

Cape Sable Seaside Sparrow Marl Prairie Indicator (*CSSSMarlPrairie version 2.2*) Ecological and Design Documentation & User's Guide

June 12, 2014

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Contents

Acknowledgments:	3
Abstract.....	4
Introduction	4
Purpose and Objective.....	5
Domain.....	5
Methods.....	6
Justification	7
Generating Hydrologic Metrics for Indicator Scoring.	10
Hydrologic Metrics and Return Period by RSM Polygons.	11
Scoring:	13
Selection of Target and Bounding RSM Polygons.	13
Suitability Index Score.....	18
Model Requirements	19
Hardware Requirements.....	19
Software Requirements	20
Installation	20
Running Marl Prairie Application.....	20
Inputs	20
Outputs	24
Spatial Time Series of Hydrologic Metrics	24
Return Periods	26
Habitat Scores	27
ESRI Shapefiles	28
Post-processing Outputs.....	28
Mapped Graphics.....	28
Charts	29
Limitations and Future Model Development.....	32
Summary and Conclusions.....	33
References Cited	34
Appendix ECB Return Periods at Target and Bounding RSM polygons.....	37

Suggested citation: Pearlstine, L., A.M. Lo Galbo, G. Reynolds, J. Parsons and K. Suir. 2014. Marl Prairie Indicator: (CSSSMarlPrairie version 2.2) Ecological and Design Documentation. National Park Service, Everglades National Park, South Florida Natural Resources, Homestead, FL.

Acknowledgments:

The authors acknowledge the Everglades National Park staff, researchers, and volunteers that collected and compiled the Cape Sable Seaside Sparrow survey data. We are very grateful for valuable reviews from Everglades National Park scientists, Jimi Sadle and Agnes McClean. The authors acknowledge the Everglades Depth Estimation Network (EDEN) project and the U.S. Geological Survey for providing the digital elevation topography data and water surface files used in this report.

Abstract

Marl prairie, the graminoid-dominated and most diverse freshwater vegetation community in the Florida Everglades provides a specialized niche for the federally endangered Cape Sable seaside sparrow (CSSS). Natural resource managers and land managers need modeling tools that simulate the anticipated response of marl prairie CSSS habitats to fluxing hydroperiods and hydropatterns resulting from anthropogenic effects such as restoration projects and water management operations as well as from climatic change. The Cape Sable Seaside Sparrow Marl Prairie Indicator (*CSSSMarlPrairie*, version 2.2) is a temporally and spatially explicit modeling tool that simulates hydrologic suitability of marl prairie habitats based on CSSS survey presence data. *CSSSMarlPrairie* generates frequency return periods of hydrological conditions allowing users to model anticipated marl prairie CSSS responses over a range of fluxing climatic conditions from average rainfall conditions to more extreme drought and above average rainfall conditions. The modeling tool integrates CSSS field survey data with marl prairie hydrologic targets at the resolution of the hydrologic simulation model (in this case the Regional Simulation Model) providing a novel approach for simulation of anticipated marl prairie responses in the southern Everglades. The tool is intended to be used for decision support in association with other ecological modeling tools. It facilitates planning of ecosystem restoration projects such as those in the Comprehensive Everglades Restoration Plan and maintenance or recovery of the marl prairie habitats of the CSSS.

Introduction

Marl prairie is composed of a diverse, relatively short-hydroperiod, freshwater plant community mosaic dominated by species such as muhly grass (*Muhlenbergia capillaris* var. *filipes*), black sedge (*Schoenus nigricans*), south Florida bluestem (*Schizachyrium rhizomatum*), and short-stature sawgrass (*Cladium jamaicense*) (Ross et al. 2006). Hydropatterns are a characterization of water levels over a defined time period and include measures such as water depth and duration, quantity, timing and distribution of surface water to a specific area. Hydropatterns are key parameters driving vegetation community composition in freshwater marshes of the Florida Everglades including marl prairies (Stober et al. 2001; Ross et al. 2006; Sah et al. 2006). The federally endangered Cape Sable seaside sparrow (CSSS, *Ammodramus martimus mirabilis*) is endemic to a restricted niche in marl prairie habitats located solely within the southern Everglades. The CSSS was originally listed as federally endangered because of its restricted range and habitat loss (32 Federal Register 48 (11 March 1967), pg. 4001). Critical habitat for the CSSS is currently designated within Everglades National Park and adjacent state lands (Figure 1, 72 Federal Register 214 (6 November 2007), pp. 62736-62766). Currently designated critical habitats do not include any part of subpopulation A, which extends into Big Cypress National Preserve, however, subpopulation A has often been a focus of hydrologic restoration concerns. Direct and indirect consequences of anthropogenic water management operations including unnatural fire frequencies, nest flooding and increased predation, coupled with broad scale climatic changes have the potential to further impact the present CSSS population and its associated marl prairie habitat. Because of its restricted range and sensitivity to fluxing hydropatterns, the CSSS is considered a key indicator species of the marl prairies. In addition, Federal Agencies have a statutory obligation to prevent taking actions that will jeopardize the survival of species listed under the Endangered Species Act of 1973 or adversely modify designated critical habitat for those species.

The CSSS Marl Prairie Indicator (*CSSSMarlPrairie*, version 1.0) is a temporally and spatially explicit modeling tool that simulates hydrologic suitability of marl prairie habitat based on CSSS survey presence

data. *CSSSMarlPrairie* scores specifically target hydrologic indicators of suitable marl prairies inhabited by the CSSS. *CSSSMarlPrairie* scores combine the habitat suitability for 4 metrics: (1) average wet season water depths (June – October), (2) dry season water depths (November – May), (3) hydroperiod (May – April of the next year), and (4) maximum continuous dry days during the nesting season (March 1 – July 15).

Purpose and Objective

CSSSMarlPrairie models and compares existing and target hydrological conditions for marl prairie habitat to conditions under various hydrologic scenarios. Specific objectives of the model are to:

1. Devise metrics that relate marl prairie hydrologic suitability to a key indicator species in the marl prairie habitat, the CSSS.
2. Better understand the temporal and spatial variability of model-based hydrologic metrics in relation to marl prairie habitats.
3. Provide spatial time series recommendations of hydrologic suitability for marl prairie habitats to support Comprehensive Everglades Restoration Plan (CERP) modeling evaluations.

Domain

The default *CSSSMarlPrairie*'s spatial domain, depicted in Figure 1, is the freshwater marsh south of the Tamiami Trail (U.S. 41) and located predominantly within Everglades National Park but also encompassing Big Cypress National Preserve and lands owned by the State of Florida. The spatial domain of *CSSSMarlPrairie* is constrained by the bounds of the input depth file.

CSSSMarlPrairie uses The South Florida Water Management District Regional Simulation Model (RSM) as the source of spatially-continuous daily water stage over the South Florida region (Figure 1). The RSM simulates groundwater flow and surface water flow using a finite volume method (SFWMD 2005). Hydrological processes as well as water management operations are simulated in the model (SFWMD 2005). Water depths and hydrologic metrics derived from the daily water depths are computed in a regular orthogonal grid at a finer resolution than the original RSM variable triangular mesh as detailed in Methods section below.

The modeled results provide the spatial relationship and distribution of marl prairie hydrologic suitability in the southern Everglades. Continuous spatially-explicit output ensures that expected shifts in hydrologic suitability for CSSS occupied marl prairies are readily apparent when alternative hydrologic scenarios are evaluated.

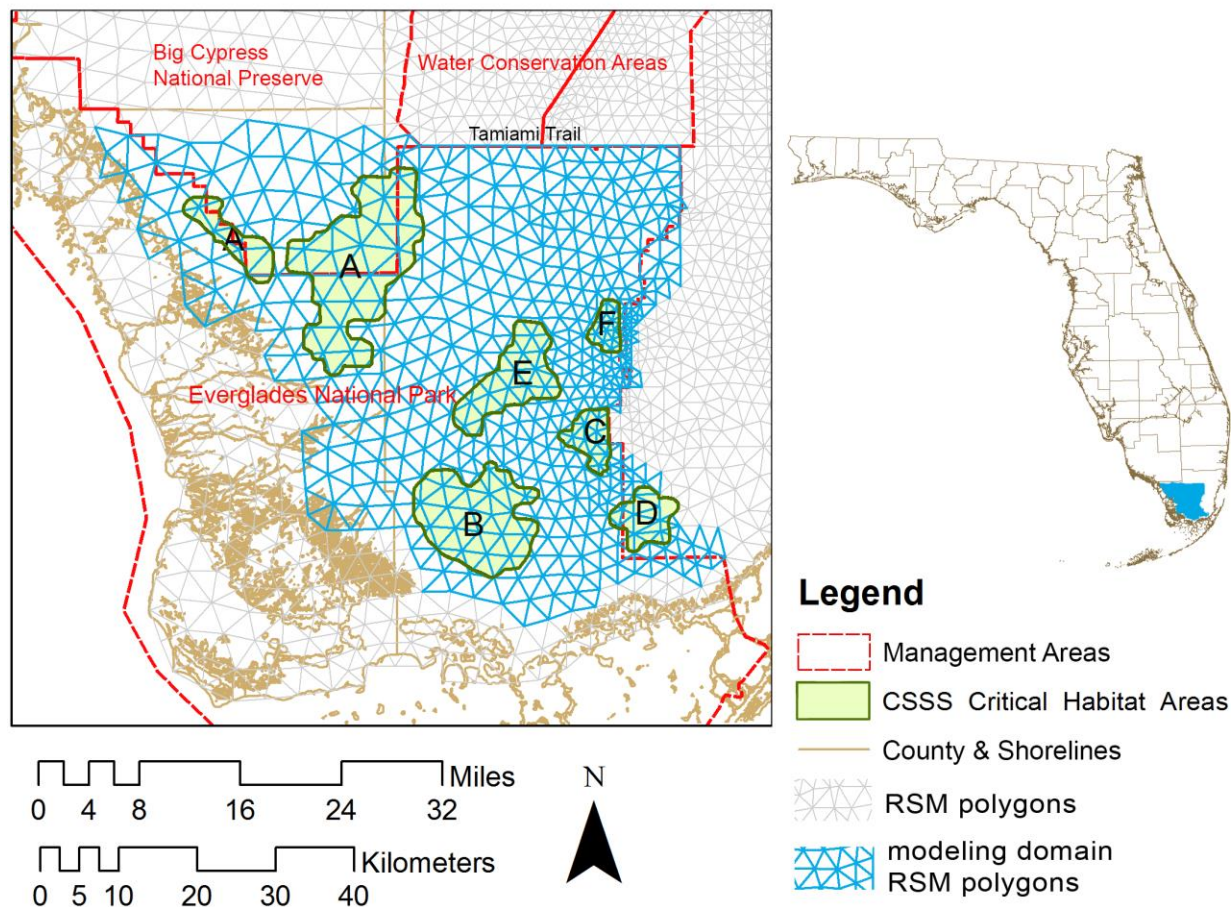


Figure 1. The default modeling domain of the CSSS Marl Prairie Indicator model. Regional System Model (RSM) mesh (triangular) polygons selected for calculating the CSSS Marl Prairie Indicator scores are shown in blue. Also shown below the mesh in light green are the Cape Sable seaside sparrow critical habitat boundaries for subpopulations B-F and the formerly proposed critical habitat boundary for subpopulation A (72 Federal Register 214 (6 November 2007), pp. 62736-62766). The RSM mesh of reference polygons is user selectable.

Methods

Methodology is generally consistent with the Lo Galbo et al. (2013) Slough Vegetation Performance Measure and adaptations by Gregg Reynolds (pers. comm., NPS) to use indicator scores in a quantification of potential impacts where scores from multiple performance measure metrics are aggregated. *CSSSMarlPrairie* scores the hydrologic suitability of a location as marl prairie habitat for the CSSS (Figure 2). Hydrologic metrics (seasonal water depths, hydroperiods and dry down duration) are derived from modeled scenario (restoration alternative) daily water depths for the 500 m grid, and then aggregated by averaging to the resolution of the RSM polygons in the model domain. Hydrologic return period tables, comprised of annual metric values for the period of simulation of the hydrologic model runs, are compiled for each of the metrics at each RSM polygon. The scenario values at each return

period are contrasted at each polygon with a baseline set of target metric values for each return period from RSM polygons that are selected to characterize 1) the most suitable and 2) the upper and lower bounding hydrological conditions (or limits) for CSSS marl prairie habitat. The target conditions were established from empirical evaluations of CSSS field survey count data and their associated hydropatterns. For details of how RSM polygons were selected from CSSS field survey presence data to generate the indicator targets, refer to the Selection of Target and Bounding RSM Polygons section below. Indicator scores ranging from 0 (unsuitable hydrological conditions) to 100 (most suitable hydrological conditions) are assigned based on the characterization.

Justification

Cape Sable seaside sparrow is dependent on the marl prairies of the southern Everglades located predominantly within Everglades National Park. These marl-forming freshwater marshes support a higher diversity of plants than the adjacent, deeper water marshes (Ross et al. 2004, Sah et al. 2008). Sparrow numbers have declined as much as 60 percent range-wide since 1992 (Curnutt et al. 1998, Nott et al. 1998) and their distribution has increasingly been restricted to core subpopulations in areas B and E (Figure 1; Pimm et al. 2002). The *CSSSMarlPrairie* model focuses on hydrologic suitability of habitat as a key attribute of CSSS presence. The timing, distribution, and duration of water depths, are modeled as a primary driver of marl prairie CSSS habitat. These broad scale hydropatterns derived from regional hydrologic modeling drive landscape habitat suitability at regional scales (see Limitations and Future Developments section). We included hydroperiod and water depth metrics in the *CSSSMarlPrairie* model as they are key driving parameters affecting vegetation community composition and structure throughout the freshwater marshes of the Everglades including marl prairie habitats (Stober et al. 2001, Ross et al. 2004, Ross et al. 2006; Sah et al. 2006).

A Conservation Committee of the American Ornithologists' Union (Walters et al. 2000) concluded that all known threats to CSSS involve habitat alteration and reduced habitat suitability. These two factors are attributed as the primary reason for population declines. The Committee attributes declines in subpopulations A and D to extending hydroperiods that suppress reproduction and alter vegetation community composition as reported by Nott et al. (1998). In subpopulations C and F, reduced hydroperiods (in concert with proximity to humans) have directly resulted in abnormally large fire frequencies which may have depressed habitat quality and, subsequently, CSSS subpopulations (Walters et al. 2000; Pimm et al. 2002). Further, the committee found no evidence that other biotic (e.g., unusual new predators, diseases, or competitors) or abiotic, including Hurricane Andrew (Curnutt et al. 1998), factors are affecting sparrow subpopulations. This finding emphasizes that there is a small window of hydrologic variation beyond which CSSS are sensitive to the resulting changes in habitat quality. Supporting research for the Walters et al. (2000) report includes Kushlan et al. (1982), Nott et al. (1998), Lockwood et al. (2001) and Ross et al. (2004, 2006).

