Final Project Report

TITLE: The Role of Aquatic Refuges in the Rockland Wetland Complex of Southern Florida, in Relation to System Restoration.

IA between USGS and NPS # 5280-7-9023

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Project Duration: Start – January 2000 **End -** December 2004
Project Support: CESI**,** USGS-BRD base
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EXECUTIVE SUMMARY

Hydrological changes resulting from canal and levee construction in South Florida have been implicated in the broad-scale decline of the Everglades ecosystem. In particular, the Rocky Glades region in eastern Everglades National Park (Figure 1) has been adversely affected by water diversions. Outside the park, this habitat has been converted to agricultural and urban land uses. However, inside the Park, the geologic structure of the habitat remains intact. Its highly eroded landscape was thought to offer dry-season refuge to aquatic animals in groundwater and in shallower solution holes (Loftus et al. 1992, Kobza et al. 2004). This report presents the results of a five-year study focusing on the environment of Rocky Glades habitats and their use by fishes and aquatic macro-invertebrates. We also were interested in determining whether groundwater habitats in and near Everglades National Park were home to aquatic crustaceans or fishes. We present the results of our use of exploratory methods to detect sub-surface cavities where subterranean aquatic animals might live, our attempts to trap or photograph those organisms, and our studies of the life history and distribution of one subterranean animal, the Miami cave crayfish. The objectives of this ambitious study were to:

- Develop effective traps and methods to capture and document crustaceans and fishes from subterranean, solution hole, and surface habitats in south Florida to describe these poorly known communities.

- Collect environmental parameters in solution holes, surface water, and wells to characterize the groundwater and surface-water aquatic environmental conditions.

- Quantify community composition, succession, and seasonal movements by aquatic animals in the Rocky Glades using drift fences with minnow traps to document dispersal at multiple sites in relation to hydropattern and flow.

- Document the use of Rocky Glades aquatic habitats by introduced fishes.

- Collect life-history data on the rare Miami cave crayfish from a captive population, and sample in wells inside and outside Everglades National Park to document its distribution.

This first project year was a pilot study in which we tested designs and methods to use in detecting directional animal dispersal. In the first year, we defined fish and macro-invertebrate composition and ecology in surface-water, and in near-surface subterranean aquatic habitats. We set up 24 visual-survey plots, six at each array, to obtain independent estimates of species composition and densities. This is a new sampling technique for shallow-water marshes with open, rugged terrain, where other methods fare poorly. We followed animal-community patterns by visual survey and by trapping until the marshes dry in the fall. We tested methods to define the habitat/topographic characteristics that make this region unique. Following the end of the pilot study, we evaluated the results and designed a more spatially expansive study for the second year. In the second year (2001-2002), we fully implemented sampling at 13 drift-fence arrays throughout the wet season. We also collected fish samples from solution holes when the marsh surface dried, and sampled groundwater

wells for organisms in the Park and on the coastal ridge. In the third year, 2002-2003, we collected data at drift-fence arrays along the Main Park Road, and periodically within Shark River Slough, near the Context Road entrance, and south of the Chekika campground. Solutions holes were sampled during marsh dry-down, with greater frequency than in previous years. We employed substrate and wire traps to attempt to collect subterranean animals in several wells throughout the Park and processed those samples. We completed the collection of life-history information on a captive population of Miami cave crayfish (*Procambarus milleri)*. We successfully began a water-quality monitoring schedule (pH, Dissolved Oxygen, Specific Conductance, Water Temperature) within the three sampling environments: wells, drift-fence arrays, and solution holes. We also used data from the third project year to assess the effects of the Interim Operations Plan (IOP), a new water-management delivery system that affected much of the park. Larger than expected samples in 2002 resulted in delays in sample processing which set the project behind schedule as it entered the fourth year in 2003. In that fourth year of the study, we continued sampling on the marsh surface, in solution holes, and in wells. We added additional solution-hole sites, including an area west of Pa-Hay-Okee that may serve as a regional refuge for fish during the dry season. In addition to regular array sampling, we performed a 24-hour catch collection to investigate diel patterns in fish movements on the marsh surface. We also implanted 15 Florida gar (*Lepisosteus platyrhincus*) with radio transmitters to learn if these large fishes inhabit the Rocky Glades during flooded conditions. During the fifth and final year (2003-2004) of the study, we completed sampling of solution holes and drift-fence arrays, while analyzing past data for the final report.

This study has provided the first inventory of aquatic animals for the Rocky Glades, and a baseline dataset for the wetland surface and solution holes that will be a useful comparison with future monitoring data during the restoration of this region. It is important to define the characteristics of the animal communities utilizing this area before restoration activities begin to interpret the effects of those actions as they are implemented. The ecological relationship between surface and subterranean habitats has shown how water management has affected this region. This series of investigations has particular relevance to the CERP program in predicting the effects of restoration activities on this region. Quantitative descriptions of aquatic-animal use of the Rocky Glades landscape, including solution holes, are needed under different water conditions. By incorporating those data and relationships into models, it should be possible to simulate the success of various management alternatives in providing a restored aquatic community. The basic inventory data and ecological information can be applied in planning and evaluating restoration actions that include the development of performance measures, the effects of the Lakebelt Project on groundwater organisms such as the Miami cave crayfish, and the relation of aquatic animal dispersal to hydrological conditions.

KEY FINDINGS:

- Water-quality parameters in groundwater changed on a diel basis. Peaks in specific conductance and corresponding rises in pH resulted from rain events that probably washed soil into the well. The concentration of dissolved oxygen was very low (less than 2 mg/L), so animals in groundwater must be tolerant of low dissolved-oxygen tensions. Water temperatures are moderated in groundwater, providing a thermal refuge for introduced tropical fishes during winter cold snaps. We observed mortality on the wetland surface when water temperatures dropped below 10^{o}C; groundwater remained above 20^{o}C during the same period.

- Using a ground-penetrating radar unit, Dr. Kevin Cunningham identified a number of subterranean cavities both inside the park and on the Atlantic Coastal Ridge. We drilled into several of these cavities to sample for aquatic hypogean animals, in cooperation with Park biologists Bruno and Perry.

- We tested trapping methods for fishes and crustaceans for use in wells and determined which to use in sampling. We also investigated the use of a borehole video camera to detect the occurrence of animals in groundwater wells. That method has great promise.

- We did not trap the rare Miami Cave Crayfish from wells in the Park; however, we recorded it from many new locations east of the Park on the Atlantic Coastal Ridge. Through monthly surveys of a captive population, we found that reproduction occurred year-round, but the proportion of juveniles increased during spring and fall. The mean size of males and females in this species was not significantly different, unlike in many other crayfish species.

- We tested the use of remote-sensing methods to characterize the density and depth-distributions of solution holes in the Rocky Glades. The results of a pilot study indicated that a combination of aerial photography and LIDAR would provide an efficient and accurate collection suite for those data.

- Samples of fishes from solution holes showed a steady decline in numbers of species and individuals the longer fishes were confined to those habitats. By the end of the dry season, most solution holes had dried, resulting in mass mortality of aquatic inhabitants. The deepest holes that retained water through the dry season were left with mainly non-native fishes and native catfish.

- The results of the solution-hole data indicate that this habitat is not a viable dry-season refuge for most fishes. The comparison of fish species that survive in holes with those that first colonize the wetlands after re-flooding shows little resemblance. It is most likely that, under today's water management, the fish fauna of the Rocky Glades depends on connections with more permanent waters from which the fishes disperse as waters re-flood the Rocky Glades.

- Collections from the drift-fence arrays showed that the short-hydroperiod wetlands of the Rocky Glades support a rich assemblage of species, despite long, annual periods of drying. The assemblage of native species continues to be supplemented by new introduced species.

- Fishes and crayfish often appeared in the drift-fence traps on the same day that the wetlands flooded, demonstrating either the existence of local subterranean refuges or rapid colonization from more distant refuges. Large catches of several species occurred within a few days of flooding.

- The fishes exhibited mass directional dispersal as the wetlands flooded in 2000 and 2001. Similar mass movements were not observed in 2002 or 2003, perhaps because of different patterns of re-flooding. Although flow velocities are relatively slow in these shallow wetlands, the animals appear to respond to flow. Individuals of some species appeared to follow the flow of water, although other species, particularly the Everglades crayfish (*Procambarus alleni*), dollar sunfish (*Lepomis marginatus*), and flagfish *(Jordanella floridae*), often moved against the flow.

- Subsequent sampling provided data on community-succession patterns as new species appeared in the traps and relative abundances changed. The majority of species appeared at each array within one week of flooding, and the assemblage was numerically dominated by small-bodied livebearers, killifish, and the dollar sunfish. The Everglades crayfish (*Procambarus alleni*) was also abundant in catches immediately after re-flooding, but declined in catch over time each year. Non-native and larger-bodied native fishes were slower to appear at the arrays, indicating dispersal from more distant refuges.

- Most fishes collected on the marsh surface were adults that began reproducing with one or two weeks of colonization. Trap-vulnerable juveniles were taken within a month after flooding.

- Stable-isotope signatures from common fish and crayfish showed high nitrogen ratios as they colonized the newly flooded wetlands. That signature diminished through the wet season, indicative of a reduction in trophic position over time, perhaps related to increased feeding on primary producers.

- In the visual plots, mosquitofish (*Gambusia holbrooki*) were most visible, probably because they are in constant motion. Sedentary, cryptic species were more difficult to observe. Visual sampling did not appear as effective in the Rocky Glades as in sparsely vegetated habitats. Although the data showed the peak of colonization after re-flooding, and the subsequent reduction in fish numbers, the method did not capture the peaks in numbers as the wetlands dried. The numbers of species detected by visual sampling were also lower than those found in the drift-fence arrays.

- In 2002-2003, we took the first specimens of pirate perch (*Aphrododerus sayanus*) and grass pickerel (*Esox americanus*) in the arrays. Both native species appear to be extending their ranges from the northern Everglades into the park, possibly as a result of changes in water deliveries to the park.

- We collected the first specimen of jaguar guapote cichlid (Cichlasoma managuense) from the arrays in 2000, and of the African jewel cichlid (*Hemichromis letourneuxi)* in the Rocky Glades at Array 1 on 24 June 2002. Many additional specimens were taken in 2003, making this the most abundant non-indigenous fish species in our samples. We also took the first specimens of the introduced brown hoplo catfish (*Hoplosternum littorale*) in the arrays in 2003. This species is beginning to invade extreme southern Florida.

- The radio-tagged gar utilized Taylor Slough during flooded conditions, taking refuge from the dry season at Anhinga Trail and the Taylor Slough culverts. They did not utilize the Rocky Glades in the wet season.

- We examined the use of otolith microchemistry (ratio of Strontium:Calcium) as a spatial marker in mosquitofish to detect movements from saltwater-influenced habitats into the Rocky Glades. Although the method appears promising, our field experiment was brought to an unsuccessful conclusion in 2004 by the severe drought. Fish from the ENP mesocosm tanks dosed with Strontium showed detectable uptake at levels higher than control fish.

- We contributed data from 2002 collections from drift-fence arrays and solution holes that were included in the 2004 NPS IOP report to Congress to assess the effects of water management.

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INTRODUCTION

Aquatic animals in the seasonally flooded wetlands of southern Florida wetlands have a variety of means by which to cope with environmental variability. These include movements among habitats to find refuge from drying habitats in winter and spring, and dispersal away from those refuges with the onset of the wet season Kushlan 1974, Loftus and Kushlan 1987). Freshwater refuge habitats in southern Florida include natural sites such as alligator holes (Craighead 1968, Kushlan 1974), and solution holes in the Rocky Glades (Loftus et al. 1992). Canals and ditches offer a relatively recent but spatially extensive form of artificial refuge for aquatic animals on the landscape (Loftus and Kushlan 1987). This pattern of movements among habitats with fluctuating water depths is a general one common to seasonal wetlands in the tropics (Lowe-McConnell 1987, Machado-Allison 1993).

Human-induced changes have affected the natural variability of environmental conditions through the construction of canals and levees that can either drain or flood wetlands (Gunderson and Loftus 1993). Several programs to restore lost structure and function to the south Florida landscape are now being planned. To have the ability to detect changes in natural and artificial habitats resulting from these restoration programs, we need to collect baseline data on the constituent aquatic communities and their ecology before the restoration actions.

The Rocky Glades region has been adversely affected by water diversions and has been reduced in aerial extent by land conversion for agriculture and urban development. This area represents an endangered landscape of the south Florida ecosystem that remains structurally intact only within the boundaries of Everglades National Park (ENP) **(Fig. 1**). It is a habitat unique to Everglades National Park in southern Florida, although similar habitat exists elsewhere in Yucatan, Cuba, and the Bahamas. This region has a high priority for restoration in the Restudy because it is the largest remnant short-hydroperiod wetland in the eastern Everglades, representing an aquatic habitat that has been disproportionately lost from the ecosystem. It is widely accepted that the quality of this habitat has been greatly altered by water diversions. This region once may have provided important summer and early dry-season feeding sites for wading birds and good habitat for alligators before it was affected by drainage. Knowledge about fishes and aquatic invertebrates there is especially important because the loss of short-hydroperiod wetlands has been implicated in the decline of nesting wading birds in the Everglades (Fleming et al. 1994).

