth.

Ross et al. (2003a) quantified this relationship, suggesting that a narrow threshold of 5- to 10-cm change in water depth or a 10- to 60-day hydroperiod change can alter the dominance of vegetation types within specific geographic settings. Brandt (2006) combined data from Richardson et al. (1990) and Jordan (1996) to surface elevation differences among vegetation communities in WCA1. She reports surface elevation differences of 10 cm between slough and wet prairie (primarily spikerush), 19 cm between slough and sawgrass, and 5 cm between sawgrass and brush/shrub. Given the fine spatial- and temporal-scale relationships between these hydrologic factors, regional models of vegetation dynamics need to account for each of these as primary drivers of change.

Childers et al. (2006) investigated biomass response patterns of sawgrass and spikerush in the Taylor Slough region to hydroperiod and salinity fluctuations. Using a non-destructive biomass sampling technique and repeated measures analysis of variance, they were able to identify temporal pattern differences in sawgrass and spikerush development. Spikerush is typically associated with longer hydroperiods than sawgrass. Water management is likely to influence the stem density and biomass of both of these indicator species. Longer-hydroperiod conditions favor spikerush while shorter-hydroperiod conditions will shift competitive advantages to sawgrass and other shorter-hydroperiod preference species (Childers et al. 2006). Increasing freshwater volumes across Taylor and Shark River Sloughs will influence the vegetation dynamics predictably; in the absence of elevated phosphorus, longer hydroperiods will favor species such as spikerush and other long-hydroperiod preference species.

Shorter hydroperiods may exacerbate the frequency of wildfire. However, short-hydroperiod plant species tend to increase their abundance when the hydroperiod conditions remain stable for a few years. Short-hydroperiod species include wand goldenrod (*Solidago stricta*) (hydroperiod length in days = 138), cypress panicgrass (*Dichanthelium dichotomum*) (165), Florida little bluestem (170), erect centella (*Centella erecta*) (173), and frogfruit (*Phyla nodiflora*) (178). In contrast, love grass (224) and bluejoint panicgrass (*Panicum tenerum*) (232) are long-hydroperiod species (Ross et al. 2003b). Hydroperiod optima were derived by examining the weighted averaging regressions and observed average hydroperiods where the species occurred weighted by their abundances at 91 locations in Taylor Slough (Ross et al. 2003b) . Finally, species tolerance was estimated as the weighted standard deviation of hydroperiods.

Fire frequency and intensity in marl prairies influences vegetation dynamics. Post-fire biomass (cover) recovery occurs rapidly. Gulf muhly biomass (cover) following the Mustang Corner Fire of 2008 was equivalent to or greater than pre-burn levels within 6 months of the fire (Rick Anderson, ENP, pers. comm., 2008). Herndon and Taylor (1986) assessed vegetation biomass recovery 1-, 2-, and 3- years after burns in the ENP boundary zone. They reported that live fuel recovery reached 90% of its pre-burn volume within the first year following fires and that biomass accumulation continued for two years (Herndon and Taylor 1986). Liu et al. (2010) characterized cattail (*Typha* spp.) and sawgrass dynamics from a physiological basis following prescribed burn experiments conducted in WCA2. Cattail is physiologically and morphologically better adapted for rapid uptake of phosphorus than is sawgrass due to photosynthesis rate differences and root growth strategies (Liu et al. 2010).

Site differences between sparse, short sawgrass and tall sawgrass sites are linked to environmental factors with hydropattern and soil depth being among the most critical. The relationship may represent a significant controlling factor in the spatial distribution patterns of tall sawgrass, sparse sawgrass, and spikerush communities. Ross et al. (2003a) investigated relationships between hydropattern, soil depths, mean water depths, and maximum water depths in Northeast Shark Slough, Central Shark Slough, and Southern Shark Slough along five transects transverse to Shark River Slough. Results, based on a series of ordinations, Analysis of Similarity, and Mantel tests indicate that local hydrologic conditions explained differences in the spatial distribution patterns of sparse sawgrass, spikerush, and tall sawgrass communities. The dense tall sawgrass communities are linked to deeper soils, a potential consequence of biomass accumulation and decomposition rates and greater resistance to surface sheet flows. Spikerush, a species with substantially lower biomass accumulation rates and less resistance to flow, was associated with shallow soil depths in Southern Shark Slough (Ross et al. 2003a). Hydropatterns in which deeper stage conditions occur enhance the likelihood for tall sawgrass development in portions of Shark River Slough. Patterns and associations of soil depth and vegetation are not globally consistent (Ross et al. 2003a).

Slough, wet prairie, and ridge communities are a continuum in which hydroperiod, depth, duration of inundation, flow, resilience to water chemistry, and upper soil (0-10 cm) phosphorus concentrations are pivotal to the structure, state change, and sustainability of these communities. They occupy interconnected ecological niches that are also spatially connected and share ecological drivers that synergistically influence responses in these systems. In essence, the open slough - wet prairie - sawgrass ridge continuum represents a complex integrated system in which ecological processes (nutrient metabolism and biogeochemistry) and functions (photosynthesis, leaf growth, and biomass production) are linked across trophic levels. Alterations in the periphyton communities are directly traceable to alterations that ultimately occur in the macrophyte communities.

Initiation of state change in the open slough - wet prairie - sawgrass ridge continuum can be triggered by fluctuations of the principal drivers. In systems where resources generally are not limiting, species replacement and community stability are regulated by changes associated with the limiting resource (Tilman 1982, Gleeson and Tilman 1992). As an oligotrophic system, minor additions of phosphorus cascade through the hydrologically connected, periphyton-dominated sloughs to ridge, wet prairie, and sawgrass-dominated systems (Gaiser et al. 2005). One of the first investigations of phosphorus dynamics in this system that used a flume system to dose phosphorus resulted in significant changes among periphyton, detritus, consumer organisms, soils, and macrophytes (Gaiser et al. 2005). Gaiser et al. (2005) observed the changes when dosing at a minimum level of 5 $\mu g\ L^{-1}$ representing a 0.16 μM concentration above ambient concentration at the head end of flumes. Such fine levels of sensitivity to phosphorus loadings identify an extremely susceptible state condition that switches to alternative state conditions with minor phosphorus changes. Gaiser et al. (2005) observed change as a temporal process as well as a spatial process at three levels of phosphorus additions. Initial changes observed in periphyton tissue cascaded upward to macrophytes and moved downstream in defined temporal patterns within the experimental 4-year study period. Slough to sawgrass community transitions are thus recognized as a process that may originate at baseline trophic levels and have long-term ecological responses at higher trophic levels.

Hagerthey et al. (2008) examined freshwater marsh, slough, and cattail dynamics in WCA2A and developed a regime-shift conceptual model describing the trajectories and how TP concentration drives these communities to altered states. The model describes two independent transition trajectories that occur when the system moves from an oligotrophic to a more eutrophic state. Open slough communities and cattail dynamics are governed by a lower TP threshold than is the sawgrass and cattail dynamic. Both trajectory paths are characterized by non-linear responses to increasing TP concentrations.

Figures 5 and 6 (reprinted from Hagerthey et al. 2008) illustrate several critical TP concentration levels and vegetation response patterns linked to these changes. Sawgrass dominance increases and displaces other native communities as TP increases in the floc, 0-10 cm soil depths, and 10-30 cm soil depths. Hagerthey et al. (2008) quantified these changes using non-linear regression methods. This framework provides a basis for Hagerthey et al. (2008) to predict slough, sawgrass, and cattail transitions.

Alterations in the bladderwort (*Utricularia* spp.) and periphyton open slough communities are trigger events for eventual change in sawgrass and cattail communities, which is central to understanding larger-scale system change. Bladderwort and the periphyton slough system are exceptionally sensitive to even minor phosphorus additions. Chiang et al. (2000) experimentally fertilized bladderwort, periphyton, sawgrass, and mixed sawgrass-cattail plots in WCA2 with nitrogen and phosphorus over a 4-year time period. In the first year, bladderwort and periphyton biomass significantly declined (four to eight times 29-50 g m^{-2} relative to the control sites 216 g m^{-2}) with 22.4 g m^{-2} phosphorus and nitrogen+phosphorus treatments. Within 2 years biomass declined to about 11 g m^{-2} and by the 3rd year it was eliminated completely (Chiang et al. 2000).

Bladderwort's ability to photosynthesize in phosphorus-laden freshwater is reduced when CO_2 (Moeller 1978) concentrations are marginal, conditions that develop under high phosphorus (>12 μg L^{-1}) and pH conditions near 7 to 9 (Richardson et al. 2007). Everglades rainwater precipitation-weighted mean pH is about 5.0 (Scheidt and Kalla 2007); however, the spatial distribution of surface-water pH indicates substantial spatial variability with the lowest recorded pH occurring in the WCA1 and the highest in ENP. Water quality pH standards were not met in WCA1 for 15 of the 736 samples collected (Scheidt and Kalla 2007).

Richardson et al. (2007) and Hagerthey et al. (2008) have independently proposed that a critical change point in nutrient concentrations is responsible for altering the states of slough communities. Change points define a significant ecological imbalance such that a system will remain in one state, here established by the lower phosphorus concentration, and then change when the phosphorus concentration exceeds the central distribution parameters in the system, thus moving the system to a different state (Richardson et al. 2007). Freshwater in the Everglades has an average pH of 7.5, a condition that supports HCO_3^- rather than CO_2 in phosphorus-enriched waters (Richardson et al. 2007, Scheidt and Kalla 2007). Photosynthesis by bladderwort species is reduced under low CO_2 state conditions. This relationship explains the "CO_2 limitation hypothesis" (Richardson et al. 2007). Periphyton populations decline concomitantly under these nutrient, pH, and CO_2 environments. Hagerthey's conceptual model (Figure 6) describes the multi-state transition dynamics between periphyton, open marsh, water lily, and cattail regimes that are controlled by surface water TP and the benthic algal floc layer.

Chiang et al. (2000), Richardson et al. (2007), and Hagerthey et al. (2008) explore a physiological basis for understanding these changes. Hotaling et al. (2009) provide estimated transition probabilities (Table 5) for wet prairie to slough and from slough to wet prairie. This investigation used multi-state (community representation) modeling methods to quantify directional trajectories between wet prairie community types and open slough communities as well as open slough to wet prairie communities. Hydrologic data from 1992 to 2007 were used to designate each year as either a Dry Season - Dry state, a Dry Season - Normal/Wet state or a Wet Season - Wet state, and Wet Season - Normal/Dry state condition based on a hierarchical clustering procedure. Five variables that were used in the cluster analysis include: 1) percent of time water levels were in the lower quartile for the season, 2) minimum seasonal water levels, 3) percent of time water levels fell in the upper quartile for that season, 4) maximum seasonal water levels, and 5) mean seasonal water depth (Hotaling et al. 2009). They found that the probability of wet prairies transitioning to slough communities was greater during normal and wet years rather than during dry years. Open slough communities alternatively transitioned to wet prairies with higher probabilities during dry years in comparison to the likelihood during normal and wet years (Hotaling et al. 2009). Zweig and Kitchens (2009) provide additional information describing transition likelihoods for wet prairie and slough dynamics in southern WCA3A (Figure 7). Zweig and Kitchen's (2009) model explores succession processes within and between vegetation state changes. This model considers the hydrologic and fire patterns as drivers in this system.

Field and mesocosm experiments (Newman et al. 1996, Lorenzen et al. 2001, Edwards et al. 2003, Ross et al. 2006b, Macek and Rejmánková 2007) have concentrated on describing the optimal hydrologic and nutrient requirements for the wetland communities throughout the Everglades. One of the major obstacles to summarizing research findings in the Everglades is the lack of standard vegetation community nomenclature. Community names and species aggregations called a community by individual investigators may differ between investigations depending on the focus of the specific research.

A rich body of literature addressing Everglades vegetation provides summary statistics that are useful in the development of realized niche space for the freshwater marsh communities. Richards and Gann (2008) present summary statistics from various authors, pooling data for hydroperiods and water depths for Everglades plant species. We partially reproduce these compilations in Appendix B. Richards et al. (2009) examined the spatial distribution of vegetation communities and hydrologic properties using EDEN data records. These investigators report water depth metrics for the wet and dry period conditions, like many other investigators. Rather than reporting wet and dry season differences in this analysis as static time periods, we follow Richards et al. (2009) and report wet conditions as periods when water depths were greater than or equal to 5 cm of surface water and dry conditions as periods when water depths were equal to or greater than -5 cm below ground level. Water deficit can develop during any time period if soil moisture conditions are less than the minimum required for the vegetation community.

Water depth has been examined as a principal driver that partially explains the spatial segregation of vegetation communities throughout the Everglades. Givnish et al. (2008) found that water depth and related metrics not only vary among the various wetland communities, but also among the different geographic zones of the system (Table 6). Freshwater marsh community dynamics are also influenced by the concentration of TP. Regime shifts were described by Hagerthey et al. (2008) as non-linear, identifying two independent processes associated with phosphorus concentrations. This pattern is seen in the probability distribution function (Figure 5) for cattail when TP concentrations range between 0 and 1,000 mg/kg (Hagerthey et al. 2008).

Marsh communities are not discretely distributed across the Everglades in hydrologically easily definable settings (Richards and Gann 2008). The landscape is a fine- to medium- scale mosaic of different vegetation types that have developed with unique spatial and temporal signatures, reflecting short and long-term historic management, and environmental conditions. Richards and Gann (2008) and Gann and Richards (2009) conducted literature reviews (Appendix B) of vegetation and ecological relationships for Everglades vegetation communities. The breadth of these reviews serves to illustrate the diversity of investigations conducted and relevant scales of inquiry that have been conducted focusing on two principle drivers; water depth and hydroperiod.

METHODS

VEGETATION CLASSIFICATION AND BASE MAP

Vegetation classification is based upon the RECOVER - South Florida Vegetation Classification Scheme developed by Rutchey et al. (2006). Rutchey et al. (2006) have completed vegetation maps representing each of the WCAs. Color infrared aerial photography (scaled at 1:24000) was used to map vegetation communities. Mapping of the vegetation in the WCAs was staggered due to the vast area covered by each management area. The vegetation map for WCA1 is based on 2004 aerial photography, WCA2A is based on 2003 photography, and the map for WCA3 is based on 1995 photography. The U.S. Army Corps of Engineers and the National Park Service, South Florida/Caribbean Network are currently developing a new vegetation map for ENP with 2009 imagery using the Rutchey et al. 2006 methodology. All mapped data and model outputs are geo-referenced to UTM Zone 17 NAD 1983 projection coordinates and datum. Because RECOVER maps of south Florida are not complete, maps for the WCAs were merged with the South Florida GAP (Pearlstine et al. 2002) vegetation map. The GAP classification is based on 1993–94 Landsat Satellite Thematic Mapper imagery. This procedure produced a single regional vegetation map that includes each of the WCAs, ENP, and BCNP (Figures 1 and 2). Recoding to merge all the conservation area and Park vegetation classes is documented in Appendices D and E. The south Florida GAP map should be replaced by the new RECOVER ENP vegetation map, currently under development, when it is completed. The current spatial extent for modeling includes the WCAs and ENP (Figure 1).

ELVeS uses the combined RECOVER-GAP vegetation map as a calibration database. The RECOVER vegetation map is based on a 50-m minimum mapping unit. A 50-m grid is digitally superimposed on each aerial photograph and the vegetation classification is assigned on a cell-by-cell basis using this grid. Digital maps are archived in an ArcGIS (Version 9.3.1) geodatabase. The South Florida GAP (Pearlstine et al. 2002) vegetation map was produced using a 30-m minimum mapping unit. This imagery was resampled using a nearest neighbor procedure to produce a map with a 50-m resolution. Vegetation classes associated with each of the WCA maps and the South Florida GAP map were slightly different, requiring the development of a series of cross-walk reclassifications (Appendices D and E) that were developed prior to merging each of these independently produced maps in ArcGIS (Version 9.3.1). WCA2B was not mapped by the South Florida Water Management District (SFWMD. This area was integrated in the final map by extracting this area from the South Florida GAP map and merging it with the otherwise combined RECOVER-GAP vegetation map. ArcGIS was also used to assign vegetation classes in this area using a heads-up image processing procedure.

Rutchey et al. (2008) used a binomial sampling protocol (Snedecor and Cochran 1978) to assess the photointerpretation accuracy of RECOVER vegetation mapping. They initially selected 1,332 random points from the aerial photographs. These sites were field visited to aid in signature recognition and vegetation class type corrections. After the final vegetation map was developed, 204 randomly selected sites were examined for overall map accuracy using the statistical sampling protocol described above. The test was established to meet an 85% accuracy level with a +/- 5% error. Accuracy is defined as the extent to which two independent photointerpreters' to classify photographsto the same communities. No accuracy assessment was completed for the Florida GAP classification in southern Florida (Pearlstine et al. 2002).

We elected to use the RECOVER classification scheme for several reasons. The classification scheme was developed as a collaborative project with contributions from the SFWMD, National Park Service, U.S. Fish and Wildlife Service, Florida International University, University of Georgia, Institute for Regional Conservation, and NatureServe. It is the current vegetation classification scheme used by the SFWMD photointerpretation program, and it is the most extensive vegetation mapping project in the Everglades. Secondly, it is anticipated that future mapping activities will follow this classification scheme. Use of the classification is supported by its use by university scientists (for example, Richards developed a crosswalk between the R-EMAP soil survey vegetation types (Jennifer Richards, pers. comm., Florida International University 2010) and the RECOVER (Rutchey et al. 2006) classification. Our use of the classification system further supports development of a standard for vegetation classification in the Everglades.

ELVeS attempts to simulate vegetation communities following the South Florida Vegetation Classification Scheme (Rutchey et al. 2006). This classification scheme presents interpretation difficulties. For example two classes: 1) Floating Emergent Marsh (MFF) is primarily a water lily slough and 2) Open Marsh (MFO) includes both sloughs and wet prairies. Attempts to model these and other community types are potentially compromised by the overlapping hydrologic niche occupied by these communities (Gann and Richards 2009).

PARAMETERIZATION OF FRESHWATER MARSH & WET PRAIRIE COMPONENT OF ELVES

Hydrologic and soils data were overlaid on the combined vegetation map to quantify vegetation distribution tendencies for freshwater marsh vegetation types. For the ELVeS freshwater marsh component, 11 vegetation community types are included:

1) Spikerush
2) Graminoid Marsh
3) Willow
4) Cattail
5) Open Marsh
6) Floating Emergent Marsh
7) *Muhlenbergia* Wet Prairie
8) Mixed Marl Wet Prairie
9) Sawgrass
10) Herbaceous Marsh
11) Open Water

Each of these community types actually represents an association of species separated by dominance (Table 7). Note that the Graminoid Marsh and Herbaceous Marsh are broad super classes that many of the other classes fit hierarchically within. They are included here to observe their responses, but, along with willow, they are not included in the final model, as will be discussed below.

By examining indicator region hydrologic data (EDEN) and vegetation distribution patterns (Florida GAP), Richards and Gann (2008) observed that differences in hydrologic maximum, minimum, and mean water depth conditions were variable and overlapping for graminoid, sawgrass, spikerush, and water lily. Modeling these communities around discretely definable hydrologic conditions is challenging. Marsh communities in the Everglades occupy overlapping hydrologic gradient regimes. ELVeS uses a probability-based approach to spatially model vegetation distribution patterns along hydrologic, nutrient, and soil gradients. Model output quantifies the probability that a community will be present in the cell. Probability values for each community for each cell recognize that many of the communities could potentially occupy the cell given the differences in hydrologic, nutrient, soil tolerances, and preferences by the communities.

Parameterization of the ELVeS model (Table 8) for the freshwater marsh communities was accomplished by developing relationships between each of the RECOVER-GAP freshwater marsh vegetation communities within the modeled domain and a subset of the 2003 EDEN hydrologic metrics, the surfaced soil LOI data layer (Reddy et al. 2005), and the surfaced soil TP data layer (Reddy et al. 2005). We selected 2003 as an average hydrologic year characterized by average water-stage conditions for model calibration (Figure 8). From previous exploration, eight hydrologic metrics were chosen for more detailed analysis: Discontinuous Hydroperiod, Discontinuous Hydroperiod Dry (e.g., discontinuous hydroperiod when water levels are less than – 5 cm), Mean Annual Depth, Standard Deviation of Mean Annual Depth, 7-Day Depth Minimum (Min), 7-Day Depth Maximum (Max), 17-Day Depth Min, and 17-Day Depth Max. Following the recommendations of the workshop participants, each of these metrics are based on a hydrologic year (April 1 of current year through March 31 of next year), not the calendar year. The spatial distribution metrics selected as model inputs for EDEN 2003 is shown in Figure 9.

The Zonal Statistics routine in ArcGIS (Version 9.3.1) was used to generate mean and standard deviation values for each metric within each vegetation class. Values were fitted to a normal distribution and the height of the curve was standardized to fit between 0 (poor conditions for the class) and 1 (best observed conditions for the class). Pearson correlation coefficients were generated in the R statistical package (R Development Core Team 2010) among all the hydrologic metrics. The metrics and correlation results are presented in Appendix A and Table 1.

The Zonal Histogram routine in ArcGIS (Version 9.3.1) was used to generate a binned count of the metric values within each vegetation class. A Java Program was created to fit a skewed normal distribution to these histograms and the height of the curve was standardized to fit between 0 (vegetation class not found) and 1 (vegetation class most frequently found). The results of these analyses are presented in Appendix C.

Taken individually, there is considerable overlap among the range of metric values for the vegetation classes, but the classes may be discriminated when a number of the metrics are taken together. For example, in Figure 10, although Soil LOI provides some of the best separation among communities, Mixed Marl Wet Prairie still overlaps with *Muhlenbergia* Wet Prairie, Floating Emergent Marsh, and Cattail. There is less confusion with Open Marsh. 17-Day Water Depth Max helps to separate these classes while Standard Deviation Annual Water Depth does the best job of separating Cattail from Open Marsh and 17-Day Water Depth Min provides the best separation between Mixed Marl Wet Prairie and *Muhlenbergia* Wet Prairie. 17-Day Water Depth Max and 17-Day Water Depth Min are both used in the model despite being highly correlated (r ≈ 0.88, Table 1), because they serve to separate different communities.

In a few cases, such as for the Open Water class under the 17-Day Water Depth Max, the histograms are bimodal, suggesting that the vegetation class may represent more than one community and could be split.

For the freshwater marsh ELVeS model run presented in this report, we selected the following input data variables and modeled distributions:

Mean Annual Depth	skewed normal
Standard Deviation Annual Depth	skewed normal
17-Day Water Depth Max	skewed normal
17-Day Water Depth Min	skewed normal
Soil LOI	skewed normal
Soil TP	logistic
marlMask	categorical

The marlMask layer restricts the two Marl Wet Prairie classes (Mixed Marl Wet Prairie and *Muhlenbergia* Wet Prairie) to ENP. Parameterization of the model for each of the input data layers is provided in Table 8. The resulting distributions match the illustrations in Appendix C for the skewed normal distributions. The logistic distributions for soil TP are illustrated in

Figure 11. Notice that hydroperiod was not selected as an input variable because of its limited ability to discriminate among freshwater communities as illustrated in Appendix C.

The water depths presented in Appendix B in which freshwater marsh and wet prairie species are observed can be contrasted to water depths derived for the ELVeS communities containing those species as illustrated in Appendix C. There are caveats to these comparisons. The ELVeS community parameterizations are from the mapped products at a 400-m resolution. This resolution is an appropriate match to the landscape-scale model inputs from the hydrologic models, but it averages environmental conditions (e.g., water depths) over large areas (400 x 400 m) relative to the field observations at a point location. While the dominant community in a 400-m grid cell should be the one being described, there may be overlap in the cell with other communities that bias the average. Point field observations are also not free of bias.

Mean Annual Water Depths, the only hydrologic metric used in ELVeS that is comparable to most literature values, are in broad agreement when the frequency histograms shown in Appendix C are contrasted with Appendix B. Sawgrass is present in water depths ranging from 0 to 68 cm. Givnish et al. (2008) and King et al. (2004) report average depths of ~ 46 to 50 cm. Ross et al. (2006a) report lower values averaging about 32 cm for tall sawgrass and 36 cm for sparse sawgrass. Steward (1984), David (1996), Jordan et al. (1997), and Childers et al. (2006) report average depths in the 20s. The frequency histogram for sawgrass in Appendix C ranges from 0 to > 60 cm with sawgrass becoming substantially less frequent (less than 40% of maximum occurrence) above ~50 cm and the mode at 34 cm, but frequently present at much lower depths down in the teens.

There are two commonly reported species of spikerush in the Everglades, Gulf Coast spikerush and slim spikerush (*Eleocharis cellulosa* and *Eleocharis elongata*, respectively). Childers et al. (2006), Craft et al. (1995), Jordan et al. (1997), and Rejmankova et al. (1995), all report annual water depths averaging ~20-26 cm for *E. cellulosa*. Ross et al. (2006a) reports a value of 41 cm and Givnish et al. (2008) reports average depths greater than 60 cm. *E. elongata* is at 46 cm in King et al. (2004) surveys, and 71 cm as reported by David (1996). The water depths histogram in Appendix C indicates the majority of spikerush (greater than 40% of maximum occurrence) is between 15 and 37 cm with a mode of 30 cm.

The frequency histogram for *Muhlenbergia* communities (mode equal 9 cm) and an average depth of 10 cm for Gulf muhly reported by Gunderson (1994) are in agreement.

White water lily (*Nymphaea odorata*) ranges from 24 to 90 cm with averages reported at 46 cm (King et al. 2004), 54 cm (David 1996), and 67 cm (Givnish et al. 2008). The Floating Emergent Marsh community mode is 35 cm with substantial presence in the 22 to 40 cm range and again in the sixties and seventies.

Average water depths for cattail (*Typha domingensis*) were reported by David (1996) at 24 cm and at 36 cm by King et al. (2004). Densest growth was found in experimental plots at 22 cm (Grace 1989) and 60 cm (Newman et al. 1996), but White and Ganf (1998) observed growth to be unaffected by water depth. The frequency histogram for Cattail communities in Appendix C shows cattail predominately in the 22 to 42 cm range and a mode of 32 cm.

TEMPORAL LAG IMPLEMENTATION

When conditions favor a new community, temporal lags are expected to influence the transition from the existing vegetation community type to another. Observations of vegetation dynamics in the Everglades have occurred over annual to decadal time frames (Doren et al. 1997, Childers et al. 2003, Ross et al. 2003a, 2003b). These investigations provide numerous examples of species level dynamics associated with long-term hydrologic, fire, and or nutrient concentration changes. Zweig and Kitchens (2008) conducted field surveys annually between 2002 and 2005 to develop a dynamic state transition model of the freshwater marsh vegetation in WCA3A. They observed species level transitions based on hydrologic conditions of the previous four years. Hotaling et al. (2009) subsequently developed transition rates for a multi-state, dynamic vegetation transition model.

