Appendix 8-1: Supplemental Information on Modeling, Demonstration Projects, Research and Assessments in the Lake Okeechobee Watershed

LAKE OKEECHOBEE WATER QUALITY MODEL RECALIBRATION

The Lake Okeechobee Water Quality Model (LOWQM) (**Figure 8-1**) was developed to improve our understanding of internal nutrient cycling, specifically total phosphorus (TP), within the lake and to assess lake-wide responses to various management alternatives. Previously calibrated/validated to hydro-meteorological and monitoring data from 1983 to 2000 (James et al., 2005), this model has been used to evaluate lake responses to watershed phosphorus management alternatives, water management alternatives, and sediment management alternatives (James and Pollman, 2011).

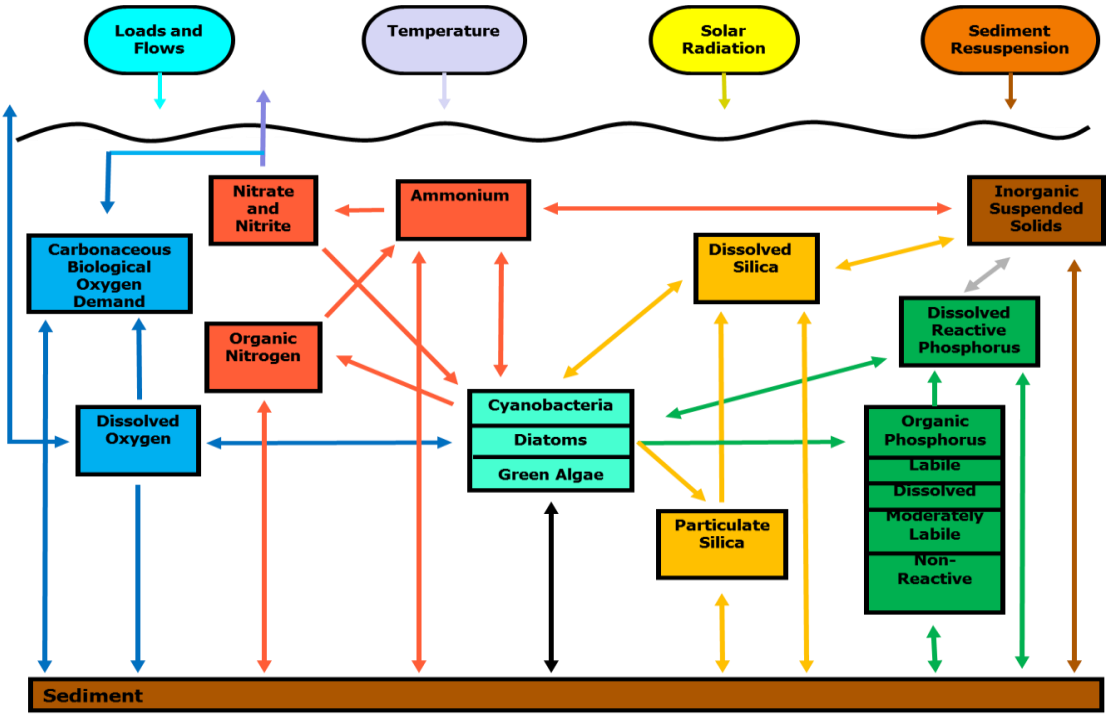


Figure 8-1. Schematic of the Lake Okeechobee Water Quality Model (LOWQM).

From 2005 to 2008, a series of extreme hydro-meteorological events occurred in the Lake Okeechobee region that was outside the range of observations in the original LOWQM model. These included three hurricanes and two major droughts that resulted in major changes to the light environment, nutrients, and phytoplankton communities in the lake. A new model calibration was developed using the time period 1997–2012 to capture these events. When compared to the original calibration, there were small improvements in goodness-of-fit measures of nitrogen and phosphorus species as well as phytoplankton and chlorophyll (**Figure 8-2**). The major differences between the two calibrations were slower cycling of phosphorus and nitrogen in the lake (**Figure 8-3**). The differences in cycles and the similarity of goodness-of-fit measures between the original and new model indicate that model structure constrains the capability of the model to produce more accurate results. Observed measurements of nutrient and algal dynamics would be useful to develop a more reliable model. However, model structure also needs to be enhanced, especially for phytoplankton species to more accurately represent the ecosystem.

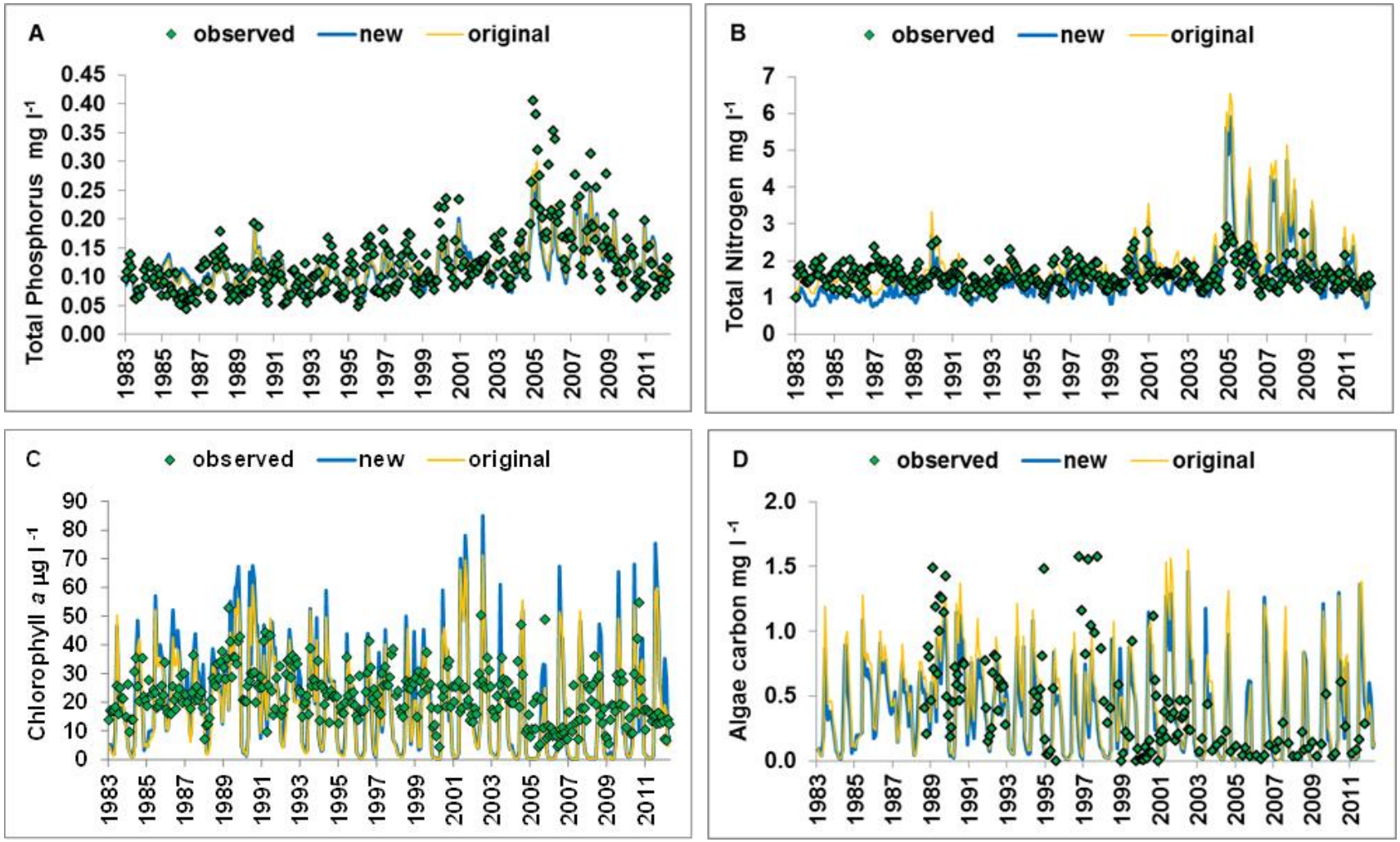


Figure 8-2. Comparisons of model predictions to observed values for the original and new LOWQM calibrations: (A) phosphorus, (B) nitrogen, (C) chlorophyll, (D) algal carbon**.** [Note: µg l^{-1} – microgram per liter and mg l^{-1} – milligrams per liter.]

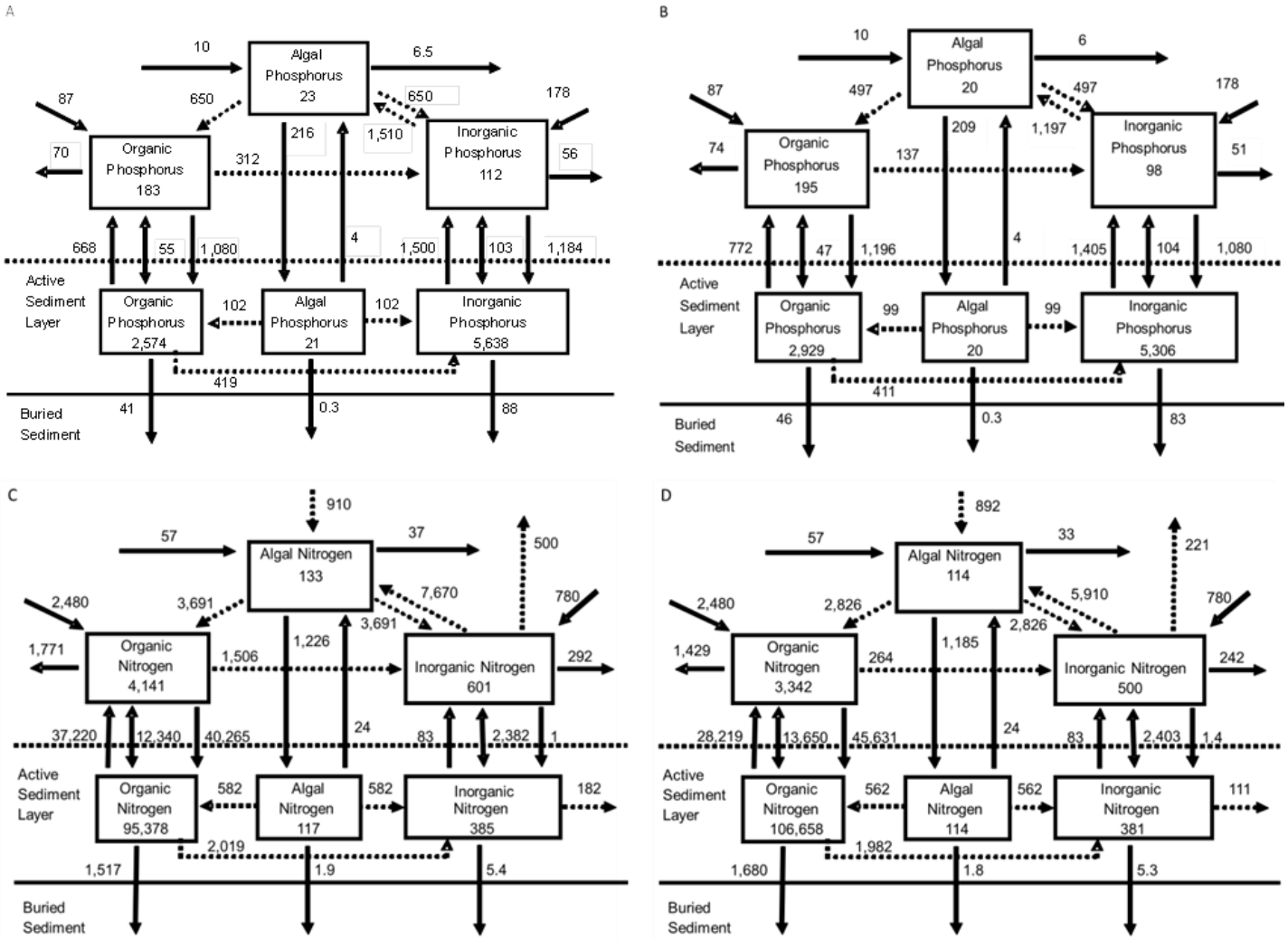


Figure 8-3. Averaged annual nutrient cycles predicted by the LOWQM (values are milligram per square meter per year for flows and milligrams per square meter for storage): (A) original calibration-phosphorus, (B) new calibration-phosphorus, (C) original calibration-nitrogen, and (D) new calibration-nitrogen.

POTENTIAL ECOLOGICAL BENEFITS FROM NORTH OF LAKE OKEECHOBEE RECOVERABLE STORAGE

Above average precipitation in the Lake Okeechobee watershed can result in inflow exceeding the capacity to release water from the lake by two to three times, causing rapid increases in water levels and pushing the lake above the ecologically preferred stage envelope of 12.5–15.5 feet National Geodetic Vertical Datum of 1929 (ft NGVD) (Havens, 2002). Conversely, during extended droughts, the combination of normal evapotranspiration and withdrawals from the lake for urban groundwater recharge and crop irrigation can lower lake stages below the bottom of the preferred envelope.

Various levels of water storage ranging from approximately 250,000 acre-feet (ac-ft) to as much as 1.3 million ac-ft have been proposed for the Lake Okeechobee Watershed as part of the Comprehensive Everglades Restoration Plan (CERP) and other initiatives (USACE and SFWMD, 2004, 2007; SFWMD et al., 2008). Storage is anticipated to provide an increase in ecological benefits to the biota in the littoral marsh and nearshore regions of the lake by reducing the extent, frequency and duration of extreme high and low lake stages and by keeping the lake within the ecologically preferred stage envelope more of the time. Storage would also reduce damaging freshwater discharges to the east and west coast estuaries during wet years and benefit water supply during droughts.

While evaluating the effects of additional water storage on water supply and flood control is relatively straightforward, the quality of the performance measures used to assess ecological effects for Lake Okeechobee biota have been inadequate; primarily because the needed analysis of long-term monitoring data sets has not been done. The primary objectives of this study were to: (1) develop scoring metrics for ecological indicators that had a significant correlation with lake stage; and (2) evaluate the potential ecological benefits provided by additional water storage capacity north of Lake Okeechobee.