In south Florida wetlands, fishes support many of the predatory animals, especially alligators and wading birds, which characterize the Everglades marsh. Fishes and aquatic invertebrates are recognized as indicators of the health of the wetland. Because of the hydrological changes wrought by drainage and impoundment, and the loss of spatial extent and functioning of former wetlands to development (Gunderson and Loftus 1993), there can be little doubt that fish standing crops and overall numbers have declined. Those changes to the original system have also altered the timing and the areas of fish availability to predators. Indirectly, the fishes have been detrimentally impacted by hydropattern alteration through effects on alligators, which prey on fishes and provide them dry-season refuge in their ponds, and through impacts on wading birds, which transfer energy from the marshes to other habitats through predation. Non-native fishes have colonized natural and disturbed habitats during the past three decades. The climate and geography of south Florida make it conducive to non-native animal invasions (Loftus and Kushlan 1987). Documented impacts on native animals include predation, nest-site competition, and habitat disturbance (Loftus 1988). The eventual extent of invasion, geographically and numerically, is uncertain. It seems likely that more species will invade and extend their ranges within the region, with unknown ecological consequences. Non-native fishes may divert food-web energy into biomass unavailable to many top-level predators. Several species of introduced species, particularly the Mayan cichlid (*Cichlasoma urophthalmus*), black acara *(Cichlasoma bimaculatum*), walking catfish (*Clarias batrachus*), and pike killifish (*Belonesox belizanus*) were common in collections from the Rocky Glades region (Loftus et al. 1992). A complete listing of common and scientific names of fishes and common crustaceans taken in the Rocky Glades is presented in **Table 1 and Appendix 1**.

Fishes and invertebrates appear on the surface of the Rocky Glades wetlands as soon as the rains re-flood the area in the early summer (Loftus et al. 1992). However, questions remain about the source of those colonists. Are solution-hole refuges spatially and physically adequate to provide the large number of re-colonizing aquatic animals that appear on the surface, or are they the result of rapid dispersal from flooded sloughs to the east and west? Little has been published about the species composition of the animals that survive below ground through the dry season, their dispersal and recruitment patterns once above-ground, and their movements back into solution holes as water recedes in autumn.

In addition to the effects of drainage on surface-water creatures, waste- and water-management may lead to problems for rare and poorly known species dependent on groundwater beneath the Rocky Glades and Atlantic Coastal Ridge. Groundwater environments are typically dark, low in oxygen, low in habitat diversity, and support fauna physiologically adapted to challenging environmental conditions. Little work in cataloguing the hypogean fauna beneath south Florida has been attempted. However, several truly subterranean animals have been found by serendipitous and directed collections, including the Miami Cave Crayfish (*Procambarus milleri*) and a sightless *Crangonyx* sp. ((Hobbs 1971, Radice and Loftus 1995, Bruno and Perry 2004). The continuing disturbance of the groundwater habitat through activities such as limestone mining has the potential to disrupt that subterranean community through habitat destruction and hydrological change.

Objectives

In this five-year study, we attempted to address a series of questions pertaining to the aquatic animals and their environments in this poorly studied landscape. Our objectives included the following:

- Collect baseline physical and biological data for surface-water, solution-hole, and groundwater environments within the karst landscape of the Rocky Glades.

- Test methods for sampling aquatic animals from groundwater in wells, including traps and videography.

- Study the distribution and life history of the Miami cave crayfish (*Procambarus milleri*)

- Test use of remote sensing tools to estimate the density and depths of solution holes on the landscape.

- Describe species composition and survival of fishes in solution holes to assess their role as dry-season refuges and sources of colonists.

- Document seasonal changes in species composition, size structure, and reproductive patterns of animals on the wetland surface

- Study seasonal movement patterns by fishes and invertebrates.

- Use implanted radio transmitters in Florida gar (*Lepisosteus platyrhincus*) to determine its use of the Rocky Glades.

Within the boundaries of the Rocky Glades and southern Atlantic Coastal Ridge **(Figure 1**), during the first three years of the study, we sampled the physico-chemical environment and faunal communities of three aquatic habitats: (I) groundwater in wells, (II) shallow sub-surface solution cavities, and (III) surface-water wetlands. The first project year was a pilot study in which we tested designs and methods to use in sampling aquatic animals from the karst surface, from solution holes, and from groundwater wells. We were able to implement the components of this work during the second year of the study. However, in 2003 and 2004, we de-emphasized efforts directed towards groundwater work because of a lack of results in capturing subterranean animals, which coincided with an increased workload in sampling Rocky Glades wetlands and solution holes brought on by unseasonable rain events. We spent much more effort than originally anticipated in fieldwork and sample processing in 2003-2004. During the fifth and final year in 2004, we collected data only from the drift-fence arrays while we planned for the next steps in studying this landscape.

I. STUDY ENVIRONMENTS

INTRODUCTION

The study area is located in Miami-Dade County in extreme southeastern Florida, including eastern Everglades National Park (ENP) (**Figure 1**). The Florida Everglades is an extensive subtropical wetland ecosystem that formed during the past 5,000 years when peat and marl were deposited within a pre-existing limestone depression in the southern Florida peninsula (Gleason and Stone 1994). Karst limestone underlies the peat and marl throughout much of the Everglades, (Fish and Stewart 1991). In the southern Everglades, limestone of the Miami Limestone and Fort Thompson Formation form the Biscayne aquifer in the upper part of the surficial aquifer. The Fort Thompson Formation is 3-17 m deep, and it thickens slightly to the east, where it underlies the Miami Limestone (Fish and Stewart 1991). The high porosity of the limestone of the Biscayne aquifer (Fish and Stewart 1991) in south Florida allows for considerable interchange between surface water and ground water. The Fort Thompson Formation generally is riddled with solution cavities or vugs that are usually 6 cm or less in diameter, but are so abundant that much of the limestone resembles a sponge. As a consequence, this formation is highly permeable (Fish and Stewart 1991). The Miami Limestone crops out along the eastern margin of ENP and is locally known as "the Rocky Glades" (**Figure 1**). In general, it does not appear that the Miami Limestone has a network of open cavities as well developed as the Fort Thompson Formation. In many areas, the cavities are at least partly clogged with lime mud and sand, reducing the average hydraulic conductivity to much less than the underlying limestone of the Fort Thompson Formation (Fish and Stewart 1991).

Under today's drained conditions, areas of the Rocky Glades are inundated between three to seven months each year. This hydroperiod has been reduced from historical conditions prior to the construction of the drainage canals to the east (Loftus et al.1992; Renken et al. 2000). They found that the region once had maximum and minimum water levels, and shortened flooding periods, which agreed with output from the South Florida Water Management District's Natural System Model. Today, surface-water generally appears in early June, with the advent of the wet season, providing aquatic animals with conditions for dispersal and re-colonization. When the dry season commences, typically in mid-October or November, the wetland quickly dries. The karst topography of the Rocky Glades is typified by thousands of shallow depressions in the form of solution holes (**Figure 2**). The holes often occur in complexes, some of which appear to be connected by an underground network of channels. Deeper holes penetrate the shallow aquifer of south Florida where groundwater may provide a refuge for organisms throughout the dry season.

The Atlantic Coastal Ridge was a historically drier and higher elevation area of southern Florida. The ridge ranges from 1.5 to 6 m above sea level in the study area and bounds the Everglades marshes on the east. The ridge is about 5 to 8 km wide throughout most of its length, widening to about 16 km at its southernmost terminus. The ridge is a natural barrier to eastward-flowing surface drainage, except in its southern part, where it is breached by low-elevation sloughs oriented perpendicular to the trend of the ridge. Surface water on the ridge during the wet season occurred mainly in the transverse glades that cut across the ridge. However, the ridge harbored both solution holes and subterranean cavities that held groundwater throughout the year. Most of these solution holes now dry each year because of the reductions in ground-water levels, but deeper cavities in the Biscayne aquifer remain perennially flooded.

METHODS

<u>Hydrological and physicochemical monitoring of study habitats</u>

We used data from continuous hydrological recorders in ENP to examine patterns of drying and flooding during this project (**Figure 3**). We also installed staff gauges to measure water depths at each surface-water and solution-hole site. In June 2002, we installed plastic rain gauges at four surface-water sampling sites. Data were collected each time we sampled. We measured flow at each array when samples were collected by averaging three measurements of the time needed for a neutrally buoyant glass vial to move across a 15-cm distance of the wetland. We tested the use of a Sontek Acoustic-doppler Flowtracker in the Rocky Glades but were unsuccessful in obtaining accurate and repeatable measurements because of the very low flow rates and lack of particulate matter in the water column.

We used five YSI 600 devices to attempt to take continuous measurements of physico-chemical conditions for one-week periods in each yearly quarter to collect seasonal data at the surface-water, solution-hole, and groundwater sampling sites (**Table 2**). The units were calibrated prior to each deployment. We collected additional data using the YSI units during the spring and early summer of 2001. However, during calibration runs, it became obvious that an older unit was not providing readings in line with the newer units. Rather than continuing to collect data that we were not confident with, we performed extensive tests on the units in the mesocosm tanks and in the wells. We returned all units to the manufacturer for calibration and checking, retested them, and returned the older unit once again. Because of this equipment problem, we missed some opportunities to gather seasonal data on the groundwater environment. After retrieving the units, we uploaded data to a PC, then used EcoWatch©, a compatible software program to generate graphs and arrange the raw data into a spreadsheet. During the dry season, we used a hand-held YSI-556 unit to collect discrete readings of temperature, specific conductance, pH, and dissolved oxygen in the solution holes.

We deployed continuous-recording thermographs (Onset Hobos) in solution holes, ponds, and arrays to collect water temperature over periods of several months through the year to compare data among habitats. Unfortunately, most data from the thermographs set since winter 2003 were lost because of a software malfunction. We corrected the problem and re-set the units in solution holes and on the marsh surface in that year.

<u>Topographic Assessment</u>

With the assistance of USGS personnel, we collected microtopographic detail of the marsh surface surrounding a study solution hole (MR2). We examined the use of standard topographic surveying methods from established benchmarks in the Rocky Glades to map the surface topography and solution hole abundance and depths. Although successful, after discussing this with our ENP cooperator, Dr. Sue Perry, we agreed with her opinion that we suspend collecting this fine-scale topographic data because it would be cost- and time-prohibitive. The data-collection process was very labor-intensive and time-consuming. Therefore, we deferred additional surveying because of time limitations, and placed that effort into additional field collections from solution holes. Discussions with USGS modelers revealed that, instead of microtopographic data, the data most needed were estimates at a landscape scale on the spatial density and depth distributions of solution holes. Clearly topographic data collection at that scale was beyond the scope of this project.

To determine the most feasible and efficient means of meeting the modelers' needs, we discussed the issue with a USGS remote-sensing specialist, Dr. John W. Jones with the USGS Geography Discipline in Reston, VA. Dr. Jones proposed a combination of fine-detail aerial photography, combined with LIDAR techniques, as a possible solution. However, those methods had not previously been applied in an environment similar to the Rocky Glades. In 2003, with input from Dr. Perry, we successfully applied for a small USGS Grant in Support of Park Needs. We tested and ground-truthed the results of this combination of remote-sensing methods from two transects flown over the Rocky Glades in 2004. The goal of the research was to develop and evaluate cost-effective methods for deriving useful information on solution-hole distribution, densities, and depths in test areas of the ENP Rocky Glades region. This goal combined the objectives of providing technology assistance to NPS and the derivation of priority information for the Comprehensive Everglades Restoration Program (CERP), as identified in the Department of Interior (DOI) Science Plan, with the USGS geographic-research objective of developing new methods for high-resolution topographic surveying in rugged, remote landscapes.

A precise definition of what constituted a target solution hole was required before techniques to detect and map them could be formulated. We begin this section by providing such a definition before discussing the overall approach taken, the study area used, the variety of data evaluated through the research, and the analyses employed.

Targeted solution holes: Too few holes have been mapped and investigated for any clear generalizations to be made regarding what sizes, shapes, depths, or distributions of solution holes are required to provide viable fish habitat. The only logical requirement is that a hole will hold sufficient water through the dry season to maintain fish populations. For this reason, biologically significant solution holes may span a continuum of depths and sizes. Furthermore, little information existed to allow generalizations regarding the relationship between solution-hole diameter at the ground surface and solution-hole depth, apart from measurements at a few study holes (Kobza et al. 2004). Our own field observations have shown that very large depression areas may be too shallow to hold sufficient water for fish survival, while seemingly small diameter solution holes may be relatively deep and perhaps interconnected underground, forming complexes large enough to provide viable aquatic habitat. While a minimum depth criteria of 20 cm is employed for fish surveys (Loftus per comm.), at the outset of this study, we defined target solution holes as those deep enough to contain water or cast shadows (inside the hole) at the time of imaging. Such a definition is based on remote-sensing technology, not biology. And, as the study progressed and new (LIDAR) technology became available, it was modified to holes of minimum-estimated depth greater than 20 cm for comparison with fish-study solution holes, and 30 cm for the identification of significantly deep solution holes. In either of the latter two cases, a width criterion of at least one LIDAR measurement (approximately 1 meter) was first employed, although as later discussion will show, automated processing techniques allowed predicted significantly deep solution holes to be easily sorted and filtered by area of coverage.

Study region and geographic referencing: The pilot study concentrated on two areas of the Rocky Glades that coincided with biological sampling sites: along the northern edge of the ENP Main Park Road, and areas at the eastern segment of Context Road, just west of

Homestead General Aviation Airport (**Figure 4**). To allow for data analysis and fusion on the basis of geography, standard map-projection and coordinate-system parameters were set for the study. The North American Datum of 1983 (NAD83) and the Universal Transverse Mercator (UTM) map projection and coordinate system were used for all data geo-referencing. While the UTM projection is non-conformal and should not be used for area calculations for large regions (Snyder 1987), errors introduced by the analysis of areas as small as that of the pilot study are negligible. Areas reported in the results section will be based on calculation made against the UTM system.

Approach: Given our desire to develop relatively cost-effective techniques for solution-hole mapping, we began by considering the efficacy of widely available data collected for general mapping purposes before investigating custom, higher-cost alternatives. Also, each input image type was first evaluated interactively and visually, to determine what information was interpretable by eye. Then, machine-based, image-processing techniques were emphasized as the ultimate endpoint because they provide objective, systematic, and replicable methods of surface-feature mapping (Jones 1987) and are generally lower cost, less labor-intensive, and less subjective then visual interpretation techniques. Once we had identified sets of solution holes and characterized them to the greatest extent allowed by imagery and present techniques, derived characteristics for specific solution holes were checked against limited field observations on solution-hole location. Finally, our ability to extract information through automated spatial processing of multiple data sets was tested through the generation of summary statistics and multi-dimensional visualizations in an exploratory fashion. This entire process began with data acquisition and fundamental pre-processing as detailed in the following section.