In the ELVeS model, the existing vegetation community is not immediately replaced when a different community has a higher probability of being at a location. If environmental conditions change such that the current community's probability of occurrence becomes low, it is increasingly likely to be replaced over time.

Probability of replacement is defined independently for each community. The probability of replacement determines how long the community retains dominance under unfavorable conditions. For each contiguous year in which the existing community is not the favored community, an index is incremented such that the index is equal to the previous year's index plus the proportional difference in the current year. The difference between the probability of the favored community and the current community is the proportional difference. The probability of replacement is then determined by evaluating the index against a probability of replacement curve (Figure 12).

Consider the situation where community A is the current dominant community and the instantaneous probability of community A is 0.87. If community B has an instantaneous probability of 0.16, then community A has a very low probability of replacement (Figure 12). If community B has an instantaneous probability of 0.89, the proportional difference is very small, but positive. Therefore, the probability of replacement will increment by 0.02, only a slight increase in this year. If the proportional difference between communities had been higher then there would be an increased probability of replacement. The function used in ELVeS for the probability of replacement curve is a transformation of the logistic equation (Brandewinder 2008) that offers more intuitive control over when growth happens and the rate of growth. The equation is:

$$a = \ln(1/PValue1 - 1)$$
$$b = (a - \ln(1/PValue2 - 1)/(End - Start)$$
$$P(x) = Peak/(1 + e^{-b*(x-(a/b+Start))})$$

where:

Peak = maximum value that can be obtained = 1.0 (constant) for this application

Start = concentration (horizontal axis position) at start of logistic curve

End = concentration at end of logistic curve

PValue1 = the proportion of the Peak that has been reached at a concentration of Mean1

PValue2 = the proportion of the Peak that has been reached at a concentration of Mean2

x = concentration at which the function is being evaluated

For this application, the function is increasing with a PValue1 of 0.01 and a PValue2 of 0.99.

If the current community is also the favored community, then the index is set to zero. If the index is greater than zero, a uniform random number is generated. If the random number is less than the replacement probability, then the current community is replaced with the favored community, otherwise the current community is not replaced. Because the process is stochastic from random number draws, multiple runs of the procedure can be performed to generate an output that is the community selected in the majority of the runs.

For this report, vegetation communities were all set with the same temporal lag probabilities (Start = 0.001, End = 4.5), however, the ELVeS v.1.1 user interface provides easy access for establishing individual lag probabilities for each community as more information becomes available.

MAPPED PROBABILITY RESULTS

Figure 13 illustrates the ELVeS conditional probability outcome from the 2003 EDEN input and the resulting instantaneous joint probability for the Sawgrass vegetation communities. The instantaneous joint probabilities for all the communities are shown in Figure 14. Figure 15 is the 2003 dominant and secondary vegetation classifications resulting from combining the joint probabilities for all communities. Contingency tables are used to evaluate how well a classification matches a known control. In our application we examine how well modeled ELVeS classification matches the RECOVER-GAP vegetation map. Tables 9 - 11 compare results from ELVeS model runs with two hydrologic input models against the RECOVER-GAP vegetation map. These results are explored in detail in the Calibration and Validaton section, below. Visually, (Figure 15) the dominant vegetation outcomes maintain the landscape distribution of communities in the calibration map quite well. A difference in the conservation areas is broad areas of Floating Emergent Marsh that would more accurately have been classified as the near-ecotone neighbor, Open Marsh. Cattail is also broader than expected, but the cattail patches are generally in the correct locations except along the Tamiami Trail. In WCA1, Open Marsh is sparser than expected. In ENP, Mixed Marl Wet Prairie is too broadly distributed in relation to the Sawgrass class west of Shark River Slough and too narrowly distributed in relation to *Muhlenbergia* Wet Prairie to the east of Shark River Slough. Sensitivity tests and parameterization against multiple water years may improve results for these communities.

The secondary vegetation outcomes are the result of selecting the second most probable vegetation community. It is less obvious how well this layer performs. This output layer would benefit from rules that restrict the selection of communities with very low probabilities and/or group communities with nearly identical probabilities.

Table 12 presents an example of the numeric output underlying the mapped results. The availability of the intermediate results allows investigators to observe each of the communities' responses to the conditions at a site and the contribution of each environmental variable to the communities' response.

ELVeS was also run with the same parameterization against SFWMM ECB3 v6.0 alternative hydrology. Figure 16 illustrates those results for 1997. A common year isn't yet available for comparison between EDEN and SFWMM ECB3. EDEN hydrology is available for 2000 to 2010 and SFWMM hydrology is available for 1965 to 2000. Water depths in 1997 are similar to those in 2003, but characterized by water stages that are typically a quarter to a half a foot lower (Figure 17).

Finally, Figure 18 illustrates the effect of the temporal lag routine on ELVeS output. SFWMM ECB3 was again used as the hydrologic scenario and year one (1965) of the simulation started with a random distribution of vegetation communities. For this simulation, all of the communities were assigned the same temporal lag response. The probability of replacement is 1% when the index of disfavor is 0.001 and 99% when the index is 4.5. That means that in conditions that are clearly favorable to a community switch, most of the transitions would be expected after 3 to 5 years. The prevailing difference in Figure 18 between the dominant communities from the instantaneous probabilities in 1977 and communities resulting when temporal community replacement lags are modeled leading up to 1977 is the larger extent of sawgrass—particularly in contrast with Open Marsh.

CALIBRATION AND VALIDATION

DEFINITIONS

Error matrices are a standard approach for testing the agreement between a classification model and field observations. An error matrix (e.g., Campbell 1996, Congalton and Green 2009) shows the distribution of modeled classes in relationship to the observed class at the same locations. The error matrix also reports user and producer accuracies by class and overall accuracies.

> **Producer accuracies** are defined as the percentage of area of a specific class on the ground that is correctly identified as that class on the map. **Omission error** is equal to 1 minus the producer's accuracy and represents the mapped area that is misclassified as a the specific class, but should be classified as a different class.
>
> **User accuracies** are defined as the percentage of areas identified as a specific class on the map that is in agreement with what is at that location on the ground. **Commission error**, equal to 1 minus the user's accuracy, is when a mapped area is included in a class to which it doesn't belong.
>
> Figure 19 illustrates these definitions.

CALIBRATION

Table 9 presents the error matrix results for the ELVeS freshwater marsh model dominant vegetation communities compared to the RECOVER-GAP data set when 2003 EDEN hydrology data are used as the model input. The error matrix when 1997 SFWMM ECB3 hydrology is used is shown in Table 10. Tables 9 and 10 both represent the dominant community from the joint instantaneous probabilities. Table 11 presents the error matrix when 1997 SFWMM ECB3 hydrology is used and the dominant vegetation includes simulation of temporal lags. The RECOVER-GAP vegetation map serves as a control in both comparisons.

Contingency tables or error matrices are standard forms for presenting classification results (Campbell 1996, Congalton and Green 2009). The tables provide a numeric comparison between the control and the modeled classification overall and for each class. The diagonal shaded cells are the number of mapped cells that are correctly classified. The non-shaded cells represent the number of mapped cells that are incorrectly modeled. Errors of omission represent the assignment of errors of a known class (from the control) to a modeled class. Errors of commission occur when a modeled class is incorrectly assigned to a known class from the control map. Producer's accuracy is the ratio of the correctly classified mapped cells to the total number of mapped cells across each row. For example in Table 9, Spikerush was correctly classified 10,500 times. The total number of mapped cells for Spikerush (summing across the row) is 34,311, yielding a Producer's Accuracy of 30.6%. The Users Accuracy is similarly calculated, but as the ration of the correctly classified mapped cells to the total number of mapped cells down each column.

The results of the error matrices are more alike than different. The RECOVER-GAP classification has a 50-m resolution, which often results in a diversity of classes under each 400 m ELVeS grid cell. Most striking is the extent with which the Sawgrass class in the RECOVER-GAP classification dominates almost all ELVeS modeled communities. To attempt to take some account of Sawgrass overwhelming the other communities, accuracies in both tables are shown with and without inclusion of Sawgrass.

For the instantaneous probabilities, the Open Water class has the poorest performance in both EDEN and SFWMM ECB3 outcomes for both omission and commission errors (Tables 10 & 11). When Sawgrass is excluded, Open Water is most often confused with Open Marsh. The high commission error of Open Water is closely followed by Spikerush and Floating Emergent Marsh. Floating Emergent Marsh also most frequently confuses with Open Marsh while Spikerush confuses with both Open Marsh and Mixed Marl Wet Prairie (still excluding confusion with Sawgrass). Cattail and Sawgrass, overall better performers, both also owe their lower scores to confusion with Open Marsh. The Open Marsh class, itself, has the highest user accuracy scores because of low commission error with other classes, but Open Marsh has higher omission error from confusion with many of the other classes. When sawgrass is excluded from the community mix (except in the case of the Sawgrass community itself), good-to-acceptable user accuracy performance was reported for Open Marsh (95% EDEN/89% ECB3), Sawgrass (70%/75%), Mixed Marl Wet Prairie (76%/71%), and Cattail (68%/68%). Producer accuracy scores were best for *Muhlenbergia* Wet Prairie (81%/77%).

Although there are notable spatial differences in the SFWMM ECB3 results when temporal lag responses are simulated versus the instantaneous probabilities, those differences are not markedly present in the error matrices (Tables 11 & 12). User accuracies for the temporal lag responses are nearly identical to the instantaneous probabilities except for a marginal improvement in Open Water and a slight decrease in *Mulhenbergia* Wet Prairie scores. Producer accuracies decreased in the temporal lag responses for Spikerush, Open Marsh, and Mixed Marl Wet Prairie. Producer accuracies increased for Floating Emergent Marsh.

VALIDATIONS

Validation of the community distribution patterns requires use of an independent vegetation map. The EPA (Scheidt and Kalla 2007) R-EMAP included vegetation surveys at 344 sites. Jennifer Richards (pers. comm., Florida International University 2010) developed a cross-walk classification scheme linking the R-EMAP vegetation data samples to the RECOVER vegetation classification scheme enabling an independent comparison of vegetation distribution patterns for freshwater marsh communities.

Prior to using the R-EMAP survey points as validation against the ELVeS output, R-EMAP observations were compared to the RECOVER-GAP (Pearlstine et al. 2002, Rutchey et al. 2006) vegetation map to quantify the degree of agreement between these data sets. HawthsTools, an add-on tool package for ArcGIS, provides a point intersection tool. R-EMAP was imported to ArcGIS and intersected with the RECOVER-GAP vegetation map to link vegetation codes associated with R-EMAP and with RECOVER-GAP. Vegetation classes assigned to the R-EMAP survey points were obtained from Jennifer Richards (pers. comm., Florida International University 2010).

Table 13 shows the confusion matrix comparing R-EMAP's five vegetation classes and RECOVER-GAP against the RECOVER-GAP 12 vegetation classes. Producer and user accuracies are reported for the five vegetation classes common to both data sets. Sawgrass has the highest producer accuracy at 78.3% and a corresponding error user accuracy of 66.6%. *Muhlenbergia* wet prairie has the next highest producer accuracy of 70% and a corresponding user accuracy of 66.7%, followed by the Cattail class with an producer accuracy and user accuracy of 40% and 83.3%, Floating Emergent Marsh at 6.4% and 27.2% producer and user accuracies and Spikerush class at 0.0% for both producer and user accuracies. Large disagreements between these two independently produced datasets highlight potential calibration and validation issues. Additional observation data (see Future Directions section) may assist with these issues.

R-EMAP survey points were also intersected with output from ELVeS using the EDEN hydrology. The error matrix for R-EMAP versus the ELVeS simulation model output (Table

14) frequently finds the same areas of confusion as the R-EMAP versus RECOVER-GAP comparison. Accuracy for Spikerush was 74%/76% (Producer/User). *Muhlenbergia* Wet Prairie has an accuracy of 55%/69% and Sawgrass has a producer's accuracy of 50%/66%. Cattail and Floating Emergent Marsh community types had the lowest accuracies of 24%/35% and 21%/24% respectively.

LIMITATIONS

Current digital elevation data for the Everglades are at 400-m resolution, which limits the resolution of water depth input data (such as EDEN) to 400 m as well. That is adequate for broad landscape analyses, but it is well above the resolution required to capture ridge and slough or tree island dynamics.

Differences in the spatial resolution of the data sets must also be considered in any interpretation of these results. Field-based vegetation surveys are site- or point-specific observations and the spatial scale of classification of this data is known to vary among investigators. RECOVER-GAP (50-m mapping units) and ELVeS (400-m mapping unit) homogenizes diverse community distribution patterns.

Soil LOI and TP layers are currently used as static inputs to ELVeS. Dynamic modeling of phosphorus and sediment transport with the Everglades Landscape Model (ELM, Fritz 2009),Transport and Reaction Simulation Engine (TaRSE) model (Jawitz et al. 2008), and other dynamic nutrient and sediment simulation models may eventually allow nutrient and sediment changes to be reflected in ELVeS.

Multi-temporal aerial photography was used to develop the RECOVER vegetation map (Rutchey et al. 2008). Together with the Florida GAP classification imagery, acquisition dates span about 11 years, 1993 – 2004. Our assessment of vegetation distribution patterns and responses to hydrologic conditions were conducted using 2003 summary statistics from EDEN, which was identified as a normal water stage year. It is likely that vegetation has experienced transitions over this time period+ that also add to class confusion in the current analysis. Further directed field study and new photointerpretation with hydrologic observations on common dates can help resolve this issue.

BCNP has been excluded because of the lack of adequate spatial input data, but we hope to include it in the future.

Invasive species were not included in this version. Invasive species often are generalists and would overwhelm the outcomes if considered without active management. These species could be included, however, in model scenarios when there is a specific objective of evaluating where they have the most probability of expanding their presence.

FUTURE DIRECTIONS

Additional datasets are available to aid validation efforts. A cross-walk between the vegetation communities described Newman and Osborne (Reddy et al. 2005), and the RECOVER-GAP classification scheme is being developed (Osborne and Friedman) to enable species distribution statistical analysis and modeling. The cross-walk will provide a link between the major freshwater marsh community types considered by ELVeS. Ross and Sah (Florida International University) have multi-year vegetation surveys across sawgrass to prairie ecotones through the marl prairies. We plan to coordinate with Ross and Sadle (ENP) to assess the use of these data sets and others that are linked to spatially well-distributed locations.

As already noted, work must continue on describing and coding ELVeS components for storms and fire. Storms will be introduced based on scenarios developed in cooperation with the U.S. Geological Survey (Catherine Langtimm, pers. comm., U.S. Geological Survey 2010).

Fire effects in ELVeS are most likely to be parameterized using a simple stochastic event model based on an approximate 12-year cycle of more severe peat fires. These fires can consume peat and release phosphorus, causing an immediate community transition (Beckage et al. 2003). Severe fire followed by flooding may result in sparse vegetation for a much longer period, potentially trending toward open marsh (Jay Sah, pers. comm., Florida International University 2010). It may not be necessary to model annual surface fires because recovery is rapid and typically does not result in community succession, but these issues still need to be explored.

Salinity tolerances also should be added to the freshwater marsh component before integrating freshwater marsh and saline communities in the model. James Watling (pers. comm., University of Florida 2011) is comparing a suite of niche modeling techniques (MaxEnt, random forests, and structured vector models) and demonstrated their potential to capture climate change impacts of temperature and precipitation for south Florida vegetation.

ELVeS was calibrated with EDEN water depth data because that information provides the best available spatially continuous estimates of actual conditions. ELVeS is expected to be used in CERP alternatives planning, however, and hydrologic conditions projected by the SFWMM, NSM, RSM or other models could depart from EDEN estimates enough to influence model outcomes based solely on the hydrologic model selected. At present (2011), it is not known if a separate calibration may be needed for the SFWMM. As the model is distributed and used, however, it is likely that some changes will be suggested. Calibration for specific purposes is an iterative process. ELVeS is designed to make those adjustments easy to implement. SFWMM ECB3 or some other representation of current conditions can be calibrated the in the same way that EDEN was if deemed necessary.

SFWMM ECB3 v.6.0 was tested (with EDEN calibration) and presented in the documentation. The problem with comparative tests or calibrations when the model was being developed is that the same years cannot be evaluated; i.e., SFWMM runs are for water years 1965–1999 and EDEN runs begin in 2000. As a result, we are using the proxy of similarity of spatial distributions in water depths to compare EDEN 2003 versus SFWMM ECB3 1997. Further tests of differences among EDEN, SFWMM, and other hydrologic models are taking place among various research groups. EDEN and SFWMM are both undergoing updates that include longer, overlapping time series. SFWMM outputs have recently become available through 2005. EDEN outputs going back to 1900 are expected to be released by the end of 2011. These products will allow a more complete evaluation.

Other approaches to determining the final dominant and secondary classification in addition to the simple maximum probability rule might be considered. A Bray-Curtis similarity index is one possibility. For the secondary classification, a different community might only be selected if the probability is greater than some defined threshold (e.g., 20%).

Several sensitivity tests can be conducted to aid in understanding the performance of ELVeS. Among the tests are: (1) How much does removing some variables (drivers) or adding others change the spatial distribution and accuracy of ELVeS' mapped classifications? It appears from visual examination of the probability maps for each species given a specific variable that there is redundancy in the information conveyed to the joint probability maps. (2) How much does varying the spread or standard deviation of a driver for a particular species change the spatial distribution and accuracy of ELVeS' mapped classifications? (3) What is the model's sensitivity to varying temporal lag parameters within probable values?

Periphyton is not modeled in ELVeS v.1.1; however, Gaiser (in prep., Florida International University 2011) is completing a report detailing periphyton environmental relations that may guide inclusion of these communities in the future. There are a number of opportunities to link ELVeS with vegetation models at other scales of spatial and mechanistic resolution. Examples include mangrove-hardwood succession models (Teh et al. 2008, Leonel Sternberg and Jiang Jiang, pers. comm., University of Miami 2010), seagrasses (Fourqurean et al. 2003), fine-scale water flow feedbacks to landscape succession (Larsen et al. 2009, Jawitz 2010, Larsen and Harvey 2011), climate change scenario models (Michael Flaxman and Juan Carlos Vargas, pers. comm., Massachusetts Institute of Technology), and broader-scale climate envelope models (James Watling, pers. comm., University of Florida 2010).

For climate change scenarios, more information may be needed on differential marsh vegetation responses to CO_2 increases. Primary productivity is generally enhanced under elevated CO_2 environments (Antlfinger and Dunn 1979, Schedlbauer et al. 2010). Combined global climate change effects (increased temperature, nitrogen deposition, CO_2 enrichment, and salinity concentrations) are likely to affect species differently (Tylianakis et al. 2008). Plants that photosynthesize following C3 (e.g., cattail, bulrush (*Scirpus* spp.), sawgrass, sedges (*Carex* spp.) and C4 (e.g., Florida little bluestem) metabolic pathways may develop different competitive strengths or weaknesses as climate change continues to develop. Alteration of the competitive status of these species can potentially result in change in both their spatial distribution, community compositional, and structural patterns.

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Table 1. Pearson correlation coefficients for a subset of the 49 hydrologic metrics derived from the EDEN archive 2000 – 2010.
Negative correlations between 0 and -0.50 are in bold text and positive correlations between 0 and +0.50 are bold and shaded. Column headings are symmetric with the row names.

	Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	Discontinuous Hydroperiod	1.0																
2	Discontinuous Hydroperiod Dry	**-0.28**	1.0															
3	Discontinuous Hydroperiod Wet	0.99	**-0.34**	1.0														
4	Continuous Hydroperiod Wet	0.95	**-0.37**	0.96	1.0													
5	Mean Annual Depth	**0.46**	**-0.36**	0.5	0.61	1.0												
6	Stand. Dev. Mean Annual Depth	0.63	0.43	0.59	0.55	0.24	1.0											
7	Median Annual Depth Dry	**0.12**	-0.88	**0.18**	**0.26**	**0.37**	-0.53	1.0										
8	Median Annual Depth Wet	**0.46**	**-0.21**	**0.49**	0.6	0.98	**0.34**	**0.22**	1.0									
9	3 Day Min Water Depth	**0.29**	-0.55	**0.34**	**0.47**	0.94	-0.09	0.6	0.88	1.0								
10	3 Day Max Water Depth	0.58	**-0.23**	0.6	0.69	0.96	**0.46**	**0.23**	0.97	0.84	1.0							
11	7 Day Min Water Depth	**0.29**	-0.55	**0.35**	0.47	0.94	-0.07	0.6	0.89	1.0	0.85	1.0						
12	7 Day Max Water Depth	0.58	**-0.24**	0.6	0.69	0.97	**0.45**	**0.24**	0.97	0.84	1.0	0.85	1.0					
13	7 Day Dry Frequency	**-0.29**	1.0	**-0.35**	**-0.37**	**-0.36**	0.42	-0.88	**-0.21**	-0.55	**-0.23**	**-0.54**	**-0.24**	1.0				
14	17 Day Min Water Depth	**0.31**	**-0.53**	**0.36**	**0.49**	0.95	-0.05	0.58	0.9	1.0	0.86	1.0	0.87	**-0.52**	1.0			
15	17 Day Max Water Depth	0.58	**-0.53**	0.6	0.69	0.97	**0.44**	**0.25**	0.98	0.85	1.0	0.86	1.0	**-0.25**	0.88	1.0		
16	31 Day Min Water Depth	**0.32**	-0.51	**0.37**	0.5	0.96	-0.02	0.55	0.91	1.0	0.87	1.0	0.88	-0.51	1.0	0.89	1.0	
17	31 Day Max Water Depth	0.57	**-0.26**	0.59	0.69	0.98	**-0.31**	**0.26**	0.98	0.86	1.0	0.87	1.0	**-0.26**	0.88	1.0	0.9	1.0
18	Dry Intensity	0.33	-0.85	0.35	0.33	0.28	-0.31	0.74	0.15	0.41	0.19	0.41	0.19	**-0.86**	0.4	0.2	0.38	0.2
19	Wet Intensity	**0.42**	**-0.26**	**0.46**	0.58	0.99	**0.27**	**0.29**	0.99	0.91	0.96	0.92	0.96	**-0.26**	0.93	0.97	0.94	0.98

Table 2. Frequency of soil survey sample locations occurring within RECOVER vegetation class categories. RECOVER– GAP vegetation map spatial resolution is 50 m, soil survey sample locations are effectively point samples. From Scheidt and Kalla (2007) and Reddy et al. (2005).

RECOVER – GAP Map Category	**Class Value**	**R-EMAP**	**Newman and Osborne**
Open Water Florida Bay	1		0.08
Open Water	2	1.74	0.39
Tropical Hardwood Hammocks	3	0.58	1.24
Mixed Mangrove Forest	5	0.87	1.55
Red Mangrove Forest	7		0.39
Pine Forest	8		1.24
Swamp Forest	9	0.29	0.93
Cypress Forest	10		3.25
Bayhead Shrublands	12		1.08
Willow Shrublands	13	1.74	5.34
Succulent Salt Marsh	14		0.31
Graminoid Freshwater Marsh	15	2.91	5.80
Sawgrass Marsh	16	56.10	43.46
Spikerush Marsh	17	0.29	2.32
Muhlenbergia Grass	18	8.72	6.19
Cattail	19	3.49	6.19
Graminoid Salt Water Marsh	20		0.15
Sand Cordgrass Grassland	21		0.23
Black Needle Rush Marsh	22		0.23

Cypress Woodland Open Marsh	23	0.87	3.79
Freshwater Marsh – Open Marsh	24	19.19	12.22
Herbaceous Freshwater Marsh	25		0.54
Dry Prairie (xeric-mesic) Complex	27		0.08
Floating Emergent Marsh	28	3.2	2.16
Swamp Scrub Sawgrass	29		0.15
Melaleuca	31		0.15
Agriculture	35		0.23
Canals	39		0.08
Spoils	40		0.15
Common Reed Giant Cutgrass	41		0.08

Table 3. Parameters for kriged surface calculations of soil physical properties as used by ESRI ArcGIS version 9.3.1.
Kriged geostatistical surfaces were developed from the soil survey provided by Newman and Osborne (Reddy et al. 2005). BD = Bulk Density, TN = Total Nitrogen, TC = Total Carbon, TM = Total Magnesium.

Metric	**TP(mg/kg)**	**LOI (% loss)**	**BD(g/cm^3)**	**TN(g/kg)**	**TC$_{\mathbf{Log(g/kg)}}$**	**TM(mg/kg)**
Major Range	8895.65	13398.4	16001.9	14699.5	17816.6	9736.29
Psill	8671.5	293.84	0.021	60	0.185	1219200
Number of Neighbors	15	15	15	15	15	15
Nugget	30356	154.73	0.008	15	0.0697	838100
Number of Lags/Size	10/1350	10/1350	12/1350	12/1450	12/1250	9/1450
Mean	0.3868	0.002	0.00004	0.021	6.43	-6.22
Root Square Mean	169.1	15.16	0.135	6.02	69.17	964.8
Ave Standard Error	189.8	15.23	0.1159	5.205	125.7	1133
Mean Standardized	0.0018	-0.0009	0.001	0.001	-0.003	-0.004
Root Mean Square Standardized	0.895	0.9954	0.156	1.175	1.032	0.853

Table 4. Marl prairie vegetation communities identified by Ross et al. (2006a). From Ross et al. (2006a) and Michael Ross (pers. comm., Florida International University 2010), communities generally “too wet” for successful CSSS nesting are shaded. CSSS nesting preferences are different in each of these types given the differences in the inferred mean hydroperiod.

Vegetation Type		**N**	**Veg-Inf Hydroperiod (Days) - Mean**	**Veg-Inf Hydroperiod (Days) - SD**	**Veg-Inf Hydroperiod (Days) - SE**
Muhlenbergia WP		72	153	47.4	5.6
Schoenus WP		19	173	54.1	12.4
Schizachyrium WP		69	175	39.0	4.7
Cladium WP		107	198	47.7	4.6
Paspalum-Cladium Marsh		20	233	29.4	6.6
Cladium Marsh		138	261	47.4	4.0
Cladium-Rhynchospora Marsh		96	280	33.6	3.4
Rhynchospora-Cladium Marsh		61	285	33.7	4.3
Eleocharis-Rhynchospora Marsh		19	303	43.3	9.9
Spartina Marsh		7	276	58.7	22.2
All Vegetation Census sites		608	231	65.3	2.7

Table 5. Transition probabilities reported by Hotaling et al. (2009) for wet prairie and slough communities in WCA3A. Probabilities shown are for models contrasting wet and dry water years, with two* and three** state variables. Agglomerative hierarchical clustering was used to identify two wet time periods for which there was plant community data as June 2003 to November 2003 and June 2005 to November 2005, two normal time periods as November 2002 to June 2003 and November 2004 to June 2005, and two dry time periods as November 2003 to June 2004 and November 2005 to June 2006. Hierarchical clustering analysis of 5 hydrologic variables was used to characterize wet, dry, and normal years.

