Evaluation of WDAT vs EDEN Water Surface Elevation data for studying vegetation: hydrology relationship in the southern Everglades

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Background

Everglades Depth Estimation Network (EDEN) has been a pivotal tool for ecologists and biologists studying the Everglades. The EDEN provides spatially explicit hydrologic information that is important in understanding and predicting ecological responses of biological communities to the hydrologic changes in the Everglades. Real time stage data and modeled daily water-surface-elevation and water-depth information (1991-present) are publically available through the EDEN's interactive web-based platform. To support EDEN, which examines stage data from all the Federal and State agencies with permanent recorders in the Everglades, funds were combined from the USGS, the SFWMD and the USACE. These funds were used to install and maintain additional water-level gages in regions where more eco-hydrologic data were needed, to create a water surface map/data, to support a user-friendly graphic user interface (GUI), and to be supportive of research requests to synthesize these data in ways that improve RECOVER's understanding of Everglades structure and function. Since funds from all three agencies have been significantly reduced over the last five years, the RECOVER Executive Committee (REC) is looking at the feasibility of shifting from EDEN to the South Florida Water Depth Assessment Tool (SFWDAT) for assessments and evaluations. The SFWDAT, developed by the South Florida Water Management District (SFWMD), intends to model realistic water surface elevations within the independent basins composing the Everglades. However, SFWDAT does not have the user-interface or the convenience of EDEN. Preliminary cost estimates indicate that EDEN-like functionality can be added to SFWDAT for a small amount of money. Thus, a procedure to compare the accuracy, precision, and utility of the SFWDAT and EDEN water surface elevations is important to evaluate SFWDAT. Short-term studies covering different aspects of ecosystem structure and function in the Everglades would help in understanding the scientific functionality of SFWDAT in comparison to EDEN.

This document describes the results of an analysis conducted to evaluate the relative effectiveness of the use of SFWDAT and EDEN water elevation data in monitoring vegetation responses to hydrologic changes in two important ecological elements of the Everglades ecosystems; i) marl prairie landscape, and ii) tree islands. The analysis integrates the information on vegetation composition with physically-surveyed ground elevation and water stage data to calculate hydrologic parameters, and compares them with the parameters based on field measurements of water depth, and modeled water-surface elevation, independently derived from both the EDEN and SFWDAT.

1. Introduction

Water stage data produced by Everglades Depth Estimation Network (EDEN) are frequently used in RECOVER-funded monitoring projects in the Everglades, including marl prairie and ridge-slough & tree island landscapes. In such projects, landscape-level assessment of vegetation dynamics is often based on an understanding of site-specific statistical models, representing the relationships between existing vegetation composition and hydrologic conditions. The use of EDEN stage data in developing the statistical models for both the marl prairie landscape and tree islands, where sites are flooded for 0-10 months, has always been challenging. In several cases, discrepancies in hydrologic metrics based on EDEN's water surface and based on the nearest stage recorder were observed. The use of water-surface produced by the South Florida Water Depth Assessment Tools (SFWDAT) could be an alternative, as the SFWDAT water-surface elevations were found to be strongly correlated with observed water levels at 24 independent USGS benchmarks in Water Conservation Areas (Godin 2012), and the correlation was slightly stronger than between observed water levels and EDEN water-surface elevations (Volin et al. 2008). However, such an analysis for evaluating water-surface elevation modeled by SFWDAT is not available for the sites in Everglades National Park (ENP). Water level measurements at independent benchmarks usually have high precision in the validation process. However, these data can only be obtained in the wet season, typically July to October, and are not always available. In such cases, existing statistical models of the hydrology:vegetation relationship for marl prairie and tree islands may be a viable alternative for assessing the usefulness of SFWDAT water-surface model in RECOVER-funded monitoring projects.

This study is designed to compare the accuracy, precision, and utility of the SFWDAT and EDEN water-surface elevations as it relates to individual MAP goals and objectives. The general question addressed in this report is: Can SFWDAT provide the data needed to develop vegetation:environment relationships in marl prairies and tree islands? The objective of the present study is to evaluate the relative effectiveness of the use of SFWDAT and EDEN water-surface model in monitoring vegetation responses to hydrologic changes in i) marl prairie landscape, and ii) tree islands.

2. Methodology

2.1 Data acquisition

The study area includes the marl prairie landscape, the habitat of Cape Sable seaside sparrow (CSSS), within the Everglades National Park (ENP), Big Cypress National Preserve (BICY) and Southern Glades Wildlife Environmental Area (SGWEA), and tree islands in the marshes and prairies of ENP and Water Conservation Area 3A &3B (WCA3A and 3B). Vegetation composition data were available for 906 plots (293 transect and 613 census sites) within the habitat of six CSSS sub-populations (A-F) in the marl prairie landscape (Ross et al. 2006), and 846 plots on nine tree islands (Ross & Jones 2004; Sah et al. 2015) (**Figure 1; Table 1**). Ground surface elevations, obtained by surveying from a USGS benchmark of known elevation, were available for 292 marl prairie plots along six transects of 2.5-11 km (Ross et al. 2006), and for 550 plots along twelve transects of 110-1000 m on three Shark Slough tree islands

(Ross & Jones 2004). Water depths, measured in the field, were available for 597 marl prairie plots (172 transect and 426 census sites; Gaiser et al. 2006, Sah et al. 2009), and for 294 tree island plots on nine tree islands (Sah et al. 2015) (**Table 1**).

Table 1: Number of plots for which vegetation, ground elevation (physically surveyed), and field measurements of water depth are available.

No. of plots	Marl prairie sites		Tree island	
	Transect	Census	Study 1: Transects on 3 SS islands	Study 2: Transects on nine islands
Vegetation data	293	613	537	309
Ground elevation (surveyed)	292		550	
Field measurement of water depth	172	426		294

For both marl prairie and tree islands sites, water stage data were extracted from the EDEN using X-Y locator tool. Comparable SFWDAT daily water stage data were obtained from South Florida Water Management District (SFWMD) for the specified sites, identified by NAD1983 UTM coordinates, for the period of 1991-2013.

2.2 Data Analysis

2.2.1 Marl prairie landscape

Ground surface elevations at 292 sites along six transects of 2.5-11 km within the marl prairie landscape were obtained by surveying by autolevel from a USGS benchmark of known elevation. Water depths were subsequently measured at 171 sites during the wet season of 2004. Using the surveyed ground elevation and water-surface elevation data produced by EDEN and SFWDAT, the water depths at those sites were estimated for the specific dates and evaluated against the observed water depths.

Hydroperiod, defined as the number of days when water level was above the ground, had been estimated for the transect sites using elevation data from topographic surveys and water level data from nearby stage recorders. A weighted averaging partial least square (WAPLS) regression model had been developed using vegetation and hydroperiod data from 292 sites along the transects, and the model was applied to calculate vegetation-inferred hydroperiod from species abundance data collected at 613 sites distributed throughout the Everglades marl prairies (Ross et al. 2006). Water depth was measured at 426 of these sites at the time of vegetation survey or in the wet season of 2008. Vegetation-inferred hydroperiods at 416 sites with available EDEN and SFWDAT data were evaluated against the hydroperiods calculated using stage data from both the EDEN and SFWDAT.

2.2.2 Tree islands

Ground elevation data obtained by surveying from USGS benchmarks of known elevation were available for 550 plots at 5-10 m intervals along 12 transects in three Shark Slough tree islands. Annual mean hydroperiod and water depth at each plot location along the transects were estimated using elevation data in conjunction with long term water level records (since 1986) at the nearest stage recorders (Ross and Jones, 2004; Sah et al. 2012). For those sites, we also calculated annual mean hydroperiod using the ground elevation data and both the EDEN and SFWDAT water-surface data. Since, water depths measured in the field were not available for these sites, hydrologic metrics obtained using EDEN and SFWDAT were directly evaluated against the stage-based hydrologic data. Moreover, species' optimum hydroperiod and water depth, estimated through a weighted averaging regression model developed from the stage-based hydrologic metric and vegetation composition data, were also available (Ross and Jones 2004; Sah 2004). We calculated species' optimum hydroperiod and water depth using the EDEN and SFWDAT model-based hydrologic metric, and then evaluated them against the values obtained using the model based on the nearest stage data.

Finally, a weighted averaging regression model was developed using the stage recorder data-based hydrologic metric and vegetation data collected in 2011 along only nine transects perpendicular to the major axis of those three islands. The model was applied to calculate vegetation-inferred hydroperiod from species abundance data collected at 307 sites along N-S transects on nine islands in different regions – Shark River Slough (SRS), Northeast Shark River Slough (NESRS) and Water Conservation Area 3A and 3B (WCA3A & 3B). Water depth was measured at 294 of these sites during the time of vegetation survey, whereas for another 13 sites, ground elevation data were estimated from other sources (Ross & Jones, 2004; Ruiz et al. 2011). Thus, the vegetation-inferred estimates of hydroperiod were evaluated against estimates calculated using EDEN and SFWDAT data for 307 sites.

2.2.3 Evaluation method

Statistical analyses were used to evaluate the relative performance of EDEN and SFWDAT water-surface model-based water depths against observed water depths. Water depth data were first assessed for normality with the Shapiro-Wilk test. When all three measures of water depths were normally distributed, we used Pearson correlation to assess the strength of correlation, and a paired-t test to examine the difference in the means between observed and EDEN or SFWDAT water depths. When data were not normally distributed, we applied logarithmic or square root transformation to normalize the data. If the transformation was not adequate and the data were still non-normal, we used Spearman's rank correlation and Wilcoxon matched-pair test to examine the correlation and differences between observed and EDEN or SFWDAT model-based water depths. Additionally, root mean square error (RMSE), a reliable index for evaluating alternative models (Willmott 1981) that measures the deviation of predicted values from observed values, was used to compare the relative performance of EDEN and SFWDAT model-based water depths. Since water depths calculated from EDEN and SFWDAT water-surface models represent predicted values, RMSE was calculated using the formula:

$$RMSE = \sqrt{\frac{1}{n}\sum\nolimits_{i=1}^{n}(y_i - y_{m,i})^2}$$

In the above equation, 'n' is the number of observations, y_i is the observed water depth at the 'i^{th}' site, and $y_{m,i}$ is the EDEN or SFWDAT model-based water depth. Further, we assessed the differences in relative performance. We randomly selected 100 sites 30 times, calculated RMSE as above for each sample, and used a paired t-test to examine the differences in mean RMSE between the two models.

Similar statistical approaches were also used for evaluating EDEN and SFWDAT model-based hydroperiods against the observed or vegetation-inferred hydroperiods. The vegetation-inferred hydroperiods were the predicted values obtained using vegetation composition data for the sites without known hydrologic conditions and the WAPLS regression model developed from an independent training data set. Correlation and paired t-tests were done using STATISTICA v. 7.0 (Statsoft Inc.). Random selection of sites and RMSE – related analyses were done in 'R' v. 3.0.3 (R Development Core Team. 2014). Finally, spatial variation in the deviations of modeled values from the observed values was visualized with ArcGIS 10.3.

3. Results

3.1 Marl Prairie

In the marl prairie landscape, observed water depths as well as EDEN and SFWDAT model-based water depths for the sites along the transects were not normally distributed (Shapiro-Wilk test; $W > 0.92$, $P<05$). Neither of data transformation methods used to normalize the water depth data was adequate. Thus, the non-parametric statistics were used to test the statistical relationships among the three water depths. Before analysis, two outliers were removed, reducing the number of sites to 169. The Spearman's rank correlation results showed that both EDEN and SFWDAT model-based water depths were strongly correlated to observed water depths ($\rho = 0.818$ and $\rho = 0.825$, respectively). Wilcoxon test for pair data showed that EDEN water depths were not statistically different from observed water depths ($n=169$, $Z = 1.288$, $p = 0.198$). In contrast, SFWDAT and observed water depths significantly differed ($n = 169$, $Z = 5.435$, $p < 0.001$). The median values of observed, EDEN and SFWDAT water depths were 12.0, 12.8 and 15.1 cm (**Table 2**). In general, both EDEN and SFWDAT model-based water depths were higher than the observed water depths (**Figure 2**). Root mean square error (RMSE) is considered informative for any model evaluation. The RMSE of EDEN model-based water depth was 6.43 cm, which was lower than 7.83 cm, the RMSE of SFWDAT model-based water depths. When the RMSEs calculated for 30 subsets of 100 sites were compared, the mean RMSE significantly differed (Paired t-test; $df = 29$, $t = 25.1$, $p < 00.1$) between two models. The SFWDAT model had higher mean RMSE (7.76 cm) than the EDEN model (6.38 cm).

Table 2: Observed and EDEN- and SFWDAT-predicted water depths at 169 sites along 6 transects within the marl prairie landscape. EDEN- and SFWDAT-predicted water depths were obtained by subtracting ground elevation from the respective water stage data. Different letters in superscript indicate the statistically different (Wilcoxon test; $p < 0.05$).

Water depth (cm)	N	Mean	Std.Dev.	Median	Minimum	Maximum	Skewness	RMSE
Field measurements	169	14.3	9.7	12.0^a	1.0	44.3	0.76	-
EDEN-predicted	169	14.9	11.4	12.8^a	-5.0	43.1	0.35	6.43
SFWDAT-predicted	169	17.6	12.4	15.1^b	-4.0	45.6	0.48	7.83

All three measures of hydroperiod, i.e., vegetation-inferred hydroperiod, EDEN and SFWDAT model-based hydroperiod, were non-normally distributed (Shapiro-Wilk test; $P<0.05$). Since neither square root nor logarithmic data transformations successfully normalized the hydroperiod data, the non-parametric statistics were used to test statistical relationship among three measures of hydroperiod. The Spearman's rank correlation results showed that both EDEN and SFWDAT model-based hydroperiods were strongly correlated with vegetation-inferred hydroperiod (ρ = 0.741 and ρ = 0.790, respectively). Wilcoxon signed rank-test for paired data showed that SFWDAT model-based hydroperiod were not statistically different from vegetation-inferred hydroperiod (n=416, Z = 1.055, p = 0.292). In contrast, EDEN model-based and vegetation-inferred hydroperiod significantly differed (n = 416, Z = 7.294, $p < 0.001$). The median values of vegetation-inferred, EDEN and SFWDAT hydroperiods were 235, 218, and 244 days (**Table 3**). The RMSEs of EDEN and SFWDAT model-based hydroperiod were 57.0 and 57.9 days, respectively, and in general, both EDEN and SFWDAT model-based hydroperiods were lower than inferred-hydroperiod, especially towards the drier end (hydroperiod < 200) of the hydrologic gradient (**Figure 3**). When the RMSEs calculated for 30 subsets of 100 sites were compared, the difference in mean RMSEs for hydroperiod between the EDEN and SFWDAT models (RMSE = 56.6 and 57.4 days, respectively) was not statistically significant (Paired t-test; df = 29, t = 0.92, p =0.364). Spatial distribution of errors revealed that there is not a consistent pattern in distribution of errors for both EDEN and SFWDAT model-based hydroperiods (**Figures 4a, b**).

