Final Report

Development of Spatially-Explicit Stochastic Models of the Cape Sable Seaside Sparrow

Critical Ecosystem Studies Initiative
Science Fellowships in Everglades Restoration Ecology

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Research Area

Ecological Modeling of Avian Populations

Summary

The purpose of this project is to provide a tool to allow personnel at the SFNRC to evaluate potential effects of various Everglades habitat restoration projects on the Cape Sable Seaside Sparrow (*Ammodramus martimus mirabilis*).

The first part of this project was to build an emulation of the Across Trophic Level System Simulation (ATLSS) Breeding Potential Index (BPI) model. The purpose of this was twofold. First, having a copy of the BPI, but within our modeling infrastructure, would have allowed initial model verification against a known baseline. Second, we intend to use the habitat and daily water maps from the BPI as the environment for our more complex model. It was necessary to understand how these maps were generated and used in the BPI to successfully integrate them into our new model. The output of our model, the Hydrologic Impact Evaluator (HIE) is the maximum number of potential nesting cycles per breeding season from the perspective of nest flooding.

Examination of the ATLSS BPI documentation lead to some perceived inconsistencies within the different descriptions so a detailed analysis code was needed. ATLSS personnel were very helpful in providing us with both actual code and explanation of the BPI design. As design of the HIE model continued, several issues came up that ended in the decision to not emulate the BPI. First, ATLSS provided us with an upgraded version of their hydrologic translator which had, at the time, not yet been integrated into the BPI model. This meant that we would not be able to verify our results against the BPI output. In addition, after consultation with field biologists, we felt that some parameters needed to be upgraded to present knowledge. Finally, during this period, consultation with field biologists and detailed analysis of present sparrow vegetation maps led to the decision that upgraded maps sparrow habitat maps are needed.

In period 2 the initial goal was the upgrade of the HIE from potential nesting cycles with respect to nest flooding to simulating actual birds. An initial design of the upgraded

model was formulated and a Preliminary Design Review (PRD) was held with members of the SFNRC staff to evaluate the design and make suggestions. Initial implementation of the model was then begun by coding various elements necessary to adding sparrows to the HIE model.

The plan was changed at this point. SFNRC expressed a desire and need to use quantitative ecological models to help the ongoing projects, and we felt that our HIE model was ready for test use. We used the HIE model to compare the SFNRC Westc51 hydrologic scenario first to the No Action scenario and then to the East Bookend scenario. The results of the comparison of the Westc51 and East Bookend scenarios are provided in Appendix B. During this effort, the HIE model went through a number of upgrades, many of which will be used in the individual based model as well. These upgrades included:

- adding a user input file
- adding the ability to use stochastic processes
- decreasing the number of input maps
- changing the output from an index (0-1) to the actual number of possible nesting cycles
- writing a utility program that takes the results of two different hydrologic scenarios and makes files that are readable by ArcMap for use in analyzing spatial distributions
- including field data as an input to identify cells associated with different populations and adding actual field bird counts to cells for later output and analysis.

There were three important issues that have come out of the work to date. The first came out the Period 1 work and is the need for a better sparrow habitat map. The second came from the Period 2 PDR and is that how sparrows move about their environment is likely to be of major importance in understanding their population dynamics. The third came out of the comparison between the Westc51 and East Bookend hydrologic scenarios. Space and time dimensions are extremely important in interpreting the model output and condensing the model results down to an index value (say a value 0-1) can cause loss of so much information that erroneous conclusions can result. In the case of the work presented in Appendix B, were the results of the Westc51 and East Bookend hydrologic scenarios compared using a single index value 0-1, the conclusion would have been that there was no different between the two scenarios from the standpoint of the Cape Sable Seaside Sparrow. Analysis of spatial distributions and time series showed that the East Bookend was potentially better for sparrows in the western most population, the Westc51 scenario had a better performance for the three eastern populations, and there was no apparent difference between the two scenarios for the two central populations.

The work accomplished for the final year of this project falls into three main categories: model upgrades, model applications, and the ATLSS project.

The model upgrades included code cleanup, incorporating new data, and adding additional model functionality. The code cleanup involved changing some variable names to avoid ambiguity and changing some execution sequences to decrease runtime. The HIE model can now run a 36 year scenario in about 10 minutes. Field data collected by the Ross lab at Florida International University was incorporated into the HIE spatial data base. This data has vegetation types and inferred hydroperiods for many of the sparrow field sites regularly monitored by NPS. Additional functionality was added to the HIE model to address new issues of interest. The first was adding hydroperiod calculations to support the new NPS sponsored Marl Prairie Performance measure. The Ross field data was also included as part of the hydroperiod output. The second addition to the code was the ability to read in the ATLSS Unix binary elevation maps and output them as an ASCII text file for analysis.

There were five major model applications accomplished in this project's final year: the sparrow CSOP report, the Marl Prairie hydroperiod data, indicator region analysis, ATLSS High Resolution Topography (HRT) analysis, and analysis of hydrological uncertainty from an ecological as opposed to strictly statistical standpoint.

The sparrow CSOP report (Appendix C) was the single most massive undertaking of the reporting period. Analysis of 9 different CSOP alternatives was performed with respect to potential nest flooding. As a simple 0-1 ranking, did not provide a reasonable resolution with which to incorporate the complex spatial and temporal dynamics of different sparrow subpopulations, an alternate analysis approach was developed. Perhaps the most important result of the analysis was that the Interim Operating Procedures presently in place seem to be better for the sparrow than any of the proposed CSOP scenarios. Also as part of the CSOP report, hydroperiods were calculated for the nine CSOP alternatives for all areas regularly sampled by NPS field biologists and supplied to Quan Dong for use in the NPS Marl Prairie performance measure.

Hydro period is a very popular measure of hydrologic impact on the Everglades system. It has some serious drawbacks however that don't seem to be addressed as part of most analysis. The basic problem is that it turns a continuous function (water depth) into a step function (wet or dry.) What gets subsumed in this translation is that for many species of flora and fauna, the difference between 1 cm. of inundation and 60 cm. of inundation could be very significant. Hydroperiod doesn't register that difference. This issue becomes even more pronounced when calculating hydroperiod for "indicator regions", which are contiguous set of spatial cells that delineate some sort of habitat range. Indicator region hydroperiod can be calculated in two different ways, by averaging the water depths over all the cells and then using that average to calculate the hydroperiod, or calculating the hydroperiod for each cell individually and then averaging those hydroperiods to get the indicator region hydroperiod. Those two methods can yield very different results.

As part of the CSOP analysis, the ATLSS HRT was upgraded to match the newer version of the SFWMM. While analyzing the CSOP data, a number of "stuck" cells were found. These were cells that were always inundated or always dry no matter what scenario was run. This led to an analysis of the elevation map where some extreme elevations in some cells were observed. The previous (version 5.0) elevation map was them compared to the present map (versions 5.4/5.5). There seem to be far more elevation differences than could be accounted for with the changes between the two SFWMM versions. This analysis is ongoing.

An important issue associated with sparrow modeling is the error associated with the hydrologic input, which is about 16 cm. This is a problem because the average sparrow nest height is also about 16 cm. This means that the water depth at which nests flood is basically within the noise region of the input hydrology. Analysis was performed to better measure this potential error combining the ATLSS high resolution hydrologic input to the HIE model with water depth measurements collected by sparrow field biologists. The results of this analysis held both bad and good news. The bad news was that the error in the water depth does look to be about 16 cm. in the sparrow regions. The good news was that the previous result indicates that there is little additional error being introduced when creating the high resolution hydrology from the SFWMM hydrology.

Clearly, from a pure statistical standpoint, the present hydrologic input is unsuitable for use with a model of the Cape Sable Seaside Sparrow. However, the sparrow doesn't view its environment as pure statistical error. The next question must be, "What hydrologic errors are biologically significant?" The sparrow does not care whether the model predicted a 50 cm. surface water depth and it was really 20 cm. In either case, its nest is flooded and the nesting cycle terminated. The 30 cm. error is not biologically significant. In the simplest terms, the sparrow only cares whether there is or isn't surface water. If there is surface water, predation rates increase and there is a chance of the nest flooding. If there isn't surface water, hydrologic conditions are nominal. Analyzing the data from this standpoint, approximately 88% of the data points fell into categories of either\ correct prediction (ex. field data said there was surface water and the model predicted the same) or errors that would underestimate nesting performance. Is this an ideal situation? No. However, it is necessary to use the tools that are available until better ones come along, and in this case maybe the adage "close enough is good enough" is good enough.

Finally, during this second year, a task was added. This was to make an attempt to revamp the ATLSS project in such a way that the models could be used in South Florida to support of the various Everglades restoration projects. A draft Statement Of Work (SOW) was developed by NPS and USGS staff. A meeting was then help at University of Tennessee, Knoxville (UT) with the ATLSS staff to finalize the SOW. In a second trip to UT, NPS and USGS staff went through initial training on creation of the ATLSS high resolution topography. To date, a draft manual for creating the high resolution topography has been delivered to NPS and USGS. In addition, Code was delivered for the White-Tailed Deer HSI. It is supposed to be all the code necessary to run the model on agreed upon Linux systems in place at both NPS and USGS. However, this has not yet been verified.

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Introduction

The Cape Sable Seaside Sparrow (CSSS) was among the first group of species listed as endangered by the U.S. Fish and Wildlife Service on March 11, 1967. The sparrow was listed as endangered because of its limited distribution and threats to its habitat posed by large-scale conversion of land in southern Florida to agricultural uses. Changes in water flows through the sparrow's range presently being evaluated for the Comprehensive Everglades Restoration Project (CERP) have the potential to adversely effect the present population. Because of this, any human caused changes to the present hydrology must take potential effects to the sparrow population into account.

With this project we intend to:

a. synthesize scientific information and help to identify the information needs,
b. develop a tool(s) to evaluate potential impact on sparrows by water management plans and Everglades restoration projects,
c. develop a tool(s) to assist in the planning of natural resource management, such as fire management, and evaluation of recovery plans.

One way to help evaluate the potential effects is through computer simulation and that is the overall purpose of our work. The initial phase of our project was to design a simple model that would act as the baseline for the development of future, more complex simulations. The best habitat and water maps were available were from the Across Trophic Level System Simulation (ATLSS) project. We therefore chose to build a model similar to a simple ATLSS sparrow simulator, the Breeding Potential Index (BPI) model. In doing this we simplified the initial integration of the ATLSS habitat and hydrologic maps into our model.

We believe this effort will assist directly with points b and c above. In addition, the information needed for the development of a stochastic individual-based model will (and already has) force synthesis of our present knowledge of the sparrow biology and habitat requirements and identify areas where further information is needed.

Plan for period 1:

1.) Recreate the BPI

a.) Create simple one cell model from the ATLSS documentation and a simulated time series input.

b.) Verify state change rules with ATLSS group.[1]

c.) Integrate 500X500 hydrological data and vegetation map.[1]

d.) Verify that our model creates identical output as BPI for same input data.

2.) Update our model to present state of knowledge.[2]

a.) Update our model

b.) Compare differences (if any) to results of BPI for same hydrological scenarios.

[1] Requires input from ATLSS group.

[2] Requires input from field biologists

Plan for period 2:

1.) Add a batch capability to our Sparrow model.

2.) Add a pseudo-random number generator.

3.) Add a file of seeds for the pseudo-random number generator when the model is run in batch mode.

4.) Add an input file that allows a user to easily change model parameters for a given run.

5.) Integrate probability distributions into the model for the purpose of simulating stochastic processes.

6.) Change the primary model state variable from habitat evaluation to that of a population measure. This will include upgrading to an individual based model but may also have an intermediate population based version as discussed in sections 3 and 4 of the task list from the initial project proposal.

Plan for Periods 3 and 4 (the final year of the grant):

1.) Continue upgrading the HIE model to from a nesting cycle based model to a sparrow based model.

2.) Attempt to develop an improved sparrow habitat map and integrate it into both the HIE and sparrow based models.

3.) Use a variant of the HIE model combined with the field data to compare water depths measured by field biologists with hydrologic model predicted water depths.

4.) Attempt to coordinate the transfer of the ATLSS models to SFNRC to make them available for use in evaluating proposed changes to the Everglades hydrology.

Research and DOI Scientific Questions

This study directly carries out the CESI objectives described as the Restoration Goal 1: Get the Water Right, Subgoal 1-A: Get the Hydrology Right, i) development of models simulating the response of species sensitive to changes in hydrology, especially those of threatened and endangered species, and k) development of parameters needed for the population of hydrologic, hydro-dynamic, and water quality numerical models (soil and ground water media hydraulic properties), including the collection field measurements in critical areas and the development of methods to estimate parameter values from commonly available information (topography, soils, vegetation, etc.). This study also contributes to the Restoration Goal 1: Get the Water Right, Subgoal 1-A: Get the Hydrology Right, j) development of performance measures and modeling tools to determine the response of key indicators to changes in water management.

Related Projects and Relation to Everglades Restoration

The tools developed in this project will be useful in planning of any restoration project that has a regional or sub-regional influences on ecosystems in ENP, for example, DECOMP and CSOP.

Details of Work Accomplished In Period 1

We achieved all our goals for this period with the exception of verifying our results with the ATLSS BPI model. This goal was not possible for technical reasons detailed below. However, we did explore the effects of changing the breeding season for the sparrows from that in the ATLSS BPI to new dates suggested by the field biologists. We also did a much more in depth analysis of the various ATLSS maps then originally anticipated.

The first part of this project was to build an emulation of the Across Trophic Level System Simulation (ATLSS) Breeding Potential Index (BPI) model. The purpose of this was twofold. First, having a copy of the BPI, but within our modeling infrastructure, would have allowed initial model verification against a known baseline. Second, we intend to use the habitat and daily water maps from the BPI as the environment for our more complex model. It was necessary to understand how these maps were generated and used in the BPI to successfully integrate them into our new model.

The first step was to recreate the logic used for the sparrow breeding season and the effects of water depth. The initial code was based on the BPI descriptions on the ATLSS web site. Test hydrologic files were designed using some of the South Florida Water Management District (SFWMD) stage data. These hydrologic files were used to verify the initial logic in our BPI emulator.

Further examination of the ATLSS documentation lead to some perceived inconsistencies within the different descriptions. I therefore contacted the ATLSS personnel and requested a copy of the actual source code. The ATLSS group provided the code in a timely manner and was very helpful in answering my questions. The BPI emulator code was then updated to exactly match the logic of ATLSS BPI code.

The second step of this phase of the project was to incorporate the various maps used by the ATLSS BPI model into our emulator. Again, the ATLSS personnel were very cooperative in providing all the BPI code and the data files related to the integration and use of the habitat maps. In addition they provided support in translating the Unix binary data files into a form that could be read by a computer using the Windows operating system. Code to read in and initialize the maps was added into our emulator.

The third step in this phase of the project was to add in hydrologic data to the model. ATLSS had just updated their hydrologic model by integrating the new HAED topographic map. The code for the BPI had yet to be upgraded at the time we needed to add hydrology to our emulator. The ATLSS personnel instead provided a standalone program to translate SFWMD hydrologic scenarios to the 500-meter resolution used by our emulator. The code necessary for reading in the daily hydrologic data translating their format from Unix to Windows format was incorporated into the emulator code.

At the initiation of this project, it was intended that the ATLSS BPI be used to verify our emulator by comparing its results directly to results from the ATLSS version. However, the hydrologic model has been upgraded using the new HEAD 400m topographic data. In addition, the ATLSS BPI has not yet been upgraded to use the new hydrologic model. As a result, our new model is the first to be using the new hydrologic model and cannot be compared directly to the present version ATLSS BPI.

Given that we could not use the ATLSS BPI to verify our model, we decided to update it to the present state of knowledge. We met with field biologists Sonny Bass and Julie Lockwood to discuss the present state of knowledge of Cape Sable Seaside Sparrow biology. Several modifications were made to our emulator including updating the dates for the breeding season and simplifying the breeding season logic.

Details of Work Accomplished In Period 2

We achieved all of our goals for this period with the exception of parts of goal #6, upgrading our simulation to an individual based model. In place of finishing goal #6, it was decided to do some unplanned work to help the ongoing restoration effort of SFNRC.

The first step in upgrading the HIE model to an individual based model was to incorporate stochasticity into the model. Stochasticity in a simulation represents uncertainty about aspects of the system we are attempting to model. Examples of these are birth and death rates. The sparrows on average produce three eggs each nesting period. However, that number can vary from one to five. It is not practical and probably not even possible to know and therefore model how and why the number of eggs produced varies in this manner. The most common alternative is to treat the number of eggs produced as a random variable distributed in some manner between one and five. Lifespan is a similar problem to number of eggs produced. The life span of an adult bird can vary from one to six years. Again, we know that disease and predation are probably primary contributors to the death rate, but we have little detailed information about the actual mechanisms. Again, we then attempt to model this process by treating the lifespan of an individual bird as a random variable.

There are several steps necessary to add stochasticity to a simulation. The first is adding a pseudo-random number generator (PRNG). PRNG's are called "pseudo" because they don't create a truly random numbers, but rather a stream of numbers that are highly uncorrelated over long periods. A generator is started by "seeding" it with a number and then it will return a number from the pseudo-random stream, usually either an integer between two bounds or a floating point number between 0 and 1.

The numbers from the pseudo-random stream are usually fed into a probability distribution to determine the value of some random variable. The shape of the probability distribution is chosen to either to fit some set of field data or to represent our best knowledge about a particular process. Three probability distributions were chosen to include in our simulation, the normal distribution, the negative exponential distribution, and the beta distribution. The normal distribution is familiar to most readers. The negative exponential is used to create times to events when the events are independent and identically distributed. An example of this is the lifespan of small birds where they do not die of “old age” but rather die off at a continuous rate from predation, disease, and environmental effects over a typical lifetime. The beta distribution is somewhat unique as it can be configure to match many different shapes with just two parameters and so is very useful when trying to match with field data.

A stochastic model does not have completely predictable outcome much like a field experiment. It therefore requires multiple model runs for a given set of parameter values to provide a quantifiable result. Each model run needs a unique seed for the PRNG. This capability was added to the simulation as described in Appendix A. The user edits the RandomSeeds.txt file to set the number of realization required (up to 200). The simulation gets the PRNG seeds for each realization from the same file. The names of the output files all have the realization number appended to them.

Work was begun on goal #6; upgrade the simulation to an individual based model, initially called the Composite-Time Spatially-Explicit Sparrow Simulation (COTSESS). A seminar to allow other researchers to comment on the preliminary design of the model was held. The primary goal of this meeting was to review how sparrows were to be implemented in the model and specifically what aspects of their biology and behavior were critical to the modeling effort. One important result of this meeting was the realization that, no matter how minimal sparrow movement over their range is, it is probably very important to their overall ecology. Objects were designed to represent birds, nests, and for the lists that will keep track of the birds within the environment. Code was added to initialize the birds within the simulation structure and variables were added to the spatial structures to accommodate the addition of birds to the simulation environment.

The plan was changed at this point. SFNRC expressed a desire and need to use quantitative ecological models to help the ongoing projects, and we felt that our model is nearly ready for test use. Application of our model to SFNRC projects a) directly contributes to SFNRC's restoration efforts, and b) provides an opportunity to evaluate the functionality and design of our model and to identify the areas that need improvements. Indeed, the test use of our model has demonstrated that our model can provide very useful quantitative information to decision makers, and has stimulated many improvements. Although work was not continued directly on the COTSESS model, a number of improvements made to the HIE model to support this work will also be used for the COTSESS model.

Numerous upgrades to the HIE model were made during this period. These included adding a user input file, general code cleanup and documentation, modifying the results to allow more detailed analysis of results, and writing a utility program to allow the spatial output to be read into ArcMap. Details of the HIE model are provided in Appendix A.

The user input file allows the user to choose values for both biological parameters and output file names. The general code cleanup included two parts. The first was removing code that was used for internal analysis and debugging. The second part was removing unnecessary input files. Originally, the HIE model was supposed to emulate the ATLSS Breeding Potential Index (BPI) model. Because of this, the model needed to use the same input files as the BPI and in the same manner. Many of the input files, from the standpoint of the BPI (but not necessarily of other ATLSS models which also use the files), were only used as intermediate steps to create the maps directly in the model calculations. Since the decision was made to make the HIE a standalone model, many of the input files (maps) were no longer needed. The maps they were used to create were saved and are now used directly as input. This decreases the amount of computer memory the simulation uses, decreases the number of input files needed to run the simulation, and decreases the simulation run time.

Upgrades to the HIE model were accomplished during this period as well as general model cleanup. The BPI model was designed as an index model. Because of this, the BPI results are normalized to a single number scaled between 0 and 1. While this may be useful when attempting to compare different performance measures, the process of scaling removes a great deal of information that may be quite important. The basic calculation of the BPI is to count the maximum number of potential nesting cycles possible per breeding season (0-3). This is now the basic output of the HIE model.

Field data was added as an input file to the HIE model. This served two purposes. First, it allowed the tagging of cells with their population designation (A-F). This is possible because the field data sampling points contain both the population to which they belong and their site coordinates. The simulation reads in the site coordinates and then translates them into the cell number. The simulation also reads in the bird counts for each cell for each year and stores them for later use in the output files (see Appendix A.)

Spatial processes are an important part of this project, and a utility program was designed to facilitate analysis of spatial data. The ArcMap utility program reads the results of the HIE model for two different hydrologic scenarios and calculates the difference between the results on a year by year and cell by cell basis. It then writes out the original data along with the difference data in a file format suitable for input into ArcMap.

The HIE was run with three hydrologic scenarios. First, the projected impacts of the Westc51 and No Action scenarios on the Cape Sable seaside sparrow were compared. 36 year time series plots were completed comparing the two scenarios for each sparrow population as well as an overall time series and statistics as well as some initial spatial plots were completed for this project, before it was determined that a comparison of a different set of hydrologic scenarios need to be conducted. A comparison between Westc51 scenario and its East Bookend counterpart was then conducted. This was intended for inclusion into the Tamiami Trail report. The details of this analysis are provided in Appendix B. There were two major finding from this study. The HIE model measures the maximum number of nesting cycles per cell per year with respect to nesting flooding. From this standpoint, The East Bookend scenario performed better in the western areas (population A) and the Westc51 scenario performed better in the eastern areas (populations C, D, and F). There was no difference in performance between the two scenarios in the two central areas (populations B and E). Another result of this analysis was the importance of the ability of the sparrow population to complete at least the first nesting cycle as detailed in Appendix B. Only a percentage of sparrows even attempt a second or third nesting cycle, and the success rate of these attempts is small. This means that it would take several years of breeding seasons where it was possible for sparrows to complete 3 nesting cycles to make up for the loss of all nesting cycles in a single season due to flooding. In addition, using global averaging for a species with this type of biology is particularly problematic. A scenario that provided three nesting cycles over one third of the cells would average out to be identical to one that allows one nesting cycle over all cells. However, the two results are in fact anything but equivalent.

Details of Work Accomplished In Periods 3 and 4 (the final year):

The work accomplished in Periods 3 and 4 falls into three main groups, HIE model upgrades, HIE model applications, and the ATLSS project. In addition, a preliminary design and operations document was completed for the HIE model and is included in Appendix A.

<u>HIE Model Upgrades</u>:

There were a number of upgrades to the HIE model over this period. These included code cleanup and speed improvements such changing all references to coordinates “x” and “y” to “column” and “row” to remove ambiguity and moving some procedure calls around to improve speed. The HIE model now can now run a 36 year scenario (which means reading in 110,000 water depth values per day) in about 10 minutes. Some of the most important modifications were:

1.) Adding hydroperiod calculations

To support the National Park Service Marl Prairie performance measure, the HIE model was modified to calculate the per year hydroperiod for the same cells that are used for the sparrow calculations, and output the data to the hydroperiod.txt file (see appendix A.). Adding and testing this code lead to a number of the analysis listed under the model applications section.

2.) Incorporating the Ross Field Data:

The Ross group at Florida international University over the last several years made a detailed categorization of the vegetation in the six sparrow populations. This included both a broad classification of "marsh" or "wet prairie" and 10 community subclasses. They also calculated an "inferred" hydroperiod at each of their sampling sites. I incorporated their data into my model database and include it as part of my hydroperiod output.

3.) Analyzing the link between the SFWMM output and the ATLSS high resolution hydrology:

As work on applying the HIE model to various Everglades restoration issues progressed, it became clear that it would be very useful to be able to compare the ATLSS predicted water depths and associated hydroperiod results to the same calculations done for the SFWMM. First, code was added that assigned each ATLSS 500 meter resolution grid cell to its (spatially) corresponding SFWMM 2 mile resolution grid cell. To simplify calculations, only cells that are completely contained within the boundaries of a SFWMM cell are marked as included within that cell. Cells that overlap boundaries are not marked (but that could be changed if needed.) Second, the 500 meter resolution cells that corresponded to the six sparrow special indicator regions were assigned accordingly. In this case, because the indicator regions are made up of multiple contiguous 2 mile resolution cells, 500 meter cells that overlapped 2 mile cells within the special indicator region were included.

HIE Model Applications:

Numerous analysis were performed over this period using the HIE model. These involved everything from comparing CSOP alternatives to comparing two versions of the ATLSS high resolution elevation maps. Five of these analyses are worth discussing in additional detail.

1.) CSOP Report: Nine hydrologic scenarios were analyzed with respect to potential impacts on the Cape Sable Seaside Sparrow. (Appendix C) The analysis focused on the potential impact on nesting cycles of surface water depths high enough to cause nest flooding. The most important finding of this report was that in the critical habitat of sparrow population A, the present operations (IOP) were better, with respect to this measure of impact, than any of the proposed CSOP alternatives. This report has been delivered to both Army Corps of Engineers and Fish and Wildlife Service (at their request) ahead of the complete National Park Service CSOP report.

2.) As part of the NPS CSOP report, Quan Dong presented a Marl Prairie performance measure. The much of the analysis was based on comparing the hydroperiods from the HIE runs for each of the nine CSOP scenarios to the Mike Ross lab inferred hydroperiods from the same spatial areas. Among other results, the simulated hydroperiods had far stronger extremes (completely wet or completely dry years) then did the field researchers inferred data. Using the HIE model, combined with the SFWMM output that was used in creating the high resolution hydrology, I was able to show that the extremes were an artifact of the SFWMM and were just passed on to the ATLSS hydrology, as opposed to being caused by the translation of the 2 mile resolution to 500 meter resolution.

3.) NPS hydrologists often analyze effects of hydrology on sparrows using indicator regions. Indicator regions are contiguous blocks of SFWMM cells used to delineate some region of interest. In the case of the sparrow, there are six indicator regions ranging in size from 8 to 36 square miles. In an effort to better understand the hydroperiod results from the Marl Prairie performance measure, the HIE model was set up to monitor all of the 500 meter resolution cells contained in each of the six sparrow indicator regions. Ambiguities relating to using hydro period as a measure of hydrologic impact became apparent while doing this analysis. The first is simply the mapping of a continuous variable (water depth) to an essentially boolean variable, hydroperiod. For example, a year could have 6 months of water at 1 cm. depth and 6 months of water below surface level (dry). A second could have surface water at 40 cm. for 6 months and dry for 6 months. In both cases the hydroperiods are identical (182 days); however the impact of the two scenarios would be very different on much of the Everglades flora and fauna.

Another related issue is the lumping together of regions as in the case of indicator regions. For a grouped set of cells, hydroperiod can be calculated by two different methods, average the water depths over all the cells and then calculate the hydroperiod from that average, or calculate the hydroperiod for each cell and then the overall hydroperiod by averaging each of the individual hydroperiods. Assume a hypothetical indicator region is made up of two cells, one cell has a surface water depth of -30 cm. over the entire year and the other has a surface water depth of 1 cm. over the same period. Calculating the hydroperiod by method one, the hydroperiod for cell one is zero days and the hydroperiod for cell two is 365 days, giving an average hydroperiod of 182.5 days. Calculating the hydroperiod via method 2, the average of the water depths over the two cells is -14.5 cm. which gives an average hydroperiod of 0 days. Although this hypothetical example is the most extreme case, analysis of the simulated hydrologic data used in the sparrow indicator region analysis also showed major differences between the two methods of calculating hydroperiod over multiple cells. What is somewhat distressing is that, although these issues with using hydroperiod as an ecologic driver are acknowledged by some researchers, the possible repercussions of this approach have, to this author's knowledge, never been analyzed.

4.) The high resolution elevation maps that are used by the ATLSS project to create the high resolution hydrology are created by a fairly complex process. In particular, there are several different types of elevation data the cover the South Florida region including for example, the High Accuracy Elevation Data (HAED) and Light Detection and Ranging (LIDAR) data. The SFWMM uses a combination of these various data sets to create its elevation map, which are in turn used in creation of the ATLSS map. In cases where there is no independent elevation measurement for a 500 meter resolution cell, ATLSS uses a complex process to combine hydrology and vegetation type to estimate the elevation.