The sensitivity of CSSS occurrence to hydropatterns (e.g, hydroperiod, Ross et al. 2004; consecutive dry days during the nesting period, Lockwood et al. 2001) is intricately linked to vegetation community composition and structure that influences CSSS nest selection; nesting success is also tightly linked to hydrology with nest predation and nest flooding being prime risks influencing population dynamics (Pimm et al. 2002). Cape Sable seaside sparrows build nests close to the ground, just above the bases of

clumps of marl prairie vegetation, making nests susceptible to flooding. Nott et al. (1998) uses a 10 cm nest height threshold for sparrow nesting. Lockwood et al. (2001) recorded a 17 cm average nest height early in the breeding season and a 21 cm average nest height late in the breeding season. Pimm et al. (2002) documented an average 16 cm nest height. Nest site selection and sparrow densities have been linked to sites with high muhly grass cover, litter, and high vegetation heights (e.g., the presence of tall sawgrass within the muhly grass habitat) (Pimm et al. 2002). Nest success has also been shown to be linked to these habitat conditions (Pimm et al. 2002). Predation is attributed as the main cause of loss of CSSS young and eggs and has been linked to rising water levels (Pimm et al. 2002). We included number of dry days during the estimated peak CSSS nesting season (March 1 – July 15) in the *CSSSMarlPrairie* model as this is a key distinguishing hydrologic metric affecting CSSS nesting habitat suitability.

Cape Sable seaside sparrow abundance decreases along transitions from short-hydroperiod, muhly grass-dominated marl prairie to longer-hydroperiod sawgrass-dominated marsh (Nott et al. 1998, Pimm et al. 2002, Ross et al. 2004, Ross et al. 2006). Abundance also decreases as woody vegetation becomes prevalent (Werner 1975, Jenkins et al. 2003a; 2003b). Cape Sable seaside sparrow habitat is limited to a subset of the vegetated fresh water vegetation community generally lacking woody vegetation and which has a dry down period during the peak breeding season from early March through May (La Puma 2010).

Hydropatterns do not have to remain constant every year to maintain suitable marl prairie habitat. Marl prairie can survive individual years with deeper inundation and long hydroperiods as long as there are also years interspersed with dry downs that allow for recovery (Kushlan et al. 1982). Plant community dominance can shift, however, within 3 or 4 years of hydrologic change (Armentano et al. 2006). The CSSS has high site fidelity and a short life-span (Walters et al. 2000), further restricting the limits of site variability. Recurrence intervals over longer time-periods of annual metrics such as hydroperiod and water depth provide a characterization of the frequency and variability of a metric's values that provide suitable habitat.

The methods documented for this model of marl prairie habitat for the CSSS builds on these concepts:

1. Hydropattern metrics can be used to simulate hydrologic suitability of marl prairie habitat used by the CSSS. Recurrence intervals (a.k.a. "return periods") for selected hydrologic metrics help to characterize CSSS habitat because they account for distribution and variability of the metrics at each site rather than just an average value. Return periods are useful to simulate the approximate range of suitable hydrological conditions for marl prairie habitat under a variety of climatic conditions.
2. Presence and abundance of CSSS in Subpopulation B, the most stable core subpopulation, can be used to estimate the most suitable hydroperiod and hydropatterns for marl prairie habitat occupied by the CSSS.
3. Habitat suitability is estimated across the entire landscape, not just at existing CSSS sites, because site conditions are shifting due to factors such as natural succession, anthropogenic

influences such as implementation of restoration projects and water management operations, and climatic change.

Model Process Overview

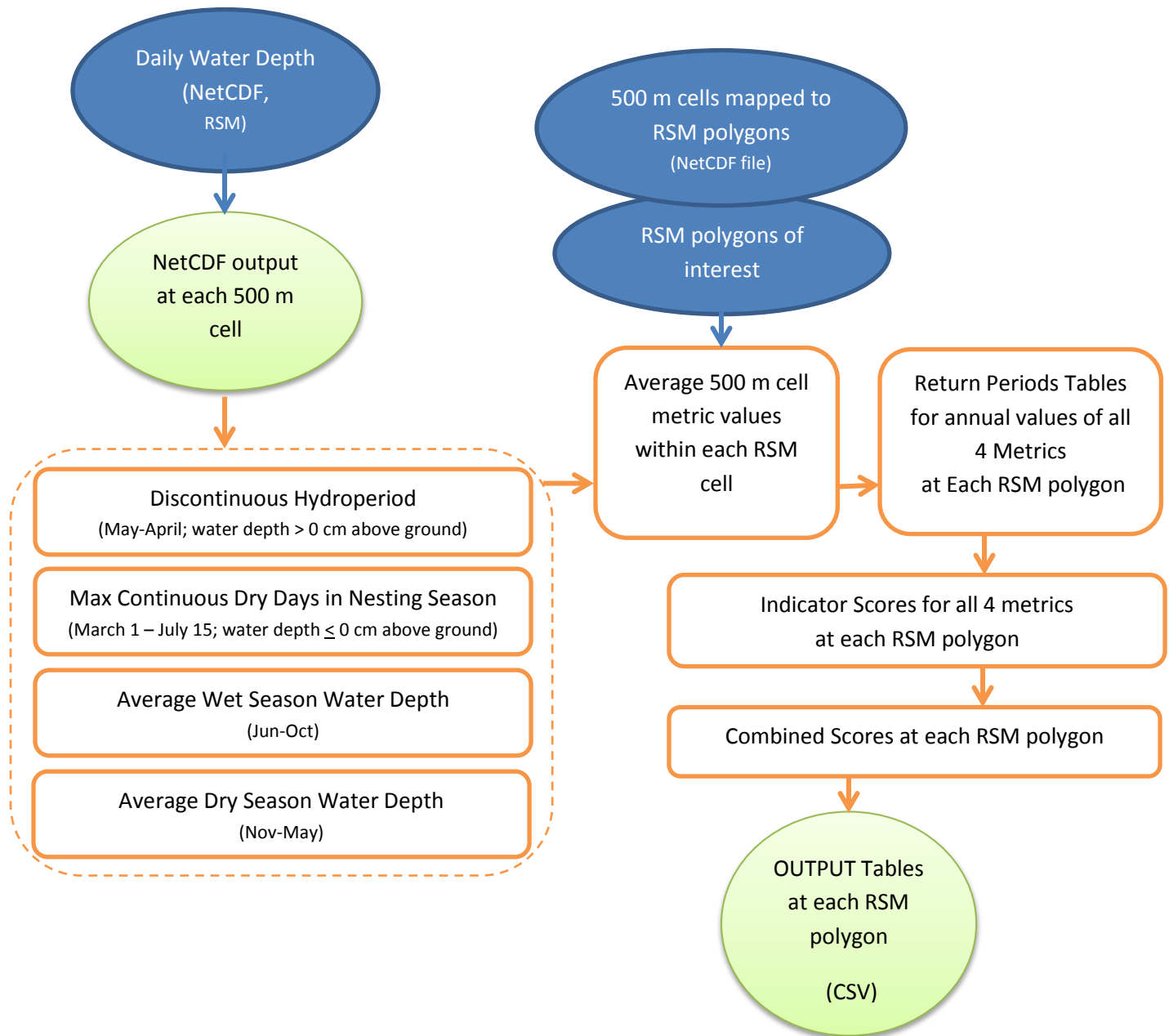


Figure 2. Flow chart overview of the *MarIPrairie* indicator scoring procedures.

Generating Hydrologic Metrics for Indicator Scoring.

Input for *CSSSMarlPrairie* can come from any continuous, daily iteration raster grid of water depths. *CSSSMarlPrairie* has been used with the RSM, South Florida Water Management Model (SFWMM), the Natural System Model (NSM), and the U.S. Geological Survey Tides and Inflows in the Mangrove Ecotone (TIME) model. Currently, however, the RSM is typically used for modeling hydrologic scenarios used for CERP planning purposes. Additionally, the RSM mesh (more specifically, the Regional System Model Glades LECSA mesh) is assumed as the output structure and resolution (although the user can specify a different structure). To simplify the narrative, the remainder of this document will refer only to the RSM for the model's input and structural mesh, however, whenever the term "RSM" is used, the reader can substitute the phrase "RSM or other user-supplied modeling mesh of choice".

RSM daily water stage output has a variable triangular resolution (Figure 1). To compute water depths and hydrologic metrics derived from water depths, however we are able to construct a finer resolution orthogonal grid. Water depths are computed by spatially continuous interpolation of the RSM water stage (Delauney triangularization) subtracted from the EDEN Digital Elevation Model (DEM; Jones and Price 2007; <http://sofia.usgs.gov/eden/index.php>). The EDEN DEM has a grid resolution of 400 x 400 m, however the final resolution of interpolated water depths has been established at 500 x 500 m to be consistent with other ecological models and legacy ecological models in use by agencies in south Florida for restoration evaluations. Additional details of the water depth interpolation methods are available at http://www.cloudacus.com/simglades/docs/WaDER_UserGuide_15Dec2011.pdf and http://www.cloudacus.com/simglades/docs/Improved_resolution_from%20coarse_hydrology_models_3-22-10.pdf. The WaDER application has been replaced by a USGS version of the program, but the principals are the same. Documentation for the USGS application is pending.

Four hydrologic metrics are created in *CSSSMarlPrairie*:

1. Annual Discontinuous Hydroperiod (May 1 - April 30 climatic year; water depth > 0 cm above ground surface). A five year averaged hydroperiod has been used in past marl prairie evaluations (e.g., Sah et al. 2009) because of potentially better representation of vegetation response. Because our end product is hydrologic return periods, however, there is explicit recognition of multiple year events making 5 year hydroperiod computation redundant.
2. Maximum Continuous Dry Days in CSSS Nesting Season (March 1 – July 15; water depth \leq 0 cm).
3. Average Wet Season Water Depth (June 1 – October 31).
4. Average Dry Season Water Depth (November 1 – May 31).

As illustrated in Figure 3, when the 4 metrics are taken together:

1. The simulation cycle is 15 months long : March of the current calendar year through May of the next calendar year.
2. There is a 3 month overlap between the cycles. When one cycle of the set of 4 metrics completes, the program back steps to start the next cycle.

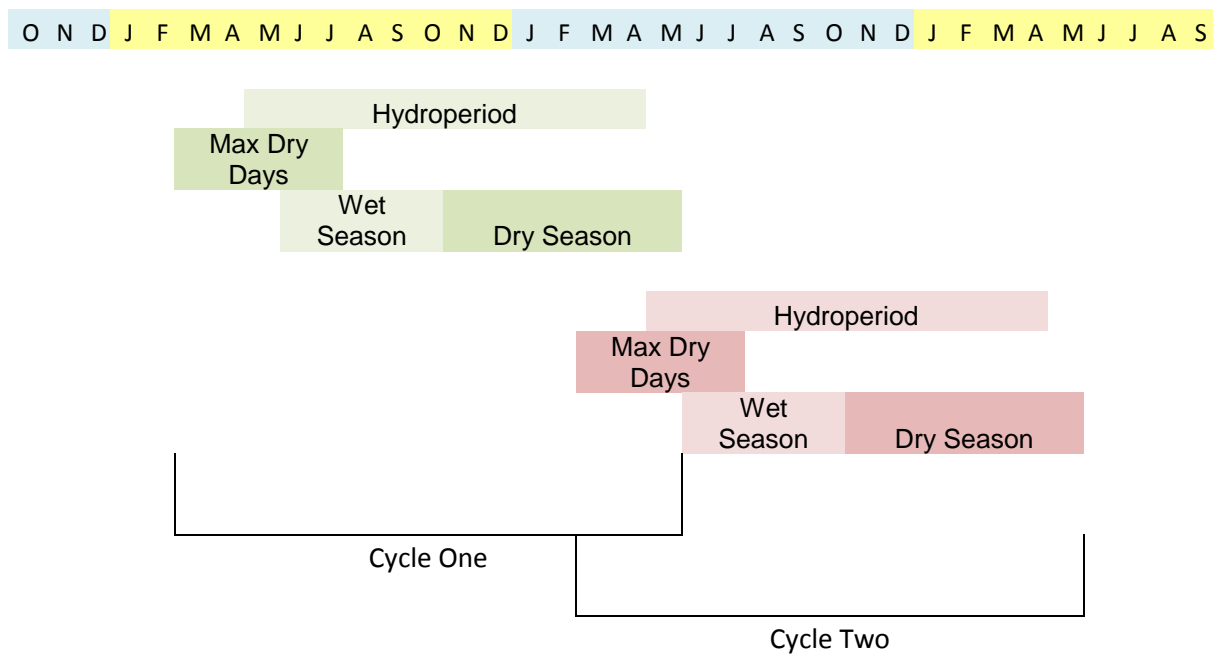


Figure 3. Metric measurement periods in relation to calendar months.

Input is daily water depths in Network Common Data Form (NetCDF) raster grid format UTM, NAD83. NetCDF is a binary data format for array-oriented, large time-series data. It has become an international standard that is widely accepted by GIS and statistical packages. NetCDF is “self-describing”, which means that metadata describing the file’s layout and projection is contained within the header. Typical input is Regional System Model output interpolated to a 500 m grid and reprojected to the UTM, NAD83 input requirement.

Output is saved as NetCDF at the spatial resolution of the input water depths file. Time step is the simulation cycle (15 month) with each time step labeled by the start calendar year of the cycle.

Hydrologic Metrics and Return Period by RSM Polygons.

To illustrate the size relationship between the input hydrologic metrics at 500 m resolution and the RSM, Figure 4 was cropped from an upper-left portion of subpopulation B. The square grids in this illustration are 500 m on a side. The unstructured triangular mesh overlaid on the grids is the RSM.

The blue RSM mesh in Figure 1 illustrates the RSM mesh polygons (cells) selected for scoring in the *CSSSMarIPrairie* application. All the fresh water wetland RSM polygons below Tamiami Trail are obtained to examine spatial distributions and shifts in habitat among modeling scenarios. It would obviously not be an appropriate goal for conditions in all the polygons to shift toward marl prairie, however. RSM polygons can be subset from the results by CSSS subpopulation boundaries or by sub-

basin or by other criteria. The user also has control of which RSM polygons the application operates on. The RSM polygons used by *CSSSMarIPrairie* are listed in a text file that can be edited before running the application.