Input data types and pre-processing: Any computer-based, geographic-data fusion requires a significant amount of data pre-processing (Jones 1993). We explored the efficacy of many data types and sources for detecting and characterizing solution holes. Various characteristics of these data types are summarized in **Table 3**, and the locations of their collection shown in **Figure 5**. Some specifics regarding each data type are provided in the following sections.

Digital orthophoto quarter quads (DOQQ): The USGS cooperatively produces standard, digital orthophotoquads with other Federal, State, and Local government agencies for the entire Nation on a revolving schedule (USGS 2002). As their name implies, each covers slightly more than ¼ of a standard USGS 1:24,000 topographic quadrangle. Generated from color-infrared aerial photography, the nominal spatial resolution of these data is one meter, and the data are either distributed as panchromatic or false-color infrared images. The DOQQs used for analysis in this project were created from color-infrared photography collected in late February of 1997 (**Figure 6**). Because the data were produced using NAD83 and UTM by default, no georeferencing or other pre-processing had to be applied.

Custom high-resolution photography (133_E): The USGS is also producing special, high-resolution digital orthophotoquads for 133 cities in the United States. For this product, true-color imagery is collected in digital format or as conventional aerial photography that is then scanned to produce digital imagery. These digital data are orthorectified using available digital-elevation model (DEM) data to create imagery with a nominal spatial resolution of one foot. Specifically for this project, a contractor was tasked with flying the study area at one-half the altitude used to produce the 133 cities data, and we stipulated a data-collection period of November through February (during the south Florida dry season). A more stringent time frame (particularly one dependent on water conditions) would have been too costly so the multi-month period was specified to keep contract mission costs low while acquiring the largest area possible. Similarly, while sufficient end and side lap was stipulated for analogue-image capture, only every other acquired photograph was scanned by the contractor to minimize project costs. Assuming a flat surface is present in the study region, project personnel used contractor-supplied camera model information and commercially available digital photogrammetric software to orthorectify these data and produce digital orthophotos with approximately 0.5-foot spatial resolution for select project sub-areas (**Figure 7**). This higher-resolution imagery is referred to here as "133 enhanced" (133_E).

Helicopter-based digital imagery (HBDI): The USGS Geographic Analysis and Monitoring and Land Remote Sensing Programs have been funding the development of low-cost, rapidly deployable, airborne digital-imaging systems for scientific research (not map production) purposes. On 29 September 2004, we deployed such a system using a Bell Jet Ranger aircraft and pilot contracted the day prior using Department of Interior, Office of Air Safety OAS standard procedures. Along with a commercially rented camera mount, we used this system to collect color-infrared imagery of approximately one-third-foot spatial resolution for targeted study sub-areas (**Figure 8**). Using the previously orthorectified 133_E data as a base, subsets of these imagery were registered to the project UTM system (**Figure 9**).

Light Detection and Ranging (LIDAR): Collaboratively with the Florida International University (FIU) International Hurricane Research Center and Environmental Studies Program, an approximately 500-meter-wide line of LIDAR data was collected across the pilot-study area (**Figure 5**). These data were collected during the period of 13-15 May, 2004 using an Optech Airborne Laser Terrain Mapper (ALTM) 1233 LIDAR mapping system[1] on a Cessna 337 platform. Data were collected from a nominal altitude of 500 meters along 360-meter-wide swaths – using multiple passes to cover the study area. Differential global positioning system (GPS) data and aircraft inertial information were used in post-processing to georeferenced data posting to UTM and NAD83. These data were also filtered using an algorithm developed by the Hurricane Research Center to yield "bare earth", "first return", and "last return" point-elevation data. Provided to the USGS in ASCII format, these data were imported into the image-processing environment and linearly interpolated to produce a one-meter resolution, digital-elevation model (**Figure 10**).

Analysis: Upon receipt, each image type was first examined to see whether solution holes could be detected and mapped through visual interpretation alone. Then a variety of enhancements were performed in an effort to extract information content for visual interpretation or to prepare imagery for automated analyses. For example, multispectral image data like the HBDI were manipulated to maximize the numeric ranges within each

[1] Use of trade names is for illustrative purposes only and does not constitute an endorsement by the U.S. Government.

band (**Figure 11**), and ratio values were calculated across these manipulated bands to emphasize water areas (**Figure 12**). LIDAR-derived DEM data were contoured and overlain with other image types to show areas of "pits" or "sinks" where solution holes were likely (**Figure 13**). For image data types where the visual detection of solution holes seemed possible, unsupervised statistical clustering and supervised classification (Lillesand and Kiefer 1987) were applied using known solution-hole locations as training and/or labeling guides. For the DEM from the LIDAR data, a terrain analysis approach was taken (**Figure 14**). While a filter size of 21 X 21 was ultimately selected as part of the developed algorithm, the DEM was processed with a lowpass filter of various sizes (e.g., 9 X 9, 21 X 21, 51 X 51) to produce smoothed or 'average' surfaces. Then, the unfiltered DEM was differenced with the filtered DEM to yield an elevation-deviation image (**Figure 15**). This result was reclassified according to difference value to produce maps of depressions with a depth equal to or greater than specified thresholds. Once identified, we grouped solution-hole pixels into contiguous clusters (**Figure 16**), and then hand-edited these for obvious artifacts (e.g., those occurring along image seams and boundaries) to produce individually labeled solution holes. Then, the size and depth statistics were calculated for each delineated solution hole. For visualization purposes, various airborne-imagery types and LIDAR-derived, digital-elevation models were fused to yield visualizations of Rocky Glades solution-hole areas (**Figures 17 and 18**). These models were viewed and manipulated interactively to conduct qualitative assessment of image geo-referencing accuracy, and to provide insights regarding LIDAR-processing challenges such as vegetation removal for "bare-earth" modeling. Also, these visualizations provided qualitative information on the distribution, estimated shape, and apparent content of solution holes in a format that was intuitively understood by those without an extensive background or experience in remote sensing. Finally, developed techniques were assessed using information on the location of known holes to evaluate whether the LIDAR-oriented approach detected them (**Table 4**), while locations of "forecasted" holes were visited in the field to determine whether the algorithm predicted many holes that don't actually exist (**Table 5**).

The results of this work is presented in the next section.

RESULTS & DISCUSSION

Temporal variation in hydrology

In general, rainfall appeared to drive hydrological conditions in the Rocky Glades so that the effects of the normal wet-dry season cycle of the Everglades is felt more strongly there. Water levels responded by rapidly rising at the onset of rains, but fell quickly when precipitation ceased **(Figure 3**). Rainfall typically caused water levels to rise to flood the wetland surface in late spring, although the onset of flooding could be initiated earlier (2003) or delayed until later in the summer (2004). Several years during this study had springtime reversals of drying, particularly in 2003. In general, 2000 and 2001 were relatively average water years. Although groundwater levels in 2002 were low, the recession was rapid and of relatively short duration. 2004 had the driest conditions of any spring, when groundwater levels fell more than a meter below ground surface over most of the area. Much of the Rocky Glades experienced a mid-summer drying event when rains slowed during the "July dry"

(**Figure 3**). Locations farther west (NP-62), on the border of Shark Slough, normally had the longest flooding periods with few reversals of flooding. Those areas may have been influenced by water-management actions upstream in that basin. Sites at higher elevations (NP-44) rarely experienced surface water. Mid-elevation locations (NTS-14) had short flooding periods with several reversals annually.

The measurements of water depth, rainfall, and flow at the study sites whenever we collected biological samples were accompanied by periodic, discrete measurements of water temperature, dissolved oxygen, pH and specific conductance. Additionally, the deployment of the YSI-600 units within the Rocky Glades habitats provided data on diel and seasonal changes in physicochemical parameters.

Specific results of hydrological and physiochemical measurements in groundwater, solution holes, and surface-water habitats will be discussed within those sections of this report. However, in general, the surface-water environments were most variable in all parameters, and showed the greatest diel cycles. Solution-hole environments represent a less variable aquatic habitat than arrays, although strong diel patterns in some parameters are obvious. Both wells and deep solution holes with groundwater contact tend to be thermally invariant compared with wetlands and alligator holes. Interpretation of these data indicates that groundwater and solution-hole environments are generally hypoxic habitats, while the surface-water habitats are often super-saturated with dissolved oxygen. Dissolved-oxygen levels vary diurnally with temperature, and to a lesser degree, pH. These environmental monitoring data contribute to our understanding of basic physiological tolerances required by aquatic species that are successful in the temporary wetlands and subterranean environment of south Florida.

Topographic Assessment

To relate the dynamics of the aquatic animals to the characteristics of solution holes, intensive data have been collected from a sample of holes of various depths and diameters in several areas of the Rocky Glades. However, to predict the consequences of increasing groundwater levels across the region on the aquatic-animal community, we must have the ability to extrapolate the ecological data from the- intensive, site-based studies to the greater landscape. This requires two pieces of information: an estimate the density of holes on the landscape, and an estimate of their depth distributions. Present topographic data planes for the Rocky Glades are of too coarse a scale to provide the resolution needed for models of solution-hole habitat use by aquatic animals. We determined it would be too time-intensive and cost prohibitive to use standard land-surveying techniques to map solution-hole densities and depth distributions at the landscape level. In addition, while survey techniques must be cost-effective and accurate, they must not compromise the wilderness features of the study area. Remote sensing appeared to be the only feasible way to acquire those data.

Four capabilities are necessary to consistently detect and map solution holes that may provide viable habitat for aquatic animals. The first is the ability to discern differences between solution-hole content or cover (e.g., water, soil, and vegetation) and that of the surrounding higher ground surface. This capability is dependent upon the spectral and spatial characteristics of the remotely sensed imagery as well as the weather, water, and vegetation conditions at the time of imaging. The second is the ability to estimate solution-hole diameter. This requires a remotely sensed image with spatial resolution finer then one-half the diameter of the target solution holes. The third is the estimation of solution-hole depth. This requires the development of diameter/depth relationships (that have not yet been formulated because of a lack of sufficient information) or the direct estimation of depth through remote-sensing analysis (an objective for this research). The fourth is the accurate specification of solution-hole location. This requires adequate geo-referencing of remote-sensing imagery used for their detection. This is not a simple task given the limited number of well-defined, human-made features on the Everglades landscape that can be used as location guides in remotely sensed image registration.

We were able to rapidly collect high-resolution imagery with little notice and at low cost. We were also able to obtain relatively expensive data-collection services by leveraging other project funds/activities, and through collaborative agreements with FIU researchers. Therefore, the overwhelming majority of effort expended on the project was put toward rigorous geo-referencing of two of the four image types analyzed. Regardless of their utility for solution-hole detection (discussed below), the 133_E data were the most accurate and highly useful for orthophoto production given the camera-model documentation provided and standard aerial-mapping technologies employed. These data were far more useful than the standard DOQQ for image geo-referencing and registration, and served as the geographic base for all other project data types.

Areas of bare limestone that were likely to include solution holes were evident in the DOQQ, 133_E, and HBDI datasets. However, for various reasons depending on the data set, none clearly and consistently showed where solution holes were cut into the limestone. The DOQQ data (**Figure 6**) were inadequate for two reasons. First, their spatial resolution (1m) was simply too gross to show solution-hole openings. Second, even where holes might be extremely large, the imagery lacked sufficient contrast between the surficial limestone and solution-hole interiors to allow solution holes to be detected. This was likely due to the extremely dry conditions prevalent at the time of imaging, and the capture of these images during the highest sun-angle conditions possible – to minimize shadows. This is common practice for aerial-mapping photography missions. It was the cause for the similar failure of the 133_E data to provide adequate spectral information to allow solution-hole delineation despite its higher spatial resolution. That is, the 133_E data, while highest in spatial quality and spectral fidelity, was also collected when sun angles were too high (no shadows were cast in the deeper holes), and hydrologic conditions were too dry (no water was present in most holes). Modification of contracting mechanisms to stipulate the staging of airplanes to collect imagery when conditions are optimal can become cost prohibitive.

In contrast, far greater deployment flexibility was provided by the HBDI system. Collected during the wet season, the HBDI clearly showed bare limestone areas, some of which included visible solution holes. Wet holes could be delineated, and some relative sub-water-surface depth characteristics could be inferred from tonal variations in water-covered areas. However, after discussions with ENP field biologists regarding minimum solution-hole depths, it appeared that the presence or absence of water without depth information was not an adequate criterion for solution-hole identification. So, these wet conditions, and a lack of information on water depths, combined to prevent consistent distinction of wet, shallow depressions from deeper, potentially significant solution holes across the range of study-area conditions. While image-data enhancements, like those illustrated in **Figures 11 and 12,** improved HBDI interpretability for solution-hole detection, we could not develop study-area wide visual interpretation rules for this purpose. As an additional problem requiring attention, the spatial resolution of some HBDI images suffered from blur caused by vibration of the helicopter. If adequate information on water levels becomes available, holes containing water as seen in the HBDI (or 133_E imagery collected at the appropriate time) could be identified both visually and through image processing. Also, with optimal water or time-of-day collection, broader dewatered areas surrounding solution holes may be separable from solution holes themselves in these higher spatial-resolution data products. It is important to note that because of the information they can provide regarding solution-hole vegetation content and their relatively low cost to acquire, data from a simplified version of this camera system might be useful in characterizing and monitoring solution holes to document when identified holes of particular depth dry out. To be used for accurate measurement purposes, however, HBDI geo-referencing and rectification requirements make the availability of high-quality image map data like the 133_E digital orthophotos necessary. Regardless, the best utility for the 133_E and HBDI data are realized when they can be combined with LIDAR data.