The CSOP analysis (Appendix C) necessitated moving from the ATLSS version 5.0 elevation map to the version 5.4 map. Analysis of the ATLSS hydrologic output gathered as part of the CSOP analysis showed some 500 meter resolution cells that seemed to be "stuck" at always flooded or always dry. As part of the investigation of this possible anomaly, the HIE model was modified to read in the ATLSS elevation map (which is in a UNIX binary format) and output it in an ASCII text format that can be read into either ArcMap or Excel for display and analysis.

Part of the anomaly analysis was a comparison of the ATLSS version 5.0 and 5.4 maps. This was a result of some elevation values in the ATLSS 5.4 maps that seemed to have extreme values. There should only be two ways that an elevation cell in the ATLSS map could change between versions, either the elevation SFWMM cell in which the ATLSS cell is contained changes, or in the case of a cell that had no external elevation available, the calibration/verification runs from SFWMM changed between the two versions. (It should be noted that only a very small subset of cells fall into the later category.) When the version 5.4 map was created support the CSOP model runs, the ATLSS personnel created a difference map comparing the SFWMM 5.0 and 5.4 maps. There were six 2 mile resolution cells that changed between the SFWMM versions 5.0 and 5.4. This should have led to at most changes in about 252 ATLSS cells. The actual number of changes runs into the thousands. Even considering possible changes in cells with no external elevation data available, there seem to be far too many changes between the two maps. In addition, the differences are widely distributed and, in many cases have differences that are one or more orders of magnitude. This analysis is continuing, and needs to be confirmed by ATLSS personnel.

5.) The term “uncertainty” is used quite often in describing models and their results (as well as field data.) It almost exclusively used as a simplified term for statistical uncertainty when discussing ecological models, with the implication that the only “uncertainty” associated with models is statistical. This is untrue.

This issue can be best explained with an example. Assume that there is a species being modeled where field biologists believe that movement/dispersal plays a strong role in their biology. However, the actual movement mechanics are not well known and have a lot of error associated with them. The argument that including movement as part of the model will significantly increase the statistical uncertainty is valid. The oft chosen solution of using a simpler model that doesn’t include movement, is not. Using a simpler model, which would perhaps by a differential equation model, does not remove dispersal/ movement. Instead, it simply includes it as an implicit part of the model. In the case of a differential equation based model, the implicit assumption is that space is always “well mixed” and that every individual is equally as likely to interact with any portion of space or any other individual at any point in time. In other words, it is the population in question in a blender set to frappe. In counterpoint, it was already known that spatial relationships were important to the species in question. While the movement/dispersal behavior of the species in question might be imperfectly known, the best knowledge of the field ecologists is certainly already better then the assumption necessary to “simplify” the model. Using the “simpler” model decreased the statistical uncertainty but **<u>increased</u>** the ecological uncertainty. In addition, with movement/dispersal included explicitly in the model, sensitivity to, and results of, different movement patterns could be explored; in the “simpler” model this could not be accomplished.

The issue of statistical versus ecological uncertainty also occurs when using the present hydrological models as input to the HIE model. The SFWMM has an error of approximately 16 cm. The mean height of sparrow nests is also about 16 cm. At first glance this would seem to be an insurmountable problem. It gets even worse as it would be expected that the translation the SFWMM output to 500 meter resolution would add to that uncertainty. The argument has been made that the result of any model’s results using this simulated hydrology would therefore fall into the “garbage in garbage out” category. However, this is again statistical, not ecological uncertainty.

Field ecologists have been collecting data on the sparrow and it’s habitat since 1992. This data has included water depth measurements at sparrow field sites along with date and GIS location. The HIE model was modified to read in this data and then pair it up with the simulated 500 meter ATLSS hydrology output. The SFWMM data used as input to the ATLSS hydrology model were the calibration/verification runs from the years 1992 to 2000. Initial analysis was performed on the non-zero field data. This is because the model provides actual water depths below surface level while the field data classifies all these data points as depth equal to 0. The analysis of this data set provided both confirmation of the error issues and some good news as well. Analysis of over 2,000 data points, the mean difference between the predicted and measured points was 18.01 cm. with a standard deviation of 15.89 and an R^2 of 0.08. This confirms the 16 cm. error of the SFWMM predictions, but also implies that there is no major additional error being added in the translation to the 500 meter resolution. The question remains, does this error lead to garbage in garbage out? Restated, the question is “How often does the hydrological model ‘get it right’ with respect to the sparrow biology, and is ‘close enough, good enough’?”

In the broadest sense, there are really just two aspects to the sparrow’s environment, wet, which increases predation risk and floods nests, or dry, the nominal nesting conditions. If its nest is flooded, the birds care not whether the water was 20 or 200 cm. and therefore, the difference is biologically irrelevant. This provides a starting point for a simple hydrologic model analysis. There are four possible results when comparing the simulated and field data as listed in the table below. The first two are the case where the model got the basic prediction incorrect: there was surface water and the model predicted it was dry (wet/dry) or it was dry and the model predicted there was ground water (dry/wet.) The other two cases are where the model got it “correct”: it was dry and the model predicted that it was dry (dry/dry), it was wet and the model predicted it was wet, (wet/wet.) Given that we are dealing with an endangered species, the most important thing is to make sure that the model results err on the side of conservatism. If we take this approach then the critical model errors would be the points where there was ground water but the model predicted it was dry, because in this case the sparrow would have actually be negatively impacted but the model results would not have reflected this. Again, in the broadest sense, the model is providing us a conservatively reasonable result 88% of the time. While this might not be perfect, in the broadest ecological sense, it could be argued that "close enough is good enough".

Combined Data: Wet vs. Dry Predictions

Field/Sim	Mean	StdDev	# data points	% Total Points
Wet/Dry	27.41	17.80	731	0.12
Dry/Wet	11.75	10.24	408	0.07
Dry/Dry	0.00	0.00	4173	0.68
Wet/Wet	13.01	12.23	861	0.14

Obviously, there needs to be a much more in depth analysis of this data and particularly for the water depth range of 0-20 cm. where predation increases but nest flooding may not occur. This research is continuing.

<u>ATLSS Project</u>:

The ATLSS project is a massive modeling effort based primarily at the University of Tennessee, Knoxville (UT). The models have had far less use than had been hoped because presently the models must be run on a network setup that is not available in the South Florida region, the manpower is not available at UT to do low frequency but high intensity bursts of model runs as are often required by South Florida agencies, and the resulting lag in turnaround time for output data is too long. Because of this, a joint effort between USGS and Everglades NPS was initiated to work with UT to modify the models so that they could be more easily installed and run locally in South Florida. A draft statement of work (SOW) was written and then a trip was made to UT by personnel from

NPS and USGS it was discussed and modified. An important part of this effort was to better understand the creation of the ATLSS high resolution hydrology and a second trip to UT was made for initial training on this topic.

To date a draft of an instruction manual for creating ATLSS high resolution hydrology has been delivered to NPS and USGS as well as code, migrated from Sun Unix to Linux, for creation of the ATLSS high resolution elevation maps and the White Tailed Deer model. Translation of the Alligator and Wading Bird model are in process and they along with two other models are expected to be delivered by the end of October. As part of this effort, software and a high power computer were purchased and delivered to NPS.

Problems or Unusual Developments Period 1

It was originally thought that Muhly grass was a necessary part of the sparrow habitat, and that is the basis of the ATLSS BPI habitat map. Further research seems to indicate that the association between Muhly grass and the sparrow may not be causal. The underlying causative mechanism may be water depth. The sparrows need dry down during their breeding season. Muhly grass may also need periods of drying to keep sawgrass from taking over and both may need periods of deeper water to keep woody vegetation from encroaching. In the long term, this means a better CSSS habitat map needs to be developed for the NPS modeling effort. For the short term, we will continue to use the maps for the ATLSS BPI model. The design of the NPS model is such that moving to a new map, when available, will take minimal effort.

Problems or Unusual Developments Period 2

There were two issues during this period that caused delays and/or changes in the original goals. The first was the request by SFNRC personnel for comparison of different hydrologic scenarios as detailed in the Period 2, Details of Work Accomplished section of this report and in Appendix B. While this change in project focus did delay some planned tasks, it also improved our HIE model, and will improve our individual based model as well.

The second issue involved problems with ArcMap. Difficulties arose with changing the color and shape of display icons. Periodically it would cause the program to freeze up necessitating use of Windows to kill the program. A great deal of time was spent both alone and with the IT staff with in an attempt to solve this issue, including a reinstall of ArcMap and attempting to run it on a different machine. An inquiry was made on a user discussion board for ArcMap users and another user has had the same problem, so it seems to be an error in ArcMap itself. However, it also seems to be a very rare error and there is no information as to what set of circumstances trigger it. It is potentially associated with reusing the same background map for different data displays and in resizing maps, but at this point the error in still unresolved.

Problems or Unusual Developments Periods 3 and 4:

There were two main issues that impacted the results of the work for the final year of this project. The first was the CSOP report which led to many improvements to the HIE model as well as a number of detailed analysis. The second was the need to make an effort to get the ATLSS modeling project in such a state that its models could be used to support the Everglades restoration project. Although these to additions displaced some planned work, they were both important to the overall objective of the NPS Everglades work, "Get the water right."

Collaborators

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Appendix A

Hydrologic Impact Evaluator Documentation

Hydrologic Impact Evaluator Model Documentation Version 1 8/24/2006

General Notes:

This document is designed on a three tiered approach that I invented as I was attempting to document the model. It has a very general overview, followed by simple descriptions of each of the classes making up the model, followed finally by the header files for each of the classes as well as for the main program. Within the header files I added descriptions of some of the critical functions. (The source code is included as separate files.) This is an attempt to provide enough documentation to allow use of the HIE model without extending documentation writing into the next century. This is a first attempt and constructive suggestions can be relayed to Douglas_D_Donalson@nps.gov . The code is written in C++. However, my C++ coding is anything but elegant and it is basically C plus objects.

Hydrologic Input Issue:

The hydrologic input for the HIE simulation is created prior to the run using a program created by the ATLSS group. This program takes a SFWMM scenario as input and creates a 500 meter resolution 36 year hydrologic file as output. This file is ~2.8 Gigabytes in size. This program is only exists at National Park Service and was created for use by the modeling effort here. The ATLSS models do not use this as they translate the hydrology on a daily basis real time (as opposed to doing it all prior to the actual model run.) This presents a problem as National Park Service (meaning me) has neither the time nor the technical knowledge to distribute/maintain this tool for other agencies. If use of the HIE model is required by another agency on a regular basis, the agency should contact Dr. Lou Gross (gross@tiem.utk.edu) who heads the University of Tennessee ATLSS team, to arrange delivery/support of this tool. (Note that a 64 bit Sparc machine is required to run the tool.) For demonstration purposes, a sample input file is included in the model distribution. I will be looking into another possible solution for this problem, running the HIE simulation off of the TIME hydrologic model. However, the feasibility of that approach is not yet determined.

Input File Size Issue:

Throughout this document there are references to two versions of this model, a windows version and a portable “console” (ANSI) version. While the code has successfully been ported to a system using a GNU C++ compiler, another issue came to light. The input hydrology is in the form of a 2.8 gigabyte binary file. Windows can handle that size file, however, the Redhat Enterprise Linux system I am using could not. (Dell Precision 670, 4 gig RAM, 2 3.4 GHz Xeon processors) This problem also occured for the ATLSS group when they created the standalone tool for me that takes the SFWMM output and translates it to 500 meter resolution. That is, they could only get it to work on a 64 Bit Sparc because of the file size issue. Given this issue, the portable code is not being released at this time.

To do:

1.) The model needs error checking/messages, which will be included in the next version of the model. This will be implemented using an error log file which gets around the issue of trying to design real time interactive error displays for both the “console” and “windows” versions of the model.

2.) Predation is another cause of nest failure that is linked to hydrology. When more field data is available, this should be incorporated into the HIE model.

Overview:

The Hydrologic Impact Evaluator (HIE) is designed to analyze the potential effects of different hydrologic scenarios on the Cape Sable Seaside Sparrow. It is evaluates one aspect of the interactions of the sparrow with its environment, the potential of nest flooding due to high water during the nesting season. The model consists of a 419x264 rectangular grid of 500 m^2 cells that bounds the extent of the South Florida Water Management Hydrologic Model (SFWMM.) Only grid cells that fall within the coverage of the SFWMM are active. The basic input to the HIE model is a high resolution (500 meter) translation of the 2 mile resolution SFWMM hydrologic output. The high resolution hydrology was developed as part of the ATLSS project by The Institute for Environmental Modeling (TIEM) at The University of Tennessee, Knoxville. There are two versions of the HIE model, a version that uses a windows interface, and a console version that can (hopefully) be ported to any machine that has a GNU C++ compiler available.

The basic mechanics of the model are quite simple. Calculations are performed on a cell by cell basis. At the beginning of the breeding season (user defined with default 3/15) the model waits until the water depth above surface level drops below a user defined depth (default 5 cm.) At that point, the model begins counting the number of days where the water is below a user defined nest flooding height (default 16 cm.) If the water depth stays below nest flooding height for a specified amount of time (default 45 days for cycle1, 40 days for cycles 2 and 3) then the cycle is completed and considered a success from the standpoint of nest flooding. If the water breeches nest height before the prescribed number of days, the nesting cycle is aborted and the cycle is marked unsuccessful. The model then again waits for the water level to drop below a defined level and then again begins counting days where the water is below nest level. This continues until three nesting cycles have been attempted or the end of the breeding season is reached (default 8/1.)

A note on the model design: The HIE model was envisioned as the landscape part of an agent based Cape Sable Seaside Sparrow model. The landscape portion took on a life of its own as NPS personal discovered its existence and asked for various hydrologic scenario evaluations. I still hope to add simulated sparrows to the landscape and designed the code with that in mind.

Sparrow History and Biology as it relates to the HIE model:

The Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) was among the first group of species listed as endangered by the U.S. Fish and Wildlife Service on March 11, 1967. The sparrow is sensitive to hydrological conditions. Changes in water flows through the sparrow's range have the potential to affect the present population. Because of this, any human caused changes to the present hydrology must take potential effects to the sparrow population into account.

The primary sparrow habitat is intermediate hydroperiod marl prairies. Within this general category, the sparrows avoid both deep water and areas with woody vegetation. At present, the sparrow seems to be primarily distributed in the mid-northern and eastern areas of the Everglades National Park. The overall sparrow population is divided into 6 geographical populations, A-F (see Figure 1). These populations are separated geographically by areas of long hydroperiod or woody vegetation. Based on their position in the landscape, each of the subpopulation habitats is subject to different environmental effects. As Cape Sable Seaside Sparrows seldom move more than a couple of kilometers from where they fledged, and also try to avoid crossing unsuitable habitat, these populations tend to be demographically decoupled (Pimm et al. 2002.)

Bass and Kushlan (1982) conducted the first extensive survey of the Cape Sable Seaside Sparrow Population in 1981. This was repeated in 1992 and has been performed annually since. The survey is done by dropping observers at sites on a grid that covers all known sparrow habitat, both previous and present. The sampling resolution is 1 km. The observers count the number of birds in the area by listening for singing males. The observers also take surface water depth samples and estimate vegetation type and cover (Pimm et al. 2002.) From 2003-2005 Ross et al. (2005) have done a much more detailed survey of the vegetation types that make up the areas in which sparrows are found. These surveys were conducted in approximately the same sites as the population census'. These studies, as well as many others (Pimm et al. 2002) make the sparrow one of the most studied species in the Greater Everglades system.

Critical to the design of this model is the basic sparrow breeding biology. Sparrows breed during the Everglades dry season, starting nesting after March 15th (Pimm et al. 2002.) Most pairs only attempt one nesting cycle per year, with some pairs attempting a second nest and even fewer attempting three nesting cycles (Lockwood per. com.). Each cycle takes approximately 40-45 days to complete (Pimm et al. 2002). Few nests are found after August 1st because of the onset of the rainy season. Because Sparrows build their nests very close to the ground, with an average height at 16 cm, water depth during the breeding season is a critical factor for nesting success. If water level rises and sparrow nests are flooded, the nesting cycle is terminated. There are many other possible impacts of hydrology on the sparrow population, both direct and indirect, but clearly, one of the most fundamental criteria for breeding success is water depths below the height of the nest. A final important aspect of CSSS biology is the decreased productivity of the second and third nesting cycles (Pimm et al. 2002). It is estimated that only about 60% of individuals attempting a first nesting cycle will attempt a second cycle, and only about 30% of those individuals will attempt a third cycle (Lockwood per. com.). In addition, the success rates of the second and third nesting cycle attempts are far lower than for the first (Pimm et al. 2002).

HIE Organization:

The HIE model is composed of 7 pairs of definition (.h) and source code (.cpp) files. It should be noted that some of the constructs (such as the event schedule) in this model are designed with the planned expansion of this code to an individual based model in mind.

Main Program: Sparrow.h Sparrow.cpp

The main program has three tasks, initialization, execution, and cleanup/exit program. In addition, the version with the windows interface contains code to handle program execution and real-time displays.

Initialization:

1.) HIE reads in the first two lines of RandomSeeds.txt. This is used to initialize the Random Number Generator and to set up the simulation for multiple stochastic runs. This is not used presently in the HIE model but is in place for future upgrades.

2.) Create a few initial variables/objects.

3.) Call "initializeParameters()" to read in the user defined parameters.

4.) Initialize main output files

5.) Create the spatial grid object.

6.) Add a "SpatialCell" object to each of the spatial grid locations by a call to "addCell()".

7.) Set each spatial cell's neighbors with a call to "setNeighbors()".

8.) Input various data files by calling "FileInput()."

9.) Create first event and add it to the event list.

10.) Run program.

Execution:

The highest level model execution is just a simple loop. In each iteration:

1.) Check to see whether there are any events on the event list (if there aren't then by default the simulation is over) and whether the Date object returns endOfSimulation true.

If either of these are true then the function "endRunCleanup()" is executed and the simulation is terminated. Otherwise:

2.) Check to see whether there is an end simulation message (windows version only) via user input and if there is end the simulation. Otherwise:

3.) Call the function "processEvent()" which executes the next time ordered event in the HIE simulation. In the case of the HIE model, there is only one event, updateLandscape. Then:

4.) (Windows version only) Check to see whether real time displays are set to be updated and if so the update the text displays (not the graphical displays which update once per year.) Then:

5.) Loop back to #1.

Cleanup/Exit:

When the simulation is complete, "endRunCleanup()" is called to release all simulation allocated memory, write the final output data, and end the simulation.

Windows interface:

The windows interface is a crude attempt at providing a control interface and real-time displays. It is not in any way intended to be elegant code and will not even be discussed other than to describe its function and operations at a very high level.

When the HIE model is started, the main window is crated along with windows that display real-time the yearly hydroperiod and the weighted potential nesting cycles (Figure 1). To start the simulation running, the "run" selection under the File menu is selected. This pops up the runtime dialog box shown in Figure 2. The simulation is actually started by clicking the "run" button on this dialog box. The day, month, and year are updated in the runtime dialog box every 20 days. (This speeds up the simulation greatly compared to updating them on a daily basis.) The fourth display is the total elapsed number of days since the simulation began. The two graphical display windows are updated at the end of each year and show the hydroperiod and weighted potential nesting cycles from the previous year so in the year 1967 you are seeing the results from 1996 (Figure 3).

There are four controls (Figure 2.) Run, Stop, Next, Continue, and Exit. "Run" starts the simulation. These were inspired by the SWARM user interface and are most useful in more complex Agent based simulations where the user may want to halt the simulation mid-run to look at some data, or temporarily step through on a single time step "Exit" terminates the main body of the simulation and returns it to the main window. The main window can then be closed with the "File->Exit" function or the kill window button in the upper right corner. "Stop" pauses the simulation. "Next" is used when in the

“Stopped” mode to step through the simulation on a time step equal to the main update rate (default 20 days.) “Continue” takes the simulation out of the “Stop” mode resumes the auto-update mode of the simulation. Warning: This thread implementation is not robust. “Run” should only be used to start the simulation. “Continue” should be used after “Stop”, and “Exit” should be used to terminate while the simulation is running (not from stopped, single-step mode.) I may be able to improve on this in a future upgrade.

Cell Object: SpatialCell.h SpatialCell.cpp

The cell object is the basic component upon which the HIE model is built. One cell object is created and placed in each of the 110616 grid sites. It has two main functions. First, it is receptacle for the model’s spatially explicit information such as UTM coordinates, field data, and simulated water depths. It also is acts as the state machine that counts days with water depths below nest flooding depths for each 500 m^2 area.

“updateCellSimple()” is the function that counts the days during the nesting season. It is called by the “update()” procedure in the Sparrow object only for cells that are within the SFWMM boundaries and where field researchers actually found birds or the ATLSS vegetation map marks as good sparrow habitat, and only during the user specified breeding season. There are two tests of water depth. The 5 cm depth trigger (now user selectable, default 5 cm) is used at the beginning of the breeding season and after a nest flooding event as a threshold to trigger a nesting cycle. The other is the flooding depth, which is the water depth in cm where at or above which the nest will flood and the nesting attempt will fail. Once the water drops below the trigger depth the nesting cycle starts. Each day the water stays below the flooding depth a counter in incremented. If the counter gets past 45 days (default, user selectable) for nesting attempt one, or 40 days (default, user selectable) for cycles two and three, a successful nesting cycle is logged. If, during a nesting attempt, the water reaches flood depth, the attempt fails and the next nesting attempt is forced to wait until the water recedes to below trigger depth before it can begin. Once three nesting cycles have been attempted, nesting is ended for that breeding season.

Date Object: Etad.h Etad.cpp

As might be guessed, the Date object handles the time keeping duties for the HIE model. It is initialized with the starting and ending dates of the simulation as defined by the SFWMM scenario being analyzed, and the starting and ending dates of the sparrow breeding season. Yes, it does do leap years. Its main duty is to report back to the main simulation when the date is within the breeding season. It also reports when the year is ended and when the simulation ends. It is called “etad” (date spelled backwards) because evidently there is a “date” object somewhere in one of the microsoft libraries and periodically (but not consistently) there would be some sort of conflict which would corrupt the HIE simulation’s date.

Random NumberGenerator Object: Mersenne twister

The Mersenne twister is a very long period pseudo-random number generator. A long period is useful for complex simulations. It also has good statistical properties. It is not used in this version of the HIE model but will be in the next upgrade. It could be used with the present HIE model to test how randomness in nest heights might effect the simulation results.

Event Object: Event.h Event.cpp

An event is any occurrence that might affect the present state of the simulation. They could be something that occurs on a regular time step (synchronous events) such as reading in the water depths on a daily basis to a weather event that occurs "randomly" (an asynchronous event.) Events are stored in a dynamic list ordered by time and executed on a next shortest time basis. The event object has previous and next pointers so that it can be inserted into the doubly linked event list.

Event List Object: EventList.h EventList.h

The Event List is a doubly linked list that is sort of the engine that drives the simulation. It stores all future possible (known) events ordered by time. At the completion of the processing of an event, the main program removes the event at the top of the event list (which, by definition, is the next thing that will happen in the simulation.) As events are removed and executed, other events may be either removed or added to the event list. For example, an egg hatching might require adding some events from a new bird's life to the event list, such as when it would fledge. A bird dying might necessitate the removal from the event list of any other pending events in that former bird's life. In the HIE simulation there is presently only one event, that of processing water depth updates for each of the active cells on a daily basis.

Global Variables Object: Variables.h Variables.cpp

Variables is just a container for global variables, the most important of which is the spatial grid.

Input/Output:

There are 10 input files (Table 1a.) and 9 output files (Table 1b.) Only 2 input files are intended for user modification (Parameters.txt and RandomSeeds.txt) and only one, Parameters.txt (Table 2) needs to be modified when running the HIE model. Each line in the Parameters.txt file consists of two parts separated by white space, the descriptor, which should not be changed, and the user modifiable data. The basic output from this model is a per-cell/per-year count of the nesting cycles that could have been completed by a bird in that cell with respect to nest flooding. This result comes in two forms, total potential cycles (0-3) and weighted potential cycles (0-1.9.) The weighted cycles take into account the fact that only approximately 60% of the population that attempts a first nesting cycle will attempt a second and only about 30% a third. At most 3 nesting cycles are attempted per breeding season. These percentages can be modified in the Parameters.txt file (Table 2.)

There are four main output files IndividualCells.csv, SubPopulations.csv, GlobalAverage.csv, and LongTermStats.csv. IndividualCells.csv lists the results for each cell for each year along with additional model and field information that may be useful for scientists analyzing the results. The other three main output files could all be derived from IndividualCells.csv, but are provided as output directly for convenience. The output formats for IndividualCells.csv and LongTermStats.csv are listed in Table 3 and Table 4 respectively. GlobalAverage.csv and SubPopulations.csv simply list the average total and weighted cycles over all cells or over each subpopulation per year respectively. There are additional output files (Table 1b) that provide information such as the ATLSS elevation map, where the elevation data came from (HAED, LIDAR, etc.), the per-cell hydroperiod (Table 5), and indicator region specific results.

HIE Input/Output Files

Table 1a. HIE Input Files			
File Name	Procedure	Input/Output	Description
Parameters.txt	initializeParameters()	Input	User definable parameters and file names. See Table 2.
RandomSeeds.txt	myMain()	Input	Used for stochastic runs. First entry is the number of runs and is user definable from 1-200. The next 200 entries are seeds for the Psuedo Random Number Generator.
WaterDepth	updateWater()	Input	Daily water depth above ground level. Created by a separate utility program that must be run on a Unix Sparc 64 machine prior to the model run.
AreaBirdCountUTM.txt	FileInput()	Input	Field data included for comparison purposes. Used primarily to label cells with correct population tag, A-F.
WaterMask.txt	FileInput()	Input	The "layout" of the simulation is a rectangle containing the cells included in the SFWM hydrologic model. This file separates the cells included in the hydrologic file from those that just fill in the rectangle.
WeightMap.txt	FileInput()	Input	This is a file provided by the ATLSS project that classifies cells according to their muhly grass coverage. It is used to filter out

			field sites that are poor sparrow habitat.
hmdt.bin	FileInput()	Input	This is a Unix binary format file that contains the elevations for each of the 500 meter resolution cells.
RossData.txt	FileInput()	Input	This file contains field data gathered by Mike Ross of vegetative species composition and inferred hydroperiod in sparrow areas.
ElevDataSource.txt	FileInput()	Input	This is the source data for the ATLSS 500 meter resolution elevations (HAED, LIDAR, etc.)
2X2-500X500.txt	FileInput()	Input	This is a translation file that allows assignment of 500 meter cells to SFWMM Sparrow indicator regions.

Table 1b. HIE Output Files			
File Name	Procedure	Input/Output	Description
GlobalAverage.csv	endYear()	Output	Maximum possible number of nesting cycles averaged over all sites per year.
SubPopsAverage.csv	endYear()	Output	Maximum possible number of nesting cycles per year averaged over each population A-F.
IndividualCells.csv	endYear()	Output	Maximum possible number of nesting cycles per cell per cell per year.
LongTermStats.txt	endRunCleanup()	Output	Average over entire time series for each cell of maximum number of potential nesting cycles.
Water1,2,3, and 4.txt		Output	These files are outputs from some tests done to compare measures water depths with model predicted depths. The code is left in for future use by the developer but are turned off by setting the "`DoWaterDepthTest`" variable in parameters.txt to zero
`ATLSSElvMap-5.4.txt`	FileInput()	Output	The elevations (mm.) of the ATLSS cells in grid format. Value 0.0 represents both a true zero elevation and cells that fall outside the boundary of the SFWMM.
`IRhydroperiod.txt`	endYear()	Output	Grouped Indicator regions
`IndicatorRegions.txt`	endYear()	Output	Individual cells that make up the indicator regions
`hydroperiod.txt`	endYear()	Output	This file provides the per-year hydroperiod in each cell where a bird was found. It includes the information gathered by the Ross group where

			available.

Table 2. Parameters.txt Input File		
Parameter Name	Default Value	Description
graphics	1	The input parameters "graphics" and "twoDDisplayGraphics" are not implemented at present and should be left at their default states. In the future the plan is to have the type of graphics output selectable with two different looks, one for each window.
twoDDisplayGraphics	0	
endSimulation	400000	endSimulation is used in situations where the end date is not specified as part of the simulation. This is reserved for future use.
startDay	1	startDay, Month, and Year specify the date to begin the simulation. They should match the starting date for the hydrologic input file.
startMonth	1	
startYear	1965	
endDay	5	endDay, Month, and Year specify the ending date for the simulation. It should be set to the 5th day of the 1st year after the end of the hydrologic input file. This is because some data storage/calculations aren't complete until the end of the year.
endMonth	1	
endYear	2001	
breedSeasonDayStart	15	breedSeasonDay/MonthStart, and breedSeasonDay/MonthEnd define the duration and position of the breeding season.
breedSeasonMonthStart	3	
breedSeasonDayEnd	1	
breedSeasonMonthEnd	8	
GlobalFileName	GlobalAverage	These three entries define the file names for the three output files. They should be kept to 20 characters and should not contain spaces. See the Output Files Section for more details on these files.
SubPopulationFileName	SubPopsAverage	
CellsFileName	IndividualCells	
WaterDepthInputFile	C:\westc51-fhmwater.bin	This is the path to and the filename for the hydrologic input file. Note that this file must be generated using the utility program provided by the ATLSS group.
BreedWaterDepthTrigger	5	The parameter defines the water depth in cm in a cell at which nest building can begin given that the simulation date is within the breeding season.