Table 3: Summary of vegetation-inferred hydroperiod and EDEN and SFWDAT water-surface model-based hydroperiod at 416 sites within the marl prairie landscape. EDEN and SFWDAT model-based hydropriods were calculated from daily water depth time series and averaged over 5 years before the date of vegetation sampling. Different letters in superscript indicate the statistically different (Wilcoxon test; $p < 0.05$).

Data source for Hydroperiod	N	Mean	Std. Dev.	Median	Minimum	Maximum	Skewness	RMSE
Vegetation-inferred hydroperiod	416	229	66	235	58	365	-0.278	-
EDEN-Water Surface Model	416	208	77	218	9	353	-0.403	57.0
SFWDAT-Water Surface Model	416	230	92	244	4	364	-0.646	57.9

3.2 Tree islands

At the plot locations for which surveyed ground elevation data were available, field-measured water depths were not available. Thus, both EDEN- and SFWDAT model-based water depths were evaluated relative to each other and to hydrologic metrics calculated from the nearest stage recorder. In general, SFWDAT model-based 20-year mean annual hydroperiods and water depths at the tree island sites were slightly higher than the EDEN model-based hydroperiods and water depths (**Table 4**). Both EDEN and SFWDAT model-based water depths were strongly correlated with nearest stage recorder-based water depths (Spearman’s correlation: ρ = 0.989 and ρ = 0.986, respectively). Despite the strong correlation, both model-based water depths differed significantly from stage recorder-based water depths (Wilcoxon paired-test: n = 613, Z = 13.6, $p < 0.001$; and Z = 16.7, $p<0.001$). The median values of stage recorder, EDEN- and SFWDAT model-based 20-year average water depths were 10.2, 11.1 and 11.8 cm. The RMSE of SFWDAT model-based water depth was 3.7 cm, which was 1 cm higher than the RMSE of EDEN model-based water depth **(Figure 5a, b**). A similar pattern was found for the 20-year annual mean hydroperiod. Both EDEN and SFWDAT model-based hydroperiods were strongly correlated with the nearest stage recorder-based hydroperiods (Spearman’s correlation: ρ = 0.990 and ρ = 0.985, respectively). However, the median values of both hydroperiods differed significantly from stage recorder-based hydroperiods (n = 613, Z = 11.6, $p < 0.001$; and Z = 15.8, $p<0.001$). The median values of stage recorder, EDEN- and SFWDAT model-based 20-year average hydroperiod were 253, 263 and 269 days. The RMSE of EDEN model-based hydroperiod was 12 days, which was lower than 17 days, the RMSE of SFWDAT model-based hydroperiod (**Table 4; Figure 5c, d**).

Table 4: Stage recorder, EDEN model and SFWDAT model-based annual mean water depth and hydroperiod averaged over 20 years for 613 sites on the three Shark Slough tree islands. Different letters in superscript indicate the statistically different (Wilcoxon test; $p < 0.05$).

20-Year average water depth (cm)	N	Mean	Std.Dev.	Median	Minimum	Maximum	Skewness	RMSE
Stage recorder-based	613	3.9	25.6	10.2	-99.6	61.5	-0.811	-
EDEN-predicted	613	5.4	25.3	11.1	-100.2	60.9	-0.906	2.72
SFWDAT-predicted	613	6.5	25.4	11.8	-100.1	61.0	-0.980	3.73
20-Year average hydroperiod (days)								
Stage recorder-based	613	224	105	253	0	364	-1.712	-
EDEN-predicted	613	230	104	263	0	364	-1.691	12
SFWDAT-predicted	613	235	105	269	0	364	-1.692	17

In agreement with the above differences in annual mean hydroperiod and water depths, the species' optimum hydroperiod and water depth calculated with a weighted averaging regression model were also in the order of Stage<EDEN<WDAT. The WA regression model using hydrologic metrics calculated from SFWDAT water-surface model consistently predicted 1-2 cm higher species' optimum water depth than EDEN water-surface model.

Water depth data obtained in the field were available for 294 sites along the N-S transects on nine tree islands. However, for those sites fine scale site specific ground elevation data were not available. Thus, the ground elevation for each plot was calculated by subtracting field water depths from both the EDEN and SFWDAT water-surface models. Both the EDEN and SFWDAT model-based ground elevations were strongly correlated (Spearman's correlation: $\rho = 0.989$; $p < 0.001$), and median values of ground elevation were not significant different between two models (Wilcoxon paired-rank test: ($n=294$, $Z = 1.35$, $p = 0.177$). The median values of EDEN and SFWDAT model-based ground elevations were 155.3 cm and 154.3 cm (**Table 5**).

Table 5: Summary of EDEN and SFWDAT model-based ground elevation on tree islands in five regions. EDEN- and SFWDAT model- based ground elevations were calculated by subtracting the field water depth from the water-surface elevation extracted for each site location. Different letters in superscript indicate the statistically different (Wilcoxon test; $p < 0.05$).

Region	N	Ground elevation (cm)							
		EDEN Model-based			SFWDAT Model-based			Wilcoxon test	
		Mean	Std. Dev.	Median	Mean	Std. Dev.	Median	Z	p-value
All regions	294	168.5	39.0	155.3	168.1	38.1	154.8	1.35	0.177
Shark River Slough	116	136.7	10.2	135.7	138.1	10.4	137.0	8.64	<0.001
Northeast Shark River Slough	64	157.7	10.9	155.3	162.0	14.9	160.5	4.54	<0.001
WCA 3A-Central	49	239.5	10.5	240.7	237.7	10.6	239.7	6.09	<0.001
WCA 3A-South	18	217.0	13.8	218.3	214.9	13.7	216.2	3.72	<0.001
WCA 3B	47	168.9	9.5	172.4	160.3	9.5	163.4	5.97	<0.001

When analyzed by region, ground elevations based on two water surface models were significantly different among SRS, NESRS, WCA3A-C, WCA3A-S and WCA3B. In the SRS and NESRS regions, SFWDAT model-based mean and median values of elevations were higher than EDEN model-based elevations, whereas in both WCA3A and 3B, the EDEN model-based values were higher (**Table 5**).

For 307 sites on nine tree islands, both EDEN and SFWDAT model-based hydroperiods were significantly correlated with vegetation-inferred hydroperiod (Spearman's rank correlation: $\rho = 0.694$ and $\rho = 0.711$, respectively), and Wilcoxon paired-test revealed that neither model's hydroperiod was significantly different from the vegetation-inferred hydroperiod ($n = 305$, $Z = 1.958$, $p < 0.051$; and $n=307$, $Z = 1.820$, $p=0.069$). The median values of vegetation-inferred, EDEN and SFWDAT model-based hydroperiods were 222, 230 and 239 days, respectively (**Table 6**).

Table 6: Summary of vegetation-inferred hydroperiod and EDEN and SFWDAT model- based hydroperiod at 307 sites along N-S transects on nine tree islands. EDEN and SFWDAT model-based hydropriods were calculated from daily water depth time series and averaged over 7 years before the date of vegetation sampling. Different letters in superscript indicate the statistically different (Wilcoxon test; $p < 0.05$).

Data source for Hydroperiod	N	Mean	Std. Dev.	Median	Minimum	Maximum	Skewness	RMSE
Vegetation-inferred hydroperiod	307	224	63	222	0	324	-1.376	-
EDEN-Water Surface	307	217	79	230	0	361	-0.850	52
SFWDAT-Water Surface	307	227	82	239	0	365	-0.832	53

The RMSE between vegetation-inferred hydroperiod and both EDEN and SFWDAT model-based hydroperiod were 52 and 53 days. At relatively dry sites, vegetation-inferred hydroperiods were lower than both EDEN and SFWDAT model-based hydroperiods (**Figure 7**). Based on 30 subsets of randomly selected 100 sites, the difference in mean RMSEs was not statistically significant (Paired t-test; $df = 29$, $t = 1.62$, $p =0.114$), suggesting that both EDEN and SFWDAT water-surface models are performing equally based on the vegetation-hydrology relationship.

4. Discussion and Conclusions

Developed for large areas and long time periods, both EDEN and SFWDAT water-surface models are useful tools to estimate water depth and hydroperiod, two important hydrologic metrics that shape Everglades plant communities and ecosystem processes. While the two models in estimating water depth and other hydrologic parameters differed in their estimates of hydrologic parameters across the landscapes, they did not differ much in terms of their application to the study of vegetation:hydrology relationships.

In the marl prairie landscape, water depths estimated using both EDEN and SFWDAT water surface models are strongly correlated with field-measured water depths. However, based on strength of the correlation, the EDEN water-surface model appears to be more reliable than SFWDAT. This finding was also supported by the error measurement. The RMSE obtained using EDEN model-based water depths was significantly lower than the error from SFWDAT model-based water depths. In general, both EDEN and SFWDAT models appeared to predict higher water depths than those present in the field, and this tendency was exacerbated as water levels exceeded 15 cm (**Figure 2**). Moreover, the SFWDAT model predicted 2-2.5 cm higher water level than EDEN. The present finding is similar to results obtained in an independent study conducted within Southern Glades Wildlife Environmental Area (SGWEA), where water depths were measured in the field during the wet season of 2011, and the ground elevation calculated using both water-surface models were compared (Sah et al. 2014).

As in the marl prairie landscape, known ground elevation and water depth data obtained in the field were not available for the same place and time in the tree islands. Thus, a different approach was used to compare the both EDEN and SFWDAT model-based hydrologic metric. This study shows that averaged over long time periods (~20 years) – a period long enough to influence the overall structure and spatial extent of tree islands - hydrologic metrics derived from these two models were similar to each other, as well as to those based on the nearest stage recorder. The annual mean water level differed by only 2.5 to 4 cm and mean hydroperiod by 12-17 days. However, these values should be interpreted cautiously, as temporal variance in the behavior of two models might have been masked by the long-term average values. On the SRS islands, the values derived from SFWDAT model were consistently higher than those from EDEN model and stage recorder-based data, a pattern also observed in the marl prairie landscape in both Shark River and Taylor Slough basins. However, the pattern does not appear to be the same across different regions in the Everglades. In a separate study, we had field measurements of water depth on nine islands in four different regions – SRS, NESRS, WCA3A and WCA3B - where ground elevations derived from field water depth in conjunction with EDEN and SFWDAT water-surface models revealed a spatially differentiated pattern. If ground elevation can be taken as a proxy for water depth and hydroperiod, SFWDAT appears to predict higher water level than EDEN in Everglades National Park, and even within the Park, the discrepancy between these two models is much higher in the NESRS than in SRS region. In contrast, the values based on SFWDAT model are lower in the WCAs, with the discrepancy between model-based hydrologic metrics greater in the WCA3B than theWCA3A. This result confirms earlier findings by other researchers (Volin et al. 2008; Liu et al. 2009). While regional variation in water conditions across the management areas in the Everglades is the result of both natural variation in topography and the water management activities, the spatial differences in prediction of water condition pattern between two models across regions appear to be the result of the different procedures integrated in developing the water surface models.

Deviations of modeled water levels from observed values depends on several factors including quality of data gathered in the field, the procedures and techniques used in modeling, landscape features, etc. For the marl prairie locations for which EDEN and SFWDAT values were extracted in our analysis, ground elevations were obtained by surveying from the nearest benchmark with known elevation, and water depths were measured at 3 locations within the plot, adjacent to the specific site location. Although, spatial differences in exact locations between two measurements might have impacted the relationships between observed and modeled water depths, the differences expressed in terms of RMSE, are close to the higher end values reported for other areas in the Everglades (Volin et al. 2008; Liu et al. 2009). In their study, Liu et al. (2009) reported RMSE for the modeled water levels as 2.48 and 7.76 cm in WCA3A south and WCA3B, respectively. A similar metric based on water depth measurements were not available for tree islands, but RMSE based on 20-year average water depths were within ± 5 cm. In the present study of the marl prairie landscape, the RMSE for water depths calculated for EDEN and SFWDAT were 6.2 and 7.1 cm, close to the value observed by Liu et al. in WCA 3B, but within the range of 5-10 cm recommended by Poiani and Johnson (1993) for studying wetlands processes. Also, any error due to ground elevation data or field measurement of water depth will be same in the comparison with modeled water depths of both EDEN & SFWDAT. Thus, the differences in relative performance of both water surface models seem to be attributable to modeling procedures incorporated into them. Though both EDEN and SFWDAT models are based on the same stage data set, the processing of the data and interpolation methods used to develop the water surface differ (Palaseanu and Pearlstine, 2008; Godin 2012).

Hydrology is the major drivers of plant communities structure and function in the Everglades, where vegetation is arranged along a hydrologic gradient from open water sloughs dominated by water lilies (*Nymphaea sp.*) and spikerush (*Eleocharis cellulosa*) to dense sawgrass (*Cladium mariscus ssp. jamaicense*), and finally to woody communities (Gunderson 1994; Todd et al. 2010). To study spatial and temporal variation in vegetation structure and composition along the hydrologic gradient, detailed estimation of hydrologic parameters across the entire landscape is important. In this respect, both EDEN and SFWDAT water-surface models, developed to make long-term hydrologic data available for use by researchers/managers across different regions in the Everglades, are critical tools. Even though the relative values of hydrologic parameters derived from these models vary between regions, their performance in vegetation study does not appear to be much different. Vegetation-inferred hydroperiod, the hydroperiod predicted for an individual site based on vegetation composition, denotes a relationship between vegetation and hydrology (Armentano et al. 2006). Since it depends on vegetation composition and the associated hydrologic conditions, changes in vegetation-inferred hydroperiod in both space and time are indicative of changes in the response of vegetation to hydrology. In this study, an agreement between vegetation-inferred hydroperiod predicted using hydrologic metrics based on stage recorder data or, alternatively, based on EDEN or SFWDAT water surface models, appeared promising in both marl prairies and tree islands, suggesting that these two models do not differ much in their relative performance in studies of vegetation response to hydrology in the Everglades ecosystems.

