Greater Everglades Performance Measure

Wetland Trophic Relationships – American Alligator Abundance, Body Condition, Hole Occupancy, and Production Suitability Index

Last Date Revised: June 5, 2014

Acceptance Status: Accepted

1.0 Desired Restoration Condition

The desired restoration condition for American alligators is that with the resumption of more natural patterns of volume, timing, and distribution of flow to the Everglades, alligators will repopulate and resume nesting in areas where hydrology is restored including northwestern Water Conservation Area 3A, the Rocky Glades and the freshwater reaches of tidal rivers in the mangrove estuaries, and will increase in relative abundance and body condition throughout most of the Greater Everglades wetlands.

1.1 Predictive Metric and Target

For the total CERP project, the predictive evaluation target is to improve total alligator production suitability scores relative to the 2050 base. For implementation runs, the evaluation target is to exceed 2012 base alligator production suitability scores.

1.2 Assessment Parameter and Target

- Assessment parameters for alligators are relative abundance (based on encounter rate), body condition, and alligator hole occupancy (Mazzotti et al. 2009). Targets for these parameters can be examined individually by management unit or combined for a system-wide score. Assessments are for marsh populations and includes examining the current year value, the five year running mean value (abundance) or three year running mean value (body condition), and the trend over the last five years (see Mazzotti et al. 2009).
- Relative abundance target is to meet or exceed 1.70 alligators/km (Hart et al. 2012) and have a stable (if abundance exceeds 1.70 alligators/km) or increasing trend in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR), Water Conservation Areas 2 and 3, Big Cypress National Preserve, Everglades National Park's Northeastern Shark River Slough, Shark River Slough, western coast estuaries (e.g., Lostmans, Broad, North, Roberts, East and Shark Rivers), C-111/Taylor Slough estuaries, and the Rocky Glades, especially in peripheral wetlands. Currently LNWR is the only area where abundance is always above 1.70 alligators/km.
- Body condition target is to meet or exceed a Fulton's K value (calculated using snout-vent length and mass) of 2.27 (Hart et al. 2012) and have a stable or increasing trend in LNWR, Water Conservation Areas 2 and 3, Big Cypress National Preserve, Everglades National Park's Northeastern Shark River Slough, Shark River Slough, western coast estuaries (e.g., Lostmans, Broad, North, Roberts, East and Shark Rivers), C-111/Taylor Slough estuaries, and the Rocky Glades, especially in peripheral wetlands.
- Alligator hole occupancy target is >70% occupancy of holes (Hart et al. 2012) with stable or increasing trends in Northeast Shark Slough, Rocky Glades, and Southern Marl Prairies.

2.0 Justification

{Used with permission from Shinde et al. 2013}

The American alligator (*Alligator mississippiensis*) is considered a key component of the Everglades ecosystem and is a keystone species in the Everglades landscape (Mazzotti and Brandt, 1994). Alligator abundance, nesting effort, growth, survival, and body condition serve as indicators of the Everglades marsh system's health (Mazzotti et al., 2003; Mazzotti et al. 2009). Alligators are a top predator in the Everglades ecosystem that consume a particularly wide variety of sizes and taxa of prey and may influence their populations (Mazzotti and Brandt, 1994). Everglades' plant and animal communities are structured by alligator activities. They shape plant communities by excavating ponds and creating trails, resulting in deeper open-water areas, and by constructing nest mounds that provide relatively elevated areas, which may be colonized by plant species not tolerant of seasonal flooding (Craighead, 1968 and 1971). These changes in landscape features provided by alligators are critical to many wildlife populations dependent on them as nesting, resting, or foraging sites (Craighead, 1968; Deitz and Jackson, 1979; Hall and Meier, 1993; Kushlan, 1974; Kushlan and Kushlan, 1980).