NestFloodDepth	16	The water depth in cm. at which nests will be flooded.
DoWaterDepthTest	0	Turn on the water depth comparison output. Suggested leave this disabled as the water test only works with Cal-Ver input.
FirstNestingCycleLength	45	Length if time to complete 1st nesting cycle.
NestingCycleLength	40	Length of time to complete 2nd and 3rd nesting cycles
MeasureHydroPeriod	1	Enable hydroperiod output.
SparrowLocationsOnly	1	Calculate data only for locations where
cycle1Attempted	1.0	Percentage of birds attempting the 1st nesting cycle.
cycle1Success	1.0	Success rate of 1st nesting cycle.
cycle2Attempted	0.6	Percentage of birds attempting the 2nd nesting cycle.
cycle2Success	1.0	Success rate of 2nd nesting cycle.
cycle3Attempted	0.3	Percentage of birds attempting the 3rd nesting cycle.
cycle3Success	1.0	Success rate of 3rd nesting cycle.

Table 3. IndividualCells.txt Output File	
Year	
Row	The row number of the cell
Column	The Column number of the cell
Easting	UTM Easting Coordinate
Northing	UTM Northing Coordinate
Population	The Population Designation A-F for cells included in field data, X for cells not included in field data.
Dry Days	Number of days that the water level in the cell was below ground during breeding season.
Wet Days	Number of days that there was above ground water in the cell that was below nest flooding depth during breeding season.
Nesting Cycles	Maximum possible number of nesting cycles completed for year.
Weighted Cycles	Maximum possible number of nesting cycles for year weighted by nesting cycle success probability.
Total Nesting Cycles	Raw Data: Total Nesting cycles completed

Nesting Cycle 1	Raw Data: Nesting cycle 1 completed
Nesting Cycle 2	Raw Data: Nesting cycle 2 completed
Nesting Cycle 3	Raw Data: Nesting cycle 3 completed
Bird Count	Bird count in cell from field data (Range 0-7) sampled that year, -1 not sampled that year.

Table 4. LongTermStats.txt Output File	
Row	The row number of the cell
Column	The Column number of the cell
Easting	UTM Easting NAD 27 Sector 17
Northing	UTM Northing NAD 27 Sector 17
Population	The Population Designation A-F for cells included in field data, X for cells not included in field data.
Total Cycles	Overall maximum possible number of nesting cycles for hydrologic scenario.
Weighted Cycles	Overall weighted maximum possible number of nesting cycles for hydrologic scenario.

Table 5. Hydroperiod.txt Output File	
Year	Year
Row	The row number of the cell
Column	The column number of the cell
Easting	UTM Easting NAD 27 Sector 17
Northing	UTM Northing NAD 27 Sector 17
Bass Easting	UTM Easting of Sparrow survey site within cell
Bass Northing	UTM Northing of Sparrow survey site within cell
Population	The Population Designation A-F for cells included in field data, X for cells not included in field data.
Hydroperiod	Predicted yearly hydroperiod for cell.
Weighted Cycles	Overall weighted maximum possible number of nesting cycles for hydrologic scenario.
Ross Site	Ross site number 1-608
Ross Year	Year sample taken
Ross Easting	UTM Easting of Ross survey site within cell

Ross Northing	UTM Northing of Ross survey site within cell
Ross General Type	1=Marsh 2=Wet Prairie
Ross Community	1-10 See Table 6.
Ross Inferred Hydroperiod	Hydroperiod inferred from vegetation type

Table 6. Conversion from HIE ID number to Ross community type.	
ID Number	Community Type
1	*Rhynchospora-Cladium* Marsh
2	*Paspalum-Cladium* Marsh
3	*Eleocharis-Rhynchospora* Marsh
4	*Schizachyrium* Wet Prairie
5	*Spirtina* Marsh
6	*Cladium-Rhynchospora* Marsh
7	*Cladium* Wet Prairie
8	*Muhlenbergia* Wet Prairie
9	*Cladium* Marsh
10	*Schoenus* Wet Prairie

Sparrow.h

```
#define NR 419  //Number of rows in spatial grid
#define NC 264  //Number of columns in spatial grid

//UTM NAD83 north west corner
#define EASTINGMAX  467165
#define NORTHINGMAX 2989069

// Windows Variables
int killThread=0;
char name1[30]="Hydroperiod ";
char name2[40]="Potential Breeding Cycles ";
int graphics=1;
int twoDDisplayGraphics=1;
int wait=0;
int singleStep=0;

//Control
double endSimulation=40000;
int batch;
int doWaterTest;
int measureHydroperiod;
int sparrowLocationsOnly;


//Objects
Variables *myVars;
EventList *eventList;
TRandomMersenne *myGenerator;

//Files
char globalOutputFile[40];
char subpopOutputFile[40];
char cellsOutputFile[40];
char hydroInputFile[60];
char File1[30];
char File2[30];
char File3[30];

//Parameters
int H2ODepthTrigger;
int floodDepth;
double cycle1Attempted;
double cycle1Success;
double cycle2Attempted;
```

```
double cycle2Success;
double cycle3Attempted;
double cycle3Success;

//Approximate mapping of 500 meter cells to SFWMM sparrow
indicator regions
int indicatorA[338][2];
int indicatorB[387][2];
int indicatorC[91][2];
int indicatorD[78][2];
int indicatorE[205][2];
int indicatorF[114][2];

//instrumentation

enum Events
{
     updateLandscape,
};

//Macros to create and destroy dynamic arrays!!!
/*

A note on the two macros below.  Under C++ the user is
supposed to be able to dynamically allocate 2 dimensional
arrays realtime using **myArray and then be able to access
them in an array format.  Visual C++ would not let me do
that, so Jane Comiskey of TIEM kindly provided the
following macros that do allow this.

*/

#define D2FREE(pprow)\
{\
delete(*pprow);\
delete(pprow);\
}\

#define DIM2(pprow,rrow,ccol,type)\
{\
int iii;\
type *pdata;\
pdata = new type [rrow * ccol];\
if(pdata == (type *) NULL){\
  fprintf(stderr, "No heap space for data\n");\
  exit(1);\
}\
```

```
pprow = new type * [rrow];\
if(pprow == (type **) NULL){\
  fprintf(stderr, "No heap space for rrow pointers\n");\
  exit(1);\
}\
for (iii=0; iii <  rrow; iii++){\
  pprow[iii] = pdata;\
  pdata += ccol;\
}\
}\


void myMain(PVOID pvoid);
void processEvent();

/*
Process event is the heart of the simulation engine.  It is
designed to run a composite schedule (combined asynchronous
and synchronous events).  In this application it just runs
the synchronous, daily timestep, event updateLandscape.
The event list is a time ordered list of all possible state
changes to the system at any particular instant.  The next
system state change will be the event with the shortest
future time, the event at the top of the event list.
processEvent pops the nest event off the event list.  The
event has three major variables associated with it, its
type, its time, and if any, the agents to be acted upon.
The type represents what state change the event represents
and is an enumerated type.  It might represent the addition
of a new agent, the death of an agent, or as in the case of
the HIE model, an operation on the landscape.  The time it
the simulation time at which the event is occurring.  The
agent(s) is what the event is acting upon.  In the case of
the HIE model, the agent is the landscape.  (As the
landscape is the only “agent” in the HIE model, the agent
pointer is left void.)

Process event first updates the system time to the time to
the new time contained in the event.  It then selects the
appropriate set of actions for that event by using a switch
statement on the type.  For the HIE model it is
updateLandscape.  First, there are two function calls,
updateWater(), where the new water depths are read in and
then update(), which handles the details of updating the
landscape.  Finally, processEvent() creates a new
updateLandscape at time equals present time+1 and inserts
it into the event list.
```

```
*/

SpatialCell *addCell(double newY, double newX);
void update();

/*

The update() function is called by processEvent().  It has
three jobs.  First it checks with the Date object to see
whether the run is in the breeding season.  If so it cycles
through the cells and has them execute upDateCellSimple()
is the cell is active for that run.

Second it checks with Date for end of year.  If that
returns true, endYear() is called.

Finally, upate() tells Date to increment the date by one
day.

*/

void printColor(int index, HDC hdc, int i, int j);
void printColorAlt(int index, HDC hdc, int i, int j);
void Update2DDisplay();
void FileInput();

/*

File input first allocates memory for some of the input
arrays and the two display arrays.  It then reads in the
ATLSS high resolution elevation map.  This map is a Unix
binary file of size double and so its “endianess” has to be
changed.  It then goes through and reads in the various
data files of field and/or simulation interest as described
in Table 1b.  Also, this is where the hydrologic input file
is opened.  (See updateWater())

*/

void updateWater();

/*
This function has three major tasks.  The first and most
important is to update all the cells with the present day’s
water depths.  The 500 meter resolution water file is
created by an ATLSS program in a UNIX environment.  The
file is in a binary short int format.  (Even as a binary
```

file it is still about 2.8 gbytes!) Therefore I have to read it as binary chars and then change its “endianess” from Unix to Dos.

The second task is to calculate the yearly hydroperiod for the cell as well as the number of days during the breeding season where the water is above surface level but below flood depth and the number of days where it is below surface level.

Lastly it is set up to output a comparison between the simulated water depths and the depths measured by NPS field biologists as read in from the file “AreaBirdCountUTM.txt” (Table 1a.) I left this code in the simulation (for my own use) enabled with a flag “doWaterTest” (Table 2) but suggest that users ignore it as it is not generally useful as an output metric and the data could be misunderstood.
*/

```
endYear();

/*
```

endYear() is made up of five tasks that do data calculation and output on a yearly basis.

First the global average is computed. The program cycles through all the cells and for each monitored cell it calculates the metric for the number of successful cycles (0-3) and the weighted metric (0-1.9). It averages these to get the global average and also adds the result to the cell.

Next the program does the same thing for the individual populations, sorting the monitored cells by “samplingArea” in a switch statement.

The same process is then performed for the monitored cells in the special indicator regions.

The stats for the individual cells are then output. (All of the above could have been calculated from this file but I found it useful to separate them real time. It also does the output for the individual indicator cells at the same time.

The last task is doing hydroperiod calculations, primarily intended for the NPS Wet Prairie performance measure.

```
Finally, in the windows version, I load the two arrays that
hold the display data with their yearly values and call
“update2DDisplays()” to send it to the monitor.

*/

void initializeParameters();
void endRunCleanup();
```

/*
The primary use of end run cleanup is to reinitialize the simulation between runs when it is being used in a stochastic mode. This includes deallocating all the memory used by HIE. It also calculates the 36 years averages for each of the cells and writes them into the file (default) longTermStats.txt (Table 4.)
*/

SpatialCell.h

```
class SpatialCell

{
public:

//Cell location information
double col,row;
double NCol,NRow;
int easting,northing;
int sonnysEasting;
int sonnysNorthing;
SpatialCell *neighborCells[20];
double cellType;
int validCell;
int indicatorCell;
int indicatorArea;
int twoXtwoRow;
int twoXtwoCol;
char samplingArea; //Area A,B,C,B,E,F

//Cell physical/biological information
int elevationDataSource;
double elevation;
double habitatQuality;
int birdFound;
int birdCount[36];
struct H20History
{
     int day;
     int month;
     int year;
     double depth;
}waterHistory[13];

struct RossFieldData
{
int site;
int year;
int easting;
int northing;
int generalType;
int species;
int hydroperiod;
} rossData;
```

```
//Reference to global variables
Variables *myVars;

//Input variables (two others are included in Variables.h)
int floodDepth;
int H2ODepthTrigger;


//Cell "State variables"
int five_cm_trigger;
double waterDepth;
int numberOfSuccessfulAttempts[4];
double weightedCellValue;
int firstTry;
int numberOfAttempts;
double hydroPeriod;
int presentState;
int successTimer;
int dryDays;
int wetDays;
double totalScore;

//{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{}{
}{}{}{}{}{}

SpatialCell();
virtual ~SpatialCell();
void updateCellSimple();

/*
This function is a bit convoluted.
The first "if" statement checks whether 3 nesting attempts
have already been made and if so returns.  (Only three
nesting attempts are allowed per breeding season.)

The second "if" statement checks whether the water depth is
above flood depth.  If it is, it then checks whether there
is a nesting attempt presently in process.  If there is,
the attempt is lost.  Regardless, the five_cm_trigger is
set to zero (as the water is now above the trigger height),
the days counter is set to zero, and firstTry is set to 1.
(firstTry is the variable that chooses between 45 and 40
days for the nesting cycle length.  The extra five days
represents the time to build the nest.  Arguably, if the
nest is flooded, it is also destroyed, and a new nest will
have to be rebuilt.  The functions then exits.
```

```
The third “if” checks whether the water is below the
breeding trigger and if so sets the five_cm_trigger to
true.  (Yes, it is redundant is the trigger is already
true, but this is probably just as fast or faster than
doing an if else statement.)

The last “if” statement is executed if the five_cm_trigger
is true.  If so, it first increments the successTimer,
which counts consecutive days with water depth below
flooding height.  It then checks whether the nesting cycle
is in a nest building cycle (default 45 day) or a shorter
(default 40 day) cycle and if so whether the success timer
is equal to 45 or 40 days respectively.  If true, the
number of successful attempts in incremented, as well as
documenting which cycle completed.  The successTimer is
then reset to zero, and the function exits.
*/

void setNeighbors();
void reset();
};
```

Etad.h

```
class Etad
{
public:

int day;
int month;
int year;
int days;
int totalDays;
int reset;
int startSeasonDay;
int startSeasonMonth;
int endSeasonDay;
int endSeasonMonth;
int endSimYear;
int endSimMonth;
int endSimDay;
int breedingSeasonFlag;

Etad();
Etad(int month,int day,int year);
virtual ~Etad();
void nextDay();
int endYear();
int breedingSeason();
int endSimulation();
};
```

Mersenne twister RNG

A full description of the Mersenne twister pseudo-random number generator can be found in the following wikipedia description and in its accompaning links.

http://en.wikipedia.org/wiki/Mersenne_twister

Event.h

```
class Event
{
public:

int type;
double time;
Event *previous;
Event *next;
void *agent;
int flag;

//#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#$#
$#$#$#$#
Event();
virtual ~Event();
};
```

EventList.h

```
class EventList
{
public:

Event head;

Event tail;

int count;

Variables *myVars;

//$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$%$
%$%$%$

EventList();

virtual ~EventList();

push(Event *aEvent);

Event* pop();

pushEnd(Event *aEvent);

Event* popEnd();

Event* peekTop();

Event* peekEnd();

remove(Event *aEvent);

insertSorted(Event *aEvent);

int contains(Event *aEvent);


};
```

Variables.h

```
class Variables
{
public:

//Required maps: input

int **waterMask;
float **weightMap;
float **waterMap;
char **temp;  //Used to read in files that need to be
endian corrected

FILE *waterPointer;

//Required maps: created

SpatialCell ***theWorld;

//Maps for display

double **waterMask1;
double **muhlyClusterMap1;

double globalTime;

Etad *date;

int firstNestingCycleLength;
int nestingCycleLength;

// Procedures

Variables();
virtual ~Variables();

};
```

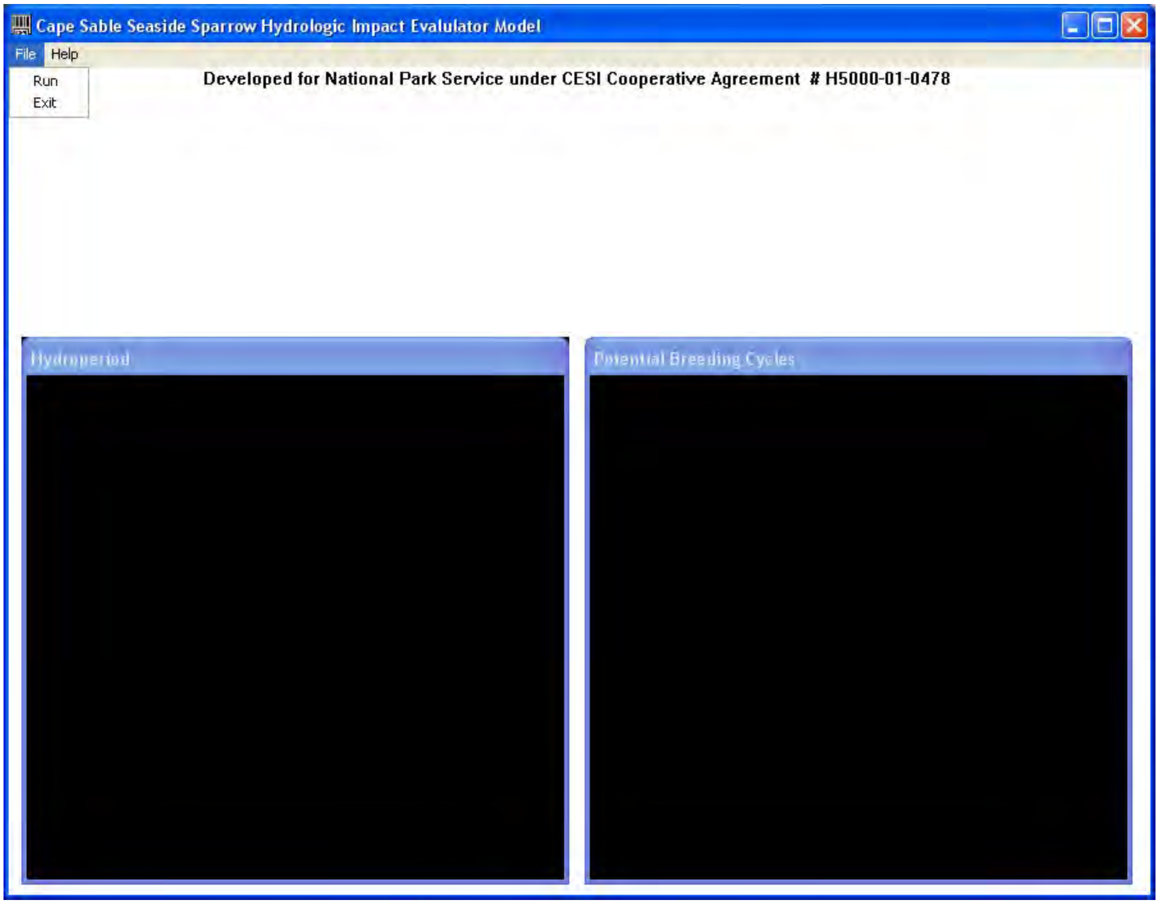

Figure 1.

Figure 2.

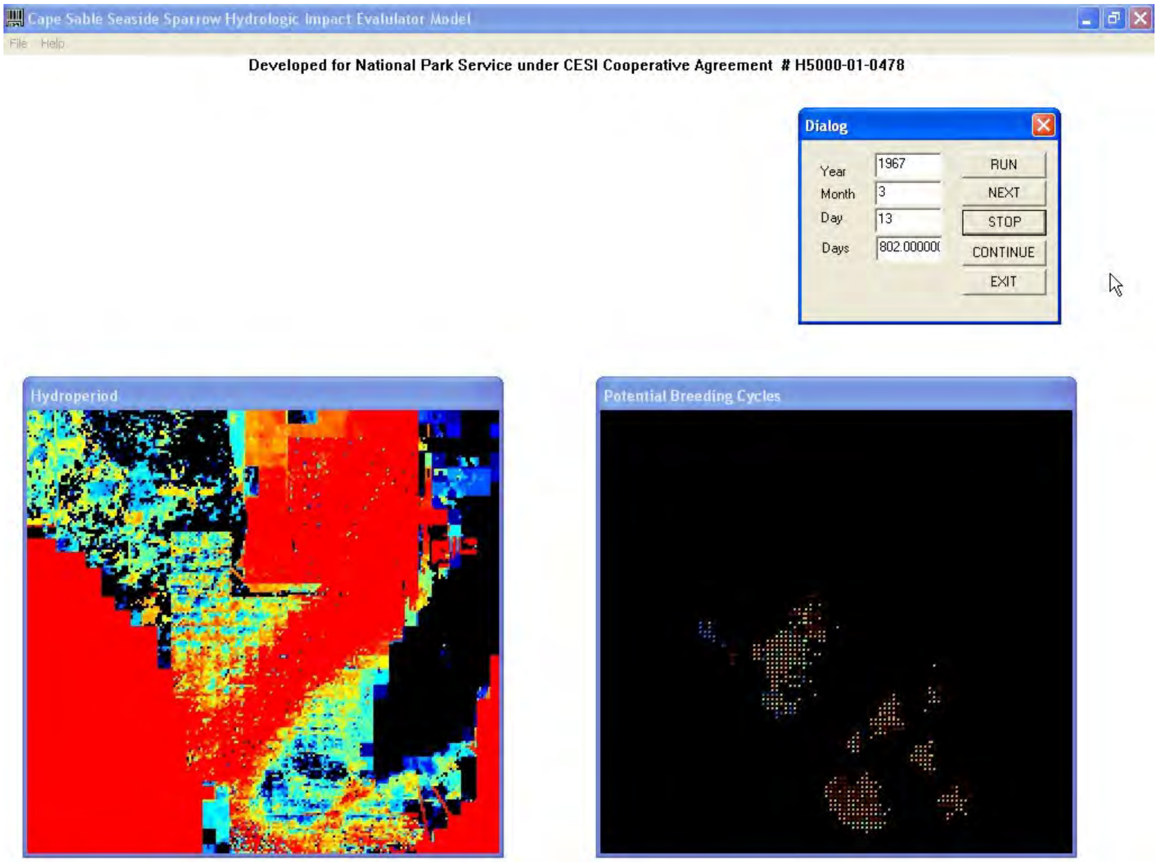
Cape Sable Seaside Sparrow Hydrologic Impact Evaluator Model
File Help
Developed for National Park Service under CESI Cooperative Agreement # H5000-01-0478
Dialog
Year 1967
Month 3
Day 13
Days 802.00000(
RUN
NEXT
STOP
CONTINUE
EXIT
Hydroperiod
Potential Breeding Cycles

Figure 3.

Appendix B

Effects of Two Hydrologic Scenarios on the Cape Sable Seaside Sparrow

A Comparative Analysis of Two Hydrologic Scenarios: The impact on the Potential Nesting Cycles of the Cape Sable Seaside Sparrow

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Introduction

The Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) was among the first group of species listed as endangered by the U.S. Fish and Wildlife Service on March 11, 1967. The sparrow is sensitive to hydrological conditions. Changes in water flows through the sparrow's range have the potential to affect the present population. Because of this, any human caused changes to the present hydrology must take potential effects to the sparrow population into account.

The primary sparrow habitat is intermediate hydroperiod marl prairies. Within this general category, the sparrows avoid both deep water and areas with woody vegetation. At present, the sparrow seems to be primarily distributed in the mid-northern and eastern areas of the Everglades National Park. They are divided into 6 populations, A-F (see Figure 1). These populations are separated by either areas of long hydroperiod or woody vegetation. As Cape Sable Seaside Sparrows seldom move more than a couple of kilometers from where they fledged and also try to avoid crossing unsuitable habitat, these populations tend to act separately from a demographic standpoint. In addition, each of the areas containing the different populations is subject to different environmental effects.

In this analysis, we compare the impact of hydrological scenarios on the potential nesting cycles of the Cape Sable Seaside Sparrow, using a newly developed quantitative tool—the Hydrological Impact Evaluator (HIE).

Methods

1. Hydrological Scenarios

Two hydrological scenarios are generated by the South Florida Water Management Model (SFWMM, or, 2x2). They are the West Bookend Version 010405 (Wc51) and the East Bookend scenario (East). These scenarios contain different structural components and operation schemes, which result in different spatial and temporal distributions of water in the Everglades National Park and in the vicinity areas.

2. Hydrological Impact Evaluator

A. Biology of the sparrow

Sparrows breed during the Everglades dry season, starting nesting after March 15th. Most pairs only attempt one nesting cycle per year, with some pairs attempting a second nest and even fewer a attempting three nesting cycles. Each cycle takes about 45 days to finish. Thus, only few nests are found after August 1st. Because Sparrows build their nests very close to the ground, with an average height at 16 cm, water depth during the breeding season is a critical factor for nesting success. If water level rises and sparrow nests are flooded, the nesting cycle is terminated. There are many other possible impacts of hydrology on the sparrow population, both direct and indirect, (see discussion) but clearly one of the most the most fundamental criteria for breeding success is water depths below the height of the nest.

B. HIE structure

The Hydrological Impact Evaluator (HIE) is designed to evaluate the one potential effect of different hydrologic scenarios on the breeding cycle of the Cape Sable Seaside Sparrow nest flooding during the breeding season. Figure 2 describes the major components of the HIE model.

There are three major areas of model input, per day water depths, user input/biological data, and selection of sample points. The HIE uses a script developed by the ATLSS project to increase the resolution of the SFWM model from 2X2 miles to 500X500 meters which is a more appropriate resolution for analyzing potential effects of hydrology sparrow dynamics. The script takes as input a standard SFWM model scenario output (water depth) and passes it over a high resolution topographic map to create a new water depth output file at the finer resolution. As this script presently can only be run on a Unix system and is done externally and prior to the model run. The output file of the script is then used as an input to the HIE model. The user input allows modification of model parameters that include defining the beginning and ending dates of the sparrow's breeding season, the maximum water depth at which nesting attempts will begin, the water depth at which nests will flood, and the beginning and ending dates of the hydrologic scenario. The points within the SFWMM that are monitored were chosen to match those sampled by the field biologists. However, the field data also includes control sample points in non-sparrow habitat. The ATLSS sparrow high resolution vegetation map was used to filter out the non-sparrow habitat points in the field data resulting in a total of 609 instrumented points on the high resolution water depth map.

The model processes data on a daily basis. Starting the date specified by the user input, the water depth for each cell is read from the hydrologic input file. If the date is within the breeding season, the state of each monitored cell is updated. The first time the water depth drops below 5 cm. within the cell during the breeding season the first nesting cycle begins. Each day during the breeding season the new water depth is compared against the nest flooding depth (by default 16 cm.) If the water is below the flood depth the cycle continues. If there are 45 consecutive days of below flood water depths then the cycle is completed successfully. If the water reaches flood depth, the cycle is terminated and a new cycle is attempted when the water again recedes to under 5 cm. The first nesting cycle requires 45 days to complete, the second and third 40 days. There are a maximum of three nesting cycles that can be attempted per breeding season.

C. Model output

The model reports the maximum number of nesting cycles possible per year per instrumented cell, a value between 0 and 3. At this time, the model produces two major results, the maximum number of nesting cycles that could have been completed, the number of days with standing water below flood depth and the number of dry ground days per monitored cell per year. This data is output in three forms, the data for each cell for each year, the data for each population for each year, and the overall average of all the monitored cells over all years. There is also a standalone utility program available that takes the output of two different scenarios and creates files that can be imported into ArcMap to produce spatial plots of the data.

D. Model Uncertainty

There are several sources of potential error in our model. The largest error comes from the SFWM hydrologic model. Its error is actually larger than the mean height of the sparrow nests. However, a reasonable assumption is that the error in the hydrologic model remains constant between scenarios and therefore it is still reasonable to compare the results of two different hydrologic scenarios. Other potential errors in the model come from the estimates of biological parameters such as breeding season and nest height.

Results

The impacts of hydrological scenarios vary at different locations and at different spatial and temporal scales. At the first look, we saw very little difference between the two hydrological scenarios. This is particularly true, when we lumped the scores over all 36 years and all sites into one statistic (Table 1). In Table 1, the mean value is the average of the mean results of each of the populations. This was done (as opposed to averaging over all points) to give equal weight to each population given that most sample points reside in either population A or B. Figure 3A shows the 36 year time series associated with the overall mean value. Again there is no significant different between the two time series exist in any year.

At sub-population level, the temporal trajectories indicate some consistent differences between two scenarios at certain years. Figures 3B-G shows the 36 year time series for populations A-F respectively. In this case we see that although averaged over 36 years, each of the populations shows little difference, there are potentially significant differences in some years. In Figure 3B, both in very wet years (1970, 1980, 1983, 1995) and very dry years (1971, 1981, 1985, 1989, 1990) there is no difference between the two scenarios. In intermediate years however, East provides the potential for more nesting cycles than does Wc51. This can be by as much as the 0.75 cycle difference in the year 2000. Figure 3C shows the time series for Population B. There is no difference between Wc51 and East in this population. Figure 3D shows the time series for population C. There is a large difference between Wc51 and East in wet years (1970, 1980, 1983, 1995, and 1998) with two years, 1970 and 1883 having a difference of a full nesting cycle.

Outside of very wet years there is no difference between the two scenarios in population C. Figure 3E shows the time series for population D. For the very wet years of 1970, 1983, 1995 and 1998 Wc51 provides a significant buffer over East with the difference in 1998 greater than one full nesting cycle. Figure 3F shows the time series for population E. There is no measurable difference between the two scenarios for population E. Figure 3G shows the time series for population F. It shows some minor buffering under Wc51 in 1970, 1983, 1995 and 1998 with a one cycle advantage under Wc51 in 1980.