In summary, both EDEN and SFWDAT water-surface models are important tools for studying vegetation composition and dynamics in the Everglades. While the values of major hydrologic parameters derived from SFWDAT model are consistently higher than those from EDEN model- and stage recorder-based hydrological data in the Everglades National Park, the SFWDAT model predicts lower values of hydroperiod and water depth than EDEN in the Water Conservation Areas. The degree of discrepancy in model-based hydrologic metrics between these two models also appears to vary depending on the water conditions of areas; in the regions with long hydroperiod and deeper water, such as SRS and WCA3A-S, the differences are small, whereas in relative dry areas such as marl prairies, NESRS and WCA3B, the two models differ more. Finally, even though they differ in predicting the hydrologic conditions to some level, their relative performance in studying vegetation composition, and possibly its dynamics too, do not appear to differ substantially.

Acknowledgements

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References

Armentano, T. V., Sah, J. P., Ross, M. S., Jones, D. T., Cooley, H. C. and Smith, C, S. (2006) Rapid responses of vegetation to hydrological changes in Taylor Slough, Everglades National Park, Florida, USA. Hydrobiologia 569: 293-309.

Gaiser, E. 2006. Characterization of periphyton response to hydroperiod in marl prairie wetlands of the Everglades. Final Comprehensive Report 2006. Everglades National Park, CA# 5284-AP00-371. pp 104.

Godin, J. 2012. South Florida Water Depth Assessment Tool. In: 2012 South Florida Environmental Report: Appendix 1-6. South Florida Water Management District, West Palm Beach, FL.

Gunderson, L. 1994. Vegetation of the Everglades: Determinants of Community composition. In: S. M. Davis and J. C. Ogden. Everglades: The Ecosystem and Its Restoration. Delray Beach, Florida.: St. Lucie Press: 323-340.

Liu, Z., J. C. Volin, V. D. Owen, L. G. Pearlstine, J. R. Allen, F. J. Mazzotti, and A. L. Higer. 2009. Validation and ecosystem applications of the EDEN water-surface model for the Florida Everglades. *Ecohydrology* 2: 182-194.

Palaseanu M. and Pearlstine L. 2008. Estimation of water surface elevations for the Everglades, Florida. *Computers & Geosciences* 34: 815–826.

Poiani K. A. and Johnson W. C. 1993. A spatial simulation model of hydrology and vegetation dynamics in semi-permanent prairie wetlands. *Ecological Applications* 3: 279–293.

R Development Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from http://www.R-project.org/.

Ross, M.S. and D.T. Jones (Eds.). 2004. Tree islands in the Shark Slough landscape: interactions of vegetation, soils, and hydrology. Final report to Everglades National Park, Homestead, FL, USA. September 2004.

Ross, M. S., Sah, J. P., Snyder, J. R., Ruiz, P. L., Jones, D. T., Cooley, H., Travieso, R., Tobias, F. and Hagyari, D. 2006. Effect of hydrological restoration on the habitat of the Cape Sable seaside sparrow. 2004-2005. Year-3. Final Report submitted to Everglades

National Park, Homestead, FL and U. S. Army Corps of Engineers, Jacksonville, FL. March 2006. 50 pp.

Ruiz, P. L., Sah, J. P., Ross, M. S., Rodriguez, D., and Lambert, A. 2011. Monitoring of tree island conditions in the Southern Everglades: the effects of hurricanes and hydrology on the status and population dynamics of sixteen tropical hardwood hammock tree islands. US Army Engineer Research & Development Center. CA#: W912HZ-09-2-0019. 136 pp.

Sah, J. P. 2004. Vegetation structure and composition in relation to the hydrological and soil environments in tree islands of Shark Slough. p. 85-111. *In* M.S. Ross and D.T. Jones (eds), Tree islands in the Shark Slough landscape: interactions of vegetation, soils, and hydrology. Final report to Everglades National Park, Homestead, FL, USA. Sept. 2004.

Sah, J. P., Ross, M. S., Snyder, J. R., Ruiz, P. L, Stoffella, S., Kline, M., Shamblin, B., Hanan, E., Lopez, L. and Hilton, T. J. 2009. Effect of hydrological restoration on the habitat of the Cape Sable seaside sparrow. Annual Report - FY 2008. A report submitted to USACOE, Jacksonville, FL. Cooperative Agreement # W912EP-08-C-0018. 52 pp.

Sah, J. P., Ross, M. S., Ruiz, P., Freixa, J. and Stoffella. 2015. Monitoring of Tree Island Condition in the Southern Everglades. Annual Report submitted to US Army Engineer Research and Development Center. Cooperative Agreement #: W912HZ-09-2-0019. Report (2011-2014). April, 2015. 100 pp.

Todd, M. J., R. Muneepeerakul, D. Pumo, S. Azaele, F. Miralles-Wilhelm, A. Rinaldo and I. Rodriguez-Iturbe. 2010. Hydrological drivers of wetland vegetation community distribution within Everglades National Park, Florida. Advances in Water Resources 33: 1279-1289.

Volin, J., Z. Liu, A. Higer, F. Mazzotti, D. Owen, J. Allen and L. Pearlstine. 2008. Validation of a spatially continuous EDEN water-surface model for the Everglades, Florida. Department of Natural Resources Management and Engineering, University of Connecticut, Storrs, CT. pp 36.

Willmott C. J. 1981. On the validation of models. *Physical Geography* 2: 184–194.

Figures

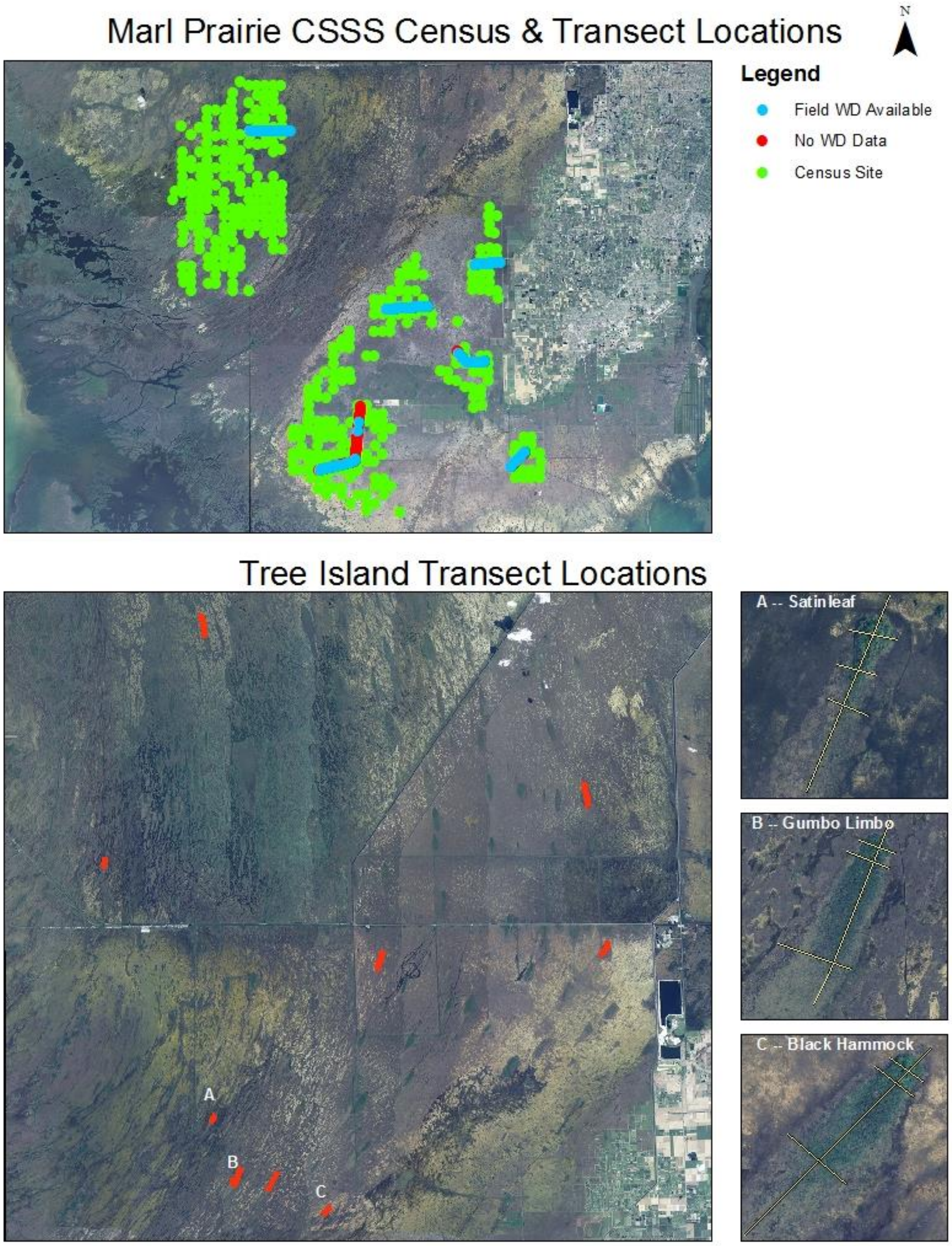

Figure 1: Maps showing the location of sites for which vegetation data, ground elevation and/or water depths measured in the field were available.

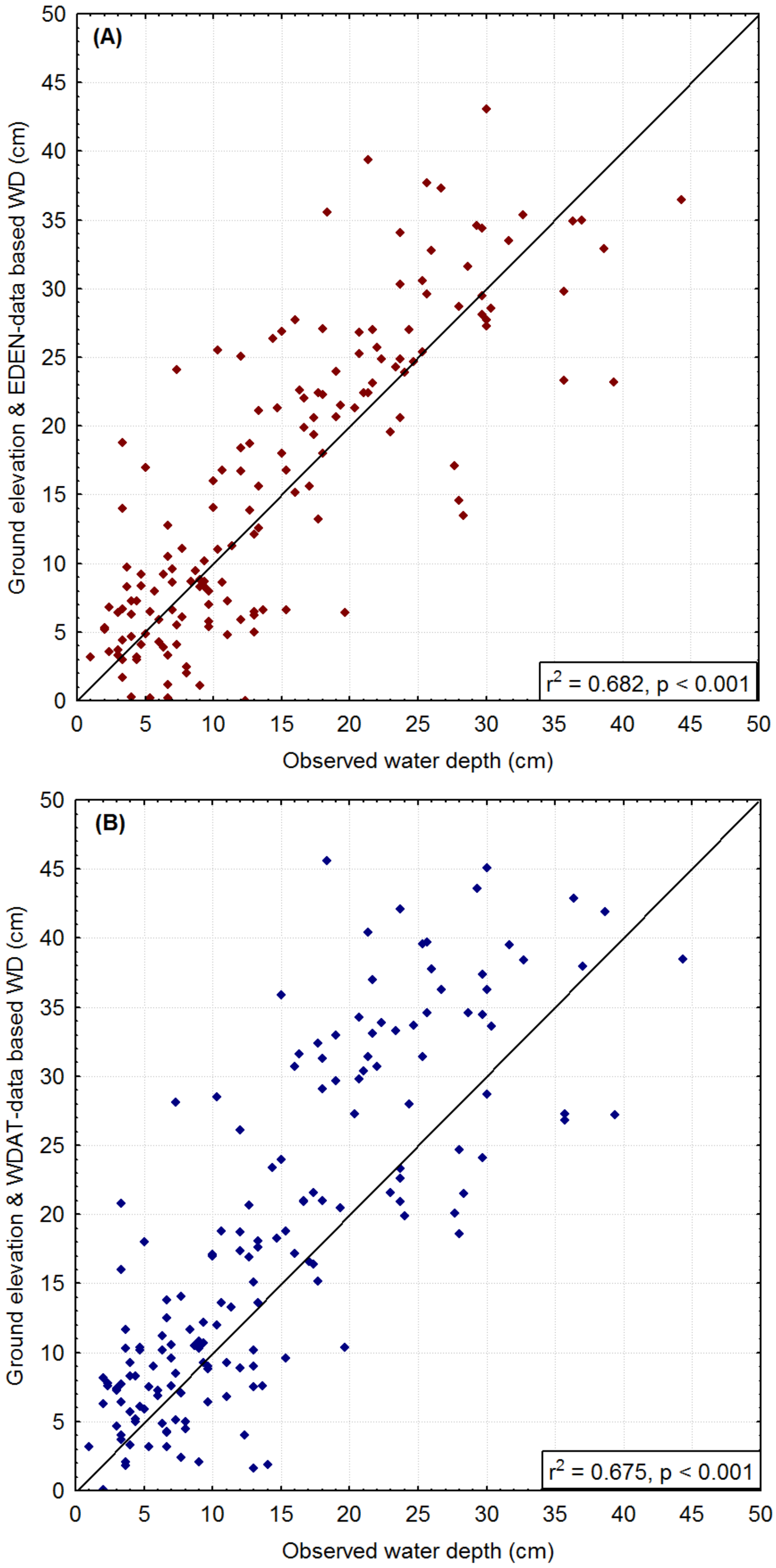

Figure 2: Relationship among field water depths and (A) EDEN- and (B) SFWDAT-predicted water depths along the transects within marl prairie landscape. Line represents 1:1 relationship.