Over the past 10 to 15 years, various ecological data have been collected under a wide variety of lake stages reducing the uncertainties associated with lake stage-ecological response relationships. For this effort, wading birds, fish, submerged aquatic vegetation (SAV), periphyton and phytoplankton abundance data were used as ecological indicators, and all except for wading birds (based on the relationship between lake stage and available foraging habitat), were examined to determine if statistically significant Pearson or Spearman correlations exist with lake stage for each data set. Where statistically valid relationships existed, scoring metrics were developed for each of the ecological indicators

Using these scoring metrics, potential ecological responses, for each of these taxa to various north of the lake storage scenarios generated by the monthly time step Reservoir Sizing and Operations Screening Model (RESOPS) were examined to evaluate how each storage scenario might benefit or impact ecology in the nearshore and littoral marsh regions of the lake.

For the modeling exercise, the current baseline [Existing Conditions Baseline (ECB)] using the 2008 Lake Okeechobee Regulation Schedule (LORS) operating schedule with the Adaptive Protocols (SFWMD, 2010) in place was compared to storage volumes of 500,000 (500k), 1 million (1mil), 2 million (2mil) and 4 million (4mil) ac-ft. A number of operational modifications intended to optimize system performance were also investigated at each of these storage volumes. It should be noted that the upper end of the storage volumes investigated were included in the study primarily as a way of discovering the inflection point for each parameter; that is, the storage volume at which ecological benefits per unit volume of storage began to decrease.

To illustrate the process being used, following are examples of how significant relationships between pan fish and lake stage, and vascular SAV and lake stages were used to develop scoring metrics for these two parameters and how the scoring methods were used to evaluate the historical hydrograph for the 41-year period of record (POR) (1965–2005), the ECB, and the five reservoir storage scenarios.

PAN FISH CREEL DATA

Angler pan fish creel data were collected in November and December from 1997 to 2005 by the Florida Fish and Wildlife Conservation Commission. Pan fish include bluegill (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*). These data had a statistically significant inverse relationship ($r = -0.88$, $p < 0.01$) with lake stage.

The following criteria were used in developing the pan fish scoring metric. When the November and December lake stages are greater than 16 feet, the successive January and February environmental conditions in the lake are considered to be poor, resulting in lower pan fish catch rates (**Figure 8-4**) and result in 0 points for that year. November and December lake stages between 15 and 16 ft NGVD or below 12 ft NGVD appear to be suboptimal, but not damaging to the fish (1 point). Optimal conditions occur when lake stages are between 12 and 15 ft NGVD; therefore 2 points are awarded during these years.

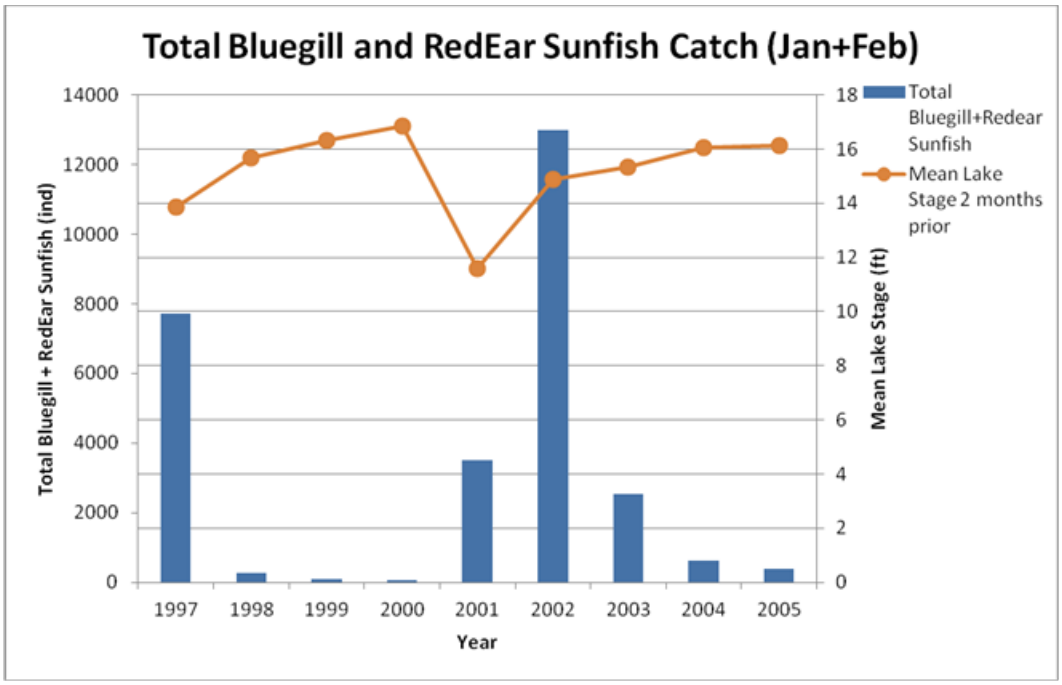


Figure 8-4. The relationship between January (Jan)–February (Feb) pan fish creel data (number of individuals [ind]) and lake stages during the prior November and December for 1997–2005.

SUBMERGED AQUATIC VEGETATION

For vascular SAV, the July–August annual nearshore mapping vascular SAV coverage data had the strongest correlation ($r = 0.59$, $p < 0.05$) with July mean lake stages (**Figure 8-5**). When the mean July lake stage is between 12 and 15.5 ft NGVD, conditions are optimal for vascular SAV coverage (**Figure 8-5**); therefore this condition scores one point. Zero points are scored for any other mean lake stage.

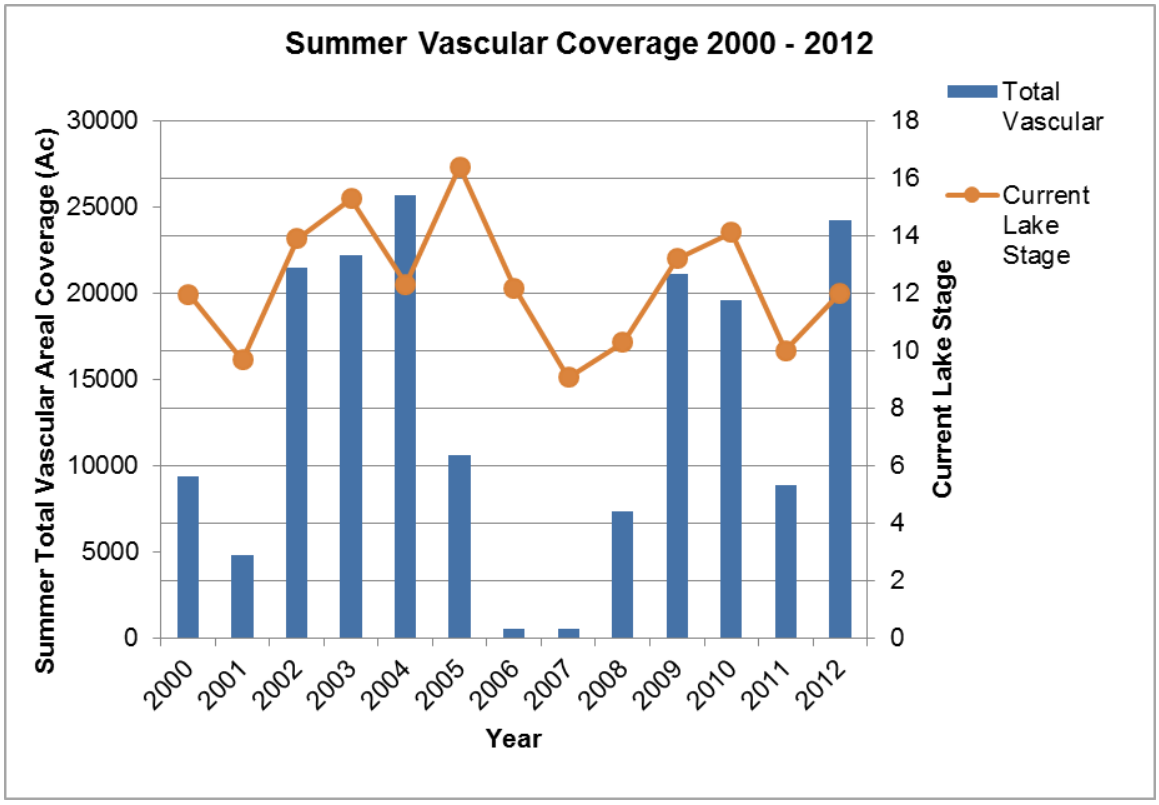


Figure 8-5. The relationship between July–August total nearshore vascular submerged aquatic vegetation (SAV) coverage (acres, or ac) and lake stages during the same period for 2000–2012.

RESERVOIR STORAGE SCENARIOS AND ECOLOGICAL INDICATORS

To evaluate the potential ecological benefits provided by additional water storage capacity north of Lake Okeechobee, the 41-year POR lake stage hydrograph, as simulated using RESOPS, operating according to 2008 LORS and the associated Lake Okeechobee Adaptive Protocols (SFWMD, 2010), was used. The frequency and amplitude of changes in lake stage that might result from adding additional recoverable storage capacity were examined. For each storage scenario, single compartment reservoirs were modeled with each having an average assigned maximum depth of 15 feet and an inflow/outflow capacity equal to the reservoir storage capacity so that it would take a month to completely fill or drain each reservoir. In the simulation, water can only flow into or out of the reservoir in a downstream direction thus water cannot be pumped upstream from the lake into the reservoir. Consequently, excess water can only be captured as it

flows towards the lake via the Kissimmee River and water in the lake can only be released south through existing structures and under existing operating protocols. Water diversion into or out of the reservoir commences when lake stage is within 0.25 feet from the top and 0.25 feet from the bottom of the stage envelope. All movement of water in and out of the reservoir is at the maximum rate whenever the lake stage is above or below the diversion trigger. Various other combinations of diversion triggers have been tried but are not reported herein because of space limitations.

Compared to the ECB, Lake Okeechobee would remain within the ecologically beneficial stage envelope 6 percent (500k), 11 percent (1mil), 17 percent (2mil and 4mil) and 18 percent (3mil) more often over the POR. (**Figure 8-6**). As reservoir storage increases, the amount of time the lake would be excessively high (> 17 feet) or low (< 10 feet) lake decreases.

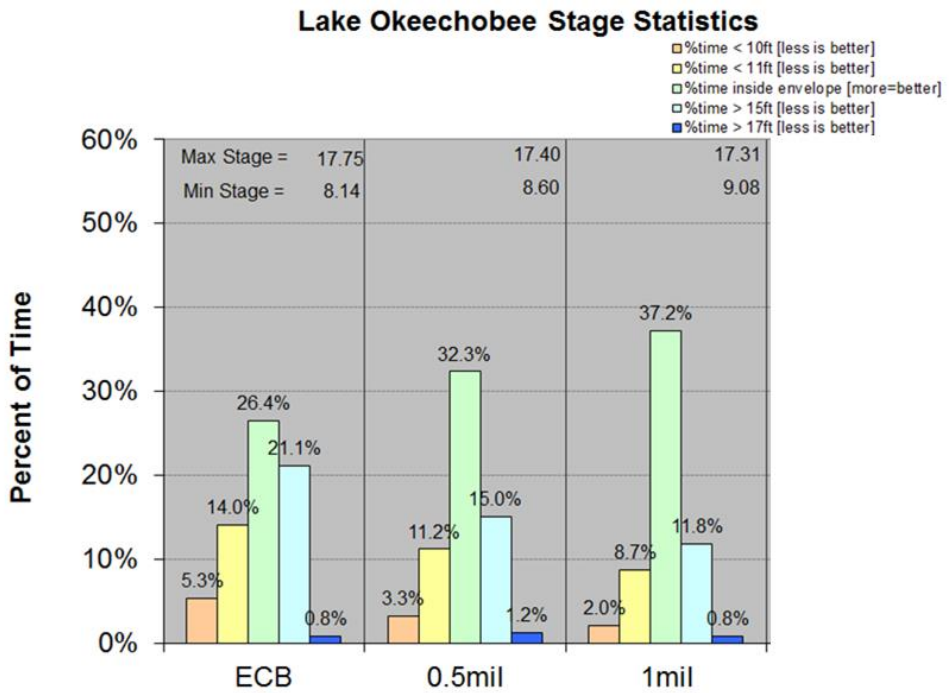
Among the model runs, ECB generally had the lowest lake stages while the highest lake stages were those of the historic hydrograph (**Figure 8-7**). This is not surprising since the lake operation schedules prior to the implementation of 2008 LORS were designed with the intent of keeping more water in the lake. For the majority of the 41-year POR, the difference in lake stages among the model runs appears to be small (e.g., < 1 foot). However, there are periods where differences in lake stages between the historic hydrograph, ECB and the 3mil and 4mil model runs approached four feet; as illustrated for 2001 (**Figure 8-7**). As might be expected, when the lake was near the lower end, or below, the bottom of the preferred stage envelope, ECB lake stages were often lower than those with reservoir storage, while under high lake stages the reverse condition was true, with lake stages under the ECB scenario often being higher than those with reservoir storage.

The model runs indicate that the larger the reservoir the less often it is at capacity. For example, the 3mil reservoir is at maximum capacity only 0.3 percent of the time (approximately 1.5 months or 2 times over the POR) while the 500k reservoir is at maximum capacity 10 percent of the time (approximately 49 months or 17 times over the POR) (**Figure 8-8**). These differences would likely play an important role in the cost-benefit analysis of any proposed reservoir project.

For the ecological indicators, higher percentage occurrences of larger point scores over the POR indicate better ecological conditions and higher abundances for the pan fish and SAV ecological indicators **(Figure 8-9**). The distribution of the point scores indicate that potential ecological benefits were enhanced for all reservoir storage scenarios. However, based on combined scores (**Figure 8-10**) for these two parameters it appears that maximum incremental benefits are obtained over the range of 0.5 mil to 1 mil ac-ft. A similar analysis can be done for each of the parameters for which statistical analysis of long-term data sets led to the development of performance metrics.

Given the much larger potential storage capacity of the 4mil storage reservoir relative to the 500k storage reservoir, it is somewhat surprising that the ecological benefits provided by the largest reservoir were not greater for the ecological indicators used in this example (and for most of the ecological parameters we have investigated to date). The failure of the 2mil–4mil reservoirs to provide ecological benefits proportional to their size is probably attributable to the fact that while these reservoirs could theoretically store the equivalent of between about four and eight feet of Lake Okeechobee stage volume when at capacity, the inherent climatological variability of the area regularly delivered either more water than the reservoirs could store at any given time or too little water to fill the reservoirs in advance of providing water during periods of drought.

It remains to be seen whether additional optimization of reservoir operations could improve the efficacy of the larger reservoirs. However, based on this study it appears that there would be little reason to provide storage in excess of between 0.5 and 1 million ac-ft.