Transition Direction	**Dry Hydrologic Time Periods**	**Normal Hydrologic Time Periods**	**Wet Hydrologic Time Periods**
Prairie to Slough**	0	0.119	0.042
Slough to Prairie**	0.181	0	0.111
Prairie to Slough*	0	-	0.091
Slough to Prairie*	0.182	-	0.048

Table 6. Water depth metrics found to be drivers of vegetation spatial pattern differentiation. Table reproduced in part from Givnish et al. (2008).

Community Type	**Max Water Depth (cm)**	**Min Water Depth (cm)**	**Average Water Depth (cm)**	**Hydroperiod (days)**
Flooded Slough	101.9 +/-1.9	26.8 +/- 1.5	67.1 +/- 1.7	363 +/- 0.4
Emergent Slough	96.9 +/- 2.6	24.0 +/- 1.9	63.6 +/- 2.4	362 +/- 0.8
Slough – Ridge Transition	90.2 +/- 1.7	16.9 +/- 1.2	56.6 +/- 1.5	361 +/- 0.7
Short Sawgrass Ridge	81.0 +/- 2.4	10.2 +/- 1.6	48.3 +/- 2.1	356 +/- 1.3
Tall Sawgrass Ridge	80.8 +/- 1.5	10.9 +/- 1.0	48.5 +/- 1.3	357 +/- 0.8

Table 7. Vegetation communities included in the freshwater marsh component of ELVeS. These are photo-interpretation-based community definitions with the community defined when greater than 50% of the 50-m cell is interpreted as belonging to the community. The exception is Open Marsh, which is defined by aerial vegetation coverage representing less than 50% of the grid cell. Graminoid Marsh and Herbaceous Marsh were included in trials with the EDEN hydrologic metrics, but they represent hierarchically higher-level communities of which the other communities are subsets. Because they are so broadly defined, they and the Willow community were not included in the final scheme for ELVeS. Communities are listed in hierarchical order according to the RECOVER ID Data are from Rutchey et al. (2006).

Community	**RECOVER ID**	**Description**	**RECOVER Class**
Spikerush	522200	Coastal spikerush (*Eleocharis cellulosa*), slim spikerush (*Eleocharis elongata*), and/or knotted spikerush (*Eleocharis interstincta*) dominated marsh.	MFGe
Graminoid Marsh	522000	Graminoid dominated freshwater marsh.	MFG
Willow	423000	Willow (*Salix caroliniana*) characterized by canopy densities from 10% - 49% in a matrix of graminoids and/or herbaceous vegetation.	CSs
Cattail	522700	Southern cattail (*Typha domingensis*) and/or broadleaf cattail (*Typha. latifolia*) dominated marsh.	MFGt
Open Marsh	526000	Open water dominated freshwater marsh often with a mix of sparse graminoids, herbaceous, and/or emergent freshwater vegetation, such as spikerush (*Eleocharis* spp.), panicgrass (*Panicum* spp.), low stature sawgrass (*Cladium jamaicense*), cattail (*Typha* spp.), arrowhead (*Sagittaria* spp.), pickerelweed (*Pontederia cordata*), water lily (*Nymphaea* spp.), green arum (*Peltandra virginica*), swamp-lily (*Crinum americanum*), spider-lilies (*Hymenocallis* spp.), among others.	MFO

		Vegetation coverage is < 50% as detected by aerial photointerpreter.	
Floating Emergent Marsh	524000	Floating emergent dominated freshwater marsh.	MFF
Muhlenbergia Wet Prairie	523500	Gulf muhly *(Muhlenbergia capillaris*) dominated wet prairie (i.e., short hydroperiod marsh). Found commonly growing with low stature sawgrass (*Cladium jamaicense*).	MFGPm
Mixed Marl Wet Prairie	523600 523700	Short hydroperiod marsh characterized by a mix of graminoids that includes low-stature sawgrass (*Cladium jamaicense*), little bluestem (*Schizachyrium scoparium*), black sedge (*Schoenus nigricans*), among others.	MFGPs/MFGPh
Sawgrass	522100	Sawgrass (*Cladium jamaicense*) dominated marsh.	MFGc
Herbaceous Marsh	521000 525000	Broadleaf emergent dominated freshwater marsh. Herbaceous dominated freshwater marsh.	MFB/MFH
Open Water	904000	Unvegetated water areas such as ponds, lakes, rivers, bays, and estuaries.	OW

Table 8. Parameters for the ELVeS freshwater marsh input data variables. Mean Annual Depth, Standard Deviation Annual Depth, 17-Day Depth Max, 17-Day Depth Min, Soil TP, and Soil LOI are presented as skewed normal distributions. The distribution is equivalent to the normal without skew when shape = 0. Soil TP uses a logistic equation. A complete description of the equations and variables used to describe each relationship is provided in the ELVeS User's Guide (SFNRC 2011b).

	Mean Annual Depth (mm)				**Standard Deviation Annual Depth (mm)**			
Community	Location	Scale	Shape	Max	Location	Scale	Shape	Max
Spikerush	417.46	350.00	-9.83	0.77	99.33	50.00	8.57	0.74
Cattail	197.46	200.00	10.17	0.76	129.33	100.00	8.57	0.76
Open Marsh	237.00	350.00	8.00	0.76	229.33	100.00	-11.43	0.77
Floating Emergent Marsh	225.00	250.00	5.00	0.72	209.33	50.00	-1.43	0.53
Muhlenbergia Wet Prairie	47.46	3350.00	-1049.83	0.80	279.33	100.00	-11.43	0.77
Mixed Marl Wet Prairie	27.46	100.00	10.17	0.77	239.33	50.00	-1.43	0.54
Sawgrass	150.00	300.00	3.00	0.66	229.33	100.00	-11.43	0.77
Open Water	187.46	200.00	10.17	0.76	199.33	50.00	-41.43	0.78

	17-Day Depth Max (mm)				**17-Day Depth Min (mm)**			
Community	Location	Scale	Shape	Max	Location	Scale	Shape	Max
Spikerush	600.00	200.00	-1.00	0.49	120.00	200.00	-3.00	0.66
Cattail	470.00	300.00	5.00	0.72	-120.00	250.00	2.00	0.59
Open Marsh	820.00	290.00	0.00	0.40	20.07	400.00	7.20	0.75
Floating Emergent Marsh	431.82	500.00	8.71	0.76	-59.93	400.00	7.20	0.75
Muhlenbergia Wet Prairie	151.82	3650.00	-101.29	0.80	-859.93	400.00	7.20	0.75
Mixed Marl Wet Prairie	111.82	250.00	68.71	0.79	-609.93	500.00	7.20	0.75
Sawgrass	371.82	400.00	8.71	0.76	-150.00	250.00	2.00	0.59
Open Water	401.82	500.00	8.71	0.76	300.00	242.00	0.00	0.40

	LOI (%)			
Community	Location	Scale	Shape	Max
Spikerush	6.83	30.00	3.79	0.69
Cattail	76.83	10.00	1.79	0.57
Open Marsh	86.83	40.00	4.79	0.67
Floating Emergent Marsh	86.83	10.00	-2.21	0.61
Muhlenbergia Wet Prairie	26.83	10.00	-2.21	0.61
Mixed Marl Wet Prairie	16.83	10.00	2.79	0.65
Sawgrass	86.83	90.00	1.79	0.46
Open Water	76.83	20.00	-1.21	0.51

	TP (mg/kg)		
Community	Mean1	Mean2	Gradient
Spikerush	350.00	460.00	-1
Cattail	500.00	650.00	1
Open Marsh	360.00	475.00	-1
Floating Emergent Marsh	390.00	450.00	-1
Muhlenbergia Wet Prairie	180.00	380.00	-1
Mixed Marl Wet Prairie	260.00	475.00	-1
Sawgrass	350.00	500.00	-1
Open Water	320.00	460.00	-1

Table 9. Contingency table for ELVeS using 2003 EDEN as the hydrologic input variables. Mapped ELVeS communities are the dominant instantaneous probability communities. RECOVER-GAP is from Rutchey et al. (2006) and Pearlstine et al. (2002).

		ELVeS									
		Spikerush	Cattail	Open Marsh	Floating Emergent Marsh	*Muhlenbergia* Wet Prairie	Mixed Marl Wet Prairie	Sawgrass	Open Water	% Producer Accuracy	% Producer Accuracy without Sawgrass
RECOVER-GAP	Spikerush	10500	17	27	379	4751	7274	11356	7	30.60	45.74
	Cattail	7175	30323	1580	17039	105	1677	31130	488	33.87	51.93
	Open Marsh	29562	11175	109705	71009	0	0	163405	8548	27.89	47.70
	Floating Emergent Marsh	3069	1625	1993	16409	17	768	15298	1119	40.72	65.64
	Muhlenbergia Wet Prairie	13515	0	0	0	55862	0	0	0	80.52	80.52
	Mixed Marl Wet Prairie	14247	2	13	83	68152	36192	16085	9	26.85	30.49
	Sawgrass	128873	75398	109559	149409	42521	110575	553423	18072	46.59	NA
	Open Water	1179	1159	1630	1188	90	1482	4087	1226	10.18	15.41
	% User Accuracy	5.05	25.33	48.86	6.42	32.57	22.91	69.63	4.16		
	% User Accuracy without Sawgrass	13.25	68.45	95.44	15.46	43.31	76.37	NA	10.76		

Table 10. Contingency table for ELVeS using 1997 SFWMM ECB3 v.6.0 as the hydrologic input variables. Mapped ELVeS communities are the dominant instantaneous probability communities. RECOVER-GAP is from Rutchey et al. (2006) and Pearlstine et al. (2002).

		ELVeS									
		Spikerush	Cattail	Open Marsh	Floating Emergent Marsh	*Muhlenbergia* Wet Prairie	Mixed Marl Wet Prairie	Sawgrass	Open Water	% Producer Accuracy	% Producer Accuracy without Sawgrass
SFWMM ECB3	Spikerush	12097	19	251	225	3442	4909	10411	1862	36.42	53.05
	Cattail	6317	31730	14116	3672	0	1662	33018	356	34.92	54.85
	Open Marsh	29251	11985	209336	21062	0	0	97504	24530	53.18	70.68
	Floating Emergent Marsh	2858	1944	9867	9682	25	150	14123	1648	24.03	36.99
	Muhlenbergia Wet Prairie	5497	0	0	0	50941	10104	2855	0	73.41	76.55
	Mixed Marl Wet Prairie	41428	0	40	115	38843	42610	11115	111	31.74	34.60
	Sawgrass	167962	63830	244092	72321	23931	68576	522113	26046	43.92	NA
	Open Water	2722	1278	547	1650	141	382	4519	782	6.51	10.42
	% User Accuracy	4.51	28.64	43.77	8.90	43.42	33.19	75.05	1.41		
	% User Accuracy without Sawgrass	12.08	67.57	89.40	26.59	54.55	71.23	NA	2.67		

Table 11. Contingency table for 1997 ELVeS output using SFWMM ECB3 v.6.0 as the hydrologic input variables. Mapped ELVeS communities are the dominant communities when temporal lag response is simulated. RECOVER-GAP is from Rutchey et al. (2006).

		ELVeS									
		Spikerush	Cattail	Open Marsh	Floating Emergent Marsh	*Mulhenbergia* Wet Prairie	Mixed Marl Wet Prairie	Sawgrass	Open Water	% Producer Accuracy	% Producer Accuracy without Sawgrass
SFWMM ECB3	Spikerush	8510	19	769	2291	7751	2973	8557	272	27.33	37.68
	Cattail	9435	31107	6770	11788	6	19	28290	708	35.30	51.99
	Open Marsh	25209	11337	104900	22681	0	0	227830	239	26.75	63.82
	Floating Emergent Marsh	2794	1855	5169	15436	31	50	12263	2374	38.62	55.71
	Mulhenbergia Wet Prairie	10008	0	0	0	50136	5304	1762	0	74.60	76.60
	Mixed Marl Wet Prairie	38042	0	78	154	44783	20127	11269	43	17.58	19.50
	Sawgrass	151596	66265	110150	113338	34108	17822	595378	15784	53.91	NA
	Open Water	2506	1307	649	1920	211	42	4463	751	6.34	10.17
	% User Accuracy	3.43	27.80	45.91	9.21	36.59	43.44	66.91	3.72		
	% User Accuracy without Sawgrass	8.82	68.18	88.65	28.44	48.71	70.58	NA	17.12		

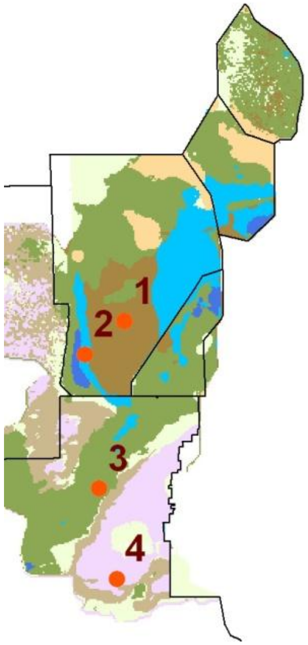
Table 12. Example of ELVeS numeric output at sample locations. Values are from EDEN 2003 as the input hydrologic data layer.

Joint Probability by Community:

	Point ID			
	1	2	3	4
Spikerush	0.06	0	0.52	0.1
Cattail	0.12	0.12	0	0
Open Marsh	0.91	0.7	0.14	0
Floating Emergent Marsh	0.65	0.79	0.42	0
Muhlenbergia Wet Prairie	0	0	0	0.95
Mixed Marl Wet Prairie	0	0	0	0.52
Sawgrass	0.77	0.69	0.8	0
Open Water	0	0.67	0.68	0

Sawgrass Probability by Each Variable:

	Point ID			
	1	2	3	4
17-Day Water Depth Min	0.68	0.46	0.38	0
17-Day Water Depth Max	0.54	0.6	0.91	0
Mean Annual Water Depth	0.51	0.4	0.97	8.60E-04
Standard Deviation of Annual Water Depth	1	0.9	0.89	1
Total Phosphoros	0.92	1	1	1
Loss on Ignition	0.94	0.74	0.73	0.12
Joint Probability of Sawgrass	0.74	0.65	0.78	0



Sample locations

Table 13. Contingency table for R-EMAP – RECOVER-GAP classification errors. Grey cells are common to both vegetation maps R-EMAP and RECOVER-GAP. RECOVER-GAP classes are from Rutchey et al. (2006), GAP is from Pearlstine et al. (2002), and R-EMAP classes are from Scheidt and Kalla (2007).

	RECOVER-GAP Vegetation Classes															
R-EMAP Veg Classes	**MFF**	**MFGc**	**MFGe**	**MFGPm**	**MFGt**	**MFG**	**MFF**	**MFO**	**FMX**	**OW**	**FS**	**FHS**	**FST**	**CSs**	**Total**	**PA (%)**	**EO (%)**
MFF	3	8	0	0	0	0	3	36	0	0	0	0	0	0	47	6.4	93.6
MFGc	2	120	1	2	2	9	2	10	1	4	0	0	0	2	153	78.3	21.7
MFGe	6	51	0	8	0	0	6	19	2	0	0	0	2	2	90	0	100
MFGPm	0	5	0	20	0	1	0	0	0	0	1	0	1	1	29	70.0	30
MFGt	0	9	0	0	10	0	0	1	0	2	0	2	0	1	25	40.0	60
Total	11	193	1	30	12	10	11	66	3	6	1	2	3	6	344		
CA(%)	27.2	66.6	0	66.7	83.3	-	27.2	-	-	-	-	-	-	-			
EC(%)	72.8	33.4	100	33.3	16.7	-	72.8	-	-	-	-	-	-	-			

MFF = Floating Emergent Marsh, MFGc = Sawgrass, MFGe = Spikerush, MFGPm = *Muhlenbergia* Wet Prairie, MFGt = Cattail, MFG = Graminoid Marsh, MFO = Open Marsh, FMX = Mixed Mangrove, OW = Open Water, FS = Swamp Forest, FHS = Tropical Hardwood, FST = Cypress Forest, CSs = Willow, PA is Producer’s Accuracy, EO = Error of Omission, CA = Consumers Accuracy, and EC = Error of Commission.

Table 14. Contingency table for R-EMAP – ELVeS classification errors. Shaded cells are common vegetation classes. R-EMAP classes are from Scheidt and Kalla (2007).

R-EMAP Veg Class	ELVeS Predicted Vegetation Class									
	MFGt	MFF	MFGPm	MFO	OW	MFGc	MFGe	Total	PA (%)	EO (%)
MFGt	6	3	2	2	1	11	0	25	24.0	76.0
MFF	4	10	0	18	0	15	0	47	21.3	76.7
MFGPm	0	0	16	0	8	0	5	29	55.2	44.8
MFGc	7	25	0	18	14	76	13	153	49.7	50.3
MFGe	0	4	5	0	0	13	63	85	74.1	25.9
Total	17	42	23	38	23	115	81	339		
CA (%)	35.3	23.8	69.6	-	-	66.1	75.9			
EC (%)	64.7	76.3	30.4	-	-	33.9	24.1			

MFGt = Cattail, MFF = Floating Emergent Marsh, MFGPm = *Muhlenbergia* Wet Prairie, MFO = Open Marsh, OW = Open Water, MFGc = Sawgrass, MFGe = Spikerush, PA is Producer's Accuracy, EO = Error of Omission, CA = Consumers Accuracy, and EC = Error of Commission.

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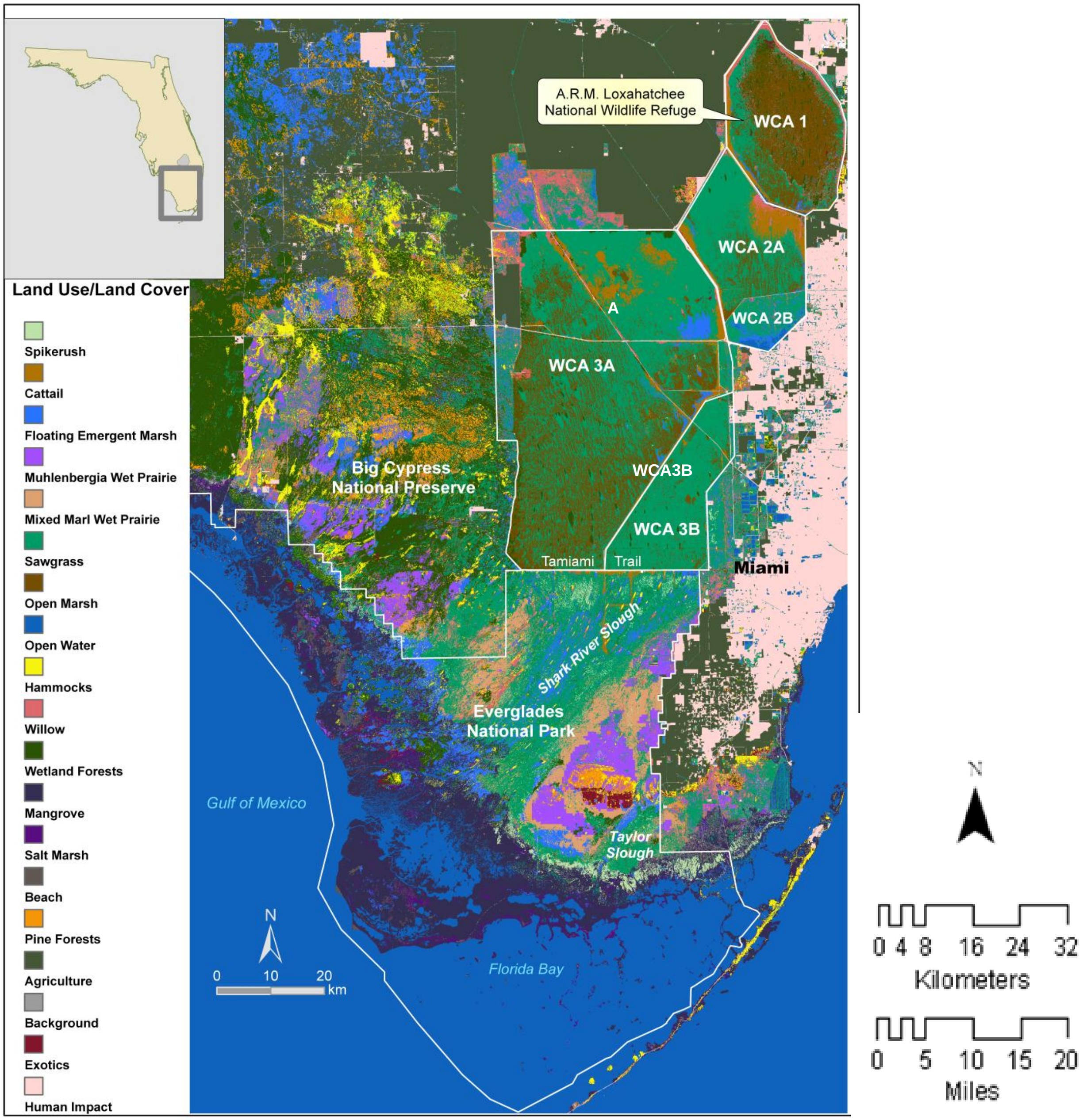


Figure 1. Combined vegetation classification of the ELVeS Everglades spatial domain.
The RECOVER (Rutchey et al. 2006) vegetation mapping geodatabase for WCA1, WCA2, and WCA3 was combined with the Florida GAP (Pearlstine et al. 2002) vegetation map to develop a comprehensive map covering the entire study area. The terrestrial areas with the white boundary outline are the extent of the ELVeS domain. (Coastal communities in the domain are not parameterized in this version of the model).

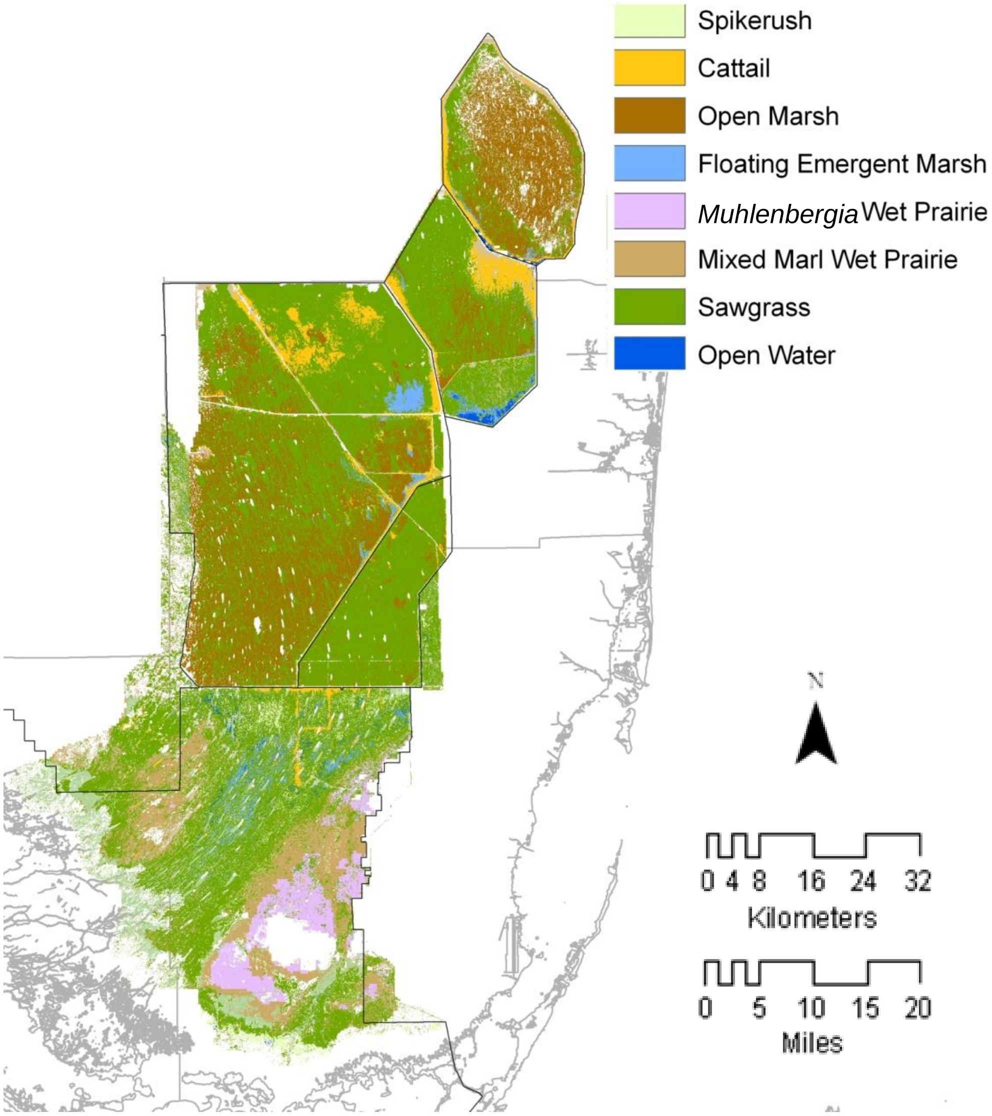


Figure 2. RECOVER-GAP classification showing the eight classes simulated within the ELVeS freshwater marsh and wet prairie model (Pearlstine et al. 2002, Rutchey et al. 2006). No color indicates other vegetation types not modeled in this version of ELVeS.