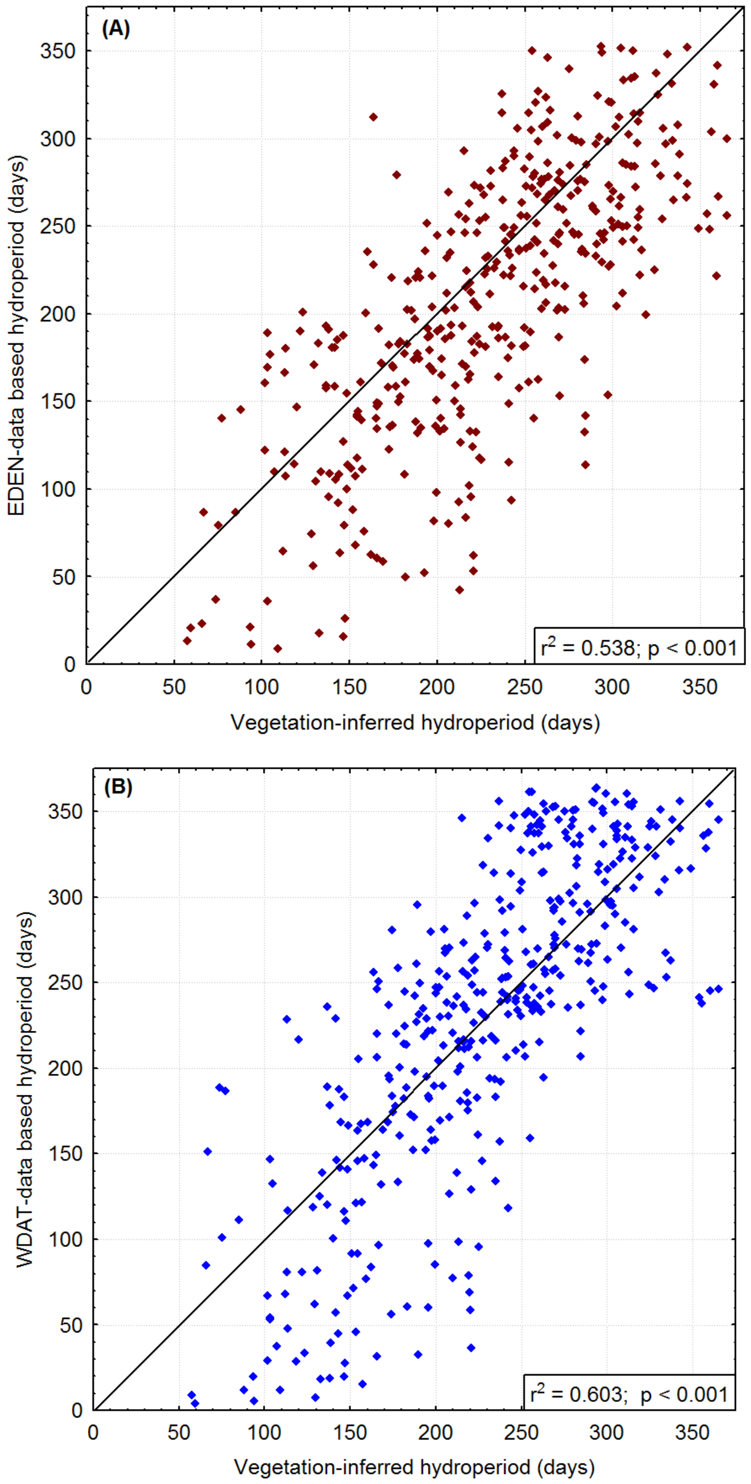

Figure 3: Relationship among vegetation-inferred hydroperiod and 5-year average EDEN- and SFWDAT modle-based hydroperiod at 416 sites within marl prairie landscape. Line represents 1:1 relationship

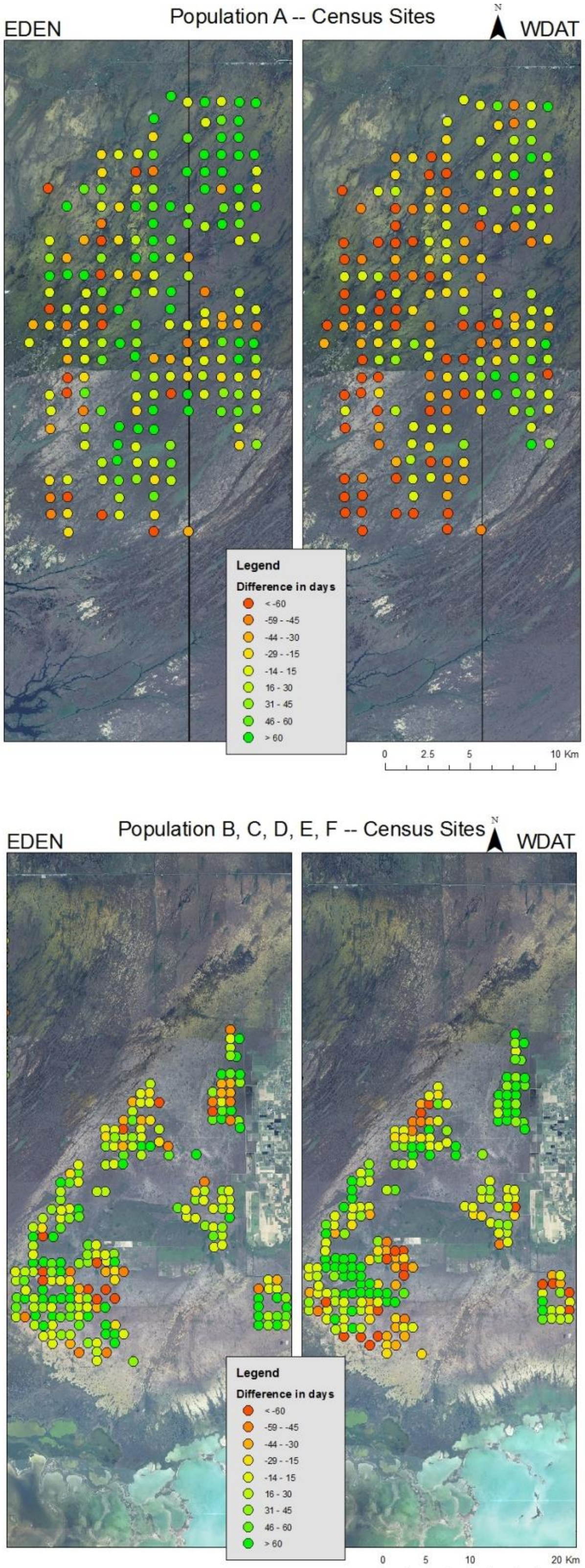

Figure 4: Spatial distribution of errors calculated between vegetation-inferred hydroperiod and EDEN or SFWDAT model-based 5-year average hydroperiod within the habitat of 6 sub-populations of Cape Sable seaside sparrow (CSSS) in the marl prairie landscape.

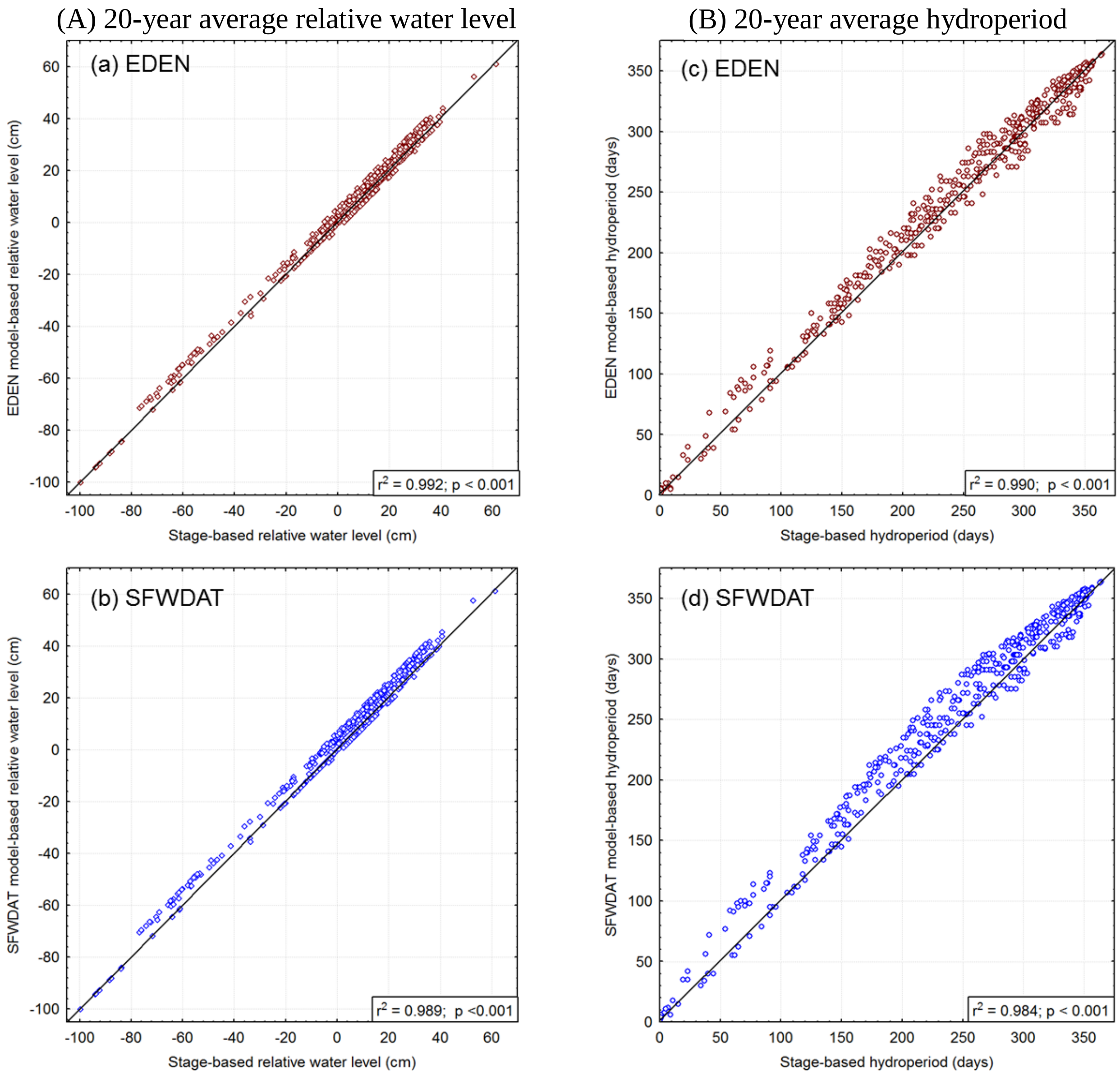

Figure 5: Relationship between stage-based and EDEN- or SFWDAT-water surface-based annual mean relative water level (a & b) and hydroperiod (c &d) for 613 plot locations along 12 transects on three Shark Slough tree islands. The annual mean relative water level and hydroperiod were averaged over 20 years (May 1, 1991 – April 30, 2001). Line represents 1:1 relationship

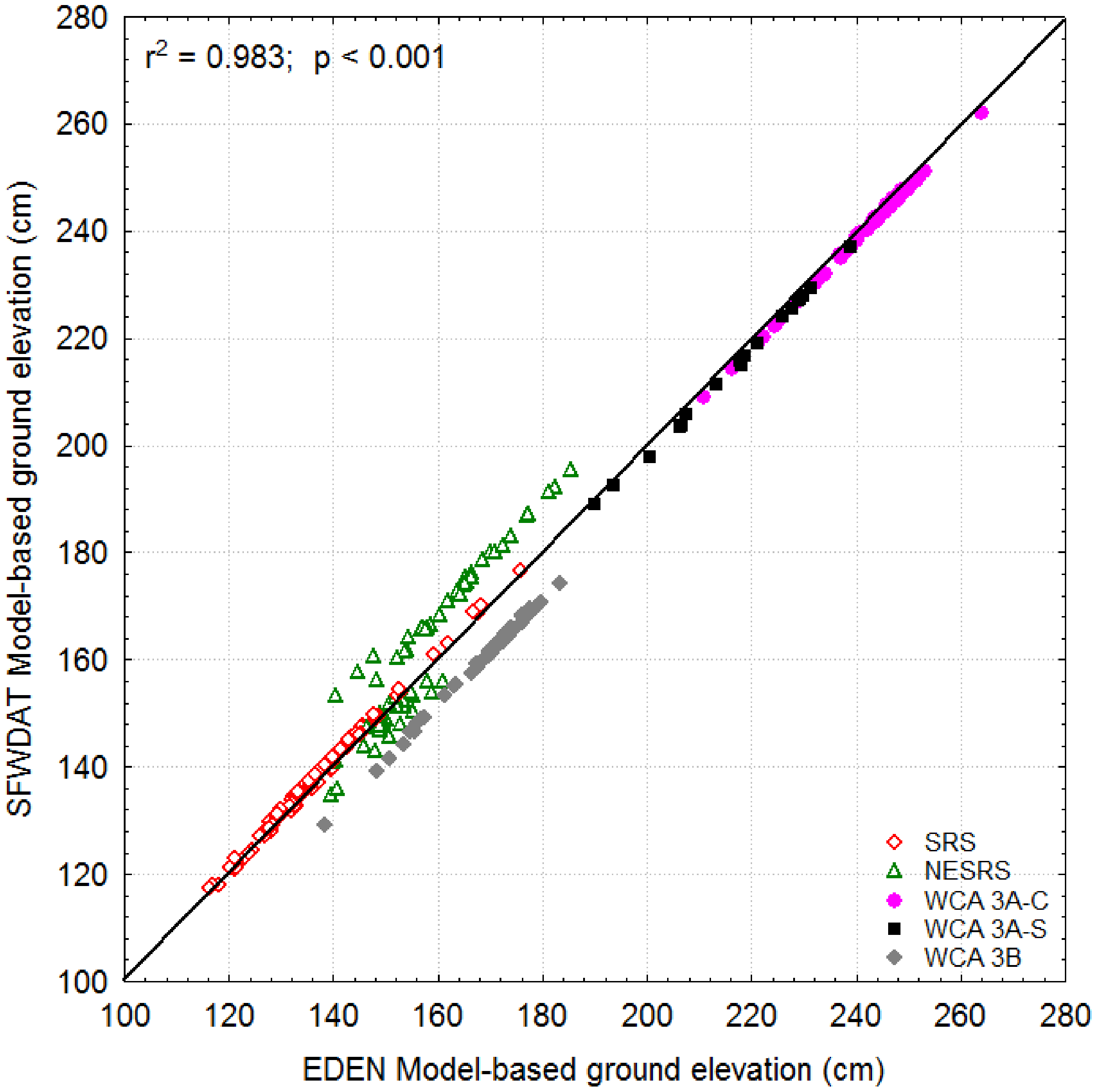

Figure 6: Relationship between EDEN and SFWDAT water surface-based ground elevation of 294 sites along N-S transects on the nine islands in three different regions. Ground elevation was calculated by subtracting the field water depths from respective water surface elevation extracted for the specified site. At the 15 sites, particularly in the hardwood hammocks, water depth data were not measured. Line represents 1:1 relationship