With the LIDAR data (**Figure 10**), visual interpretation of solution-hole locations and boundaries was also very difficult and inconsistent across the study area. Similarly, automated image-processing approaches like supervised or unsupervised classification on LIDAR data alone proved inadequate. However, LIDAR data allowed for the most extensive automated derivation of solution holes using the process outlined in **Figure 14**. Ultimately, the lowpass filter of 21 X 21 cells that we first selected was employed based upon investigator field observations of terrain variations and distances among solution-hole complexes. But exploratory research showed that larger filter sizes resulted in the generation of considerably higher average-elevation values where vegetation obscured the ground surface because LIDAR-processing algorithms assigned vegetation heights to surface elevations. This resulted in over-prediction of significant solution-hole presence, while too small a filter size had the opposite effect. The prescription of a 21 X 21-element lowpass filter in the algorithm resulted in the identification of over 5900 solution holes greater than approximately 30 cm in depth and 1 m in diameter within the LIDAR flightline of imagery. Size-class distributions for these holes were calculated using GIS to yield the following statistics: maximum size – 91 square meters; average size - 3.81 square meters, and standard deviation of the size – 6.09 square meters. When a minimum approximate area was also imposed (e.g., five square meters), the number of predicted holes dropped to 1300. We evaluated this result from a number of perspectives. First, we evaluated the ability of the procedure to forecast known fish study sites. When a depth threshold of 20 cm was stipulated, the terrain analysis correctly forecasted the presence of all known holes in the image area (**Table 4**). When a depth criterion of 30 cm or greater was applied, just under 75% of the holes were detected. (Additional survey-grade, field-data collections would be necessary to accurately determine whether the terrain-analysis-attributed depths are significantly erroneous). The results in **Table 5** detail a different approach. In this case, we located previously undocumented holes and non-solution-hole depressions in the field and compared those against terrain-analysis predictions. In this case, only one significantly deep (but very small in area) solution hole was not forecasted by the analysis (**Table 5**). It is important to note that these accuracy assessments are biased by issues of accessibility. That is, only forecasted or field-observed holes that could be reached by walking across the rugged landscape from the ENP Main Park Road (about one km from the road) were observed for this analysis. Reaching other potential holes was both difficult and potentially disruptive to landscape vegetation.

In this study, we could not quantitatively assess whether the presence of water affected LIDAR elevation estimates. It is possible that the depth estimates for solution holes that contained water have higher error rates than those without water. Using other project-collected data to indicate where higher errors are likely, it would be necessary to gather survey-grade field measurements to test this possibility. When location information on holes is available from LIDAR data analysis, the 133_E and HBDI data can be used to document solution-hole water conditions and to rudimentarily classify solution-hole land cover as "open" or "vegetated" through the merger of information derived from each (**Figures 17 and 18**). The advantages and disadvantages of each remote-sensing system are briefly summarized in **Table 6**.

Finally, a regional map of solution-hole distribution could be generated for the entire area covered by the LIDAR data collection, as was done for this transect (**Figure 19**). Filtered for solution holes of significant size (e.g., greater than five square meters in area), this map shows that larger solution holes are not uniformly distributed throughout the region. This information generates new questions regarding the Rocky Glades land surface and can be used to guide more efficient biological sampling by depicting areas of greater and lesser densities of solution holes.

This study explored the potential of applying remote-sensing technologies for detection and characterization of very small solution or sinkholes at the spatially heterogeneous and temporally dynamic land surface of the Florida Everglades. These technologies were unproven for any environment, let alone that of the Rocky Glades, where rough terrain and the difficulty of access made use of other techniques infeasible. Less than optimal results from airborne-multispectral imagery showed that the timing of data collection was critical. If image collection can be timed so that water is present in the holes but not on the surrounding land surface, very-high-resolution multispectral imagery like the 133_E and HBDI are useful for hole location and delineation purposes. This may be suitable for estimating solution-hole densities across the landscape. However, because no generalizations regarding solution-hole openings and depth seem likely, multispectral imagery cannot provide hole-depth information with a high degree of accuracy. In contrast, LIDAR technology has been shown to provide information on solution-hole depth if collected during very dry conditions. For this study, the dry-season collection of LIDAR data also proved most effective for solution-hole identification. We developed a terrain-processing approach that uncovered thousands of potential fish-habitat solution holes along the ENP Main Park Road, and portrayed spatial variations in relative hole abundance along a transect of the Rocky Glades region. Maps generated by this research will be distributed to other researchers for voluntary evaluation and use. Further research will investigate new ways of combining project-collected multispectral and LIDAR data with field data from other projects to characterize identified solution holes. Although the Rocky Glades habitat is unique to ENP, similar karst wetlands exist in the Caribbean region and elsewhere, where this approach would be similarly applicable to landscape characterization.

As habitat restoration through CERP continues, the Rocky Glades should receive increased hydrological input that is anticipated to extend surface flooding periods and raise average groundwater levels. To predict the consequences of increasing groundwater levels across the region on the aquatic-animal community, the approach we have described here can help extrapolate ecological data from the intensive, site-based studies to the larger Rocky Glades landscape. The estimates of the density of solution holes and their depth distributions will help ecological modelers in that task.

II. GROUNDWATER

METHODS

Physicochemical water monitoring

In addition to earlier deployments of the YSI-600 units in wells along the Atlantic Coastal Ridge (see Miami cave crayfish section below), we also made 28 deployments at wells in the Long Pine Key (LPK) region of ENP (**Table 2**). The units were set in existing wells dug to provide water for fighting wildfires. We also sampled a series of wells on LPK specifically drilled for this project after ground-penetrating radar showed the presence of subterranean cavities. The units were calibrated for all parameters (water temperature, dissolved oxygen, pH, and specific conductance) before being set in the field. Data were collected at 30-min intervals for one week, before the units were returned to the lab to offload the data. Spot readings in the wells were taken with a YSI-556 unit as a check on the YSI-600s. Data are reported a hourly means from seven-day sampling periods during each season

Ground-Penetrating Radar (GPR)

We rented the use of a USGS ground-penetrating radar (GPR) unit from Storrs, Connecticut. Our collaborator, Dr. Kevin Cunningham of USGS-FISC, worked closely with Dr. M. Cristina Bruno, ENP contract biologist and us to identify a number of variously sized cavities both inside the park at LPK, and on the Atlantic Coastal Ridge. The most porous wells are those that we believed should have the greatest potential for subterranean-animal collections in that they should provide both habitat and conduits for dispersal by those organisms. In 2001 we contracted a drill rig to penetrate the most promising of those cavities in LPK to sample for aquatic hypogean animals. With the GPR, we examined the geologic structure around the Homestead aquaculture facility where we collected Miami cave crayfish (*Procambarus milleri* – see section below), and around the Fruit and Spice Park on SW 187th Ave. and SW 248th St. We also worked with Dr. Cunningham to identify, using his data on geologic structure and porosity, promising wells, that he had drilled previously on the Coastal

Ridge so that we might trap in them. The transect method used to tow the GPR to detect cavities in the underlying limestone is described in Cunningham (2004).

Video exploration of subterranean wells

We tested a Polaris© B/W infrared Lipstick Camera for video-sampling subterranean wells. The camera was deployed into the well with a cable attached to a VCR on the surface. We also tested the feasibility of using a borehole color Laval® camera that was deployed from a tripod and connected to a cable/wench system. The cables then fed into a van equipped with a control box, monitor, and a VCR to observe and record the presence of aquatic animals in wells. David Schmerge of USGS in Miami brought the equipment to Angel's Hatchery (Homestead, FL) where we deployed it in a well. We used this equipment in two subsequent trials in wells on the Atlantic Coastal Ridge and in the wells drilled by Dr. Cunningham at Long Pine Key, ENP.

Hypogean faunal sampling and trap testing

Beginning in 2000, we worked closely with Dr. Bruno to develop a sampling protocol for well-dwelling fauna. To capture larger groundwater organisms in wells, we developed two types of traps: substrate traps (**Figure 20**) and plastic bottle traps (**Figure 21**). Bottle traps were constructed from 0.5 L or 2.0 L plastic water or soft-drink bottles. The top of the bottle was removed and inverted (spout facing inward), and was reattached to the lower half using plastic ties (**Figure 21**; Loftus et al. 2001). In addition to the plastic bottles, we also constructed cylindrical wire-mesh traps, miniature copies of standard wire minnow traps used by fisherman to collect bait (**Figure 22**). We tested the effectiveness of each, with the permission of the owner of a Homestead aquaculture facility, using captive Miami cave crayfish and fishes. In several trials performed in the captive-crayfish tank at the facility, we used baited and unbaited 0.5 L and 2.0 L plastic bottles with the funnel at the top of the bottle, Bottle traps were suspended vertically in the water column. Bait consisted of a sponge soaked in menhaden-oil chum. We also tested a 2.0 L bottle with a side funnel, and 2.0 L bottles with nylon netting secured to the outside of the bottle to allow crayfish to grasp the bottle more securely. We also deployed several bottle traps in wells on the facility, where *P. milleri* had been caught previously with similar traps. We also baited the well traps with either light sticks, chum, or both. Cyalume sticks were used to encourage visits by subterranean animals. We ran several trials before deciding which combination of attractants to use. Bottle traps were deployed both at the bottom of each well, or suspended midway down the well, by an anchored rope, and retrieved after 24 h.

Substrate traps consisted of a 3.8-cm diameter, 30-cm long, perforated PVC tube inserted with air-conditioning filter material to provide artificial cover for small invertebrates or fish (**Figure 21**). A cap of nylon netting was attached to one end of the pipe to prevent the loss of the filter during retrieval, while the open end of the pipe was attached to a rope. The tethered trap was dropped to the bottom of a well and remained undisturbed for one month. When we retrieved the traps, the filter material was removed, cut into sections, and immersed in 70% ethanol. The trap was fitted with fresh material and redeployed. Filter material was examined beneath a dissecting microscope to remove and identify organisms. Because few animals colonized the trap after one month of sampling, we changed deployment time to six months in 2002-2003.

We tried the use of bottle traps in LPK wells in FY00. In 2001, we sampled organisms in two sets of wells along the eastern ENP boundary and at LPK with bottle traps and substrate traps. One set consisted of four monitoring wells located within the Long Pine Key area between Palma Vista Hammock to the east and Pine Glades Lake to the west. We drilled those wells after cavities in the bedrock limestone were detected by GPR. We also haphazardly sampled other wells drilled to provide water for fighting wildfire at LPK. The second set of wells included four located on the northeastern Park boundary adjacent to L-31N canal. These wells are described more fully by Bruno et al. (2003), Cunningham (2004), and Bruno and Perry (2004). In 2002, we continued to sample these sites with bottle and substrate traps. Substrate traps were deployed again in 2003, but we reduced the sampling effort because our collections were not yielding many animals and because unseasonable weather conditions required us to increase our sampling efforts in solution holes and drift fence arrays.

<u>Life history and distribution of *Procambarus milleri*</u>

Florida is a global hotspot for stygobitic crayfish (Franz and Lee 1982), in large part because of the habitat provided by huge, porous limestone aquifers that lie beneath its surface. Fifteen species, eleven of which are endemic, have been described from the waters of the state (Franz, 1994). Accounts of the geographic and ecological distribution of 12 of the Floridian stygobites were presented by Franz and Lee (1982), with several additional species having since been described. Thirteen of the stygobitic crayfish belong to the genus *Procambarus,* and one each to the genera *Troglocambarus* and *Cambarus*. Most of the stygobitic crayfishes occur in northern and central Florida where they are associated with the extensive Floridan aquifer. Only one species has been described from extreme southern Florida, *Procambarus (Leconticambarus) milleri* Hobbs 1971, the subject of this section of the report.

We conducted a study of the life history of the poorly known Miami cave crayfish (*Procambarus milleri*), a species endemic to groundwater in Miami-Dade County that may become a candidate for federal listing. A population of about 1,500 of these subterranean crayfish was being raised in tanks at a Homestead aquaculture facility, where the colony was set up in 1992 with crayfish captured from a well at the site. We obtained permission from the owner to gather data on this captive population. Presently, the female of this species has not yet been formally described (**Figure 23**), but we will do so in a manuscript based on work funded by this project. From the captive population, we collected information on sex ratios, fecundity, and life stages each month for three years.

Hobbs (1971) described forms I and II of the male from six specimens of form I and eight males of form II collected from a well at a plant nursery in Miami-Dade County in the late 1960s (**Figure 24)**. Three juvenile males and one juvenile female were also taken there. The well was 6.7 m deep, with a 5.5 m-deep casing. The next collection of this species was made in 1992, about 25 km south of the original site. Nineteen male and female specimens, adults and juveniles, were collected by Radice and Loftus (1995) in a well nine-meters deep, located at an aquaculture facility north of Homestead, Miami-Dade County (**Figure 24**). Live specimens taken from the well have been propagated at the same location since that time. We used that captive population to gather information on the biology and life history of this species, which we report here. In 1993, one female and two male adults were sent to H.H. Hobbs II, who confirmed the identification, provided a description of the female, and amended the description of color for males and females. Until then, no female representative of the Miami cave crayfish had been described. The objectives of this segment of the project are to describe new collections for this species and update its distributional range, as a result of several years of sampling in groundwater in Miami-Dade County, and to provide new information on the biology, size-structure, coloration, fecundity, and life history based on the captive population.