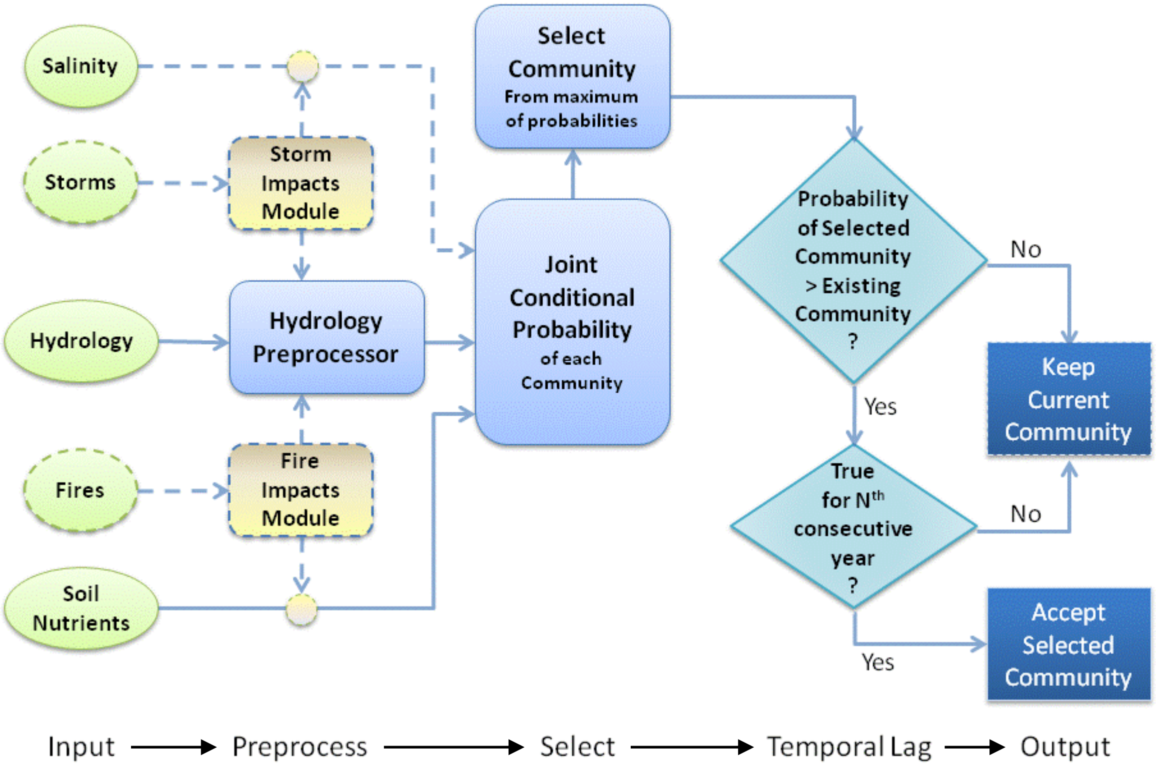


Figure 3. Schematic diagram of the ELVeS model.
Processing moves from left to right in the diagram and dashed connections are design elements under development for future versions.

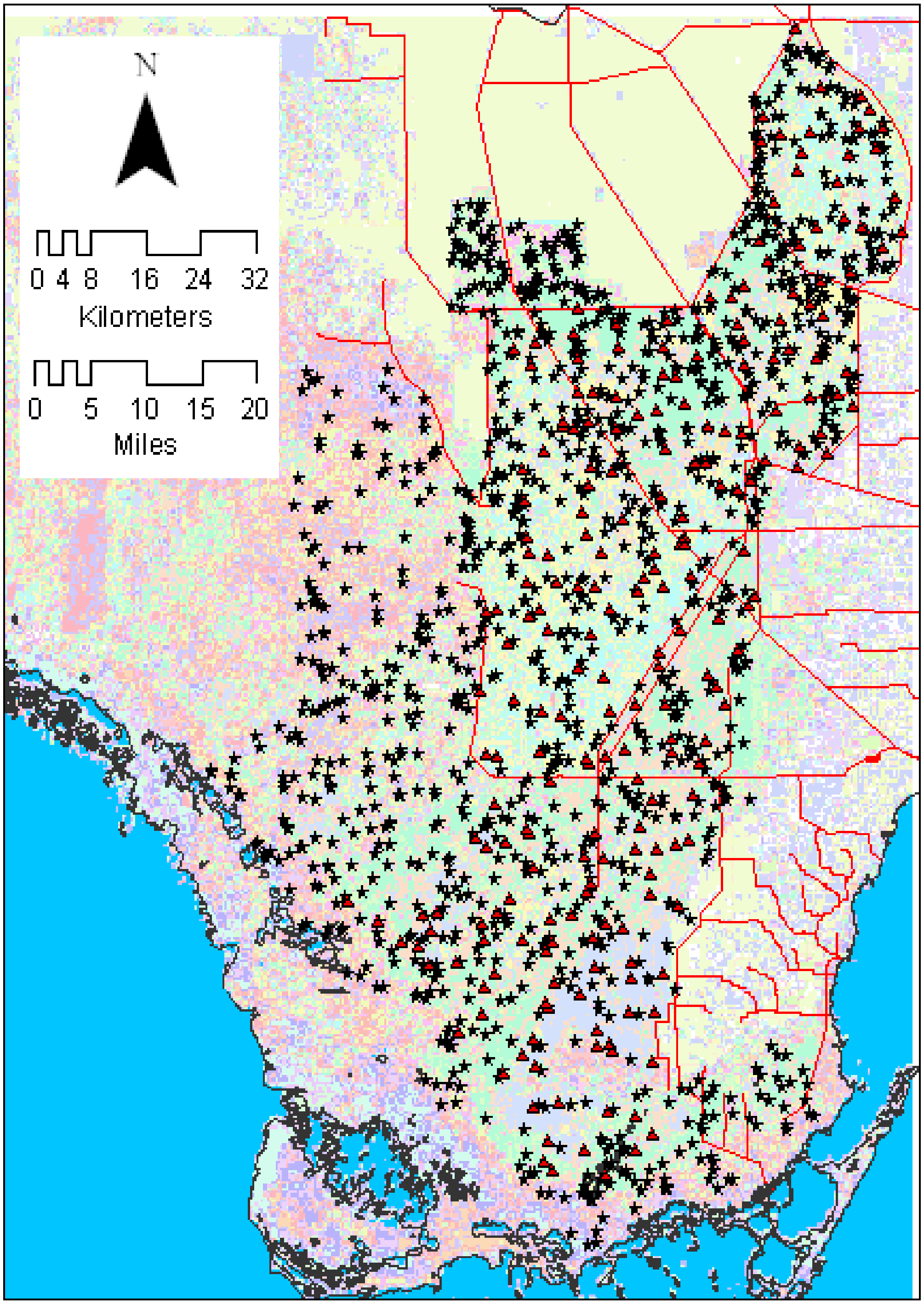


Figure 4. Site location map of R-EMAP (red triangles) and Newman and Osborne (black stars) soil surveys. (Reddy et al. 2005, Scheidt and Kalla 2007).

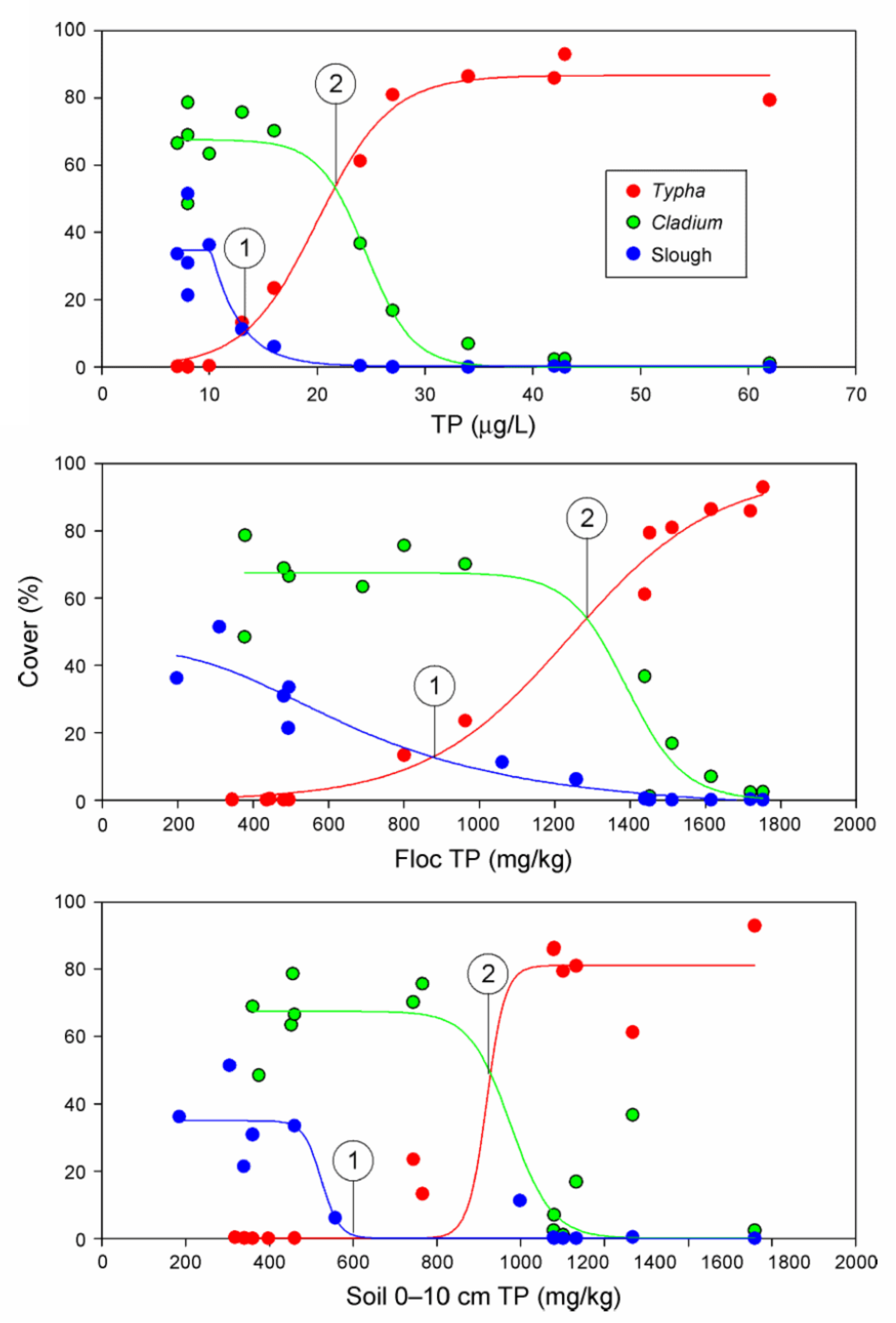


Figure 5. Non-linear response of Typha, Cladium and Slough vegetation cover to P concentrations (Hagerthey et al. 2008). Reprinted with permission © Ecological Society of America.

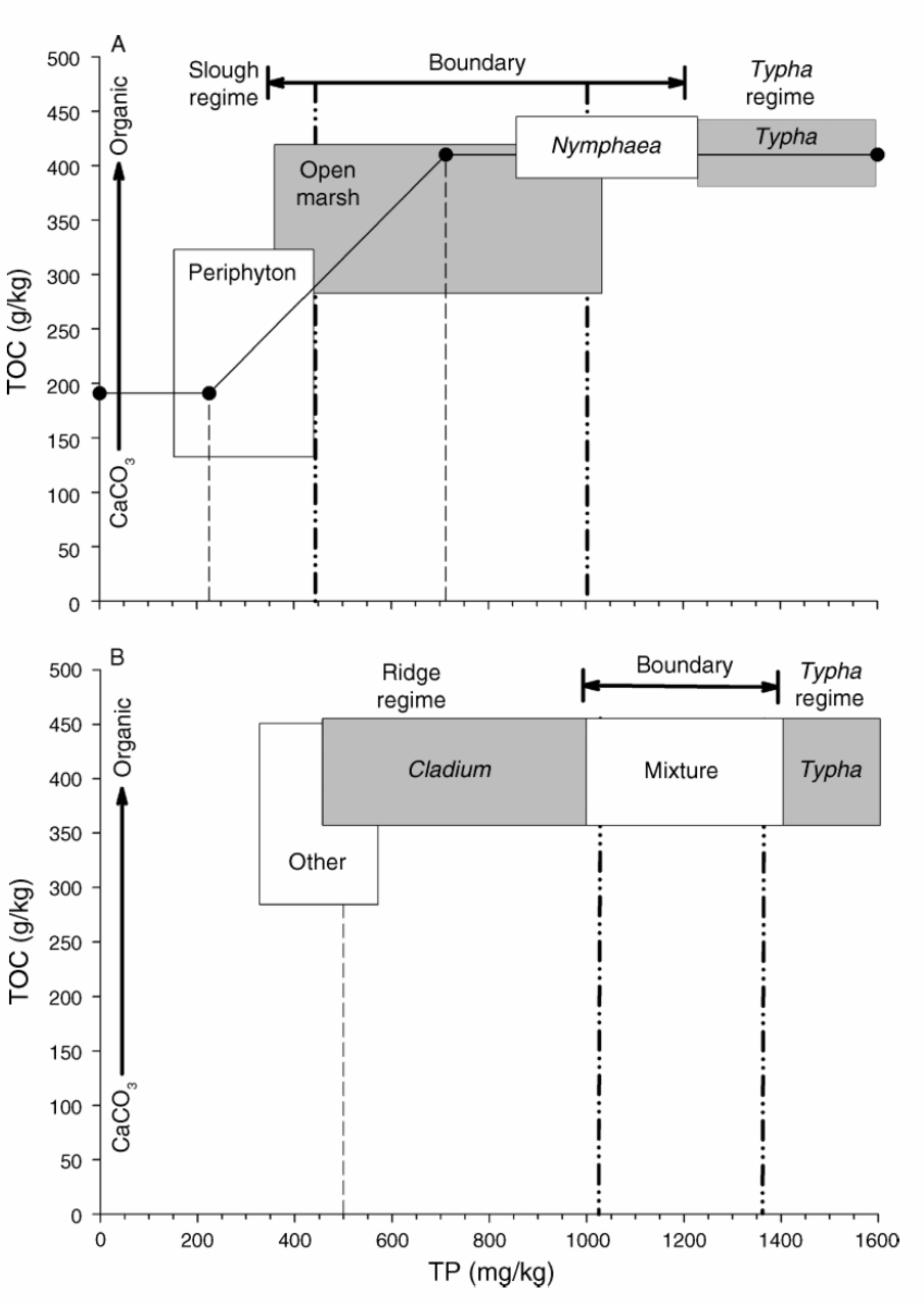


Figure 6. Transition trajectories that occur when the system moves from an oligotrophic to a more eutrophic state (Hagerthey et al. 2008). Reprinted with permission © Ecological Society of America.

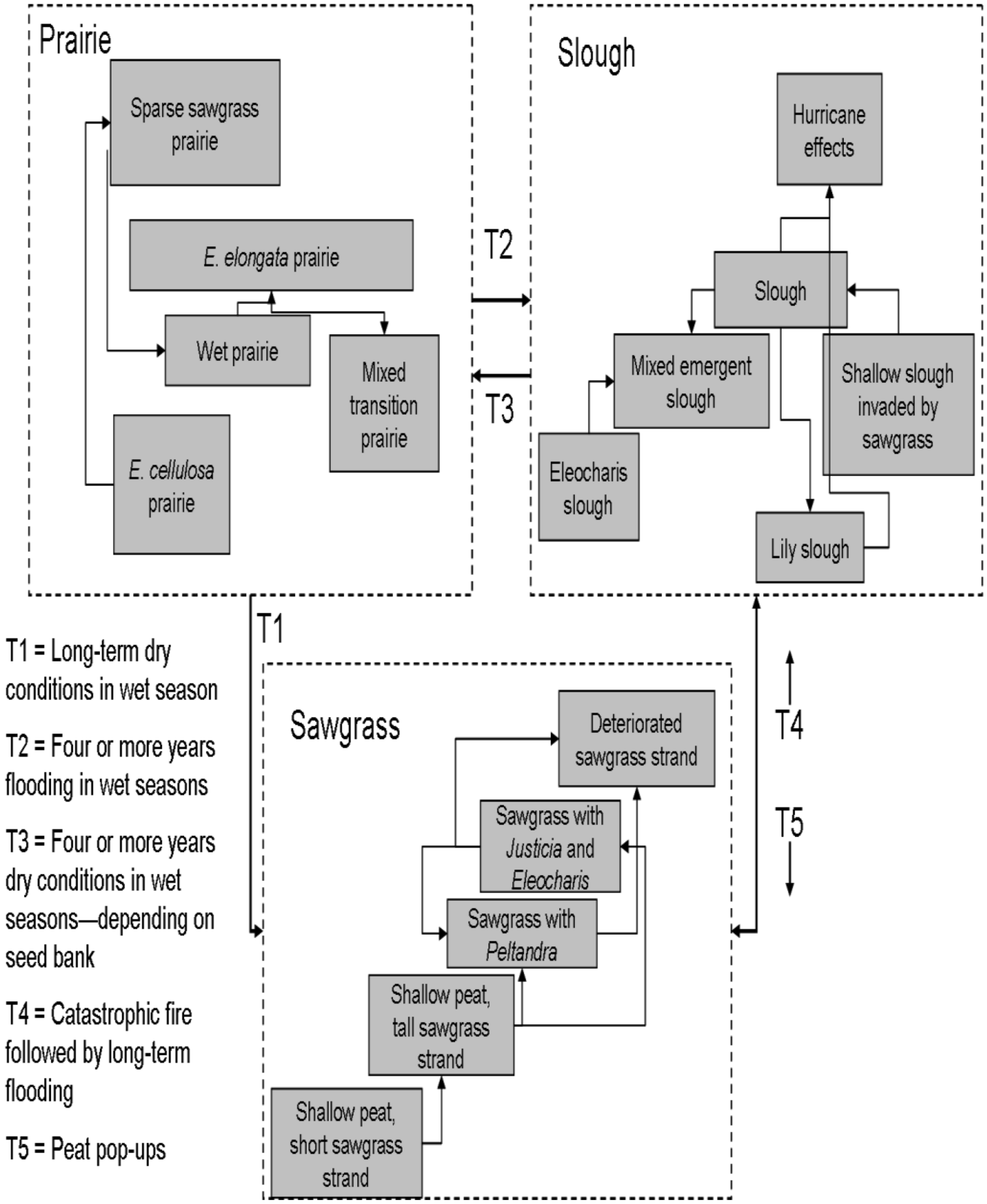


Figure 7. Transition rate in multi-state wetlands succession (Zweig and Kitchens 2009). Reprinted with permission © Ecological Society of America.

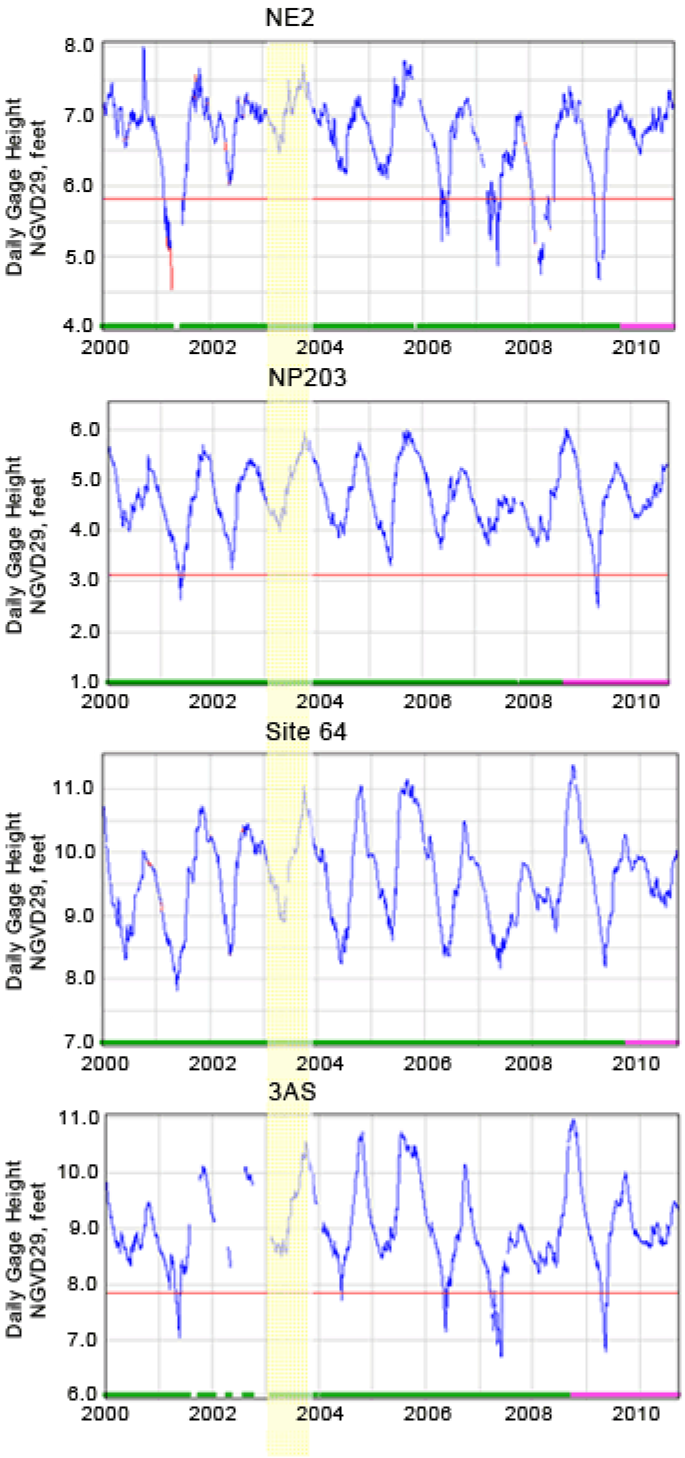


Figure 8. Hydrographs at two ENP sites, NE2 and NP203, and two WCA3A sites, Site 64 and 3AS. 2003 is highlighted to illustrate its selection as a normal year for stage heights. Red horizontal lines (when present) indicate ground elevation (graphs from U.S. Geological Survey 2010a).

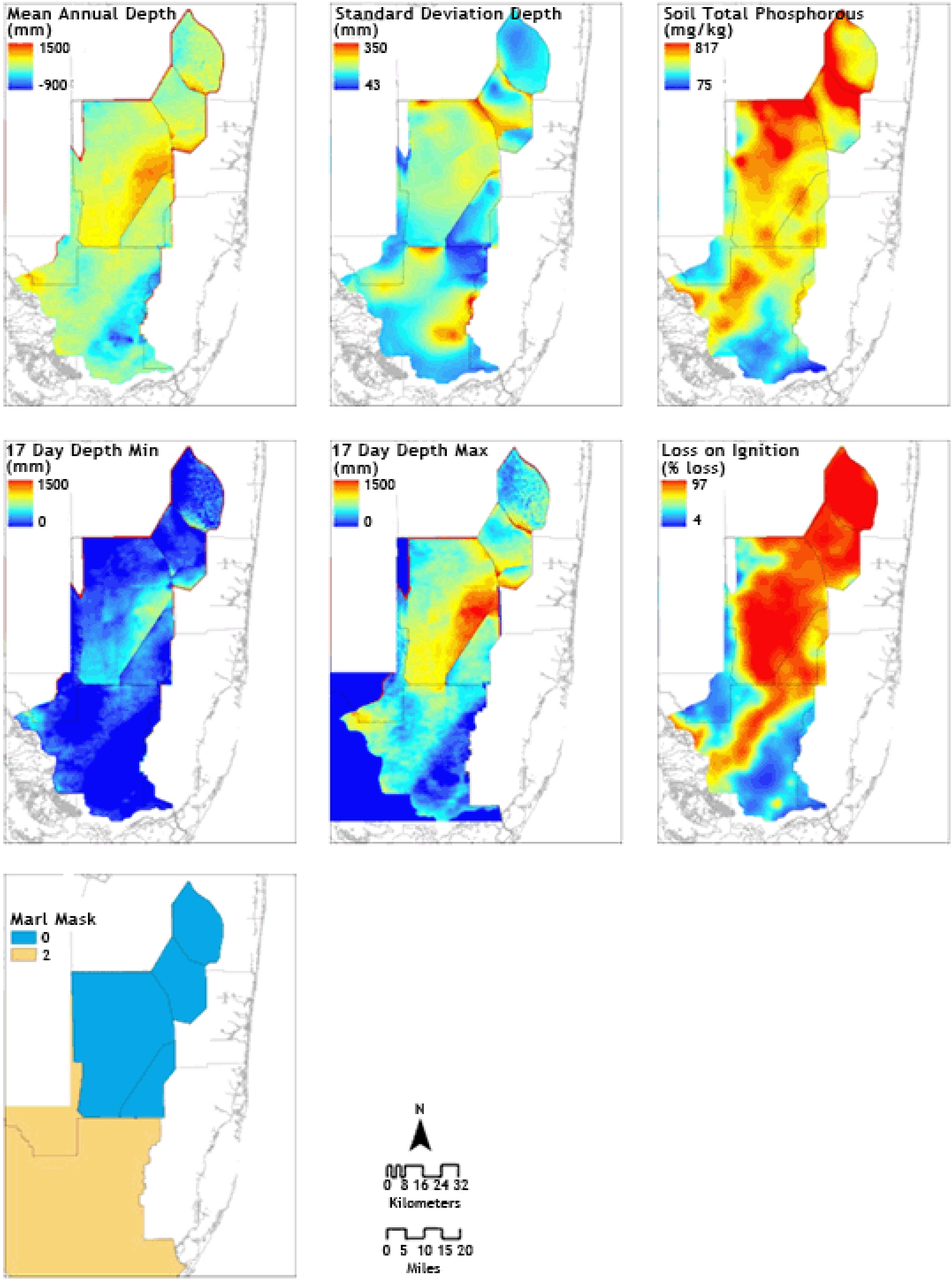


Figure 9. 2003 input data layers. Hydrologic layers are derived from EDEN (U.S. Geological Survey 2010b). Soil TP and Soil LOI layers are derived from Newman and Osborne (Reddy et al. 2005).