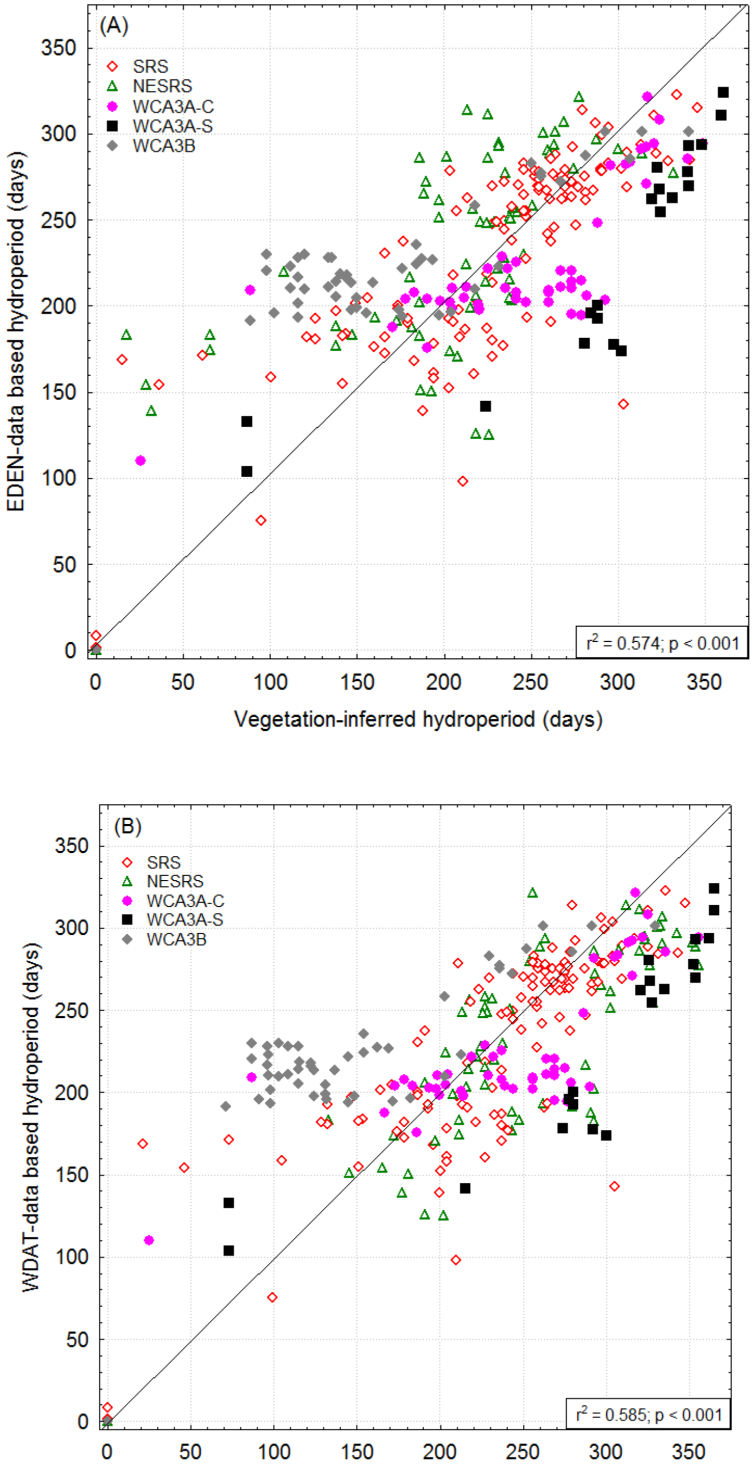

Figure 7: Relationship among vegetation-inferred hydroperiod, and 7-year average EDEN- and SFWDAT data based hydroperiod at 305 sites on nine tree islands. Line represents 1:1 relationship.

Appendices

Appendix 1: Mean water depths averaged over three field measurements taken in the vegetation survey plots at the transect sites in the habitat of Cape Sable seaside sparrow (CSSS) within the marl prairie landscape.

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
TA-0000	517165	2841401	10/8/2004	23.7	TA-4500	512665	2841401	10/8/2004	18.0
TA-0100	517065	2841401	10/8/2004	29.7	TA-4600	512565	2841401	10/8/2004	25.3
TA-0200	516965	2841401	10/8/2004	28.0	TA-4700	512465	2841401	10/8/2004	30.0
TA-0300	516865	2841401	10/8/2004	23.7	TA-4800	512365	2841401	10/8/2004	20.7
TA-0400	516764	2841401	10/8/2004	24.0	TA-4900	512265	2841401	10/8/2004	15.0
TA-0500	516665	2841401	10/8/2004	14.7	TA-5000	525699	2808079	10/8/2004	23.3
TA-0600	516565	2841401	10/8/2004	13.3	TB-02000	525477	2805891	10/7/2004	9.0
TA-0700	516446	2841401	10/8/2004	14.3	TB-03000	525377	2804896	10/7/2004	3.3
TA-0800	516365	2841401	10/8/2004	35.7	TB-06400	525044	2801613	10/7/2004	5.3
TA-0900	516265	2841401	10/8/2004	26.7	TB-06600	524927	2801396	10/7/2004	6.7
TA-1000	516165	2841401	10/8/2004	12.0	TB-06800	524733	2801349	10/7/2004	8.7
TA-1100	516065	2841401	10/8/2004	16.7	TB-07200	524344	2801254	10/7/2004	9.3
TA-1200	515965	2841401	10/8/2004	19.3	TB-07400	524150	2801206	10/7/2004	3.7
TA-1300	515865	2841401	10/8/2004	17.3	TB-07800	523761	2801111	10/7/2004	3.7
TA-1400	515765	2841401	10/8/2004	16.7	TB-08400	523178	2800968	10/7/2004	9.3
TA-1500	515665	2841401	10/8/2004	30.0	TB-08600	522983	2800919	10/7/2004	4.3
TA-1600	515565	2841401	10/8/2004	24.3	TB-08800	522790	2800873	10/7/2004	13.3
TA-1700	515465	2841401	10/8/2004	37.0	TB-09000	522596	2800824	10/7/2004	2.3
TA-1800	515365	2841401	10/8/2004	28.7	TB-09200	522403	2800775	10/7/2004	7.0
TA-1900	515265	2841401	10/8/2004	32.7	TB-09400	522207	2800730	10/7/2004	4.7
TA-2000	515164	2841401	10/8/2004	29.7	TB-09600	522012	2800684	10/7/2004	6.3
TA-2100	515065	2841401	10/8/2004	22.0	TB-09800	521817	2800635	10/7/2004	4.0
TA-2200	514965	2841401	10/8/2004	29.7	TB-10000	521625	2800587	10/7/2004	7.0
TA-2300	514865	2841401	10/8/2004	30.3	TB-10200	521431	2800541	10/7/2004	9.3
TA-2380	514765	2841401	10/8/2004	25.7	TB-10400	521237	2800493	10/7/2004	6.3
TA-2500	514665	2841401	10/8/2004	25.3	TB-10600	521041	2800445	10/7/2004	9.0
TA-2600	514565	2841401	10/8/2004	31.7	TB-10800	520847	2800397	10/7/2004	11.3
TA-2700	514465	2841401	10/8/2004	20.3	TB-11000	520652	2800349	10/7/2004	13.7
TA-2800	514365	2841401	10/8/2004	15.0	TC-0000	540658	2813483	10/4/2004	13.0
TA-2900	514264	2841401	10/8/2004	23.7	TC-0100	540558	2813478	10/5/2004	17.0
TA-3000	514165	2841401	10/8/2004	28.3	TC-0200	540458	2813473	10/4/2004	12.0
TA-3100	514065	2841401	10/8/2004	36.3	TC-0300	540359	2813467	10/5/2004	5.0
TA-3200	513965	2841401	10/8/2004	21.0	TC-0400	540258	2813462	10/4/2004	11.0
TA-3300	513865	2841401	10/8/2004	19.0	TC-0500	540158	2813457	10/5/2004	3.3
TA-3400	513765	2841401	10/8/2004	19.0	TC-0700	539959	2813446	10/5/2004	4.3
TA-3500	513665	2841401	10/8/2004	22.3	TC-0900	539760	2813436	10/5/2004	2.7
TA-3600	513565	2841401	10/8/2004	38.7	TC-1200	539460	2813420	10/4/2004	12.3
TA-3700	513465	2841401	10/8/2004	29.3	TC-1300	539360	2813414	10/5/2004	2.3
TA-3800	513365	2841401	10/8/2004	16.3	TC-1400	539260	2813409	10/4/2004	13.0
TA-3900	513265	2841401	10/8/2004	21.3	TC-1500	539161	2813399	10/5/2004	28.0
TA-4000	513165	2841401	10/8/2004	24.7	TC-1600	539061	2813394	10/4/2004	26.0
TA-4100	513064	2841401	10/8/2004	21.7	TC-1700	538961	2813389	10/5/2004	7.3
TA-4200	512965	2841401	10/8/2004	17.7	TC-1800	538861	2813383	10/4/2004	10.7
TA-4300	512865	2841401	10/8/2004	21.7	TC-1900	538761	2813378	10/5/2004	3.0
TA-4400	512765	2841401	10/8/2004	18.3	TC-2300	538410	2813462	10/4/2004	35.7

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
TC-2400	538347	2813539	10/4/2004	39.3	TE-2600	531097	2819947	10/6/2004	3.3
TC-2500	538283	2813617	10/5/2004	16.0	TE-2900	530797	2819927	10/6/2004	6.7
TC-2600	538220	2813694	10/4/2004	12.7	TE-3100	530598	2819913	10/6/2004	23.7
TC-2800	538092	2813848	10/4/2004	8.3	TE-3200	530498	2819907	10/6/2004	15.3
TC-3000	537965	2814002	10/4/2004	4.0	TE-3400	530299	2819893	10/6/2004	6.7
TC-3100	537902	2814080	10/5/2004	3.3	TE-3600	530099	2819880	10/6/2004	10.7
TC-3200	537838	2814157	10/4/2004	27.7	TE-3700	529999	2819873	10/6/2004	3.3
TC-3500	537647	2814388	10/5/2004	3.3	TE-3800	529899	2819867	10/6/2004	11.0
TC-3700	537520	2814543	10/5/2004	13.3	TE-3900	529799	2819860	10/6/2004	12.7
TD-0000	545523	2802485	10/4/2004	6.3	TE-4100	529607	2819847	10/6/2004	30.0
TD-0600	545105	2802054	10/4/2004	5.7	TE-4200	529500	2819840	10/6/2004	9.0
TD-0700	545035	2801983	10/5/2004	6.3	TE-4300	529401	2819833	10/6/2004	12.0
TD-0800	544966	2801911	10/4/2004	8.0	TE-4400	529301	2819827	10/6/2004	23.0
TD-0900	544896	2801839	10/5/2004	13.0	TE-4500	529201	2819820	10/6/2004	25.7
TD-1000	544827	2801768	10/4/2004	2.0	TE-4600	529101	2819813	10/6/2004	9.7
TD-1200	544687	2801624	10/4/2004	16.0	TE-4700	529001	2819807	10/6/2004	44.3
TD-1300	544617	2801553	10/5/2004	12.0	TE-4900	528802	2819793	10/6/2004	14.0
TD-1400	544548	2801481	10/4/2004	7.7	TE-5000	542581	2825475	10/6/2004	17.7
TD-1500	544478	2801409	10/5/2004	6.7	TF-0000	542482	2825465	10/5/2004	17.3
TD-1600	544408	2801337	10/4/2004	4.0	TF-0600	541885	2825411	10/5/2004	10.3
TD-1700	544339	2801266	10/5/2004	9.7	TF-0800	541685	2825393	10/5/2004	15.3
TD-2300	543920	2800836	10/5/2004	6.0	TF-0900	541586	2825384	10/5/2004	20.7
TD-2400	543851	2800764	10/4/2004	3.7	TF-1100	541387	2825365	10/5/2004	10.0
TD-2500	533791	2820127	10/5/2004	13.0	TF-1200	541287	2825356	10/5/2004	7.3
TE-0000	533691	2820120	10/6/2004	2.0	TF-1400	541088	2825338	10/5/2004	19.7
TE-0100	533591	2820113	10/6/2004	4.0	TF-1500	540988	2825329	10/6/2004	13.0
TE-0400	533292	2820093	10/6/2004	7.0	TF-1600	540889	2825320	10/6/2004	7.7
TE-0600	533129	2820081	10/6/2004	9.7	TF-1700	540789	2825311	10/6/2004	3.7
TE-0900	532793	2820060	10/6/2004	6.0	TF-1800	540689	2825302	10/6/2004	5.3
TE-1100	532593	2820047	10/6/2004	4.3	TF-1900	540590	2825293	10/6/2004	2.0
TE-1200	532494	2820040	10/6/2004	7.7	TF-2000	540491	2825283	10/6/2004	6.7
TE-1300	532391	2820031	10/6/2004	9.7	TF-2100	540390	2825275	10/6/2004	18.0
TE-1400	532294	2820027	10/6/2004	21.3	TF-2200	540291	2825265	10/6/2004	18.0
TE-1500	532194	2820020	10/6/2004	4.7	TF-2300	540192	2825256	10/6/2004	4.7
TE-1700	531995	2820006	10/6/2004	5.7	TF-2400	540092	2825247	10/6/2004	8.0
TE-2100	531596	2819980	10/6/2004	3.3	TF-2600	539893	2825229	10/6/2004	10.0
TE-2200	531496	2819973	10/6/2004	7.3	TF-2700	539793	2825220	10/6/2004	10.3
TE-2300	531396	2819967	10/6/2004	5.0	TF-2800	539693	2825211	10/6/2004	2.0
TE-2400	531296	2819960	10/6/2004	3.0	TF-3100	539495	2825193	10/6/2004	1.0
TE-2500	531197	2819953	10/6/2004	3.0					

Appendix 2: Mean water depths averaged over three to five field measurements taken in the vegetation survey plots at the census sites in the habitat of Cape Sable seaside sparrow (CSSS) within the marl prairie landscape.

