Long-Term Population Trends (1958-2008) of Bald Eagles (*Haliaeetus leucocephalus*) in Florida Bay, Everglades National Park

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The Bald Eagle is one of the most well studied North American birds, and yet despite its status and attention, throughout the 20th century there have been dramatic fluctuations in its populations that continue to this day. Florida currently supports 11% of the nesting population in the lower 48 states, more than any state other than Alaska and Minnesota. In addition, the estimated number of adults in Florida has increased more than 300% during the past three eagle generations as defined as a total of 24 years (FWC, 2008). While Bald Eagle populations statewide have demonstrated a dramatic recovery over the past 25 years, the population of Bald Eagles breeding in Florida Bay, Everglades National Park (ENP) has shown a troubling decrease. Changes in the hydrology of Florida Bay and the southern estuaries of ENP have drastically altered these ecosystems and are listed as key landscapes vital to Everglades restoration. The fish eating birds of Florida Bay and southern estuaries are particularly sensitive to salinity levels and fluctuations in freshwater flows from the Everglades (Crozier and Gawlik, 2003; Lorenz et al., 2009; Frederick et al., 2009). Bald Eagles here have been highly impacted by these changes as well, and should be considered an imperiled species in this region. From the start of ENP monitoring in 1958 through the 1970's, the Bald Eagle maintained a dynamically stable breeding population and was considered to potentially be at carrying capacity (26 active territories) for the Florida Bay system (Ogden, 1975). From 1970-1979, 92.1% +/- 0.02 of breeding territories surveyed were active, however from 1999-2008 only 53.2% +/- 0.03 were active with a record low of only 35.5% in 2001. Changes in breeding activity from historical benchmarks have led us to examine the relationship of Bald Eagle territory location, nesting activity, nesting success, and productivity in Florida Bay for the period 1958-2008.

The significance of this study to the restoration of Florida Bay and the southern estuaries is that:

- There have been negative changes in the nesting activity of Bald Eagles in Florida Bay beginning in the 1980s correlating with documented dramatic hydrologic and ecological changes in Florida Bay.
- Preliminary analysis indicates that nesting activity is driving the decrease in Bald Eagle reproduction in Florida Bay more than nesting success or nest productivity.
- Provides a long-term database of Bald Eagle reproduction that can be used as performance measures for restoration activities of Florida Bay and the southern estuaries.

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Effects of Lake Stage and Marsh Elevation on Wading Bird Nesting Effort at Lake Okeechobee

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Aerial wading bird surveys of the lake have been conducted from 1957-1960, 1971-1972, 1974-1975, 1977-1992, and from 2005 through the present to monitor timing and nesting of wading birds. Historically, approximately 10,000 birds a year nested at Lake Okeechobee until the regulation schedule increased water levels in 1978. Thereafter nest numbers declined, likely because wading birds need shallow marshes to access their prey. Today, the Lake operates under a schedule which tries to minimize extreme high lake stages and allows for recessions in the interior marsh during the dry season.

Past research has focused on the stage level in reference to both wading bird nesting and foraging. Although very important, this does not take into effect the actual topography of the lake bottom. In this study, we used lake stage levels and an interpolated predictive surface of the littoral zone to develop predicted water depths. We estimated the daily availability of habitat in the littoral zone using depths found in the literature to be suitable for wading bird foraging. Habitat was unavailable if it was too deep or dry. We examined the relationship between monthly nest effort for three species, the Great Egret (*Ardea Alba*), Snowy Egret (*Egretta thula*), and White Ibis (*Eudocimus albus*), and predicted available habitat 2006-2009.

We detected a total of 10176 and 6116 nests in 2006 and 2009, respectively. In contrast, we detected only a total of 550 and 20 nests in 2008 and 2009, respectively. Average daily available habitat for each season was higher in good nesting years of 2006 and 2009, at 600.6 km^2 and 671.0 km^2 respectively than in the poor years of 2007 and 2008, at 160.1 km^2 and 84.5km^2 per day respectively. There was a high correlation ($r=0.78$, $p<.01$) between monthly nest effort and average daily area of habitat per month between February and May. Plotting lake stage against available habitat showed a quadratic function that coincided with a peak area at 3.91 m NGVD88 (approximately 14 ft msl). This coincides with reported high nest efforts historically at moderate lake stages of 3.77 m to 4.36 m. Future research is aimed at refining a habitat suitability model that incorporates other environmental factors.