Values for each of the input hydrologic metrics are accumulated and averaged by RSM polygon for each time interval (hereafter, “cycle”). The respective metrics are each used to create empirical frequency curves of the recurrence interval of an event (Figure 5). The curves are referred to as return periods and are generally computed from an exceedance probability. These represent the average length of time in years for an event (e.g. water stage) of a given magnitude to be equaled or exceeded as illustrated by Figure 5. Return periods can also be based on a non-exceedance probability. The remaining figures in this document show the return period based on an exceedance probability for wetter than average conditions, and a return period based on a non-exceedance probability for drier than average conditions (e.g., Figure 10). The *CSSSMarIPrairie* scores are derived from an exceedance probability. Return periods account for temporal variability associated with multiple years with varying climatic conditions.

Figure 4. 500 m interpolated Regional Simulation Model (RSM) water depths in relation to the original RSM mesh. This example is from the RSM existing conditions baseline (ECB) scenario for August 6, 2003.

To compute return periods, the resulting vector for each RSM polygon of averaged values for each cycle is sorted in descending order.

The return period (or the recurrence interval), **Tr**, is:

$$Tr = (N+1)/M$$

N = total number of annual events

M = rank where largest annual event has rank M = 1. The smallest event has rank M = N

Baseline return periods for each RSM polygon are computed from RSM Existing Conditions Baseline (ECB). The program creates these tables for any RSM alternatives runs and then scores the alternative's conditions relative to baseline conditions.

There are 2 RSM configurations that could have been used for measuring hydrologic baseline conditions. ECB represents the Interim Operational Plan (IOP) implemented in 2002 and which expired in November 2010. IOP was replaced by the Everglades Restoration Transition Plan (ERTP) and is modeled in RSM with the 2012EC alternative. ECB was chosen as the default baseline for *CSSSMarIPrairie* because the CSSS survey data used in this report was collected during IOP, prior to ERTP. Within subpopulation B, however, there is no discernable hydrologic difference between ECB and 2012EC. From a practical standpoint, either alternative could have been selected as the baseline since target hydrologic conditions were selected from subpopulation B (described below).

Location A	Location B	rank	Tr
365	200	1	7.00
365	150	2	2.50
345	130	3	2.33
210	80	4	1.75
202	50	5	1.40
123	46	6	1.17

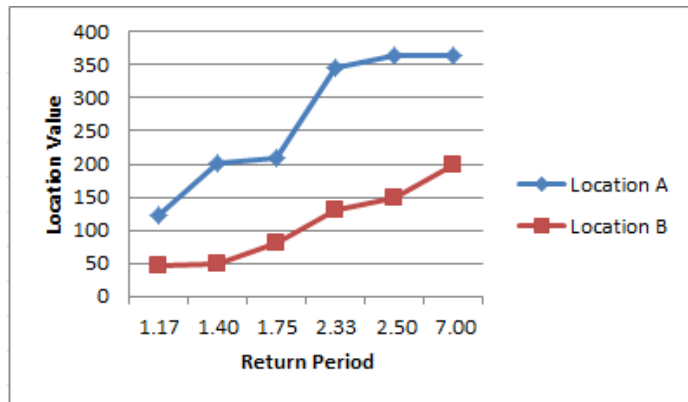


Figure 5. A small example illustrating the calculation of return period curves at two locations. Notice the two locations have their values sorted in descending order. The two locations have very different metric values associated with the same return period intervals. This type of plot is the basis for comparing alternative conditions as described in the Scoring section below.

Scoring:

Indicator scores for marl prairie habitat are generated at each RSM polygon. Two approaches are used to score alternative hydrologic scenarios:

1. Score the magnitude of hydrologic change an alternative scenario provides relative to a baseline condition at each RSM polygon.
2. Score the habitat suitability of a scenario at each RSM polygon.

To compute either score, a target hydrological condition for most suitable habitat must be provided. Four RSM polygons are selected within the baseline modeling domain to represent:

1. The upper and lower bounds of potential marl prairie habitat for CSSS based on their hydrologic conditions. RSM polygons with hydrologic conditions that fall within the range prescribed by these 2 polygons are modeled as having some level of habitat potential for which a score can be computed. RSM polygons with conditions beyond the hydrologic bounds prescribed by these 2 polygons have a modeled habitat suitability score of 0.
2. The upper and lower targets for most suitable CSSS marl prairie habitat. RSM polygons with hydrologic conditions that fall within the range prescribed by these 2 polygons have a modeled habitat score of 100.

Selection of Target and Bounding RSM Polygons.

Target and bounding RSM polygons for CSSS marl prairie habitat were selected based on the presence and relative abundance of singing male CSSSs in point count surveys conducted in 1981 and 1992-2012 (Pimm et al. 2002). During the survey, observers counted the number of singing male CSSSs during the breeding season during a seven minute timeframe at set survey point locations located across a 1 km grid in Everglades National Park, Big Cypress National Preserve, and adjacent state lands (Figure 6).

Model parameterization selected targets from CSSS subpopulation B because this subpopulation has the most stable abundance year to year since 1981 (Kushlan and Bass 1983, Curnutt et al. 1998, Lockwood and Fenn 2000, Pimm et al. 2002) and has the largest spatial extent of high sparrow abundances.

Cape Sable seaside sparrow Percent Presence was estimated as the total number of survey points (for years when the point was surveyed) with CSSS presence / the total number of survey points (for years when the point was surveyed) * 100.

and

Cape Sable seaside sparrow Percent Relative Abundance = $\text{sumBC} / \text{maxBC} * 100$

where:

sumBC = the sum of abundance counts at all survey points within the RSM polygon (for years when the point was surveyed).

maxBC = maximum potential count = the number of survey points (for years when the point was surveyed) in the RSM polygon multiplied by 7. For the purpose of estimating a maximum potential count, 7 is used as a multiplier to estimate the maximum potential count at a survey point and was based on the maximum bird counts recorded in the 1981 and 1992-2012 CSSS survey data.

Because percent relative abundance and percent presence are highly correlated (0.98 Pearson's correlation coefficient) and percent presence has a wider data spread (Figure 7), only percent presence is discussed further. Also, percent presence is a more direct metric as it does not require maximum potential count to be estimated.

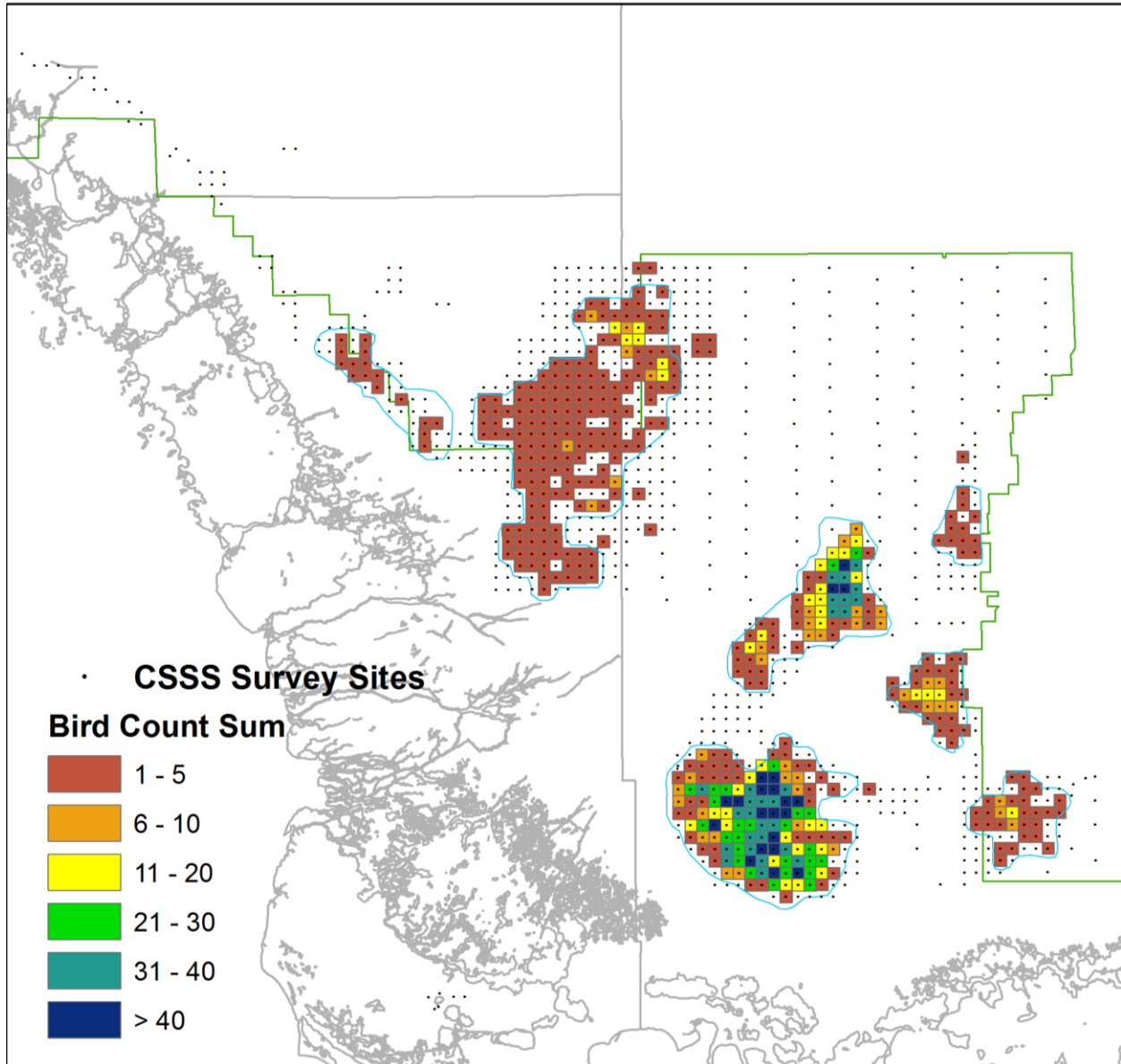


Figure 6. Cumulative Cape Sable seaside sparrow counts, 1981, 1992-2012. Not all survey locations are sampled in all years.

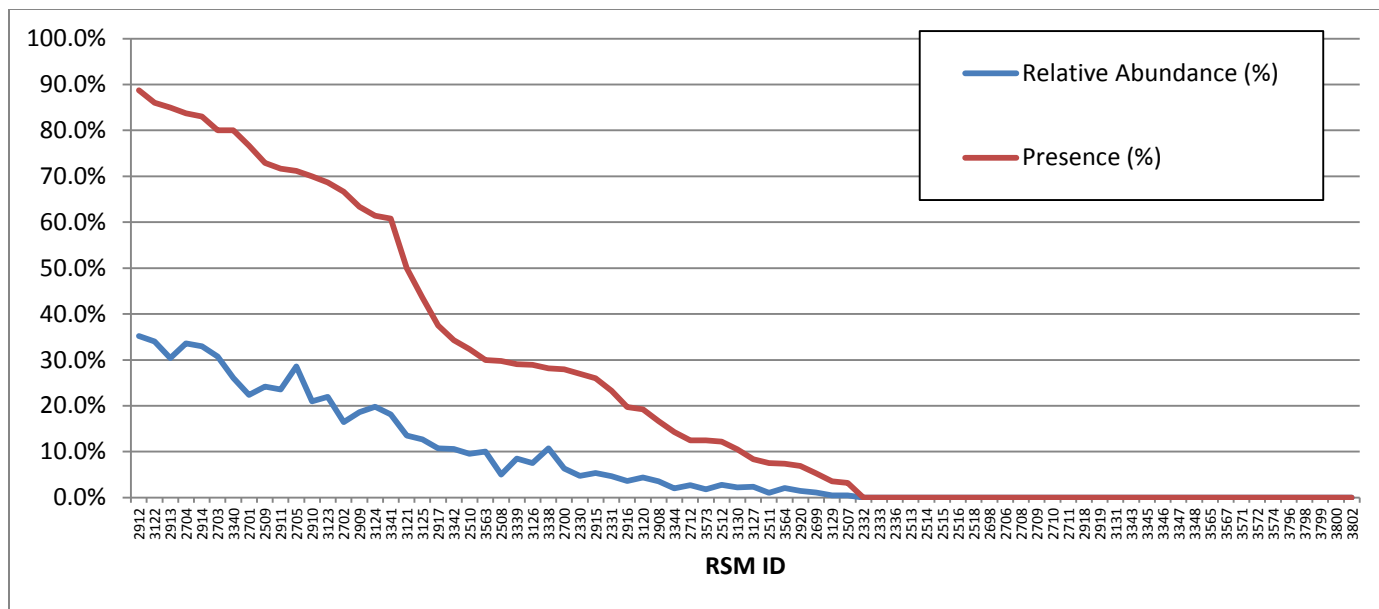


Figure 7. Percent relative abundance and percent presence by Regional Simulation Model polygon. Values are sorted by percent presence.

The criteria for selecting target habitat was to find RSM polygons that bound hydrologic conditions on the wet and dry ends of CSSS habitat and that were found to have a sparrow presence that exceeded 50%. The habitat was also bounded on the high (drier) and low (wetter) ends of the hydrologic gradient by RSM polygons that contained CSSS presence greater than 10%.

Figure 8 illustrates the selected RSM polygons in relation to CSSS presence as well as how those polygons lay in relation to the elevation gradient. The selected polygons are:

	<u>RSM Identifier</u>
Lower Bounds (drier)	2712
Lower Target	2703
Upper Target	2909
Upper Bounds (wetter)	2908

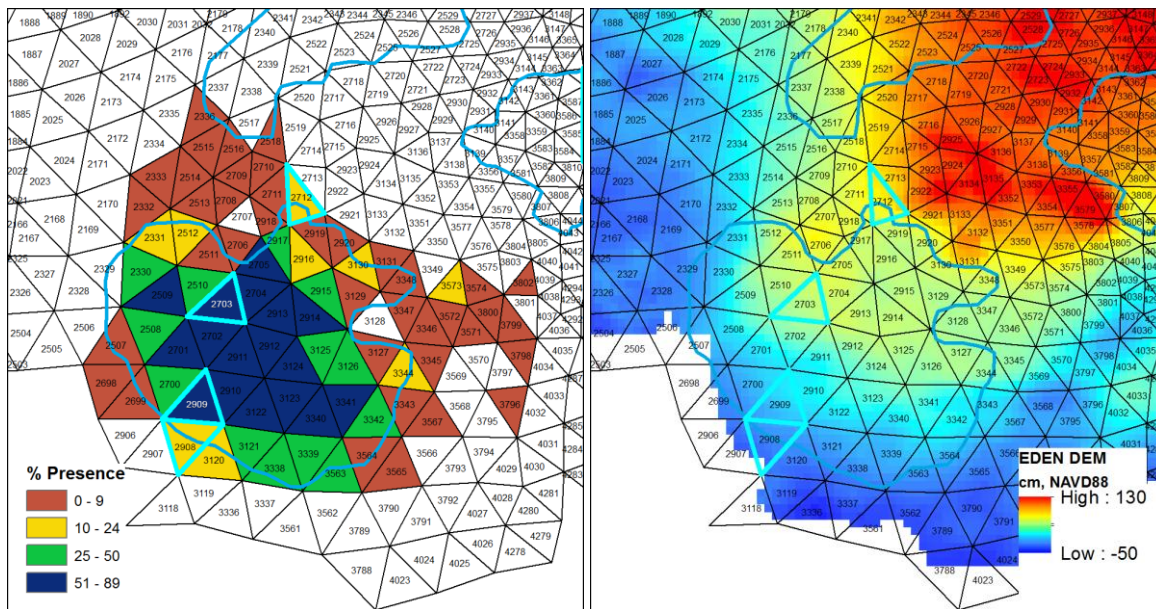


Figure 8. Cape Sable seaside sparrow subpopulation B percent presence (Left) and elevation (Right). Target and bounding polygons are highlighted in light blue.