Study Area: The study area is located in Miami-Dade County in extreme southeastern Florida, including eastern Everglades National Park (**Figure 24**). The Florida Everglades is an extensive subtropical wetland ecosystem that formed during the past 5,000 years when peat and marl were deposited within a pre-existing limestone depression in the southern Florida peninsula. Karst limestone underlies the peat and marl throughout much of the Everglades (Gunderson and Loftus 1993). In the southern Everglades, limestone of the Miami Limestone and Fort Thompson Formation form the Biscayne aquifer in the upper part of the surficial aquifer. The Fort Thompson Formation is 3-17 m deep, and it thickens slightly to the east, where it underlies the Miami Limestone (Fish and Stewart 1991). The high porosity of the limestone of the Biscayne aquifer (Fish and Stewart 1991) in south Florida allows for considerable interchange between surface water and ground water. The Fort Thompson Formation generally is riddled with solution cavities or “vugs” that are usually 6 cm or less in diameter, but are so abundant that much of the limestone resembles a sponge. As a consequence, this formation is highly permeable (Fish and Stewart 1991). The Miami Limestone crops out along the eastern margin of ENP and is locally known as “the Rocky Glades” (**Figure 24**). In general, it does not appear that the Miami Limestone has as well developed a network of open cavities as the Fort Thompson Formation. In many areas, the cavities are at least partly clogged with lime mud and sand, reducing the average hydraulic conductivity to much less than the underlying limestone of the Fort Thompson Formation (Fish and Stewart 1991). The Atlantic Coastal Ridge ranges from 1.5 to 6 m above sea level in the study area and bounds the Everglades marshes on the east. The ridge is about five to eight-km wide throughout most of its length, widening to nearly 16 km at its southernmost terminus. The ridge is a natural barrier to eastward-flowing surface drainage, except in its southern part, where it is breached by low-elevation sloughs oriented perpendicular to the trend of the ridge.

To survey for Miami cave crayfish and other hypogean animals, we developed a sampling effort that covered the southern part of Miami-Dade County, south of US Hwy. 41, and focused particularly on the Long Pine Key area of Everglades National Park. We used a variety of sampling techniques: bottle traps, substrate traps, pumping, and baited vials. Those techniques are described below.

The use of an electric pump is not the elective method for collecting crayfish. Adult crayfish are probably too large to be displaced by the suction action of the pump, and they would be destroyed when passing through the impeller. This collecting method is designed for micro-crustaceans. However, Bruno (unpubl.) collected larger crustaceans, such as amphipods and isopods, in ENP. Therefore, juvenile crayfish were the target for this sampling method, given their small size. Also, the collection of fragments of exuviae would represent the evidence of the presence of crayfish in the aquifer. Pumping from wells was carried on during several studies in ENP and outside ENP eastern and north-eastern border (Bruno and Perry, 2004, in press; Bruno et al., 2003). For those studies, the following wells and locations were investigated:

1. 15 wells northeast of ENP, located either on the levees of canals, or in the immediate proximity of levees along the north-south and east-west boundary canals (Fig. 1). Samples were collected from each well at depths corresponding to highly porous strata identified by geological analysis. A total of 41 samples were collected monthly, from June 2000 to May 2001 (see Bruno et al., 2003 for details);
2. 10 wells in the Rocky Glades in ENP, some of which were near surface-water lakes (**Figure 24**). A total of 26 samples were collected monthly, from June 2000 to May 2002 (see Bruno and Perry, 2004 for details).
3. Two sites were selected in the Rocky Glades in ENP, in areas with high porous limestone (Cunningham, 2004) in spring, 2000, using GPR. Nine wells were drilled, and cased to the bottom where each reached a high-porosity layer. Twelve samples were collected monthly, from May 2001 to April 2004 (see Bruno and Perry, in press, for details).

In all the wells described above, samples were collected using a Wayne® 1/2HP portable pump connected to a Coleman® 1750 watt portable generator, and several 1.5-m long PVC pipes that were connected to the pump through a flexible plastic hose. The displacement action of the pump can allow the collection of organisms at a good distance from the pump (Malard et al. 1997). A total of 1,000-2,000 L of water per sample was filtered using a 63-μm mesh, 20-cm-diameter plankton net. The samples were fixed in 5% buffered formalin for sorting. We continued to sample until we had not collected any animal for five consecutive days. We sorted all copepods using a Leica® Stereoscope. At some of these wells, we used a YSI 6000 datasonde to characterize the groundwater environment by recording temperature, pH, specific conductance, dissolved oxygen (mg/l), and % dissolved oxygen every 30 minutes for about one week at different seasons.

During four weeks in July 2001, we set micro-traps baited with shrimp pieces at each well (Bruno and Perry, in press) and retrieved it after 24 hours. Trapping was repeated for four weeks in October 2001. The target organisms for those micro-traps were smaller crustaceans, such as isopods, amphipods, and crayfish juveniles.

We built funnel traps constructed from standard 0.5-2.0 L clear-plastic water or soft-drink bottles, which were cut below the neck, and that piece inverted inside the bottle. We tested capture efficiency on the captive population. We suspended the bottle traps in wells for 24 h by suspending it in the water column and at the bottom, and recorded the catch upon retrieval. The traps were not set according to a strict schedule, but each well described above was sampled at least three times. In addition, we collected samples from wells along the

Atlantic Coastal Ridge between Miami and Homestead (**Figure 24**) at least once, and in the case of the Homestead aquaculture facility, on a routine basis for a total of 20 collections.

We built artificial substrate traps for colonization following Vervier (1990). They were constructed of 30 cm long PVC pipes, with 1-cm diameter holes drilled haphazardly along the pipe. The pipe was stuffed with pieces of porous plastic air-conditioning filter material that acted as the artificial substrate. The bottom of the pipe was covered with a piece of 1-mm mesh netting for drainage on retrieval. Those traps were set at each of the wells described in the section below, and retrieved after either 1 month or 6 months. Trapping was repeated from 3-4 times at a subset of the wells described above.

To gather additional information on the distribution on *Procambarus (L.) milleri*, we phoned or mailed inquiry letters to local well drillers, fish farmers, and plant nurserymen and requested them to contact us if they observed or collected crayfish or other groundwater organisms from wells on their properties in southern Florida.

Captive Population: A captive population of about 1,500 crayfish has been maintained and propagated at the aquaculture facility in Homestead, in a cement tank measuring 2.5 m wide by 6.7 m long by 1.25 m deep. The tank conditions are kept as similar as possible to the limestone-groundwater environment. Most of the tank is covered with a wooden top, except for a small gap on one side for feeding and cleaning. The entire tank is kept covered with two layers of dense black-plastic shadecloth, which prevents exposure of the crayfish to sunlight. Crayfish were fed a commercial, algal-based fish food once a day, and large population of amphipods (*Hyalella azteca*) in the tank provided a supplemental food source. A well-pump continuously pumps groundwater through the tank. We recorded temperatures in the tank at 30-min intervals with a Hobo Tidbit, from 11/25/2001 to 2/12/2003; values were not recorded from 8/13/1002 to 8/30/2002 due to an instrument malfunction.

We collected data from this population monthly for three years from March 2000 to March 2003. We missed the November 2002 sample, and did not take samples in November 2000 or April 2001 because 150 and 110 adult males, respectively, were harvested for sale from the tank, affecting the size frequencies and sex ratio of the captive population. Each month, we recorded the carapace length (CL – distance from the rostrum to the posterior margin of the cephalothorax), gender, reproductive state, and color. Juveniles were classed as any animal less than 1 mm CL, because we found no Form I males or females with eggs below that length. If a female held eggs or larvae, we estimated the approximate number of eggs or larvae released and recorded the egg color. The crowding of eggs in the egg mass made precise counts on live females impossible. We classed males as form I (reproductively active) based on the presence of ishial hooks and corneous processes on the first pleopods. Sample size was based on the capture of 30 females each month. When we had collected 30 females, and all co-collected males and juveniles, we ceased sampling. After measurements were taken, we returned the live specimens back to the tank. When we captured an ovigerous female, we placed her in an indoor 10-l aquarium with continuous groundwater flow at a constant temperature of 24 ^{o} C, after estimating the number of eggs she carried. When she released her young, we counted them to determine her true fecundity and to provide a check on our original egg estimate.

In summer 2004, we isolated 9 ovigerous females in individual 10-l indoor aquaria. We recorded the time between the larval release and the next moult by the female. After the females moulted, we added a male to each aquarium. After several weeks, we removed the males and watched until the female produced eggs. We then measured the time between egg production and larval release.

We noted variation in color. Although dark orange body with a red dorsal abdominal stripe was the most common color in both the captive and wild populations, we observed several other colors. We recorded the carapace color as (1) Dark Orange with red abdomen stripe (normal), (2) Light Orange, (3) Pink, (4) Blue, (5) Albino, (6) Red, (7) Green, (8) Beige, and (9) Brown.

RESULTS & DISCUSSION

Physicochemical Water Monitoring

The ground-water environment was relatively invariant, as shown in comparison plots of hourly means from seven-day sampling events during fall, winter, and spring (**Figures 25-28**). Temperatures in groundwater were constant at around 25 ^{o} C in fall and winter, but fell slightly during spring to about 23 ^{o} C. Both wells and deep solution holes with ground water contact tend to be thermally invariant compared to wetlands and alligator holes. We collected data during a hard freeze in January 2003, when air temperatures in the park fell below 0^{o} C. Thermograph data at one of the surface-water, drift-fence arrays used for sampling fishes reached a minimum of less than 6^{o} C at a water depth of 12 cm. Temperatures in a 1-m deep Taylor Slough alligator pond fell to about 11^{o} C. However, data from groundwater in two deep solution holes showed minimum temperatures from 19-22 ^{o} C. The maintenance of warm water temperatures in groundwater has major implications for the survival of cold-temperature-sensitive species, particularly non-native fishes.

The pH of groundwater changed very little seasonally, always ranging slightly above neutral (7.0) at about 7.3. There were occasional spikes in groundwater pH and specific conductance that appeared to coincide with rainfall events, and probably resulted from inputs of carbonate material washing into the wells in which the sampling units were positioned. However, the changes are generally transient and conditions return to pre-saturation conditions quickly (**Figure 29**). Specific conductance was lowest in spring when rainfall was at a minimum and reached higher levels during the wet season in summer to about 0.4 mS/cm. The percentage of dissolved oxygen was always very low in groundwater, ranging from about 2-5 %. Rarely did measurements exceed 10 % saturation in groundwater. These dissolved-oxygen levels present extremely challenging conditions for the survival of many aquatic organisms.

Ground-Penetrating Radar (GPR)

Results of the geological structure in the area of Long Pine Key (LPK), where cavities were located using GPR, were thoroughly described by Cunningham (2004). In January and April 2001, we drilled monitoring wells at two sites on LPK east of the campground, based on the GPR results. Each well reached a high porosity zone and was cased from the surface to the high porosity zone as follows: during January 16-19, three coreholes (CH) were drilled, two at LPK Site 1 and one at LPK Site 2. At LPK Site 1, the CH1 was drilled to 43 ft near the base of the Fort Thompson Formation and completed open hole from 38.5 ft (the bottom of the hole back filled from 43 to 38.5 ft) to 21 ft. At LPK Site 1, the CH2 was drilled to 48 ft into the top of the Pinecrest Member of the Tamiami Formation (quartz sand) and completed open hole from 42.3 ft (the bottom of the hole back filled from 48 to 42.3 ft) to 28 ft. At LPK Site 2, the CH3 was drilled into the top of the Pinecrest Member to a total depth of 38 ft. Also at LPK Site 2, one monitoring well was drilled with a tricone roller bit to 11 feet. Gamma ray, induction, and caliper logs were collected from the CH1, CH2, and CH3. Digital-optical-image logs and heat-pulse, flow-meter data were collected at CH1 and CH 2. Due to a malfunctioning of the BIPS digital optical imager, CH3 was completed at the end of April 2001, after optical-image logs and heat-pulse flow meter data were collected. Later, several monitoring wells (MW#) were drilled in the same LPK areas, and are described below.

Well specifics*:* Site 1: Monitoring Well 5 (MW 5): 10 feet deep, casing to 7.5 feet, open hole from 7.5 to 10 feet; MW4: 15 feet deep, casing to 10.15 feet, open hole from 10.15 to 15 feet; MW9: 37 feet deep, casing to 17.5 feet, open hole from 17.5 to 37 feet; CH1: 38.5 feet deep, casing to 21 feet, open hole from 21 to 38.5 feet; CH2: 42.3 feet deep, casing to 28 feet, open hole from 28 to 42.3 feet. Site 2: MW6: 10 feet deep, casing to 7.5 feet, open hole from 7.5 to 10 feet; MW7: 10 feet deep, casing to 10 feet, open hole from 10 to 16.25 feet; MW8: 20.9 feet deep, casing to 17.1 feet, open hole from 17.1 to 20.9 feet; CH3: 32 feet deep, casing to 22 feet, open hole between from 22 and 32 feet. The GPS coordinates for the well site are 17R 0529724 and 2811798.

In the Rocky Glades, two formations have been described for the oolitic limestone, the Miami Limestone and the Fort Thompson Formation. These form the Biscayne aquifer in the upper part of the surficial aquifer. In ENP, the Fort Thompson Formation underlies the Miami Limestone, is 3-15 m deep, and thickens slightly from west to east (Fish and Stewart 1991). These formations are composed of five stratigraphic marine units termed from oldest to youngest in time as Q1 through Q5 (Q for Quaternary) (Perkins 1977). Earlier investigations suggested that there was at least one unit of limited groundwater flow within the Biscayne Aquifer (Genereux and Guardiario 1998, Sonenshein 2001), at the top of the Q3 in the Fort Thompson Formation (Genereux and Guardiario 1998). Optical images showed the presence of vuggy porosity areas that may provide habitat in the limestone for subterranean aquatic animals, confirming the information interpreted from the GPR survey output. However, there appeared to be poor horizontal and vertical continuity in the radar reflections from some of the stratigraphic units at LPK (Cunningham 2004), perhaps indicating that conduits for dispersal were not well developed here (Bruno and Perry 2005). Results from sampling for aquatic animals in these and other LPK/L-31N wells are presented below.

GPR output from transects run at the Fruit and Spice Park, where we attempted to trap subterranean aquatic animals with no success, showed little or no evidence of vuggy porosity in the limestone. Output from the Homestead aquaculture facility also showed little evidence for porosities in the underlying limestone, despite our taking a variety of groundwater organisms from that location. However, because of physical structures on the surface, we were unable to deploy the GPR unit precisely at the sites of animal capture. This may indicate that subterranean habitats are very localized and easily missed by GPR or well-drilling.