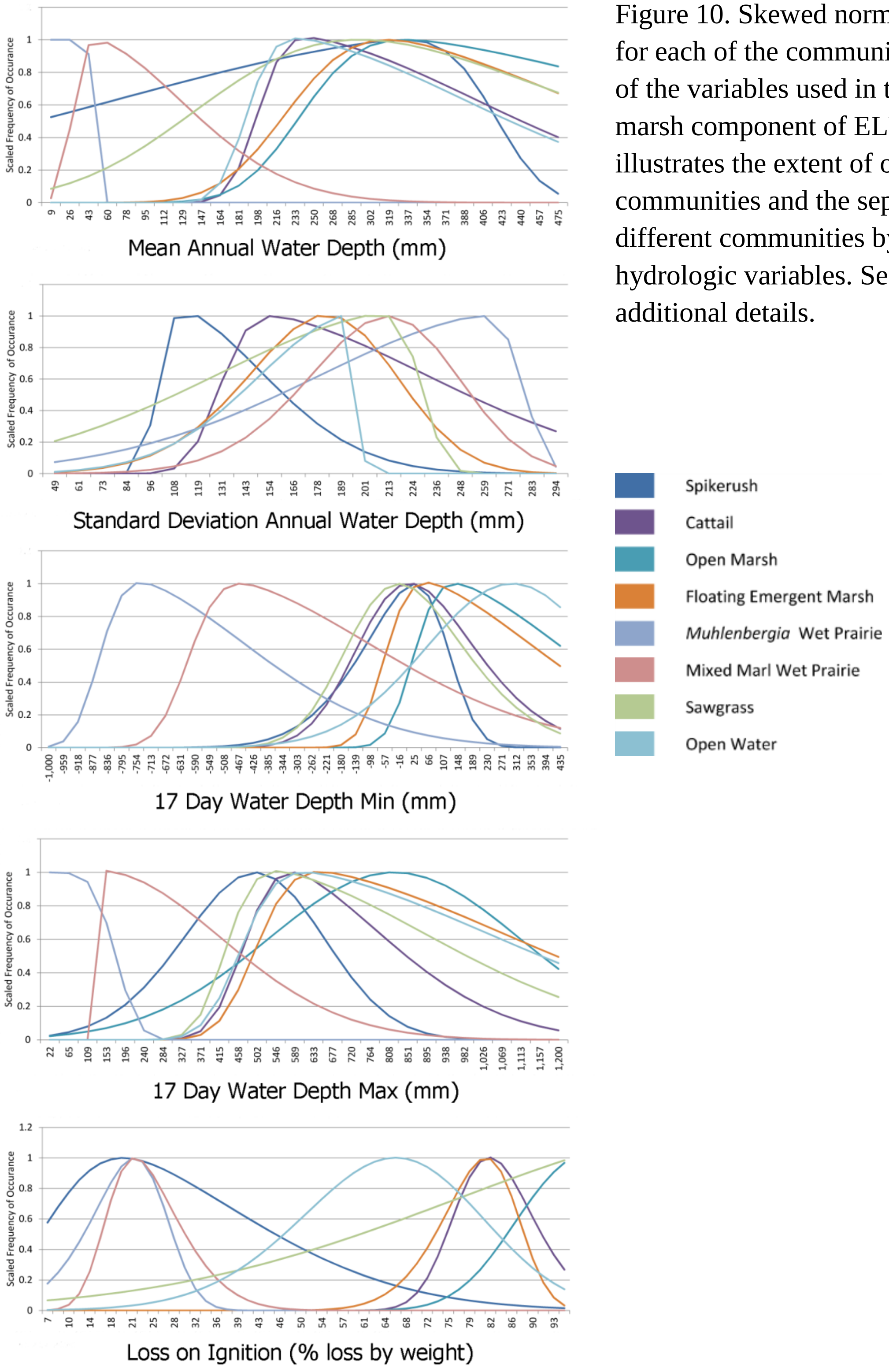


Figure 10. Skewed normal distributions for each of the community types for five of the variables used in the freshwater marsh component of ELVeS. This figure illustrates the extent of overlap among communities and the separation of different communities by different hydrologic variables. See Appendix C for additional details.

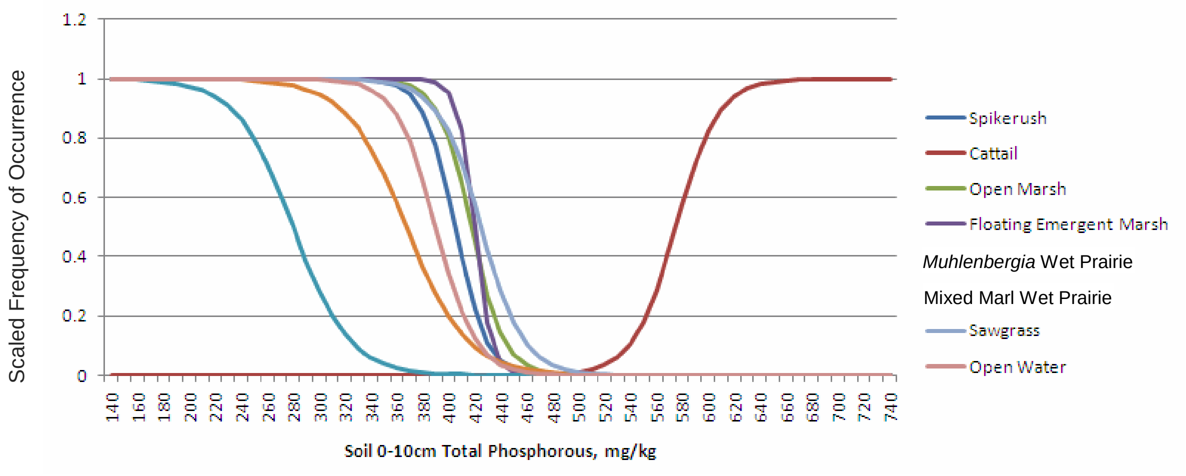


Figure 11. Logistic equation distributions for vegetation community response to soil TP.

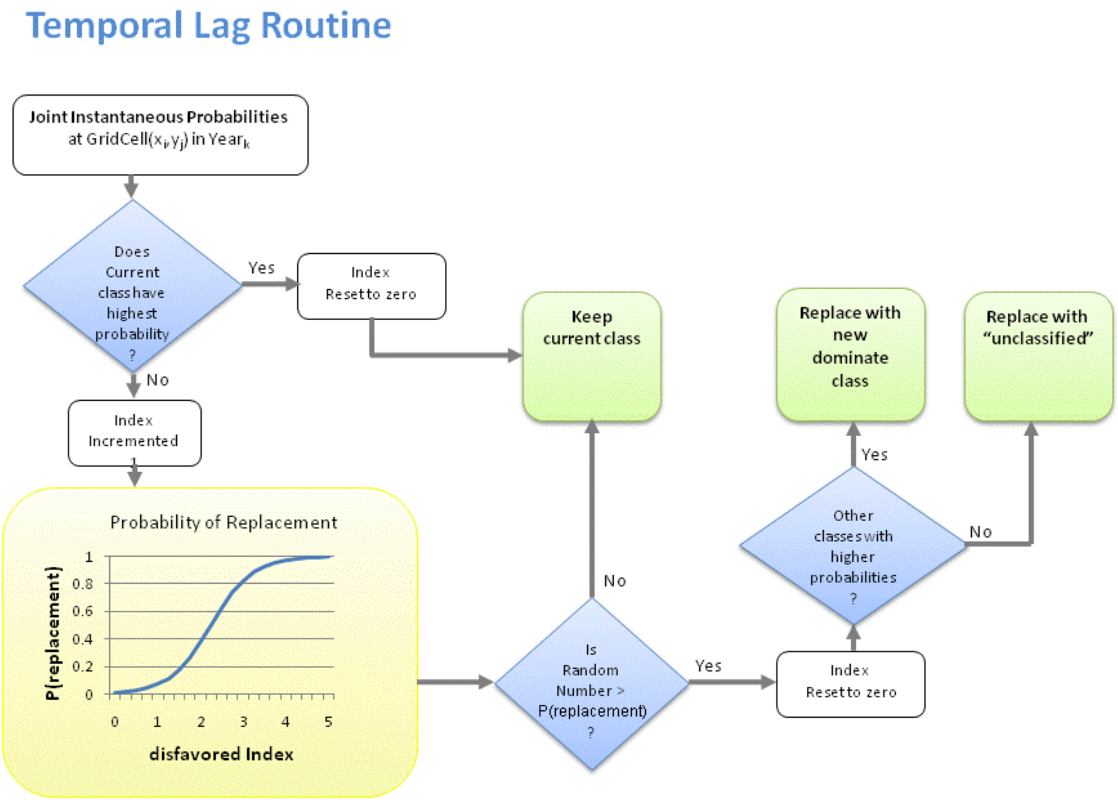


Figure 12. Schematic diagram of the approach used to introduce temporal lags into ELVeS community transitions.

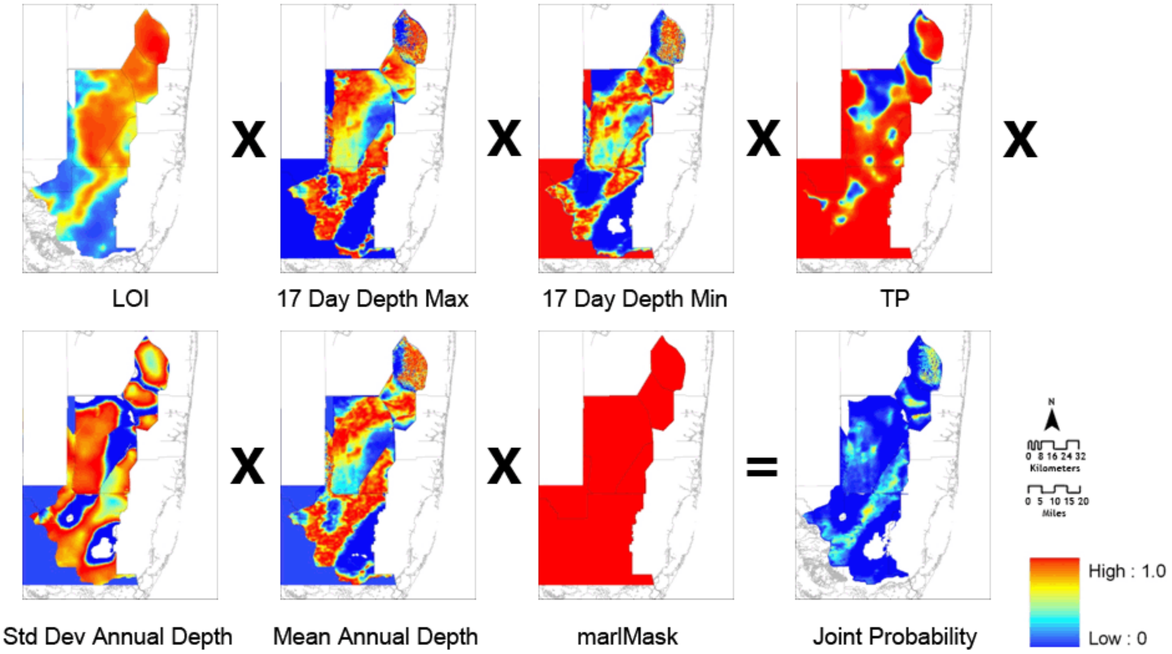
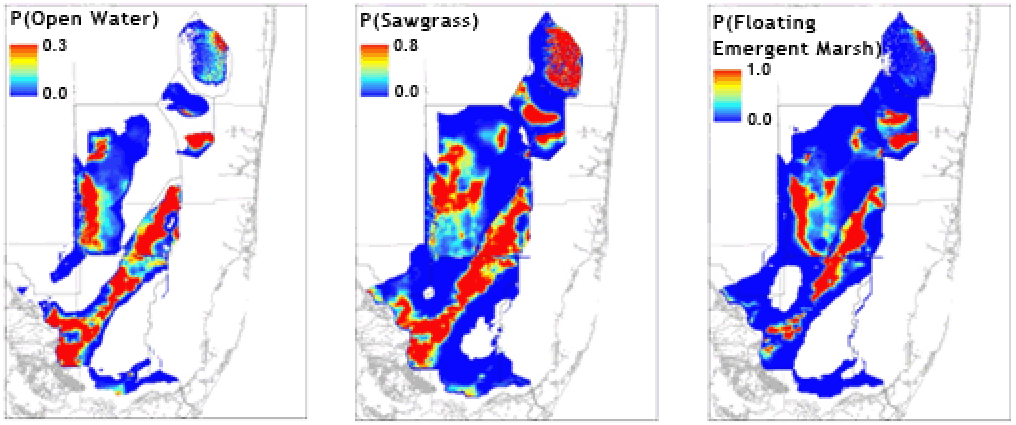
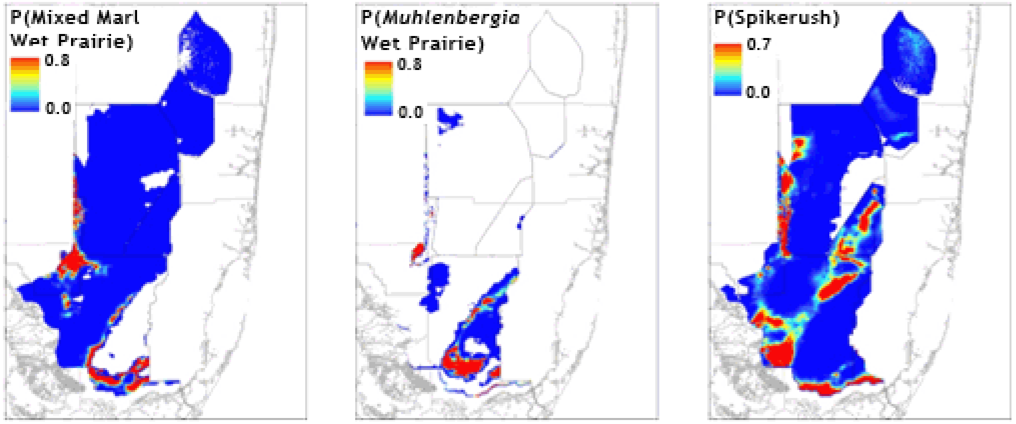


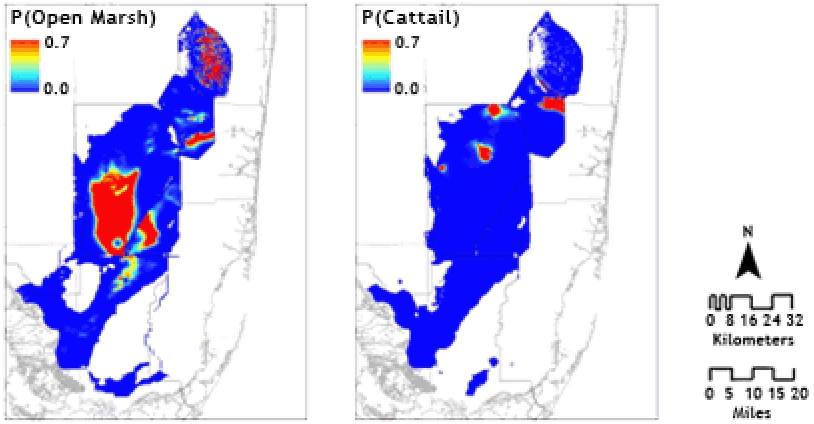
Figure 13. Instantaneous joint probabilities for sawgrass (used as an example community) are the product of the conditional probabilities for each of the variables. Probabilities were derived from EDEN 2003 input hydrology and Newman and Osborne (Reddy et al. 2005) survey data.



Open Water Sawgrass Floating Emergent Marsh



Mixed Marl Wet Prairie *Muhlenbergia* Wet Prairie Spikerush



Open Marsh Cattail

Figure 14. Joint instantaneous probabilities for each of the vegetation communities using EDEN 2003 input hydrology and Newman and Osborne (Reddy et al. 2005) soil survey data. When comparing probabilities among layers, note that each layer is scaled differently to maximize the value details within a layer.

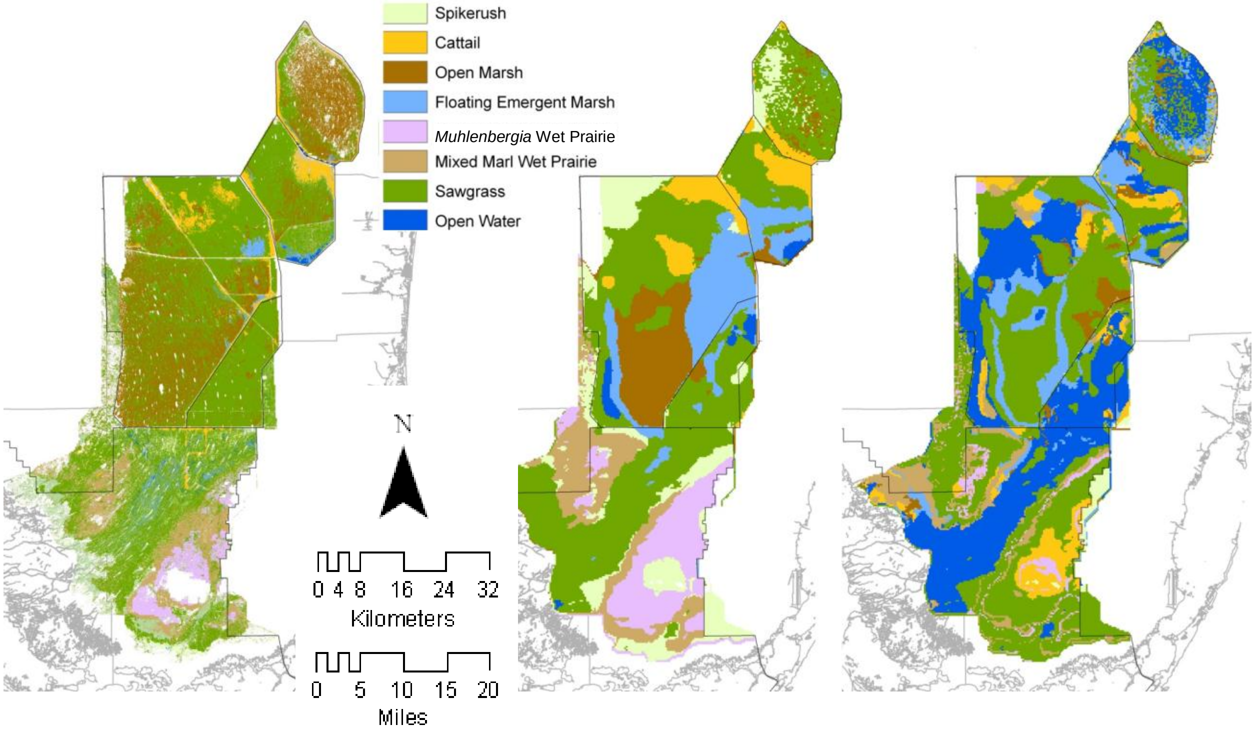


Figure 15. RECOVER-GAP classification of freshwater marsh communities at 50-m spatial resolution (left). ELVeS instantaneous probability dominant vegetation (middle) and instantaneous probability secondary vegetation (right), both at 400-m resolution. ELVeS results are from EDEN 2003 input hydrology.

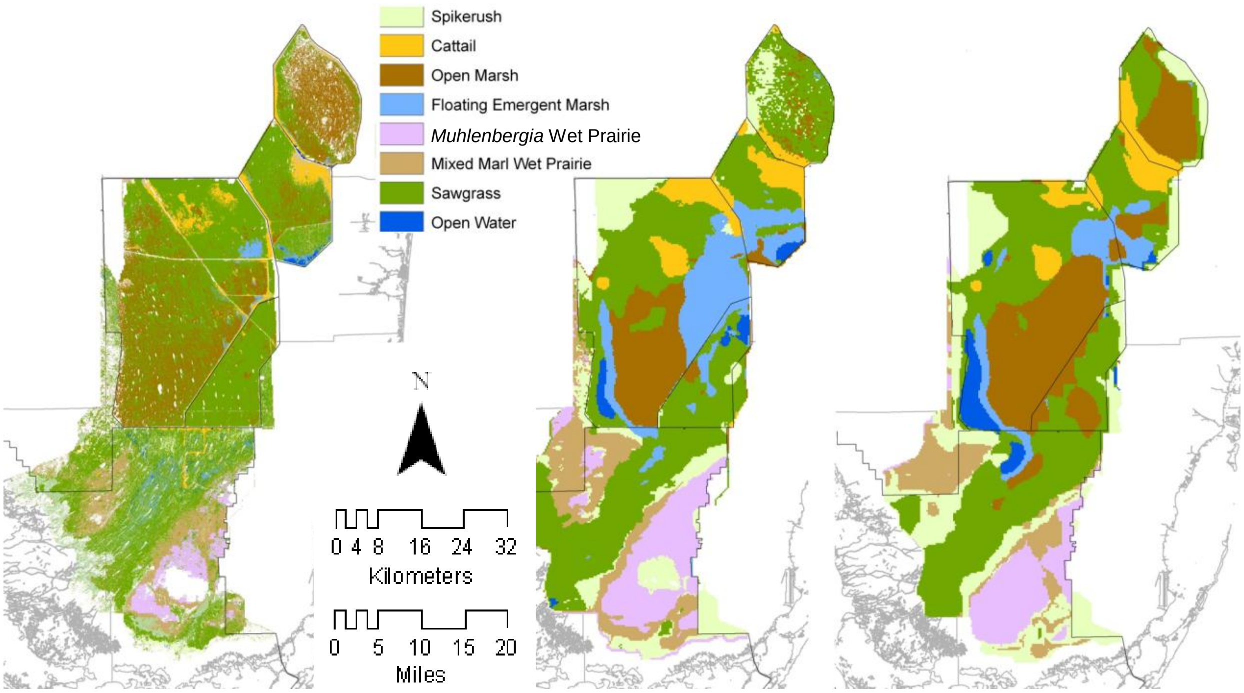


Figure 16. RECOVER-GAP classification of freshwater marsh communities at 50-m spatial resolution (left). ELVeS instantaneous probability dominant vegetation from EDEN 2003 hydrology (middle) at 400-m resolution and ELVeS instantaneous probability dominant vegetation from SFWMM ECB3 1997 hydrology (right) at 500-m resolution.

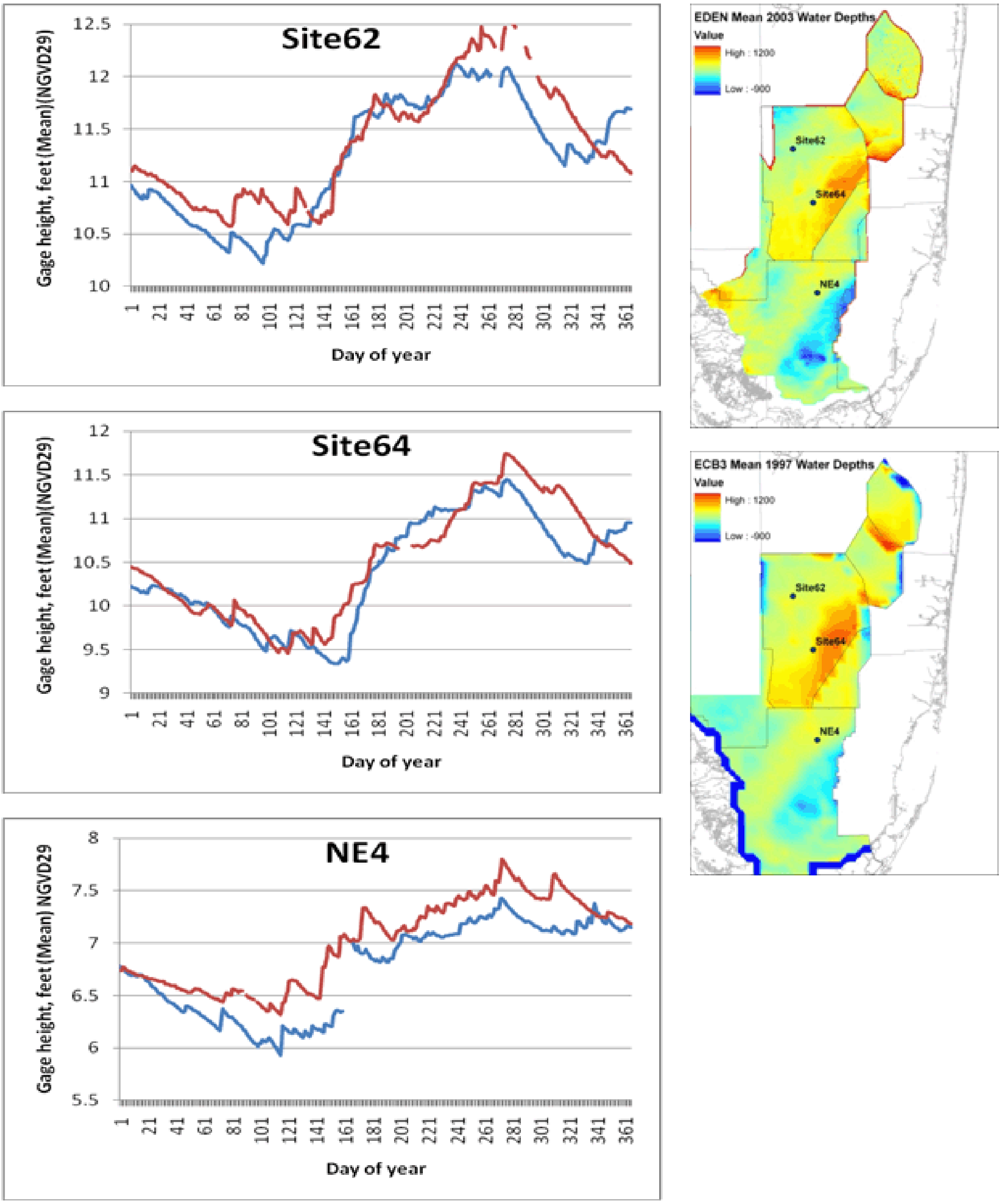


Figure 17. Gage height at three locations in 1997 (blue) and 2003 (red). Right: Distribution of water depths from EDEN and SFWMM ECB3 for the same years.
Site62 and Site64 are in upper and mid WCA3A respectively. NE4 is in Shark River Slough.
Gage data source: U.S. Geological Survey (2010a).

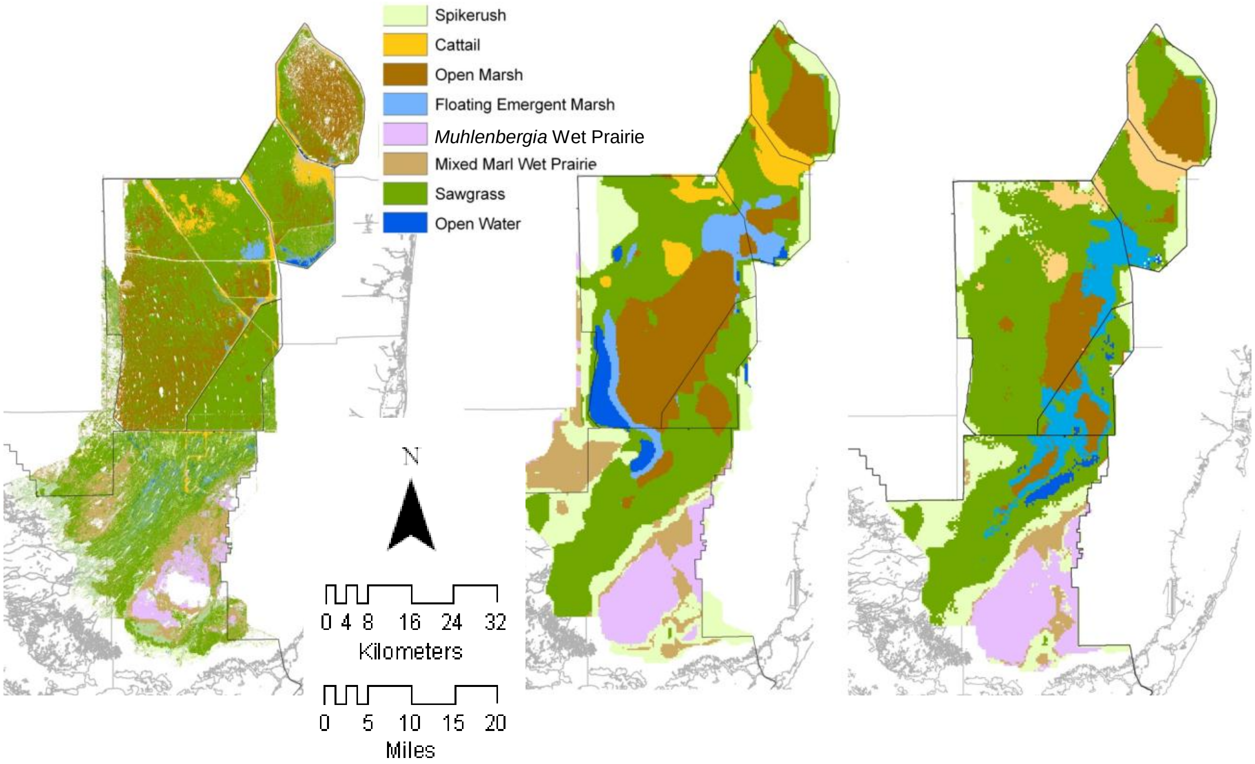


Figure 18. RECOVER-GAP classification of freshwater marsh communities at 50-m spatial resolution (left). ELVeS instantaneous probability dominant communities from SFWMM ECB3 1997 hydrology (middle) and dominant communities when temporal lags are included in the model (right).