Because *CSSSMarlPrairie* is designed for operation with RSM scenarios, it uses the RSM existing conditions, ECB, as the baseline for identifying target hydrologic metrics. It is informative, however, to compare ECB to EDEN water depths since EDEN is a direct interpolation of water stage gauge data. EDEN water depths were less variable, but within the same range as RSM existing conditions (ECB) water depths (Figure 9).

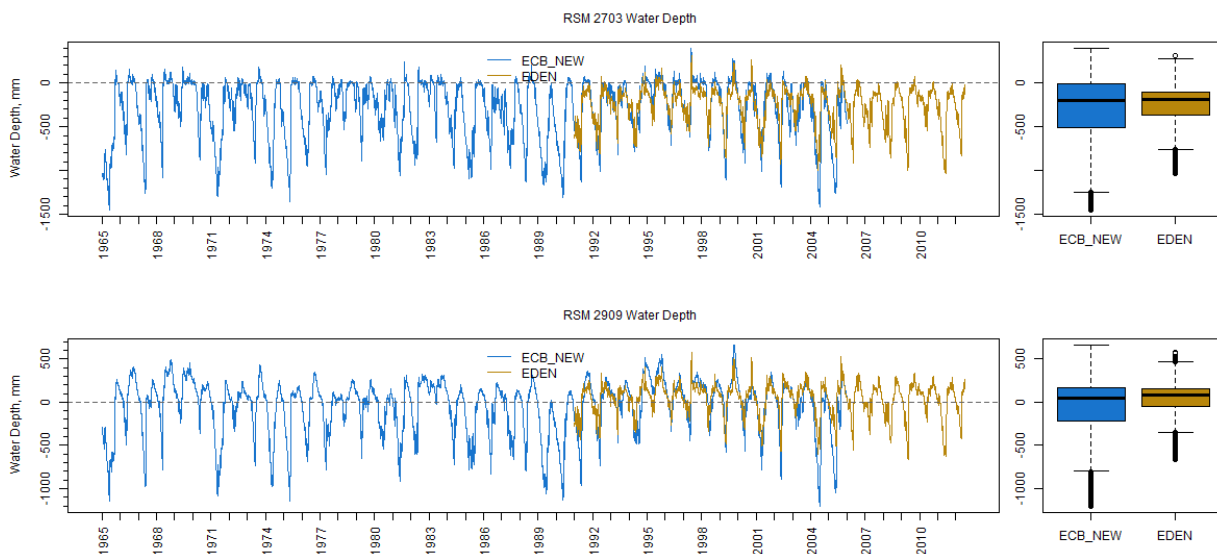


Figure 9. Marl prairie daily hydrographs contrasting Regional System Model (RSM) Existing Conditions Baseline water depths with the Everglades Depth Estimation Network. The top chart is for lower target

suitability at RSM polygon (cell ID) 2703 and the bottom chart is for upper target suitability at RSM polygon 2909.

Suitability Index Score.

The Suitability Index scores the habitat suitability of a scenario at each RSM polygon. Suitability index scores increase in value from zero at unsuitable conditions to 100 within the most suitable range of conditions (Figure 10).

In addition to selecting RSM polygons that represent an upper and lower target (i.e., “most suitable”) site, RSM polygons are selected that represent the habitat bounds. Conditions below the lower bounds and above the upper bounds are considered unsuitable CSSS habitat and receive a score of 0.

Alternative values that fall within the target (most suitable region), between the upper and lower targets, receive a score of 100.

Alternatives that fall between the bounds and most suitable region have a score that is the proportion of its position in the range, such that:

$$Score_{RSM} = \frac{\sum_1^{\# of cycles} \frac{(|Alternative - Bounds|)}{(|Target - Bounds|)} * 100}{(\# of cycles)}$$

Combined Score is then the arithmetic average of the scores for maximum dry days, hydroperiod, wet season water depth, and dry season water depth. Each of the hydrologic scores contributes equally to the suitability index, however, the scores could be weighted in the future if a rationale for weighting is developed.

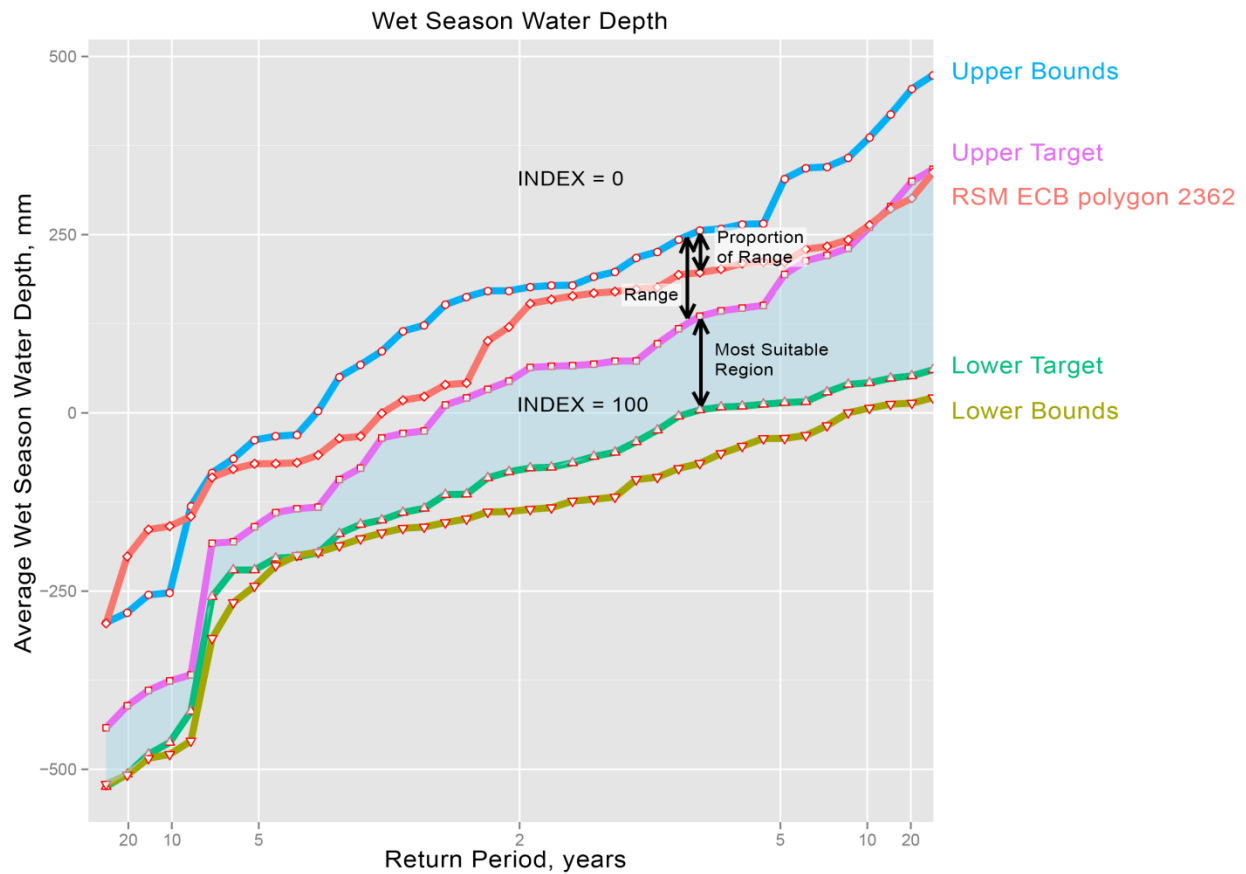


Figure 10. Illustration of computing the habitat suitability index. In this example, the wet season water depth return period for example Regional Simulation Model polygon 2362 from the existing conditions baseline (ECB) scenario falls between habitat bounds and the most suitable region. The linear proportion of the range from habitat bounds to the most suitable region that is the distance from the bounds to the alternative is the suitability score.

Model Requirements

Hardware Requirements

Operating System: Platform-independent (tested on Windows 7)

CPU: 1GHz or faster

System Memory (RAM): 1 GB or greater

Hard Disk: 400 MB free space

Software Requirements

Java JRE 1.7 or greater

Installation

There is no installer for the Marl Prairie Model. Simply unzip to the desired location.

Running Marl Prairie Application

Open the folder that was unzipped in the Installation step, and double click on *MarlPrairie.exe*.

Inputs

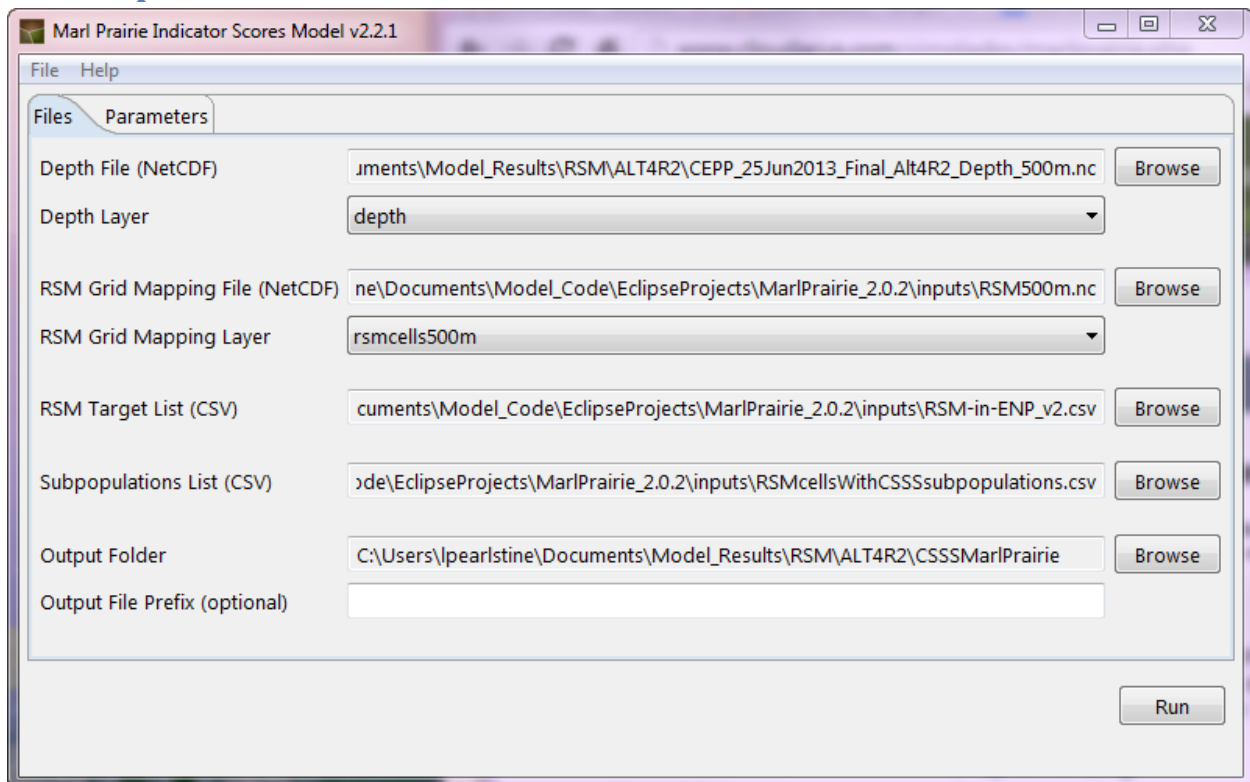


Figure 11. *MarlPrairie* user interface shown with the Files tab open.

When *MarlPrairie.exe* is run, the dialog box in Figure 11 is opened.

All of the inputs and parameters supplied by the user can be saved to an .xml file for retrieval later. **File/Save** and **File/Open** in the menu bar are used for that purpose. The model proceeds by clicking on the **Run** button at the bottom right of the interface.

NetCDF files inputs are expected to follow the CERP, CF-compliant standard. In addition to promoting data interoperability, the CERP NetCDF standard will also allow leveraging of the widely available suites

of software tools for viewing, charting and analysis. See <http://www.jem.gov/Standards> for more information on the CERP NetCDF standard.

Files Tab

Depth File (NetCDF): The path and filename of the input netCDF water depths file.

Depth Layer: The name of the water depth layer to use from the water depths file. This is usually “depth” or “Depth”. Note that capitalization matters.

RSM Grid Mapping File (Net CDF): The path and filename of a netCDF file at the resolution of the water depths file that contains the polygon IDs of the RSM polygons.

RSM Grid Mapping Layer: The name of the layer to use in the in_RSM file.

RSM Target List (CSV): An input list of RSM polygon IDs to use in the evaluations. The text file should have a header followed by a list of the RSM polygon IDs. Each ID should be on a separate line.

Subpopulation List (CSV): An input list of RSM polygon IDs and the subpopulation or other designated area that the RSM polygon is associated with. Any IDs of target RSM polygons (RSM Target List) that are not listed in this file will get a label of “Outside”. The text file has a header followed by the IDs and their labels. Each ID and label pair should be on a separate line; e.g.:

```
RSM, Population
866,A-west
867,A-west
941,A-west
1027,A-west
1028,A-west
1029,A-west
1037,A
1038,A
1039,A
.
.
.
```

Output Folder: the path and filename for the output file. Do not include the filename extension. A set of output files will be created from this file string.

Output File Prefix (optional): The program automatically generates output filenames. The user can optionally include additional text as a prefix to the filename.