It is useful to look at not only time series but also spatial distributions of the maximum nesting cycle data. Spatial trends differ between two scenarios, reflecting the different water distribution in space. Figures 4-7 show this data for the average over all the populations over 36 years, a sample very wet year (1995) a sample very dry year (1981) and a sample intermediate year (1996). Figure A shows the difference between the two scenarios (Wc51-East) for each sampled point and Figures B and C show the maximum number of nesting cycles for Wc51 and East respectively. As would be expected from the data in Table 1, Figure 4A shows the two scenarios having little performance difference in the central populations of B and E, while East performs slightly better in the western population A and Wc51 performs slightly better in the eastern populations C, D, and F. Figures 4B and C show clearly that population A suffers more from nest flooding under either scenario than any of its 5 siblings. Figure 5 shows the spatial data for a very dry year, 1981. In this case the performance of the two scenarios is identical and nest flooding only occurs in 7 sites in the south and west of population A. (Those seven sites also show no cycles in Figure 4 and are apparently always flooded at least within the error bounds of the SFWM hydrologic model.) For 1995 (a very wet year) there is virtually no difference between the two scenarios in populations A, C, E, and F with Wc51 performing slightly better in populations C and D. Here population A basically has no reproduction occur during the breeding season in either scenario. Finally, Figure 7 shows an example of the spatial distributions of potential nesting cycles for an intermediate year. Although Wc51 has some minor performance advantage in the eastern part of population E, as well as populations C and F, population A is where the major difference in the two scenarios occurs. Under the East scenario, almost every point in population A has water depths low enough to allow at least one cycle to occur whereas under Wc51 there would be at least 40 sites that would be flooded the entire breeding season.

Discussion

From a global perspective, there is little to no difference between the two hydrologic scenarios with respect to the number of potential sparrow breeding cycles. If the average over space and time were used as a performance measure, the difference would be five hundredths of one nesting cycle. However, this ignores a majority of the available data.

From the standpoint of potential sparrow nesting cycles, there are three general trends. East provides a slightly better result than Wc51 in the western most population, A. There is no significant difference between the two scenarios in the central populations B and E. In the eastern populations C, D, and F, Wc51 provides a better result.

Another important aspect of sparrow nesting success is contained in some additional sparrow biology. In general, only about 60% of the sparrow population attempts a second nest and only 30% attempts a third nest. The success of the second and third nesting attempts is only about 20% in each case. Therefore, the availability of water levels allowing multiple nesting cycles takes on less importance than the ability of the sparrows to complete the first cycle each year. It would take a number of years at 2-3 nesting cycles per year to make up for the loss of all cycles as happens in the very wet years. From this standpoint, Wc51 seems to provide a buffer against these flooding events in populations C and D and to a lesser extent F.

For population A, neither scenario provides a buffer against the very wet years. However, in the intermediate years as demonstrated by figure 7, although overall East only provides on average half a nesting cycle improvement, it has a major advantage over Wc51. This is because it provides at least one nesting cycle in at least 40 sites where Wc51 is flooded for the entire breeding season.

As important as understanding what information a model does provide is understanding its limitations. For the HIE model, there are three primary areas that must be understood.

Non-hydrologic biological factors: The HIE model does not predict the magnitude of sparrow populations or number of sparrows, it only predicts the maximum number of breeding cycles that could occur given a particular hydrologic scenario from the standpoint of nest flooding. Many other factors affect the actual sparrow population including, but not limited to, predation, food supply, dispersal, and number of eggs produced.

Non-breeding season and long term hydrologic factors: Non-breeding season hydrology is also important. Very wet or very dry off season conditions could increase the breeding season fire risks or affect the sparrow’s food supply. Very dry long term hydrologic factors can cause the intrusion of woody vegetation into sparrow habitat making is unusable by the sparrows. Consistent flooding in the wet season also has the potential to modify vegetation types to less desirable sparrow habitat.

Non-flooding factors: The nest predation rate seems to depend on water depth and particularly on the presence or absence of water. As non-flooding nest destruction such as nest predation accounts for the vast majority of loss of young and eggs, standing water below nest flooding depth has the potential to have far more impact on sparrow nesting success than nest flooding.

In conclusion, given the limitations of our model, to maximize the chance of nesting success in wet years for the eastern populations (C, D, and F) Wc51 would be a better choice. To maximize the nesting success of the western population (A) East would be the best choice. The central populations (B and E) would be little effected by choice between these two scenarios. Perhaps a more important result of this study is its demonstration that of the importance of analyzing all of the output of a model that with potentially complex dynamics over space and time. Were the results to have been limited to a single result scaled 0-1, the conclusion would have been that there was no difference between the two hydrologic scenarios. Even looking at the time series averaged data for each population, the difference is so small that there is basically no difference between the two hydrologic scenarios. It is only by looking at the data over both space and time that clear determination could be made of the potential effects of the two scenarios on the different sparrow populations.

Table 1. Average maximum number of nesting cycles 1965-2000 for two alternate hydrologic scenarios. Wc51 is the West Bookend scenario version 010405 and East is the East Bookend scenario. The 36 year average of the maximum number of nesting cycles available to the sparrow population with respect to nest flooding are listed for each population (A-F). The mean is the average of all six population results.

Figure 1. The locations of the sparrow populations A-F in Everglades National Park and immediate vicinity.

Figure 2. A block diagram of the major components of the Hydrologic Impact Evaluator. Elements in red were provided by the ATLSS project, elements in blue were provided by Everglades National Park personnel.

Figure 3. 36 year time series of maximum number of nesting cycles with respect to nest flooding for two hydrologic scenarios Wc51 (West Bookend scenario version 010405) and East (East Bookend). The global mean (A), and individual populations A-F (B-G).

Figure 4. Spatial distribution of mean (36 years) of maximum number of nesting cycles with respect to nest flooding. Difference between Wc51 scenario and East scenario (A), Number of nesting cycles for Wc51 scenario (B), number of nesting cycles for East scenario (C).

Figure 5. Example spatial distribution for very dry year (1981). Maximum number of nesting cycles with respect to nest flooding. Difference between Wc51 scenario and East scenario (A), Number of nesting cycles for Wc51 scenario (B), number of nesting cycles for East scenario (C).

Figure 6. Example spatial distribution for very wet year (1995). Maximum number of nesting cycles with respect to nest flooding. Difference between Wc51 scenario and East scenario (A), Number of nesting cycles for Wc51 scenario (B), number of nesting cycles for East scenario (C).

Figure 7. Example spatial distribution for intermediate year (1996). Maximum number of nesting cycles with respect to nest flooding. Difference between Wc51 scenario and East scenario (A), Number of nesting cycles for Wc51 scenario (B), number of nesting cycles for East scenario (C).

Tables and Figures

Table 1. Average Maximum Number of Nesting Cycles 1965-2000

	W010405	East	Difference
Mean	2.47	2.42	0.05
A	1.88	2.12	-0.23
B	2.75	2.74	0.01
C	2.60	2.38	0.22
D	2.69	2.54	0.15
E	2.47	2.47	0.00
F	2.44	2.29	0.15

Figure 1.

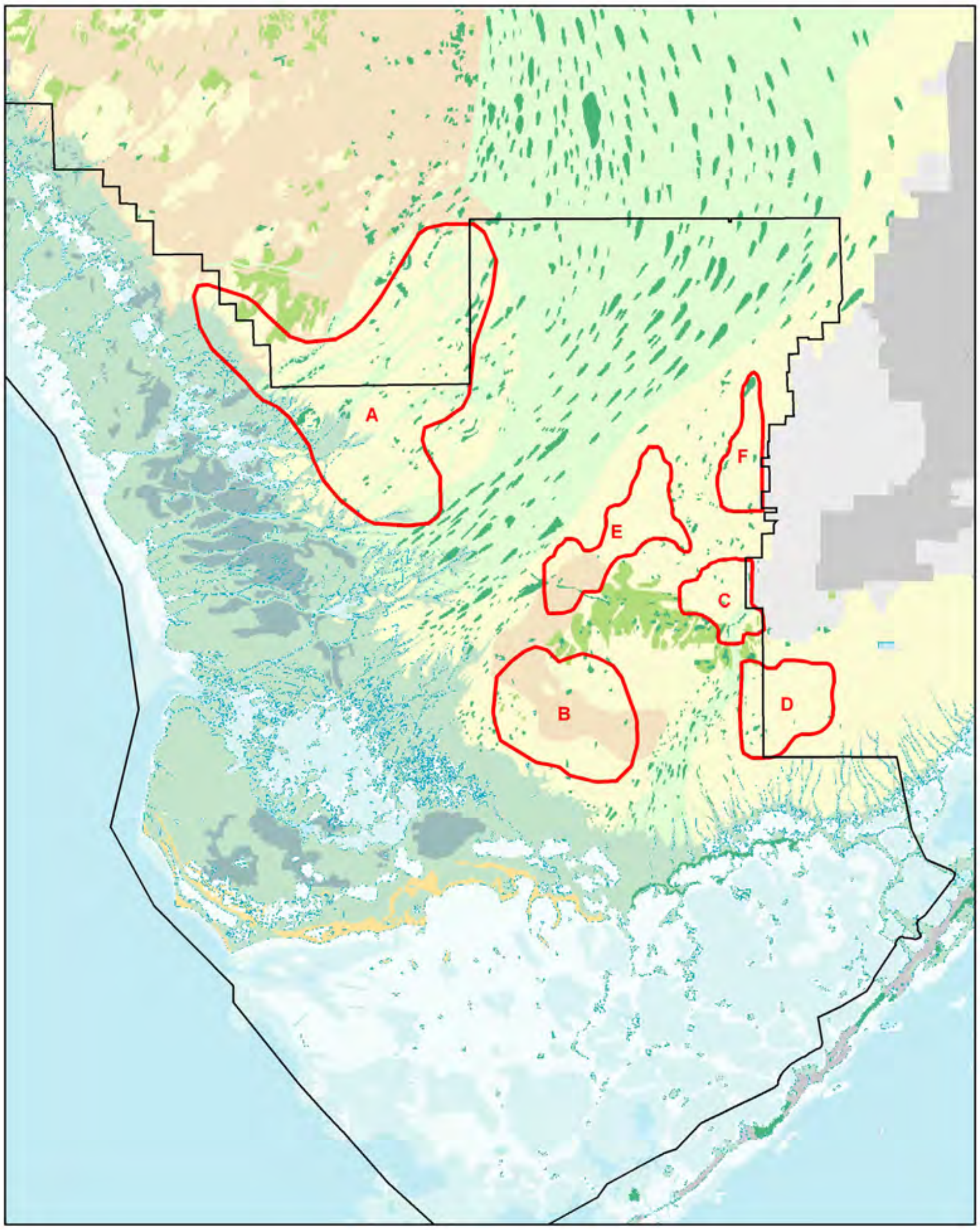


Figure 2.

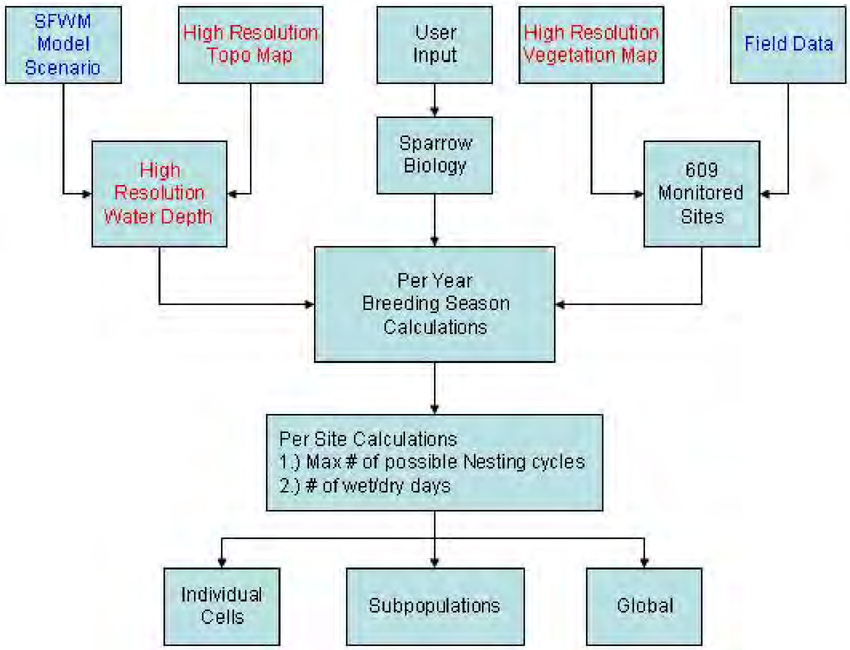

SFWM Model Scenario
High Resolution Topo Map
User Input
High Resolution Vegetation Map
Field Data
High Resolution Water Depth
Sparrow Biology
609 Monitored Sites
Per Year Breeding Season Calculations
Per Site Calculations
1.) Max # of possible Nesting cycles
2.) # of wet/dry days
Individual Cells
Subpopulations
Global

Figure 3A.

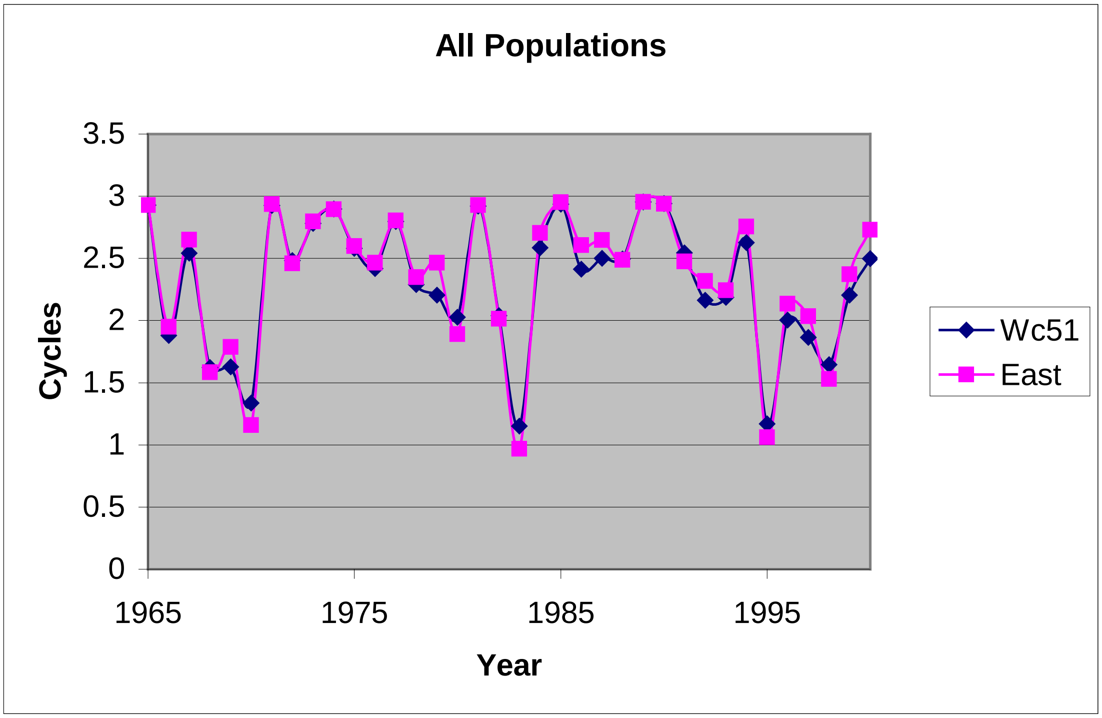


Figure 3B.

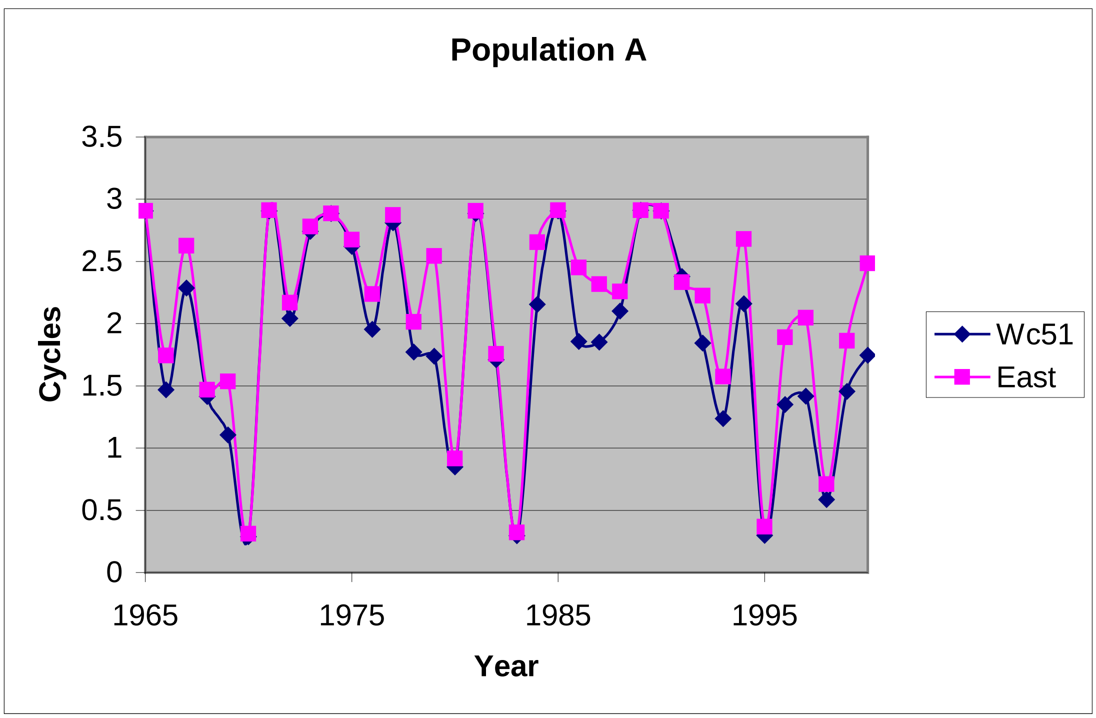


Figure 3C.

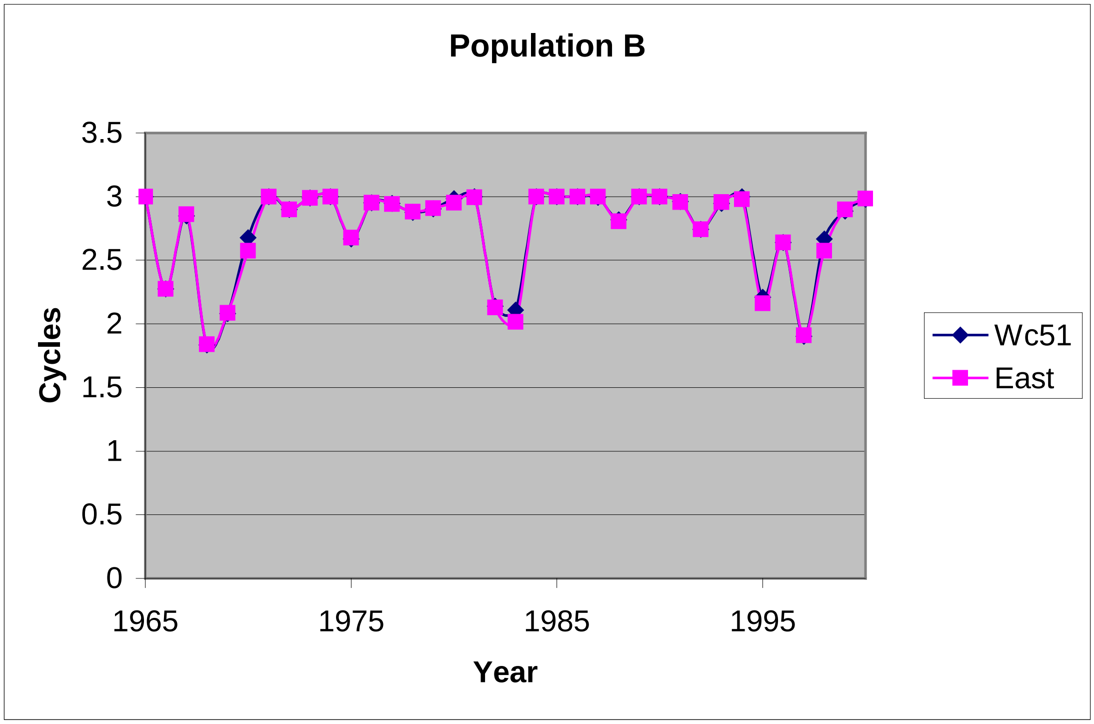


Figure 3D.

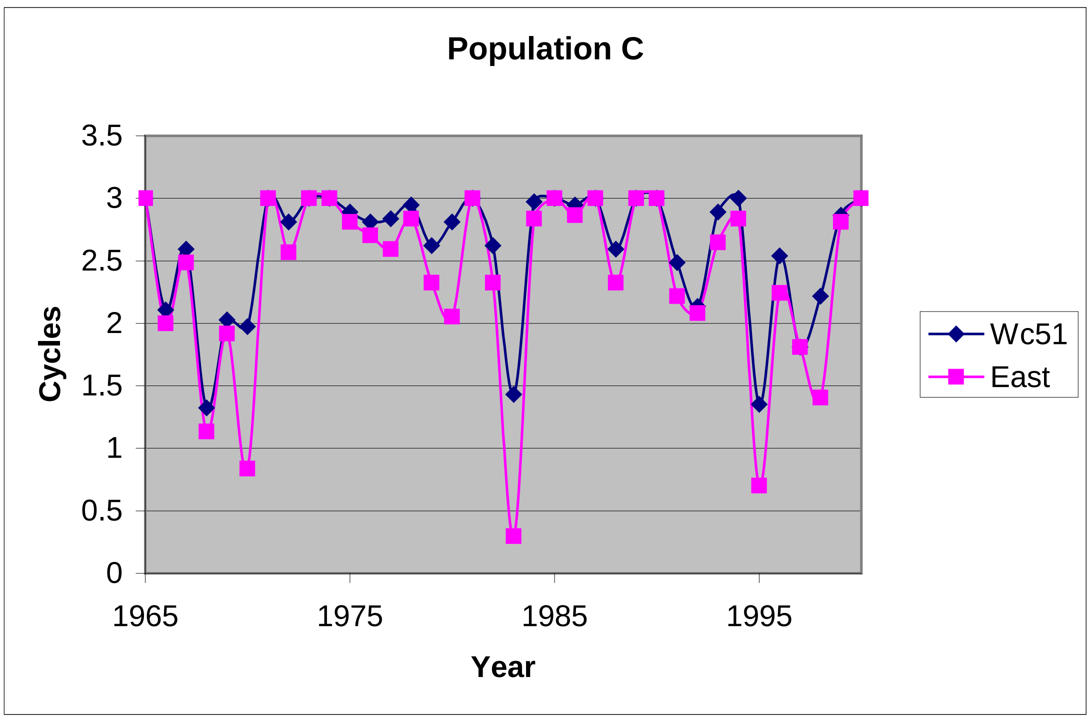


Figure 3E.

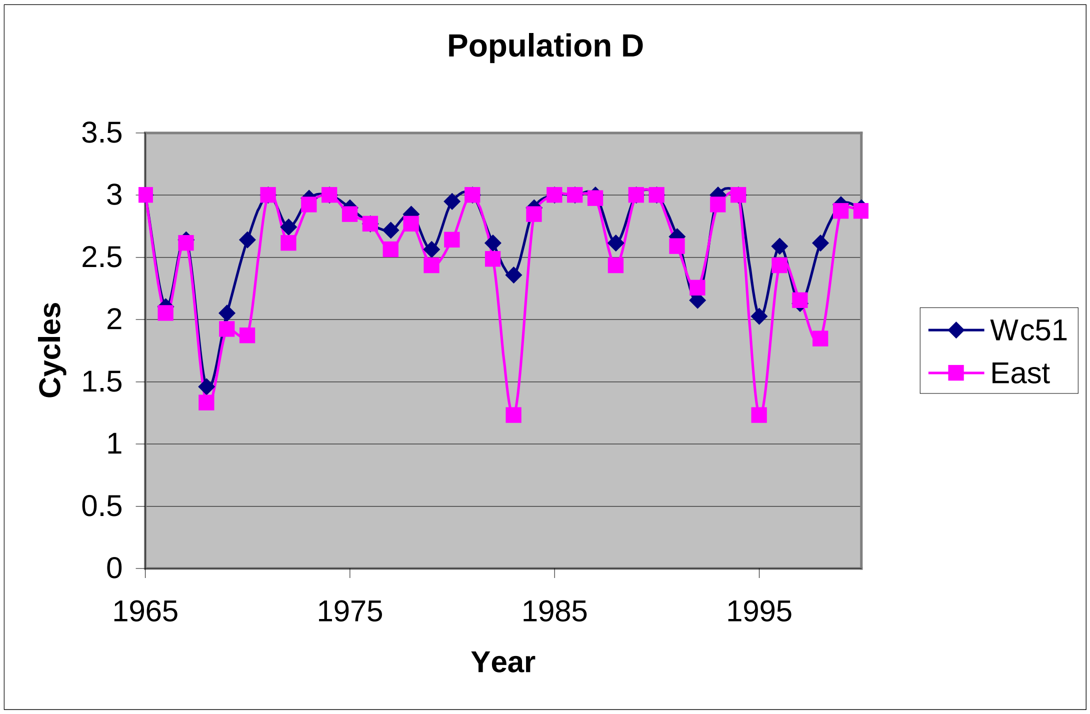


Figure 3F.

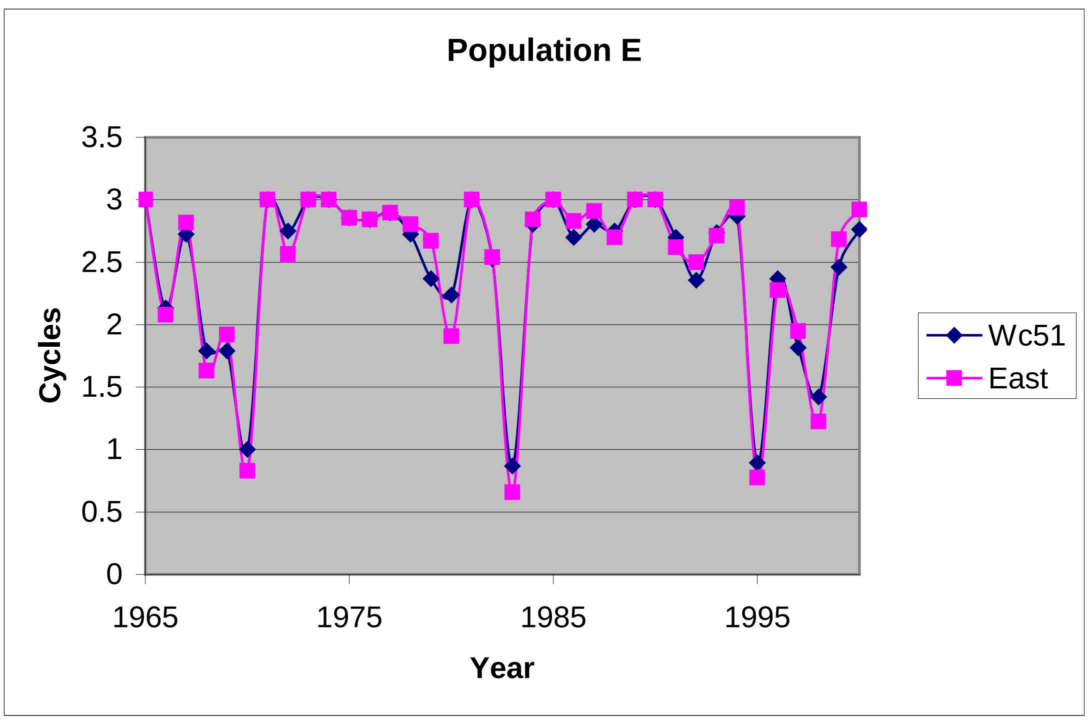


Figure 3G.