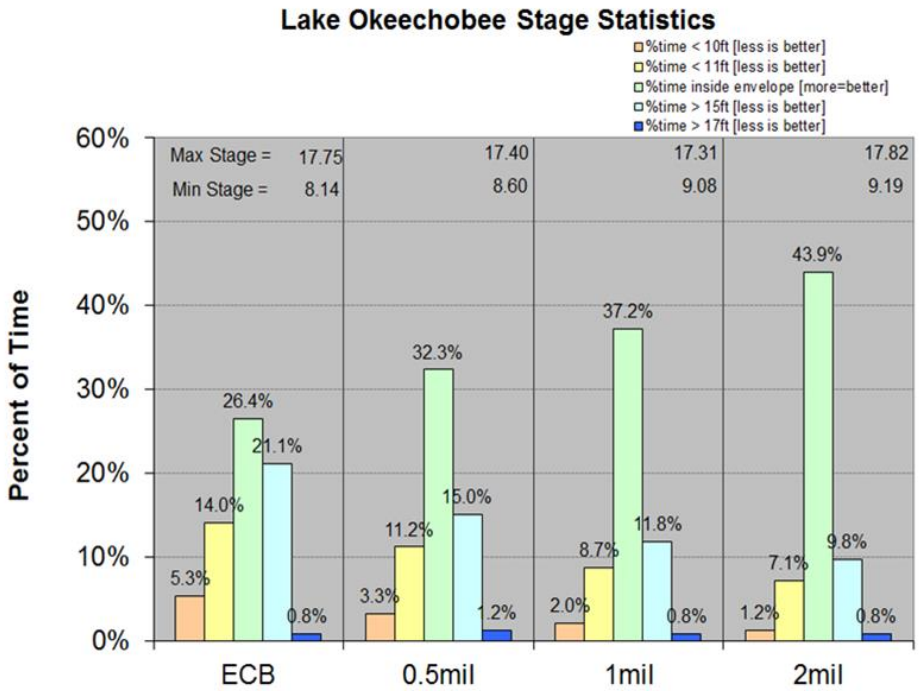


Figure 8-6. Percent of time that Lake Okeechobee is within the ecologically preferred stage envelope (inside envelope) and above and below various lake stages for each of the storage scenarios, as indicated in the legend. The maximum and minimum lake stages for each storage scenario are also listed above the bars and percent of time not shown is time the lake was between 11 feet and 12 feet and due to overlap between percent of time > 15 feet and percent of time >17 feet. [Note: ft – feet and mil – million acre-feet.]

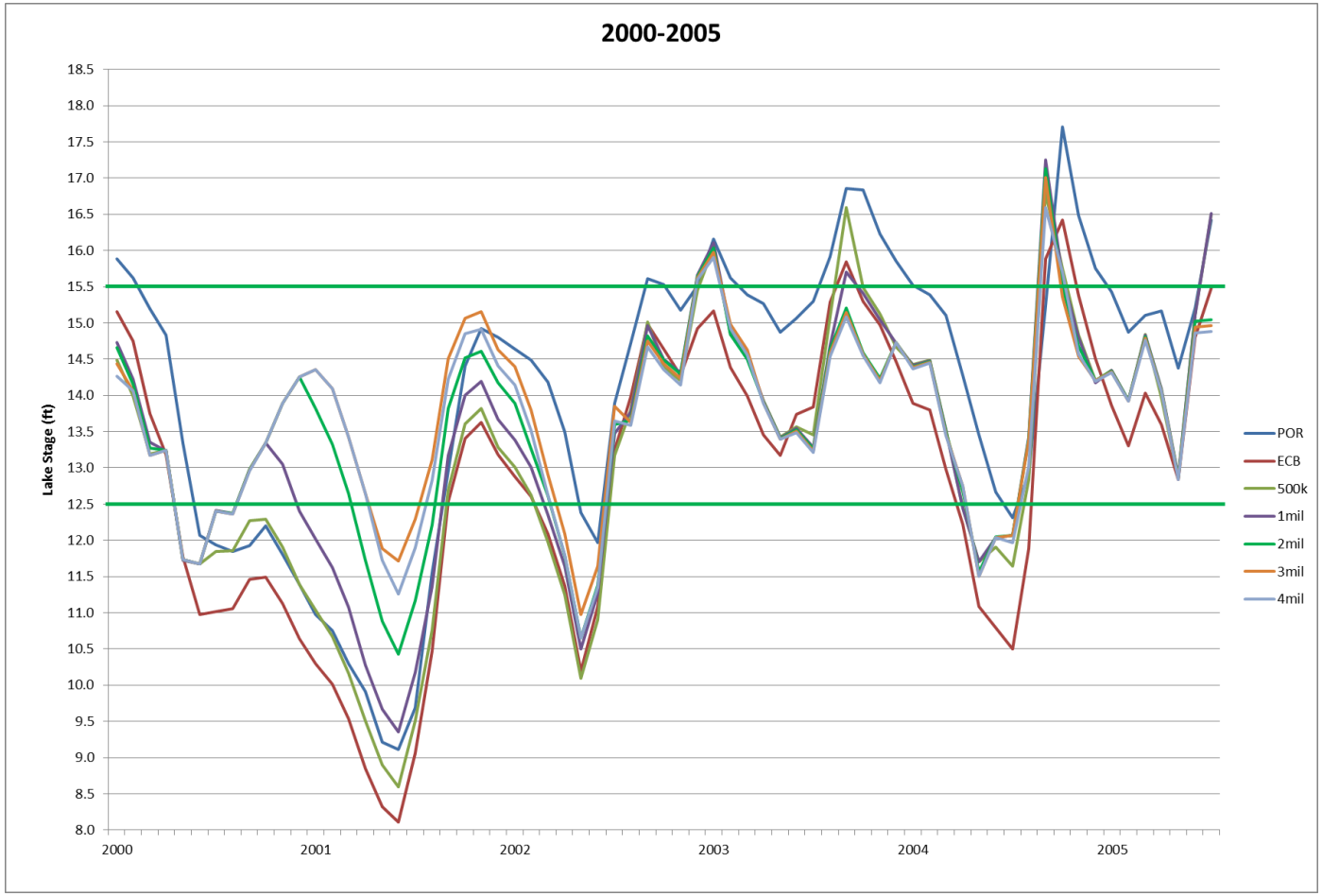


Figure 8-7. Lake stages (in feet National Geodetic Vertical Datum of 1929 though labeled as just ft) for the historical stage hydrograph the Existing Condition Base (ECB) and the five storage reservoir scenarios for the 2000–2005 period. The horizontal lines (green) indicate the elevation component of the ecologically preferred stage envelope.

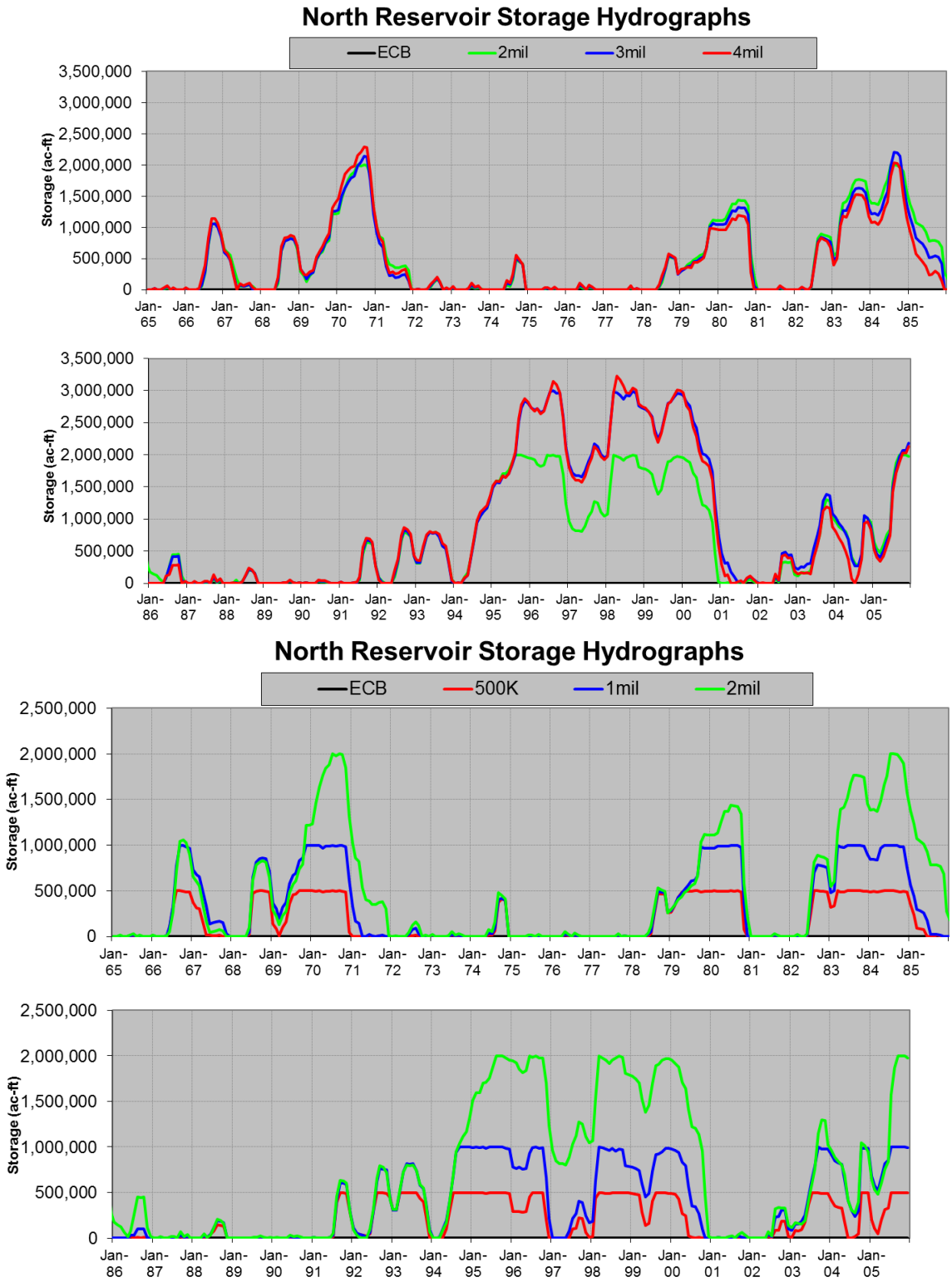
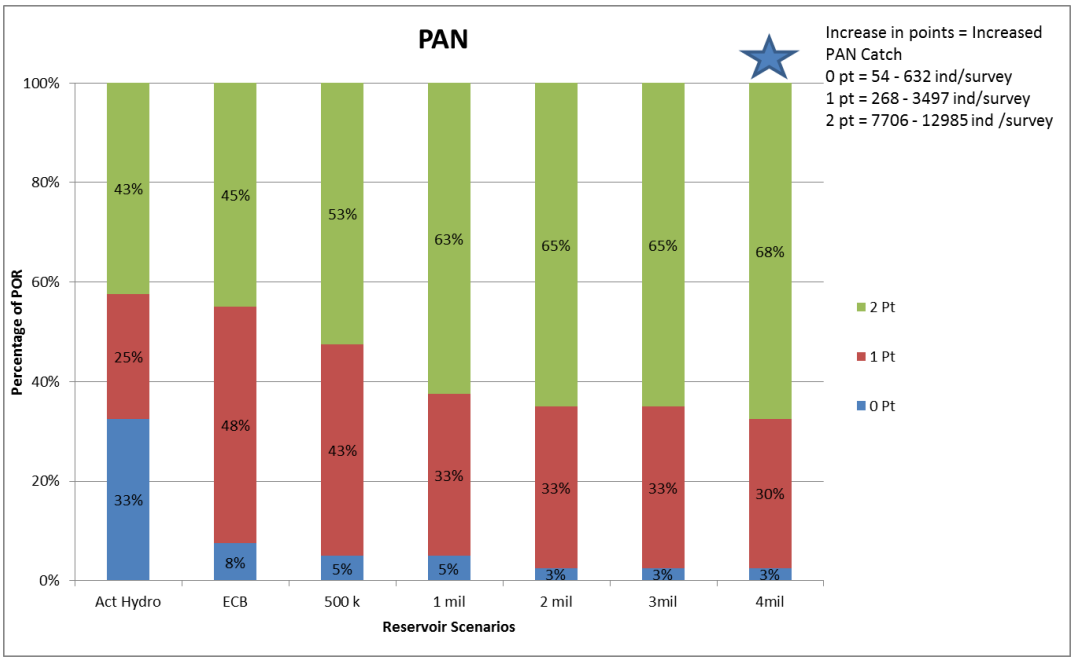


Figure 8-8. Reservoir storage hydrographs over the 1965–2005 period of record (POR).



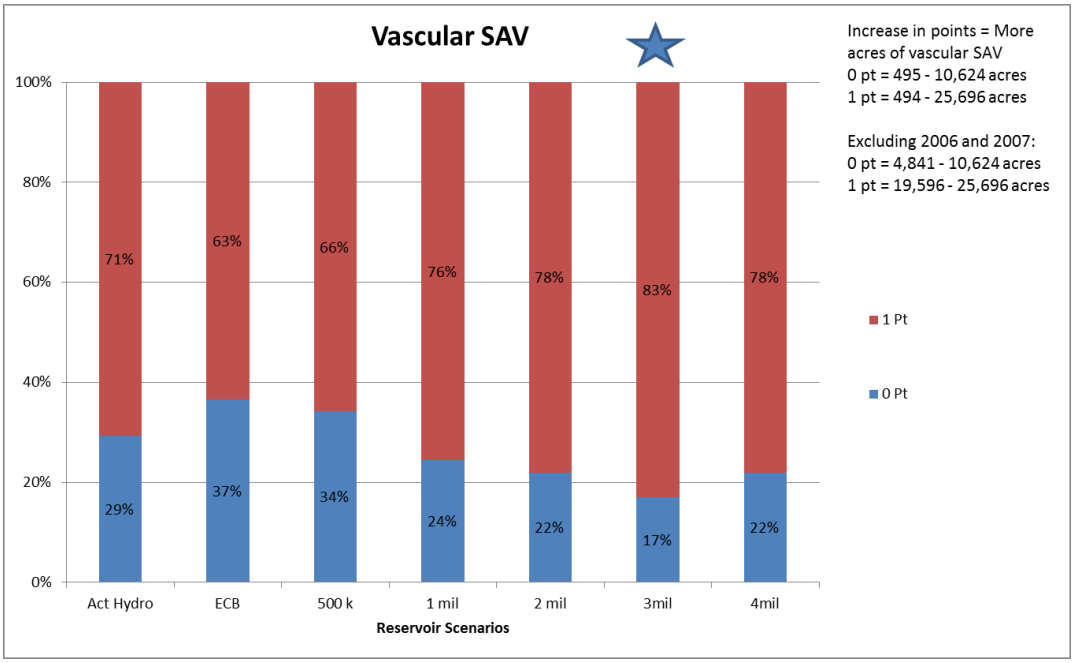


Figure 8-9. Percentage of time over the 41-year POR for the individual point distribution and range of estimated abundances for each point value for the ecological indicators [Notes: PAN – pan fish creel catch abundances per creel survey and SAV – summer vascular areal coverage). The model run scores are for POR historic hydrograph (Act Hydro), ECB and reservoir storage (500k, 1mil, 2mil, 3mil and 4mil) scenarios. The stars indicate the reservoir scenario that potentially provides the most ecological benefits to the PAN and vascular SAV ecological indicators.]