Alligators were historically most abundant in wetland habitats fringing the deeper slough areas, where the limestone bedrock was near the surface, and in freshwater mangrove areas (Craighead, 1968). Alligators now are most abundant in the central sloughs and canals of the current Everglades landscape (Kushlan, 1990; Morea, 1999) and are absent or rare in the peripheral wetlands, which have been lost to development or altered hydrologically (Mazzotti and Brandt, 1994; Mazzotti et al., 2009). The spatial pattern of habitat use by alligators has changed as a result of land use change and water management practices in southern Florida and modified and artificial aquatic habitats (canals, impoundments, and borrow pits) have become occupied by alligators. Canals often contain mostly larger animals because they do not provide good juvenile alligator habitat and can be reproductive sinks because of low nest success and high hatchling mortality (Chopp, 2003). Mazzotti and Brandt (1994) conclude that region-wide there are fewer alligators in the natural habitats of the Florida Everglades today than historically due to loss and alteration of wetland habitats.

In addition, changes in water management have influenced the pattern of water levels in the southern Everglades causing unnatural flooding of alligator nests (Kushlan and Jacobsen, 1990). Hydrologic alterations of the system have reduced the prey availability corresponding to lower growth, survival and reproduction of alligators (Mazzotti et al., 2007). Increasing drought frequency and depth of drying have reduced suitability of Southern Marl Prairie and Rocky Glades habitats and occupancy of alligator holes by alligators (Mazzotti et al., 2009; Fujisaki et al., 2012). Increasing drought frequency and depth of drying also increase the time required for fish and macroinvertebrate populations to recover to levels considered representative of the historical Everglades (Trexler et al., 2003; Trexler and Goss, 2009) and sufficient to sustain large predators such as alligators (Loftus and Eklund, 1994; Turner et al., 1999; Trexler et al., 2005). This may be correlated to lower growth and reproductive rates for alligators in the Everglades when compared to other parts of their range (Mazzotti and Brandt, 1994). Repeated drying events also may wipe out entire age classes, as alligators are forced to congregate in remaining water bodies where they may suffer predation and cannibalism (Mazzotti et al., 2009; Fujisaki et al., 2011).

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

Alligators are attributes in the Total System (Ogden et al., 2005), Everglades Ridge and Slough (Ogden, 2005), Southern Marl Prairies (Davis et al., 2005a), Everglades Mangrove Estuaries (Davis et al., 2005b), and Big Cypress Regional Ecosystem (Duever, 2005) Conceptual Ecological Models.

Ecological Premise: The distribution, reproduction, and body condition of American alligator populations have been reduced as a result of altered hydrologic conditions and the reduced abundance and accessibility of prey organisms that accompany the hydrologic alterations.

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

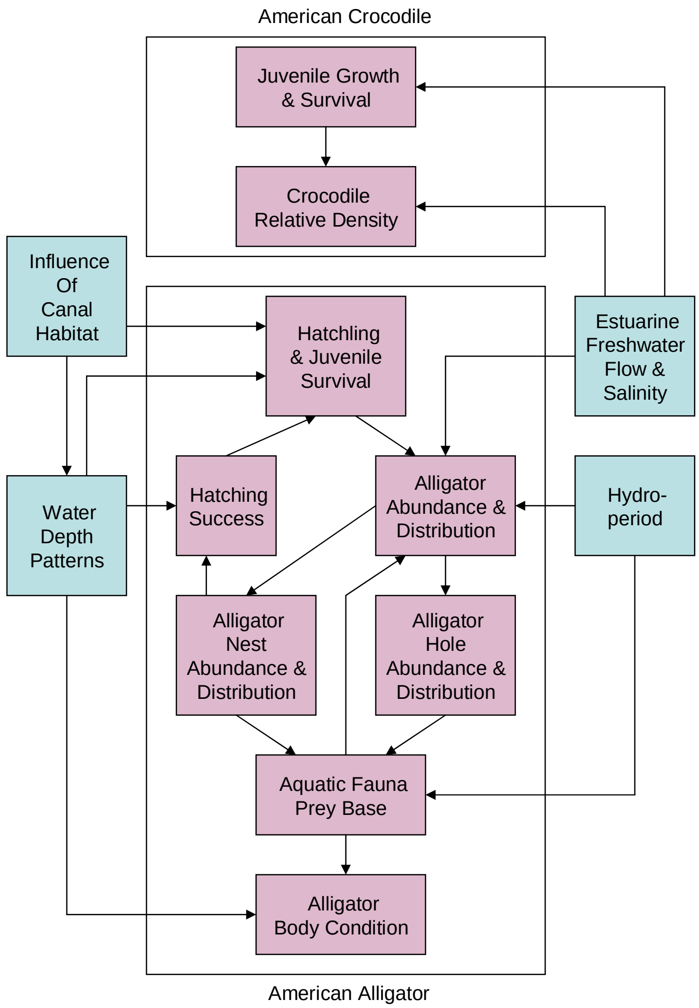
Greater Everglades Wetlands Module Everglades Crocodilian Population Hypothesis:

Hypothesis 1: American alligator populations in relation to hydroperiod, water table, water depth, and salinity in the Everglades.