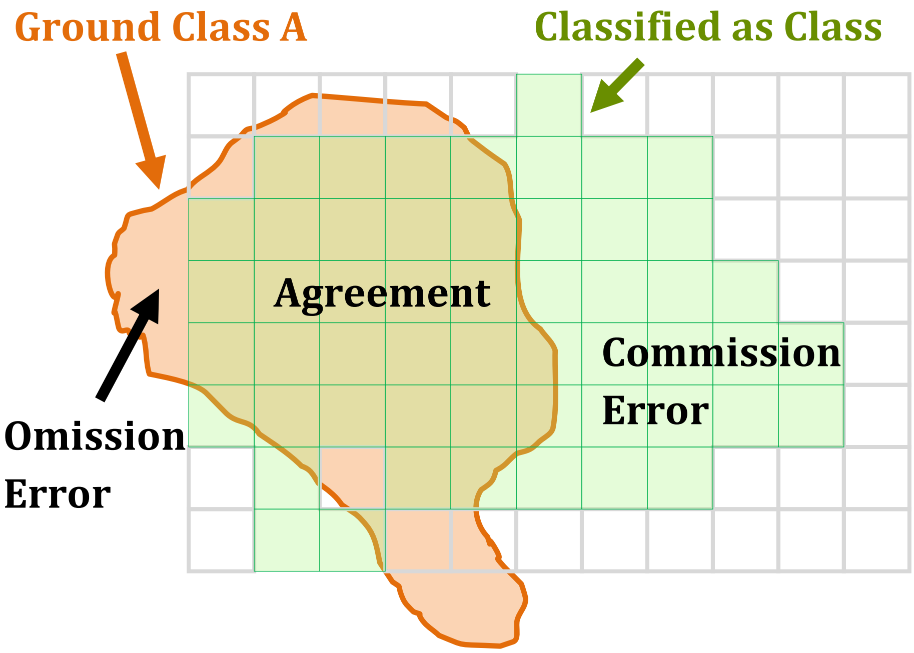


Figure 19. Illustration of accuracy assessment measures.

In this example producer's accuracy is high because most of the class has been correctly mapped and omission error is low. User's accuracy is low because the mapped class includes a large area that is misidentified and, therefore, commission error is high.

APPENDIX A. HYDROLOGIC METRICS CALCULATED FROM THE EDEN DATA ARCHIVE

These metrics are based on a hydrologic year of April 1 of current year through March 31 of next year.

	Metric Name	Description
1	Discontinuous Hydroperiod	number of days water above 0 mm
2	Discontinuous Hydroperiod Wet	number of days where water above 50 mm
3	Discontinuous Hydroperiod Dry	number of days where water below -50 mm
4	Continuous Hydroperiod Wet	annual continuous days where water above 50 mm
5	Continuous Hydroperiod Dry	annual continuous days where water below -50 mm
6	Mean Annual Depth	mean annual water depth
7	Standard Deviation Annual Depth	standard deviation of annual water depth
	Median Annual Depth	median annual water depth
8	Upper Quartile Annual Depth	upper quartile annual water depth
9	Lower Quartile Annual Depth	lower quartile annual water depth
10	Mean Annual Depth Wet	mean annual water depth where water above 50 mm
11	Standard Deviation Annual Depth Wet	standard deviation of annual water depth where water above 50 mm
12	Median Annual Depth Wet	median annual water depth where water above 50 mm
13	Upper Quartile Annual Depth Wet	upper quartile annual water depth where water above 50 mm
14	Lower Quartile Annual Depth Wet	lower quartile annual water depth where water above 50 mm
15	Mean Annual Depth Dry	mean annual water depth where water below -50 mm
16	Standard Deviation Annual Depth Dry	standard deviation of annual water depth where water below -50 mm
17	Median Annual Depth Dry	median annual water depth where water below -50 mm

18	Upper Quartile Annual Depth Dry	upper quartile annual water depth where water below -50 mm
19	Lower Quartile Annual Depth Dry	lower quartile annual water depth where water below -50 mm
20	7 Day Dry Frequency	count of seven day periods where water depth was below -50 mm
21	3 Day Water Depth Min	minimum of the three day moving average water depth
22	Standard Deviation 3 Day Water Depth Min	standard deviation of the minimum of the three day moving average water depth
23	3 Day Water Depth Max	maximum of the three day moving average water depth where water depth above 50 mm
24	Standard Deviation 3 Day Water Depth Max	standard deviation of the maximum of the three day moving average water depth
25	3 Day Water Depth Min Day	day of year 3 Day Water Depth Min occurred
26	3 Day Water Depth Max Day	day of year 3 Day Water Depth Max occurred
27	7 Day Water Depth Min	minimum of the seven day moving average water depth
28	Standard Deviation 7 Day Water Depth Min	standard deviation of the minimum of the seven day moving average water depth
29	7 Day Water Depth Max	maximum of the seven day moving average water depth where water depth above 50 mm
30	Standard Deviation 7 Day Water Depth Max	standard deviation of the maximum of the seven day moving average water depth
31	7 Day Water Depth Min Day	day of year 7 Day Water Depth Min occurred
32	7 Day Water Depth Max Day	day of year 7 Day Water Depth Max occurred
33	17 Day Water Depth Min	minimum of the seventeen day moving average water depth
34	Standard Deviation 17 Day Water Depth Min	standard deviation of the minimum of the seventeen day moving average water depth
35	17 Day Water Depth Max	maximum of the seventeen day moving average water depth where water depth above 50 mm
36	Standard Deviation 17 Day Water Depth Max	standard deviation of the maximum of the seventeen day moving average water depth

37	17 Day Water Depth Min Day	day of year 17 Day Water Depth Min occurred
38	17 Day Water Depth MaxDay	day of year 17 Day Water Depth Max occurred
39	31 Day Water Depth Min	minimum of the thirty one day moving average water depth
40	Standard Deviation 31 Day Water Depth Min	standard deviation of the minimum of the thirty one day moving average water depth
41	31 Day Water Depth Max	maximum of the thirty one day moving average water depth where water depth above 50 mm
42	Standard Deviation 31 Day Water Depth Max	standard deviation of the maximum of the thirty one day moving average water depth
43	31 Day Water Depth Min Day	day of year thirty Day Water Depth Min occurred
44	31 Day Water Depth Max Day	day of year thirty Day Water Depth Max occurred
45	Dry Intensity	dry intensity
46	Wet Intensity	wet intensity
47	Dry/Wet Intensity	(Dry Intensity)/(Wet Intensity)
48	Percent Dry Days	percent of dry days
49	Percent Wet Days	percent of wet days

Appendix B. Hydrologic metrics comparison of the literature by Richards and Gann (2008)

Partial reproduction of these tables is with permission of the authors. Summary tables of hydrologic metrics for Everglades vegetation types.

Summary of the literature review of hydrologic regimes for Everglades plant species. For each species, the type of study (TS) was classified as a community description (CD), mesocosm, microcosm, rhizotron or growth chamber experiment (E), field characterization (F), or field experiment (FE). Studies where data were derived from a field experiment that tested non-hydrologic variables but for which hydrologic data were provided also were classified as field characterizations (F). Data on water depth and hydroperiod were extracted from the reference, as well as the location (Region), and length of the study (Duration). Comments are results or a comment explaining something about the result.

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
Cladium jamaicense						
CD		dry to flooded if not too long	Everglades	community descp.	sawgrass marsh	Gunderson 1994
CD	avg. ann. 10 cm	3-7 mo hydroperiod	Everglades	community descp.	comments on marl prairies	Gunderson 1994
CD		5-10 mo	East Everglades	community descp.	sawgrass glades	Hilsenbeck et al. 1979
CD	rel hyd = 6 out of 1(wet)-8	rel hyd = 6 out of 1(wet)-8	Everglades	community descp.	comments on wet prairie marl	White 1994
CD	rel hyd = 4 out of 1(wet)-8	rel hyd = 4 out of 1(wet)-8	Everglades	community descp.	comments on sawgrass	White 1994
E	5/15, 5/30, 5/60 cm	365d	mesocosm	2 yr. experiment	like *Typha* at 15 and 30 cm	Newman et al. 1996
F		(2-) 5-9mo (lit)	ENP Taylor Slough	1961-2002		Armentano et al. 2006
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d	N ENP slough	10 yrs (1985-1995)	sawgrass in drier sites	Busch et al. 1998
F	21 cm (5-64 cm) ann avg	258 d (135-365 d) ann avg	ENP	6 yrs (1998-2004)		Childers et al. 2006
F	5 cm (0-11)	1 dry down in 2 yrs (365 d)	WCA 2B	2 yrs.	sawgrass site in nutrient expt.	Craft et al. 1995
F	< 50 cm	< 6-10 mo	Lox,WCA2&3, ENP		sawgrass less above these (lit.)	Doren et al. 1997
F	48 cm (10-81 cm)	356 d	WCA3A, 3B	6 yr for water	short sawgrass (< 125 cm)	Givnish et al. 2008
F	49 cm (11-81 cm)	357 d	WCA3A, 3B	6 yr for water	tall sawgrass (>125 cm)	Givnish et al. 2008
F	13 ± 11 cm	selected 30-180 d	ENP	one-time sample	short hydroperiod species	Gottlieb et al. 2006
F	18 cm est. (2-38 cm range)	365, then dry down 2nd yr	LOX	30 mo.	selected sawgrass sites	Jordan et al. 1997
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8%	WCA 2A	18 yr for water	reference site species	King et al. 2004

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
F	0-54 cm (max = 82 cm)	260-338 d (183-366 range)	Shark Slough, ENP	27 or 7 yrs H_20	sparse sawgrass	Olmsted&Armentano 1997
F	0-39 cm (max = 68 cm)	276-328 d (0-366 range)	Shark Slough, ENP	27 or 7 yrs H_20	tall sawgrass	Olmsted&Armentano 1997
F		53-364 d	ENP	1953-1980 H_20	tall CLJ marsh (225 cm)	Olmsted & Loope 1984
F		183-365 d	ENP	1953-1980 H_20	sparse CLJ marsh (130 cm)	Olmsted & Loope 1984
F	44 cm (25-65)	mostly 365 d	Belize	one-time sample	depths from end of dry season	Rejmankova et al. 1995
F	58 (wet)/18 (dry) cm	331 ± 4 d	LOX to ENP	6 yrs for water	sawgrass community	Richards et al. 2008
F	9.5 (wet)/-44.2 (dry) cm	233 ± 18 d	LOX to ENP	6 yrs for water	muhly community	Richards et al. 2008
F	36.9 (30 d max = 57.8)	339.3 d	ENP south	5 yrs for water	sparse sawgrass	Ross et al. 2006a
F	32.2 (30 d max = 52.4)	322.6 d	ENP south	5 yrs for water	tall sawgrass	Ross et al. 2006a
F		215/51/291[1]	ENP	5 yrs for water		Ross et al. 2006b
F	27 cm (14.8-44.5)		WCA3B, at L67	1 year		Steward 1984
F	26-41 cm avg.		WCA 2A	2 yr (1994-1995)	less wt. in deep, oligotropic sites	Weisner & Miao 2004
F	18-48 cm		ENP, WCA 3	2 yr (1986, 1987)	Tall sawgrass	Wood&Tanner1990
F	20-49 cm		ENP, WCA 3	2 yr (1986, 1987)	medium sawgrass	Wood&Tanner1990
FE	25 ± 18 cm	0-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
FE	18-50 cm wet yrs,	68-84% of time wet yrs,	WCA 2A	5 yrs, 1986-1991	cattail increased more rapidly	Urban et al. 1993
FE	8-16 cm dry yrs	20-36% of time dry yrs	WCA 2A	5 yrs, 1986-1991	than sawgrass in wet years	Urban et al. 1993
Eleocharis cellulosa						
CD		dry to flooded if not too long	Everglades	community descp.	sawgrass marsh	Gunderson 1994
CD		central, wetter Everglades	Everglades	community descp.	peat wet prairie	Gunderson 1994
CD		6-10 mo	East Everglades	community descp.	spikerush-beakrush flats	Hilsenbeck et al. 1979
CD		longer than all but slough	Everglades	community descp.	can tolerate high water	Loveless 1959
CD	rel hyd = 3 out of 1(wet)-8	rel hyd = 3 out of 1(wet)-8	Everglades	community descp.	comments on wet prairie peat	White 1994
E	-30, 10, 45 cm		rhizotron	expt, 107 d	greater biomass at 45 cm	Busch et al. 2004
E	-150, +150, +600 mV	in nutrient solution	growth chamber	2 mo.	pH had no effect on biomass	Chen et al. 2005
E	7, 45 cm	365 d	mesocosm expt	80 wks	biomass decreased with depth	Edwards et al. 2003
E	0, 50, 90 cm(+ 25 cm)	plants emerged	Belize	119 d expt	biomass decreased with depth	Macek et al. 2006
E		plants kept submerged	Belize	130 d expt	survived 4 mo.	Macek et al. 2006
F		6-9 mo (lit)	ENP Taylor Slough	1961-2002		Armentano et al. 2006
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995	common w/ more depth/inundat.	Busch et al. 1998

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
F	21 cm (5-64 cm) ann avg	258 d (135-365 d) ann avg	ENP	6 yrs (1998-2004)	*Eleocharis* sp., prob. *E. cellulosa*	Childers et al. 2006
F	density not related to hydrologic variables; increase in density in year following higher water and sawgrass decline in ANPP					Childers et al. 2006
F	app. 20 cm (15-31 range)	365 d	WCA 2B	2 yrs.	slough site, but no water lily	Craft et al. 1995
F	64 cm (24-97 cm)	363 d	WCA3A, 3B	6 yr for H$_2$0	samples in emergent sloughs	Givnish et al. 2008
F	73 ± 4 cm	selected 300-365 d	ENP	one-time sample	long hydroperiod species	Gottlieb et al. 2006
F	26 cm est. (9-44 cm range)	365, then some dry 2nd yr	LOX	30 mo.	selected wet prairie sites	Jordan et al. 1997
F	1-61 cm (max =90 cm)	315-352 d (143-366 range)	Shark Slough, ENP	27 or 7 yrs H$_2$0	Spikerush marsh (NYO here)	Olmsted&Armentano 1997
F		248-365 d	ENP	1953-1980 H$_2$0	*Eleocharis* marsh	Olmsted & Loope 1984
F	21 cm (0-40)	mostly 365 d	Belize	one-time sample	depths from end of dry season	Rejmankova et al. 1995
F	45 (wet)/4 (dry) cm	327 ± 7 d	LOX to ENP	6 yrs for water	spikerush community	Richards et al. 2008
F	41.2 (30 d max = 64.0)	344.1 d	ENP south	5 yrs for water	spikerush marsh	Ross et al. 2006a
F		253/24/83[1]	ENP	5 yrs for water		Ross et al. 2006b
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990
FE	34 ± 22 cm	45-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
Eleocharis elongata						
F	26 cm est. (9-44 cm range)	365, then some dry 2nd yr	LOX	30 mo.	selected wet prairie sites	Jordan et al. 1997
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8%	WCA 2A	18 yr for water	reference site species	King et al. 2004
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990
FE	71 ± 11 cm	100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
Muhlenbergia ***capillaris***						
CD	avg. ann. 10 cm	shorter hydroperiods (3-7 mo)	Everglades	community descp.	comments on marl prairies	Gunderson 1994
CD		3-7 mo	East Everglades	community descp.	muhly prairies	Hilsenbeck et al. 1979
CD		2-3 mo	East Everglades	community descp.	muhly-beard grass prairies	Hilsenbeck et al. 1979
CD	rel hyd = 6 out of 1(wet)-8	rel hyd = 6 out of 1(wet)-8 2-4 (6) mo (lit)	Everglades ENP Taylor Slough	community descp. 1961-2002	comments on wet prairie marl	White 1994
F						Armentano et al. 2006
F		no more than a few mo	ENP	1953-1980 H$_2$0	muhly prairie (with sawgrass)	Olmsted & Loope 1984

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
F	9.5 (wet)/-44.2 (dry) cm	233 ± 18 d	(LOX to) ENP	6 yrs for water	muhly community (only in ENP)	Richards et al. 2008
F		198/49/224[1]	ENP	5 yrs for water		Ross et al. 2006b
Nymphaea odorata						
CD	avg. ann. 30 cm	wettest (year-round)	Everglades	community descp.	comments on sloughs	Gunderson 1994
CD		longer than sawgrass	East Everglades	community descp.	maidencane flats	Hilsenbeck et al. 1979
CD	inches to 1-2 ft.	water filled or wet 365 d	Everglades	community descp.		Loveless 1959
CD	rel hyd = 2 out of 1(wet)-8	rel hyd = 2 out of 1(wet)-8	Everglades	community descp.	comments on sloughs	White 1994
F	est. 0-38 cm.	16 of 36 yrs, 1-9 mo dry	Okefenokee	1 yr, extrap. 36 yr	data from well at 1 site	Duever 1982
F	67 cm (27-102 cm)	363 d	WCA3A, 3B	6 yr for water	samples in sloughs	Givnish et al. 2008
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8 %	WCA 2A	18 yr for water	reference site species	King et al. 2004
F	1-61 cm (max =90 cm)	315-352 d (143-366 range)	Shark Slough, ENP	27 or 7 yr $H_2$0	Spikerush marsh (water lily here)	Olmsted&Armentano 1997
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F	to 1.9-2 m max	365 d, but have winter	Rhode Island	2 yr (1992-1993)	data from 7 dissimilar ponds	Sinden & Killingbeck 1996
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990
F	38 cm (19-52 cm range)	365 d	LOX	30 mo.	selected slough and alligator holes	Jordan et al. 1997
FE	54 ± 21 cm	63-100% inund freq.	WCA 3A	6 yr (1978-1984)	increased with water depth	David 1996
Rhynchospora tracyi						
CD		central, wetter Everglades	Everglades	community descp.	peat wet prairie	Gunderson 1994
CD		6-10 mo	East Everglades	community descp.	spikerush-beakrush flats	Hilsenbeck et al. 1979
CD		longer than all but slough	Everglades	community descp.		Loveless 1959
CD	rel hyd = 3 out of 1(wet)-8	rel hyd = 3 out of 1(wet)-8	Everglades	community descp.	comments on wet prairie peat	White 1994
E	-30, 10, 45 cm		rhizotron	expt, 107 d	greater biomass at -30 cm	Busch et al. 2004
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995	weak correlation with depth	Busch et al. 1998
F	13 ± 11 cm	selected 30-180 d	ENP	one-time sample	short hydroperiod species	Gottlieb et al. 2006
F	26 cm est. (9-44 cm range)	365, then some dry 2nd yr	LOX	30 mo.	selected wet prairie sites	Jordan et al. 1997
F	45 (wet)/4 (dry) cm	327 ± 7 d	LOX to ENP	6 yrs for water	spikerush community	Richards et al. 2008
F		220/51/220[1]	ENP	5 yrs for water		Ross et al. 2006b
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990
F		248-365 d	ENP	1953-1980 $H_2$0	in *Eleocharis* marsh	Olmsted & Loope 1984

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
Typha domingensis						
CD		3-10 mo	East Everglades	community descp.	cattail marshes	Hilsenbeck et al. 1979
E	15-105; 30-90; 45-75 cm	2 wk fluctuations in level	Australia; ponds	100 d experiment	less biomass in 15-105 cm flux	Deegan et al. 2007
E	-5 to 115 cm	365 d, but temperate	AR pond	experiment, 3yr	densest at 22 cm; fewer flws deep	Grace 1989
E	5/15, 5/30, 5/60 cm	365d	mesocosm	2 yr. experiment	best growth at 60 cm	Newman et al. 1996
E	5, 25, 45, 65 cm		perspex chambers	18 wk expt	growth unaffected by water depth	White & Ganf 1998
F	5 cm (3-31 cm range)	365 d	WCA 2B	2 yrs.	mixed sawgrass/cattail site	Craft et al. 1995
F	35.7 ± 8.3 cm	freq < -10 cm, 3.1 ± 0.4 %	WCA 2A	water 1 & 18 yr	impacted site (cattail)	King et al. 2004
F	< 20 cm, then > 60 cm	80% inundated >9 mo	Holey Land	4-5 yr. water data	Changed hydrology in Holey Land	Newman et al. 1998
F	0-20 cm	81% inundated 5-8 mo.	Rotenberger	4-5 yr. water data		Newman et al. 1998
F	27 cm (15-45)	mostly 365 d	Belize	one-time sample	depths from end of dry season	Rejmankova et al. 1995
F	57 (wet)/15 (dry) cm	338 ± 6 d	LOX to ENP	6 yrs for water	cattail community	Richards et al. 2008
F		242/1/2[1]	ENP	5 yrs for water		Ross et al. 2006b
F	26-67 cm avg.		WCA 2A	2 yr (1994-1995)	64 cm diff in water between years	Weisner & Miao 2004
FE	24 ± 12	63-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
FE	18-50 cm wet yrs,	68-84% of time wet yrs,	WCA 2A	5 yrs, 1986-1991	cattail increased more rapidly	Urban et al. 1993
FE	8-16 cm dry yrs	20-36% of time dry yrs	WCA 2A	5 yrs, 1986-1991	than sawgrass in wet years	Urban et al. 1993
Utricularia foliosa						
CD	avg. ann. 30 cm	wettest (year-round)	Everglades	community descp.	comments on sloughs	Gunderson 1994
CD	rel hyd = 2 out of 1(wet)-8	rel hyd = 2 out of 1(wet)-8	Everglades	community descp.	comments on sloughs	White 1994
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F		258/32/9[1]	ENP	5 yrs for water		Ross et al. 2006b
Utricularia purpurea						
F	73 ± 4 cm	selected 300-365 d	ENP	one-time sample	long hydroperiod species	Gottlieb et al. 2006
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8 %	WCA 2A	18 yr for water	reference site species	King et al. 2004
E		1, 3, not 8 mo dry-down	microcosm	1, 3, 8 mo. dry	Regrowth from periphyton	Gottlieb et al. 2005

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
					mat	
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F		246/32/26^1	ENP	5 yrs for water		Ross et al. 2006b
***Utricularia* sp.**						
CD	inches to 1-2 ft.	water filled or wet 365 d	Everglades	community descp.		Loveless 1959
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995		Busch et al. 1998
F	app. 20 cm (15-31 range)	365 d	WCA 2B	2 yrs expt	in slough, but no water lily	Craft et al. 1995
F	67 cm (27-102 cm)	363 d	WCA3A, 3B	6 yr for H$_2$0	samples in sloughs	Givnish et al. 2008
F	38 cm (19-52 cm range)	365 d	LOX	30 mo.	chose slough and alligator holes	Jordan et al. 1997
FE	37 ± 22 cm	48-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
<u>Additional Species of Interest:</u>						
Bacopa caroliniana						
CD		dry to flooded if not too long	Everglades	community descp.	sawgrass marsh	Gunderson 1994
CD		8-12 mo	East Everglades	community descp.	flag-pickerelweed marshes	Hilsenbeck et al. 1979
CD	inches to 1-2 ft.	water filled or wet 365 d	Everglades	community descp.	common in slough community	Loveless 1959
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995	assoc. w/ periphyton, *Utricularia*	Busch et al. 1998
F	45 (wet)/4 (dry) cm	327 ± 7 d	LOX to ENP	6 yrs for water	spikerush community	Richards et al. 2008
F		242/39/125^1	ENP	5 yrs for water		Ross et al. 2006b
FE	36 ± 24	33-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
Eleocharis interstincta						
E	5/15, 5/30, 5/60 cm	365d	mesocosm	2 yr. experiment	wt. decreases with water depth	Newman et al. 1996
F	9-76.5 cm avg.	2 dry downs	Rio de Janeiro	1 yr.	RGR independent of water depth	DosSantos&Esteves 2002
F	19-48 cm		ENP, WCA 3	2 yr (1986, 1987)	medium sawgrass species	Wood&Tanner1990
***Nuphar advena* (= *N. lutea*)**						
CD	avg. ann. 30 cm	wettest (year-round)	Everglades	community descp.	comments on sloughs	Gunderson 1994
CD		longer than sawgrass	East Everglades	community descp.	maidencane flats	Hilsenbeck et al. 1979