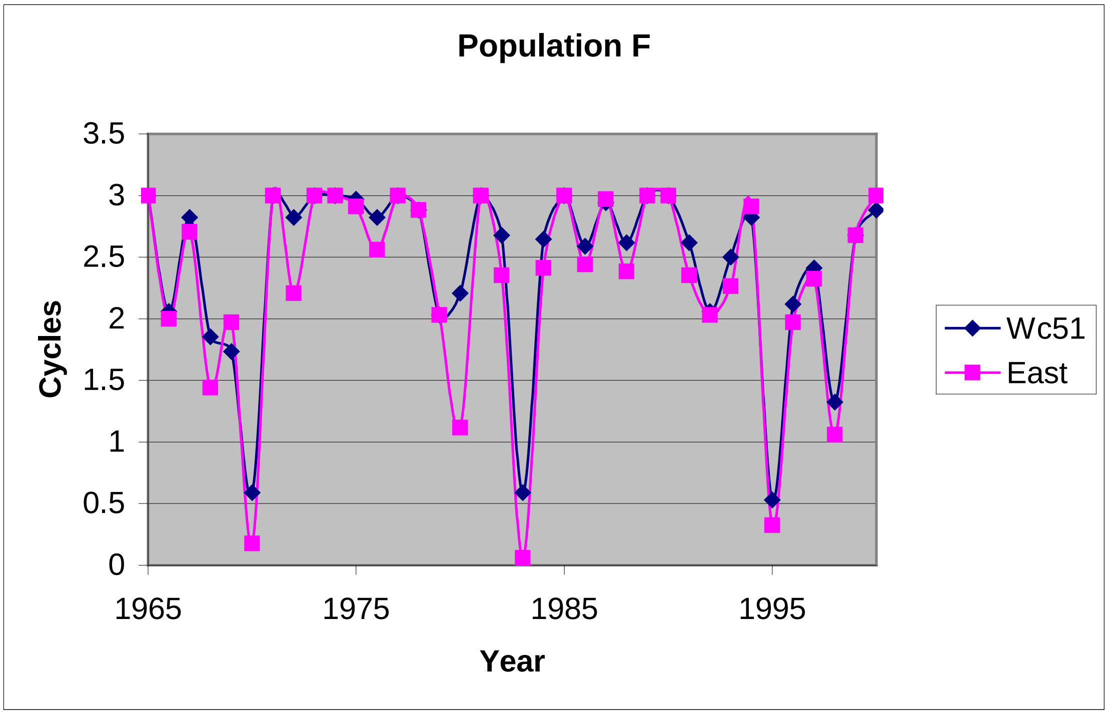

Population F
3.5
3
2.5
2
1.5
1
0.5
0
Cycles
1965
1975
1985
1995
Year
Wc51
East

Figure 4A.

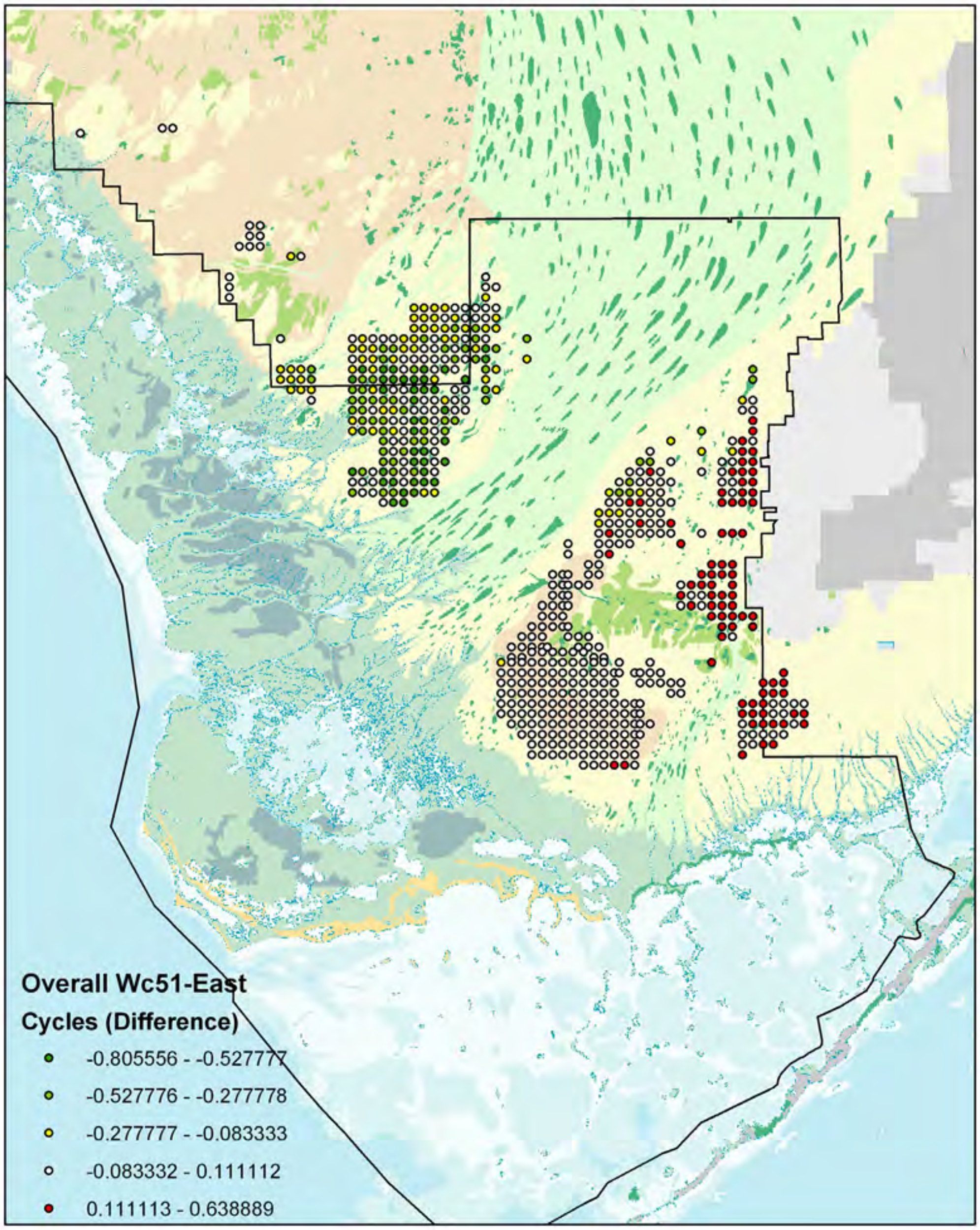

Overall Wc51-East
Cycles (Difference)
-0.805556 - -0.527777
-0.527776 - -0.277778
-0.277777 - -0.083333
-0.083332 - 0.111112
0.111113 - 0.638889

Figure 4B.

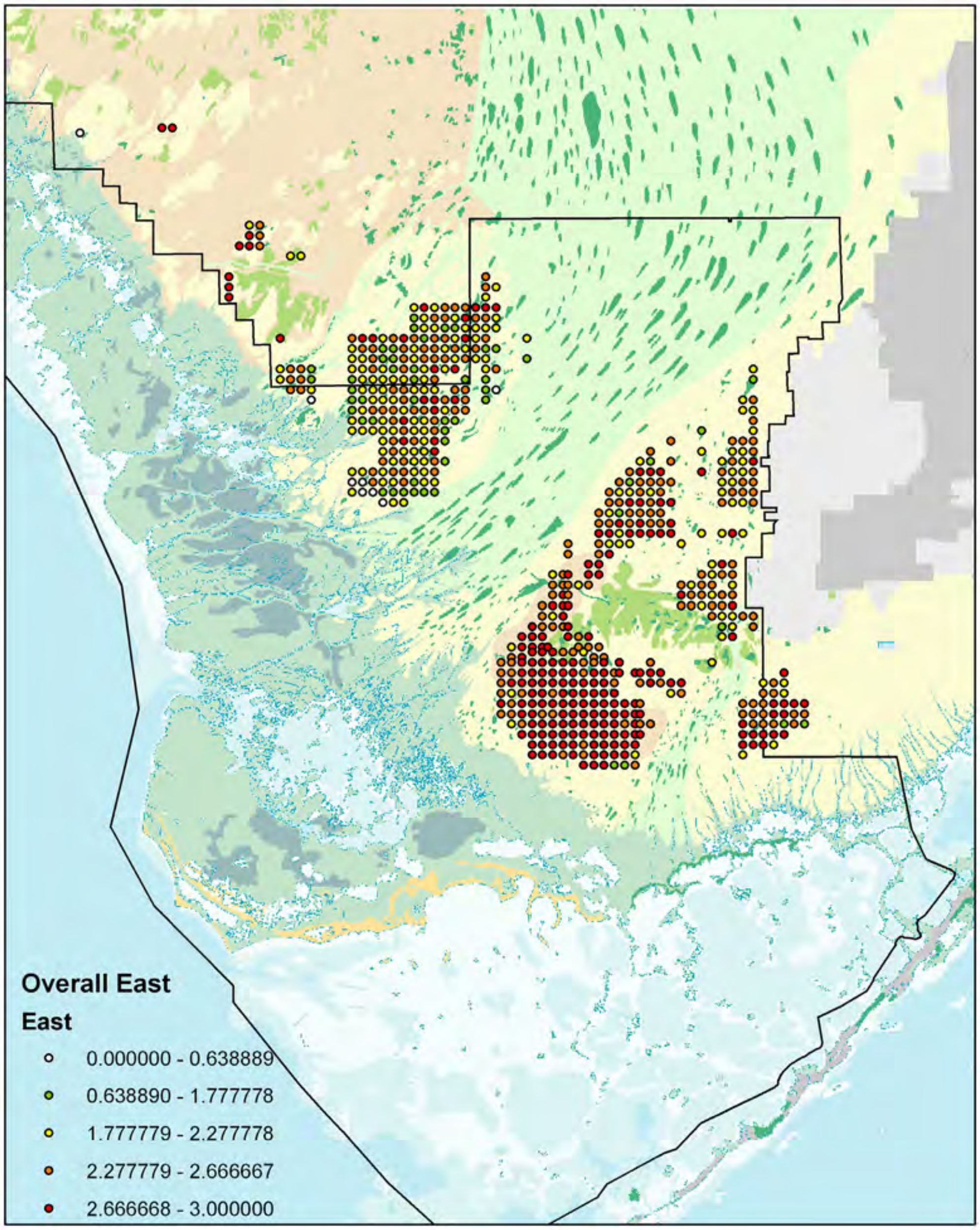

Overall East
East
0.000000 - 0.638889
0.638890 - 1.777778
1.777779 - 2.277778
2.277779 - 2.666667
2.666668 - 3.000000

Figure 4C.

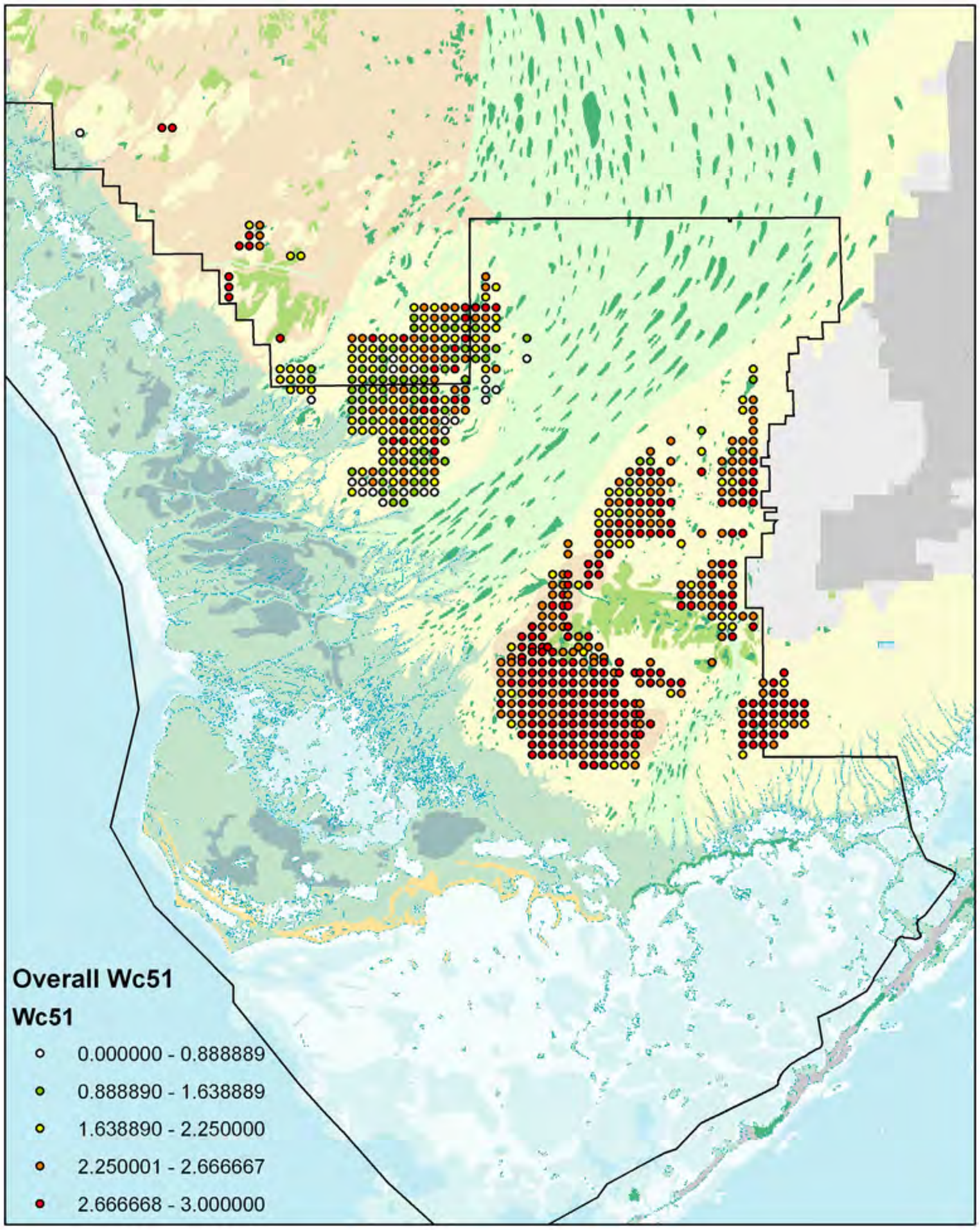

Overall Wc51
Wc51
0.000000 - 0.888889
0.888890 - 1.638889
1.638890 - 2.250000
2.250001 - 2.666667
2.666668 - 3.000000

Figure 5A.

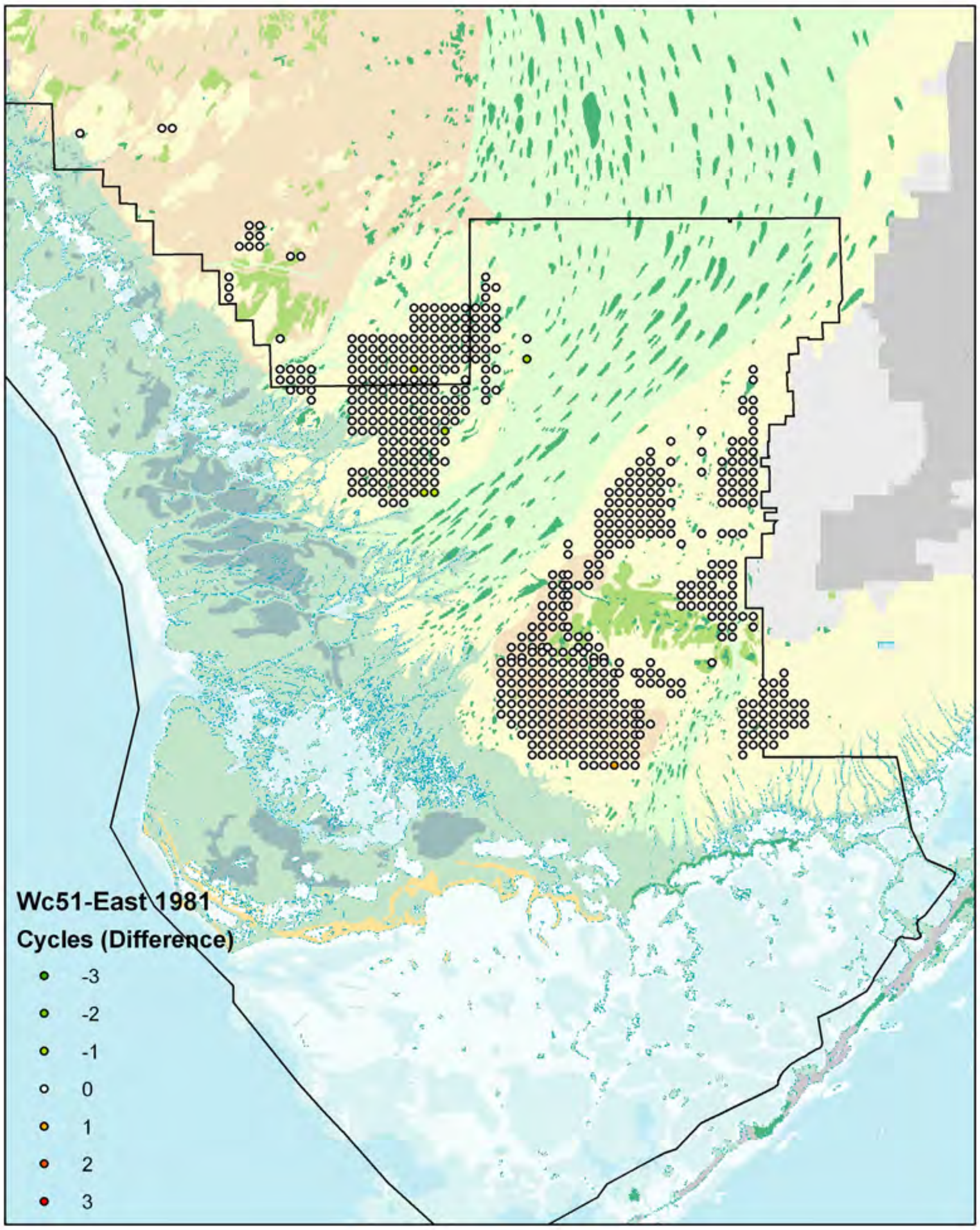


Figure 5B.

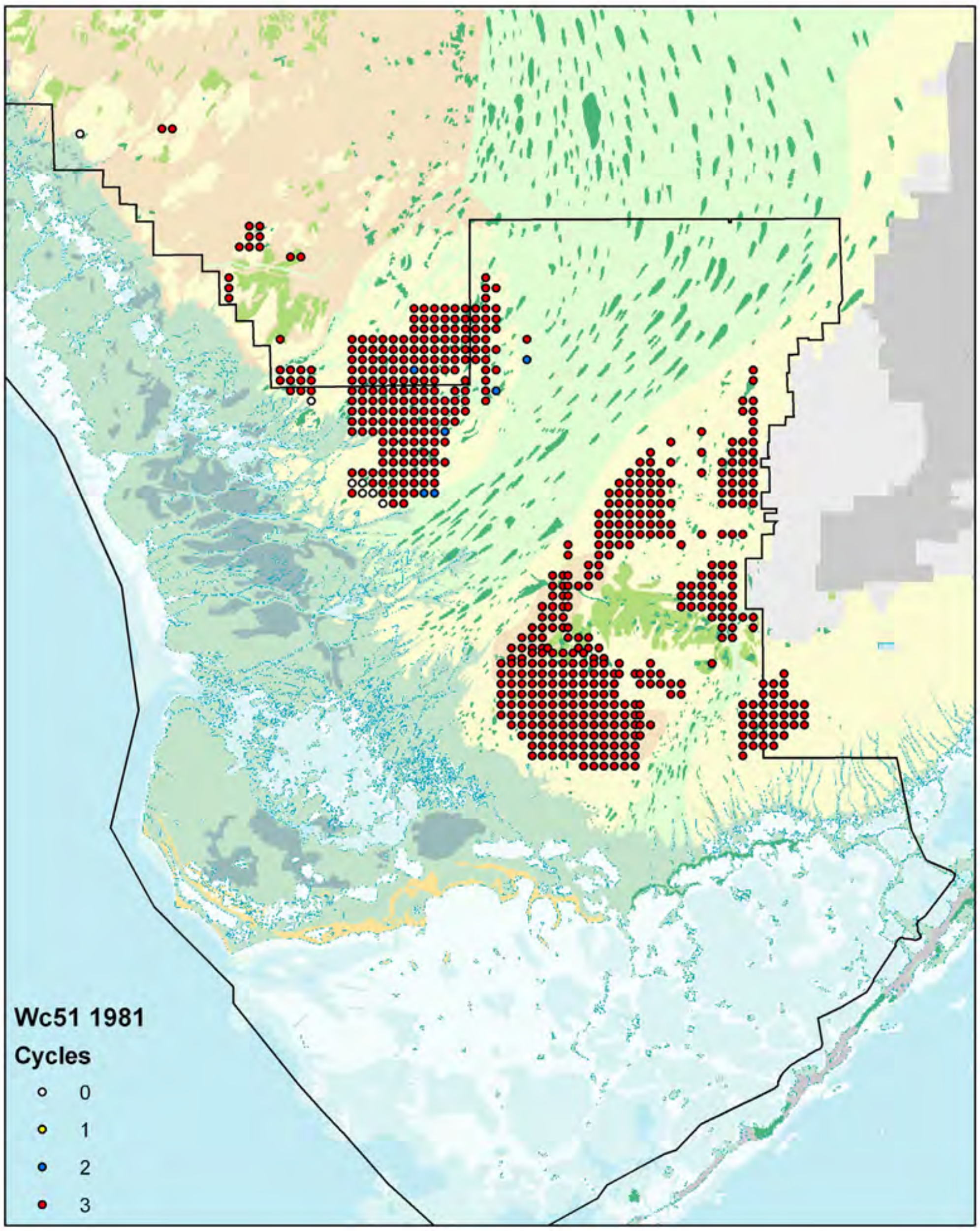


Figure 5C.

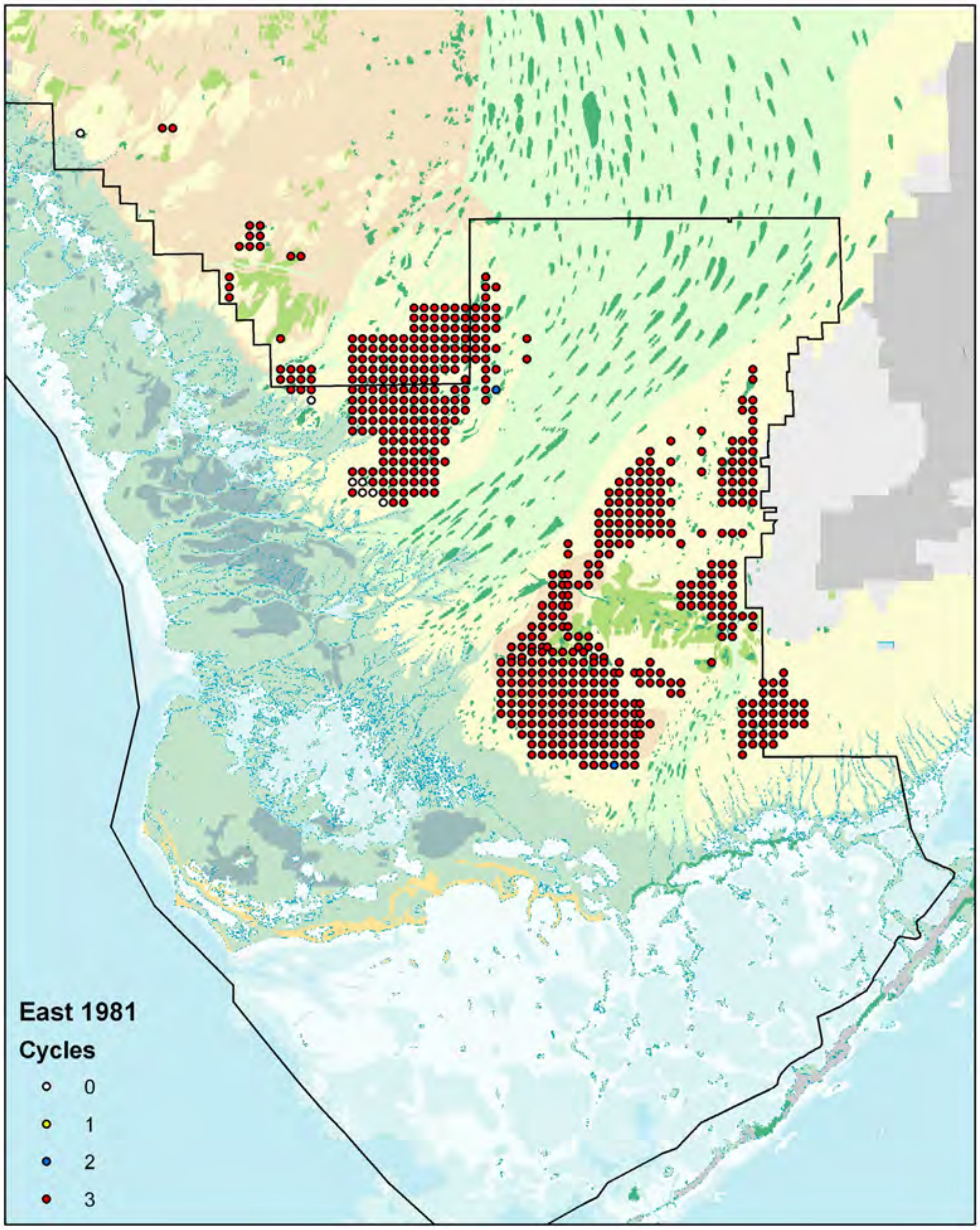


Figure 6A.

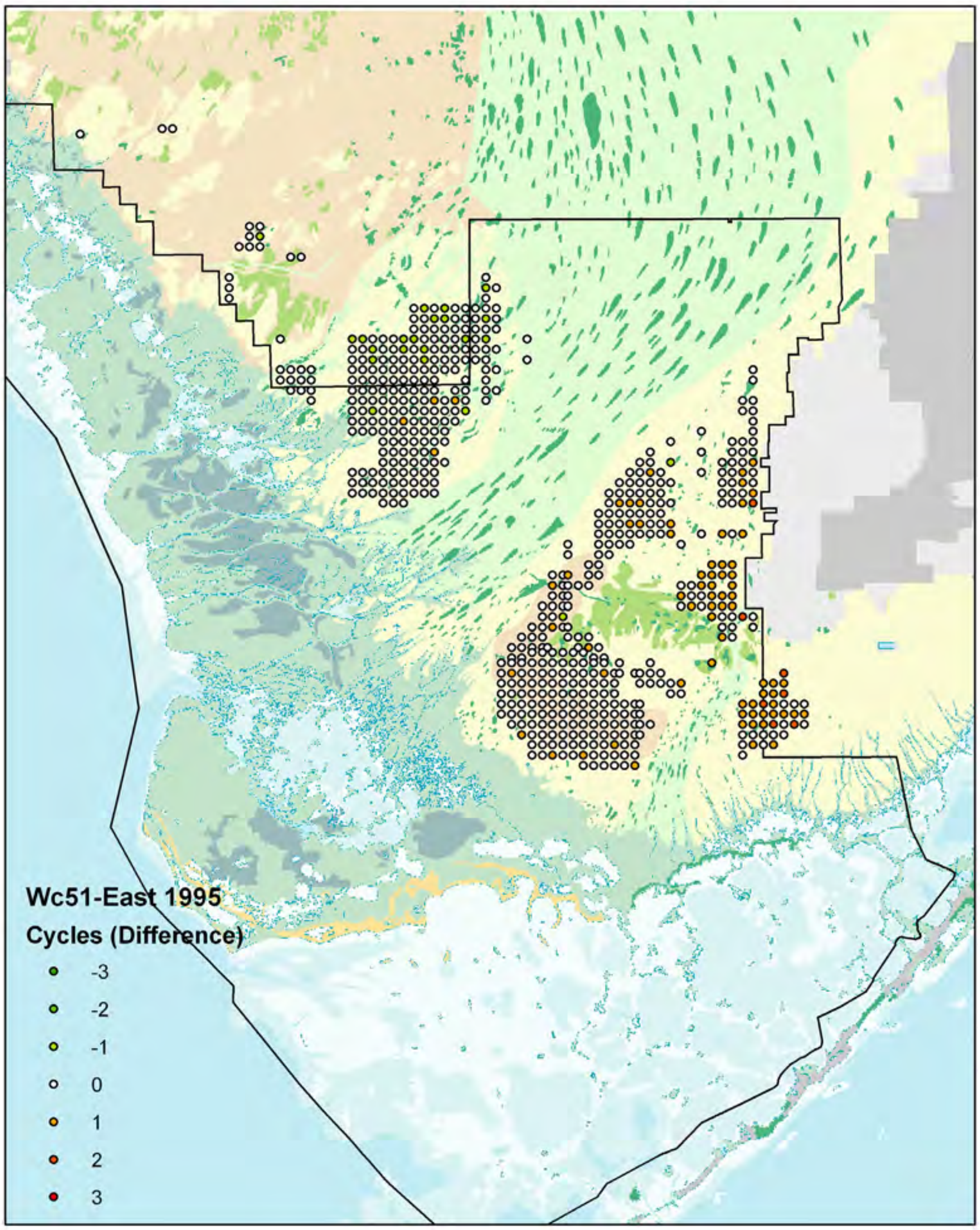


Figure 6B.