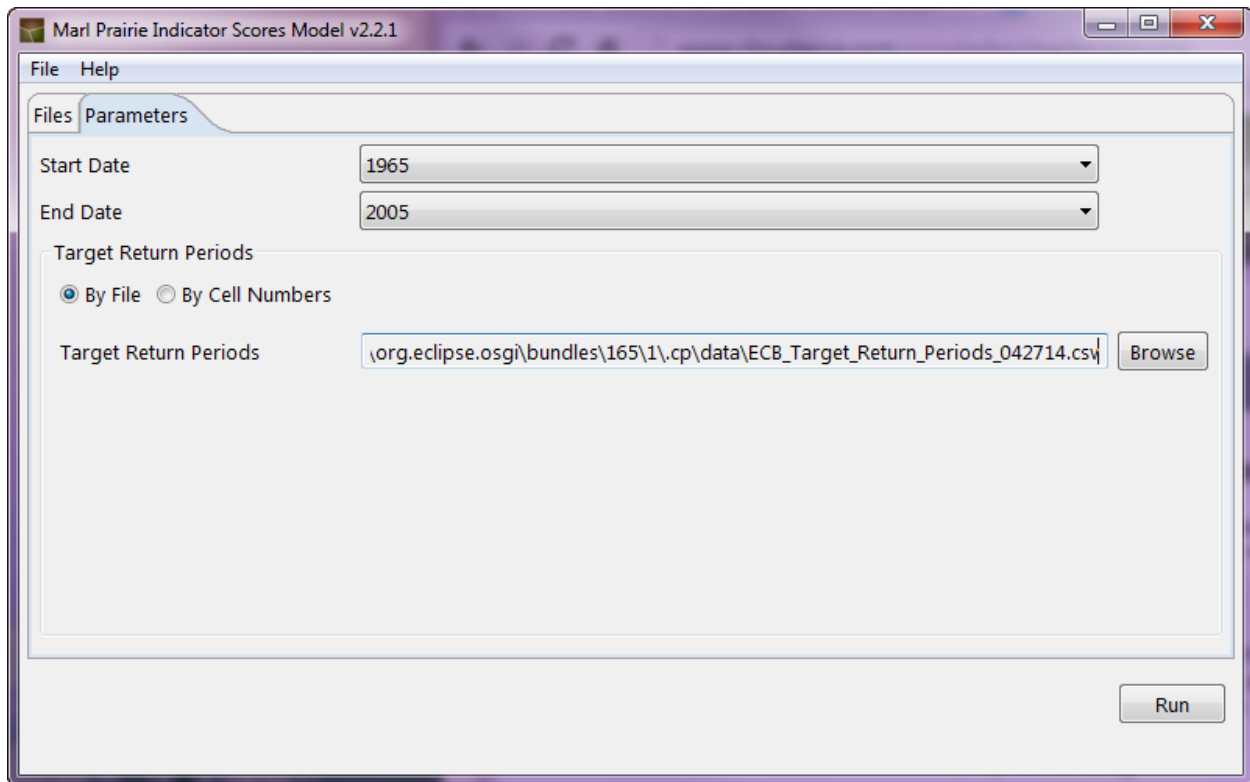


Figure 12. *MarIPrairie* user interface shown with the Parameters tab open and target return periods specified in an external file.

Parameters Tab

Start Date: The year to start the model. Select from the pull-down list of dates in the water depth files.

End Date: The year to end the model. Select from the pull-down list of dates in the water depth files.

There are two options for specifying target and bounding return periods.

“**By File**” is the default selection (figure 12). With this option,, the user specifies target and bounding return periods directly in an external file. The file entered in this option contains the return periods for the target and bounding habitat conditions. This is particularly useful if:

- a. Default target and bounding return periods are used (see Methods section above) so the model doesn’t need to compute new return periods.
- b. The target or bounding conditions are only found outside of the modeled region.
- c. The user wants to model conditions for which the target and bounding polygons would be unknown such as historic conditions and it is desirable to maintain consistent target and bounding limits with the present runs.

ReturnPeriod	wetSeason				drySeason				discHydroperiod				MaxNestingDryDays			
	Lower Bound	Lower Target	Upper Target	Upper Bound	Lower Bound	Lower Target	Upper Target	Upper Bound	Lower Bound	Lower Target	Upper Target	Upper Bound	Lower Bound	Lower Target	Upper Target	Upper Bound
1.03	-457.90567	-524.13196	-441.8649	-294.26715	-741.1519	-779.6096	-627.659	-242.774	5	6	21	96	67	71	2	0
1.05	-448.17557	-506.7737	-410.91147	-280.14462	-655.1479	-723.9346	-479.715	-192.258	10	6	81	162	70	76	18	0
1.08	-411.2353	-478.85052	-389.31625	-255.35744	-654.30524	-707.76025	-449.279	-191.886	11	16	90	170	80	88	51	7
1.11	-407.11157	-462.27127	-376.00287	-252.43054	-651.7814	-697.92096	-435.885	-181.391	28	32	91	180	88	89	71	10
1.14	-398.39264	-418.63968	-367.52032	-130.97998	-639.1914	-690.2721	-435.472	-132.449	29	34	108	183	88	92	72	14
1.17	-252.73903	-257.89215	-182.91357	-83.95384	-602.2032	-652.2981	-367.355	-128.103	31	39	113	189	92	92	72	17
1.21	-202.58264	-220.38481	-180.88345	-64.36356	-561.02795	-599.67773	-342.439	-122.155	36	40	113	203	92	95	77	21
1.24	-164.82304	-220.30107	-159.80354	-37.98856	-513.7863	-561.5926	-332.792	-114.915	37	43	117	204	94	99	80	24
1.28	-150.71382	-203.779	-139.92882	-32.720997	-504.35873	-533.6095	-273.199	-79.9351	41	44	129	207	99	103	82	30
1.32	-149.86789	-202.05228	-134.48909	-30.854576	-493.84232	-527.76447	-264.304	-36.1731	41	45	136	212	101	104	83	33
1.37	-132.62558	-196.24632	-132.25963	2.7144608	-477.1584	-526.86707	-254.597	-31.6414	41	49	143	212	103	106	87	38
1.41	-126.91083	-169.44691	-93.63035	50.412174	-459.1648	-486.46307	-241.399	-15.5702	45	50	147	235	105	110	87	40
1.46	-125.56396	-156.33948	-77.45134	67.54044	-457.2465	-474.8932	-237.337	-3.23231	46	52	149	240	105	111	87	41
1.52	-112.62838	-150.29413	-35.24655	86.544106	-426.13785	-466.10022	-213.521	15.15845	51	56	165	243	109	111	90	46
1.58	-112.528946	-139.60947	-28.844591	114.61766	-410.85114	-460.55487	-204.512	15.87264	51	59	169	261	112	113	95	47
1.64	-103.45098	-133.87418	-25.422295	122.880714	-399.11603	-438.75793	-183.489	32.29754	55	60	172	263	113	113	95	50
1.71	-101.93371	-114.61356	11.061363	151.88564	-383.32797	-417.56454	-167.983	36.99676	55	64	178	263	114	114	97	50
1.78	-101.65032	-113.93097	20.986567	162.68423	-370.15738	-415.93958	-164.595	57.55071	56	65	182	268	115	116	98	65
1.86	-94.21381	-91.08006	33.063904	171.27	-369.84634	-394.98495	-152.182	62.74295	59	65	184	273	115	119	103	70
1.95	-89.906624	-82.57353	44.503998	171.29002	-356.58286	-390.26385	-148.405	66.7503	60	69	185	274	119	120	103	73
2.05	-82.36974	-77.246735	63.721855	176.68176	-340.40332	-385.42984	-109.835	70.92928	64	72	194	279	121	125	106	74
2.16	-81.419235	-76.204254	65.45824	178.66339	-339.81738	-381.6406	-94.0373	71.56397	67	74	200	283	124	125	109	75
2.28	-71.83006	-69.97426	66.228035	179.09149	-326.83185	-363.91776	-90.7424	83.77583	67	81	204	287	124	127	111	83
2.41	-70.38188	-61.052288	68.32027	191.07434	-325.51685	-359.4269	-90.5886	92.22995	71	83	207	297	125	128	111	85
2.56	-67.9846	-55.282272	72.482574	197.79492	-323.9832	-346.1021	-81.2705	96.87471	78	94	208	298	129	129	114	86
2.73	-45.056953	-40.4567	72.789764	217.69934	-307.79477	-341.3558	-71.2112	102.3774	86	96	210	303	131	132	118	86
2.93	-40.514004	-24.140522	96.8406	226.01677	-277.90936	-339.3865	-69.4418	105.14	90	98	216	313	132	134	127	88
3.15	-23.261904	-4.614788	117.9764	243.16096	-266.80228	-300.18185	-69.0445	112.7226	94	100	218	315	133	135	127	89
3.42	-10.916433	4.2013893	135.65433	255.87746	-257.49396	-294.40994	-59.0472	125.1397	94	100	219	319	135	136	129	93
3.73	-7.4267035	8.248364	143.13654	258.17154	-248.11488	-266.2579	-58.7794	127.1472	96	101	230	321	136	136	130	99
4.1	-4.2119513	9.433823	147.0519	264.5372	-246.13379	-254.78511	-54.5989	140.6598	105	104	232	321	136	136	130	104
4.56	5.843138	12.16871	150.66193	265.3652	-239.65128	-238.41772	-37.2393	169.8122	119	105	233	322	136	136	135	110
5.13	10.003266	14.488151	194.1961	328.45956	-217.9155	-226.53893	3.538261	174.3299	123	124	253	328	136	136	135	114
5.86	18.697947	15.830886	213.31445	343.54163	-217.48112	-224.9874	21.73344	188.125	138	132	254	331	136	136	135	116
6.83	24.116713	29.223856	221.0323	345.15976	-181.99797	-198.26974	40.82417	204.8117	162	136	265	334	136	136	136	121
8.2	42.85014	40.06658	230.97057	357.80798	-176.12332	-185.0507	46.53912	211.0258	171	156	290	338	136	136	136	130
10.25	52.372547	42.29902	260.53738	386.3493	-124.92554	-173.05867	111.4911	259.1716	178	158	303	341	136	136	136	131
13.67	58.887028	48.63848	289.43137	418.9587	-109.35378	-119.6763	112.3952	267.2609	185	168	323	345	136	136	136	132
20.5	65.57796	51.9661	324.76038	454.57806	-82.26382	-103.73644	130.5723	279.6754	197	182	326	353	136	136	136	133
41	76.75117	60.582508	341.8431	473.80554	-0.12331499	-60.380302	265.9578	402.3248	210	214	336	355	137	137	137	135

The input file for target and bounding return periods must be saved as a comma-delimited .CSV file following the layout example in Figure 14. The first 2 rows are headers. The first column contains the return period. Four columns each follow for wet season, dry season, discontinuous hydroperiod, and maximum nesting dry days in that order. The four columns for each metric are the return period values for that metric for the lower bound, lower target, upper target, and upper bound in that order.

Figure 13. Example of the file layout for specifying the habitat targets and bounds. The file is illustrated in spaced columns for clarity, however, it must be saved as a comma-delimited .CSV file.

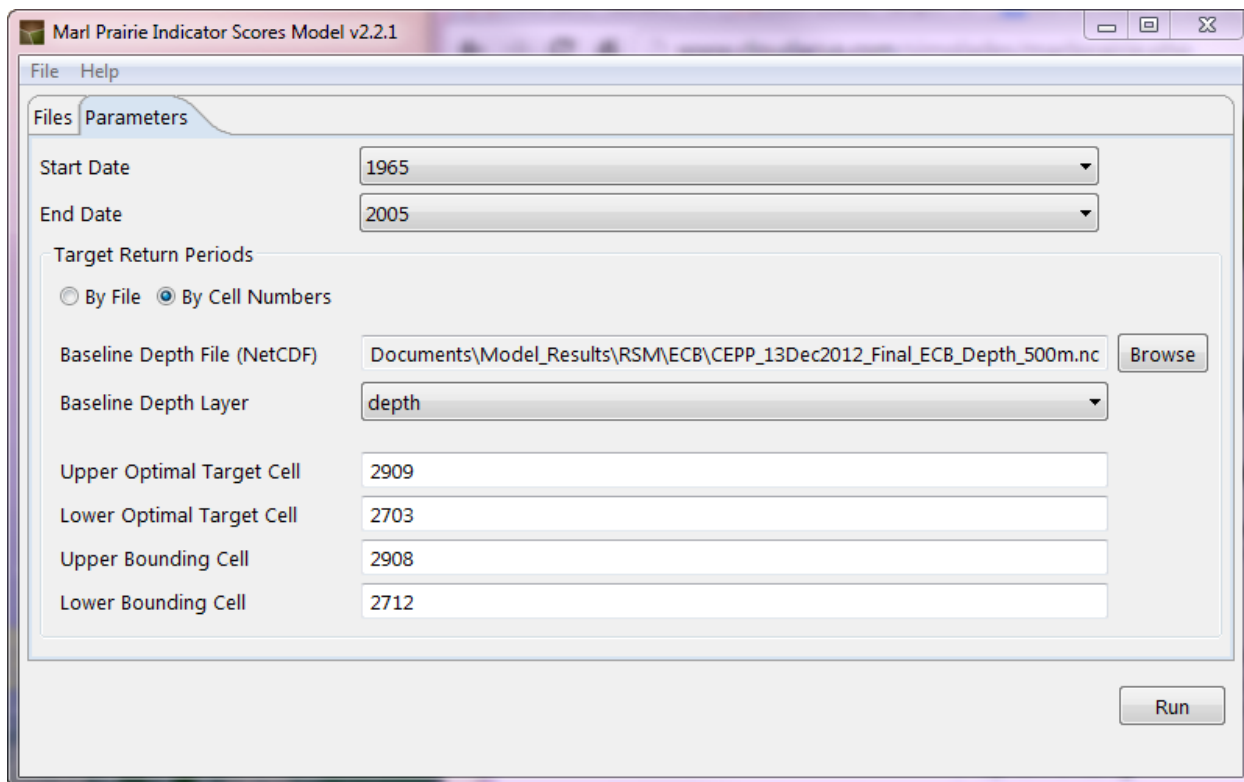


Figure 14. *MarIPrairie* user interface shown with the Parameters tab open and target return periods specified by cell number.

When “**By Cell Numbers**” is selected (Figure 14), the user is asked to enter the baseline condition RSM file path and filename and the RSM cell ID of the polygons that the model will use to generate return periods for the target and bounding habitat conditions. The baseline conditions file is typically RSM ECB (see Methods section). The target and bounding RSM polygons published in this document are presented as the default values.