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
CD	1-2 ft.	water filled or wet 365 d	Everglades	community descp.	in deeper sloughs, gator holes	Loveless 1959
CD	rel hyd = 2 out of 1(wet)-8	rel hyd = 2 out of 1(wet)-8	Everglades	community descp.	comments on sloughs	White 1994
F	> 1.5 m		lake in Finland	1 season	looking at particle resuspension	Horppila&Nurminen 2005
F	+ corr. w/ lake depth	variable	lakes, Netherlands	one-time sample	not in plots with drawdown	Van Geest et al. 2005
FE	60-70 (40-120) cm	365d	Rhone River, FR	5 yr.	looking at seed regeneration	Barrat-Sagretain 1996
FE	20 and 60 cm		lake in Finland	1 mo	looking at herbivory/heterophylly	Kouki 1993
Nymphoides aquatica						
CD	avg. ann. 30 cm	wettest (year-round)	Everglades	community descp.	in comments on sloughs	Gunderson 1994
CD	inches to 1-2 ft.	water filled or wet 365 d	Everglades	community descp.	a dominant in slough community	Loveless 1959
CD	rel hyd = 2 out of 1(wet)-8	rel hyd = 2 out of 1(wet)-8	Everglades	community descp.	in comments on sloughs	White 1994
F	57-67cm avg. ann.	361-363 d	WCA3A, 3B	6 yr for water sample	slough to slough/ridge transition	Givinish et al. 2008
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F		216/56/5[1]	ENP	5 yrs for water		Ross et al. 2006b
FE	48 ± 24	48-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
Panicum hemitomon						
CD		central, wetter Everglades	Everglades	community descp.	peat wet prairie	Gunderson 1994
CD		longer than sawgrass	East Everglades	community descp.	maidencane flats	Hilsenbeck et al. 1979
CD		longer than all but slough	Everglades	community descp.	can withstand large fluctuations	Loveless 1959
CD	rel hyd = 3 out of 1(wet)-8	rel hyd = 3 out of 1(wet)-8	Everglades	community descp.	comments on wet prairie peat	White 1994
E	moist, 0, 13 cm				greater flood tolerance	Kirkman&Sharitz 1993
E	39 cm		experiment	4 wk	18 pop.; among pop variance	Lessmann et al. 1997
E	-5, 5, 20 cm		mesocosm	1 yr	biomass greater in -10 cm	Spalding&Hester 2007
E	0, 10, 20 cm					Willis&Hester 2004
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995	no correlation with depth	Busch et al. 1998
F	app. 20 cm (15-31 range)	365 d	WCA 2B	2 yrs.	slough site, but no water lily	Craft et al. 1995
F	est. 0-30 cm.	27 of 36 yrs, 1-9 mo dry	Okefenokee	1 yr, extrap. 36 yr	present in water lily slough	Duever 1982
F	0-105 cm max	variable	SC, Carolina bays	2 yr water data	examining VAM in maidencane	Miller&Bever 1999
F	-120 to 90 cm		SC, Carolina bays	3 wk	8 bays; *Panicum* at these depths	Miller 2000

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
F		248-365 d	ENP	1953-80 for water	in *Eleocharis* marsh	Olmsted & Loope 1984
F	45 (wet)/4 (dry) cm	327 ± 7 d	LOX to ENP	6 yrs for water	spikerush community	Richards et al. 2008
F		248/32/36[1]	ENP	5 yrs for water		Ross et al. 2006b
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie site	Wood&Tanner 1990
FE	28 ± 21 cm	0-100% inund freq.	WCA 3A	6 yr (1978-1984)		David 1996
					negatively affected by depth	Mckee&Mendelssohn 1989
Sagittaria lancifolia						
CD		central, wetter Everglades	Everglades	community descp.	peat wet prairie	Gunderson 1994
CD		8-12 mo	East Everglades	community descp.	flag-pickerelweed marshes	Hilsenbeck et al. 1979
E	-10, 10 cm		mesocosms	1 yr	biomass higher in flooded	Baldwin&Mendelssohn1998
E	1 and 15 cm	constant wet	mesocosms	4 mo	no effect of water depth	Howard&Mendelssohn 1999
E	5, 30 cm		mesocosms	3 yr	no effect of water depth	Martin&Shaffer 2005
E	-5, 5, 20 cm		mesocosm	1 yr	biomass greater in 5 and 20 cm	Spalding&Hester 2007
F	.1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	3 sites, N ENP slough	10 yr., 1985-1995	inversely correlated with depth	Busch et al. 1998
F	32-64 avg. ann.	317-362 d	WCA3A, 3B	6 yr for water sample	slough to low tree island comm.	Givinish et al. 2008[3]
F	35.7 ± 8.3 cm	freq < -10 cm, 3.1 ± 0.4%	WCA 2A	18 yr for water	impacted site with weedy spp.	King et al. 2004
F	45 (wet)/4 (dry) cm	327 ± 7 d	LOX to ENP	6 yrs for water	spikerush community	Richards et al. 2008
F		231/44/73[1]	ENP	5 yrs for water		Ross et al. 2006b
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990
FE	24 ± 18 cm	0-100% inund freq.	WCA 3A	6 yr		David 1996
FE	est. 15, 22.5, 30 cm		Louisiana	1 yr 3 mo.	biomass unaffected by H2O depth	Howard&Mendelssohn 1995
Utricularia gibba **(=** ***U. biflora, U. fibrosa*****)**						
CD	avg. ann. 30 cm	wettest (year-round)	Everglades	community descp.	comments on sloughs	Gunderson 1994
CD		8-12 mo	East Everglades	community descp.	flag-pickerelweed marshes	Hilsenbeck et al. 1979
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8%	WCA 2A	18 yr for water	reference site species	King et al. 2004
F	73 (wet)/29 (dry) cm	340 ± 10 d	LOX to ENP	6 yrs for water	water lily community	Richards et al. 2008
F	est. 30 cm avg, 1981-95	365 d	WCA 2B	43 yr for water	lost with higher P enrichment	Vaithiyan &Richard. 1999
Chara sp.						
F	. 1-.4 m (dry), .3-.8 m (wet)	343 d, 312 d, 294 d avgs.	N ENP slough	10 yr., 1985-1995	9th most abundant spp.	Busch et al. 1998

TS	Water Depth	Hydroperiod	Region	Duration	Comments	Reference
F	app. 20 cm (15-31 range)	365 d	WCA 2B	2 yrs.	took over in higher P	Craft et al. 1995
F	46.4 ± 10.4 cm	freq < -10 cm, 6.0 ± 0.8%	WCA 2A	18 yr for water	reference site species	King et al. 2004
F	27 cm (15-45)	mostly 365 d	Belize	one-time sample	depths from end of dry season	Rejmankova et al. 1995
F	est. 30 cm avg, 1981-95	365 d	WCA 2B	43 yr for water	lost with higher P enrichment	Vaithiyan&Richard. 1999
F		variable	lakes, Netherlands	one-time sample	in most plots with drawdown	Van Geest et al. 2005[2]
F	24-58 cm		ENP, WCA 3	2 yr (1986, 1987)	wet prairie species	Wood&Tanner1990

[1] Data are model-derived hydroperiod (d) optimum/hydroperiod tolerance (d)/sample size

[2] *Chara* species identified as *C. vulgaris*

[3] Species identified as *Sagittaria latifolia* is assumed to have been *S. lancifolia*

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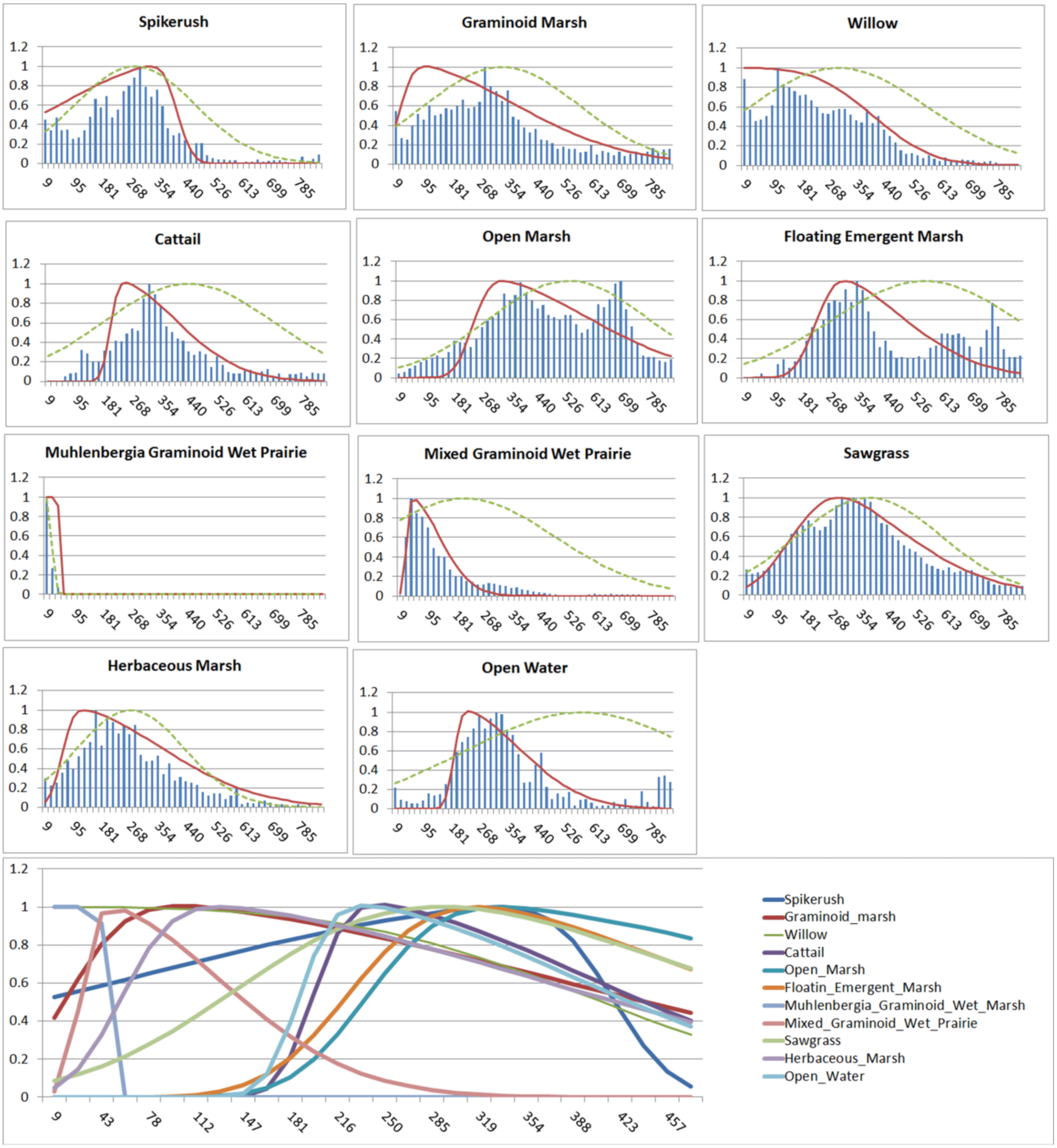
APPENDIX C. HISTOGRAMS OF THE RELATIVE FREQUENCY OF OCCURRENCE OF BINNED VALUES FOR EACH OF THE MODELED VARIABLES WITHIN EACH OF THE MAPPED FRESH WATER MARSH AND WET PRAIRIE VEGETATION CLASSES.

The mapped vegetation classes used in this analysis are described in the text. The frequency histograms of each metric represent the distribution of values found within the modeled domain (the WCAs and ENP). The dashed green lines are normal distributions fitted to the mean and standard deviation of the frequency histograms (blue bars). The solid red lines are skewed normal distributions fitted to the histograms. The bottom chart presents all the skewed normal distributions for all the vegetation classes together.

Figures start on next page.

Mean Annual Depth (mm)

Vertical axis is scaled frequency of occurrence.



Standard Deviation of Annual Depth (mm)

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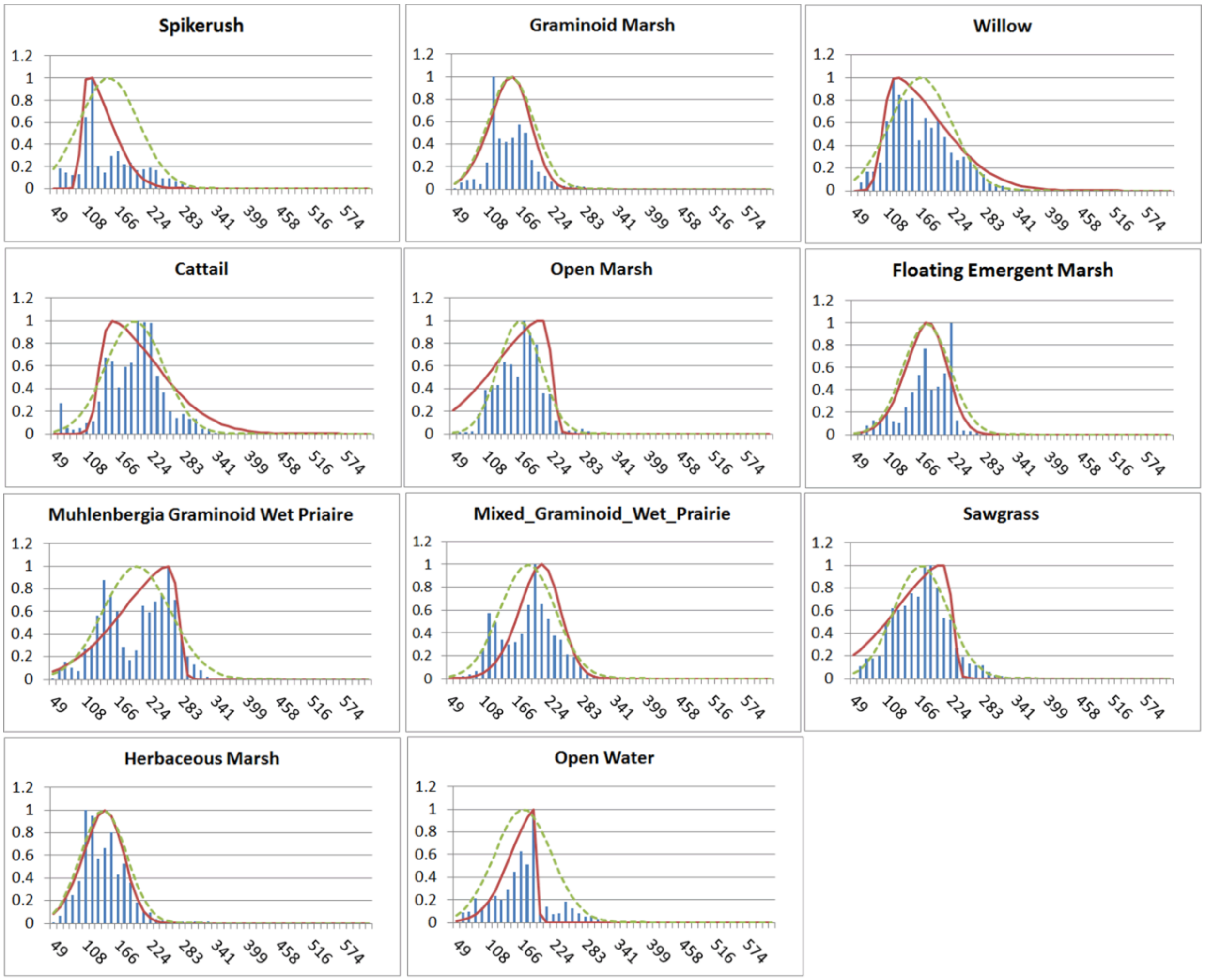
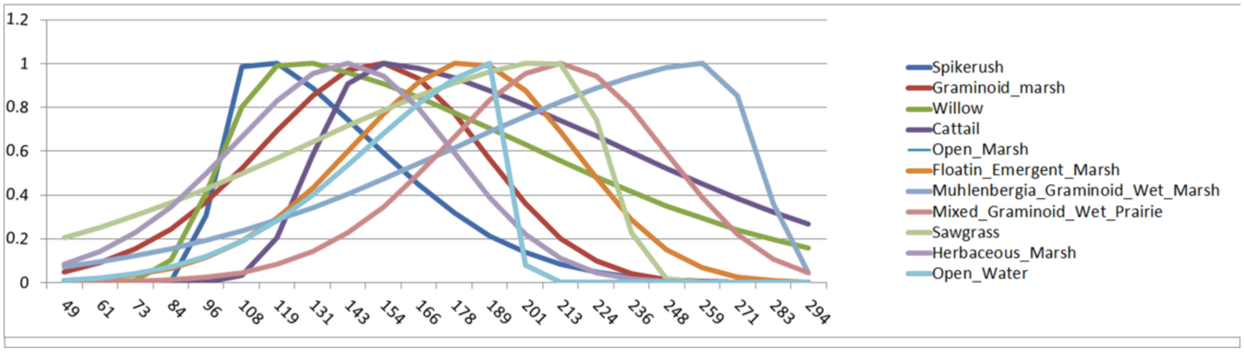
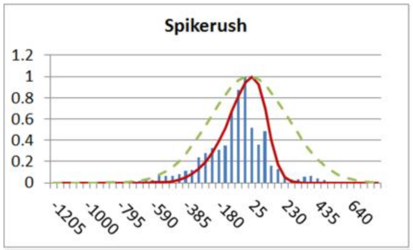
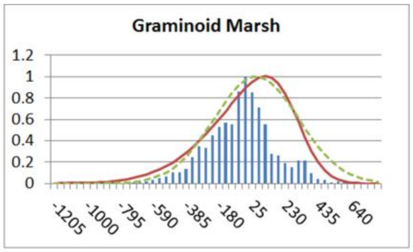


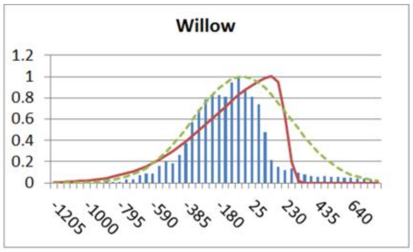


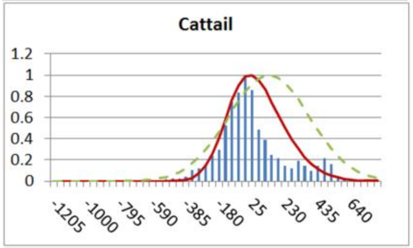
17 Day Depth Min (mm)

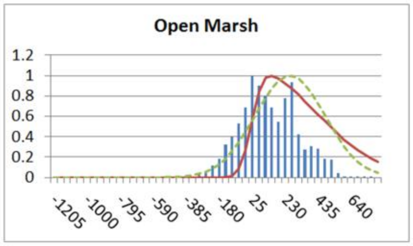
Vertical axis is scaled frequency of occurrence.

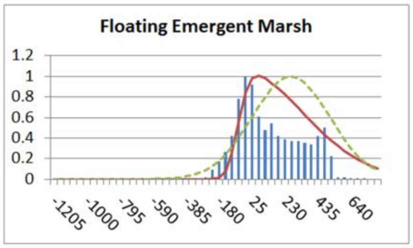


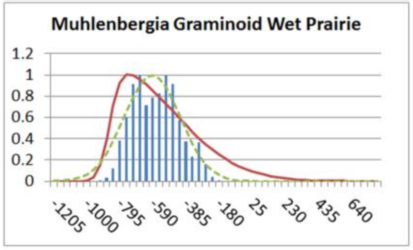


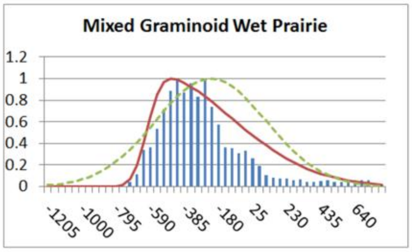


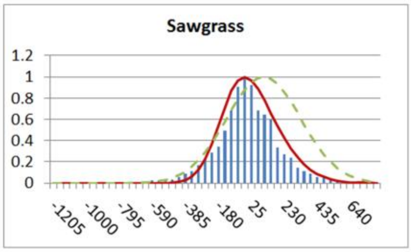


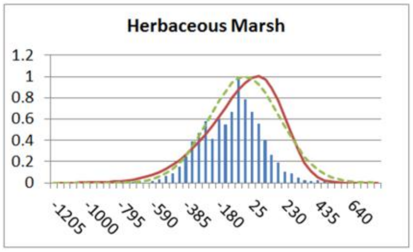


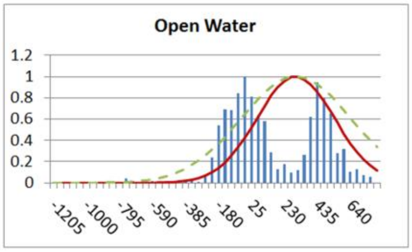


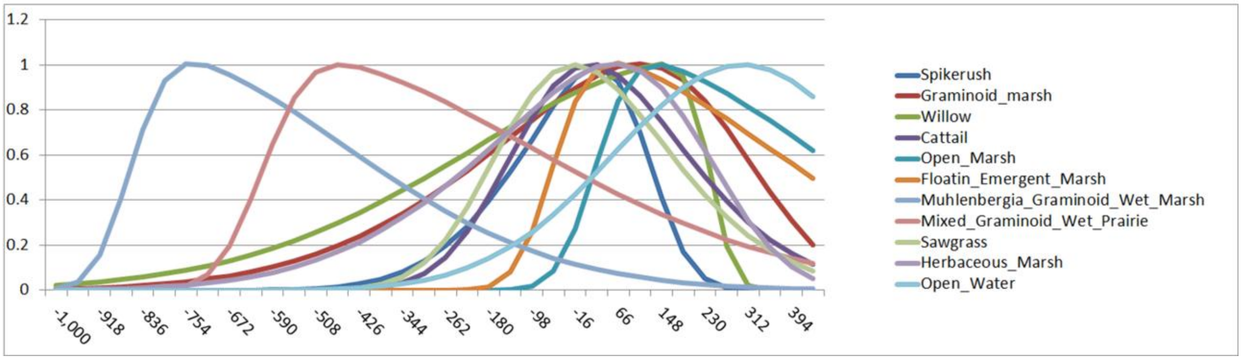






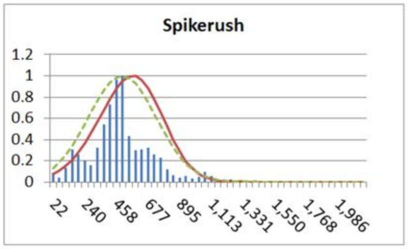


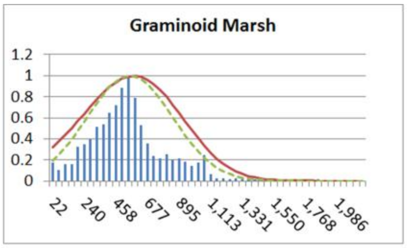


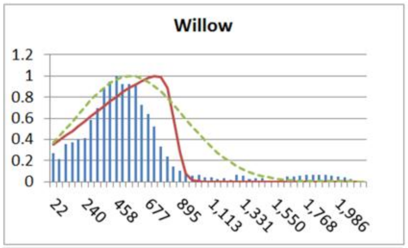


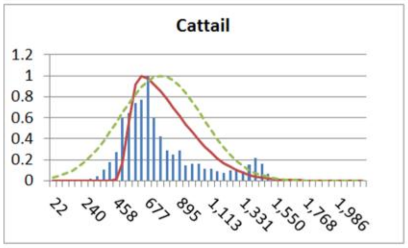
17 Day Depth Max (mm)

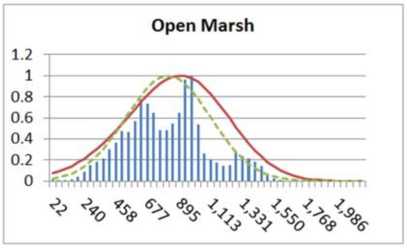
Vertical axis is scaled frequency of occurrence.