Shortened hydroperiod, more frequent dry-downs, and lowered water table have reduced alligator abundance, body condition, and reproduction because of loss of aquatic habitat required for survival and reduced aquatic prey base (lower food resources contributing to lower body condition). In addition, dry-downs can result in declining trends in smaller size classes (Fujisaki et al. 2011) and overall negative population trends (Waddle et al., in prep). Lack of dry-downs and high water during nesting also can contribute to lower body condition (food resources are dispersed) and lower nest success (nest flooding). Higher salinities in estuarine areas have resulted in reduction in alligator nesting and relative abundance of alligators. Canals further reduce abundance and survival of juvenile alligators due to increased predation and there are fewer alligator holes within 1-km of a canal than in interior marshes (Brandt et al., 2010).

Working Hypothesis: Restoration of sheet flow and related water depth patterns consistent with the understanding of pre-drainage conditions, in combination with the removal of canals, will result in a widespread increase in alligator abundance and body condition in the Everglades. Alligators are expected to repopulate and resume nesting in restored areas that have recently been too dry including northwestern Water Conservation Area 3A and the Rocky Glades or have too high salinities such as the freshwater reaches of tidal rivers along the southern coastline of the Everglades. Hydroperiods > 11 months with dry-downs (water levels < 15 cm) no more frequently than an average of once every 3-5 years that follow natural patterns of recession and ascension will support healthy populations of alligators. Healthy populations of alligators will contribute to maintaining marsh microtopography and healthy populations of aquatic fauna and wading birds by providing additional refugia and foraging sites through creation and maintenance of alligator holes and trails.

Everglades Crocodilian Populations Conceptual Ecological Model



4.0 Evaluation Application

4.1 Evaluation Protocol

The Alligator Production Suitability Index (APSI) (Shinde et al., 2013; see http://www.cloudacus.com/simglades/alligator.php, Ecological and Design Document [GATOR-PSIM v. 2.1]) models habitat suitability annually for five components of alligator production: (1) land cover suitability, (2) breeding potential (female growth and survival from April 16 of the previous year - April 15 of the current year), (3) courtship and mating (April 16 – May 31), (4) nest building (June 15 – July 15) and (5) egg incubation (nest flooding from July 01 – September 15), and aggregates them into an overall production suitability score for that nesting year. Components 1-3 of the alligator production suitability index are included in the alligator nest abundance and distribution box in the conceptual model above and component 5 is included in the hatching success box.

4.2 Normalized Performance Output

Output for all components and the overall alligator production suitability index are on a scale of 0 (not suitable) to 1 (most suitable).

4.3 Model Output

Output is both spatial by cell and a post-production utility makes tabular summaries readily available.

The model retains the annual score by geo-referenced grid cell for each of the component indices and for the overall APSI computed as the geometric mean of the component scores. The model also retains the intermediate metrics generated in the computation of the component scores, allowing the user to review the conditions that lead to a given result. See output descriptions and example model output in Appendix A.

4.4 Uncertainty

Recognition of model uncertainty is needed when interpreting the ecological significance of model output. The Model Uncertainty Workshop Report provides guidance on the potential implications of uncertainty on model output interpretation (RECOVER 2002). The APSI provides a deterministic response to changing environmental conditions. Future iterations of the model may consider modeling probable variation around the response and thus providing a response envelope rather than a singular result.

A number of uncertainties were identified in development of the model (see Future Model Development section in Shinde et al., 2013). When interpreting the output it is important to keep in mind that each yearly index score is independent of the previous yearly score. We know that this is not the case in the real world. In addition, the scores should be used only for relative comparisons among alternatives and do not represent actual alligator production values. Higher scores should indicate better conditions, but we have not determined the relationship between a specific score and expected number of successful nests. Ecological models do not incorporate all factors that affect the modeling target and so have limitations in their predictive capacity.