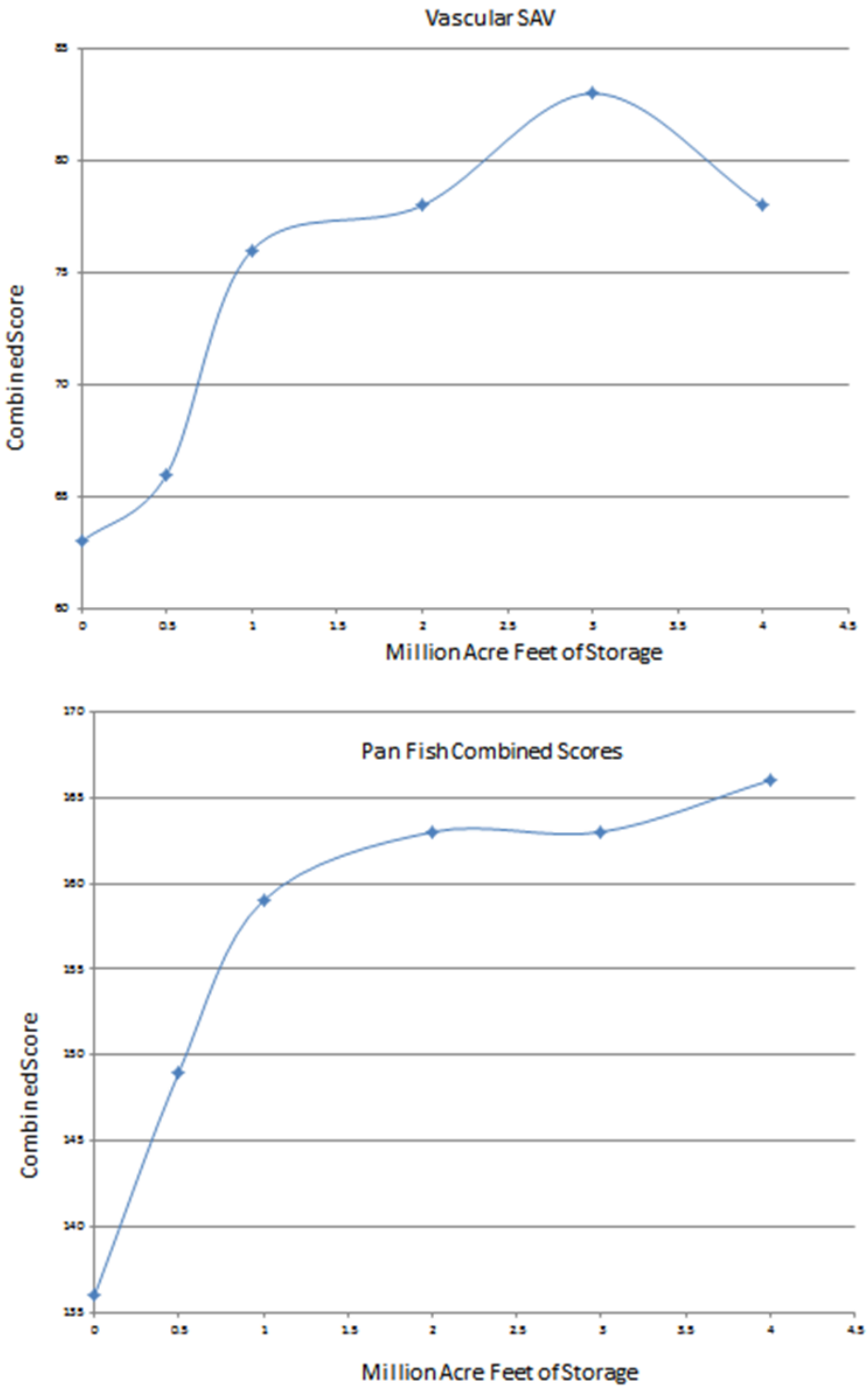


Figure 8-10. Combined scores for pan fish and vascular SAV over the range of 0 to 4 million acres indicated that ecological benefits obtained per unit volume of storage substantially decrease beyond a storage capacity of 1 million acre-feet of storage under 2008 Lake Okeechobee Regulation Schedule (LORS) operating parameters.

APPLE SNAIL STOCKING EXPERIMENTS

Recent water management actions, climatic conditions, and perhaps other unknown factors have resulted in a reduction of the native apple snail population accompanied by an expansion of the population of the exotic island apple snail (*Pomaceae maculata,* formerly *insularum*) in Lake Okeechobee and in much of the Greater Everglades ecosystem. As it is unclear what the long-term effects of this change in apple snail species dominance will be on snail kites, on the native snail population, and on the nearshore and littoral zone habitats of Lake Okeechobee, a native apple snail stock enhancement study was initiated within the Lemkin Creek isolated wetland. The intent of this study was to test various stock enhancement scenarios to identify the most effective stocking strategies for achieving optimal survival and population reestablishment of the native species. Interim information on this study was reported in Chapter 8 of the *2014 South Florida Environmental Report (SFER)_ – Volume I.* In this year's reporting, additional data was added and the statistical analysis of the full data set was completed.

In 2012, twelve large [225-square meter (m^2)] snail enclosures were constructed in Lemkin Creek marsh and stocked at 0.0, 0.4, 0.9, or 1.8 snails per m^2, representing control, low, medium, and high density treatments, respectively. Over a two-year period, total clutch production was monitored along 4 transects in each enclosure to examine density pressure on the reproduction potential of stocked juvenile/adult snails. Population estimates and average survival rates were also estimated from throw trap sampling. For detailed methods refer to Chapter 8 of the 2014 SFER–Volume I.

EGG PRODUCTION

Snails stocked into the enclosures came from a number of different age cohorts. Therefore, some of the snails stocked into the experimental enclosures in March 2012 had not yet reached sexual maturity, which is evident from the low overall production rates seen over the first month and in the delay in peak production by more than two months (**Figure 8-11**). According to Darby et al. (1997) reproduction typically begins in March and peaks in April and May; given adequate hydrological conditions. The production pattern seen in the enclosures the following year was closer to the typical pattern (**Figure 8-11**). It is unclear why production in 2012 plunged in the two weeks prior to the July peak giving the impression of a dual or cyclical pattern but this same pattern was seen in hatchery enclosures in the same wetland (Zhang and Sharfstein, 2012); although the decrease, which occurred in March, was not as dramatic.

At the time that the Lemkin Creek wetland began to be used for native apple snail studies, there was no natural *P. paludosa* population in the marsh. However, when the stocking study started in March 2012 it became evident that there was a low density of reproductive snails (as evidenced by the presence of small numbers of egg clutches) immediately outside of the enclosures; presumably the result of escapees from the nearby hatchery enclosures. By April 2013, the number of egg clutches in the surrounding wetland, and in the marsh as a whole, had increased dramatically. Therefore, beginning in June 2013, egg production in three 225-m^2 areas of the wetland immediately surrounding the stocking enclosures was also estimated.

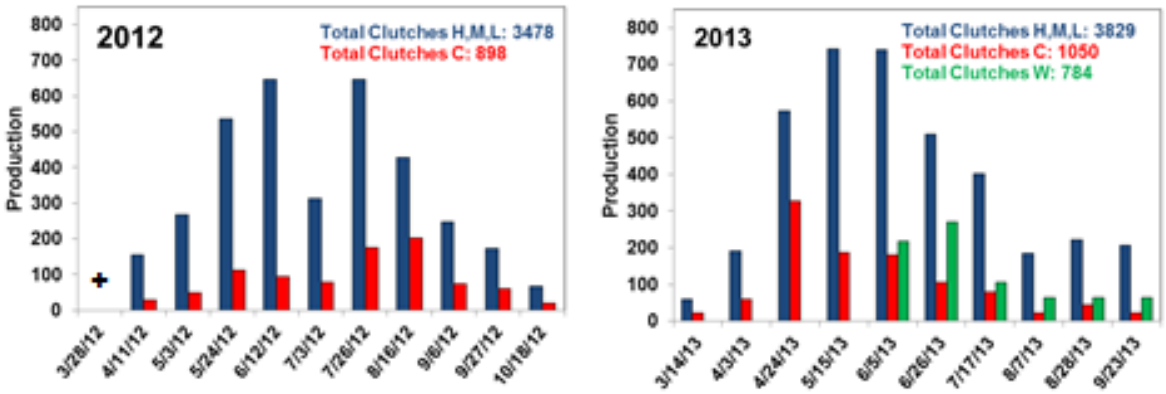


Figure 8-11. Total number of egg clutches produced per 225-square meter (m^2) area in the high (1.8 snails per m^2), medium (0.9 snails per m^2), and low (0.4 snails per m^2) stocking density treatments combined (blue), and in the control (0 snails per m^2) treatments (red) and an equivalent area in the wetland immediately outside of the enclosures (green) during 2012 and 2013. The + indicates the initial stocking event.

In 2012, a total of 4,376 egg clutches were produced across all treatments (control = 898, low = 959, medium = 872, high = 1,647) while in 2013 a total of 4,879 were produced in the same treatments (control = 1,050, low = 1,148, medium = 1,114, high = 1,567). Production in the high treatment decreased the second year while production in the control, low and medium treatments increased; however, none of the differences were significant. Assuming an average clutch size of 33 eggs (determined from the 2012 hatchery results), approximately 144,169 and 161,000 eggs were produced over the 2012 and 2013 breeding seasons, respectively. In both years, approximately 21 percent of the egg clutches produced were from within the control enclosures. Results from the 2012 hatchery enclosures indicated that the average hatch rate was 79 percent. Therefore, applying this hatch rate to the eggs in the stocking enclosures, approximately 113,893 snails were hatched into the enclosures in 2012 and 127,189 snails were hatched into the enclosures in 2013.

Average production in the control treatment the first year was 30 egg clutches while production in the low, medium and high treatments averaged 32, 29 and 55 egg clutches, respectively. Additionally, average production in the medium density treatment was actually lower than production in the control treatment. In 2013, average production was 35 egg clutches in the controls, 38 in the low, 37 in the medium and 52 in the high. There were no significant differences between the control treatment and the stocking density treatments among years ($p > 0.0988$, 2012 and $p > 0.3354$ in 2013) nor were there any between year differences ($p > 0.2723$).

Over the two year sampling period, production in the control treatment exceeded the stocked treatment in 14 instances, 11 of which were during the first year (**Figure 8-12**). In 2012, production in the control treatment was greater than in the medium treatment on seven of the ten sampling events and it was greater than the low density treatment on four of the ten events. The three instances in 2013 when production in the controls exceed the stocked treatments occurred during the same sampling event (April 24, 2013) and on that date the control production was greater than all three stocking treatments. During the August 2012 sampling event, production in the controls accounted for 32 percent of the overall production while in April 2013 production in the controls increased slightly to 36 percent of overall production. Although no egg clutches were seen in the stocking enclosures immediately after they were built or just prior to stocking, it is

evident from the control treatment that reproductive adult snails were present. It is not known, however, whether they were escapees from hatchery enclosures that were present in the same marsh and happened to get trapped inside the enclosures during construction or whether they were snails that emigrated from nearby enclosures after stocking occurred.

Production in the wetland surrounding the stocking enclosures accounted for 23 percent of the overall production from June 2013 through the end of the breeding season and it was always higher than production in the controls for the same time period (perhaps suggesting that the enclosure walls in all treatments provided a partial barrier to the free movement of snails into and out of enclosures). At the end of June, production in the wetland was also higher than production in all of the treatment enclosures (**Figure 8-12**). As the breeding season progressed, production in the wetland was higher than the medium treatment on all but two sampling events.

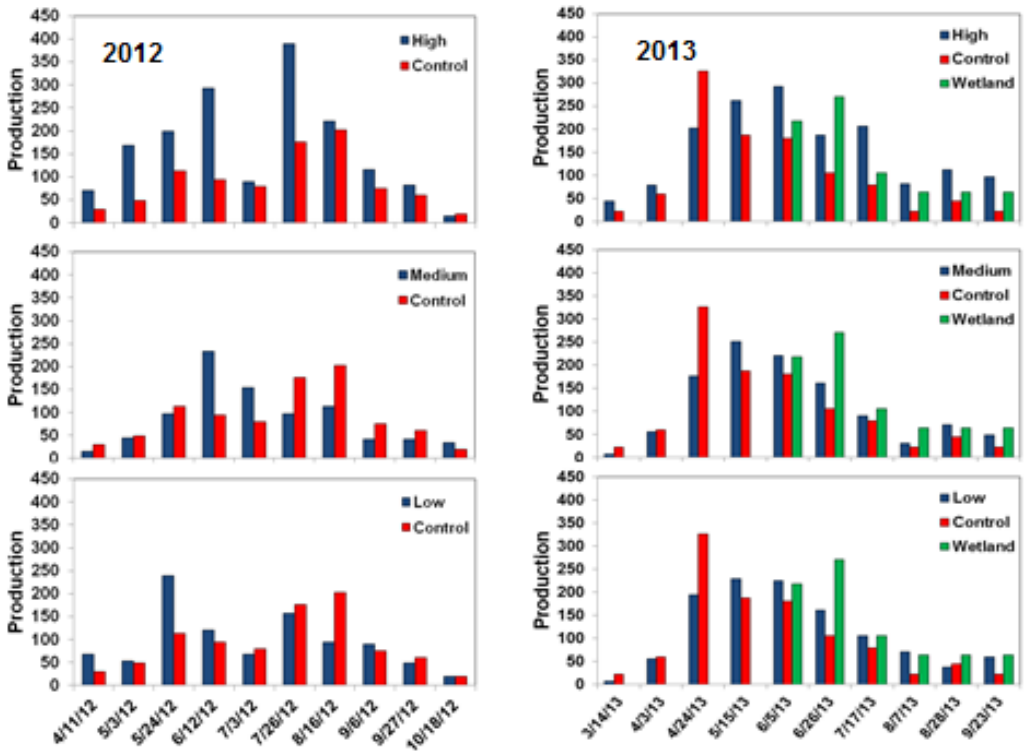


Figure 8-12. Comparison of the total number of egg clutches produced per unit area in the control treatments and in the wetland to those in the high, medium and low density treatments over time (control = 0 snails per m^2, low = 0.4 snails per m^2, medium = 0.9 snails per m^2, and high =1.8 snails per m^2).