Upper Optimal Target Cell: The RSM ID of the polygon used as the reference upper target.

Lower Optimal Target Cell: The RSM ID of the polygon used as the reference bottom target.

Upper Bounding Cell: The RSM ID of the polygon used as the reference upper bounds.

Lower Bounding Cell: The RSM ID of the polygon used as the reference lower bounds.

Outputs

Spatial Time Series of Hydrologic Metrics

CSSSMarIPrairie generates time series netCDF files for six metrics (Figure 15), however only four of the metrics (in bold) are used for *CSSSMarIPrairie* scoring, the other 2 metrics, Continuous Hydroperiod and

Max Continuous Annual Dry Days, are available from the model output for viewing, but they are not used by *CSSSMarIPrairie*:

1. **Discontinuous Hydroperiod** (May-April climatic year, water depth > 0 mm).
2. Continuous Hydroperiod (May-April climatic year, water depth > 213 mm).
3. **Max Continuous Nesting Dry Days** -March 1 – July 15 (water depth \leq 0 mm).
4. Max Continuous Annual Dry Days (May-April climatic year, water depth < 213 mm).
5. **Average Wet Season Water Depth** (Jun-Oct).
6. **Average Dry Season Water Depth** (Nov-May).

(Notice that the 2 metrics not being used are not comparable to the other metrics because they use a different measurement origin: measured from 213 mm water depth versus 0 mm water depth.)

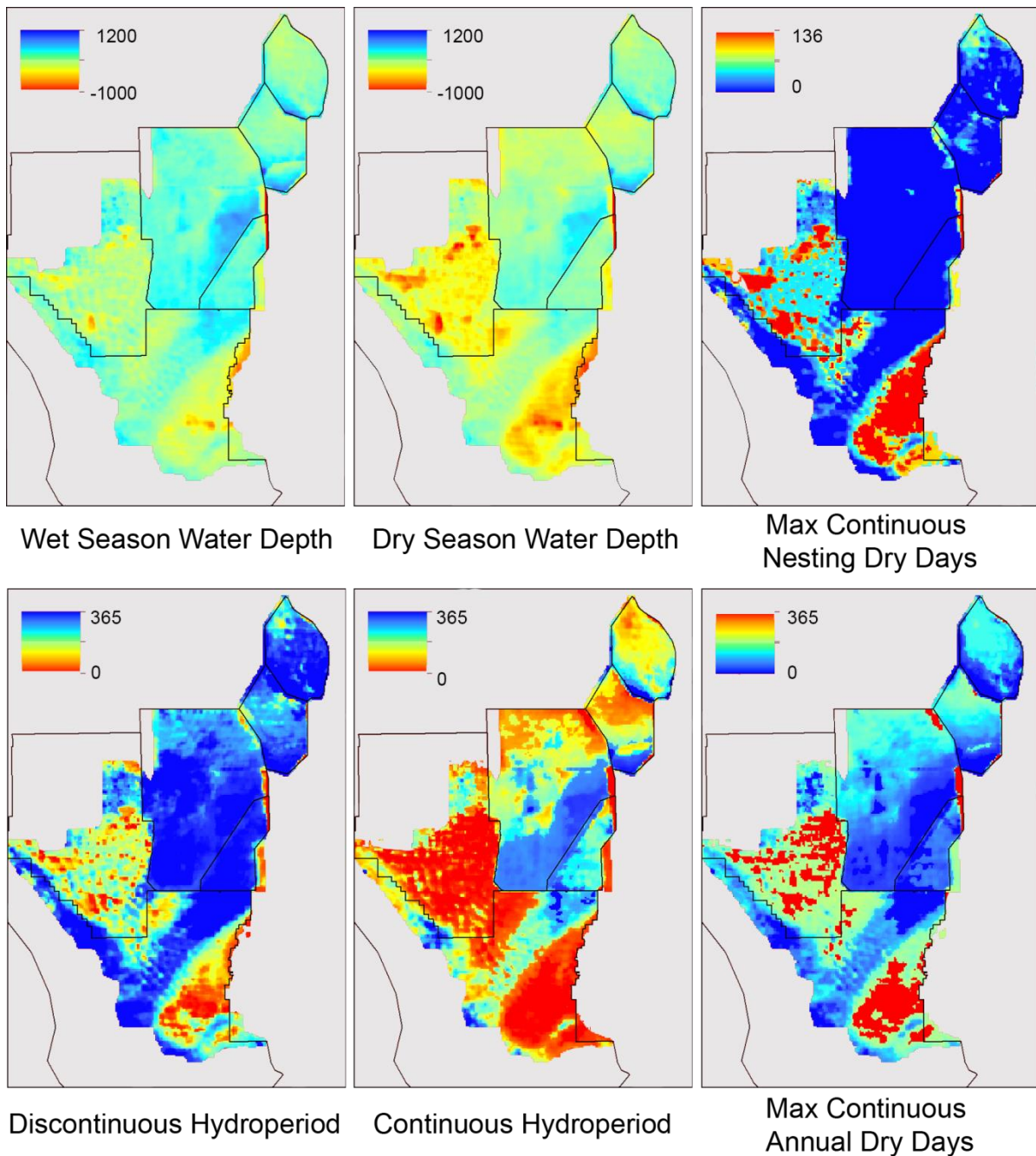


Figure 15. Example Hydrologic metrics netCDF outputs from the *CSSMarIPrairie* model. This example is for the 2000 cycle from Regional Simulation Model input for an Alt4R2 Central Everglades Planning Project alternative run.

Return Periods

Text files (.csv) of the return periods at each RSM polygon for each metric computed over the number of years in the hydrologic input file are created (Figure 16).

ReturnPeriod	41	20.5	13.67	10.25	8.2	6.833	5.857	5.125	4.556	4.1	3.727	3.417	3.154	2.929	2.733	2.563	2.412	2.278	:
786	366	366	366	365	365	365	365	365	365	362	359	358	356	356	352	346	346	341	
787	366	366	366	366	366	365	365	365	365	365	365	365	364	361	361	359	354	350	
788	366	365	365	365	365	365	365	365	361	361	358	358	349	347	346	343	343	339	...
789	356	355	350	331	326	321	321	320	317	316	316	316	310	309	306	304	298	295	
790	336	335	321	304	287	273	270	270	267	265	264	261	256	256	255	249	245		
791	362	362	361	361	360	360	359	348	346	341	338	334	333	328	326	326	326	324	
792	291	291	285	270	260	259	255	249	247	245	245	244	240	238	237	234	233	232	
860	302	302	302	302	302	302	302	302	302	301	300	299	298	297	294	292	290	284	
861	307	307	303	302	296	296	289	288	287	287	287	284	282	281	275	273	271	271	
862	366	366	366	365	365	365	365	365	365	361	360	359	358	356	355	354	349	348	

Figure 16. Example text output of hydroperiod return periods. Return periods are in the first row, RSM polygons are listed in the first column.

Habitat Scores

The program scores the alternative's conditions relative to target conditions and produces text files (.csv) of the results (Figure 17).

SubPop	RSM	%improve_MaxDryCount	%improve_HydroPeriod	%improve_WetSeasonDepth	%improve_DrySeasonDepth	%improve_CombinedScore	hsi_MaxDryCount	hsi_HydroPeriod	hsi_WetSeasonDepth	hsi_DrySeasonDepth	hsi_CombinedScore
B	3123	4.583333	1.833333	10.49943	2.45816	4.843564	77.5	92.125	67.5	72.5	77.40625
B	3124	9.895834	10.13158	17.67376	17.2902	13.74784	40	73.92708	29.18468	37.5	45.15294
B	3125	12.32143	7.083334	9.685926	8.330766	9.355364	60	90	66.01868	85	75.25467
B	3126	0	0	-2.13233	0	-0.53308	100	97.5	93.52428	100	97.75607
B	3127	-19.0965	-11.8403	-4.59291	-5.20423	-10.1835	71.08416	95.58949	68.6267	98.50654	83.45172
B	3128	-10.416	-40.2639	-3.97222	-59.6213	-28.5684	54.20416	69.99154	62.14942	86.69178	68.25922
B	3129	-36.756	-8.75	-3.51742	-10.1371	-14.7901	83.34394	99.67127	70.09067	99.19255	88.0746
B	3130	-5.83333	21.06838	0.160797	2.588385	4.496057	91.83543	57.77133	53.73552	99.80864	75.78773
B	3131	2.230769	1.733603	3.311286	43.6154	12.72276	35	0	12.5	50	24.375
Outside	3132	5.737847	1.255983	8.596712	48.43617	16.00668	30	0	12.39552	27.5	17.47388
Outside	3133	3.009853	1.607516	6.395939	18.73635	7.437414	32.5	0	0	0	8.125
Outside	3134	1.994467	2.749049	7.59074	17.04421	7.344616	30	0	0	0	7.5
Outside	3135	5.337017	6.605891	11.12706	22.69414	11.44103	30	0	0	0	7.5
C	3143	4.285714	24.90735	-8.73581	87.46046	26.97943	88.05556	88.5625	92.67128	97.5	91.69733
C	3144	-16.5	13.05556	-17.2417	62.5	10.45346	94.22521	97.44383	82.4297	98.41956	93.12958
C	3145	-16.25	23.5302	-52.1686	86.61604	10.4319	89.57274	87.75	93.22727	94.911	91.36525
Outside	3146	20.1706	20.21196	11.92202	95.92176	24.47427	94.21274	97.5	92.89264	97.27204	97.04726

Figure 17. Example text output of scores for all metrics. Both percent improvement from baseline conditions and habitat suitability index (HSI) scores are shown in the output because the current version of the model generates both scores. However, percent improvement scores are not documented in the

Methods because those scores will not be included in future versions. This figure will be updated along with updates to the model inputs and GUI sections with the release of the next version of *CSSSMarIPrairie*.

ESRI Shapefiles

Final scores data joined to target RSM cells in an ESRI shapefile.

Post-processing Outputs

Mapped Graphics.

Hydrologic metrics, scores, and combined scores can be depicted as mapped products presenting the values at each RSM polygon. The maps illustrated in Figure 18 were created in ArcGIS 10.1 with the ESRI shapefile output of the model.

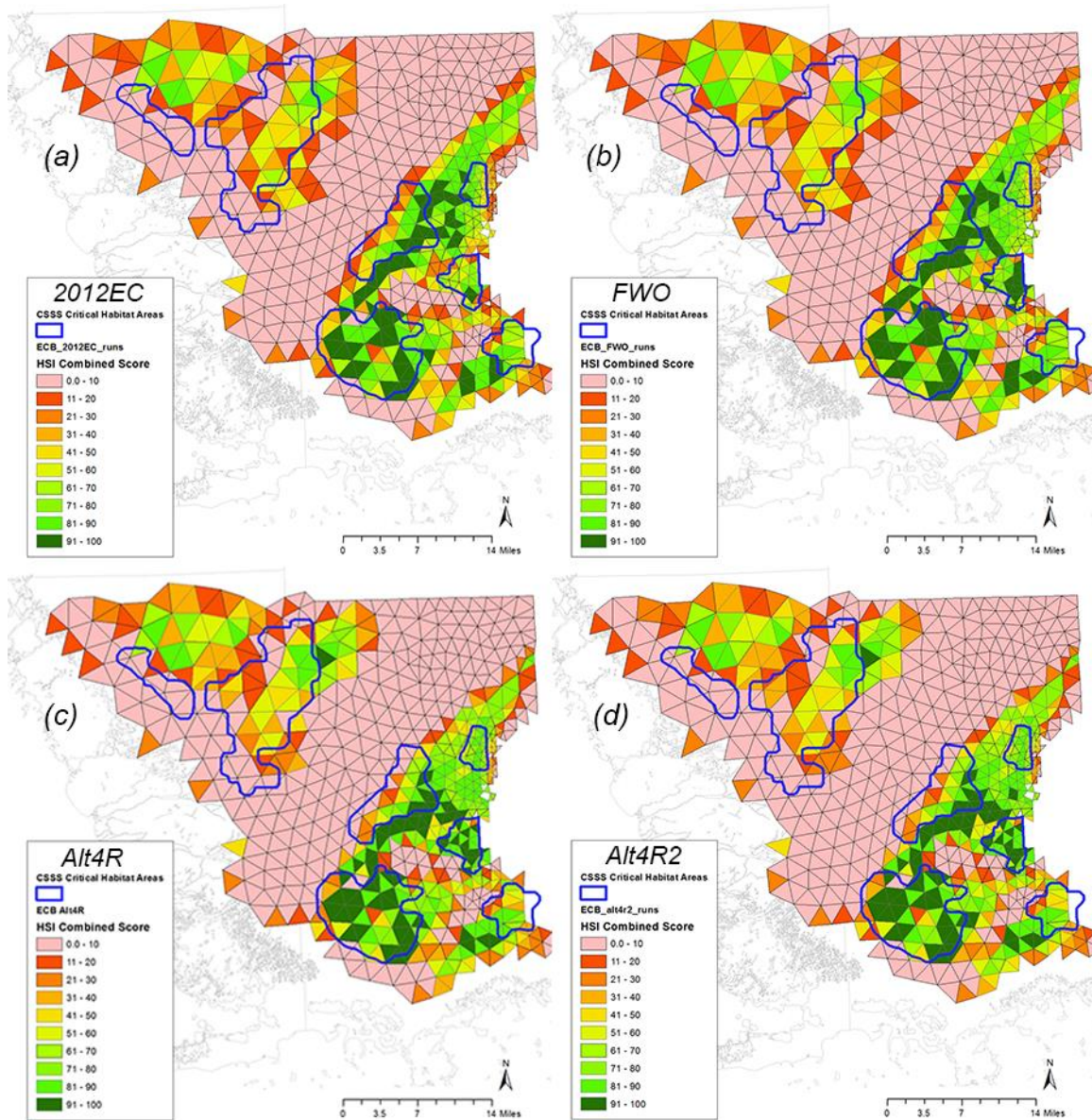


Figure 18. Example mapped habitat suitability scores.

Charts

Figures 19 – 22 illustrate some typical charting of the *CSSSMarlPrairie* results. Sample model output from the Central Everglades Planning Project (CEPP), a Comprehensive Everglades Restoration Plan project, is provided below.