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Diet Composition of White Ibis Chicks in Loxahatchee National Wildlife Refuge: Crayfish, Crayfish and more Crayfish

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While the ecological goals of Everglades restoration have been identified for some time now, the prey types capable of supporting large populations of nesting White Ibis have been unclear. The main objective of this study was to quantify and compare White Ibis diets in Loxahatchee National Wildlife Refuge (Lox) throughout the 2008 and 2009 nesting seasons. Water levels were relatively higher and stable and the total nesting numbers were lower in 2008 than in 2009. We collected 105 boluses in 2008 and 146 in 2009 from the largest nesting colonies in Lox. Boluses were collected during 5 and 4 weeks of the provisioning period each year. Boluses were sorted and analyzed in the lab; all prey were identified and their sizes (g dry mass) were estimated using regressions and comparisons with whole animals. The food types were categorized into 8 groups based on habitat and taxonomy for multivariate analyses. The groups were crayfish, small fishes (mosquitofish, killifishes, flagfish), large fishes (mostly sunfishes), grass shrimp, aquatic insects, terrestrial insects, vertebrates, and garbage (mostly rotten meat or dog food).

The mean total biomass per bolus in 2008 was 1.46 g (SE = 0.23) and in 2009 it was 1.68 g (0.17) and did not differ between years. Crayfish biomass dominated the diets (>50%) in both years and were present in 80-85% of all boluses indicating that crayfish are a heavily used prey type over all water conditions during these years in Lox. Fish biomass made up 0% to 36.2% of all prey biomass across collections in 2008 and 0.8% to 27.4% in 2009. Terrestrial prey and garbage use was highest when water depths were highest.

The contribution of crayfish biomass to overall similarity of boluses for any collection in both years ranged from 66% to 100%; crayfish typified the diets. Multivariate analyses of prey biomass composition within years revealed no significant variation between collections (weeks) in 2008. In 2009 prey composition did vary by date; in general the biomasses of both small- and large- bodied fishes increased and crayfish biomass decreased in collections at the end of 2009 (shallower landscape water depths) compared with collections earlier in the season. Our results indicate that crayfish are a dominant component of White Ibis diets in Loxahatchee. The good nesting in 2009 was probably caused by greater crayfish availability with continuous recession.

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Anthropogenic Resource Utilization in the Diet of the Sacred Ibis, *Threskiornis aethiopicus*, a Non-Native Wading Bird in Southeastern Florida, USA

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The sacred ibis, *Threskiornis aethiopicus*, is a non-native wading bird in the Western Hemisphere. It is believed that in North America the sacred ibis escaped captivity from zoo aviaries and private collections following the destruction caused by Hurricane Andrew in 1992. Sightings of the species were restricted to urban areas until 2005 when breeding birds were detected in wading bird colonies in the Everglades region. There was concern that the establishment in the Everglades by this large wading bird would put pressure on the larger bodied endangered Wood Stork (*Mycteria American*), and the smaller bodied White Ibis (*Eudocimus albus*), through chick predation and resource competition. An eradication program was initiated by a consortium of government agencies in Florida in 2008 to avoid a case of exponential population growth of the Sacred Ibis as was seen in Europe. This study investigated the degree to which the population of sacred ibis in South Florida consumes anthropogenic food items, which may have contributed to its population expansion. Morphometric measurements, the first such data for this species in North America, were obtained for 8 adult males and 5 adult females. The contents of the esophageal tract and gizzards were used to classify ibis diets as being of anthropogenic origin if they contained cheese, meat, paper pulp, and/or pellet meal. Diets were comprised of predominately anthropogenic items (58% of the cumulative biomass). Ibis utilizing anthropogenic resources consumed more biomass (26.99g ± SE 5.35g) than birds utilizing natural resources (8.74g ± SE 2.21g) ($H = 8.05$, d.f. = 1, $p < 0.01$). Natural diets, on average, contained a significantly greater percent vegetative matter (63% ± SE 12%) than anthropogenic diets (8% ± SE 3%) ($H = 8.44$, d.f. = 1, $p < 0.01$). Novel organic and inorganic items found in anthropogenic diets included bacon, glass, hot dog, pellet meal, and plastic. The notion that some species of birds can adapt to newly available anthropogenic resources has wide support, and the impacts these resources have on avian ecology and physiology are becoming apparent through multiple studies. The ability of this species to heavily utilize anthropogenic resources may have helped it become established in South Florida, as it has helped the bird invade parts of Europe. However it is not clear whether this species prefers anthropogenic resources or whether they simply serve as a buffer when natural resources are scarce. Further investigation, of ecologically similar species, may elucidate linkages between resources in urbanized areas and impacts in nearby natural habitats.