When the production data within each enclosure was standardized to reflect the number of clutches produced per female in 2012, the average production per female in the low density treatments (0.35 clutches per female per week) was two to three times as much as it was in the high (0.13 clutches per female per week) and medium (0.14 clutches per female per week) density treatments (**Figure 8-13**). The production per female could not be calculated for the control treatment because the initial population density was not known. Production per female for the 2013 breeding season could not be directly calculated because no population estimate sampling was conducted at the beginning of the breeding season to determine overwinter survival of juveniles to adults. However, a conservative estimate of the total number of females within each enclosure can be calculated using the population estimates from the fall 2012 throw trapping event (see results below). Based on these results, the average production per female in the high

and low treatments was 1.16 clutches per female per week and 1.30 clutches per female per week, respectively (**Figure 8-13**). Because the density estimates from the throw traps are based on the number of snails captured and not the number of snails originally stocked, as was the case for the 2012 production data, standardized production in the control treatments was possible in 2013. Production per female in the control was 0.58 clutches per week. No snails were captured in the medium treatment enclosures so production could not be calculated (see the *Population Estimates* section below for an explanation).

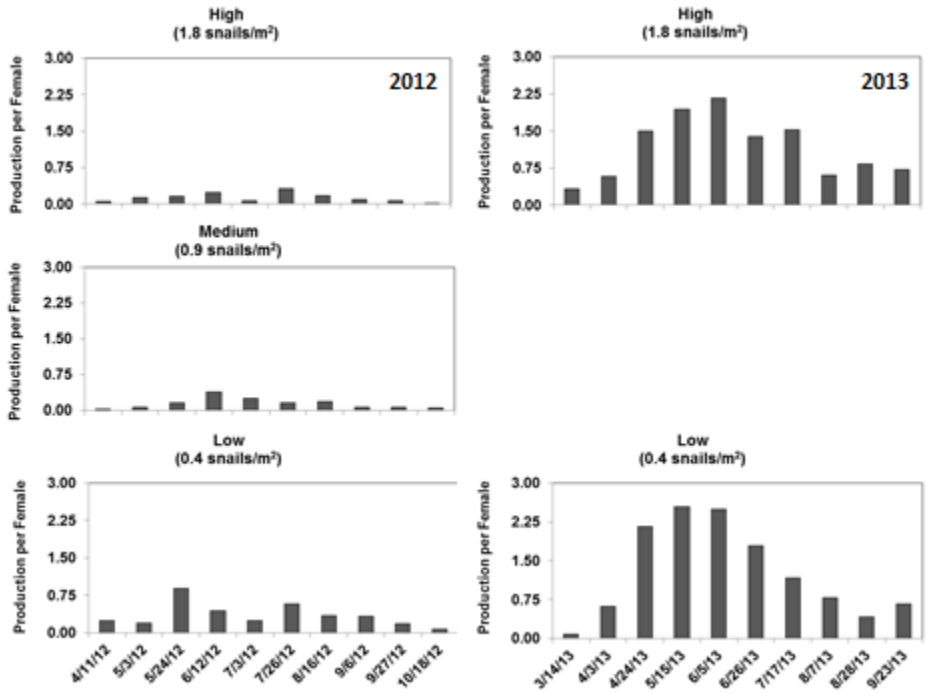


Figure 8-13. Average production per apple snail female per week for each treatment during the 2012 and 2013 breeding seasons. Production per female could not be determined for the medium density treatment in 2013.

As was the case in the hatchery study, the stocking densities used were low when compared to laboratory standards (50 to 100 snails per m^2), but high compared to what is typically found in natural habitats (0.5 to 1 snails per m^2). These stocking results are similar to the hatchery results in that they both suggest that to maximize production on a per female basis, it is best to stock at densities closer to what is typically found under natural conditions. However, if the goal is to maximize total production per enclosure, then stocking at 1.5 to 2 snails per m^2 is the best strategy.

POPULATION ESTIMATES

The following results from the three throw trapping events seem low compared to what was being observed in egg production in the enclosures and in the surrounding wetland. One reason for this discrepancy may be related to sample size. For throw trap sampling to provide reliable estimates of snail density, a large number of traps are needed. It has been suggested that enough throw traps should be done in order to obtain a coefficient of variation (CV) of between 20 and 30 percent. The CV in our sampling was almost 75 percent suggesting that many more throw traps per enclosure were needed. It is also recommended that the vegetation within the throw traps be uprooted, rinsed and examined for snails. This protocol was not followed in our sampling as clearing three to six percent of the vegetation in this relatively small area during each of the three

sampling events would have decreased the vegetation dramatically and could have had an effect on snail behavior. Given these limitations, the population estimates reported here are probably lower than the actual apple snail population. The fact that a total of almost 2,000 egg clutches were recorded in the medium treatment enclosures, yet out of a total of 56 throw traps only two snails were captured illustrates this point.

During the June 2012 population estimate sampling, eight of the twelve enclosures were sampled (2 replicates for each treatment) for a total of 56 throw traps. A total of nine tagged snails were caught (control = 1, low = 3, medium = 2 and high = 3) and density estimates ranged from 0 to 0.40 snails per m^2 after adjusting for sampling bias. The average population estimates were 67 snails in the low treatment, 45 snails in the medium treatment, and 67 snails in the high treatment. These populations equate to 74, 22 and 16 percent of the initial stocking densities in the low, medium and high treatments, respectively. It is not known whether these decreases in snail populations were a result of mortality (predation, resource or density pressures) or the net result of immigration and emigration into and out of the enclosures. During the 2012 snail breeding season, snail kites were very active in the wetland and it was not uncommon for there to be six to eight snail kites soaring overhead while sampling was being conducted. On numerous occasions, snail kites were spotted capturing apple snails from the area around or in the enclosures. It was also noted that egg clutch density increased substantially in the area immediately surrounding the stocking enclosures after they were stocked, indicating possible emigration of snails out of the enclosures. The population in the control enclosures also increased to 22 snails (assuming all enclosures were snail free prior to the stocking event) indicating possible immigration of snails into the control enclosures. Additionally, during the June throw trapping, three untagged snails were captured (two in high treatment enclosures and one in a low treatment enclosure). These untagged snails may have been juveniles that were hatched from eggs deposited in the enclosure in April or they may have been snails that had immigrated from another enclosure or from the wetland surrounding the enclosure. If the latter, then this is another indication that snails may be moving freely within the wetland and enclosures.

To estimate population and juvenile survival rates over the 2012 breeding season, all twelve enclosures were sampled in October. Ten untagged and zero tagged snails were captured in the 84 throw traps and density estimates per m^2 ranged from 0 to 0.4 which was the same as in June. The adjusted average population estimates were all lower than the June sampling with 30 snails in the low treatment, 0 snails in the medium treatment, and 45 snails in the high treatment. Conversely, the control treatment population increased to 60 snails. Using the egg clutch results to determine the number of snails that were hatched into each enclosure, it was determined that the percent survival of the juveniles over the breeding season was 0.59, 0, 0.36, and 0.75 percent in the low, medium, high and control treatments, respectively; much lower than the estimated 1.5 to 4 percent survival in the hatchery enclosures. This is not surprising since the hatchery enclosures were covered with bird netting to keep out avian predators, and being smaller, probably had a lesser likelihood of trapping predators within the enclosures when they were originally set up.

When the study was initially developed, the intent was to conduct a throw trapping event in early March 2013 to determine the over winter survival rate of the snails hatched during the 2012 breeding season. However, the issue of migration in and out of the enclosures precluded this sampling. Nevertheless, it became evident at the beginning of the 2013 breeding season that juvenile snails hatched into the enclosures in 2012 had survived the winter and grown to become reproductive adults the following year even though the October 2012 throw trapping population estimates seemed low (**Figure 8-11**). Additionally, egg production continued in the wetland surrounding the enclosures as well.

The final throw trapping event was conducted in October 2013 at the end of the breeding season. In addition to the twelve treatment enclosures, three similarly sized areas in the wetland

immediately surrounding the enclosures were sampled to obtain population estimates. In a total of 105 throw trap, no tagged snails were captured. This was expected as the normal life span of a native apple snail is 1 to 1.5 years so those snails that were stocked in March 2012 would not have survived to the end of the second breeding season. Four untagged snails were caught in the treatment enclosures (control = 1, low = 1, medium = 0, and high = 2) compared to ten the previous year. Six untagged snails were caught in the surrounding wetland. Density estimates ranged from 0 to 0.20 snails per m^2 in the treatment enclosures, which is about half of what it was in October 2012. The wetland density estimates were higher than the treatment enclosures, ranging from 0.2 to 0.6 snails per m^2. These density estimates equate to average population estimates of 15 snails in the low treatment, 0 snails in the medium treatment, 30 snails in the high treatment, 15 snails in the control treatment and 89 snails in the wetland. The average populations decreased by 50 percent in the low treatment, 33 percent in the high treatment and 75 percent in the control treatment compared to the previous year. The percent survival of the juveniles hatched into the enclosures over the breeding season was 0.12, 0, 0.34, and 0.17 in the low, medium, high and control treatments, respectively. With the exception of the high treatment, these survival rates were lower than in 2012. Survival rates in the wetland could not be obtained because egg production was not measured throughout the entire breeding season.

Despite all the difficulties encountered both in containing snails within enclosures and counting snails by trapping, these stocking results suggest that it is feasible to stock juvenile apple snails at relatively low densities to improve or reestablish native populations; even when the snails are exposed to normal rates of predation. Observational monitoring of the wetland will be continued annually each summer to determine whether the established snail population persists for an extended period of time.

ESTIMATING EGG NUMBERS IN EGG MASSES OF THE EXOTIC APPLE SNAIL *P. MACULATA*

The exotic island apple snail *P. maculata* (previously *P. insularum*) appears to be gradually extending its range and increasing its density throughout much of South Florida; as well as in other locations in the southern United States. A closely related species, *P. canaliculata* has caused major damage to taro and rice crops in Hawaii and southeast Asia (Carlsson et al., 2004, Levin, 2006) and *P. maculata* has already caused a major vegetation crash in one cell of the District's storm water treatment areas and has created similar problems in small wetlands in central and northern Florida (J. Bernatis pers. comm.). As a consequence, there is increasing interest in understanding its life history. While some of this information is currently available in the literature, there has been a great deal of taxonomic confusion regarding the correct identification of the species resulting in the need to confirm much of what is available in print.

One difficulty encountered in studying *P. maculata* is that it lays large, multilayered clutches (**Figure 8-14**) of very small eggs that are impossible to count without disaggregating the egg mass; which results in the loss of viability and renders the eggs useless for life history studies. Using a previously described dis-aggregation technique (Barnes et al., 2008), 70 egg masses of *P. maculata* collected from various locations in Lake Okeechobee over the course of much of the breeding season (May–September) were weighed, dis-aggregated (**Figure 8-15**), photographed, and counted. Using the resulting mass and egg numbers, an algorithm was developed that reliably relates clutch mass to the number of eggs in a clutch (**Figure 8-16**) allowing the estimation of the number of eggs in a clutch without impacting the integrity of the egg mass. Egg masses that have been removed from their original substrate and weighed can be reattached to an artificial substrate using methacrylate cement and successfully hatched. This paves the way for investigations into studies on fecundity, hatching rate and other aspects of the snails' life history.

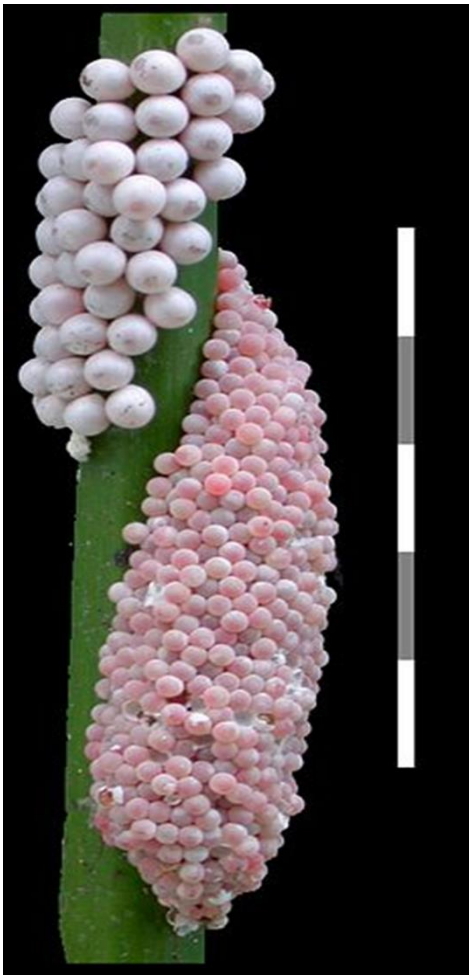


Figure 8-14. *Pomacea maculata* egg mass (lower right) compared to a *P. paludosa* (native Florida applesnail) egg mass.

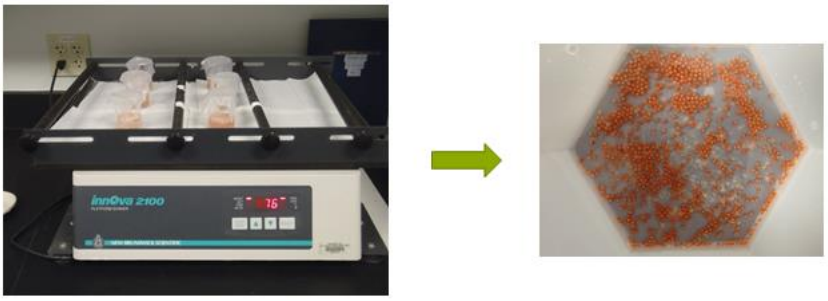


Figure 8-15. *P. maculata* eggs being chemically disaggregated and then spread out for photographing prior to counting.