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
A-01-01	512149	2846885	10/1/2003	37.3	A-07-04	505231	2831993	11/9/2005	55.0
A-01-02	513139	2846878	10/8/2010	15.7	A-07-05	506192	2831975	11/9/2005	62.0
A-01-03	514119	2846904	10/1/2003	40.7	A-07-06	506175	2832964	11/9/2005	55.0
A-01-04	515129	2846856	10/1/2003	44.3	A-07-07	507216	2832954	11/9/2005	50.0
A-01-05	514124	2845851	10/8/2010	22.3	A-07-08	507193	2831970	11/9/2005	41.7
A-01-06	515125	2844858	10/1/2003	32.3	A-08-01	503198	2833998	10/1/2003	75.0
A-01-07	514102	2843847	10/8/2010	10.0	A-08-02	504183	2834899	10/1/2003	81.3
A-01-08	516146	2842899	10/1/2003	52.7	A-08-03	506187	2834007	10/1/2003	87.7
A-01-09	516149	2841886	11/9/2005	37.0	A-08-04	507197	2834010	10/1/2003	90.3
A-01-10	512155	2844803	10/8/2010	20.0	A-08-05	507212	2834897	10/1/2003	71.0
A-03-01	511118	2833996	10/15/201	17.5	A-08-06	507207	2835892	10/1/2003	64.0
A-03-02	513155	2834079	10/2/2003	32.7	A-08-07	508180	2836880	10/1/2003	62.0
A-03-03	515162	2834850	10/15/201	25.7	A-08-08	507113	2836904	10/1/2003	69.3
A-03-04	515132	2832965	10/2/2003	29.0	A-08-09	505223	2836901	10/1/2003	58.7
A-03-05	516090	2831118	10/2/2003	45.7	A-09-01	506169	2838881	10/1/2003	51.3
A-03-06	515089	2830946	10/15/201	29.7	A-09-02	507173	2839844	5/21/2003	8.4
A-03-07	513029	2831037	10/2/2003	33.3	A-09-03	508173	2838913	10/1/2003	56.7
A-03-08	511174	2831001	10/15/201	12.7	A-09-04	509143	2838908	10/1/2003	59.0
A-03-09	511168	2831996	10/15/201	28.3	A-09-05	509217	2836866	10/1/2003	59.0
A-03-10	510182	2832018	10/2/2003	45.3	A-09-06	510180	2837905	11/27/2009	15.2
A-04-01	510162	2829023	10/2/2003	21.7	A-09-07	510174	2835906	10/8/2010	31.0
A-04-02	512186	2829011	10/2/2003	23.0	A-09-08	511185	2835905	10/8/2010	14.0
A-04-03	514251	2830027	10/15/201	17.7	A-09-09	511196	2838896	10/8/2010	19.7
A-04-04	516131	2829091	10/2/2003	39.3	A-09-10	513152	2835885	10/1/2003	58.0
A-04-05	515117	2828015	10/2/2003	40.7	A-10-01	511203	2829990	10/1/2003	64.7
A-04-06	515133	2827012	10/15/201	32.7	A-10-02	512167	2831000	10/1/2003	40.7
A-04-07	516163	2827057	10/2/2003	41.7	A-10-03	513091	2831909	10/1/2003	42.0
A-05-01	504238	2823026	10/2/2003	58.3	A-10-04	514126	2830961	10/1/2003	48.3
A-05-02	505216	2823052	10/2/2003	40.0	A-10-05	516092	2832015	10/1/2003	56.7
A-05-03	505226	2824020	10/15/201	36.0	A-10-06	515974	2832913	10/1/2003	47.0
A-05-04	505225	2825013	10/2/2003	51.3	A-10-07	516154	2833899	10/1/2003	50.7
A-05-05	507234	2825015	10/2/2003	47.0	A-10-08	514137	2833992	10/1/2003	55.3
A-05-06	509224	2825064	10/2/2003	43.3	A-10-09	514158	2834463	10/1/2003	45.3
A-05-07	510251	2825027	10/2/2003	40.7	A-10-10	513144	2834674	10/1/2003	58.0
A-05-08	510217	2824036	10/2/2003	37.0	A-13-01	504181	2824977	4/7/2004	8.6
A-05-09	510265	2822985	10/2/2003	42.3	A-13-09	510208	2822032	4/7/2004	9.0
A-06-01	504236	2829002	10/2/2003	75.0	A-13-10	512196	2822009	4/7/2004	18.4
A-06-02	505168	2830027	10/2/2003	65.7	A-14-03	504225	2827957	11/9/2005	54.0
A-06-03	506201	2830025	10/2/2003	54.7	A-15-02	504153	2833951	4/14/2004	21.2
A-06-04	506210	2827998	10/2/2003	57.0	A-15-03	503015	2832949	4/14/2004	16.4
A-06-05	506227	2827023	10/2/2003	52.0	A-15-04	505171	2832943	11/9/2005	57.3
A-06-06	507215	2826006	10/15/201	34.0	A-15-05	506185	2830955	11/9/2005	49.7
A-06-07	508219	2828071	10/2/2003	40.7	A-15-10	506122	2828979	4/14/2004	8.2
A-06-08	508131	2827035	10/2/2003	37.0	A-16-01	509163	2837860	11/27/2009	11.0
A-06-09	509274	2827943	10/15/201	18.7	A-16-10	512172	2832969	11/9/2005	47.3
A-06-10	509227	2826008	10/2/2003	39.3	A-17-01	510176	2840851	11/27/2009	10.0
A-07-01	504175	2829916	11/9/2005	56.7	A-17-02	510172	2839859	11/27/2009	2.7

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
A-17-03	510174	2838837	11/27/200	8.6	A-25-07	506180	2836853	10/8/2010	24.7
A-18-06	504070	2841875	4/26/2004	10.2	A-25-08	505186	2837839	10/8/2010	44.7
A-18-10	507188	2842805	4/26/2004	11.2	A-25-09	507158	2837840	10/8/2010	28.7
A-19-03	512122	2842830	11/27/200	4.1	A-25-10	507181	2838842	10/8/2010	37.3
A-19-07	516120	2840834	11/9/2005	28.3	A-26-01	505172	2833963	10/15/2010	66.0
A-19-08	515144	2839865	11/9/2005	21.3	A-26-02	506190	2834854	10/15/2010	40.7
A-19-09	515136	2838845	11/27/200	7.8	A-26-03	508179	2834854	10/15/2010	23.0
A-19-10	516073	2839044	11/27/200	1.7	A-26-04	509178	2833968	10/15/2010	22.7
A-20-05	513181	2845696	11/27/200	19.8	A-26-05	511172	2834890	10/15/2010	25.7
A-21-01	511191	2847210	10/8/2010	10.7	A-26-06	509181	2835841	10/8/2010	23.0
A-21-02	510218	2845943	10/8/2010	15.0	A-26-07	510194	2836875	10/8/2010	45.0
A-21-03	510151	2844890	10/8/2010	25.0	A-26-08	511155	2837869	10/8/2010	32.3
A-21-04	510154	2843822	10/8/2010	15.3	A-26-09	512183	2837879	10/8/2010	45.7
A-21-05	509283	2843872	10/8/2010	15.7	A-26-10	512202	2836814	10/8/2010	17.3
A-21-06	508166	2843826	4/25/2005	6.8	A-27-01	512150	2833964	11/9/2005	33.0
A-21-07	507169	2843834	4/25/2005	5.8	A-27-02	512145	2831869	11/9/2005	50.7
A-21-08	510179	2842895	10/8/2010	26.7	A-27-03	513111	2832943	11/9/2005	48.7
A-21-09	509161	2842834	10/8/2010	25.0	A-27-04	514096	2831997	10/15/2010	19.3
A-21-10	509194	2841839	10/8/2010	29.7	A-27-05	515104	2831980	10/15/2010	15.3
A-22-01	516104	2846819	10/8/2010	29.0	A-27-06	514137	2832972	11/9/2005	25.0
A-22-02	515118	2845783	10/8/2010	15.0	A-27-07	515060	2834026	10/15/2010	31.3
A-22-03	514116	2844847	10/8/2010	19.0	A-27-08	516117	2834840	10/15/2010	34.3
A-22-04	513113	2843822	10/8/2010	16.7	A-27-10	515128	2835840	10/8/2010	28.0
A-22-05	513134	2842827	11/27/200	3.2	A-28-01	505190	2830912	11/9/2005	60.3
A-22-06	514127	2841864	11/9/2005	37.0	A-28-02	507184	2828993	10/15/2010	32.0
A-22-07	515122	2841829	11/9/2005	33.0	A-28-03	510198	2827923	10/15/2010	5.2
A-22-08	514134	2842821	10/8/2010	8.7	A-28-04	511171	2826989	10/15/2010	24.0
A-22-09	515116	2843812	10/8/2010	15.3	A-28-05	509156	2826898	10/15/2010	34.0
A-22-10	516024	2843849	10/8/2010	14.0	A-28-06	509211	2828988	10/15/2010	12.7
A-23-01	510168	2841826	11/27/200	11.7	A-28-07	509180	2831039	10/15/2010	26.3
A-23-02	513134	2841823	10/8/2010	13.0	A-28-08	509126	2832172	10/15/2010	36.7
A-23-03	511170	2840852	10/8/2010	9.3	A-28-09	509183	2832949	10/15/2010	34.3
A-23-04	512252	2840716	10/8/2010	27.0	A-28-10	508265	2832912	10/15/2010	35.7
A-23-05	514256	2840750	11/9/2005	38.3	A-29-01	504191	2823944	10/15/2010	44.7
A-23-06	515133	2840844	11/9/2005	36.0	A-29-02	505257	2821970	10/15/2010	29.3
A-23-07	512145	2839844	10/8/2010	6.7	A-29-03	507218	2822973	10/15/2010	40.7
A-23-08	513149	2839676	11/27/200	10.7	A-29-04	508226	2822985	10/15/2010	30.7
A-23-09	514139	2839805	10/8/2010	8.7	A-29-05	508211	2823965	10/15/2010	27.3
A-24-01	506180	2841849	10/8/2010	17.3	A-29-06	508180	2824969	10/15/2010	28.7
A-24-02	507169	2841834	10/8/2010	20.3	A-29-07	508062	2826150	10/15/2010	40.0
A-24-03	505169	2840845	10/8/2010	7.3	A-29-08	510220	2825986	10/15/2010	17.7
A-24-04	507180	2840827	10/8/2010	16.3	A-29-09	511189	2825973	10/15/2010	14.8
A-24-05	508190	2840801	11/27/200	24.6	A-29-10	511192	2824959	10/15/2010	21.7
A-24-06	509169	2840828	11/27/200	12.8	A-30-01	510186	2830972	10/15/2010	14.0
A-25-01	504156	2838835	10/8/2010	29.0	A-30-02	509192	2829824	10/15/2010	17.7
A-25-02	504185	2837840	10/8/2010	25.0	A-30-03	510187	2829964	10/15/2010	13.7
A-25-03	504181	2836826	10/8/2010	27.0	A-30-04	512152	2829941	10/15/2010	10.3
A-25-04	504188	2835849	10/8/2010	38.0	A-30-05	513124	2829962	10/15/2010	20.0
A-25-05	505172	2834893	10/15/201	55.0	A-30-06	515090	2829964	10/15/2010	17.8
A-25-06	506308	2835807	10/8/2010	38.7	A-30-07	516118	2829970	10/15/2010	27.3