Video exploration of subterranean wells

A potential method for detecting the presence of aquatic animals in groundwater is through videography. In 2001, we tested a Polaris© B/W infrared Lipstick Camera for video-sampling wells, but it produced images of very poor resolution and we abandoned its use. We also tested a Laval® camera that produced color images of very good resolution. We tested the use of this camera system at the Homestead aquaculture facility, where we were able to observe and record images of eastern mosquitofish (*Gambusia holbrooki*) near the surface of the test well. We also were able to identify several African cichlids near the bottom of the 10-m deep well. These fishes had been washed into this discharge well during fish-farming operations. We also had the opportunity to examine a videotape taken with a similar Laval® camera system in wells in Orlando, FL, from which we were able to identify walking catfish (*Clarias batrachus*) living in groundwater. We also employed the USGS system at LPK wells and wells along L-31N, in which we did not observe organisms. Unfortunately, the USGS camera unit that we hoped to borrow had recurrent technical problems that USGS was unsuccessful in correcting. Borehole-camera surveys have great promise as a technique for recording and identifying larger groundwater animals. We had planned to do timed deployments of the camera for 30 min at the surface and at the bottom of each well, during which time images would be recorded on videotape. The videotape would be watched in the lab and any animal observed would be identified and recorded. We had hoped to use this method as a screening technique to identify wells that housed animals, after which we would then trap in that well to try to capture the animal. When the USGS system failed, our plans also failed because we could not afford to purchase one of these expensive systems.

Sampling hypogean fauna by trapping

We tested several trap designs to capture aquatic animals from groundwater in wells. In trials performed in tanks and wells at the Homestead aquaculture facility, we used baited and unbaited 0.5 L and 2.0 L plastic bottles with the funnel at the top of the bottle, which was suspended vertically in the water column. Bait consisted of a sponge soaked in menhaden-oil chum. We also tested a 2.0 L bottle with a side funnel, and 2.0 L bottles with nylon netting secured to the outside of the bottle to allow crayfish to grasp the bottle more securely. We also tried using small, wire-mesh funnel traps (**Figure 22**), but these proved to be mostly ineffective at capturing fish and crayfish in captivity.

In the captive Miami cave crayfish tank, we performed the bottle-trap tests over 23 trap-nights, and compared the catches of crayfish by standardizing the results to the number of crayfish per trap-night. The highest catch rate was made by the 2.0-L, top-funnel bottle with bait at 5.5 animals per trap night. The next highest rate was with the 2.0-L, top-funnel bottle with netting on the outside, with 4.8 animals per trap-night. The unbaited 2.0-L, top-funnel bottle caught 4.0 crayfish per trap night. The 2.0-L bottles with side funnels, and the 0.5-L bottles had much lower catch rates. Because the netted bottles were more time-consuming to construct, and did not differ much in catch rates from the unnetted bottle traps, we used unnetted traps for subsequent sampling.

We also deployed several bottle traps in wells on the facility. We had previously captured *P. milleri* in those wells with similar traps. In our initial tests, we deployed bottle traps at various depths, with the bottles suspended upwards, downwards or sideways. The tests revealed that upright bottle traps baited with light sticks were the most successful in capturing Miami cave crayfish in wells. Traps containing chum were also successful in luring crayfish, though in lesser numbers. For our subsequent sampling in wells, we therefore used bottle traps with funnels at the top of the bottle, baited with a commercial fish-oil attractant and a cold-light (Cylume) source to maximize the potential for animal captures. The wells at the facility housed a few eastern mosquitofish that were also captured by the bottle traps. Because one of our objectives was to test for the presence of subterranean fishes in south Florida, we decided this trap design would serve to capture both fishes and macroinvertebrates.

We also tested the use of the substrate trap for capturing smaller-bodied animals by providing a large amount of cover for them. In the testing of designs, a prototype of the substrate trap was left in the cave crayfish tank at.the facility. After several days, no crayfish colonized the substrate material, probably because most were too large for the trap, but a large number of *Hyalella azteca*, a common amphipod, did take up residence. Therefore, we decided to use this method in wells to collect smaller macroinvertebrates and perhaps juvenile Miami cave crayfish.

We sampled many of the same series of wells using bottle and substrate traps that Dr. Cristina Bruno sampled (for microcrustaceans) in western Miami-Dade County and the Park (Bruno and Perry 2004, 2005). We also continued occasional collections in the aquaculture facility wells. We began to deploy the substrate sampler in the fall of 2000. We set and pulled both bottle and substrate traps in the wells, neither of which contained any visible macrofauna. In the first year, we placed the tethered trap at the bottom of a well to sample undisturbed for one month. Because few animals colonized the trap after one month of sampling, we changed deployment time to six months before retrieval. When we retrieved the trap, the filter material was removed, cut into sections, and immersed in alcohol. The trap was fitted with fresh material and redeployed. After storage in alcohol, we sorted the filter material for microcrustaceans. In 2001, we sampled in some wells that were located using Ground-penetrating radar (GPR) in the Long Pine Key area in 2001 (see GPR section below). In 2002, we continued to sample these sites and also sampled in wells within the pineland along Research Road. Substrate traps were deployed again in 2003, but we reduced the sampling effort because our collections were not yielding many animals and because unseasonable weather conditions required us to increase our sampling efforts in solution holes and drift fence arrays.

Bottle-trap samples from wells on the coastal ridge near Homestead and Miami produced records for a sightless species of undescribed *Crangonyx* amphipod (identified by Dr. Tom Bowman of USNM), a subspecies of *H. azteca* (identified by Dr. Gary Wellborn, Oklahoma State University), isopods of the genus *Caecidotea*, and other invertebrates. Densities of most were low. Samples from wells in and near ENP from bottle and substrate traps produced very few organisms, most of which appeared to be surface-water species that entered groundwater (**Table 7**). These species are considered to be stygoxenes, animals that occur accidentally in groundwater but have no special adaptations to that environment. They may be washed into wells during rain events and survive for a time below ground. A good example of that were the collections from Pine Glades Lake (PGL-**Table 7**) well, located in a pineland that periodically floods. Those samples had high numbers of aquatic invertebrates, and this was the only well in which we captured *Palaemonetes paludosus*, the riverine grass shrimp (24 January 2001). We believe that those species entered the well when the surface was temporarily flooded, particularly because we found aquatic insect larvae and adults, which are rarely found in groundwater. Aquatic insects are replaced by aquatic crustaceans as the major invertebrate group in groundwaters around the world.

We did not collect any species like the unusual amphipods from the coastal ridge in the ENP wells. Bruno and Perry (2005), in their ENP well samples, collected copepods mainly at the surface/groundwater ecotone, and detected a sharp decline in species richness with increasing depth into groundwater. They attributed the decline in species richness of copepods to low oxygen concentrations known to be limiting to invertebrates (Danielopol and Niederreiter 1987). Our physical data confirm the hypoxic conditions in ENP groundwaters. Bruno and Perry (2005) stated that the different permeability of limestone layers reported by Cunningham (2004) probably affects the local functioning of the entire subsurface habitat by reducing the exchange of oxygen and resources from the surface into the depauperate groundwater environment. They also believed that because densities of groundwater populations of copepods are low in ENP, they are at risk of being affected low groundwater levels during the dry season or reduced surface inundation during the wet season which could result in reduced dispersal, increased populations isolation, and habitat fragmentation. Our findings of low numbers of species and individuals of aquatic invertebrates in ENP wells support the general pattern described by Bruno and Perry (2005).

We were unsuccessful in trapping fishes in wells, except for the accidental releases at the aquaculture facility. We postulated that, because of the geological affinities of southern Florida and its karst to other locations around the Caribbean basin (Cuba, Yucatan, Bahamas) that have endemic blind fishes of the family Bythitidae (the viviparous brotulas), that it was possible that a member of this family might have adapted to groundwater here. Based on our questionnaire distributed to well drillers and farmers outside ENP, we received several anecdotal reports from local residents of blind white shrimp and fish in wells. There is also a written account of blind white fish being uncovered during excavation for a road bridge on the coastal ridge (Taylor 1986). In total, we have gathered five verbal or written accounts of high quality from people who have seen blind white fish from Atlantic Coastal Ridge groundwater. Unfortunately, we were unable to confirm those reports with collections. Some of the locations were on private property to which we could not gain access. Also, our trapping method may not be suitable for species of this family which, elsewhere in the Caribbean, have been collected by scientists entering caves and netting individuals. Trapping in wells also has a low chance of success in that the well would have to be positioned precisely over the fish's habitat in order to capture it. The existence of subterranean bythitid fishes beneath south Florida remains to be confirmed, but the evidence is tantalizing.

Life history and distribution of Procambarus milleri: In addition to collecting the aquatic invertebrates described above, we employed the same methods along with pumping and contacting landowners, to gather records on the distribution of the Miami cave crayfish. As was the case for other invertebrates, we collected no specimen records for *Procambarus (L.) milleri* from the 19 wells in ENP, or from the 15 wells along the Park border (**Figure 24**). There may be differences in the connectivity of subterranean habitats beneath ENP and areas to the east on the Atlantic Coastal Ridge where populations are known to exist. From sampling, and as a result of contacts with landowners along the coastal ridge, we confirmed the presence of *P. milleri* at 12 new locations, all of which were located east of ENP (**Figure 24**). Specimens were taken only by baited bottle traps in wells, and by dip netting at the most recent location. We took many specimens at the Homestead aquaculture facility before this study began (Radice and Loftus 1995), and these formed the basis for the captive population that we studied here. We measured the environmental conditions in the wells in which we trapped the crayfish, and found low dissolved-oxygen levels (**Figure 29a**), similar to those in wells from ENP (**Figure 26**)

While most of our records for *P. milleri* came from wells that penetrated the Fort Thompson Formation, usually at about 7-10 meters deep, the last population we located occurred in two pits 25-m apart in groundwater that had been exposed by scraping away the surficial limestone with a backhoe. The water depth was only 2.41 m below the ground surface, in a very porous section of Miami limestone. The owner stated that, although the pits were dug in 2001, he did not observe crayfish there until 2003.The crayfish could be seen crawling on the bottom and sides of the two pits, and they freely moved in and out of sight into crevices in the limestone. Because of the proximity to the surface, water in the pit had higher dissolved oxygen levels than in groundwater in other wells we sampled (**Figure 29b**). The pH and specific conductance measurements were more variable towards the end of the sample period when rainfall apparently washed limestone material into the pit. We collected a total of 33 *P. milleri* from one of the pits on three trips to this site. Mean carapace length ($\pm$ 1 SD) was 18.9 (6.3) mm. Twenty animals were females, eight were Form I and three Form II males, and two were juveniles. All were normally colored, and no female was gravid. We marked captured animals on the first two trips by cutting the left (14 marked) and right sides (12 marked) of the uropod, respectively. Two weeks after the first visit, we captured 13 animals, of which five were marked. Three weeks later, on the final visit, we took two marked animals from the first visit and three marked animals from the second visit. The number of recaptures indicates the presence of a sizable population, with some animals that reside in the local area. This location offers a good opportunity to study a large wild population of this endemic species, which would complement the data we have collected from the captive population.

Captive population - Coloration: In describing this crayfish from preserved material, from which the pigment had been completely bleached, Hobbs (1971) may have erred in stating “Body without pigment”. The lack of pigment caused him to assume that in life the integument was translucent white. In his defense, however, he may have received albino specimens, which although rare, do occur in this species. The first statement of the "Diagnosis" of the species provided in Hobbs (1971) should be amended to "Body normally pinkish to brick red, eyes large and with black pigment confined to small faceted, distal disc".

The eye spot is black. The normal coloration of specimens larger that 10 mm CL is a carapace that is vermilion with rostral margins and lateral spots/splotches of pale pink, and the gastric and posterior hepatic region suffused with brown. The abdomen has a broad, brick-red median longitudinal stripe extending from base of first abdominal segment onto sixth, and the stripe narrows gradually posteriorly. The telson and uropods are pink to dark pink. Cheliped has the dorsal parts of merus and more distal podomeres dark pink but fading over the length of finger to pinkish cream; tubercles and spines are pinkish cream; ventral surfaces of podomeres pinkish cream to white. Remaining pereiopods pale pink dorsally, darkest on merus, and almost cream (some podomeres with pink blush) to white ventrally.

Approximately 82% of the 2,451 captive-reared crayfish collected had the normal dark orange coloration with a red stripe on the dorsum of the abdomen (**Figure 30a);** almost 9% had a lighter orange coloration (**Table 8**). In 1994, while inspecting juveniles in the captive tank, several were found to be albinos. Of 150 individuals examined at that time, 15 were albinos, with no pigment at all, even in the eye stalk (**Figure 30b**). Unfortunately, an unidentified disease struck the rearing tank, and the albinos disappeared from the captive population. None has been recorded since 1995. Observation of colored juveniles just released from the eggs show the red pigment present in cromatophores on the cephalosome and abdomen (**Figure 30c**), as well as lipid globules on the cephalosome.

This is the third stygobitic crayfish that exhibits pinkish to reddish pigments, and one of the only ones with pigment in the chromatophores. Specimens of *Procambarus (O.) orcinus* Hobbs and Means (1972) were described as having a pinkish-orange coloration. However, some isopods from the same cave system also were colored and, since "the pigmented crayfish emitted an orange-colored fluid from their mouths when placed in formalin" (Hobbs and Means 1972), it may be that the pigment was not confined to chromatophores but was acquired from a food source. Such a conclusion, however, would hardly explain the reddish pigment associated with the eye spots. *Procambarus (O.) erythrops* Relyea and Sutton (1975) is the only other crayfish reported to exhibit reddish pigment, where it is confined to the eye. In neither of those crayfishes, which are much lighter in color than *P. milleri*, was pigment observed in chromatophores.

Species biology, size structure, fecundity, and life history: The water temperatures in the crayfish tank were quite constant, ranging between 19.72 and 26.12 °C ($\pm$0.94 °C) (**Figure 31**), similar to the average groundwater temperatures that range from 22-25° C year-round (**Figures 25 & 29**). We assembled records for 2,451 crayfishes during the three years of monthly sampling of the captive population: 1,023 females, 832 males, and 596 juveniles.