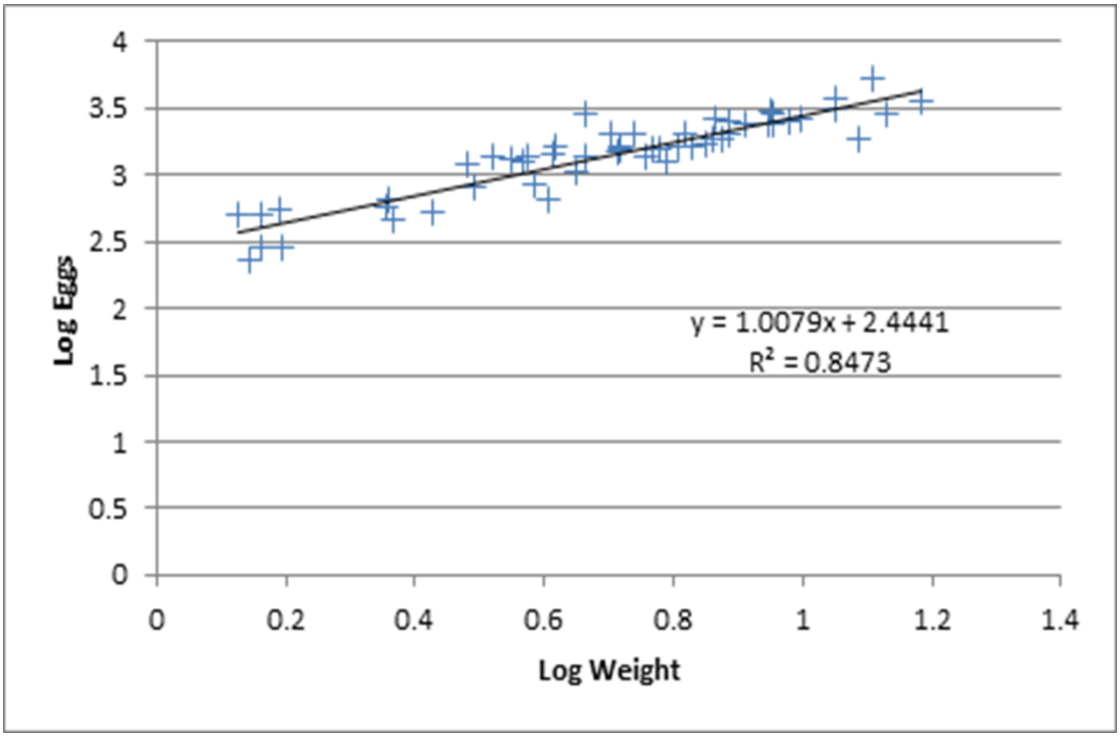


Figure 8-16. Relationship between egg mass weight and number of eggs based on 70 clutches of *P. maculata* collected over the course of a normal breeding season, disaggregated and counted.

LAKE OKEECHOBEE LITTORAL MARSH AQUATIC PLANT COMMUNITIES FOOD WEB CHARACTERISTICS

In 2006, The South Florida Water Management District (District and SFWMD) initiated a five-year study with Malcolm-Pirnie, Inc. to characterize the abundance and distribution of fish, macroinvertebrates and herpetofauna as they related to emergent aquatic vegetation (EAV) and SAV community attributes (e.g., vegetation type, density, and water quality variables) in the nearshore region of Lake Okeechobee. However, prolonged low lake stages associated with a multi-year drought and budget constraints resulted in only one of 10 sampling events being conducted, during fall 2006. The results from this one-time sampling event indicated that plant biomass was very low as a result of hurricane-related impacts in 2004–2005 (Malcolm-Pirnie, 2007).

An additional sampling event was conducted by the University of Florida during July 2009. The EAV communities (*Eleocharis*, *Scirpus* and *Typha*) and SAV community (*Vallisneria*) sampled during this event were located at the intersection of the western littoral marsh and western nearshore region, between Mayaca Cut and Cochran's Pass, and reflected changes primarily in the EAV communities between 2006 and 2009. Three levels of plant density (sparse, moderate, and dense) were sampled in each plant community. However, small sample sizes and lack of multiple temporal sampling events precluded rigorous statistical analysis and only fish and macroinvertebrates were sampled. As a consequence, information about habitat utilization and differences among various EAV communities remains somewhat limited.

After six years (2007–2013) of lake stage being primarily in either the ecologically preferred stage envelope (12.5–15.5 feet mean sea level) or lower, coupled with an absence of substantial physical disturbance events, such as the passage of strong tropical systems, several notable changes to the nearshore and littoral marsh EAV communities have been observed. The extremely low lake stages in 2007–2008 resulted in formerly inshore open water SAV habitat being colonized by EAV, while further inshore, terrestrial vegetation replaced a majority of the EAV. Despite the return of lake stages, at the upper end of the preferred stage envelope during portions of 2009, 2010, 2012 and 2013, the expanded portion of the EAV community has persisted.

The establishment of this marsh EAV habitat in formerly SAV nearshore areas may have resulted in a significantly modified nearshore food web. For example, increased periphyton productivity may be translating into increases in higher trophic level consumer populations such as macroinvertebrates and fish in the nearshore and littoral regions with bottom up impacts on key faunal components such as wading birds. However, relatively little data have been collected to document changes among the littoral food web trophic levels. To facilitate habitat utilization comparisons among three of the dominant littoral marsh aquatic plant habitats, throw-trap sampling (one square meter area) is being conducted by Lake and River Ecosystem Section staff to collect data on water quality and on ecological attributes including fish, macroinvertebrates, periphyton, phytoplankton and zooplankton (plankton).

Since February 2014, data has been collected on a monthly basis, in lily (*Nymphaea sp.*), smartweed (*Polygonum sp.*) and pickerelweed (*Sagittaria sp.*) habitats, all of which are located in Moonshine Bay in the western marsh within the foraging range (< 5 kilometers) of an established wading bird colony (**Figure 8-17**). Sampling has been conducted at four sites in each of these macrophyte habitats (12 sites total). This study has been designed to complement concurrent wading bird foraging habitat sampling anticipated to begin in fall 2014. Information from the monitored producer and consumer populations will be evaluated to address two questions. First, are the food webs similar or different among the three littoral marsh plant communities and second, is wading bird foraging potentially affecting the food webs in these habitats in an observable way.

During each sampling event, water column depth and physical water quality data are collected with a multiprobe sonde at the midpoint of the water column. Then, following deployment of the throw trap, plankton and epiphyte samples are collected. All of the remaining vegetation is then removed from each throw trap. Seine net sweeps in each throw trap are then conducted until three consecutive sweeps yield zero fish and macroinvertebrates. To date, the mean number of seine net sweeps conducted in the throw traps has varied between 14 (*Sagittaria*) and 37 (*Nymphaea*). Fish and macroinvertebrates collected from the seine net sweeps, are being preserved and archived for abundance determination, body measurements (fish) and taxonomic identification. The plankton samples are also being preserved and archived for taxonomic identification.

In each habitat, water depths decreased during the spring and varied between 0.24 meters (m) (June) and 0.65 m (February), both being recorded in the *Polygonum* habitat. Similar depths were recorded in the *Nymphaea* habitat, while in the *Sagittaria* habitat, depths were 0.15 m to 0.3 m lower and by the June sampling date, too shallow (< ~5 cm) to collect samples. Water temperatures varied between 18.1 degrees Celsius ($^{\circ}$ C) (*Nymphaea* sites, March) and 30.3° C (*Polygonum* sites, June). Dissolved oxygen was usually low, varying between 0.8 mg l^{-1} (*Sagittaria* sites, March) and 4.7 mg l^{-1} (*Nymphaea* sites, February) and half of all readings were < 2 mg l^{-1}. Among the three habitats, specific conductivity varied between 307 micromoles per square centimeter (µmols cm^{-2}) and 438 µmols cm^{-2} and pH values varied between 6.4 and 7.7.

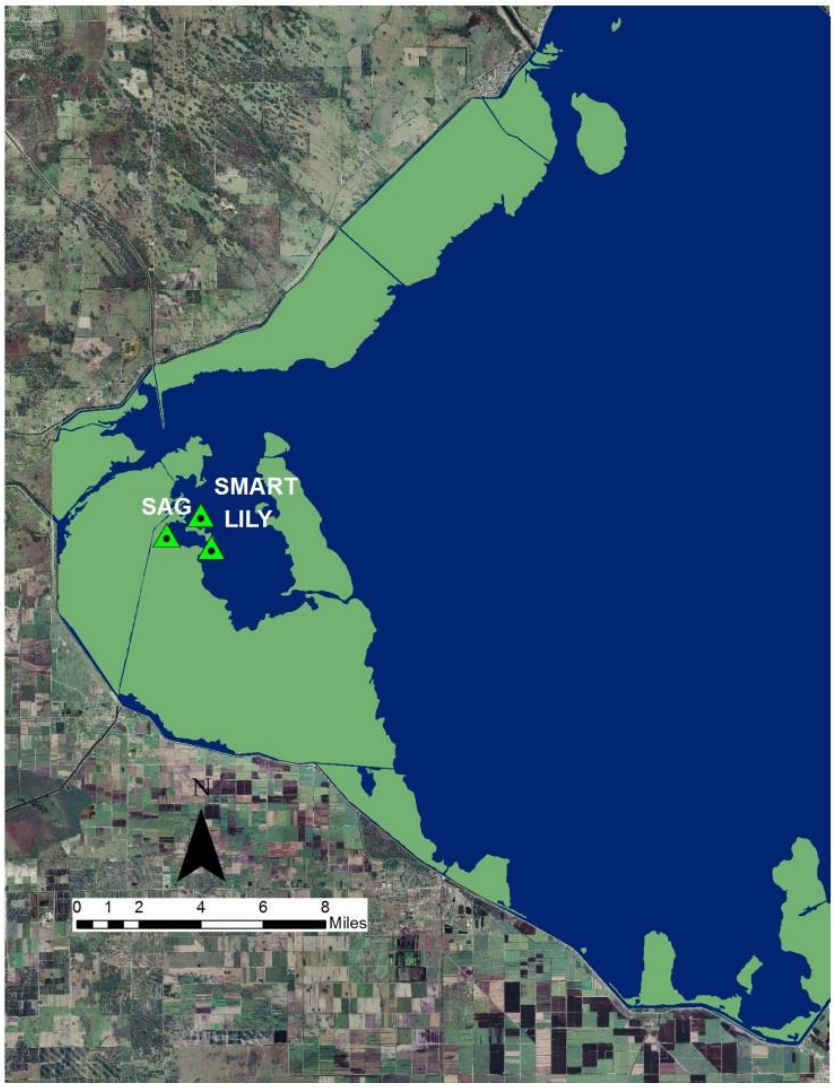


Figure 8-17. Habitat locations in the Moonshine Bay area of the Lake Okeechobee western marsh.

Mean epiphytic host plant densities varied between 15 and 64 stems per m^2 (stems m^{-2}) for *Polygonum*, 22 and 47 stems/m^2 for *Sagittaria*, and 37 and 62 stems/m^2 for *Nymphaea*. Mean *Nymphaea* host plant dry weights (DW) were the lowest [4±2 - 30±13 grams (g)] while *Polygonum* had the highest mean DW (19± 6 - 51±24 g) (**Figure 8-18**). No seasonal patterns in host plant DW were evident in any of the habitats and visual examination of the preliminary data suggests that there are no significant differences in mean host plant DW amongst the habitats, although *Polygonum* plant DW appeared to be higher than those in the other habitats during May, 2014. Mean epiphytic DW was lowest on *Sagittaria* [6±1 - 15±8 milligram per gram (mg/g) host plant DW] and highest on *Polygonum* (18±13 - 38±12 mg/g host plant DW) (**Figure 8-18**). The data to date suggest a seasonal trend, with highest mean epiphytic DW recorded in May or June and the lowest recorded in March or April. Visual examination of the preliminary mean epiphytic DW data suggests that *Polygonum* associated epiphytic DW may be somewhat higher than that on the other two host plant taxa, with no significant difference between the *Nymphaea* and *Sagittaria* associated epiphytes. In the case of *Polygonum*, it may be that epiphytes utilizing abundant thin

root hairs rather than epiphytes on the stems themselves, that account for the higher epiphytic DW compared to the epiphytic DW associated with the other host plant taxa.

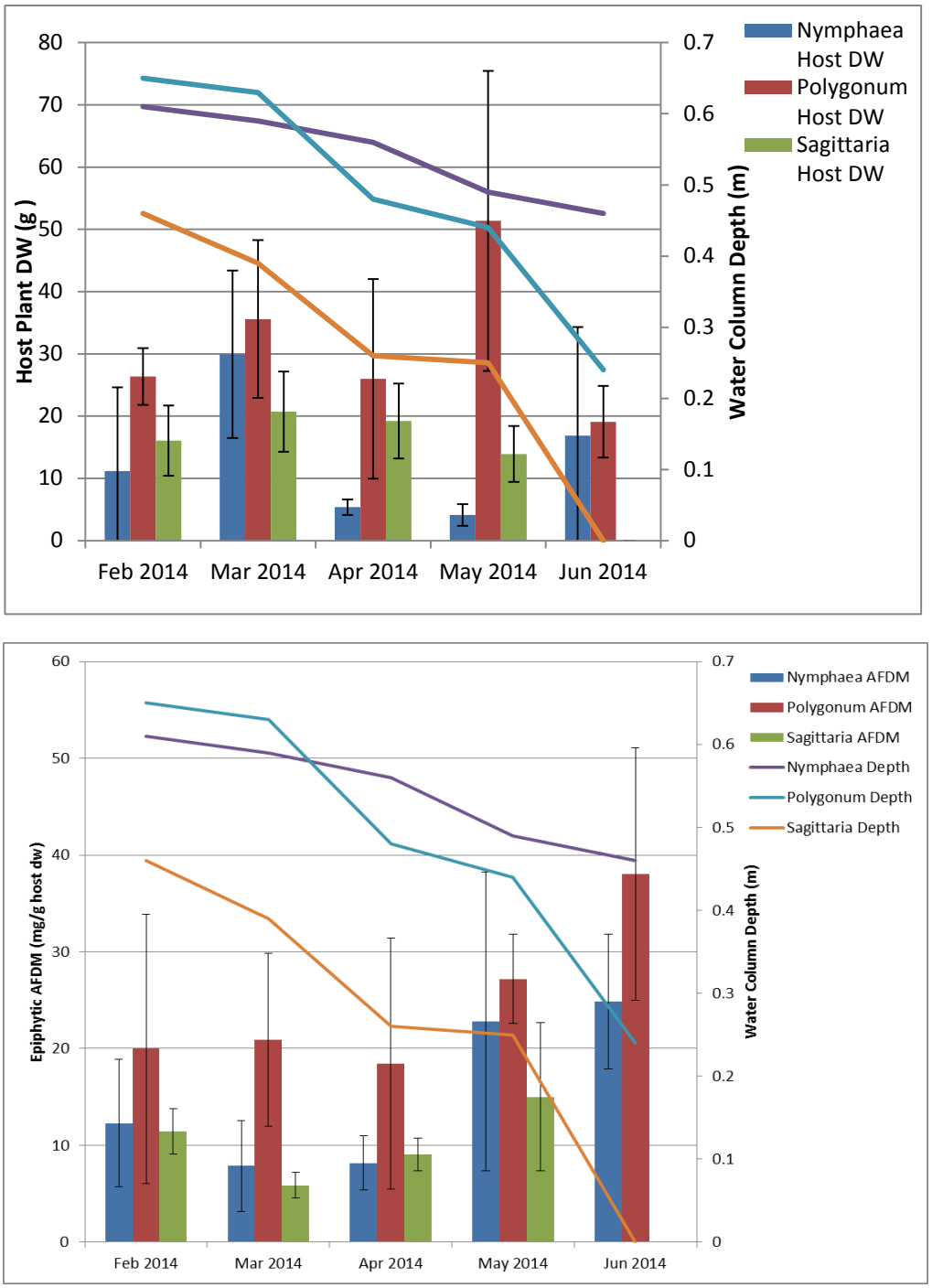


Figure 8-18. Mean host plant dry weights (DW) in grams (g) ±1 standard deviation for each habitat sampling site and month (top). Mean epiphytic algal ash-free dry mass (AFDM) in miligrams per gram host dry weight (mg/g) ±1 standard deviation (bottom). Mean water column depths in meters (m) for each habitat sampling site and month also are included with associated second vertical axes.