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research - Greater Everglades Wetlands Module section 3.1.3.15 (RECOVER 2004a)

See CERP Monitoring and Assessment Plan 2009 Greater Everglades Module Section 3.3.9 (RECOVER 2009)

See *The RECOVER Team's Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan* – Interim Goal 3.10 American Alligator (RECOVER 2005)

5.2 Assessment Approach

See RECOVER Team's 2006 Assessment Strategy for the Monitoring and Assessment Plan. Final Draft (RECOVER 2006). In addition, see above and Mazzotti et al. 2009 on how parameters are combined to provide assessments for individual years, management units, and system-wide.

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

The alligator production suitability index would be improved by addressing the uncertainties identified in the Future Model Development section of the documentation. In addition, model output based on actual hydrology should be compared to data on body condition, abundance, and nesting to further develop the relationship between the suitability scores and actual ecological values.

6.2 Assessment Tools Needed

Systematic, long-term data on alligator abundance, body condition, hole occupancy, and nesting are needed to conduct assessments and validate the model and to refine model parameters.

7.0 Notes

This performance measure supersedes and addresses Wetland Trophic Relationships - American Alligator Distribution, Size, Nesting and Condition (Last Date Revised: December, 2006).

8.0 Working Group Members

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Appendix A

Model Output

The APSI produces annual, spatially-explicit output layers for the overall alligator production habitat suitability, the component index scores, and the metrics derived in creating the component scores (**Table A-1**). The output is NetCDF format, UTM, NAD83, 17N; coordinate units are meters. The example in **Figure A-1** illustrates the output for a single year; however the spatial distribution of habitat suitability varies considerably from year to year. NetCDF data viewers that support animation, such as JEM EverVIEW (www.jem.gov), can be particularly helpful in evaluating the model results.