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Multi-Scale Characterization of Biogenic Gas Dynamics in Peat Soils Using Hydrogeophysical Methods: Implications for Biogenic Gas Distribution and Carbon Fluxes

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Peatlands are a major component of the Earth's carbon cycle, containing about one third of the carbon in the pedosphere and influencing climate by sequestering and releasing carbon dioxide and methane to the atmosphere. Ground penetrating radar (GPR) is a geophysical method based on measuring the travel times of continuous high-frequency electromagnetic (EM) waves between a transmitting and a receiving antenna. Velocity of this EM wave is primarily controlled by changes in water content and thus is very sensitive to variability in free phase gas content. The method has been effectively applied as a non-invasive technique for investigating biogenic gas dynamics in peat soils over a wide range of spatial scales with minimal disruption to the *in situ* gas regime. Several applications of GPR at both the laboratory and field scale are presented here in order to further investigate the spatial distribution and temporal dynamics of biogenic gases in peat soils. Laboratory measurements on samples extracted from both northern peatlands (from Maine and Minnesota) and subtropical peatlands (from the Everglades) are shown and compared here. Several field-scale applications of the technique in northern peatlands are described, and the potential implementations of the technique to research in the Everglades are discussed. We conclude with some further recommendations for future applications of GPR for investigating gas distribution and dynamics in peat soils.

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Wetland Drying has Substrate- and Species-Dependent Effects on Crayfish (*Procambarus* spp.) Populations

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Wetland drying can be a severe disturbance for aquatic animal communities that provide prey for seasonally nesting wading birds. However the disturbance levels of wetland drying, measured as population reduction, and the net impact on animal densities will be context dependent. I conducted a 2 month experimental dry-out to compare burrowing success and survival (i.e., drying resistance) of two species of crayfish (*Procambarus fallax* and *Procambarus alleni*) in three common south Florida wetland soils (sand, marl, and peat). Throw trap density data taken from WCA 3A and Loxahatchee from 2005-2009 were used with local hydrologic covariates (modeled using EDEN water surfaces and local depth measurements) to consider the net effects of low water and drying on crayfish densities.

Burrowing observations when the water first dropped below the sediment surface indicated that the two species burrowed equally well in peat while *P. alleni* burrowed more successfully in the heavier marl and sand substrates. Survival after two months depended on species and substrate conditions. Survival was low for both species in sand and no *P. fallax* survived in that substrate. Survival was high for both species (~66%) in peat. *P. alleni* survived better than *P. fallax* in marl substrates. Both species experienced loss of body mass from initial conditions although *P. fallax* tended to lose more than *P. alleni*. The difference in survivorship of the two species in the marl was greater in this study with a 2 month drought than in an earlier experiment with a 3 week long drought. These results explain in part why *P. alleni* comes to near complete dominance in temporary marl wetlands while *P. fallax* can persist and maintain their densities in temporary wetlands with peat substrates and moderate drying.

Hydrologic covariates at six sites sampled through time in Loxahatchee explained little of the temporal and spatial density variation; *P. fallax* were abundant in Loxahatchee (3.75-9.75/m^2 averaged for each site over time) and seem able to re-grow quickly even following dry events of up to 10 weeks. While densities tended to be lower in central WCA 3A (2.2-4.7/m^2) densities were generally higher when water levels over the past year approximated conditions found in Loxahatchee. Taken together the results of these studies suggest *P. fallax* are resilient to moderate drying in wetlands with peat substrates and may achieve higher densities in response to moderately low water depths.