The largest Form I male described from the first wild population discovered was 13.8 mm CL and the smallest, 8 mm CL (Hobbs 1971). The largest Form I male in wild collections from our sampling was 27.4 mm CL and the smallest, 16.2 mm CL. In samples from the captive population, the smallest Form I male recorded was 10.4 mm CL and the largest was 29.3 mm CL. The smallest ovigerous female was 16.0 mm CL, but the mean carapace length (±1 s.d.) of ovigerous females was 22.3 (2.6) mm. The largest female sampled was 29.3 mm CL.

We calculated a carapace length to total length regression relationship using untransformed data from 36 adult animals ranging from 10.9-30.9 mm CL. The equation describing the relationship was Carapace Length = 1.54 + 0.45 (Total Length), $r^2 = 0.90$.

In the captive population, the mean size of males and females did not differ (**Figure 32a**), unlike many other crayfish species that exhibit strong sexual dimorphism. We analyzed the sizes of crayfish larger than 10-mm rostrum-carapace length to test for differences in lengths between males and females. There was no significant difference in the carapace lengths of males versus female Miami cave crayfish (t-test with unequal variances, t = 1.808, df = 906.7, P = 0.071; 401 males with mean (±1 s.d.) = 18.8 (4.3) mm CL, and 547 females with mean (±1 s.d.) = 19.3 (4.7) mm CL. Gravid females were larger than non-gravid females, with an average difference of 0.34 cm (**Table 9**). Form I males, were smaller then gravid females, with an average difference of 0.15 cm (**Table 9**).

We examined 1023 females from the captive population over a period of 3 years, and 80 were gravid, representing 8% of the total number of females examined (**Figure 32c**). Gravid females were carrying eggs (63 females, 78% of the total), eggs at a late developmental stage so that eyes were visible (10 females, 13% of the total), or larvae (7 females, 9% of the total). Gravid females were present every month, with few exceptions (**Figure 32c**); they were more abundant in January-March **(Figure 32c**). Of the 832 males, 450 (54% of total males) were Form I, 352 (42% of total males) were Form II, and 30 (4% of total males) were not classified, and will not be considered in the following summaries. Data from February 2000 will not be used either, because all 20 males collected that month were not identified as developmental stage. Form I males were present every month, with peaks in abundance generally in summer through winter. Juveniles were present during every month, but their abundance peaked in late summer-early winter every year (**Figure 32b**). These data suggest continuous reproduction throughout the year, although there may be greater reproductive effort from late summer to the beginning of winter.

Eggs were black (**Figure 23**), with a mean diameter (±1 s.d.) of 1.86 (0.38) mm (n = 37 females). A few red or orange eggs were sometimes present, but were probably infertile or unfertilized. The mean number (± 1 s.d.) of eggs estimated from ovigerous females was 50.5 (21.1). The largest number estimated from any female was approximately 100. Larvae, when released by the female ranged from 2.54 mm to 3.55 mm in CL, with a mean (±1 s.d.) CL of 2.86 (0.36) mm (n = 21). Larvae released by a single female varied by as much as 0.91 mm in CL. At release, the eyes have black pigment, and there is a patch of orange pigment on the cephalothorax (**Figure 30c**).

We found little relationship between the number of young released with the estimated egg numbers for a female. The number of larvae counted at release varied from 4 to 110, with a mean (±1 s.d.) of 46 (30). The correlation between the number of eggs or larvae estimated on the live female and the number of larvae released was poor (Pearson's r = 0.19). It was difficult to accurately count the eggs because they are clumped in layers on the pleopods. In some cases, more young were released than expected from the estimated egg count, while in many cases, fewer young were dropped. The latter situation probably resulted from mortality during development, and cannibalism upon release by the female.

We calculated the regression relationship of the number of eggs to the female's carapace length using untransformed data from 66 females for which egg number had been counted, and for an additional 32 females with estimated egg counts. The equation describing the relationship was $y = 30.776x - 17.29$; $R^2 = 0.0742$. For 48 of the females with eggs, we were able to count the amount of juveniles released. We calculated a number of young released to number of eggs regression, and the equation describing the relationship was $y = 0.3838x + 19.635$; $R^2 = 0.0544$.

We are uncertain how often an individual female may reproduce each year. We attempted to determine this at the aquaculture facility in 2004 by isolating nine females, allowing them to drop the young, then introducing males into each tank for breeding. In at least three cases the male killed the female, and in one case the male was killed. We found that females molted within two to three weeks after releasing the young. The females often mated shortly after molting, usually within one to three days after we introduced males into their tanks. Once mating was observed to have occurred, we removed the male and observed the female for oviposition. One female mated on 10 July 2004, produced eggs on 13 August 2004, but the eggs disappeared before they hatched. A second female produced two broods in the summer of 2004. She released one group of 82 young on 10 June, mated again on 6 August, produced eggs on 6 September, and released 27 young on 27 September. Time between egg deposition and release of juveniles was 21 days at 24^{o} C. A third female mated on 25 January 2005, produced eggs on 14 March 2005, but the eggs disappeared. A fourth female, 24.6 mm CL, also mated on 25 January 2005, produced eggs on 1 March 2005, and released 64 young on 29 March 2005. Time between egg deposition and release of juveniles was 28 days at 24^{o} C.

Compared to the closely related Everglades crayfish (*P. alleni*) (Hobbs 1971), the Miami cave crayfish produced fewer and larger eggs. Rhoads (1970) reported that young of *P. alleni* would remain attached to the female's pleopods for as long as possible, up to 45 days in captivity, even reattaching to her when she returned from independent activity. However, young were able to survive independent of the female much sooner. From a sample of 55 females with eggs or young, he found that the mean egg number was 230, and the mean number of larvae carried was 175. From records in the U.S National Museum, egg counts (female size) from three Florida specimens of *P. alleni* were 531 (34.6 mm CL), 261 (30.2 mm CL), and 215 (28.0 mm CL). Egg diameters ranged from 1.1-1.7 mm. Life-history theory would predict that the Miami cave crayfish, living in presumably food-resource-limited subterranean waters, would produce larger and fewer ova than congeners inhabiting surface waters.

Like all stygobitic crayfishes in Florida, the Miami cave crayfish is found in carbonate rocks but not all aquifers in those rocks are inhabited (Franz and Lee 1982). Although the exact extent of the Miami cave crayfish range is difficult to determine, it is likely to coincide with a specific geological structure. *P. milleri* has been collected mainly in wells that penetrate through the Fort Thompson formation of the Miami oolitic limestone. That formation in the study area ranges from about 5-10 m beneath the land surface. The Biscayne aquifer is an eogenetic karst aquifer, i.e. it is young limestone (generally not older than Quaternary) undergoing shallow, meteoric diagenesis (Vacher and Mylroie, 2002), that results in a dual porosity system consisting of matrix and conduit porosity. The movement of groundwater in the karstic Biscayne aquifer is both counduit and diffuse-carbonate groundwater flow. In a recent study Cunningham et al. (2004) characterized the upper part of the Biscayne aquifer in north-central Miami-Dade County (corresponding to the northern limit of our sampling area) as highly heterogeneous, and mostly constrained to secondary permeability caused by dissolution features (enlargements of depositional textures, bedding planes, cracks, and root molds), causing a non-uniform groundwater flow. The presence of semi vertical and irregular pores in the limestone at the base of the Miami Limestone to the top of Fort Thomson Formation provide flow through a small-scale network to a depth of about 1-6 m below ground level (Cunningham et al., 2004). Beneath this layer, a low permeability layer extends to a depth of about 4-8 m, followed by another deeper higher permeability layer that spans to a depth of 5-12 m.

The differential structure of this limestone matrix and associated presence of cavities could explain the patchy distribution of *Procambarus milleri*. Although juveniles might be able to crawl through the cavities, adults are likely restricted to larger cavities. *Procambarus milleri* has been collected in wells spanning from 9 to 2.5 m depth, and appears able to move through the voids to reach different levels in the aquifer. Several specimens were recently collected in the shallow aquifer, which represents the surface-water and ground-water interface sites, where hydraulic exchanges are intense. The biogeochemical activity at these interfaces is higher than in neighbouring surface- and ground-water systems (Gibert et al. 1997), and provides more trophic resources for groundwater organisms, and higher oxygen content (Strayer, 1994). The surface- and ground-water ecotones usually sustain highly diverse communities (Danielopol et al. 1997). A restricted distribution such as the one recorded for *P. milleri* is not unusual. It is generally acknowledged that specialized groundwater invertebrates have much more restricted distributions than their epigean relatives, and populations densities are usually very low when compared to epigean ones (Strayer, 1994). Thus, the lack of collections in some wells we investigated might be due to the low chances of effectively collecting in the right point in space and time when specimens are present. We also recognize that our sample results are conservative in detecting the presence of this animal because, from 21 samples taken from the active well at the aquaculture facility, we collected only three animals and a recapture. These factors make locating and capturing the Miami cave crayfish more difficult than collecting species elsewhere in Florida where stygobitic crayfishes appear to be more abundant, and may be detected and studied by divers working in cave systems.

The captive population provided useful information on the biology, size structure, fecundity, and life history. In view of the few wild-caught specimens that have been collected, those data could only be acquired from the captive population. Many animals taken from wells have been smaller than captive animals, and we recognize that thecaptive animals represent the maximum potential for size, growth, and fecundity for this species because of the comparatively rich food resources they receive.

The strong affinities between *P. milleri* and *P. alleni* were pointed out by Hobbs (1971) on the basis of the similarities between the first pleopods of the males, which have a combination of characters which exists in no other crayfishes (Hobbs, 1971). The affinities were due to the common ancestry (Hobbs, 1971). According to Caine (1974), *P. milleri* originated from populations of an ancestor similar to *P. alleni*, which "burrowed in the subterranean habitat…or entered through exposures of the oolitic limestone", followed by isolation from the surface habitat. According to Caine (1974), *P. milleri* is not as old as the other troglobitic procambarids collected in Florida, as shown by the remains of pigment and faceted eye, and Caine (1974) suggested that the isolation process may have occurred when the aquifer was lowered in southern Florida in the 1920s. Hobbs et al. (1977) agreed that these two crayfishes share a common ancestry, but they disagreed on the isolation of the two stocks from only approximately 50 years. Geologic (Hoffmeister 1974) and zoogeographic patterns indicate that the most recent submergence of south Florida occurred about 100,000 years BP (see Franz and Lee, 1982, for review). Although all of southeast Florida was submerged at that time, in later times, a narrow strip of the coastal ridge served as a refuge for freshwater and terrestrial species. Southeastern coastal Florida and the Florida Keys (Neill 1957) (including the area inhabited by *P. milleri*) hosts numerous races and/or disjunct populations of terrestrial vertebrates, suggesting that some type of refuge persisted in this region for a long period. This evidence suggests that *P. milleri* must have appeared long before the 1920s (Franz and Lee, 1982).

The recent origin of the subterranean populations of *P. milleri* is suggested by its pigmentation pattern, which indicates a stygobization process still in process. The reproduction in *P. milleri* takes place continuously during the year, as opposed to *P. alleni*, which lives on the surface and reproduces mainly at the end of the dry season (Acosta and Perry 2001; Loftus, personal observations). Fecundity in *P. milleri* is lower than that reported for *P. alleni*. All these morphological and physiological features suggest that the population of *P. milleri* is in the process of adapting to subterranean habitats; they are probably best classified as stygophiles (epigean organisms that occur in both surface water and ground-water without adaptation to subterranean life (Gibert et al., 1994)), and will attain the stygobite (specialised subterranean forms, obligatory hypogean (Gibert et al. 1994)) status if the populations continue being isolated in the groundwater system.

In conclusion, the Miami cave crayfish is adapted to life in conditions that would be difficult for most aquatic organisms, particularly surviving in darkness with low dissolved-oxygen concentrations (**Figure 29**). Based on our data, this uncommon subterranean crayfish is restricted to southern Miami-Dade County, mainly on the Atlantic Coastal Ridge. It appears to mainly inhabit the highly porous interstices of the Fort Thompson formation, although the recent collection of animals from Miami limestone is the first from that formation. The small numbers and limited range of the Miami cave crayfish make it vulnerable to human activities that destroy or pollute its groundwater environment, including withdrawal of water from the aquifer by pumping, degradation of water quality, and limestone removal.

III. SHALLOW SUB-SURFACE REFUGES

METHODS

Physicochemical water monitoring

We used several YSI-600 devices to take continuous measurements of physico-chemical conditions for one-week periods in different seasons at solution-hole sites (see **Table 2** for a summary of when and where units were deployed). We calibrated each unit prior to deployment, and if consistently out of range, the unit was returned to the factory for repair. After retrieving the units, we uploaded data to a PC and used EcoWatch© to transform raw data onto a spreadsheet. During the dry season, we used a hand-held YSI 556 unit to collect discrete readings of temperature, specific conductance, pH, and dissolved oxygen in the solution holes. To ensure their precision and accuracy, the units have been tested simultaneously in a variety of conditions and environments. Additionally, we deployed continuously recording thermographs in solution holes to collect water temperature over periods of several months through the year to compare data among habitats.

Faunal sampling

In the winter of 2001, we began sampling solution holes in the Rocky Glades region using un-baited, 3 mm-square, wire-mesh minnow traps (Gee-8 double-funnel traps). Tests of the effectiveness of baited vs. unbaited traps showed no significant differences in catch, fish size, or species composition (J. Kline, ENP, Personal Comm.). Holes were located in four principal areas in the Park: along Pa-Hay-Okee Road, Main Park Road, Context Road, and Wilderness Road **(Figure 33)**. The solution holes at those sites varied from shallow, isolated depressions to deep, karstic complexes. Solution holes were sampled during dry seasons, soon after surface-water sites dried. Data analyses focused on samples collected from 10/04/02 – 07/23/04, because data from earlier sampling were inconsistent and exploratory. Samples were collected weekly from 10/04/02 – 11/22/02 and 10/24/03 – 07/23/04, and bi-weekly from 10/22/02 – 05/23/03 (24-h soak time). One minnow trap was deployed in each solution hole and fished for 24 h. Upon retrieval of the traps, we identified and enumerated all fishes, and recorded the standard length (SL), mass, and gender. All fishes were returned alive to the hole in which they were captured.