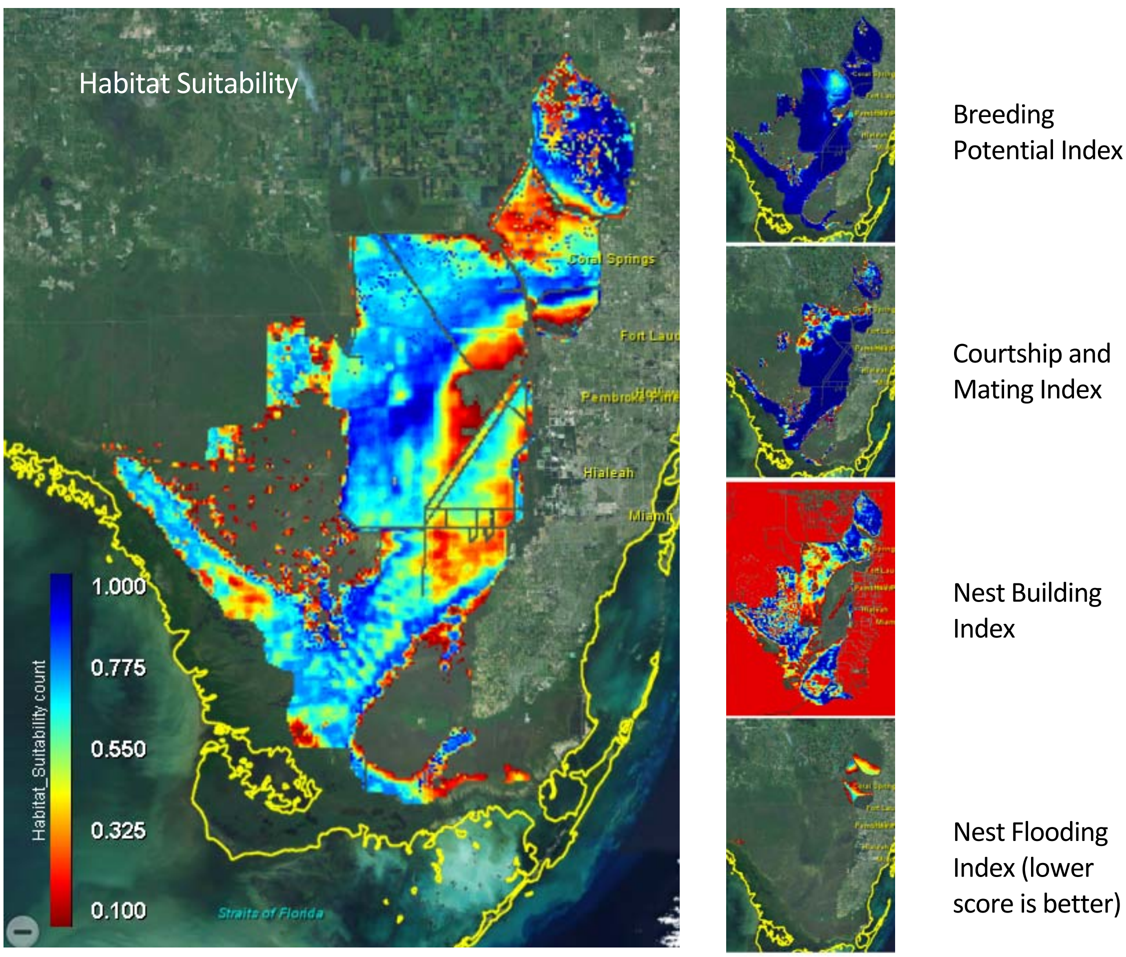

Figure A-1. Example annual output of alligator production habitat suitability in a good year (1983, Central Everglades Planning Project (CEPP) Alternative (Alt) 4r2). Left: Combined index (the geometric mean of the components). Right: The component indices. The index scale (0 to 1) and color scheme is the same in all the panels. The metric data layers generated by the model are not shown.

Table A-1. Spatially explicit data layers created by APSI. All output is NetCDF.

Output		Description
1.	Habitat Area	Suitability for area of habitat within the grid cell.
2.	Tree Island Height	Average height of tree island ground surface above marsh surface
3.	Sum Alligator Holes	Number of alligator holes in the grid cell.
4.	Percent Edge Habitat	Proportion of edge habitat in the grid cell.
5.	Breeding Potential	Suitability for breeding potential.
6.	Courtship and Mating	Suitability for courtship and mating.
7.	Nest Building	Suitability for nest building.
8.	Nest Flooding	Probability of flooding during egg incubation.
9.	Habitat Suitability	Overall alligator production suitability
10.	BP Wet/Dry	Proportion of days during breeding when too wet or dry.
11.	CM Depth	Average water depth during courtship and mating.
12.	NB Depth	Average water depth during nest building.
13.	NF Depth Max	max water depth during egg incubation.

Post-Processing

A plotting utility, *CEPP Plotter* (so named because it was originally created during CEPP alternative evaluations), facilitates rapid creation of model summaries. Summaries are illustrated here by CEPP zones (**Figures A-2 – A-5**), however, other area zonations can be specified. The box and whiskers plots, cumulative score plots and median years map product will also produce summaries by all years, average years, wet years, and dry years (user specified). Only the 'all years' plots are presented here as examples.

Box and whiskers

Box and whisker plots present the median, mean and data quartiles for habitat suitability summaried by zones (**Figure A-2**).