In comparison with *Eleocharis* and *Panicum repens* (torpedograss) associated mean epiphytic DW monitored previously at nearby sites (Rodusky et al., 2013), the mean epiphytic DW values in the three currently monitored habitats range between 13 and 25 percent and 3 and 5 percent of that documented for the *Eleocharis* and *Panicum repens* associated epiphytes, respectively. The difference in sediment composition (sand versus mud) and associated water column light regime differences among the former and currently monitored habitats may be a significant factor in the difference in epiphytic DW. Light penetration at the currently monitored habitats appeared to be less than 50 percent of the water column on most sampling dates as compared to the formerly monitored sites, where light penetration was greater than 70 percent of the water column.

EMERGENT VEGETATION DECOMPOSITION AND NUTRIENT CYCLING RATES

Major differences in nutrient cycling occur in Lake Okeechobee at low versus high water levels (James and Havens, 2005). Periodically, rapid increases in lake levels occur as a result of extreme weather events such as hurricanes and tropical storms. Increased waves and turbulence associated with these events uproot and tear emergent vegetation leading to significant amounts of fresh litter. As this fresh litter decomposes, the nutrients they contain are likely introduced to the water column contributing to the increased nutrient concentrations observed at higher water levels.

To understand how plant decomposition is affected by such rapid water increases and how this decomposition contributes to nutrient dynamics under high water conditions, a standard method to measure fresh plant decomposition was tested under both wet and dry conditions. Litterbags (mesh bags filled with approximately 10 grams of plant material) of cattail (*Typha* spp.) or bulrush (*Scirpus* spp.) were placed in dry or wet (submerged) locations within the lake. Three litterbags of each plant at each location were retrieved at six time points over the course of 120 days. The material was removed from the bags, dried in a 60° C oven to a constant weight and weighed.

The changes of weight indicate the rates of decomposition over time (**Figure 8-19**). Initial findings indicate that a majority of the material decomposed within the first 120 days. Preliminary analyses indicate that rates of decomposition were different in the first two weeks between the wet and dry conditions and between cattail and bulrush (e.g., different intercepts). However, the slopes of the regression lines were nearly identical indicating that there was very little difference in the overall decomposition in the succeeding time period. These results suggest that the more recalcitrant material decomposed at a similar rate irrespective of plant type or wet/dry conditions.

In addition to the reduction of weight, nutrients (carbon nitrogen and phosphorus) in the litter material are being measured. The changes in nutrient mass over time will indicate how rapidly they move into the water column. Repeating this experiment with other major emergent plant taxa within the lake will provide better overall estimates of the decomposition processes under wet conditions. This information will increase the reliability of predictions from the LOWQM (James et al., 2005; James, 2013) and give a better understanding of the effects of rapid increases in lake level on the water quality of Lake Okeechobee.

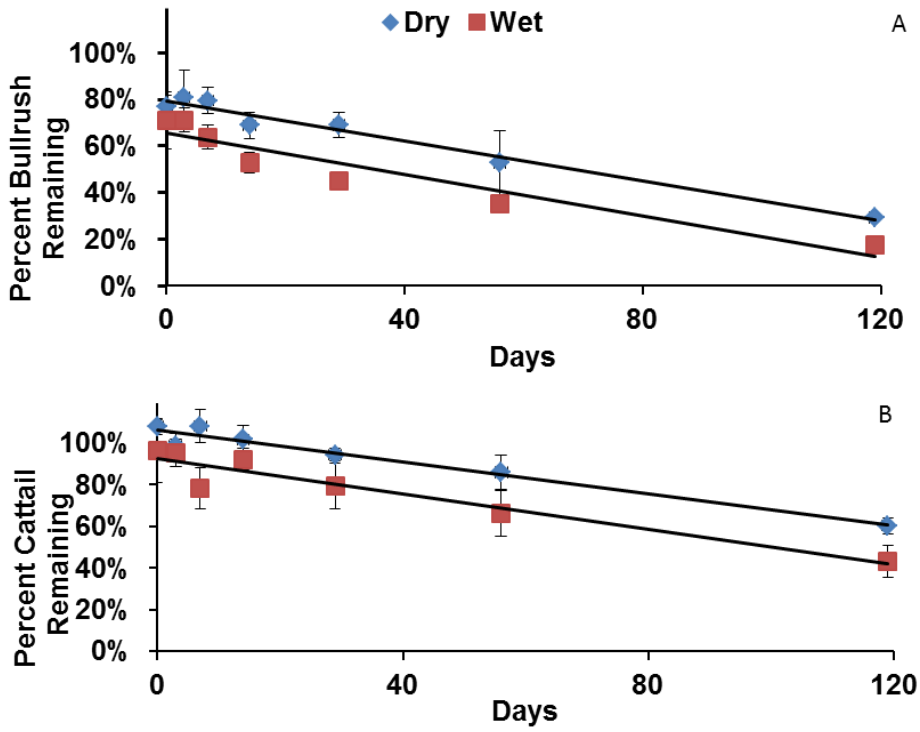


Figure 8-19. (A) Bulrush and (B) cattail percent dry weight remaining over time for litterbags in wet or dry conditions. Lines are linear regressions of the data. Error bars are 1 standard deviation.

WADING BIRD FORAGING PREDICTION MODEL

It is known that the wading bird population in the South Florida region has been reduced dramatically from historical numbers. With continual changes to habitat and habitat quality the long-term success of wading bird populations is unknown. A better understanding of how wading birds respond to changes in these managed systems is necessary. One of the more important limiting factors for nest productivity is foraging success and the ability to understand responses of foraging wading birds to dynamic hydrological and environmental variables is imperative in learning how to improve both short- and long-term success of their populations. Ecological models that predict outcomes of these variables can also be a useful tool in understanding the effects of management decisions and in evaluating restoration strategies. Although wading bird models exist for other geographic regions within the greater South Florida ecosystem, Lake Okeechobee presents a somewhat unique situation and as a consequence, a model specific to the lake is being developed.

Environmental variables to be considered for this model, based on past research on the lake and published models for areas outside of the lake, include water depth, days since dry down, hydroperiod, dry-to-wet reversals, recession rates, disruptions (reversals), and vegetation community (emergent and submersed) (David, 1994; Russell et al., 2002; Kwon et al., 2011; Beerens et al., 2011). These variables are known to play a role in prey density, and prey availability to wading birds but exactly how is not entirely understood. The large continuous data set on lake hydrological conditions and current foraging survey data can be used to model and validate predictions of wading bird foraging.

There may be limitations to fully understanding cause-and-effect relationships since local and regional conditions outside of the lake can influence responses on the lake. However, completing a Lake Okeechobee model will allow a better understanding of wading bird population ecology in the Greater Everglades watershed.

EVALUATION AND DEVELOPMENT OF ALTERNATIVE MONITORING TECHNIQUES

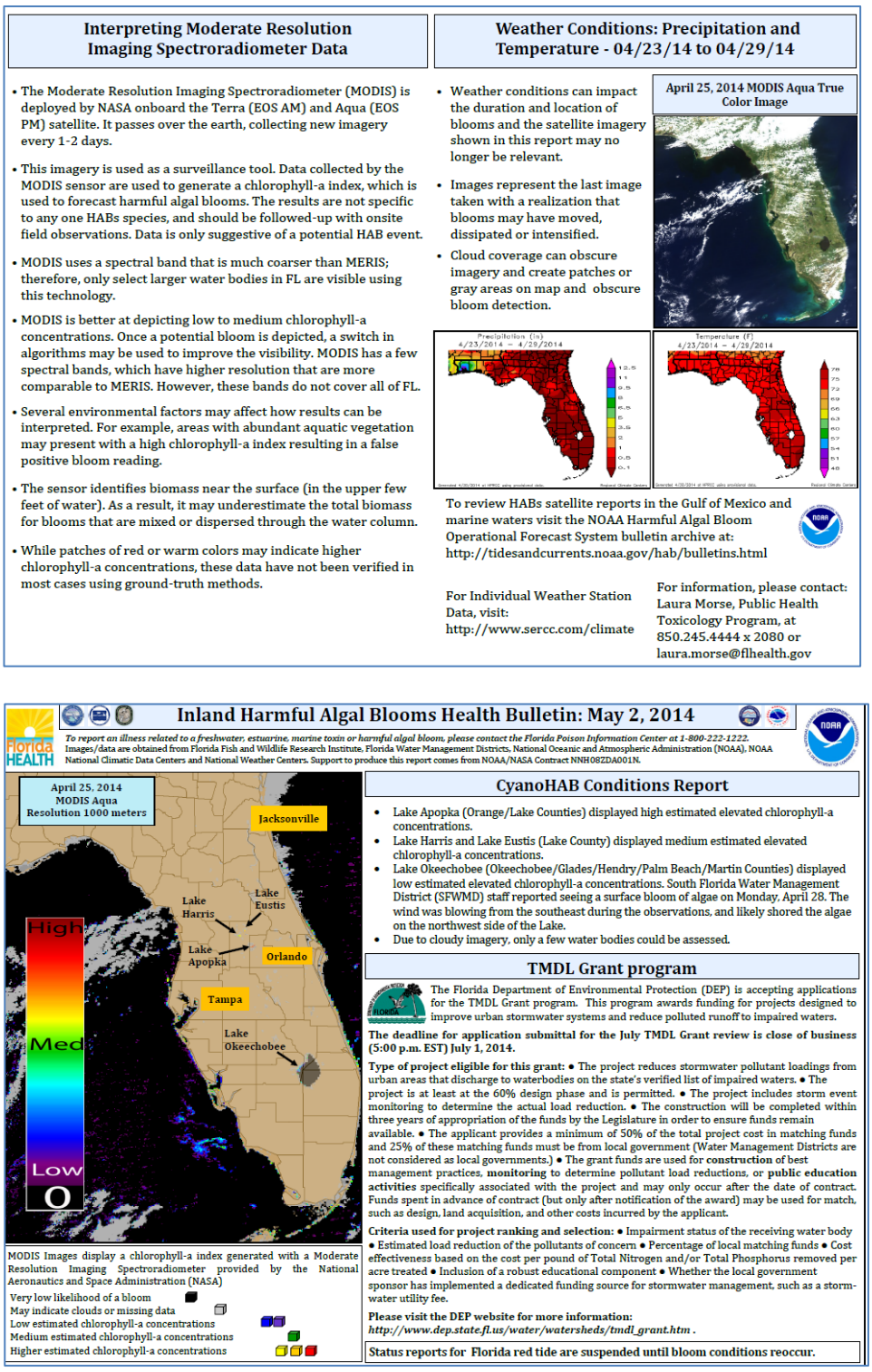
SATELLITE IMAGERY FOR ALGAL BLOOM MONITORING

The Florida Department of Health (FDOH) Aquatic Toxins Program, through a partnership with the National Oceanic and Atmospheric Administration (NOAA), has been using satellite imagery as a tool for monitoring and forecasting algal blooms within temperate lakes (e.g. Lake Superior). Over the past two years, the St. Johns River Water Management District (SJRWMD) partnered with FDOH to evaluate the efficacy of this technology in Central Florida systems by evaluating the relationship between ambient environmental data and moderate resolution imaging spectroradiometer (MODIS) satellite images to develop area specific equations converting MODIS images to chlorophyll estimates. This collaborative effort has generated promising results for detecting the presence of surface and near-surface algal blooms in North Florida. A weekly Satellite Health Bulletin reporting algal blooms is produced by FDOH and distributed to over 100 subscribers in eight different agencies (**Figure 8-20**). This tool provides local environmental managers with locations of possible blooms, offers early warning of potential blooms facilitating proactive event responses by local (e.g., public water systems) and state (e.g., water management districts) agencies. Currently, SJRWMD relies upon the satellite images to direct their field sampling efforts.

Since the District's current Lake Okeechobee algal bloom monitoring program is based on a finite number of stations sampled once monthly, it is primarily useful for providing an estimate of seasonal or annual trends. A more frequent, less time consuming and quicker determination of algal bloom conditions on Lake Okeechobee would allow for a more thorough understanding of bloom dynamics and might lead to information that would allow for the development of management strategies to prevent or prematurely end ongoing blooms. Therefore, District staff collaborating with the NOAA and FDOH partnership, are working to further refine the satellite imagery tool for use on Lake Okeechobee. Currently, the groundtruthing phase of the project is underway with staff collecting instantaneous surface reflectance data using a NOAA-provided radiometer, along with concurrent chlorophyll sample collections during Lake Okeechobee ambient monitoring program trips. These data will be used to calibrate the NOAA and FDOH algal bloom model and evaluate how well the model reflects the NOAA satellite imagery.