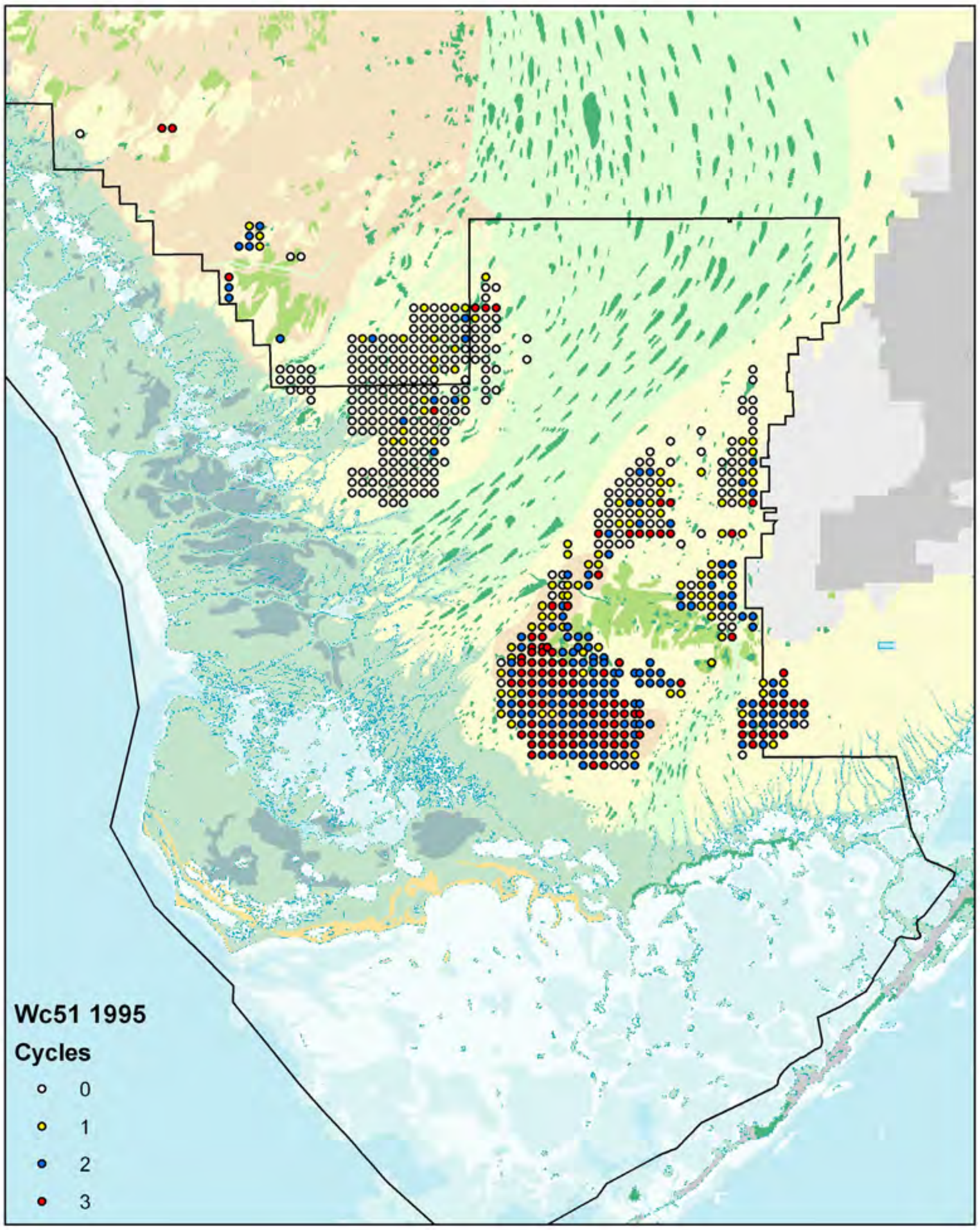


Figure 6C.

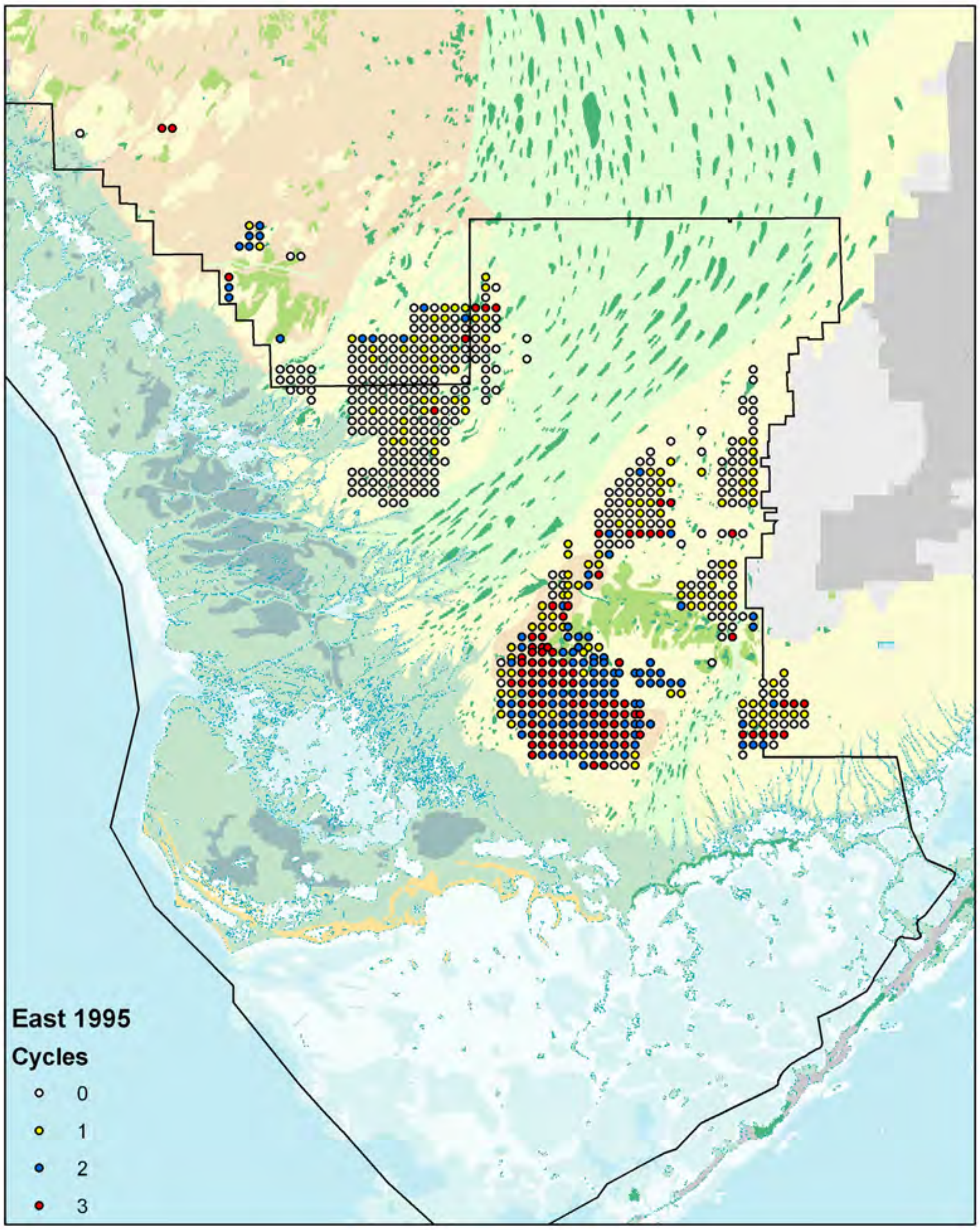


Figure 7A.

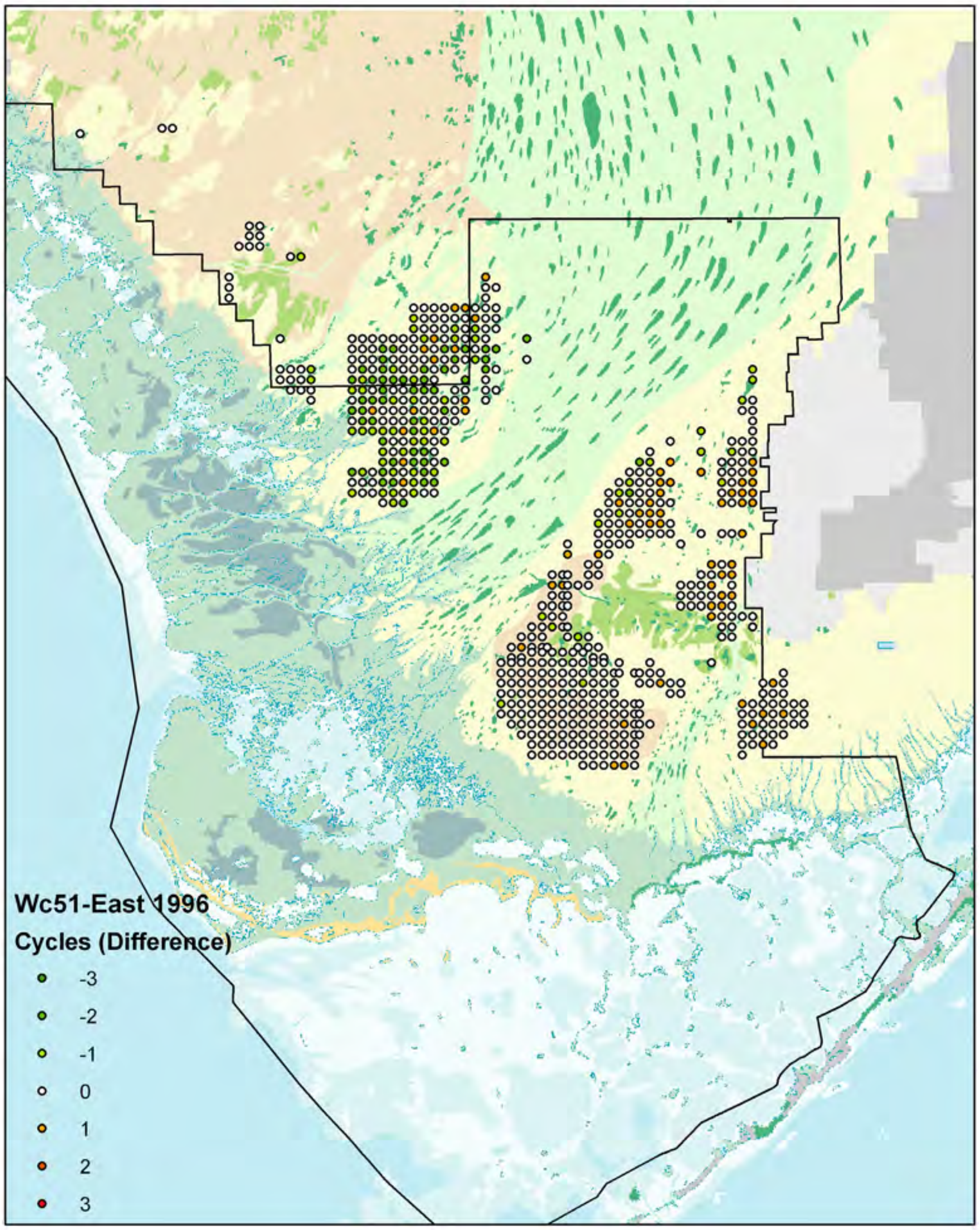


Figure 7B.

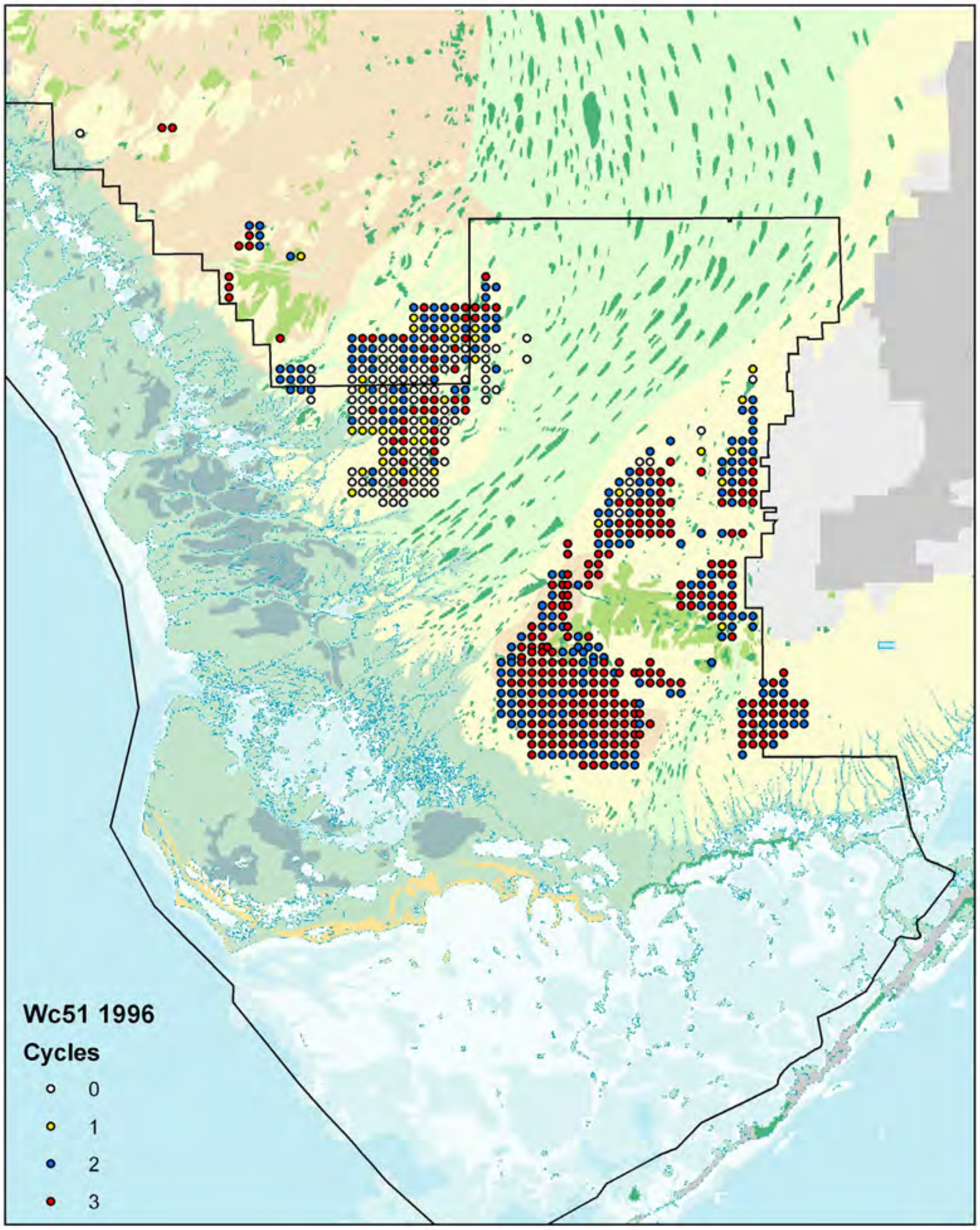
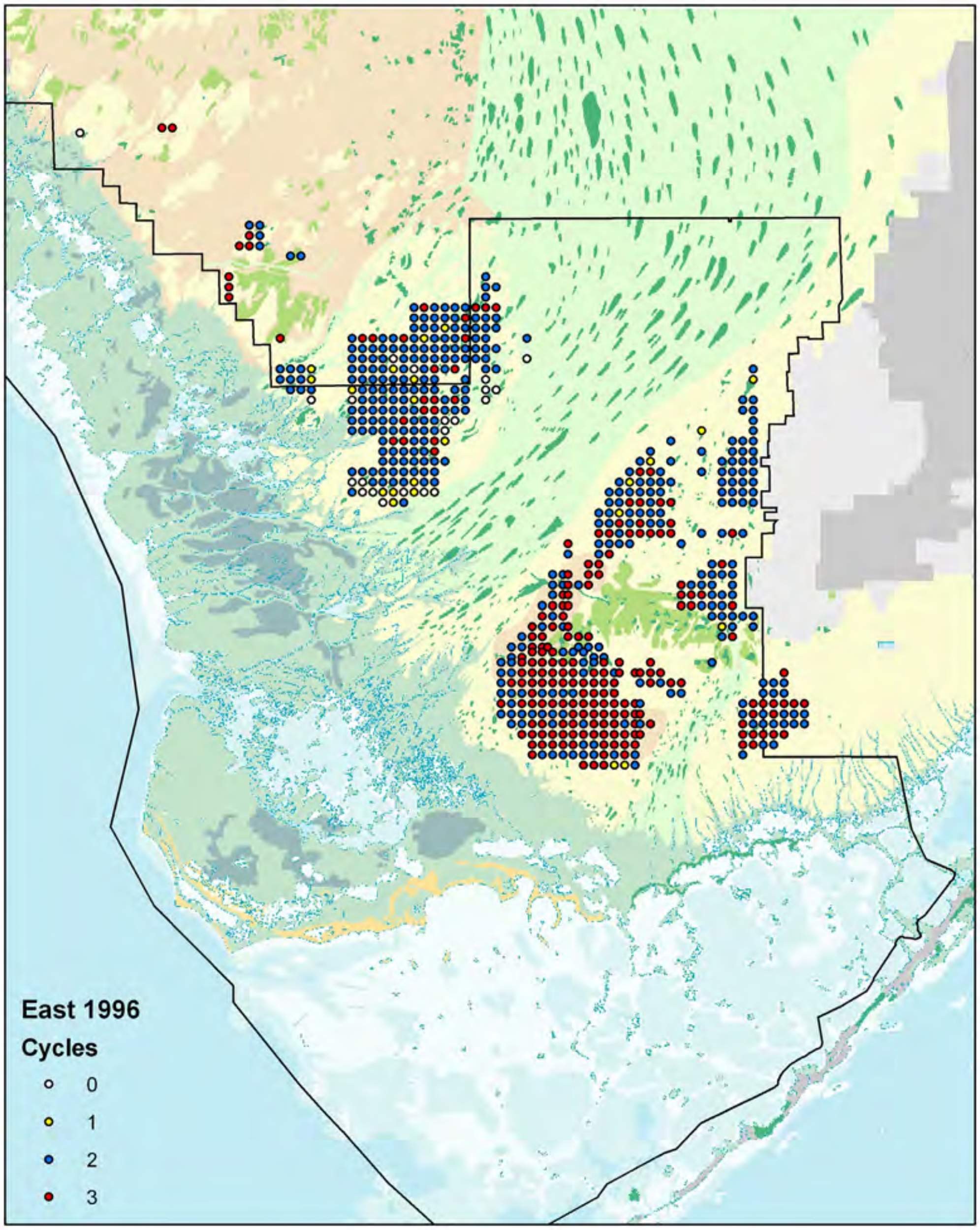


Figure 7C.



A Comparative Analysis of Nine CSOP Hydrologic Scenarios: The impact on the Potential Nesting Cycles of the Cape Sable Seaside Sparrow

Introduction

The Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) was among the first group of species listed as endangered by the U.S. Fish and Wildlife Service on March 11, 1967. The sparrow is sensitive to hydrological conditions. Changes in water flows through the sparrow's range have the potential to affect the present population. Because of this, any human caused changes to the present hydrology must take potential effects to the sparrow population into account.

The primary sparrow habitat is intermediate hydroperiod marl prairies. Within this general category, the sparrows avoid both deep water and areas with woody vegetation. At present, the sparrow seems to be primarily distributed in the mid-northern and eastern areas of the Everglades National Park. The overall sparrow population is divided into 6 geographical populations, A-F (see Figure 1). These populations are separated geographically by areas of long hydroperiod or woody vegetation. Based on their position in the landscape, each of the subpopulation habitats is subject to different environmental effects. As Cape Sable Seaside Sparrows seldom move more than a couple of kilometers from where they fledged, and also try to avoid crossing unsuitable habitat, these populations tend to be demographically decoupled (Pimm et al. 2002.)

Bass and Kushlan (1982) conducted the first extensive survey of the Cape Sable Seaside Sparrow Population in 1981. This was repeated in 1992 and has been performed annually since. The survey is done by dropping observers at sites on a grid that covers all known sparrow habitat, both previous and present. The sampling resolution is 1 km. The observers count the number of birds in the area by listening for singing males. The observers also take surface water depth samples and estimate vegetation type and cover (Pimm et al. 2002.) From 2003-2005 Ross et al. (2005) have done a much more detailed survey of the vegetation types that make up the areas in which sparrows are found. These surveys were conducted in approximately the same sites as the population census'. These studies, as well as many others (Pimm et al. 2002) make the sparrow one of the most studied species in the Greater Everglades system.

In this analysis, we compare the impact of hydrological scenarios on the potential nesting cycles of the Cape Sable Seaside Sparrow, using a newly developed quantitative tool, the Hydrological Impact Evaluator (HIE) (Donalson et al. 2005.)

Methods:

1. Hydrological Scenarios

We analyzed SFWMM hydrologic data from each CSOP alternative by developing high resolution hydrology datasets. These data were used as input files for the HIE. The high resolution hydrology is developed using a script developed by the ATLSS project to increase the resolution of the SFWMM model from 2X2 miles to 500X500 meters (Duke-Sylvester 2000). This resolution is a more appropriate for analyzing potential effects of hydrology sparrow dynamics. The script integrates standard SFWMM model scenario output (water depth) with a high resolution topographic map to create a new water depth output file at the finer resolution. The output file of the script is then used as an input to the HIE model.

2. Hydrological Impact Evaluator

A. Biology of the sparrow

Sparrows breed during the Everglades dry season, starting nesting after March 15th (Pimm et al. 2002.) Most pairs only attempt one nesting cycle per year, with some pairs attempting a second nest and even fewer attempting three nesting cycles (Lockwood per. com.). Each cycle takes approximately 40-45 days to complete (Pimm et al. 2002). Few nests are found after August 1st because of the onset of the rainy season. Because Sparrows build their nests very close to the ground, with an average height at 16 cm, water depth during the breeding season is a critical factor for nesting success. If water level rises and sparrow nests are flooded, the nesting cycle is terminated. There are many other possible impacts of hydrology on the sparrow population, both direct and indirect, (see discussion) but clearly, one of the most fundamental criteria for breeding success is water depths below the height of the nest. A final important aspect of CSSS biology is the decreased productivity of the second and third nesting cycles (Pimm et al. 2002). It is estimated that only about 60% of individuals attempting a first nesting cycle will attempt a second cycle, and only about 30% of those individuals will attempt a third cycle (Lockwood per. com.). In addition, the success rates of the second and third nesting cycle attempts are far lower than for the first (Pimm et al. 2002).

B. HIE structure

The Hydrological Impact Evaluator (HIE) is designed to evaluate one potential effect of different hydrologic scenarios on the breeding cycle of the Cape Sable Seaside Sparrow; nest flooding during the breeding season.   Figure 2 lists the major HIE model components.

There are three primary model inputs, daily water depths, user input/biological parameters, and selection of sample points.   The user input allows modification of model parameters that include defining the beginning and ending dates of the sparrow's breeding season, the maximum water depth at which nesting attempts will begin, the water depth at which nests will flood, and the beginning and ending dates of the hydrologic scenario. The points within the SFWMM that are monitored were chosen to match those sampled by the field biologists. However, the field data also includes control sample points in non-sparrow habitat. The ATLSS sparrow high resolution vegetation map is a measure of the distribution of muhly grass wet prairie from a 1992 vegetation census. It is used to filter field data sampling points that are outside of even marginal sparrow nesting sites (such as the center of Shark River Slough.) The HIE model has several options for choosing cells to be used for simulation output. In this report, only cells in which birds were found in a field survey are used in the output. This is a total of 448 cells.

The model processes data on a daily time step by reading water depth for each cell from the hydrologic input file, starting the date specified by the user input,. If the date is within the breeding season, the state of each monitored cell is updated. The first time the water depth drops below 5 cm. within each cell during the breeding season, the first nesting cycle begins. Each day during the breeding season the new water depth is compared against the nest flooding depth (16 cm.) If the water is below the flood depth the cycle continues. If there are 45 consecutive days of water depths below the flooding threshold, the cycle is completed successfully. If the water reaches flood depth, the cycle is terminated and a new cycle is attempted when the water again recedes to under 5 cm. The first nesting cycle requires 45 days to complete, the second and third 40 days. There are a maximum of three nesting cycles that can be attempted per breeding season. In addition to calculating the number of potential nesting cycles for each site for each year, the HIE model also stores data on which of the three attempted cycles were completed. These data can be factored into the potential breeding cycle calculation.

C. Model output

The model reports the maximum number of nesting cycles possible per year for each cell. Specifically, model output data include a value between 0 and 3, and a scaled potential breeding cycle success rate (0-1.9 where completing cycle 1 is given a value of 1, cycle 2, 0.6, and cycle 3, 0.3) The scaled success rate represents the percent of the population attempting a first cycle, second, and third cycle. The model produces three major results, the maximum number of nesting cycles that could have been completed, the scaled version of the number of cycles that could have been completed, and the number of days with standing water below flood depth and the number of dry ground days per monitored cell per year. These data are output in three forms, the data for each cell for each year, the data for each population for each year, and the overall average of all the monitored cells over all years. In addition, we generate files for each scenario that can be imported into ArcMap to produce spatial plots of the data. Appendix A contains a more detailed description of the HIE model.

D. Model Uncertainty

There are several sources of potential error that can affect model results. The largest source of error in our analysis may be a result of simulated water depths from the SFWMM. Estimated error in simulating water depths has been reported as ± 6”(cite). In addition, we may introduce additional error in our analysis by converting 2 mile resolution hydrologic data to 500 meter resolution hydrologic data Donalson (unpublished) compared the model predicted water depths with the surface water depth data measured by the field observers (Pimm et al. 2002) and found the error to be statistically no different from the error predicted in the SFWMM. Regardless, this error estimate is similar to the mean height of the sparrow nests, 16 cm (Pimm et al. 2002). If we assume that the error in the hydrologic model remains constant between scenarios; it is reasonable to compare the results of two different hydrologic scenarios. There is also uncertainty in the estimates of biological parameters such as breeding season and nest height and the effects of predation with changing surface water levels.

E. Model Limitations:

Biological factors: The HIE model does not predict the magnitude of sparrow populations or number of sparrows; it only predicts the maximum number of breeding cycles that could occur given a particular hydrologic scenario from the standpoint of nest flooding. Many other factors affect the sparrow population including, but not limited to, predation, food supply, dispersal, and number of eggs produced.

Non-breeding season hydrology: Non-breeding season hydrology is also important. Very wet or very dry non-breeding season conditions could increase breeding season fire risks or affect the sparrow's food supply. Extended dry periods can cause the intrusion of woody vegetation into sparrow habitat making is unusable by the sparrows. Consistent flooding in the wet season also has the potential to modify vegetation types to less desirable sparrow habitat.

Non-flooding factors: The nest predation rate may depend on water depth and particularly on the presence or absence of water (Lockwood per. com.) As non-flooding nest destruction such as nest predation accounts for the vast majority of loss of young and eggs (Pimm et al. 2002), standing water below nest flooding depth has the potential to have far more impact on sparrow nesting success than nest flooding.

F. Metrics

The impacts of hydrological scenarios vary at different locations and at different spatial and temporal scales. In order to capture these impacts, several measures were used in evaluating the various hydrologic scenarios. The following measures were calculated for each scenario for the global population and each individual population (A, B, C, D, E, F): the mean number of potential breeding cycles completed (0-3), the scaled mean number of potential cycles completed (0-1.9), the difference between the scaled score for the highest scoring scenario and the other seven scenarios, the percentage loss off the maximum scaled score (1.9) from choosing another scenario, and the number of years where hydrology constrained the global or an individual population to less than one complete breeding cycle.

Results:

Figures 3-9 show the mean scaled number of potential breeding cycles per year for the 36 year hydrologic scenario time frame. Figure 3 shows the data for each of the eight hydrologic alternatives averaged over all 448 data points. Figures 4-9 show the same data but averaged over the data points representing each individual population, A, B, C, D, E, and F respectively. Because of the different spatial extents of each population, there are a different number of data points for each: Population A has 203 data points, Population B, 125, Population C, 27, Population D, 27, Population E, 55, and Population

F, 11. There are two points in these times series that are of particular interest. The first are the years where the number of potential scaled breeding cycles are less than one. The second are any major deviations from the group trajectories as is seen, for example, with the Alt7r5e scenario in Populations C and F. Tables 1-7 show the 36 year average statistics for Figures 3-9. The first column is the mean number of actual cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. This is important because not all hydrologic scenarios have the same rankings between populations so tradeoffs must be evaluated. The last column is the number of years (out of 36) that a hydrologic scenario had a score representing less than one breeding cycle for a year. Because the number of pairs attempting a second and third breeding cycle decreases drastically from the number of pairs attempting a first, and the success rates for the second and third cycles are also lower than the success rates for pairs attempting the first cycle, completion of at least one cycle takes on increased importance for successful maintenance and restoration of the sparrow populations. Two different global measures are provided as well as data for each population (A-F), Table 1 shows the global data weighting all data points equally and Table 8 shows the data giving each population equal weight.