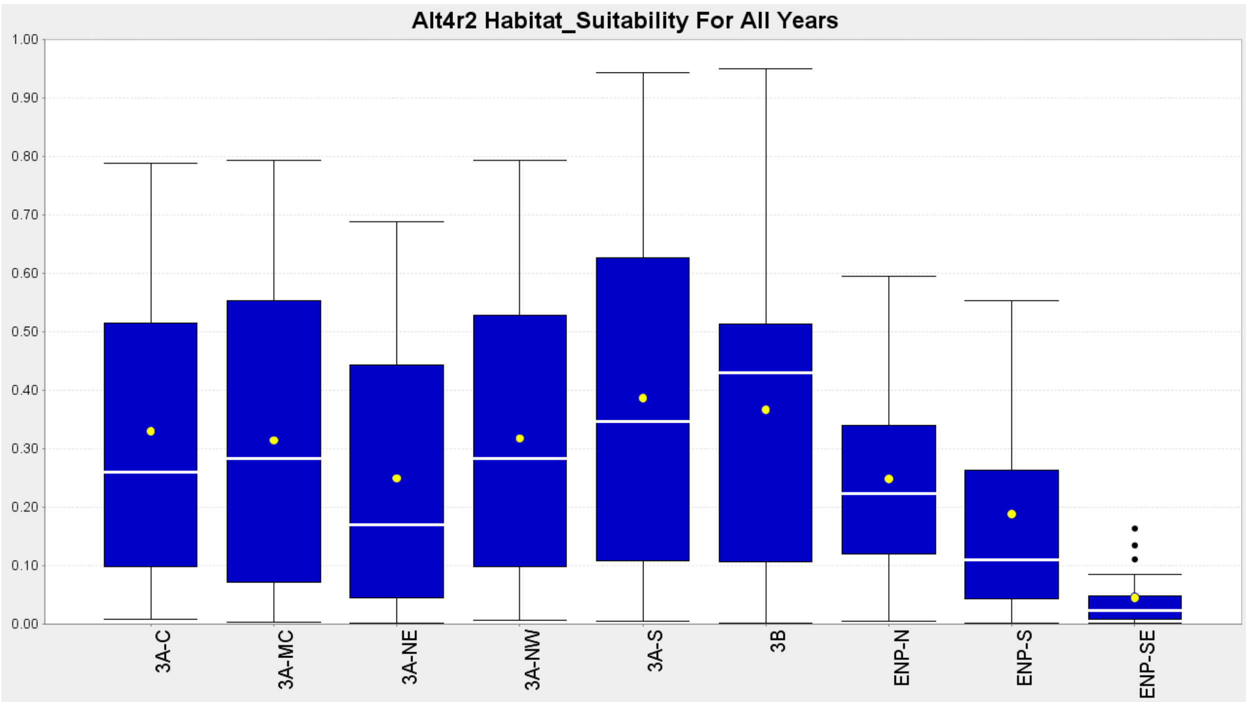

Figure A-2. Example box and whisker plot for CEPP Alt4r2 alligator production habitat suitability by CEPP zones. Yellow dot is the mean, white line is the median, boxes are the limits of the 1st and 3rd quartiles, and whiskers are the range of the data with black dots beyond the range indicating outliers.

Cumulative plots

Graphs of cumulative alligator production habitat suitability scores plot the sum of habitat suitability in the current year and all past years. In the example in **Figure A-3**, the plots aids in quickly diserning that habitat scores in all the CEPP zones were very low from 1971-1978 because each additional year did little to raise the cumulative score. Those poor years were followed by 2 excellent years in 1979 and 1980. Across all the modeled years, the relative position of the CEPP zone scorings remained pretty constant, with 3A-S and 3B averaging the highest scoring cumulative suitable habitat and ENP-SE having the least (ENP-SE is largely marl prairie).