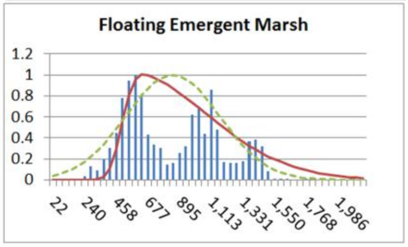


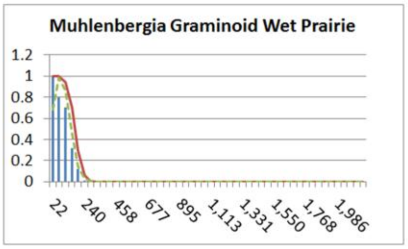


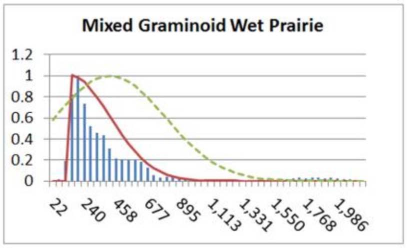


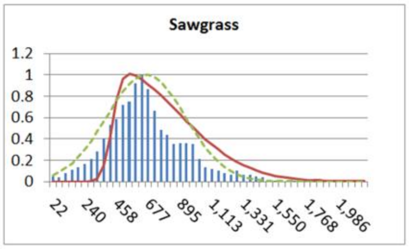


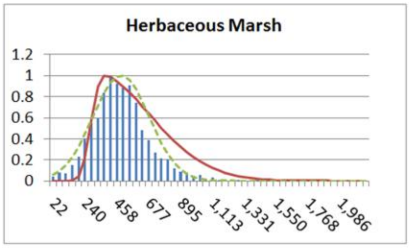


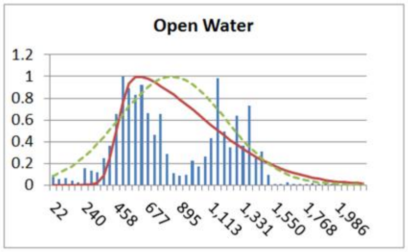


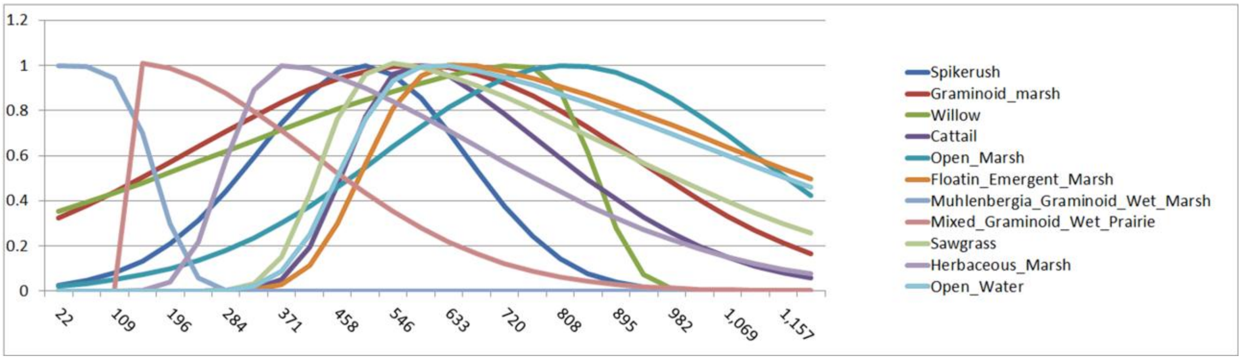












Discontinuous Hydroperiod (days)

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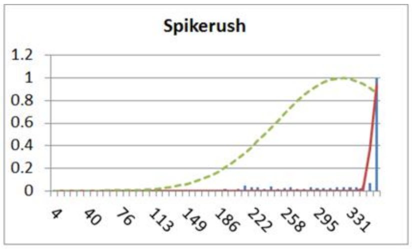
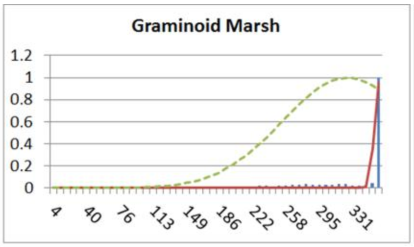
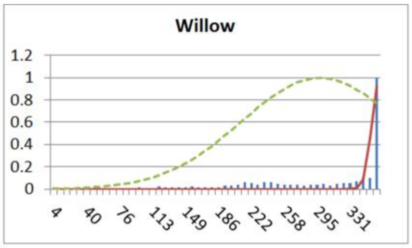
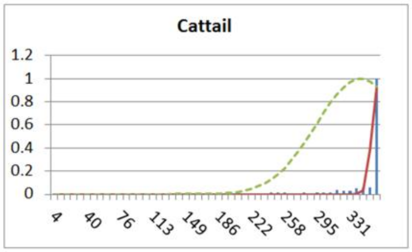
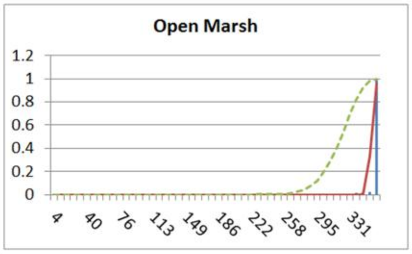
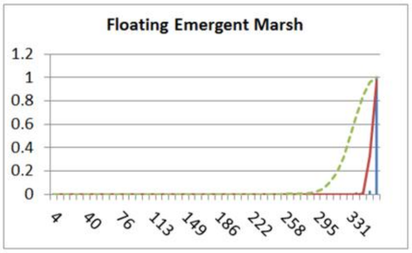


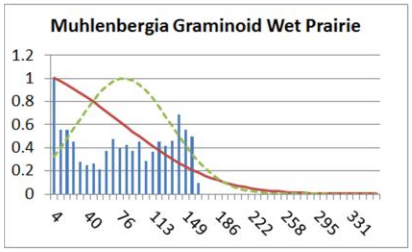


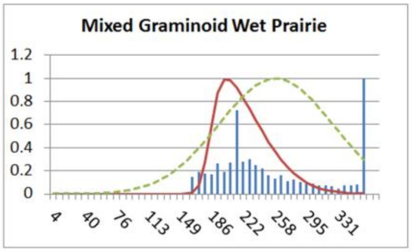


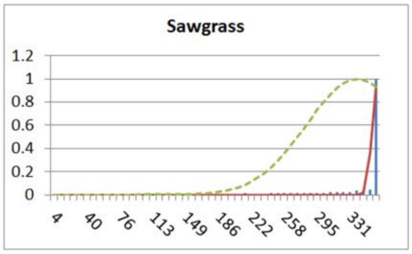


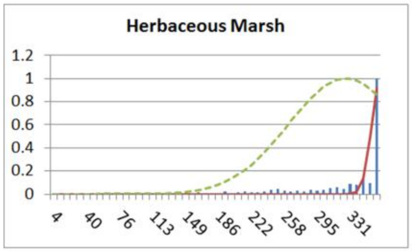


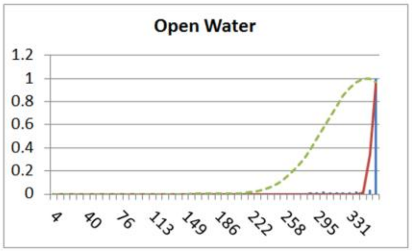


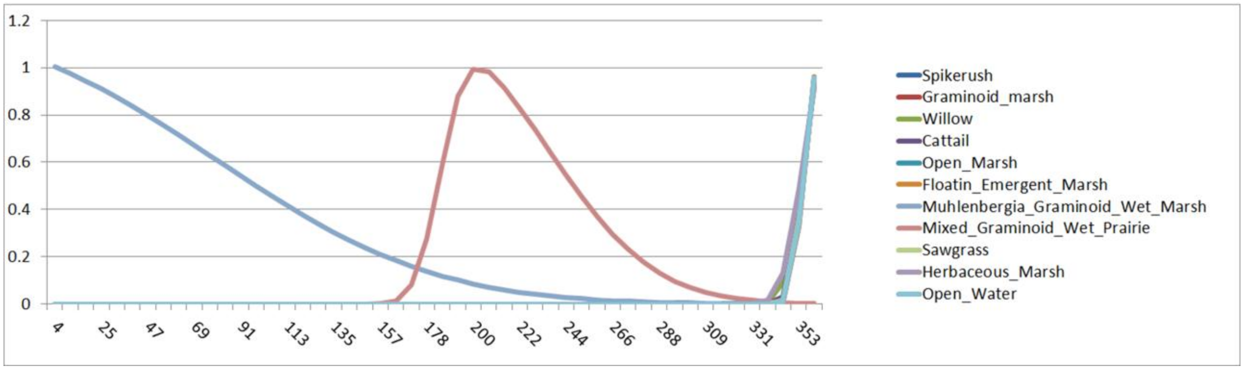










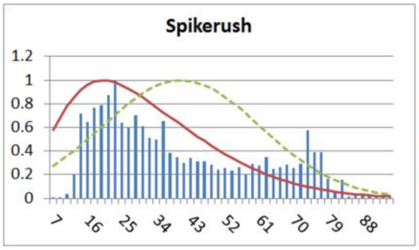


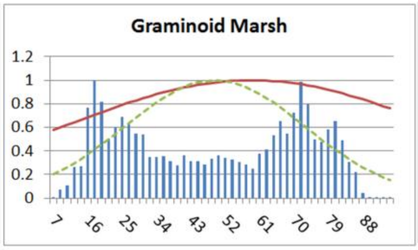
Discontinuous Hydroperiod (days) when water levels are < -5 cm

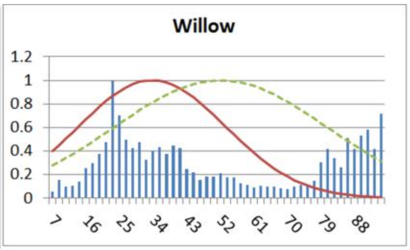
Vertical axis is scaled frequency of occurrence.

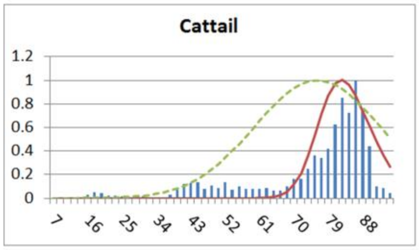
Loss on Ignition (% loss by weight)

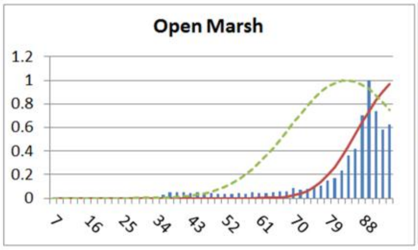
Vertical axis is scaled frequency of occurrence.

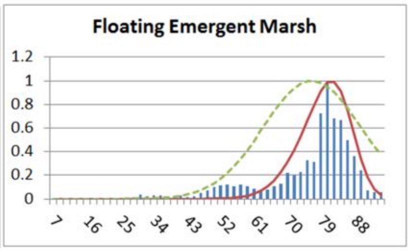


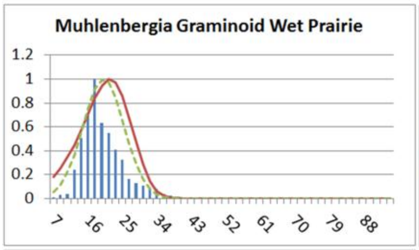


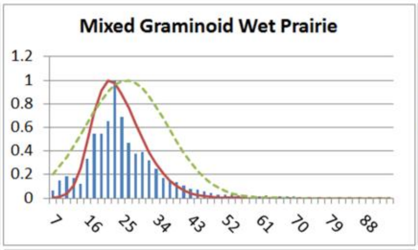


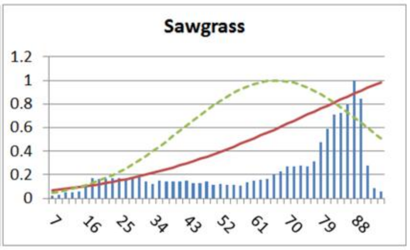


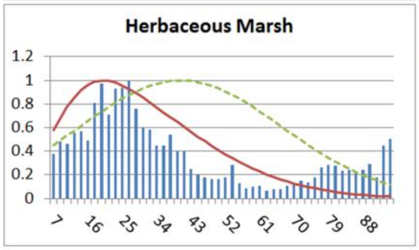


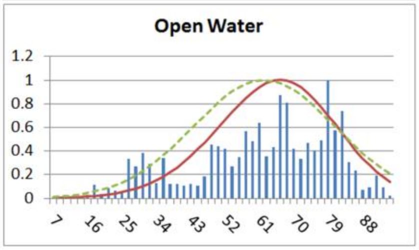


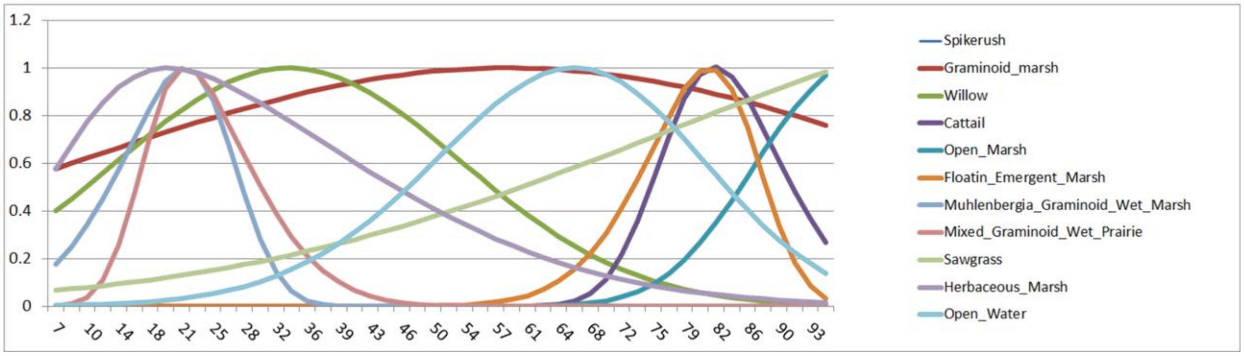












APPENDIX D. RECODE TABLES FOR CROSS-WALKING RECOVER VEGETATION MAPPING WITH THE FLORIDA GAP VEGETATION CLASSIFICATION.

Water Conservation Area vector maps were rasterized and recoded assigning a common value to vegetation communities. The Florida GAP imagery covering ENP and BCNP was recoded to match the values assigned to the WCA maps and then merged with the WCA Maps to produce the final GAP-SFWMD RECOVER vegetation map. Data presented here are the recoding scheme. Codes for the abbreviations are included at the end of the table. (Pearlstine et al. 2002, Rutchey et al. 2006)

RECOVER Community	**WCA1**		**WCA2**		**WCA3**		**Florida Gap**		**RECOVER-GAP**	
	Original	Recode	Original	Recode	Original	Recode	Original	Recode	Code	SFWMD
Background	0	0	0	0	0	0				
Ocean Florida Bay							0	1	1	Ocean
Canal	1	39	3	39	12	39				Canal
Open Water	2	2	4	2	10	2	1	2	2	OW
Spoil	3	40			1	40				SP
Temperate Hardwood Hammock	4	4							4	FHT
Tropical Hardwood Hammock Formation							2	3	3	FHS

Semi-Deciduous Tropical / subtropical Swamp Forest							3	3	3	FHS
Mesic-Hydric Live Oak /Sabal Palm Ecological Complex							5	4	4	FHT
Mixed Mangrove Forest Formation							9	5	5	FMX
Black Mangrove Forest							10	5	6	FMa
Red Mangrove							11	7	7	FMr
Dwarf Mangrove Ecological Complex							32	4	4	FMx
Swamp Forest	5	9			16	9				FS
Flooded Broad-leaved Evergreen Shrub Compositional Group							28	12	12	CSmE
South Florida Slash Pine							13	8	8	WMcG
Dry Prairie (Xeric-Mesic) Ecological Complex							29	29	27	Wus
Australian Pine Dominant	6	45							42	Ec

Open Marsh	7	24	7	24	6	24			24	MFO
Cattail Dominant	8	19	8	19	4	19	46	19	19	MFGt
Willow Shrubland	9	13	10	13	9	13			13	SSs
Saturated – Flooded Cold-Deciduous and Mixed Evergreen							37	13	13	
Cattail Monotypic	10	19	11	19					19	MFGt
Melaleuca Dominant	11	31			22	31			31	EM
Melaleuca Sparse	12	31							31	EM
Cajeput Forest Compositional Group							8	31	31	EM
Floating Emergent Marsh	13	28	17	28					28	MFF
Cattail Sparse	14	19	12	19					19	MFGt
Swamp Shrubland	15	9							9	SS
Spikerush	16	17	13	17	24	17	44	17	17	MFGe
Graminoid Freshwater Marsh	17	15			11	15			15	MFG

Graminoid Emergent Marsh Compositional Group							42	15	15	MFG
Broadleaf Emergent Marsh	18	25	20	25					25	MFB
Water Lily or Floating Leaved Marsh							57	25	25	MFFy/MFF
Herbaceous Freshwater Marsh					23	25			25	MFH
Forb Emergent Marsh							56	24	25	MFB
Black Needle Rush Marsh							49	22	22	MSGj
Leather Fern	19	9	15	29	13	29			29	MFBa
Graminoid Fresh Water Prairie (*Muhlenbergia*)							45	18	18	MFGPm
Sawgrass	20	16	5	16			43	16	16	MFGc
Brazilian Pepper Dominant	21	30			17	30			30	Es
Cocoplum Shrubland					25	9			12	SSy
Pond Apple Shrubland					14	9			12	SSa
Buttonbush Shrubland					21	9			9	SSc

Common Reed	35	41	22	41					41	MFGh
Sand Cordgrass Grassland							48	21	21	MSGs
Giant Cutgrass			23	41					41	MFGz
Wax Myrtle			16	12	26	9			12	SSm
Swamp Scrub Sawgrass	22	29	14	29					29	CSGc
Brazilian Pepper Sparse	23	30	6	30					30	Es
Bayhead Shrubland	24	12	29	12					12	SSSB
Brazilian Pepper Monotypic	25	30					31	30	30	Es
Panicgrass	26	15			28	15				MFGa
Treated Melaleuca Sparse	27	31							31	Em
Treated Melaleuca Dominant	28	31	9	31					31	Em
Swamp Scrub Open Marsh	29	9							9	CS
Herbaceous Freshwater Marsh	30	25							25	MFH
Treated Melaleuca Monotypic	31	31							31	Em

Bayhead Forest	32	12	18	12					12	FSB
Cypress Forest	33	10			15	10			10	FSt
Cypress Scrub					18	10			10	FStS
Cypress Forest Dome					19	10			23	FStD
Sparsely Wooded Wet Prairie Compositional Group							52	23	23	MFGPc
Dwarf Cypress Prairie							53	23	23	WSt or CStGP
Primrosewillow Shrubland	34	9	24	9	27	9			29	SSI
Arrowhead			19	25					25	MFBs / MFO
Lygodium Dominant	36	45							31	El
Melaleuca Monotypic	37	31							31	Em
Salt Marsh Ecological Complex							47	20	20	MSG
Saltwort / Glasswort Ecological Complex							38	14		MSSb

Graminoid Dry Prairie Ecological Complex							39	31	14	WUs
Pump Station	38	44							44	PS
Treated Australian Pine Sparse	39	42							42	Ec
Water Spinach Dominant			28	25					25	Eip
American Cupscale			27	25					25	MFGs
Wild Taro Dominant / Sparse			25/26	52/52					43	Eo
Agriculture							65	35	35	AG
Pasture Grassland Agriculture, Groves / Ornamentals							66/67	35	35	AG
Urban, Urban Residential, Urban-Open / Other							62/63/64	32/34/38	34	HI
Agriculture Confined Feeding Operations							68	35	35	AG
Road			1	51	31	51	61	28	51	RD

Sand - Beach							59	26	40	BCH
Extractive Mining							69	36	36	QUR
Bare soil / Clear Cut							60	35	40	
Recreation Areas							70	38	37	FC
Fish Camp			21	37					37	FC
Levee			2	46					46	LEV
Exotic					30	43			43	E
Clouds							71	37	60	Cloud

Vegetation community codes are as follows: OW = open water, FHS = Tropical Hardwood Hammock, FHT = Temperate Hardwood Forest, FMX = Mixed Mangrove Forest, FMa = Black Mangrove Forest, FMr = Red Mangrove Forest, WMcG = Buttonwood Woodland Graminoid, SS = Swamp Shrubland, FS = Swamp Forest, SSc = Buttonwood Shrubland, CS = Swamp Scrub, FSt = Cypress Forest, FStS = Cypress Forest Strand, CSmE = Wax Myrtle Scrub Emergent, SSy = Cocoplum Shrubland, FSB = Bayhead Forest, SSB = Bayhead Shrubland, SSA = Pond Apple Shrubland, SSM = Wax Myrtle Shrubland, SSs = Willow, CSW = Hardwood Swamp Scrub, WUs = Cabbage Palm Woodland, MFG = Graminoid Marsh, MFGc = Sawgrass, MFGe = Spikerush, MFGPm = *Muhlenbergia* Wet Prairie, MGFt = Cattail, MSG = Graminoid Salt Marsh, MSGs = Cordgrass, MSGj = Black Rush, FStD = Cypress Forest Dome, WSt / CStGP = Cypress Woodland /Cypress Scrub – Graminoid Prairie, MFO = Open Marsh, MFB = Broadleaf Emergent Marsh, MFFy / MFF = Floating Emergent Marsh, MFH = Herbaceous Marsh, MFB = Broadleaf Emergent Marsh, Eip = Water Spinach, MFGs = American Cupscale, MFBa = Leatherfern, CSGc = Swamp Scrub Sawgrass, Es = Brazilian Pepper, MFGa = Panicgrass, EM = Melaleuca, EL = Lygodium, HI = Urban, AG = Agriculture, QUR = Extractive Mining, SP = Spoil, FC = Recreation / Fish Camp, BCH = Sand Beach, MFGz = Giant Cutgrass, MSSb = Saltwort /Glasswort Ecological Complex, E = Exotic, PS = Pump Station, Eo = Wild Taro, LEV = Levee, RD = Road

APPENDIX E. VEGETATION RECODING AND CROSS WALKS FOR SOUTH FLORIDA GAP AND THE RECOVER VEGETATION MAPS.

Recoding of the South Florida GAP satellite imagery. Classification schemes used by the South Florida GAP investigation and the SFWMD RECOVER vegetation mapping program differ. This table establishes the common nomenclature and recoding definitions to link the two classification schemes.

Value	Recode Value	Class Name Florida GAP	Raster ID SFWMD	RECOVER Community
0	1	Ocean Florida Bay	0	Ocean Florida Bay
1	2	Open Water	904000	Open Water
2	3	Tropical Hardwood Hammock Formation	133000	Tropical Hardwood Hammock
3	3	Semi-deciduous Tropical / Subtropical Swamp Forest	133000	Tropical Hardwood Hammock
5	4	Mesic-Hydric Live Oak / Sabal Palm Ecological Complex	134000	Temperate Hardwood Hammock
8	31	Cajeput Forest Compositional Group	819000	Melaleuca
9	5	Mixed Mangrove Forest Formation	115000	Mixed Mangrove Forest
10	6	Black Mangrove Forest	111000	Black Mangrove Forest
11	7	Red Mangrove Forest	114000	Red Mangrove Forest
13	8	South Florida Slash Pine Forest	211010	Pine Lowland Graminoid
16	8	Mesic-Hydric Pine Forest Compositional Group	221010	Pine Lowland Graminoid

17	9	Swamp Forest Ecological Complex	120000	Swamp Forests
18	10	Cypress Forest Compositional Group	127000	Cypress Forest
20	11	Buttonwood Woodland	211000	Buttonwood Woodland
21	5	Mixed Mangrove Woodland	115000	Mixed Mangrove Forest
22	6	Black Mangrove Woodland	111000	Black Mangrove Forest
23	7	Red Mangrove Woodland	114000	Red Mangrove Forest
25	8	South Florida Slash Pine Woodland	221010	Pine Lowland Graminoid
28	12	Flooded Broad-leaved Evergreen Shrubland Compositional Group	323000	Bayhead Forest
29	29	Dry Prairie (Xeric-Mesic) Ecological Complex	232000	Cabbage Palm Woodland
31	30	Brazilian Pepper Shrubland	827000	Brazilian Pepper
32	4	Dwarf Mangrove Ecological Complex	210000	Mangrove Woodland
37	13	Saturated - Flooded Cold-Deciduous and Mixed Evergreen Cold Deciduous Shrubland Ecological Complex	331000	Willow Shrublands
38	14	Saltwort / Glasswort Ecological Complex	514000	Succulent Salt Marsh
39	31	Graminoid Dry Prairie Ecological Complex	610000	Graminoid Dune
42	15	Graminoid Emergent Marsh Compositional Group	522000	Graminoid Freshwater Marsh
43	16	Sawgrass Marsh	522100	Sawgrass
44	17	Spikerush Marsh	522200	Spikerush
45	18	*Muhlenbergia* Grass Marsh	523500	*Muhlenbergia* Grass

46	19	Cattail Marsh Compositional Group	522700	Cattail
47	20	Salt Marsh Ecological Complex	511000	Graminoid Salt Marsh
48	21	Sand Cordgrass Grassland	511400	Cordgrass
49	22	Black Needle Rush Marsh	511200	Black Rush
52	23	Sparsely Wooded Wet Prairie Compositional Group	222020	Cypress Woodland-Open Marsh
53	23	Draft Cypress Prairie	222000	Cypress Woodland
56	24	Forb Emergent Marsh	520000	Freshwater Marsh
57	25	Water Lily or Floating Leaved Vegetation	525000	Herbaceous Freshwater Marsh
59	26	Sand - Beach	901000	Beach
60	35	Bare soil / Clearcut	900000	Non-Vegetative
61	28	Pavement, Roadside	902100	Road
62	32	Urban	902000	Human Impacted
63	34	Urban Residential	902000	Residential
64	38	Urban Open / Others	902000	Human Impacted
65	35	Agriculture	902010	Agriculture
66	35	Pasture Grassland Agriculture	902010	Agriculture
67	35	Pasture Groves Ornamentals	902010	Agriculture
68	35	Agricultural Confined Feeding Operations	902010	Agriculture
69	36	Extractive	905000	Quarry
70	38	Recreation Area	905000	Human Impacted
71	37	Clouds	905000	Other

Recoding for WCA1. Vegetation communities mapped in WCA1, WCA2, and WCA3 were recoded.

Object ID	Original Value	Recoded Value	Community
1	0	0	Background
2	1	39	Canal
3	2	2	Open Water
4	3	40	Spoil
5	4	4	Temperate Hardwood Hammock
6	5	9	Swamp Forest
7	6	45	Australian Pine Dominant
8	7	24	Open Marsh
9	8	19	Cattail Dominant
10	9	13	Willow Shrubland
11	10	19	Cattail Monotypic
12	11	31	Melaleuca Dominant
13	12	31	Melaleuca Sparse
14	13	28	Floating Emergent Marsh
15	14	19	Cattail Sparse
16	15	9	Swamp Shrubland
17	16	17	Spikerush
18	17	15	Graminoid Freshwater Marsh
19	18	25	Broadleaf Emergent Marsh
20	19	9	Leather Fern
21	20	16	Sawgrass
22	21	30	Brazilian Pepper Dominant
23	22	29	Swamp Scrub-Sawgrass
24	23	30	Brazilian Pepper Sparse
25	24	12	Bayhead Shrubland
26	25	30	Brazilian Pepper Monotypic
27	26	15	Panicgrass
28	27	31	Treated Melaleuca Sparse
29	28	31	Treated Melaleuca Dominant
30	29	9	Swamp Scrub-Open Marsh
31	30	25	Herbaceous Freshwater Marsh
32	31	31	Treated Melaleuca Monotypic
33	32	12	Bayhead Forest
34	33	10	Cypress Forest

35	34	9	Primrosewillow Shrubland
36	35	41	Common Reed
37	36	45	Lygodium Dominant
38	37	31	Melaleuca Monotypic
39	38	44	Pump Station
40	39	42	Treated Australian Pine Sparse

Recoding of WCA2.

Object ID	**Original Value**	**Recoded Value**	**Community**
1	0	0	Background
2	1	51	Road
3	2	46	Levee
4	3	39	Canal
5	4	2	Open Water
6	5	16	Sawgrass
7	6	30	Brazilian Pepper Sparse
8	7	24	Open Marsh
9	8	19	Cattail Dominant
10	9	31	Treated Melaleuca Dominant
11	10	13	Willow Shrubland
12	11	19	Cattail Monotypic
13	12	19	Cattail Sparse
14	13	17	Spikerush
15	14	29	Swamp Scrub - Sawgrass
16	15	29	Leather Fern
17	16	12	Wax Myrtle
18	17	28	Floating Emergent Marsh
19	18	12	Bayhead Forest
20	19	25	Arrowhead
21	20	25	Broadleaf Emergent Marsh
22	21	37	Fish Camp
23	22	41	Common Reed
24	23	41	Giant Cutgrass
25	24	9	Primerosewillow Shrubland
26	25	52	Wild Taro Dominant
27	26	52	Wild Taro Sparse
28	27	25	American Cupscale

29	28	25	Water Spinach Dominant
30	29	12	Bayhead Shrubland

Recoding of WCA3.

Object ID	**Original Value**	**Recoded Value**	**Community**
1	1	40	Spoil
2	2	9	Swamp Shrubland
3	3	24	Broadleaf Emergent Marsh
4	4	19	Cattail
5	5	16	Sawgrass
6	6	24	Open Marsh
7	7	28	Floating Emergent Marsh
8	8	41	Common Reed
9	9	13	Willow Shrubland
10	10	2	Open Water
11	11	15	Graminoid Freshwater Marsh
12	12	39	Canal
13	13	29	Leather Fern
14	14	9	Pond Apple Shrubland
15	15	10	Cypress Forest
16	16	9	Swamp Forest
17	17	30	Brazilian Pepper
18	18	10	Cypress Scrub
19	19	10	Cypress Forest-Dome
20	21	9	Buttonbush Shrubland
21	22	31	Melaleuca
22	23	25	Herbaceous Freshwater Marsh
23	24	17	Spikerush
24	25	9	Cocoplum Shrubland
25	26	9	Wax Myrtle Shrubland
26	27	9	Primerosewillow Shrubland
27	28	15	Panicgrass
28	30	43	Exotics
29	31	51	Road