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
A-30-08	515041	2828959	10/15/201	26.7	B-06-01	517488	2804319	10/3/2003	31.3
A-30-09	514119	2828965	10/15/201	23.7	B-06-02	517585	2802389	10/3/2003	23.0
B-01-01	520439	2809224	10/6/2003	48.0	B-06-03	517502	2800325	10/3/2003	38.7
B-01-02	521601	2809144	10/6/2003	9.0	B-06-04	518519	2802327	10/3/2003	19.7
B-01-03	522385	2813225	10/6/2003	46.3	B-06-05	519370	2806264	10/3/2003	26.0
B-01-04	522408	2811219	11/27/200	13.0	B-06-06	519593	2800468	10/3/2003	21.3
B-01-05	524414	2816166	10/6/2003	39.3	B-06-07	520553	2806330	10/3/2003	9.7
B-01-06	524388	2815203	10/22/201	25.2	B-06-08	520492	2803321	10/3/2003	16.3
B-01-07	524394	2812179	10/6/2003	21.0	B-06-09	522412	2806292	10/3/2003	8.0
B-01-08	524480	2811369	10/22/201	3.5	B-06-10	522395	2805268	10/3/2003	5.0
B-02-01	524473	2806170	10/6/2003	6.0	B-07-06	523397	2812236	11/27/2009	10.7
B-02-02	525433	2808246	11/4/2005	5.3	B-07-09	520399	2810165	11/27/2009	20.0
B-02-03	525452	2806350	10/6/2003	20.3	B-08-01	526367	2807205	11/4/2005	15.3
B-02-04	526393	2808207	10/6/2003	8.7	B-08-06	528412	2804346	11/27/2009	0.8
B-02-05	527489	2806438	10/22/201	11.3	B-10-03	521451	2804319	11/27/2009	4.9
B-02-06	527435	2805325	10/22/201	10.8	B-10-05	523463	2805304	11/27/2009	4.4
B-02-07	528345	2807219	10/6/2003	2.0	B-10-09	524434	2803412	11/27/2009	2.6
B-02-08	528417	2806348	10/6/2003	5.0	B-10-10	524432	2802329	11/9/2005	6.0
B-02-09	528443	2805331	10/6/2003	16.7	B-11-02	517457	2805255	11/9/2005	34.7
B-02-10	529434	2805326	10/22/201	15.5	B-11-03	519415	2805291	11/27/2009	2.2
B-03-01	523480	2800352	10/3/2003	20.7	B-11-04	520452	2805280	11/27/2009	1.3
B-03-02	524426	2801401	10/3/2003	16.0	B-11-05	520421	2804293	11/27/2009	6.7
B-03-03	524439	2800361	11/9/2005	12.0	B-11-07	518598	2803217	11/27/2009	6.7
B-03-04	524436	2799379	10/3/2003	17.3	B-11-09	518472	2800294	4/16/2004	2.0
B-03-05	525424	2800358	10/3/2003	9.0	B-12-01	524372	2817140	10/22/2010	25.8
B-03-06	526436	2801374	11/9/2005	7.0	B-12-02	523451	2816140	10/22/2010	36.0
B-03-07	527362	2801328	10/3/2003	8.7	B-12-03	523443	2815143	10/22/2010	28.3
B-03-08	527456	2799384	10/3/2003	12.3	B-12-04	522437	2815166	10/22/2010	31.5
B-03-09	527439	2798381	10/3/2003	9.0	B-12-05	522442	2814156	11/4/2005	54.3
B-03-10	528456	2799370	10/22/201	8.3	B-12-06	522530	2812136	10/22/2010	29.8
B-04-01	524473	2796383	10/3/2003	41.0	B-12-07	521450	2812176	11/4/2005	43.0
B-04-02	525449	2797381	10/3/2003	22.7	B-12-08	520427	2811166	10/22/2010	26.7
B-04-03	526451	2797378	10/22/201	23.7	B-12-09	522421	2810163	10/22/2010	8.3
B-04-04	526445	2796391	10/3/2003	32.7	B-12-10	523438	2811188	10/22/2010	13.7
B-04-05	526466	2795453	10/3/2003	40.0	B-13-04	519427	2810172	10/22/2010	34.7
B-04-06	527480	2796378	5/7/2003	21.4	B-13-05	519422	2809180	10/22/2010	27.8
B-04-07	528432	2798371	10/3/2003	8.3	B-13-06	519423	2808150	10/22/2010	20.7
B-04-08	528439	2797388	10/3/2003	13.3	B-13-07	519399	2807175	10/22/2010	19.3
B-04-09	529431	2798383	5/7/2003	7.6	B-13-09	521471	2806227	11/27/2009	1.7
B-04-10	530465	2795357	11/9/2005	26.7	B-13-10	521440	2805254	11/27/2009	5.5
B-05-01	519555	2799379	11/9/2005	22.7	B-14-01	527374	2807213	10/22/2010	4.0
B-05-02	521570	2802185	10/22/201	7.7	B-14-02	525389	2807179	11/4/2005	5.7
B-05-03	521517	2800333	10/3/2003	23.3	B-14-03	526437	2806276	10/22/2010	5.3
B-05-04	521530	2799348	11/9/2005	15.3	B-14-05	523434	2804305	10/22/2010	2.0
B-05-05	521529	2797361	10/3/2003	32.7	B-14-06	527417	2803299	10/22/2010	9.7
B-05-06	522496	2802327	10/03/03	18.7	B-14-07	528422	2802307	10/22/2010	6.3
B-05-07	523462	2803358	10/03/03	14.0	B-14-08	526426	2802291	10/22/2010	9.7
B-05-08	523477	2802369	10/3/2003	15.3	B-14-09	525408	2802317	11/9/2005	3.0
B-05-09	523517	2801335	10/3/2003	23.3	B-14-10	525414	2801318	11/9/2005	7.3
B-05-10	525444	2803323	10/22/201	5.0	B-15-01	518447	2805257	10/22/2010	10.3

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
B-15-02	518443	2804296	10/22/201	14.0	D-02-09	547308	2799387	11/7/2005	33.3
B-15-04	522454	2804296	10/22/201	2.2	D-03-05	545355	2800360	11/7/2005	23.3
B-15-06	520484	2802294	10/22/201	4.7	D-03-06	546344	2800374	11/7/2005	23.0
B-15-07	519507	2802329	10/22/201	11.5	D-03-07	546342	2799381	11/7/2005	24.3
B-15-08	520448	2801352	11/9/2005	15.0	D-03-08	545390	2799424	11/7/2005	25.3
B-15-09	519446	2801343	10/22/201	7.0	D-03-09	544337	2799375	4/11/2005	3.8
B-15-10	517465	2801321	10/22/201	22.3	D-03-10	544335	2800362	4/11/2005	6.0
B-16-01	521462	2801315	11/9/2005	19.7	E-01-01	529376	2822048	10/7/2003	28.7
B-16-02	522463	2800314	10/22/201	28.5	E-01-02	530372	2824055	10/7/2003	36.0
B-16-03	521459	2798303	10/22/201	18.3	E-01-03	530393	2823020	10/7/2003	19.3
B-16-04	522492	2798313	10/22/201	26.0	E-01-04	530350	2822044	10/7/2003	18.3
B-16-05	523472	2797316	10/22/201	24.3	E-01-05	531351	2822037	10/7/2003	27.0
B-16-06	523487	2798320	10/22/201	14.7	E-01-06	531320	2821059	10/7/2003	27.3
B-17-01	520502	2799309	11/9/2005	25.0	E-01-07	532350	2826036	10/7/2003	22.0
B-17-02	520511	2798160	10/22/201	28.7	E-01-08	532285	2825069	10/7/2003	32.0
C-01-01	535369	2812323	10/6/2003	11.3	E-01-09	532348	2822051	10/7/2003	24.0
C-01-02	536377	2811375	10/6/2003	17.0	E-01-10	533308	2821023	10/7/2003	14.3
C-01-03	537345	2813237	10/6/2003	18.0	E-02-01	527367	2821022	10/7/2003	46.3
C-01-04	538307	2815194	10/6/2003	32.3	E-02-02	527404	2820182	10/7/2003	38.3
C-01-05	540298	2814227	10/6/2003	18.3	E-02-03	527394	2819182	10/7/2003	25.7
C-01-06	538380	2810405	10/6/2003	21.3	E-02-04	529367	2820210	10/7/2003	28.7
C-01-07	539371	2807964	10/6/2003	45.3	E-02-05	529373	2818187	10/7/2003	24.7
C-01-08	540341	2808244	11/7/2005	9.0	E-02-06	531403	2820153	10/7/2003	21.3
C-01-09	540262	2809327	10/6/2003	21.0	E-02-07	531375	2819176	10/7/2003	12.0
C-01-10	541130	2811251	10/6/2003	23.0	E-02-08	532358	2819185	10/7/2003	9.0
C-02-03	538290	2813192	11/4/2005	19.3	E-02-09	534364	2818180	10/7/2003	17.3
C-02-08	541130	2813219	11/7/2005	28.7	E-02-10	537394	2818253	10/7/2003	13.3
C-02-09	541150	2812221	11/7/2005	35.3	E-03-02	527397	2817139	11/27/2009	12.6
C-03-02	541061	2814191	11/7/2005	26.7	E-03-04	528365	2819163	11/4/2005	27.0
C-03-03	540287	2813210	11/7/2005	18.0	E-03-05	529344	2819141	11/4/2005	26.3
C-03-04	540287	2812220	11/7/2005	23.3	E-03-07	528348	2817156	5/29/2009	6.1
C-03-05	539309	2812241	11/27/200	5.4	E-03-09	529326	2817183	11/27/2009	4.3
C-03-07	539279	2810232	11/7/2005	48.3	E-04-01	531307	2824025	11/27/2009	6.8
C-03-08	539305	2809190	11/7/2005	33.7	E-04-04	529346	2821021	11/4/2005	30.0
C-03-09	540310	2810188	11/7/2005	35.7	E-04-07	533352	2819621	11/4/2005	16.0
C-04-01	538297	2814206	11/4/2005	12.7	E-05-03	531318	2825013	11/27/2009	17.0
C-04-02	537346	2814186	11/4/2005	14.3	E-05-04	532300	2824026	11/4/2005	31.7
C-04-06	536304	2812211	11/4/2005	12.3	E-05-05	533322	2824011	11/4/2005	28.0
C-04-08	537337	2811189	11/4/2005	7.3	E-05-10	534342	2819154	11/4/2005	24.3
D-01-01	544330	2802350	10/6/2003	11.0	E-06-01	528381	2820973	11/4/2005	36.7
D-01-02	544353	2801405	10/6/2003	10.7	E-06-02	528372	2820118	11/4/2005	16.0
D-01-03	545411	2804403	10/6/2003	12.7	E-06-03	530353	2820150	11/4/2005	10.0
D-01-04	545491	2803420	10/6/2003	8.3	E-06-04	530349	2819144	11/4/2005	16.0
D-01-05	546405	2803429	10/6/2003	9.7	E-06-06	531333	2818167	6/3/2009	11.3
D-01-06	546354	2802405	10/6/2003	10.3	E-06-08	527361	2814156	11/4/2005	5.7
D-01-07	547357	2802409	10/6/2003	9.0	E-06-09	526403	2814131	6/3/2009	5.6
D-01-08	547475	2801336	10/6/2003	20.0	F-01-01	541821	2829046	10/07/03	14.0
D-01-09	547382	2800398	10/6/2003	22.7	F-01-02	542251	2826192	10/7/2003	12.0
D-02-03	546334	2804374	11/7/2005	14.0	F-01-03	540249	2827107	10/7/2003	18.7
D-02-05	544339	2803368	11/7/2005	7.0	F-01-04	539257	2825111	10/7/2003	29.7

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
F-01-05	539212	2822102	10/7/2003	25.7	F-02-09	540244	2824095	11/4/2005	19.7
F-01-06	540198	2822176	10/7/2003	16.7	F-03-01	541200	2831069	11/27/09	**9.3**
F-01-07	540277	2823126	10/7/2003	20.3	F-03-02	542240	2827075	11/27/2009	2.3
F-01-08	541255	2823107	10/7/2003	12.3	F-03-03	541228	2826091	6/2/2009	10.8
F-01-09	542139	2821962	10/7/2003	11.0	F-03-04	540232	2826077	11/4/2005	32.0
F-01-10	542267	2821167	10/7/2003	5.3	F-03-05	540235	2825066	11/4/2005	41.7
F-02-01	541214	2832059	11/4/2005	35.3	F-03-06	539228	2824074	11/4/2005	48.0
F-02-02	541218	2830079	11/27/200	1.5	F-03-07	539231	2823030	6/2/2009	25.6
F-02-03	541215	2829129	11/27/200	5.4	F-03-08	541226	2822038	6/2/2009	9.8
F-02-05	541226	2827151	11/27/200	2.1	F-03-10	541220	2824087	6/2/2009	6.3
F-02-06	541225	2825084	6/2/2009	10.2	F-04-03	542228	2831060	11/27/2009	2.4

Appendix 3: Mean water depths averaged over three field measurements taken in the vegetation survey plots at the transect sites in the habitat of Cape Sable seaside sparrow (CSSS) within the marl prairie landscape.

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
BL_01	531360	2832690	10/18/201	46.8	Chek_15	534302	2847268	11/14/201	14.0
BL_02	531330	2832661	10/18/201	57.0	Chek_16	534301	2847238	11/14/201	-1.0
BL_03	531297	2832630	10/18/201	NA	Chek_17	534267	2847209	11/14/201	15.0
BL_04	531263	2832595	10/18/201	35.6	Chek_18	534270	2847178	11/14/201	14.0
BL_05	531239	2832568	10/18/201	52.0	Chek_19	534264	2847154	11/14/201	20.0
BL_06	531208	2832540	10/18/201	35.0	Chek_20	534240	2847121	11/14/201	19.0
BL_07	531179	2832510	10/18/201	42.2	Chek_21	534239	2847083	11/14/201	13.0
BL_08	531149	2832482	10/18/201	35.2	Chek_22	534237	2847060	11/14/201	13.0
BL_09	531120	2832450	10/18/201	37.9	Chek_23	534210	2847028	11/14/201	28.0
BL_10	531089	2832421	10/18/201	50.6	Chek_24	534213	2847001	11/14/201	19.0
BL_11	531059	2832391	10/18/201	42.1	Chek_25	534209	2846970	11/14/201	11.0
BL_12	531030	2832360	10/18/201	41.3	Chek_26	534178	2846943	11/14/201	22.0
BL_13	531000	2832330	10/18/201	38.0	Chek_27	534182	2846909	11/14/201	21.0
BL_14	530970	2832300	10/18/201	53.0	Chek_28	534178	2846881	11/14/201	28.0
BL_15	530940	2832270	10/18/201	46.0	Chek_29	534149	2846850	11/14/201	20.0
BL_16	530910	2832240	10/18/201	50.0	Chek_30	534149	2846820	11/14/201	23.0
BL_17	530880	2832210	10/18/201	47.0	Chek_31	534151	2846790	11/14/201	27.0
BL_18	530850	2832180	10/18/201	52.7	Chek_32	534122	2846760	11/14/201	21.0
Chek_01	534417	2847689	11/14/201	44.0	Chek_33	534120	2846730	11/14/201	26.0
Chek_02	534418	2847665	11/14/201	39.0	Chek_34	534123	2846700	11/14/201	31.0
Chek_03	534420	2847631	11/14/201	36.0	Chek_35	534092	2846670	11/14/201	25.0
Chek_04	534390	2847596	11/14/201	30.0	Chek_36	534089	2846640	11/14/201	27.0
Chek_05	534390	2847571	11/14/201	19.0	Chek_37	534091	2846610	11/14/201	31.0
Chek_06	534389	2847541	11/14/201	7.0	Chek_38	534060	2846580	11/14/201	37.0
Chek_07	534357	2847510	11/14/201	NA	Chek_39	534058	2846550	11/14/201	33.0
Chek_08	534360	2847480	11/14/201	NA	Chek_40	534058	2846520	11/14/201	27.0
Chek_09	534357	2847447	11/14/201	NA	GL_01	526081	2834941	10/12/201	61.7
Chek_10	534361	2847419	11/14/201	NA	GL_02	526079	2834912	10/12/201	66.0
Chek_11	534361	2847391	11/14/201	2.0	GL_03	526049	2834880	10/12/201	53.7
Chek_12	534329	2847362	11/14/201	18.0	GL_04	526050	2834846	10/12/201	35.3
Chek_13	534331	2847323	11/14/201	7.0	GL_05	526048	2834824	10/12/201	40.3
Chek_14	534302	2847299	11/14/201	3.0	GL_06	526020	2834821	10/12/201	NA