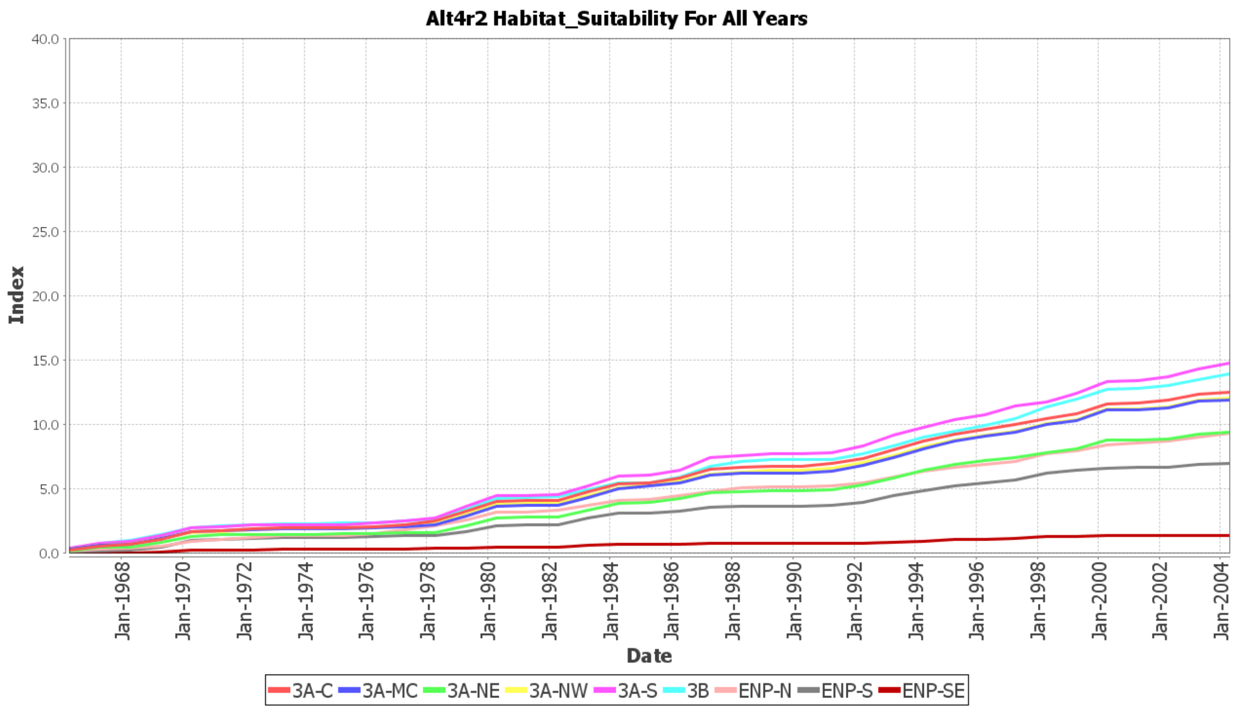

Figure A-3. Example cumulative alligator production habitat suitability scores for CEPP Alt4r2 by CEPP zones. There are 41 years in this example, so a maximum score of 41 is possible if Alt4r2 has a 1.0 score every year.

Lift from baseline

The lift from baseline graph plots the difference between the final year's cumulative score for the hydrologic model alternative and a baseline hydrologic condition as shown in the example in **Figure A-4**.