Discussion:

Two criteria were used to analyze these results. Our restoration goal for CSOP is to maximize the results for Population A without compromising any of the other populations. Historically, the area covered by Population A contained a large number of birds (Pimm et al.2002). This population provided a buffer against the possibility of a catastrophic occurrence in the other historically large combined populations of B and E (Pimm et al. 2002). In the early and mid 1990's, large releases of water through the S-12 gates resulted in multi-year flooding of Population A during the CSSS breeding season (Pimm and Bass per. com.) These releases resulted in severe degradation of the habitat quality as well as complete disruption of the sparrows breeding cycle over subsequent years. The result was the almost complete elimination of sparrows for Population A. (Pimm et al, 2002.) Because of its historical importance as a population buffer and the goals of previous endangered species evaluations (US Fish and Wildlife Service 2002) the results for Population A are weighted heavily in scenario evaluation. However, even with the restoration of Population A a high priority, it is still important to not sacrifice another of the populations in pursuit of this goal.

Global:

The global metrics (Table 1, Figure 3) show a relatively small difference between the eight hydrologic scenarios. Alt7r5e resulted in the highest score, with an average of 1.57 scaled cycles per year over all 448 data points. The worst scenario, Alt2, would only degrade the result by approximately 4% with respect to the maximum possible score of 1.9. The range of years with less than one cycle was 2-5 with Alt7r5e and Alt5r performing best and Alt2 performing worst. However, this performance estimate is heavily biased toward the populations with larger land areas because they contain a majority of the data points (A, B, and E) thereby weighting the results of any data analysis toward those populations. Both because of this bias, and the fact that the individual populations occur in physically different environments, each population is also analyzed separately.

Population A:
The Population A metrics are provided in Table 2 with the time series provided in Figure 4. Given that the majority of data points fall within this subpopulation area and the results from the global analysis, it is not surprising that Alt7r5e again has the best performance. However, unlike the Global metrics, there is a much wider range of lost potential nesting success if the best performer is not chosen, with a range of 2-11%. In addition, the number of years that supported less than one breeding cycle is substantially increased over the Global result, with a range of 6-11 years. Two scenarios stand out as poor performers, Alt3 and Alt2, which have degradations of 7% and 11% and years with less than one breeding cycle of 9 and 11, respectively. Given the importance of Population A, these two scenarios would require further modification to be included in the list of possible CSOP candidates.

Population B:
The Population B metrics are provided in Table 3 with the time series provided in Figure 5. Population B results are not highly affected by the different CSOP scenarios (Figure 5). Although Alt7r5e displays the best performance, no scenario has more than a 0.6% degradation and no scenario has a year with less than one breeding cycle.

Population C:
Results for population c provide a contrasting view with that for population A; the Alt2 has the best performance (Table 3, Figure 6). The range of degradation among alternatives is from 4% to 15%, with Alt7r5e by far having the worst performance. The years 1979 and 1980 are good examples of where Alt7r5e deviates significantly from the other scenarios (Figure 5). The number of cycles with less than one breeding cycle range from 2-7 with Alt7r5e performing the worst. The performance of Alt7r5e makes it the least preferable candidate a CSOP alternative from the perspective of sparrow restoration/preservation with respect to Population C.

Population D:
Alt2 has the best performance for Population D (Table 3, Figure 7). The range of degradation for not choosing Alt2 is 4%-5% and the range of years with less than one breeding cycle is 0-2. The difference between the seven non-optimal hydrologic scenarios is small enough that there may be no measurable difference between them.

Population E:
Alt7r5e had the best performance in Population E (Table 3, Figure 8). The range of degradation for not choosing the optimal scenario was 3%-5% and the range of years with less than one potential breeding season was 1-4 years. As was the case with Population D, there are very few differences among the seven non-optimal scenarios.

Population F:
For Population F, Alt4 had the best performance (Table 3, Figure 9). Excluding Alt7r5e, which displayed the worst results, the difference between degradations for not choosing Alt4 ranged from 0.2%-4% and the range of years with potential breeding cycles of less than one year was 3-5, leaving little to distinguish among those six scenarios. Alt7r5e had a degradation of 14% and 13 years with potential breeding cycles less than one. The years 1992-1994 in are a good example of where Alt7r5e's performance deviates from the basic trajectories of the other seven alternatives (Figure 9). As in the case of Population C, population F performance is very poor. Therefore, Alt7r5e would be difficult to recommend, regardless of how well it performed in the other populations.

Overall
When considering the global metrics, Alt2 has the best degradation score, while Alt5r has the best less than one year breeding cycle score (Table 8). In this case, instead of weighting each point equally, the results for each population are given equal weight. Each percent degradation is the mean of the scenario's performance over each population (and in the case where a scenario had the best performance for a particular population, a zero is averaged in.) The number of years with potential breeding cycles less than one is also an average over the six population results. However, both scenarios Alt3 and Alt2 scored poorly in Population A, suggesting that further modification would be necessary to reduce impacts to population A. The performance of Alt5r is close to the overall score of Alt2, yet it reduces impacts in population A. Overall there are four hydrologic scenarios that are very similar: Alt4, Alt5, Alt5r, and Enp85b, with Alt5r having the best score of those four.

There is one major anomaly in these scenario results, that of Al7r5e. This scenario represents the Interim Operating Plan and the results for the eastern populations C, F (and to a lesser extent D) seem almost anomalous. Similar results were seen in simulations run by National Park Service hydrologists and Fish and Wildlife ecologists. It is unclear whether these results represent the actual operations that are presently controlling water delivery to eastern populations or whether it is an artifact of the SFWMM simulations that are used as inputs to the various models. If the potential anomaly is an artifact of the SFWMM output, then Alt7r5e would have been the top performer out of the eight hydrologic scenarios evaluated. CSOP planners should determine whether the results for the eastern population are an artifact of the SFWMM output or an actual operational implementation.

Addendum:

After most of the above data was created and analyzed, it was discovered that the high resolution elevation map used for the hydrologic data was created using the SFWMM v5.0 elevation map, as opposed to the v5.4 elevation map (which is used in the SFWMM v5.4 and v5.5 models.) An updated high resolution elevation map was created for NPS by the ATLSS group and the data was rerun. Although some small changes were seen comparing the runs using the 5.0 and 5.4 high resolution elevation maps, their magnitude was not great enough to change any of the analysis or conclusions already presented.

In addition to the high resolution elevation map upgrade, reanalysis of thee Alt2 scenario was necessary after NPS learned that Alt2 had been run using an outdated version of the SFWMM. There were enough changes in the sparrow analysis to warrant including the differences in this report. The base conditions and alternatives 1-3 were developed with a different version of the SFWMM model (5.5.4) than alternatives 4, 5, and 5r (version 5.5.6). During the technical analyses conducted by ENP, it was revealed that significant changes in the output resulted from the simulation of Alternative 2 using the newer version (SFWMM v5.5.6) when compared to the original version (SFWMM v5.5.4). The problem with using two versions to compare all alternatives is that it is very difficult, if not impossible in some cases, to discern the effects due to model version from the effects due to changes associated with an alternative.

Table 9 shows the data for Population A in the same format as the tables used in the body of this report. The numbers for Alt2 from Table 2 in the main body of this report are included for ease of comparison. Figure 10 shows the 36 year time series for Population A for the Alt2 and Alt2u scenarios. Analysis of the new results showed that the only substantial difference between Alt2 and Alt2u was in sparrow Population A, where Alt2u showed an improvement over Alt2. The scores averaged over the six populations are shown in Table 10. The most obvious changes were in the years 1996, 1997, 1999, and, 2000, but there are other smaller improvements from Alt2 to Alt2u as well. The changes made Alt2u the clear winner when comparing the mean percentage off the maximum value. It also decreased the mean number of years where there was less than one potential breeding cycle with respect to nest flooding. The results Population A also show an improvement with Alt2u with respect to Alt2. The percentage off the maximum value improved by over 3% and there were three less years where the potential breeding cycles were less than one. This brought the West Bookend results much closer to those of the other scenarios. However, given the importance of Population A in the overall restoration of the Cape Sable Seaside Sparrow, the percent off maximum value was still far enough below the results of other scenarios, particularly Alt5r, that it would not displace any of the previously recommended scenarios.

References

Bass, O. and J. Kushlan. 1982. Status of the Cape Sable Seaside Sparrow. USDI, National Park Service, South Florida Research Center Report T-672, Homestead Florida.

Donalson, D., Q. Dong, and D. L. DeAngelis. 2005. Development of Spatially-Explicit Stochastic Models of the Cape Sable Seaside Sparrow. Annual Report to The Critical Ecosystem Studies Initiative Science Fellowships in Everglades Restoration Ecology, Everglades National Park.

Duke-Sylvester, S. 2000. The Institute for Environmental Modeling, ATLSS: *Across Trophic Level System Simulation for the Freshwater Wetlands of the Everglades and Big Cypress Swamp*. Available at http://www.tiem.utk.edu/~sylv/HTML/Work/Everglades/index.html.

Pimm, S. J. Lockwood, C. Jenkins, J. Curnutt, M Nott, R. Powell, O. Bass. 2002. Sparrow in the Grass, A report on the first ten years of research on the Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*). Report to National Park Service, Everglades National Park, FL.

Ross M., J. Sah, P. Ruiz, D. Jones, H. Cooley, R. Travieso, F. Tobias, J. Snyder, D. Hagyari. 2005. Effect of Hydrologic Restoration on the Habitat of The Cape Sable Seaside Sparrow Annual Report of 2004-2005. Report to National Park Service, Everglades National Park, FL.

Service (U.S. Fish and Wildlife Service). 2002. Interim Operational Plan (IOP) For Protection of the Cape Sable Seaside Sparrow. Final Amended Biological Opinion. U.S. Fish and Wildlife Service; Vero Beach, Florida.

Figure 1. Locations of sparrow populations A, B, C, D, E, and F in Everglades National Park and immediate vicinity.

Figure 2. Major components of the Hydrologic Impact Evaluator. Elements in red were provided by the ATLSS project, elements in blue were provided by Everglades National Park personnel.

Figure 3. Global mean potential breeding cycles per year scaled (0-1.9) for each of the eight hydrologic scenarios.

Figure 4. Mean potential breeding cycles per year scaled (0-1.9) for each of the eight hydrologic scenarios averaged over the data points in Population A.

Figure 5. Mean potential breeding cycles per year scaled (0-1.9) for each of the eight hydrologic scenarios averaged over the data points in Population B.

Figure 6. Mean potential breeding cycles per year scaled (0-1.9) for each of the eight hydrologic scenarios averaged over the data points in Population C.

Figure 7. Mean potential breeding cycles per year scaled (0-1.9) for each of the eight hydrologic scenarios averaged over the data points in Population D.

Figure 8. Mean potential breeding cycles per year (scaled 0-1.9) for each of the eight hydrologic scenarios averaged over the data points in Population E.

Figure 9. Mean potential breeding cycles per year scaled 0-1.9 for each of the eight hydrologic scenarios averaged over the data points in Population F.

Figure 10. Mean potential breeding cycles per year scaled 0-1.9 For Alt2 and Alt2u.

Table 1. Global Hydrologic Impact Evaluator results for eight CSOP scenarios. Results were calculated by using 448, equally weighted, data points . Column 1 is the mean number of potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.161	1.473	0.056	2.938	4
Alt4	2.205	1.501	0.028	1.462	3
Alt5	2.206	1.505	0.024	1.252	3
Alt5r	2.210	1.507	0.022	1.155	2
Alt7r5e	2.242	1.529	0.000	0.000	2
Alt1	2.216	1.511	0.018	0.946	3
Enp85b	2.189	1.494	0.036	1.873	4
Alt2	2.140	1.454	0.076	3.974	5

Table 2. Hydrologic Impact Evaluator results in Population A for eight scenarios. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	1.730	1.215	0.132	6.935	9
Alt4	1.817	1.272	0.075	3.927	7
Alt5	1.819	1.275	0.072	3.815	7
Alt5r	1.823	1.278	0.069	3.643	7
Alt7r5e	1.930	1.347	0.000	0.000	6
Alt1	1.857	1.302	0.045	2.346	7
Enp85b	1.784	1.253	0.094	4.956	8
Alt2	1.629	1.146	0.201	10.582	11

Table 3. Hydrologic Impact Evaluation results in Population B for each of the eight scenarios. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.672	1.767	0.012	0.618	0
Alt4	2.678	1.770	0.009	0.483	0
Alt5	2.681	1.772	0.007	0.377	0
Alt5r	2.680	1.771	0.008	0.428	0
Alt7r5e	2.691	1.779	0.000	0.000	0
Alt1	2.676	1.768	0.011	0.556	0
Enp85b	2.680	1.771	0.008	0.401	0
Alt2	2.679	1.771	0.008	0.436	0

Table 4. Hydrologic Impact Evaluation results in Population C. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.260	1.585	0.115	6.027	3
Alt4	2.279	1.588	0.111	5.848	3
Alt5	2.300	1.609	0.091	4.765	2
Alt5r	2.312	1.615	0.084	4.429	2
Alt7r5e	2.004	1.422	0.277	14.582	7
Alt1	2.285	1.574	0.125	6.574	3
Enp85b	2.293	1.608	0.091	4.781	2
Alt2	2.502	1.699	0.000	0.000	2

Table 5. Hydrologic Impact Evaluation results in Population D. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.457	1.675	0.074	3.882	0
Alt4	2.422	1.647	0.102	5.344	2
Alt5	2.439	1.671	0.077	4.077	0
Alt5r	2.464	1.679	0.069	3.655	0
Alt7r5e	2.423	1.651	0.097	5.128	0
Alt1	2.422	1.647	0.101	5.339	2
Enp85b	2.447	1.672	0.077	4.029	1
Alt2	2.612	1.749	0.000	0.000	0

Table 6. Hydrologic Impact Evaluation results in Population E. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.358	1.585	0.083	4.357	4
Alt4	2.393	1.606	0.062	3.248	4
Alt5	2.391	1.609	0.059	3.091	4
Alt5r	2.387	1.607	0.061	3.198	3
Alt7r5e	2.468	1.668	0.000	0.000	1
Alt1	2.372	1.601	0.067	3.509	4
Enp85b	2.370	1.594	0.074	3.902	4
Alt2	2.353	1.579	0.089	4.697	4

Table 7. Hydrologic Impact Evaluation results in Population F. Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	2.328	1.572	0.012374	0.651249	3
Alt4	2.341	1.584	0	0	3
Alt5	2.240	1.560	0.024495	1.289208	3
Alt5r	2.240	1.561	0.023485	1.236045	3
Alt7r5e	1.894	1.323	0.261111	13.74269	13
Alt1	2.162	1.503	0.081061	4.266348	5
Enp85b	2.288	1.561	0.023737	1.249335	4
Alt2	2.331	1.580	0.004545	0.239234	4

Table 8. Overall results for each of the eight scenarios. Summary statistics were calculated for all populations (equally weighted). Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Mean % off Max	Mean < 1 cycle years
Alt3	3.744999	3.166667
Alt4	3.141808	3.166667
Alt5	2.902405	2.666667
Alt5r	2.764931	2.5
Alt7r5e	5.57541	4.5
Alt1	3.764926	3.5
Enp85b	3.219812	3.166667
Alt2	2.659159	3.5

Table 9. Hydrologic Impact Evaluator results using Alt2u in place of Alt2 in Population A for eight scenarios. (Alt2 results from Table 2 are included for ease of comparison.) Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Total	Scaled	Difference	% off Max	< 1 cycle years
Alt3	1.730	1.215	0.132	6.935	9
Alt4	1.817	1.272	0.075	3.927	7
Alt5	1.819	1.275	0.072	3.815	7
Alt5r	1.823	1.278	0.069	3.643	7
Alt7r5e	1.930	1.347	0.000	0.000	6
Alt1	1.857	1.302	0.045	2.346	7
Enp85b	1.784	1.253	0.094	4.956	8
Alt2u	1.732	1.212	0.135	7.121	8
Alt2	1.629	1.146	0.201	10.582	11

Table 10. Overall results for each of the eight scenarios when Alt2 is replaced by Alt2u. Summary statistics were calculated for all populations (equally weighted). Column 1 is the mean number of actual potential breeding cycles (0-3) for each scenario. Column 2 shows the scaled mean (0-1.9). Column 3 shows the difference between the best scoring (scaled) scenario and the other seven alternatives. Column 4 shows the percentage of the maximum score (1.9) that would be lost by choosing a hydrologic scenario other than the optimal. Column 5 shows the number of years (out of 36) for which a hydrologic scenario had less than one potential breeding cycle.

	Mean % off Max	Mean < 1 cycle years
Alt3	3.846	3.167
Alt4	3.243	3.167
Alt5	3.003	2.667
Alt5r	2.866	2.500
Alt7r5e	5.676	4.500
Alt1	3.866	3.500
Enp85b	3.321	3.167
Alt2u	2.141	3.000

Alt2	2.659159	3.5

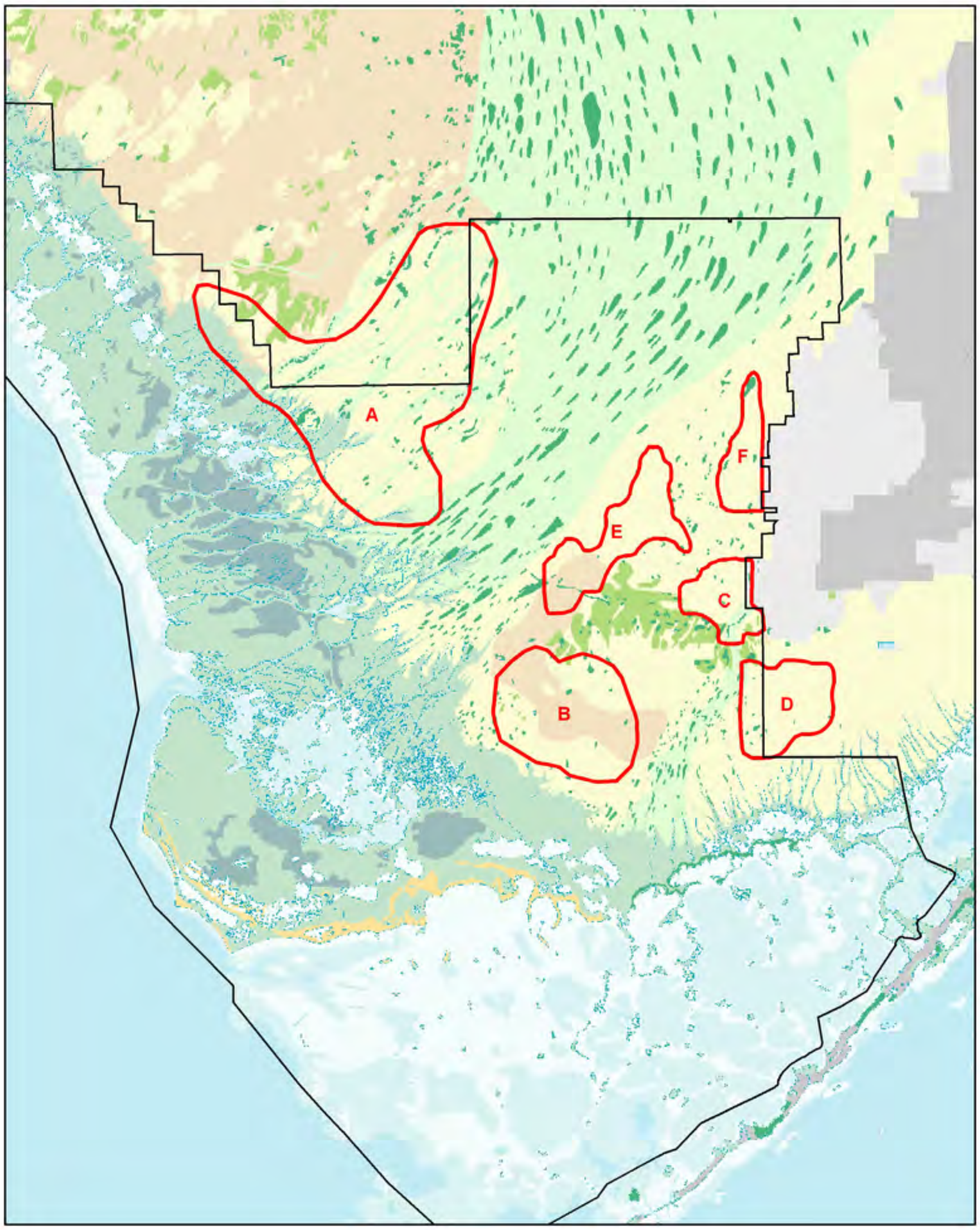


Figure 1.

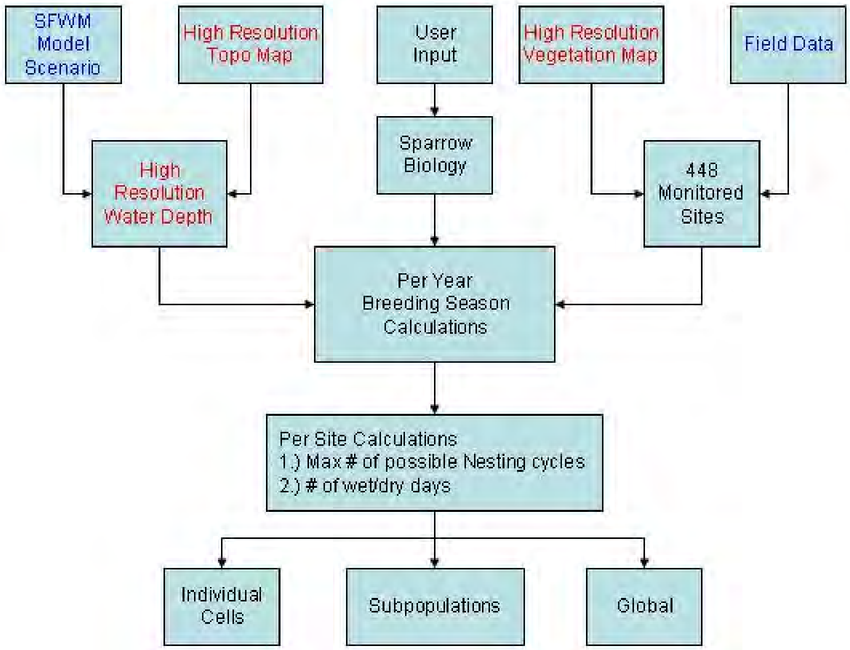

SFWM Model Scenario
High Resolution Topo Map
User Input
High Resolution Vegetation Map
Field Data
High Resolution Water Depth
Sparrow Biology
448 Monitored Sites
Per Year Breeding Season Calculations
Per Site Calculations
1.) Max # of possible Nesting cycles
2.) # of wet/dry days
Individual Cells
Subpopulations
Global

Figure 2.

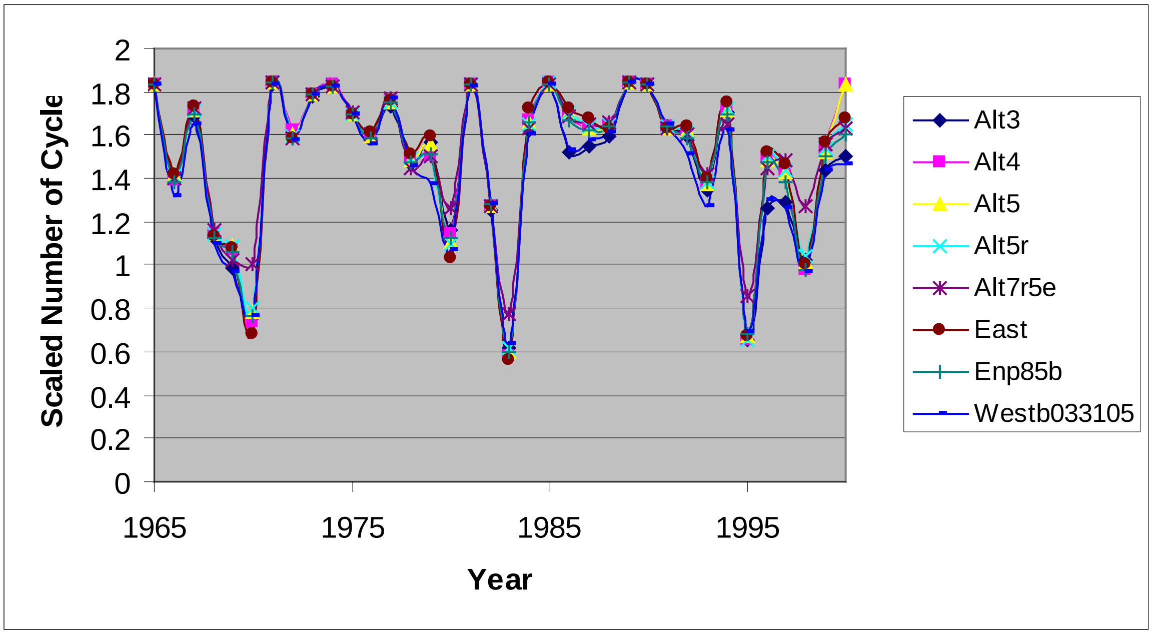

Scaled Number of Cycle
Year
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1965
1975
1985
1995
Alt3
Alt4
Alt5
Alt5r
Alt7r5e
East
Enp85b
Westb033105

Figure 3.

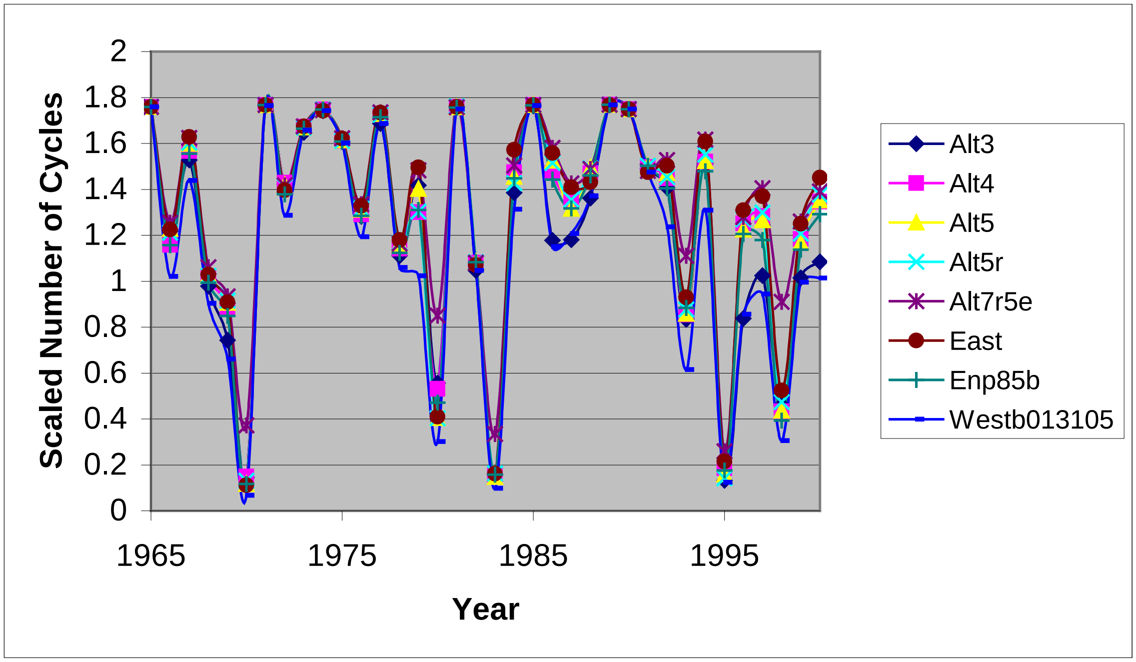


Figure 4.

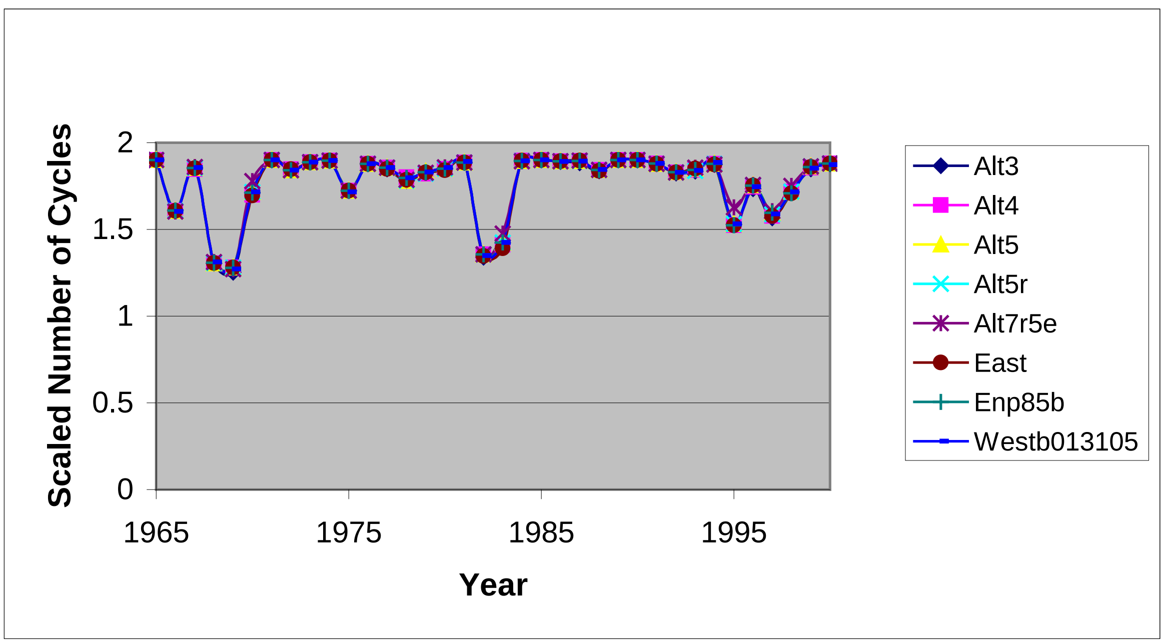


Figure 5.