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A Synthesis of Recent Studies Showing How Prey Availability Affects Wading Bird Habitat Selection, Physiology, and Productivity

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The trophic hypothesis rests on the premise that food limits wading bird nesting in the Everglades and that hydrology controls the production and availability of aquatic prey animals. This synthesis paper tests part of that idea with a set of studies on wading birds and their prey conducted in 2005-2009. Data from a study of prey concentrations from the CERP Monitoring Aand Assessment Plan were linked to studies of wading bird habitat selection, physiology, and productivity. The responses of the Great Egret (*Ardea alba*) and White Ibis (*Eudocimus albus*), two species with contrasting foraging strategies, were compared in a year with high and low prey availability. Habitat selection was also determined from a comparison of random and used sites, and in enclosures where water depth, food, and habitat were manipulated.

White Ibises were more selective of foraging sites, particularly after hydrological reversals, lowered their clutch size, and fledged chicks in poorer physiological condition relative to Great Egrets in poor habitat condition years, suggesting that they are more constrained in their use of Everglades habitat. Poor foraging conditions should produce earlier and larger negative responses in White Ibis than Great Egrets, and may explain the difference in population trends between the two species.

When experimentally controlling for fish density, wading birds select sites where vegetation is present rather than open areas where prey are vulnerable. Prey concentrations are highest in areas with dense vegetation so it is likely that birds are selecting sites based on expected prey density rather than actual prey density or prey vulnerability. Receding water is more important to both species in years with poor habitat conditions than in years with good habitat conditions; however, egrets are more dependent on recession rate than are ibises. Fish-eating birds are reportedly more dependent on receding water than birds like the White Ibis, which eat primarily crayfish. Our study confirms that crayfish density does not increase as much as fish density during a drydown. The shape of the response to recession shows that recession rates below 5 mm per day or above 7 mm per day will increase nest failures. When prey availability is low, water level recession is more important to both species than when prey availability is high, supporting the idea that receding water is more important in a degraded landscape.

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Foraging Ecology of Nesting Bald Eagles (*Haliaeetus leucocephalus*) in Florida Bay, Everglades National Park

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It is well documented that starting in the late 1980's, Florida Bay began to undergo a series of dramatic hydrologic and ecological changes due to altered freshwater inflows which affected salinities, causing seagrass die-offs, algal blooms, increased turbidity, and changes in prey-fish assemblages. It has never been documented before how these changes may have affected the Bald Eagle (*Haliaeetus leucocephalus*) population. We believe that changes in hydrological conditions may have lead to changes in prey communities, thus altering Bald Eagle foraging and nesting activity. The Bald Eagle is an opportunistic predator, scavenger, and prey thief. While there is a wide range of studies on Bald Eagle foraging, there is limited data available for their southern most range. It has been reported that eagles in southern Florida feed predominantly on fish and also wading birds, waterfowl, small mammals, and turtles, but there is no comprehensive study of diet for eagles residing in mangrove estuaries.

The purpose of this study is to document foraging ecology and test the hypothesis that food is the limiting factor to the success of Bald Eagle nesting in Florida Bay. We used digital videomonitoring
equipment to monitor prey deliveries to the nest and provisioning rates of four eagle nests during the 2009-2010 breeding season. From these recordings we examined the foraging ecology of nesting Bald Eagles and determined prey consumption, percent composition of prey items, changes in provisioning rates, and changes in prey selection in relation to nest location, time throughout the breeding season, and productivity. We also collected prey remains from nests at the end of the breeding season and compared these to historical data from 1970's to examine for a potential change in prey composition, also in relation to nest location and productivity.

The significance of this study to the restoration of Florida Bay and the southern estuaries is that:

- An initial analysis of prey types and provisioning rates influence on current nesting success and productivity for nesting Bald Eagles in Florida Bay will be determined.
- Establishment of a data set of Bald Eagle prey items selected during the breeding season from nests located throughout Florida Bay based on current conditions and historical data.

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The Effect of Hydrology, Fire Regime and Exotic Invasion on the Postburn Successional Trajectory of Plant Communities in the Big Cypress National Preserve

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Relatively little is known about how exotic invasion interacts with hydrology and fire regimes to influence community composition and successional trajectories. In April 2009, severe fires burned through more than 12,000 hectares of pine flatwoods and hardwood hammocks in the northwestern portion of the Big Cypress National Preserve (BICY), presenting a unique opportunity to collect baseline data and study how the interactions among long-term hydrology, fire history, and invasion by exotic plant species affect the regeneration of canopy species in forested communities of the Big Cypress.