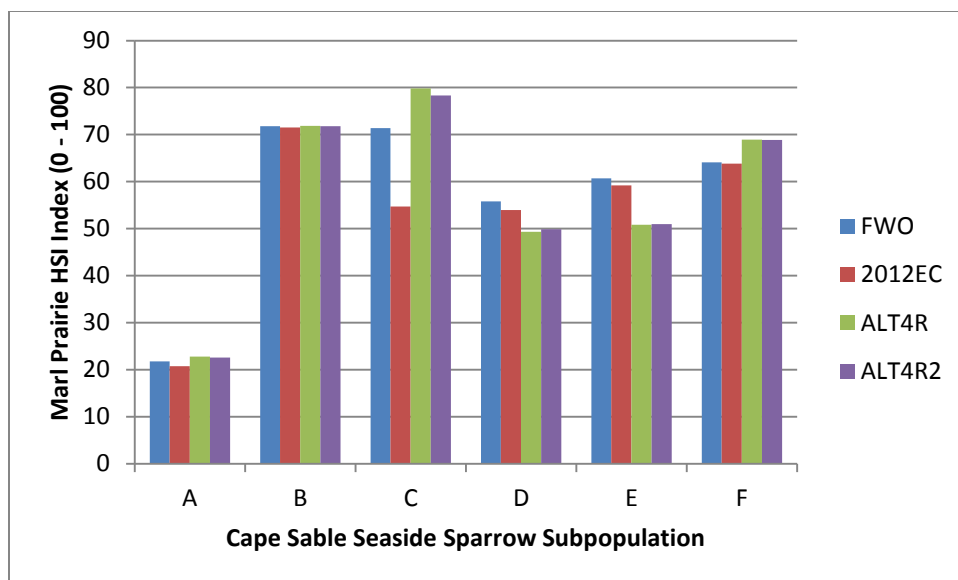


Figure 19. Average Marl Prairie Habitat Suitability Index scores (1965-2005) for existing conditions (2012EC), future conditions (FWO) without Central Everglades Planning Project (CEPP), and CEPP scenarios (Alt4R and Alt4R2) within Cape Sable seaside sparrow critical habitat and formerly proposed critical habitat for subpopulations (A-F).

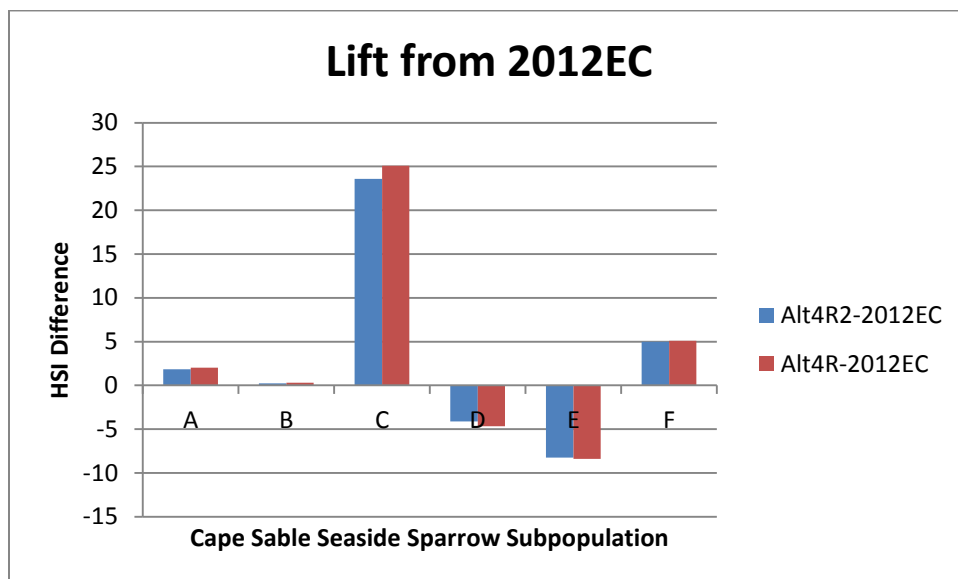


Figure 20. Suitable marl prairie habitat (1965-2005) lift from existing conditions baseline (2012EC) for Central Everglades Planning Project scenarios (Alt4R and Alt4R2) within respective Cape Sable seaside sparrow critical habitat and formerly proposed critical habitat for subpopulations (A-F). A maximum lift of 100 is possible if 2012EC has an averaged suitability score of 0.0 and the alternative has an averaged suitability score of 100.

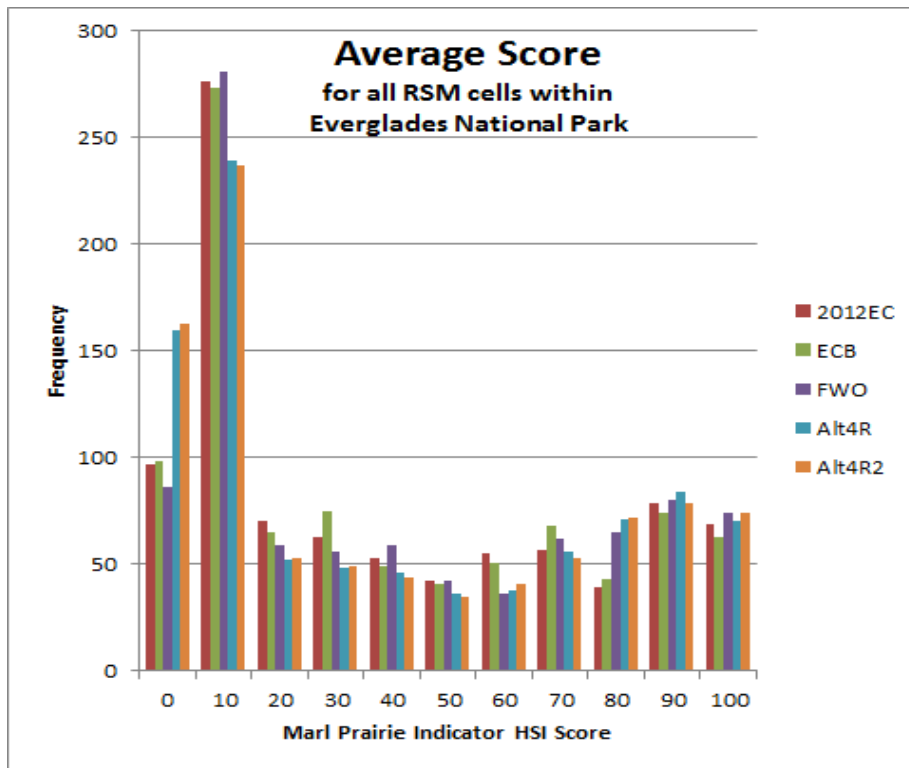


Figure 21. Average Marl Prairie Habitat Suitability Index scores (1965-2005) for existing conditions baseline (2012EC), future conditions (FWO) without Central Everglades Planning Project (CEPP), and CEPP scenarios (Alt4R and Alt4R2) for all RSM polygons in the model domain. This chart may be useful because habitat shifts do not only occur within critical habitat or subpopulation boundaries.

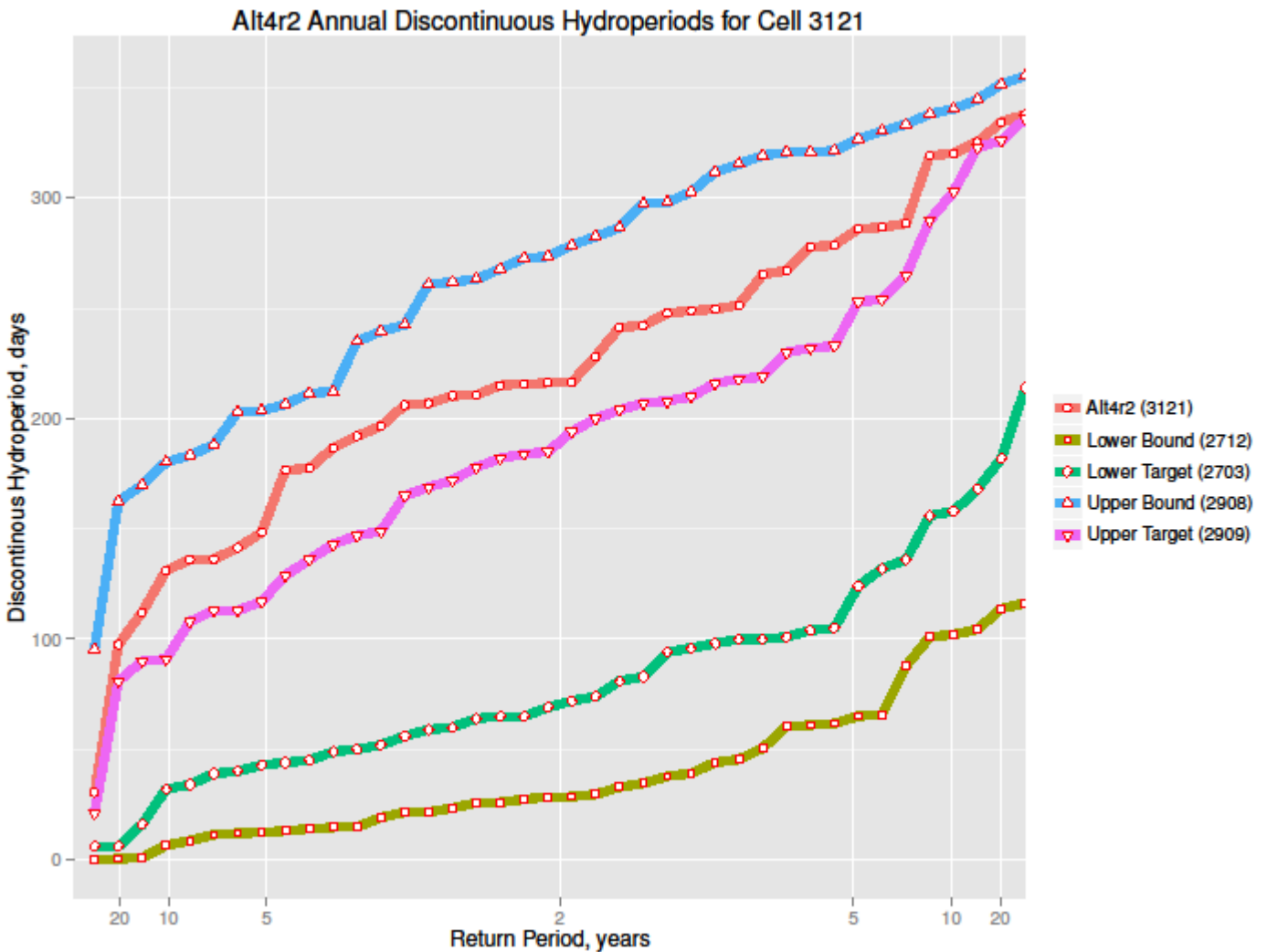


Figure 22. Return periods for discontinuous hydroperiods for existing conditions baseline (ECB) at the target and bounding RSM polygons and for Central Everglades Planning Project scenario Alt4R2 at RSM polygon 3121 on the southern boundary of Subpopulation B.

Limitations and Future Model Development

The CSSS Marl Prairie Indicator model is designed with flexibility to allow modifications as new information becomes available. This section addresses some of the foreseeable changes that should be explored for future versions.

Model scale – The marl prairie community and CSSS are responding to the environment at a much finer spatial resolution than even our finest topographic data provided by EDEN. Increased understanding of spatial hydrologic relations at these fine scales would be valuable for CSSS and marl prairie conservation. It is important to recognize, however, that relations observed at fine scales do not necessarily translate to the coarser scales of regional hydrologic

modeling used as the input data. The CSSS Marl Prairie Indicator is a novel approach in that we have scaled our hydrological targets to the scale of the hydrological simulation model providing a substantial advantage versus developing a model without taking into account the resolution of the hydrologic input data. For the purposes of CERP restoration planning, our approach is recommended as we have scaled our targets to the resolution of the hydrologic input that is provided by the hydrologic simulation models.

Other physical variables – The metric application is limited by exclusion of additional covariates influencing the marl prairie habitats. Fire dynamics (and interaction of fire with flooding), nutrient effects, effects of invasive species, and vegetation succession are of primary concern. Fire's contribution to maintaining marl prairie structure and composition is not well understood (Hanan et al. 2010). Hanan et al. (2010), specifically, found that woody plant recruitment in marl prairies is a complex response to seed source, hydrologic effects and fire. La Puma et al. (2007) found that sparrows tolerate fire, however, habitat suitability, as measured by sparrow densities and nest success, are not enhanced by fire. Effects of water quality, nutrient flux, and other disturbance effects may also warrant investigation.

The *CSSSMarlPrairie* hydrologic metrics (average dry season water depth, maximum continuous dry days or discontinuous hydroperiods) may be inadequate for capturing short duration nest flooding event that impact a breeding subpopulation (Pimm et al. 2002). A nesting cycle takes approximately 34 to 44 days to complete and the number of nesting attempts depends on the length of favorable conditions (Pimm et al. 2002). A scoring metric that flags water depths in excess of nesting heights, such as was implemented by Donalson et al (2006), may be considered as a potential improvement to the model.

Data issues – Understanding the sequence of CSSS temporal variability in relation to vegetation response is challenging. Time series prior to 1992 have data gaps that create further challenges to analysis of environmental response.

Modeling Uncertainty -- *CSSSMarlPrairie* is a deterministic model in its current form. A greater understanding of the confidence bounds of the model outcomes would be helpful to provide in future model versions.

Summary and Conclusions

The CSSS Marl Prairie Indicator model allows users to evaluate the potential response of CSSS marl prairie habitat to changes in hydrology within and adjacent to the unique marl prairie community. Spatially-continuous habitat scoring provides information to the user on habitat distributions and potential shifts in habitat distributions beyond the extent of current population habitat. Patterns of habitat shifts could be missed by reliance on site specific analyses alone. The derived spatially and temporally explicit hydrologic metrics allow the user to more closely examine the specific hydrologic influences on the final habitat scores and give the user a greater understanding of the spatial and temporal variability of hydrology in the marl prairie habitats and across the region. The CSSS Marl Prairie Indicator model produces

hydrologic metrics at 500 m spatial resolution and aggregates the results to produce habitat scores at the resolution of an RSM polygon. Because it is unclear that CSSS relocate in response to changes in hydrology, the user should be aware that changes in habitat/hydrology do not necessarily translate into changes in distribution.

This model provides a coarse filter, regional methodology that is at an appropriate temporal and spatial scale for CERP evaluations. It can and should be effectively combined with site-specific field study and more localized gradient-response analyses to provide the best available information for natural resource, land, and conservation management.

References Cited

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Appendix

ECB Return Periods at Target and Bounding RSM polygons

The charts in Figures A.1 – A.4 present the return period distributions for each of the four hydrologic metrics from Existing Condition Baseline (RSM ECB) water depths at the default target and bounding RSM polygons.