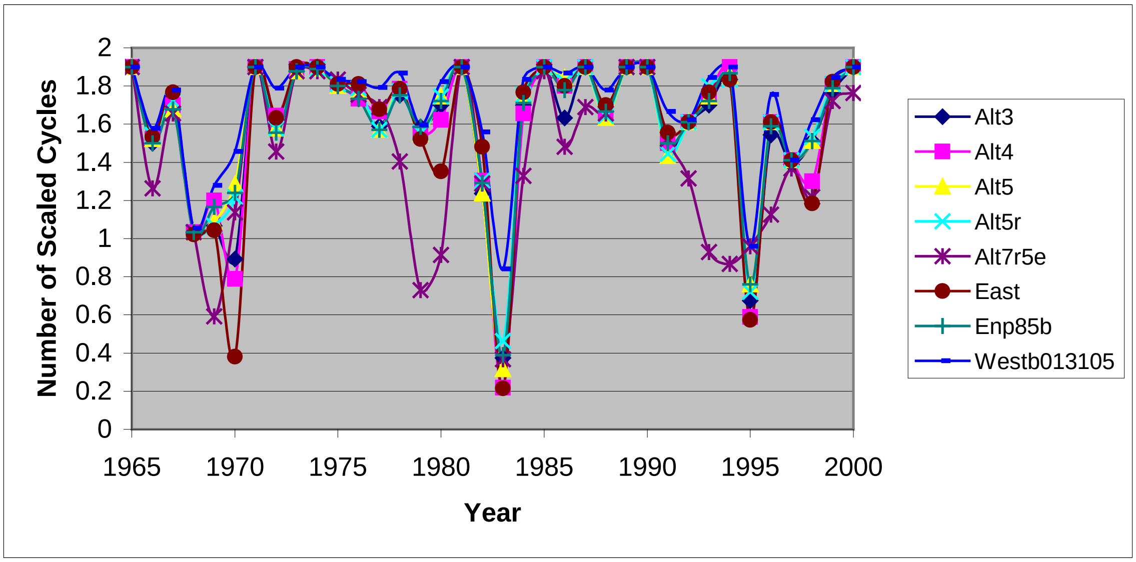


Figure 6.

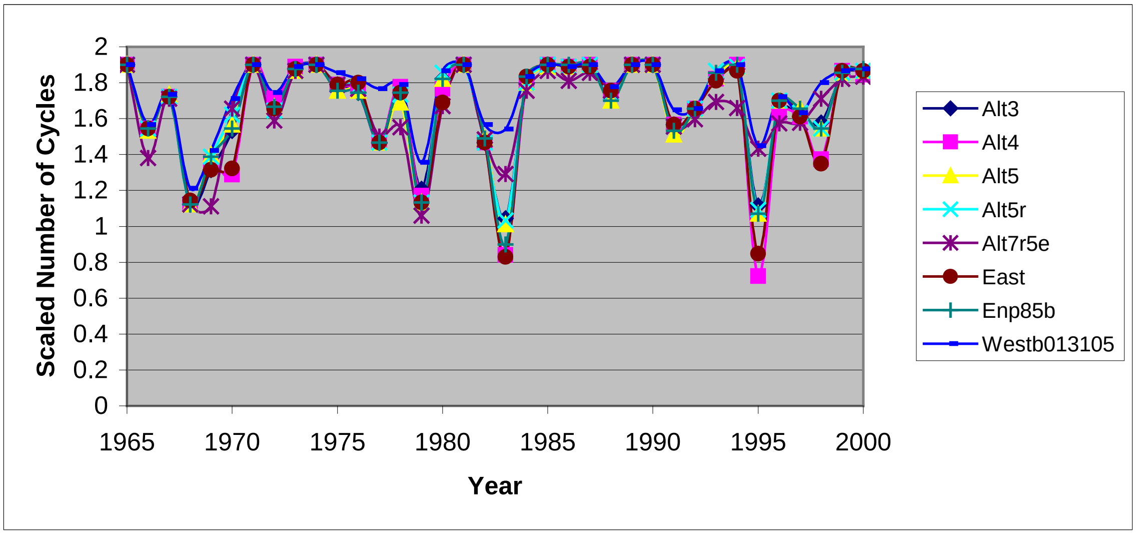


Figure 7.

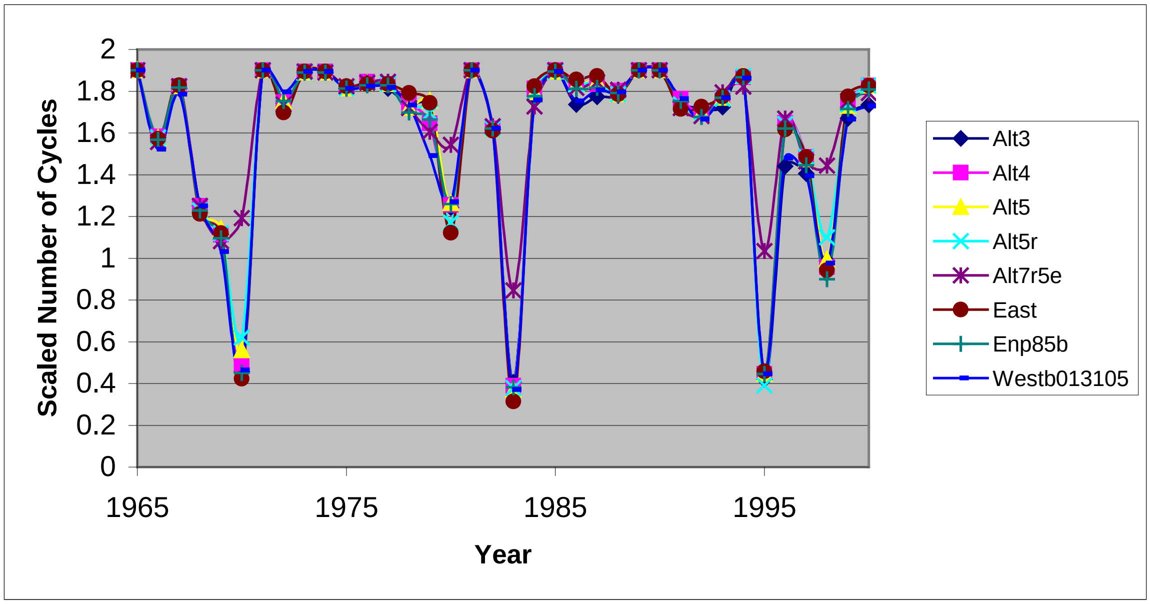


Figure 8.

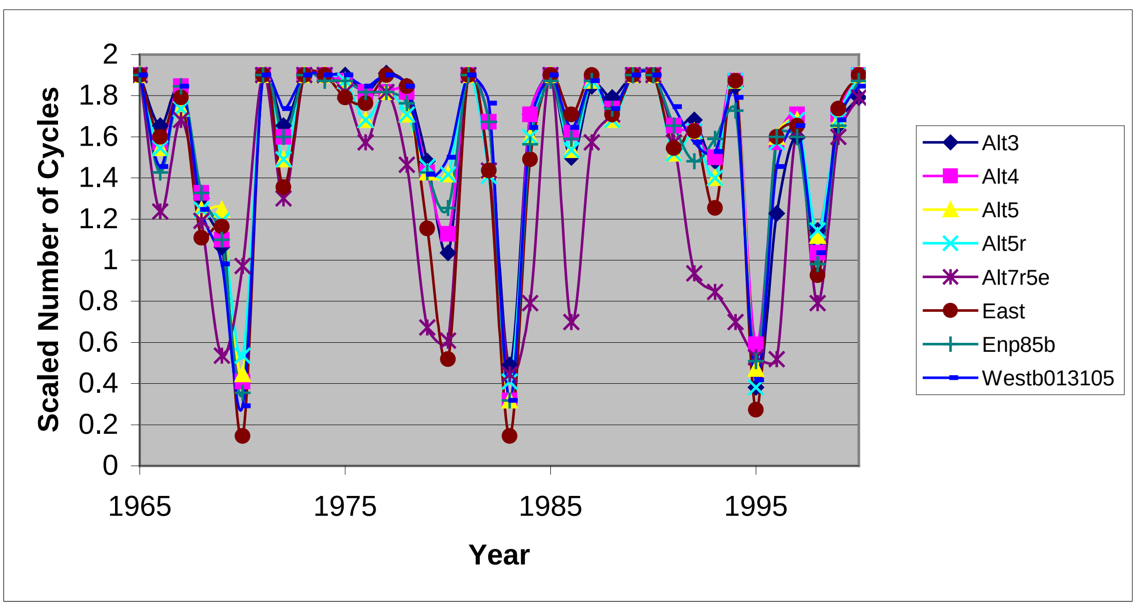
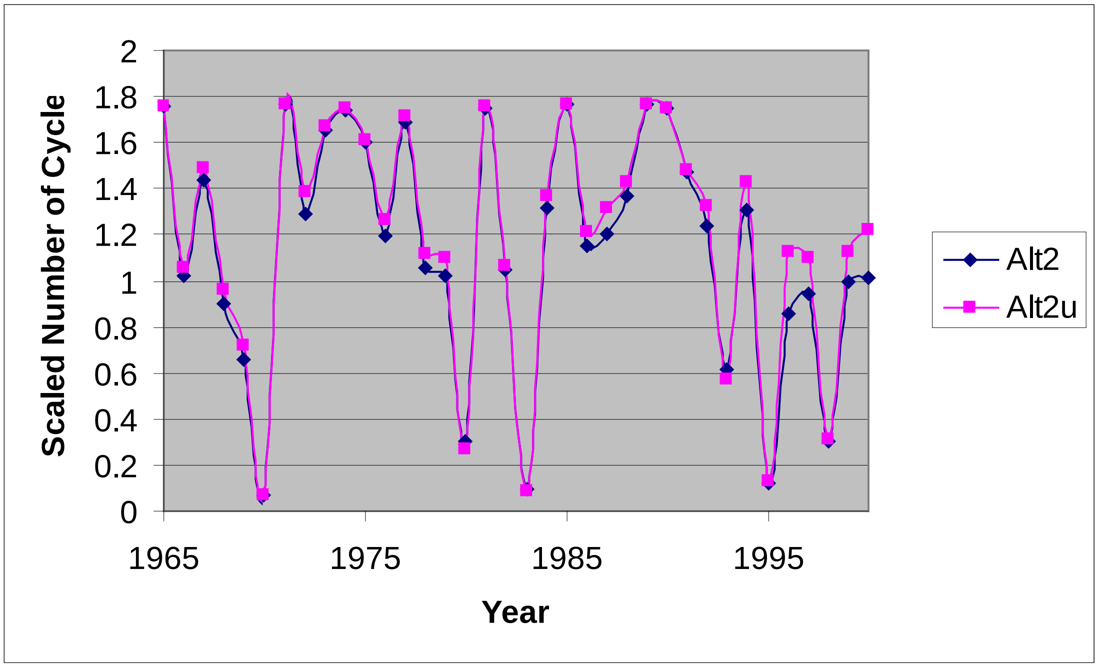


Figure 9.



Scaled Number of Cycle
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1965
1975
1985
1995
Year
Alt2
Alt2u

Figure 10.

Appendix A
Detailed Hydrologic Impact Evaluator Description

The Hydrologic Impact Evaluator

developed by

Dr. Douglas D. Donalson

Post Doctoral Fellow

under the

Critical Ecosystem Studies Initiative

Cooperative Agreement # H5000-01-0478

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The following is a description of the Hydrologic Impact Evaluator (HIE) model taken from the annual report for the CESI Cooperative Agreement #H5000-01-0478 dated 06-08-2005. Since that report was submitted, many improvements have been made to the model and those will be included in the final report for the project. The actual mechanics of the present model are largely unchanged, with the major changes being increased data content of the input and output.

Hydrologic Impact Evaluator Model Description

The Hydrologic Impact Evaluator is designed to analyze the potential effects of different hydrologic scenarios on the Cape Sable Seaside Sparrow. It is evaluates one aspect of the interactions of the sparrow with its environment, the potential of nest flooding due to high water during the nesting season. The following description is based on Figure 1 which is a block diagram of the model. It is divided up into two parts, the first section is a description of the input and output to the model and the second section is a description of the major variables and the model computations that create the results.

HIE Input/Output Files

The HIE has 6 input and 4 output files as listed in Table 1. The water depth file (Block 3 in Figure 1) is created by running the daily_stg_minus_lsel.bin (water depth above ground level in cm.) file from the appropriate hydrologic scenario (SFWMM Scenario in Figure 1) through a program provided by the ATLSS group. This program breaks up the 4 square mile grid of cells from the SFWM model into a grid of 0.25 km. cells using a combination of HAED and other fine scale topographic data (High Resolution Topo Map in Figure 1).

There are two user input files, Parameters.txt and RandomSeeds.txt, which make up the blocks User Input/Sparrow Biology of Figure 1. Parameters.txt (Table 2) includes inputs such as biological parameters, dates, and output file names. RandomSeeds.txt is meant to be used when there is stochasticity incorporated into the model. The parameter "runs" defines the number of realizations of the model to be run for a given configuration and can be from 1 to 200. Following it are the random seeds used to initialize the Random Number Generator for each of the realizations. The seeds are defined in advance for repeatability of results. Output file names are appended with a number 1-200 to identify which stochastic realization created it.

AreaBirdCountUTM.txt (Field Data Figure 1, Table 3) contains field data from bird surveys started in 1981. This file's data is primarily used is to easily tag cells in the HIE with their correct population designation (A-F). This is done by converting the UTM coordinates of he field locations to row and column numbers of the HIE grid. In addition, the counts of actual birds found are included in the HIE cell data to assist in later data analysis. The files WaterMask.txt and WeightMap.txt make up High Resolution Vegetation Map of Figure 1. WaterMask.txt delineates all cells that are a covered by the SFWM model. WeightMap.txt is a weighting of sparrow habitat quality with respect to coverage of muhly grass and is scaled 0-1 and was provided by the ATLSS group. The HIE does not use the actual weightings but rather uses this file both to approximate good sparrow habitat to filter out points in the field data sampling sites that are outside of good sparrow habitat. These files are combined to isolate the 4437 or 488 cells that are used for the HIE output**.**

The HIE output is split into four files for ease of data analysis. There are two sets of cells that are monitored by the simulation. The cells defined by WeightMap.txt greater than 0 (4437 total cells) are an estimate of muhly grass coverage, a good indicator of prime sparrow habitat. A subset of this data, sites covered by WeightMap.txt that were also sampled by field researchers, is also used. This covers 448 cells and is useful as the results can be compared directly to field data. IndividualCells.txt (Individual Cells Figure 1 and Table 4) contains data from all 4437 monitored cells for each breeding season. SubPopsAverage.txt provides the mean maximum number of potential nesting cycles for each breeding season for each individual population (A-F) (Subpopulations Figure 2). Global (Figure 1) consists of two files, LongTermStats.txt and GlobalAverage.txt. LongTermStats.txt (Table 5) provides the mean number of potential nesting cycles over the entire simulation for each of the 448 cells that represent the sites that have field data associated with them. GlobalAverage.txt provides the mean number of potential nesting cycles over all 4437 monitored cells for each breeding season.

The HIE Simulation

The actual HIE program is comprised of three main operational components, objects that handle space and time, and the controller, which is the code that drives the simulation.

The date object handles time for the simulation. The unit of time is days and the date function keeps track of the day, month, and year, including leap years. It is incremented using a call from the simulation controller. The controller queries the date object for information on whether the date is within the breeding season, the date is the end of the year, and the date is the end date for the simulation run.

The object that handles space is called the SpatialCell or cell. Space is made up of a grid of 264 columns by 419 rows, a total of 110,616 cells. Row one column one is the northwest corner of the grid and has UTM NAD27 Zone 17 coordinates of Easting 467165 and Northing 2989069. The size of each cell is 500X500 meters or 0.25 km^2. This rectangle bounds the spatial area covered by the SFWMM. Each cell contains a large amount of information about its location, history, and present state. The location parameters include information such as the cell's row and column within the spatial grid, its UTM coordinates, whether it falls within the bounds of the SFWMM, whether it falls within the bounds of one of the spatial populations (A-F) and reference addresses for its 20 closest neighbors. At present, the cell history is confined to information on whether and when the cell has been sampled by field biologists and the year and number of birds found within. The design of the SpatialCell is such that it will be easy to upgrade it in the future to add additional history information such as long term water depth information.

At present, the main task of the SpatialCell is to calculate the number of possible nesting cycles for that area in space for each year. For a given year, the cell begins monitoring its water depth on a daily basis once the simulation is within the breeding season. Once the water drops below the value of the variable *H2ODepthTrigger* (BreedWaterDepthTrigger from Table 2) the simulation begins counting days. While the water depth stays below the variable *floodDepth* (NestFloodDepth Table 2) the counter increments on a daily basis. The first nesting cycle is completed if the counter increments to 45 and the variables *numberOfAttempts* and *numberOfSuccessfulAttempts* are incremented. If during this time the water level reaches *floodDepth* then the present nesting cycle is terminated and *numberOfAttempts* is incremented but *numberOfSuccessfulAttemps* is not. Nesting cycles two and three are handled in the same manner except that the number of days to complete the cycle is decreased from 45 to 40. A maximum of three nesting attempts are allowed so if *numberOfAttempts* is equal to three the cell object makes no further attempts at nesting cycles for that year.

The HIE controller handles simulation initialization and termination, and integrates the other components during the simulation run.

To initialize the simulation, the controller reads in the parameter.txt file. It then creates a cell object at each grid site. The space for the input files (Table 1) is created and their data is read in. At this point, the actual simulation begins running. It first checks with the date object to see is the end simulation date has been reached. If it hasn't, the water depths are updated for each cell. (Cells that fall outside the area of the SFWMM are given a dummy value.) The controller then cycles through each of he 4437 cells described in the input/output section. Each cell is instructed to update its state by one day. When this task is complete, the date object is instructed to increment the date by one day. Finally the controller checks with the date function to see if it is year end. If it is, then the data for GlobalAverage.txt, SubPopulation.txt, and IndividualCells.txt are calculated and written to the appropriate. In addition, a variable in each cell, *totalScore*, is updated with the number of successful nesting cycles for future use at the end of the simulation in LongTermStats.txt. When the date function reports that the date for the end of the simulation has been reached, the controller performs the tasks necessary for simulation termination. These include first creating the LongTermStats.txt file and then returning the memory used by the simulation to the computing system.

Table 1. HIE Input and Output Files		
File Name	Input/Output	Description
Parameters.txt	Input	User definable parameters and file names. See Table 2.
RandomSeeds.txt	Input	Used for stochastic runs. First entry is the number of runs and is user definable from 1-200. The next 200 entries are seeds for the Pseudo Random Number Generator.
WaterDepth	Input	Daily water depth above ground level. Created by a separate utility program that must be run on a Unix Sparc 64 machine prior to the model run.
AreaBirdCountUTM.txt	Input	Field data included for comparison purposes. Used primarily to label cells with correct population tag, A-F.
WaterMask.txt	Input	The “layout” of the simulation is a rectangle containing the cells included in the SFWM hydrologic model. This file separates the cells included in the hydrologic file from those that just fill in the rectangle.
WeightMap.txt	Input	This is a file provided by the ATLSS project that classifies cells according to their muhly grass coverage. It is used to filter out field sites that are poor sparrow habitat.
GlobalAverage.txt	Output	Maximum possible number of nesting cycles averaged over all sites per year.
SubPopsAverage.txt	Output	Maximum possible number of nesting cycles per year averaged over each population A-F.
IndividualCells.txt	Output	Maximum possible number of nesting cycles per cell per cell per year.
LongTermStats.txt	Output	Average over entire time series for each cell of maximum number of potential nesting cycles.

Table 2. Parameters.txt Input File		
Parameter Name	Default Value	Description
graphics	1	The input parameters "graphics" and "twoDDisplayGraphics" are not implemented at present and should be left at their default states. In the future the plan is to have the type of graphics output selectable with two different looks, one for each window.
twoDDisplayGraphics	0	
endSimulation	400000	endSimulation is used in situations where the end date is not specified as part of the simulation. This is reserved for future use.
startDay	1	startDay, Month, and Year specify the date to begin the simulation. They should match the starting date for the hydrologic input file.
startMonth	1	
startYear	1965	
endDay	5	endDay, Month, and Year specify the ending date for the simulation. It should be set to the 5th day of the 1st year after the end of the hydrologic input file. This is because some data storage/calculations aren't complete until the end of the year.
endMonth	1	
endYear	2001	
breedSeasonDayStart	15	breedSeasonDay/MonthStart, and breedSeasonDay/MonthEnd define the duration and position of the breeding season.
breedSeasonMonthStart	3	
breedSeasonDayEnd	1	
breedSeasonMonthEnd	8	
GlobalFileName	GlobalAverage	These three entries define the file names for the three output files. They should be kept to 20 characters and should not contain spaces. See the Output Files Section for more details on these files.
SubPopulationFileName	SubPopsAverage	
CellsFileName	IndividualCells	
WaterDepthInputFile	C:\westc51-fhmwater.bin	This is the path to and the filename for the hydrologic input file. Note that this file must be generated using the utility program provided by the ATLSS group.
BreedWaterDepthTrigger	5	The parameter defines the water depth in cm in a cell at which nest building can begin given that the

		simulation date is within the breeding season.
NestFloodDepth	16	The water depth in cm. at which nests will be flooded.

Table 3. AreaBirdCountUTM.txt Input File	
Population	Population that this site belongs to A-F.
Year	Year that the data was recorded.
Easting	UTM Easting NAD 27 Sector 17
Northing	UTM Northing NAD 27 Sector 17
Bird Count	Bird count for site in year.

Table 4. IndividualCells.txt Output File	
Year	
Row	The row number of the cell
Column	The Column number of the cell
Easting	UTM Easting Coordinate
Northing	UTM Northing Coordinate
Population	The Population Designation A-F for cells included in field data, X for cells not included in field data.
Dry Days	Number of days that the water level in the cell was below ground during breeding season.
Wet Days	Number of days that there was above ground water in the cell that was below nest flooding depth during breeding season.
Nesting Cycles	Maximum possible number of nesting cycles for year.
Bird Count	Bird count in cell from field data. 0-7 sampled that year, -1 not sampled that year.

Table 5. LongTermStats.txt Output File	
Row	The row number of the cell
Column	The Column number of the cell
Easting	UTM Easting NAD 27 Sector 17
Northing	UTM Northing NAD 27 Sector 17
Population	The Population Designation A-F for cells included in field data, X for cells not included in field data.
Bird Count	Overall maximum possible number of nesting cycles for time series.

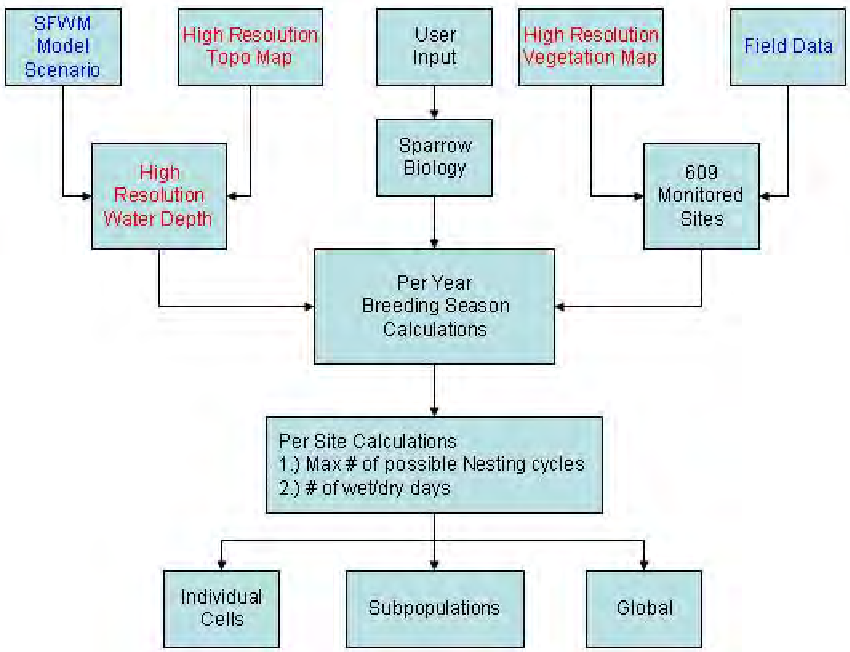

Figure 1. A block diagram of the major components of the Hydrologic Impact Evaluator. Elements in red were provided by the ATLSS project, elements in blue were provided by Everglades National Park personnel.

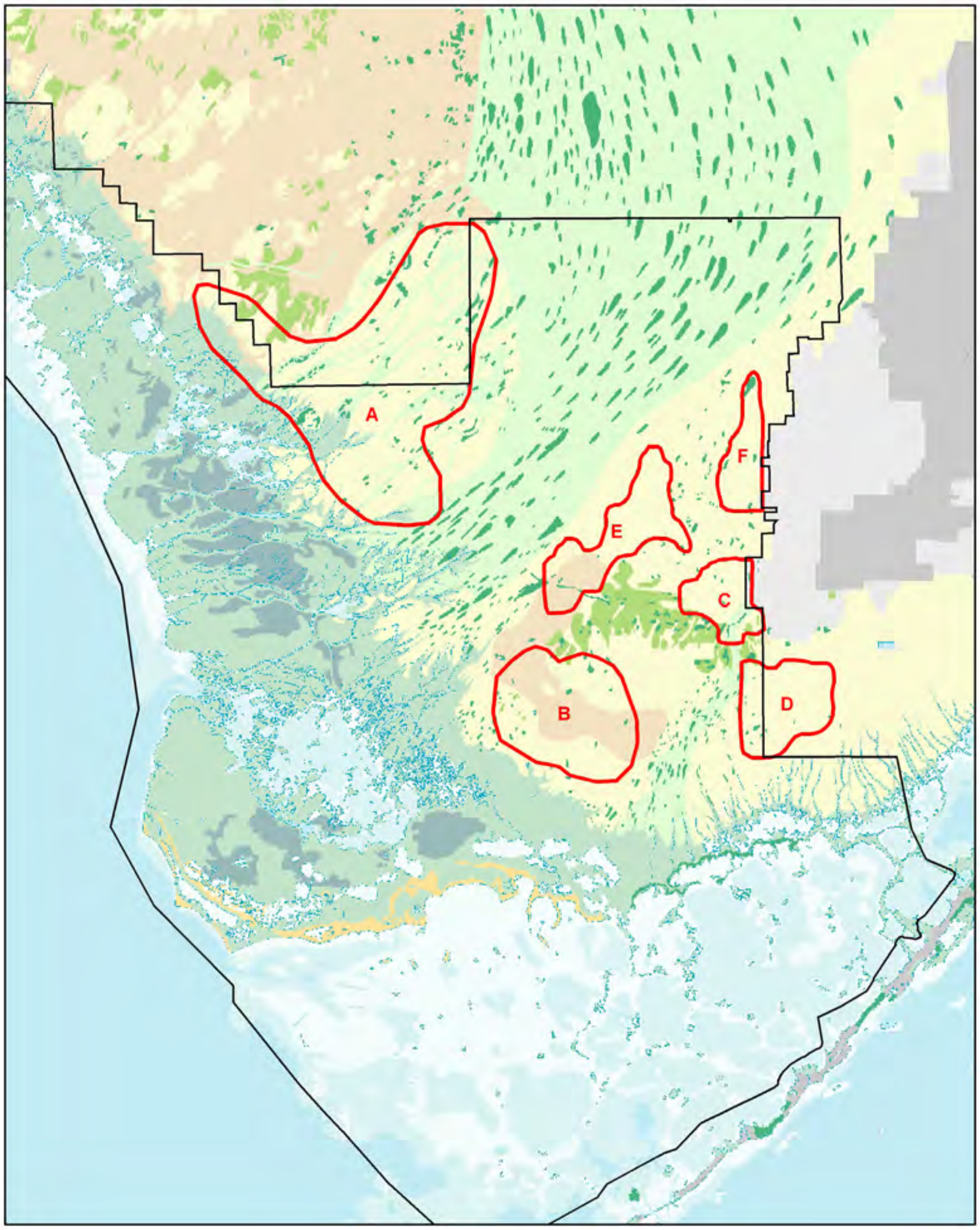

Figure 2. Six Cape Sable Sea Sparrow Populations. Sparrows are spatially distributed in six populations (A-F) divided by natural barriers of unsuitable habitat such as deep water or woody vegetation.