The study area encompassed approximately 25,000 hectares of BICY to the north of I-75 between the Okaloacooche Slough and the L-28 Interceptor Canal. Forested communities within the study area included deep cypress strands, cypress prairies, cypress domes embedded in wet prairies and marshes, hydric pine flatwoods, hydric oak hammocks (dominated by *Quercus laurifolia*), and mesic oak hammocks (dominated by *Quercus virginiana*). With the exception of the deep cypress strands and swamp forests, large portions of the study area experienced a wildfire or prescribed burn at least once since 2000 and many areas had burned at least twice since 1980. GIS maps of vegetation cover, burn history since 1980, and exotic invasion history were used to select sampling locations that captured the spatial variation of these attributes within the study area. During the wet season in 2009, vegetation cover and seedling density was sampled at a total of 53 100m x 100m plots across the hydrologic gradient at 19 locations. Water depths measured at sample plots on a given day were related to water surface elevation data generated by the Everglades Depth Estimation Network (EDEN) for the same day to determine the offset between the EDEN water surface and the ground level at the plot. The offsets were then used in combination with the EDEN time series data to generate the hydrograph of water depth for each plot, and measures of hydrological conditions were derived from the resulting hydrographs for the period from January 2000 through September 2009.

NMS ordination of plot data produced three significant axes. One of the significant axes was strongly correlated with average annual hydroperiod, inundation depth, and soil thickness. A second significant axis was significantly correlated with percent cover of the invasive exotic *Schinus terebinthifolius* in the shrub and canopy layer. This axis was not correlated with the density of *Schinus* seedlings, but was significantly correlated with the presence of *Q. laurifolia* and *Q. virginiana* in both the canopy and seedling layer, suggesting that exotic invasion may not have a significant effect on the post-burn regeneration of canopy species in intact hammocks. Direct gradient analyses showed that the highest density of *Quercus* seedlings was found in relatively short-hydroperiod plots that had recently burned. High densities of *Quercus* seedlings were also observed early in the wet season at locations with a known history of exotic disturbance where prescribed burns had taken place during the previous dry season, highlighting the importance of integrating fire management and invasive control.

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Seedbank, Germination and Abiotic Factors Control *Ruppia maritima* Dynamics across the Freshwater-Marine Transition Zones in Florida Bay

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The marine transition or ecotone zone of Florida Bay is an extremely unique habitat that provides foraging grounds and a prey base for both terrestrial and marine species of ecological and economic importance. The highly productive and critical habitat characteristic of this zone is highlighted by the fact that it is a key component of Everglades' restoration. One of the major goals of Everglades' restoration is to restore the functionality of the submerged aquatic vegetation habitat at the Everglades-Florida Bay ecotone with *Ruppia maritima* as an explicit CERP restoration target. However, we understand very little about the biology, life history and abiotic factors controlling this species dominance and variable presence in Florida Bay. In fact, at several ecotone locations where *R. martima* was in the recent past a dominant SAV, it has been absent over the last few years.

Our research group at FAU has been conducting laboratory and field experiments over the last decade to support CERP and MFL planning by determining the salinity thresholds of various seagrass species in Florida Bay. We are examining the mechanisms controlling *R. maritima* establishment from seed and the factors driving the overall distribution of this species in Florida Bay in support of the SFWMD seagrass ecosystem model and ENP landscape habitat model. Model-driven scenarios of water management operations and forecasting require a mechanistic understanding of factors that promote SAV species shifts because a majority of these species are recruiting from seed and/or spores. Thus, both the factors controlling recruitment and germination are critical to understanding SAV dynamics at the Everglades-Bay ecotone. Based on our results, we have shown that, although *R. maritima* in its adult form can tolerate salinities up to 60 psu, seed germination appears to be limited to salinities <25 psu with optimal germination at 0-5 psu. Further, we determined that high salinity exposure, even up to 45 psu, did not negatively affect *R. maritima* seeds, rather high salinity exposure had a stimulatory effect on subsequent germination once salinities were lowered to freshwater conditions. These results indicate an osmotic effect on seed coat stratification. We also present data on a large spatial analysis of the *R. maritima* seed bank and seed viability encompassing six transects across the ecotone. Finally, we present preliminary results from data recorders at three sites in Joe Bay where detailed life history and SAV dynamics are being assessed. We have developed a conceptual model on the biotic and abiotic factors controlling *R. maritima* and the SAV community at the Everglades-Florida Bay transition zone and incorporate climate change and Everglades' restoration influences on this species ability to be sustained in the Greater Everglades Ecosystem.