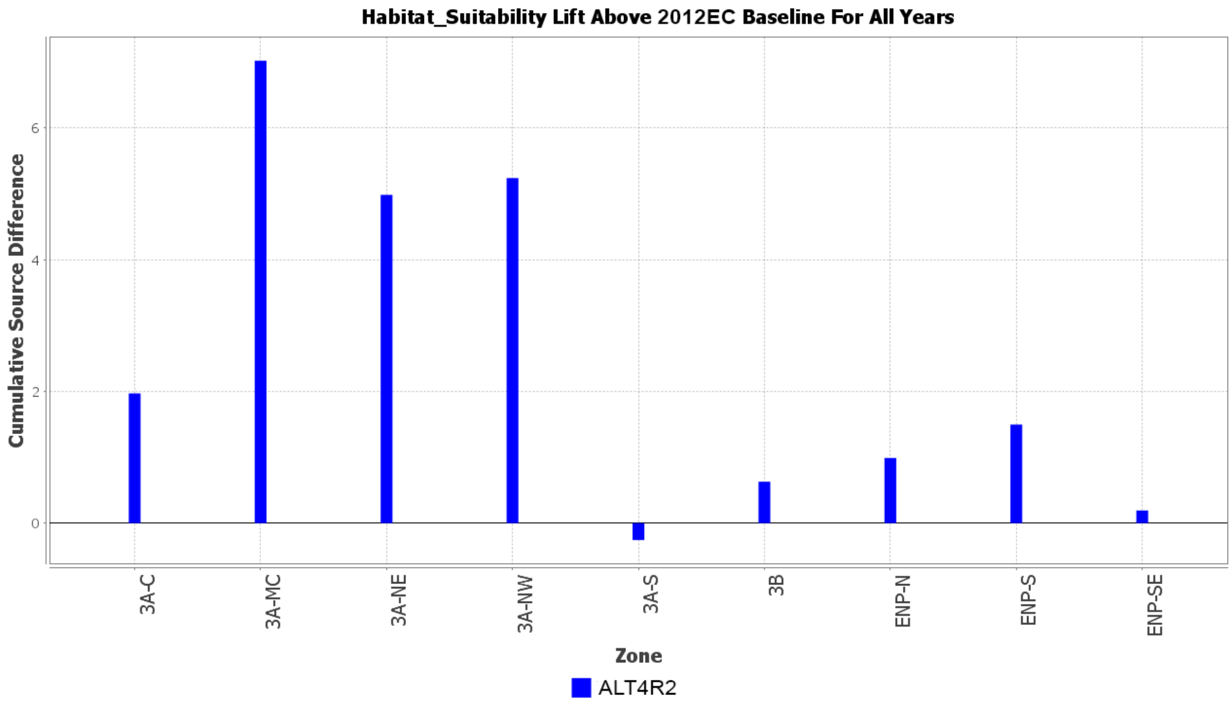

Figure A-4. Cumulative alligator production habitat suitability (1965-2005) lift from existing conditions (2012EC) for CEPP Alt4r2 within each CEPP zone. A maximum score of 41 is possible if 2012EC has a suitability score of 0.0 every year and the alternative has a suitability score of 1.0 every year.

Median habitat scores

In addition to mapping alligator production habitat suitability scores for each year (**Figure A-1**), the APSI can be mapped for the median of a user specified set of years (**Figure A-5**).

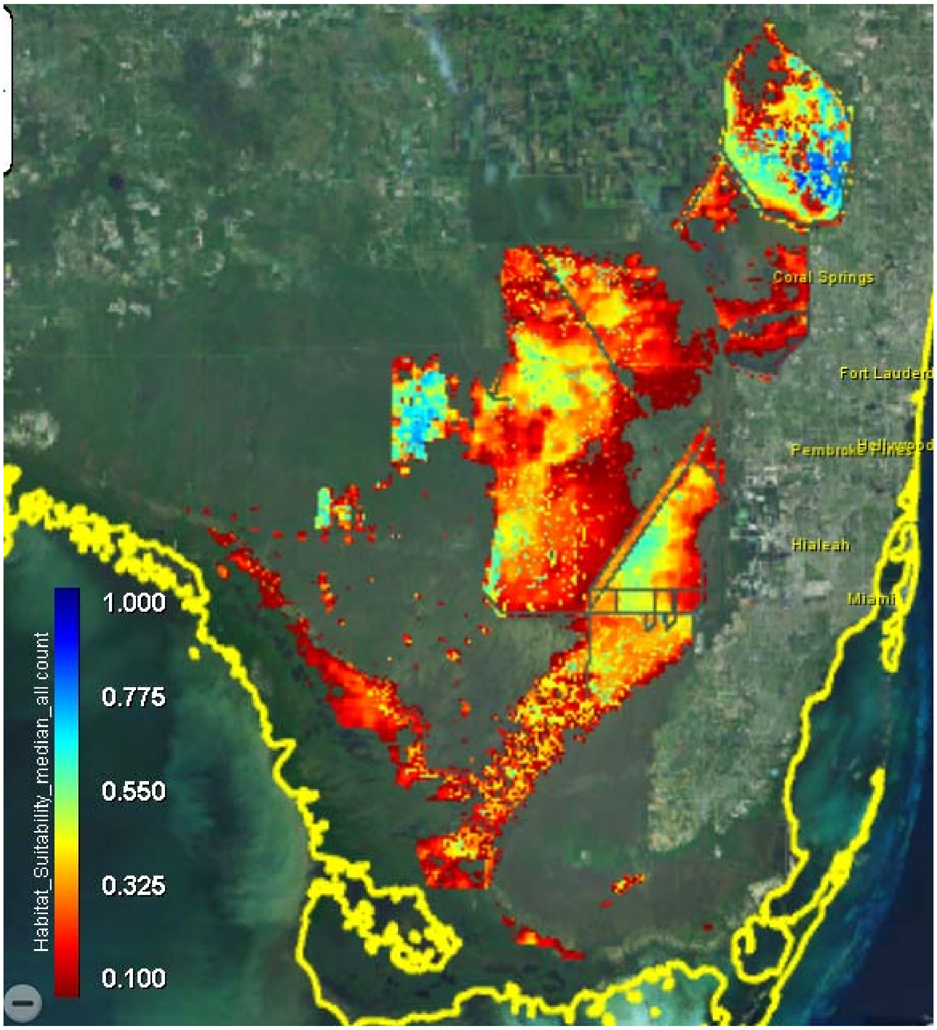

Figure A-5. CEPP Alt4r2 average alligator production suitability index for all years (1965-2005).