If successful, this satellite technology has the potential to be a rapid, effective and affordable option for monitoring lake-wide scale blooms and their potential severity on a routine and near-real-time basis. Additional uses for the imagery includes (1) linking to current and future models (e.g. Lake Okeechobee Ecological Model) to allow predictions of bloom movements as is currently being done with Great Lakes data, and (2) providing algal bloom data for other District water bodies that are large enough to be "seen" by the MODIS satellite.

Satellite technology does have limitations including reduced image quality or the inability to collect images during periods of heavy cloud cover or sun "glint" and the lack of penetration below a few centimeters of the water's surface. The latter limitation does not allow the depth of bloom dispersal through the water column to be detected, thus field observations will continue to be needed to fully describe blooms of interest. However, with the satellite tool the District could conduct targeted rather than hit-or-miss sampling of algal blooms.



Interpreting Moderate Resolution Imaging Spectroradiometer Data

- The Moderate Resolution Imaging Spectroradiometer (MODIS) is deployed by NASA onboard the Terra (EOS AM) and Aqua (EOS PM) satellite. It passes over the earth, collecting new imagery every 1-2 days.
- This imagery is used as a surveillance tool. Data collected by the MODIS sensor are used to generate a chlorophyll-a index, which is used to forecast harmful algal blooms. The results are not specific to any one HABs species, and should be followed-up with onsite field observations. Data is only suggestive of a potential HAB event.
- MODIS uses a spectral band that is much coarser than MERIS; therefore, only select larger water bodies in FL are visible using this technology.
- MODIS is better at depicting low to medium chlorophyll-a concentrations. Once a potential bloom is depicted, a switch in algorithms may be used to improve the visibility. MODIS has a few spectral bands, which have higher resolution that are more comparable to MERIS. However, these bands do not cover all of FL.
- Several environmental factors may affect how results can be interpreted. For example, areas with abundant aquatic vegetation may present with a high chlorophyll-a index resulting in a false positive bloom reading.
- The sensor identifies biomass near the surface (in the upper few feet of water). As a result, it may underestimate the total biomass for blooms that are mixed or dispersed through the water column.
- While patches of red or warm colors may indicate higher chlorophyll-a concentrations, these data have not been verified in most cases using ground-truth methods.

Weather Conditions: Precipitation and Temperature - 04/23/14 to 04/29/14

- Weather conditions can impact the duration and location of blooms and the satellite imagery shown in this report may no longer be relevant.
- Images represent the last image taken with a realization that blooms may have moved, dissipated or intensified.
- Cloud coverage can obscure imagery and create patches or gray areas on map and obscure bloom detection.

April 25, 2014 MODIS Aqua True Color Image

To review HABs satellite reports in the Gulf of Mexico and marine waters visit the NOAA Harmful Algal Bloom Operational Forecast System bulletin archive at: http://tidesandcurrents.noaa.gov/hab/bulletins.html

For Individual Weather Station Data, visit: http://www.sercc.com/climate

For information, please contact: Laura Morse, Public Health Toxicology Program, at 850.245.4444 x 2080 or laura.morse@flhealth.gov

Inland Harmful Algal Blooms Health Bulletin: May 2, 2014

To report an illness related to a freshwater, estuarine, marine toxin or harmful algal bloom, please contact the Florida Poison Information Center at 1-800-222-1222.
Images/data are obtained from Florida Fish and Wildlife Research Institute, Florida Water Management Districts, National Oceanic and Atmospheric Administration (NOAA), NOAA National Climatic Data Centers and National Weather Centers. Support to produce this report comes from NOAA/NASA Contract NNH08ZDA001N.

April 25, 2014
MODIS Aqua
Resolution 1000 meters

Jacksonville
Lake Harris
Lake Eustis
Lake Apopka
Orlando
Tampa
Lake Okeechobee
High
Med
Low
0

MODIS Images display a chlorophyll-a index generated with a Moderate Resolution Imaging Spectroradiometer provided by the National Aeronautics and Space Administration (NASA)

Very low likelihood of a bloom
May indicate clouds or missing data
Low estimated chlorophyll-a concentrations
Medium estimated chlorophyll-a concentrations
Higher estimated chlorophyll-a concentrations

CyanoHAB Conditions Report

- Lake Apopka (Orange/Lake Counties) displayed high estimated elevated chlorophyll-a concentrations.
- Lake Harris and Lake Eustis (Lake County) displayed medium estimated elevated chlorophyll-a concentrations.
- Lake Okeechobee (Okeechobee/Glades/Hendry/Palm Beach/Martin Counties) displayed low estimated elevated chlorophyll-a concentrations. South Florida Water Management District (SFWMD) staff reported seeing a surface bloom of algae on Monday, April 28. The wind was blowing from the southeast during the observations, and likely shored the algae on the northwest side of the Lake.
- Due to cloudy imagery, only a few water bodies could be assessed.

TMDL Grant program

The Florida Department of Environmental Protection (DEP) is accepting applications for the TMDL Grant program. This program awards funding for projects designed to improve urban stormwater systems and reduce polluted runoff to impaired waters.

The deadline for application submittal for the July TMDL Grant review is close of business (5:00 p.m. EST) July 1, 2014.

Type of project eligible for this grant: • The project reduces stormwater pollutant loadings from urban areas that discharge to waterbodies on the state's verified list of impaired waters. • The project is at least at the 60% design phase and is permitted. • The project includes storm event monitoring to determine the actual load reduction. • The construction will be completed within three years of appropriation of the funds by the Legislature in order to ensure funds remain available. • The applicant provides a minimum of 50% of the total project cost in matching funds and 25% of these matching funds must be from local government (Water Management Districts are not considered as local governments.) • The grant funds are used for **construction** of best management practices, **monitoring** to determine pollutant load reductions, or **public education activities** specifically associated with the project and may only occur after the date of contract. Funds spent in advance of contract (but only after notification of the award) may be used for match, such as design, land acquisition, and other costs incurred by the applicant.

Criteria used for project ranking and selection: • Impairment status of the receiving water body • Estimated load reduction of the pollutants of concern • Percentage of local matching funds • Cost effectiveness based on the cost per pound of Total Nitrogen and/or Total Phosphorus removed per acre treated • Inclusion of a robust educational component • Whether the local government sponsor has implemented a dedicated funding source for stormwater management, such as a storm-water utility fee.

Please visit the DEP website for more information:
http://www.dep.state.fl.us/water/watersheds/tmdl_grant.htm .

Status reports for Florida red tide are suspended until bloom conditions reoccur.

Figure 8-20. Algal Bloom Health Bulletin distributed by Florida Department of Health reporting bloom conditions in major water bodies in the St. John's River Water Management District and in Lake Okeechobee. Data from Lake Okeechobee is in the process of being validated.

NEW TECHNOLOGIES FOR ECOLOGICAL MONITORING

DIGITAL ELEVATION MODEL

SFWMD staff merged and interpolated existing bathymetric data sets for Lake Okeechobee—Maptech's Inc. 2008 pelagic bathymetric survey and United States Army Corps of Engineer's (USACE) 2007 South Florida 100-foot Digital Elevation Model (DEM)—with the Florida Department of Emergency Management's 2007 coastal light detection and ranging (LIDAR) project using advanced raster analysis techniques in ArcGIS to create a 5-foot digital elevation model of Lake Okeechobee (**Figure 8-21**). Creation of this data set compiled all of the most current and best quality data that was available into a single product to support ecological analyses that are dependent on bathymetric or lake stage data. Water depth data, in combination with several other retrievable data sets such as vegetation and water quality, aid field ecologists with planning and executing monitoring projects and is often the vital factor in the interpretation of conditions at a given site.

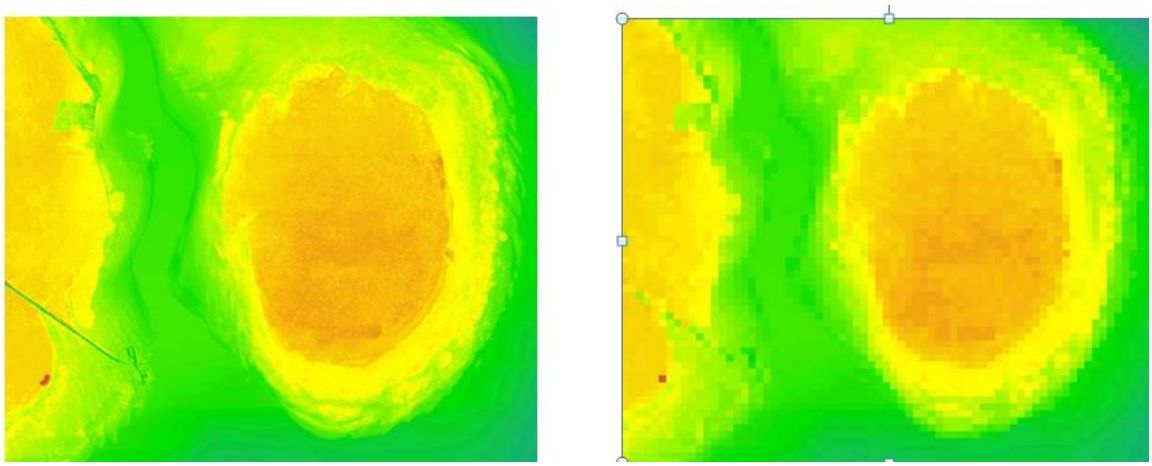


Figure 8-21. Two digital elevation model snapshots of Kings Bar. The 5-foot grid cell is to the left and the 250-foot grid cell is to the right.

SONAR TECHNOLOGY

The current Lake Okeechobee annual SAV survey involves visiting up to 500 sampling sites laid out in a 1-square kilometer (km^2) grid. This coarse sampling methodology results in interpolated maps based on the assumption that if SAV is present at the center point of a 1-km^2 grid cell, the entire 247-acre grid cell contains SAV. In addition, the annual mapping exercise is incapable of estimating canopy height or SAV biovolume, and yields only an approximation of underlying sediment type; all important parameters for understanding the ecology of SAV in the lake. In an attempt to gather data on a finer scale and delineate how SAV changes between sampling sites in its spatial distribution and biovolumes and canopy height Lake Okeechobee staff have been investigating the use of a Lowrance sonar transducer mounted on an airboat. It appears that using this technology, lake scientists will have the ability to map small areas at a very high level of accuracy, or to collect continuous sonar data in-between sites over a large area.

Post processing of field data generated by Lowrance is accomplished by uploading the data to Contour Innovations, LLC, a Navico Inc. subsidiary, for instantaneous processing based on a

three-step algorithm. The acoustic signal is flagged or cleansed, interpreted, and data is then kriged outward from the boat's path to a predetermined distance. The final product is a map (**Figure 8-22**) showing the areal coverage, biovolumes and canopy height that SAV occupies in the surveyed area. The data are stored at a secure website account at www.CIBiobase.com, which allows for multi-organizational data sharing of all historical field trips without concerns about server space restrictions. The data uploads can be rapidly converted to ArcGIS format for spatial analysis or Google Earth format for email delivery.

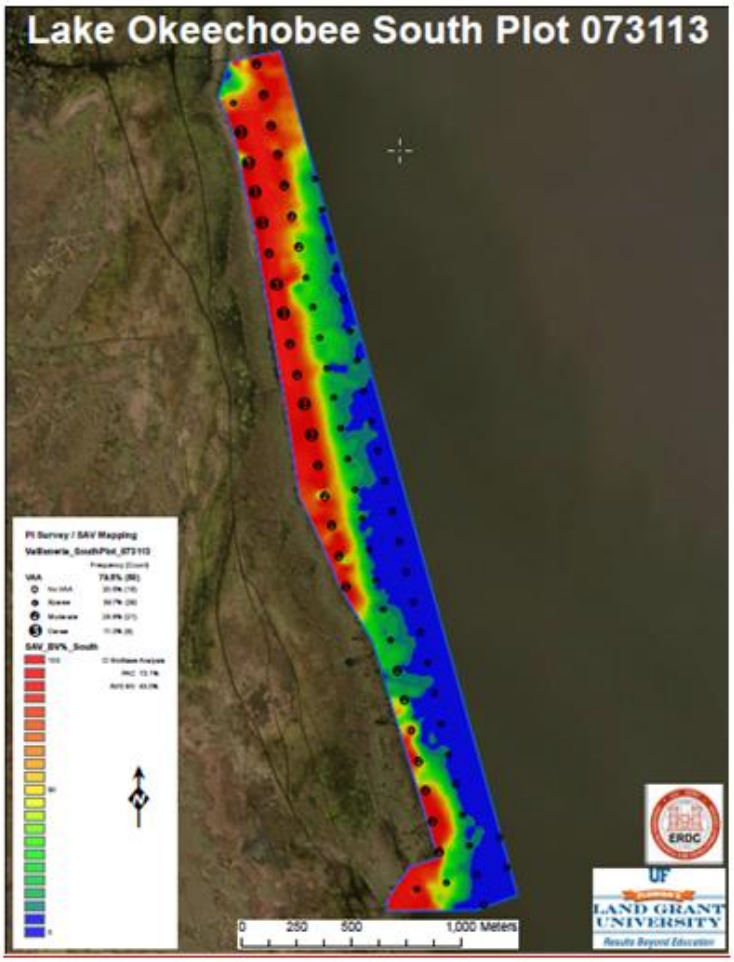


Figure 8-22. A Lowrance map example of biovolume and canopy height for *Vallisneria americana* surveyed by Dean Jones, Senior Biological Scientist at the University of Florida Center for Aquatic and Invasive Plants.

In addition to SAV data, the acoustic log files provide bathymetry and sediment hardness measurements, which may improve our ability to identify sediment types supporting SAV growth in Lake Okeechobee

UNMANNED AIRCRAFT SYSTEMS

Recently, Lake Okeechobee scientists have been exploring the potential to collaborate with geodesists at the USACE that are currently using unmanned aircraft systems (UAS) technology to monitor the rehabilitation of the Herbert Hoover Dike as well as for monitoring floating invasive

aquatic plants for control operations. Possible ecological missions being explored include emergent vegetation surveys, algal bloom surveys, and wading bird surveys.

A major constraint of this technology is that only approximately 3,000 acres can be photographed a day at a high pixel resolution, making it most appropriate for detailed investigation of relatively small areas. However, if a project proves to be more cost effective utilizing a UAS than our current methodology, there would be the additional benefits of USACE already being Florida Aviation Administration approved to fly in the airspace and their willingness to host the resultant data files on their server.

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