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Revision and Assessment of Water-Surface Modeling of the Everglades Depth Estimation Network (EDEN)

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The water-resources products of the Everglades Depth Estimation Network (EDEN) quantify spatial and temporal hydrologic patterns at the landscape scale, and supply critical and easily accessible hydrologic data in support of the Everglades ecosystem restoration. The EDEN watersurface
model forms the foundation of the hydrologic dataset and, together with the digital elevation model of ground surface, provides principle investigators and water-resource managers with computations of daily water depths and hydroperiod throughout landscapes in the greater Everglades.
The EDEN water-surface model interpolates water-level data from a network of real-time waterlevel
gaging stations operated by multiple agencies, including the National Park Service, the South Florida Management District, and the U.S. Geological Survey. The hourly water-level readings are compiled and quality-assured, and missing data are estimated. The daily water-level medians are computed and used by the water-surface model to create daily water surfaces on a 400-meter grid. The model utilizes a radial basis function (RBF) algorithm and a combination of real and pseudo canal gages to model the discontinuities of water level across sub-region boundaries of the Everglades.
The objective of the recent and ongoing revisions to the EDEN surface-water model is to incorporate new data from gages, re-parameterize the interpolation program using the newest version of the RBF, and use the recent independent measurements of water levels at benchmark stations to assess the performance of the revised model. Input data for the model was improved by filling missing data gaps, making datum survey corrections to selected gages, and adjusting water-level data for canal gages to better represent observed flow patterns. New protocols for handling gage data under dry or near-dry conditions were incorporated. The revised surfacewater model is due to be completed in August 2010 and will be used to update EDEN daily water-level and water-depth surfaces from 2000 to current in September 2010.

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Revisions to the EDEN Ground-Surface Digital Elevation Model and Water Surface Model in the Water Conservation Area 1

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The Everglades Depth Estimation Network (EDEN) is a network of water-level gages used to create daily surfaces of water level and water depth for the greater Everglades. The water-surface model and ground-surface digital elevation model (DEM) were revised for Water Conservation Area 1 (WCA1) after investigators in the field reported EDEN water depths significantly different from their observations.

To better account for heterogeneity, changes were made to the input data filtering, area subdivision, and interpolation processes for the WCA1 portion of the EDEN DEM. As with previous releases, Airborne Height Finder data points falling on "upland" locations in EDEN cells with less than 33% upland area were removed before model development. However, for this revision, "upland" land cover in the WCA1 was defined using 2008 South Florida Water Management District vegetation data rather than USGS National Gap Analysis Program data. The EDEN DEM is actually a mosaic of ground-surface models covering smaller subareas. The entire WCA1 constituted a single model subunit in the previous DEM, but 4 new models (north, central, southeast and southwest) were created within WCA1 during the revision with the loosely defined boundaries of Comprehensive Everglades Restoration Plan landscape units. The resultant DEMs produced encouraging results. Moreover, evaluation of water depths estimated using the revised DEM with field-measured water depths for multiple dates and locations show improved consistency compared to those output using the previous WCA1 DEM.

Adding new canal gaging stations to the EDEN network and using them to develop canal boundary files significantly revised the water-surface model in WCA1. Additionally, a new protocol was implemented to estimate and use water-level data during dry conditions. Daily water-level surfaces created by the revised model were compared with independent measurements of water level at a new network of benchmarks. These results were used to reparameterize the water-surface model and improve the confidence in the EDEN daily surfaces. The revised ground surface DEM and water surface model for WCA1 will be used to update the water-level and water-depth surfaces for the period January 1, 2000 to current and be posted to the EDEN website (www.sofia.usgs.gov/eden) in September 2010.

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