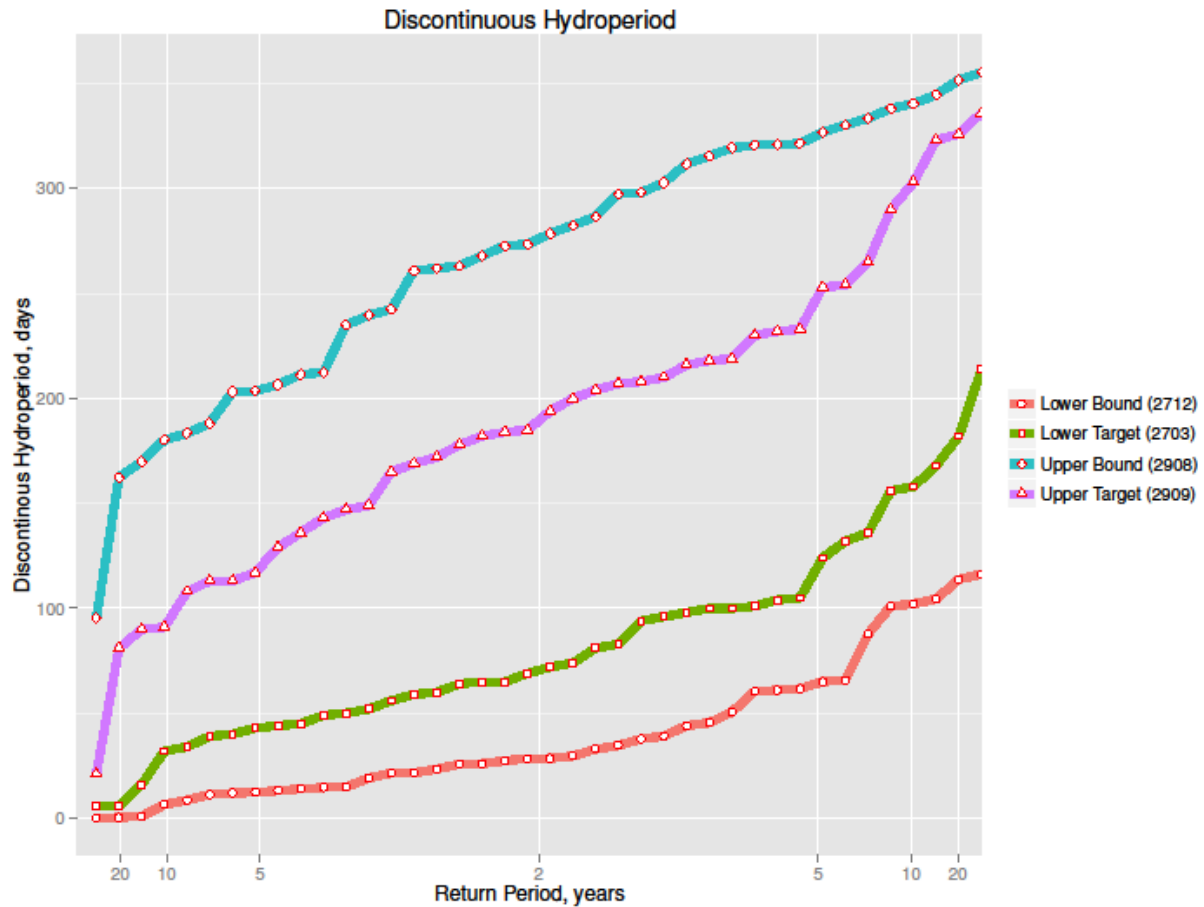


Figure A.1. Regional Simulation model existing conditions baseline (ECB) return periods for discontinuous hydroperiod.

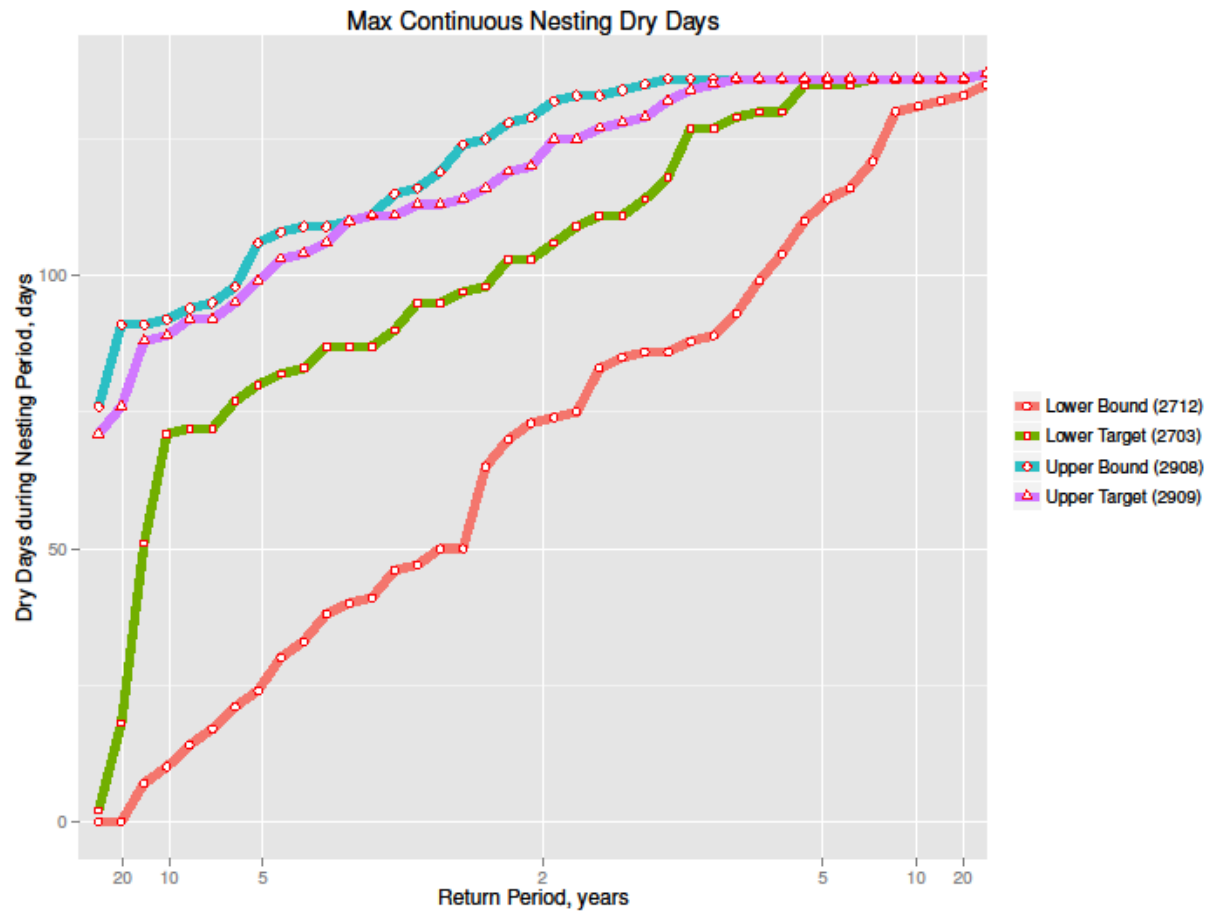


Figure A.2. Regional Simulation Model existing conditions baseline (ECB) return periods for maximum continuous nesting dry days.

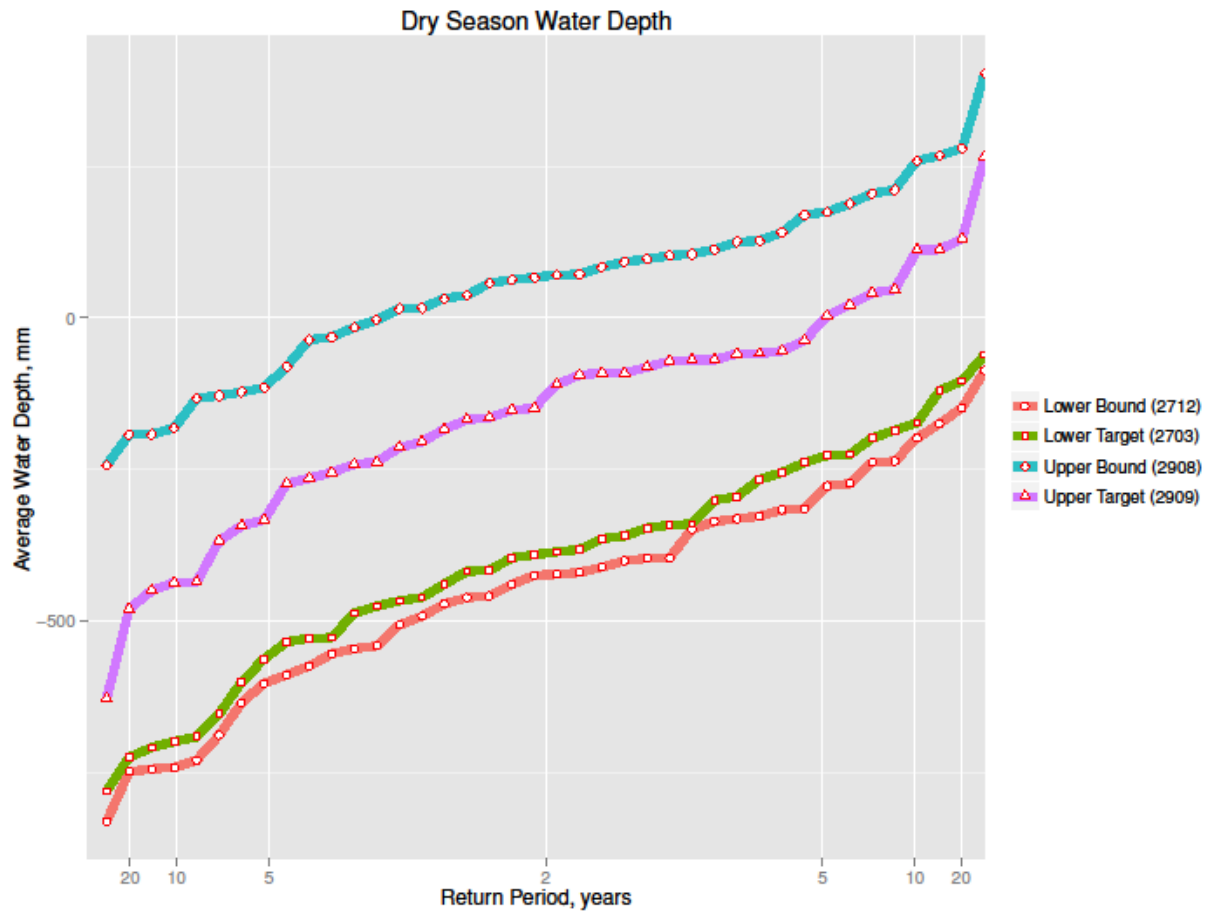


Figure A.3. Regional Simulation Model existing conditions baseline (ECB) return periods for dry season water depths.

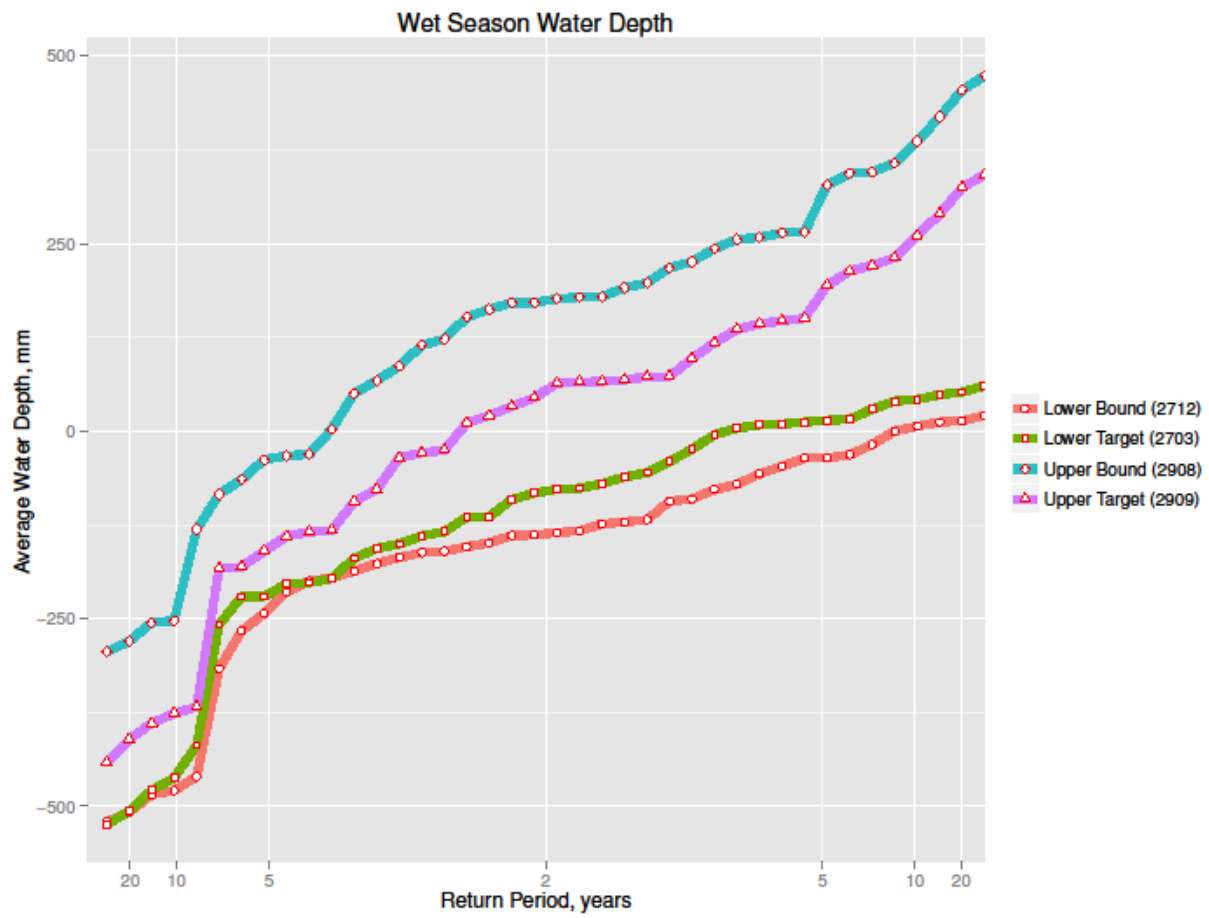


Figure A.4. Regional Simulation Model existing conditions baseline (ECB) return periods for wet season water depths.