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
GL_07	526019	2834794	10/12/201	NA	HL_14	547620	2847871	1/15/2013	19.0
GL_08	526020	2834760	10/12/201	19.0	HL_15	547590	2847840	1/15/2013	19.7
GL_09	525989	2834729	10/12/201	34.3	HL_16	547558	2847811	1/15/2013	19.0
GL_10	525994	2834699	10/12/201	38.3	HL_17	547528	2847779	1/15/2013	15.7
GL_11	525989	2834671	10/12/201	38.0	HL_18	547497	2847752	1/18/2013	14.0
GL_12	525963	2834669	10/12/201	39.3	HL_19	547469	2847720	1/18/2013	16.7
GL_13	525958	2834641	10/12/201	41.3	HL_20	547438	2847691	1/18/2013	19.3
GL_14	525965	2834605	10/12/201	41.0	HL_21	547438	2847660	1/18/2013	19.7
GL_15	525928	2834580	10/12/201	45.5	HL_22	547410	2847629	1/18/2013	20.2
GL_16	525929	2834553	10/12/201	40.1	HL_23	547379	2847600	1/18/2013	19.0
GL_17	525929	2834521	10/12/201	37.5	HL_24	547349	2847570	1/18/2013	17.2
GL_18	525900	2834521	10/12/201	34.6	HL_25	547318	2847539	1/18/2013	16.0
GL_19	525900	2834490	10/12/201	40.9	HL_26	547289	2847510	1/18/2013	21.5
GL_20	525901	2834463	10/12/201	43.2	HL_27	547261	2847480	1/18/2013	27.7
GL_21	525870	2834430	10/12/201	36.4	HL_28	547228	2847448	1/18/2013	28.2
GL_22	525868	2834403	10/12/201	38.7	JB_01	528297	2834788	11/27/201	58.0
GL_23	525869	2834370	10/12/201	44.6	JB_02	528302	2834760	11/27/201	62.0
GL_24	525839	2834371	10/12/201	33.6	JB_03	528269	2834723	11/27/201	25.0
GL_25	525842	2834340	10/12/201	45.5	JB_04	528268	2834700	11/27/201	NA
GL_26	525840	2834310	10/12/201	38.3	JB_05	528241	2834670	11/27/201	2.0
GL_27	525807	2834281	10/12/201	44.2	JB_06	528242	2834641	11/27/201	10.0
GL_28	525809	2834252	10/12/201	43.0	JB_07	528211	2834611	11/27/201	35.0
GL_29	525809	2834218	10/12/201	44.7	JB_08	528210	2834579	11/27/201	33.0
GL_30	525780	2834220	10/12/201	41.5	JB_09	528181	2834551	11/27/201	30.0
GL_31	525778	2834189	10/12/201	42.0	JB_10	528182	2834518	11/27/201	26.0
GL_32	525780	2834159	10/12/201	46.0	JB_11	528150	2834491	11/27/201	29.0
GL_33	525753	2834126	10/12/201	42.7	JB_12	528150	2834460	11/27/201	33.0
GL_34	525740	2834092	10/12/201	45.0	JB_13	528119	2834430	11/27/201	38.0
GL_35	525720	2834069	10/12/201	45.3	JB_14	528120	2834399	11/27/201	41.0
GL_36	525723	2834039	10/12/201	50.3	JB_15	528090	2834369	11/27/201	37.0
GL_37	525688	2834009	10/12/201	50.3	JB_16	528090	2834335	11/27/201	40.0
GL_38	525690	2833981	10/12/201	41.7	JB_17	528060	2834303	11/27/201	40.0
GL_39	525660	2833952	10/12/201	47.7	JB_18	528056	2834283	11/27/201	35.0
GL_40	525661	2833923	10/12/201	49.7	JB_19	528031	2834249	11/27/201	40.0
GL_41	525628	2833890	10/12/201	49.3	JB_20	528026	2834223	11/27/201	39.0
GL_42	525630	2833860	10/12/201	51.0	JB_21	528000	2834187	11/27/201	40.0
HL_01	547619	2848260	1/18/2013	30.3	JB_22	528002	2834160	11/27/201	38.0
HL_02	547619	2848230	1/18/2013	29.2	JB_23	527966	2834131	11/27/201	43.0
HL_03	547620	2848200	1/18/2013	22.1	JB_24	527971	2834101	11/27/201	41.0
HL_04	547619	2848171	1/15/2013	19.3	JB_25	527941	2834070	11/27/201	43.0
HL_05	547620	2848141	1/15/2013	11.1	JB_26	527935	2834038	11/27/201	40.0
HL_05.1	547636	2848126	1/15/2013	NA	JB_27	527910	2834010	11/27/201	40.0
HL_06	547619	2848113	1/15/2013	17.0	JB_28	527914	2833984	11/27/201	40.0
HL_07	547620	2848080	1/15/2013	14.7	JB_29	527881	2833950	11/27/201	40.0
HL_08	547619	2848049	1/15/2013	14.7	JB_30	527882	2833921	11/27/201	40.0
HL_09	547618	2848021	1/15/2013	9.0	JB_31	527849	2833892	11/27/201	42.0
HL_10	547621	2847990	1/15/2013	12.7	JB_32	527855	2833866	11/27/201	46.0
HL_11	547621	2847961	1/15/2013	14.7	JB_33	527820	2833832	11/27/201	46.0
HL_12	547619	2847932	1/15/2013	10.0	JB_34	527791	2833799	11/27/201	46.0
HL_13	547619	2847900	1/15/2013	22.2	JB_35	527756	2833771	11/27/201	44.0

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
JB_36	527727	2833740	11/27/201	40.0	TI66_25	523861	2866801	2/1/2013	11.3
JB_37	527700	2833711	11/27/201	41.0	TI66_26	523859	2866771	2/1/2013	15.8
JB_38	527669	2833681	11/27/201	40.0	TI66_27	523889	2866741	2/1/2013	14.8
JB_39	527643	2833655	11/27/201	42.0	TI66_28	523890	2866711	2/1/2013	10.5
JB_40	527609	2833622	11/27/201	42.0	TI66_29	523890	2866682	2/1/2013	12.8
JB_41	527583	2833593	11/27/201	41.0	TI66_30	523889	2866650	2/1/2013	16.0
SL_01	524520	2838121	11/1/2012	59.7	TI66_31	523919	2866622	2/11/2013	7.7
SL_02	524520	2838091	11/1/2012	67.9	TI66_32	523921	2866589	2/11/2013	10.3
SL_03	524486	2838060	11/1/2012	22.2	TI66_33	523920	2866561	2/11/2013	14.3
SL_04	524488	2838030	11/1/2012	NA	TI66_34	523919	2866531	2/11/2013	4.0
SL_05	524490	2838003	11/1/2012	20.8	TI66_35	523949	2866499	2/11/2013	7.3
SL_06	524458	2837971	11/1/2012	27.9	TI66_36	523949	2866470	2/11/2013	11.0
SL_07	524457	2837939	11/1/2012	39.2	TI66_37	523949	2866439	2/11/2013	5.0
SL_08	524457	2837910	11/1/2012	44.0	TI66_38	523950	2866410	2/11/2013	2.3
SL_09	524428	2837881	11/1/2012	46.0	TI66_39	523949	2866379	2/11/2013	17.0
SL_10	524429	2837850	11/1/2012	34.3	TI66_40	523951	2866351	2/11/2013	6.7
SL_11	524398	2837820	11/1/2012	45.1	TI66_41	523949	2866322	2/11/2013	18.8
SL_12	524399	2837791	11/1/2012	50.5	TI66_42	523948	2866291	2/11/2013	5.5
SL_13	524368	2837759	11/1/2012	49.0	TI66_43	523948	2866259	2/11/2013	21.8
SL_14	524370	2837731	11/1/2012	44.7	TI66_44	523947	2866230	2/11/2013	26.5
SL_15	524374	2837706	11/1/2012	48.3	TI66_45	523949	2866201	2/11/2013	26.7
SL_16	524340	2837670	11/1/2012	46.0	TI66_46	523949	2866171	2/11/2013	22.3
SL_17	524340	2837642	11/1/2012	47.7	TI66_47	523949	2866141	2/11/2013	25.7
SL_18	524308	2837612	11/1/2012	49.3	TI66_48	523949	2866109	2/11/2013	28.7
SL_19	524310	2837582	11/1/2012	51.0	TI66_49	523952	2866079	2/11/2013	34.7
SL_20	524282	2837550	11/1/2012	50.7	TI66_50	523952	2866049	2/11/2013	40.0
TI66_01	523709	2867521	2/1/2013	30.3	W3A266_01	518070	2853240	2/28/2014	50.0
TI66_02	523709	2867489	2/1/2013	33.7	W3A266_02	518070	2853210	2/28/2014	46.0
TI66_03	523710	2867461	2/1/2013	10.7	W3A266_03	518071	2853177	2/28/2014	22.0
TI66_04	523712	2867431	2/1/2013	NA	W3A266_04	518071	2853148	2/28/2014	1.0
TI66_05	523739	2867399	2/1/2013	6.8	W3A266_05	518071	2853121	2/28/2014	NA
TI66_06	523739	2867371	2/1/2013	-9.0	W3A266_06	518071	2853092	2/28/2014	NA
TI66_07	523738	2867339	2/1/2013	2.7	W3A266_07	518069	2853060	2/28/2014	9.0
TI66_08	523768	2867312	2/1/2013	2.0	W3A266_08	518069	2853028	2/28/2014	11.0
TI66_09	523773	2867280	2/1/2013	17.8	W3A266_09	518072	2852998	2/28/2014	14.0
TI66_10	523770	2867248	2/1/2013	5.3	W3A266_10	518042	2852968	2/28/2014	11.0
TI66_11	523802	2867223	2/1/2013	5.0	W3A266_11	518043	2852939	2/28/2014	10.0
TI66_12	523799	2867191	2/1/2013	7.3	W3A266_12	518041	2852907	2/28/2014	12.0
TI66_13	523801	2867159	2/1/2013	18.0	W3A266_13	518041	2852879	2/28/2014	19.0
TI66_14	523829	2867128	2/1/2013	17.0	W3A266_14	518009	2852848	2/28/2014	21.0
TI66_15	523832	2867101	2/1/2013	16.7	W3A266_15	518003	2852820	2/28/2014	27.0
TI66_16	523831	2867074	2/1/2013	21.3	W3A266_16	518001	2852790	2/28/2014	32.0
TI66_17	523831	2867042	2/1/2013	8.3	W3A266_17	517978	2852757	2/28/2014	22.0
TI66_18	523829	2867012	2/1/2013	8.7	W3A266_18	517979	2852729	2/28/2014	33.0
TI66_19	523858	2866983	2/1/2013	16.7	W3A266_19	517980	2852702	2/28/2014	34.0
TI66_20	523860	2866952	2/1/2013	16.3	W3A266_20	517951	2852671	2/28/2014	39.0
TI66_21	523860	2866919	2/1/2013	4.3	W3B12_01	546299	2857591	12/7/2012	44.7
TI66_22	523859	2866891	2/1/2013	3.5	W3B12_02	546299	2857560	12/7/2012	54.7
TI66_23	523859	2866861	2/1/2013	12.0	W3B12_03	546299	2857529	12/7/2012	42.3
TI66_24	523860	2866833	2/1/2013	6.7	W3B12_04	546299	2857500	12/7/2012	39.7

SiteID	Easting	Northing	Date	Ave. Water depth (cm)	SiteID	Easting	Northing	Date	Ave. Water Depth (cm)
W3B12_0	546300	2857471	12/7/2012	37.5	W3B12_27	546420	2856810	12/7/2012	18.0
W3B12_0	546329	2857442	12/7/2012	22.2	W3B12_28	546420	2856781	12/7/2012	19.3
W3B12_0	546330	2857412	12/7/2012	9.7	W3B12_29	546420	2856750	12/7/2012	20.0
W3B12_0	546300	2857383	12/7/2012	NA	W3B12_30	546449	2856722	12/7/2012	12.3
W3B12_0	546330	2857381	12/7/2012	NA	W3B12_31	546450	2856690	12/7/2012	16.0
W3B12_0	546329	2857351	12/7/2012	16.0	W3B12_32	546450	2856660	12/7/2012	13.0
W3B12_1	546329	2857321	12/7/2012	22.7	W3B12_33	546452	2856632	12/7/2012	18.7
W3B12_1	546330	2857294	12/7/2012	20.6	W3B12_34	546450	2856600	12/7/2012	15.3
W3B12_1	546326	2857263	12/7/2012	19.8	W3B12_35	546480	2856570	12/7/2012	22.3
W3B12_1	546328	2857232	12/7/2012	15.8	W3B12_36	546479	2856543	12/7/2012	23.0
W3B12_1	546360	2857204	12/7/2012	19.6	W3B12_37	546481	2856511	12/7/2012	25.7
W3B12_1	546359	2857171	12/7/2012	19.2	W3B12_38	546481	2856480	12/7/2012	24.3
W3B12_1	546361	2857140	12/7/2012	19.3	W3B12_39	546478	2856450	12/7/2012	19.0
W3B12_1	546359	2857110	12/7/2012	15.8	W3B12_40	546480	2856420	12/7/2012	13.7
W3B12_1	546359	2857082	12/7/2012	21.7	W3B12_41	546509	2856390	12/7/2012	28.0
W3B12_1	546361	2857050	12/7/2012	20.8	W3B12_42	546511	2856361	12/7/2012	29.7
W3B12_2	546389	2857020	12/7/2012	14.7	W3B12_43	546508	2856329	12/7/2012	27.7
W3B12_2	546389	2856988	12/7/2012	16.0	W3B12_44	546510	2856299	12/7/2012	23.7
W3B12_2	546390	2856961	12/7/2012	14.3	W3B12_45	546509	2856269	12/7/2012	33.7
W3B12_2	546388	2856929	12/7/2012	18.0	W3B12_46	546540	2856240	12/7/2012	35.0
W3B12_2	546391	2856899	12/7/2012	22.3	W3B12_47	546541	2856213	12/7/2012	34.1
W3B12_2	546421	2856870	12/7/2012	18.3	W3B12_48	546540	2856179	12/7/2012	36.3
W3B12_2	546422	2856838	12/7/2012	17.3					