Data analysis

Solution-hole hydrology: We examined average water depths in solution holes, and the proportion of time flooded, using ANOVA. We calculated average water depth in each hole in each of the two dry seasons (excluding site visits when hole was dry), and used a two-way crossed ANOVA to compare depth between dry seasons and depth categories. We then used a one-way ANOVA to compare the relative proportion of the dry season that holes contained water (number of visits when water depths exceeded 0 cm, divided by the number of visits) at shallow, medium, and deep holes in the 2002-2003 and 2003-2004 dry seasons.

Spatial and temporal patterns in fish-community structure and abundance: Patterns in fish-community structure and abundance were examined in shallow (0-40 cm maximum depth), medium (41-80 cm maximum depth), and deep (>80 cm maximum depth) solution holes in the 2002-2003 and 2003-2004 dry seasons (**Table 10**). ANOSIM (from standardized Bray-Curtis dissimilarity matrix) was used to compare fish community structure across dry seasons and depth categories, and SIMPER (similarities percentage breakdown analyses) was used to determine which species were responsible for observed variation. ANOVA was then used to delineate patterns in common-fish species abundance (CPUE) and relative abundances. CPUE was $\sqrt{y}$ transformed and relative abundances were arcsine ($\sqrt{y}$)-transformed to satisfy assumptions of normality.

Impact of physicochemical conditions on non-indigenous fish species: We examined variation in the relative abundance of non-indigenous species in solution with an ANCOVA, testing the effect of sampling years (2002-2003 and 2003-2004 sampling seasons), region (Main Park Road East, Main Park Road West, Wilderness Road, and Hidden Lake), depth category (shallow, medium and deep solution holes), and interactions. Relative abundances of non-indigenous species (CPUE of all non-indigenous species divided by total CPUE of minnow trap) were log-transformed (logarithm of observed value +1) prior to analysis. We examined the effect of physicochemical conditions on the relative abundance of non-indigenous fishes (dissolved oxygen, specific conductivity, temperature, and pH) with principal components analysis (PCA), using the first two principal components that accounted for 95 % of the variation in the physicochemical data, as covariates in the ANCOVA.

RESULTS & DISCUSSION

Solution-hole Physicochemistry and Hydrology

Although the physicochemical environment of solution holes in the Rocky Glades was more variable seasonally than that in groundwater wells **(Figures 25-28)**, the variation is not as marked as in surface habitats of the Everglades (Loftus and Kushlan 1987). Conditions also change on a diel basis (**Figures 34-37**), and is likely the result of the physical and biological characteristics of individual holes which can be quite different (**Appendix 2**). Water temperatures ranged about 7^{o} C through the year and were relatively stable through the diel cycle (**Figure 34**). Measurements of pH were above 7.5 in fall and winter, as expected in a karst environment, but dropped to a mean below 7.0 in the spring (**Figure 35**). We attribute this to production of CO_2 and other metabolites by the fishes and other aquatic animals confined to the holes at that season, which would lower the pH. Coincident with the drop in pH in the spring, dissolved-oxygen levels also fall from fall, through winter, to spring (**Figure 36**), again the result of poor water exchange and high bioload of aquatic animals in the holes. Specific conductance in the holes increased from fall to winter, but declined in spring (**Figure 37**). This pattern was unexpected because high numbers of aquatic animals excreting in these small-volume holes with little exchange of water ought to cause a rise in specific conductance. The highest levels of specific conductance in Everglades freshwaters was reported by Loftus and Kushlan (1987) from dry-season alligator holes in which large numbers of fishes and other animals sought refuge from drying.

The dissolved-oxygen concentration recorded in this environment was very low in the spring, suggesting that animals must be tolerant of low dissolved-oxygen tensions to survive. Additionally, ammonia levels are often very high in solution holes in the dry season (Liston et al. unpublished data), further stressing the fishes. Also, the extreme variations in depth that occur on a seasonal to daily basis create a challenging situation.

Dry-season rainfall in 2000 was lower than the long-term average in 2000, while wet-season rainfall was slightly above normal (Ahn 2003). Although 2001 dry-season rainfall was lower than normal, wet-season rainfall was very high (Ahn 2003). Flooding patterns in 2001 differed from 2000, with rains arriving later in the wet season delaying the flooding of the marshes. Although rainfall in the winter and spring of 2002 were near normal, groundwater levels in the spring fell well below the levels of 2001. Surface water returned to the westernmost regions of the Rocky Glades in late May (**Figure 3**). There were no reversals during the summer so the area was continuously flooded until August. There were no tropical-storm events in the late summer or fall of 2002 to bring extra moisture to the region. Coupled with pre-storm drawdowns from September to December, most of the Rocky Glades lost surface water several months earlier than in previous years (**Figure 3**). Early winter rains brought back surface water for a short period, but then the area dried rapidly. Water in solution holes in the 2003-2004 dry season was significantly deeper than that of the 2002-2003 season ($F_{1,65} = 6.81$, $P = 0.011$). Average water depths in shallow, medium, and deep solution holes varied significantly ($F_{2,65} = 63.34$, $P < 0.001$) and as expected (average depths (cm) ± SE: shallow = 20.70 ± 2.41, medium = 33.82 ± 1.84, deep = 57.03 ± 2.02). We saw significant variation in the proportion of visits to solution holes of different depth categories held water in the 2002-2003 and 2003-2004 dry seasons (02-03: $F_{2,29} = 16.01$, $P < 0.001$; 03-04: $F_{2,37} = 13.75$, $P < 0.001$; **Figure 38**). In the 2002-2003 dry season, shallow solution holes held water for significantly less time than medium and deep holes (Tukey's pairwise comparison: $P < 0.001$), which were not different from each other. In the 2003-2004 dry season, shallow and medium solution holes (which were not different from each other) held water for significantly less time than deep solution holes (Tukey's pairwise comparison, $P < 0.001$).

<u>Spatial and temporal patterns in fish-community structure and abundance</u>

Temporal-sampling narrative: We sampled several holes throughout the 2001 dry season and collected fishes in most holes (**Tables 11-12**). In 2001, fishes entered the holes as surface water disappeared from the wetlands. Those in shallow holes expired when the holes dried, but the deepest holes retained water and fish through most of the dry season (**Table 13**). We concluded the solution-hole sampling for the 2001 dry season with a final sample at the end of June/beginning of July (**Table 13**). These fishes had probably been on the marsh surface while it was flooded in early June and had retreated to solution holes when the wetlands dried in mid-to-late June. Of all non-native fishes captured, most were taken in deep holes. Alternatively, most native fishes came from holes less than or equal to 126 cm. Invertebrates also showed a strong negative relationship with hole depth; 62.9% of crayfish and prawns were captured in holes less than or equal to 126 cm. Of all non-native fishes captured, 76.19% were from holes greater than or equal to 130 cm deep; 57.14% from holes 100-130 cm deep, and 0% in holes less than 100 cm. Alternatively, the proportion of native fishes from holes less than or equal to 126 cm was 85.24%; 54.55% being from holes 126 cm deep, and 26.14% from holes 50 cm deep. Introduced fishes were most prevalent in samples from holes in the eastern area of the Rocky Glades and were less commonly collected from holes farther west

By hiking and flying in the 2001 dry season, we located many extensive and deep solution-hole complexes along the north face of the Pa-Hay-Okee tree island and along Pineland road between gates 9 to 11. The complex along the north face of Pa-Hay-Okee hammock was the most interesting, consisting of dozens of large interconnected holes that held water through the dry season. Qualitative dip net/minnow trap samples and visual observations showed the presence of all species of fishes and invertebrates taken in the Rocky Glades arrays. We also observed adult *Lepisosteus platyrhincus* (Florida gar), centrarchids, *Ameiurus natalis* (yellow bullhead) and various cichlids, although the size of the trap opening (23 mm diameter) prevented capture of some of these species. Many alligators and turtles were also present. This area appeared to serve as an important regional aquatic refuge. Some holes were >1 m deep and clear water indicated sub-surface flow. We continued to sample this complex of holes in 2002-2003, finding that all major fish species that occur in the Rocky Glades took refuge here in the dry season. Although it was not possible to estimate population sizes for those species, our impression was that these holes could not have held the numbers of fishes that colonized our surface traps in the Rocky Glades in the wet season. Although this location may provide some of those early colonists, we feel that additional refuges, probably in Shark River Slough and its downstream drainages, contributed greatly to that colonization.

In 2002, the low groundwater levels in the spring resulted in complete drying by early May of all holes monitored. Groundwater levels declined gradually until April when the rate of decline increased (**Figure 3**). Holes that had fishes surviving within dried quickly and high fish mortality resulted. Water levels in the holes rose rapidly in mid to late May, but too late for most fishes.

In the fall of 2002, water intended for release into the Park was diverted to the oceans in anticipation of a tropical weather system that never made landfall. This, compounded by a drier than usual fall, resulted in reductions to groundwater levels without recharge earlier than under normal conditions. Because of the low-water conditions in the fall of 2002, fishes entered the solution holes months earlier than usual and were trapped there until the unseasonable spring rains of March and April 2003. Following the March rains, there were few fish in the solution holes, but the pulse in water level allowed a few individuals to recolonize the shallow holes by May. We have observed that under an extended dry season, shallow and medium holes tend to dry, leaving only the deepest holes inundated. These deep holes support all fishes inhabiting them in the early dry season, but during the dry period, predatory fish in these holes reduce the numbers of other fishes (2004 observations). Further, these holes become very harsh environments for fishes late in the dry season, with mainly yellow bullhead and introduced species (Kobza 2004) capable of surviving in low-dissolved oxygen conditions. This observation was not as pronounced in the 2003 data, but that, likely, was due to the fluctuating water levels during the spring months. In 2003, fishes periodically moved onto the marsh surface during the spring floods, but retreated to solution holes as water levels dropped. This explains the occurrence of fishes in shallow solution holes late in the dry season, when these holes would otherwise be dry and devoid of aquatic life. We sampled 32 holes throughout the Rocky Glades (**Figure 33**) throughout the dry season of 2003, collecting fishes until water reached the surface. The reversals of drying in April and May caused us to alternate sampling in solution holes and surface habitats. We stopped sampling holes in late May 2003. However, when dry conditions in July occurred, we placed traps in solution holes in the eastern part of the Rocky Glades until rain in mid-August flooded the area. The region stayed flooded until late October 2003, when we again began solution-hole sampling. We added eight more holes in the dry season of 2004, and continued collections weekly in holes until summer 2004. These holes ranged in depth and complexity, with the most complex holes having submerged vegetation and irregularities in the limestone (**Appendix 2**).

Overall, we collected 1,939 fish from the solution holes in 2003. We calculated relative abundance of the shallow, medium, and deep holes both prior to and following the wet season in 2003. The medium and deep holes had the greatest species richness both before and after the wet season. However, species composition changed between the two time periods. By the end of the dry season, four species remained in the shallow holes. These were all small-bodied species: marsh killifish (*Fundulus confluentus*), eastern mosquitofish, flagfish (*Jordanella floridae*), and golden topminnow (*Fundulus chrysotus*). In the months following the wet season, richness in the shallow holes increased to 16 species, with the same four species being the most abundant (**Table 14**). Prior to the wet season, dollar sunfish (*Lepomis marginatus*), sailfin molly (*Poecilia latipinna*), pike killifish (*Belonesox belizanus*), eastern mosquitofish, and black acara (*Cichlasoma bimaculatum*) were the most abundant species in the medium holes (**Table 14**). Following the wet season, species composition changed with African jewelfish (*Hemichromis letourneuxi*) comprising over 25% of the fishes captured, and small fishes including mosquitofish, flagfish, marsh killifish, and sailfin molly being the next most abundant. A mixture of small and large species occupied the deep holes prior to the wet season. Again, this likely demonstrates the periodic usage of solution holes by fishes migrating onto the marsh surface and retreating back to solution holes as the water levels fluctuated during the spring months. As with the medium holes, African jewelfish were the most abundant fish captured in the deep holes following the wet season, comprising nearly half of the catches in these habitats. Dollar sunfish, black acara, sailfin molly, and yellow bullhead (*Ameiurus natalis*) were the next most abundant species collected in the deep holes in the later months of 2003. The prevalence of African jewelfish in Rocky Glades habitats is interesting given that this species has only occupied this ecosystem since summer of 2002.

In contrast to observations made in the field season of 2004, non-native species were rarely the most abundant fishes collected in the solution holes prior to the wet season of 2003 (**Table 15**). Conversely, relative abundances of non-native fishes dramatically increased after the wet season, particularly following the November flood event. These abundances were greatly influenced by large catches of African jewelfish in the medium and deep holes in December 2003 and January 2004.

Examination of species compositions in solution holes near Hidden Lake (**Figure 33**) revealed few fishes present prior to the wet season, but those fishes that were present consisted of mosquitofish, marsh killifish, and dollar sunfish. The Hidden Lake solution holes remained flooded for most of the wet season. In January 2004, when these holes became isolated, CPUEs of fishes increased compared to the months before flooding. Shallow and medium holes had the most fish and were dominated mainly by mosquitofish, marsh killifish, and flagfish. Few fishes were collected before the wet season, but the catches increased afterwards with African jewelfish dominating the catches in deep and medium holes.

Fish-community patterns: Analyses of solution-hole fish inhabitants between the dry seasons of 2002-2003 and 2003-2004 focused on 11 common fish species (incidence ≥ 5%). Two-way crossed ANOSIM revealed significant variation in community structure between dry-seasons (Global R = 0.247, P=0.001) and the depth categories (Global R = 0.247, P = 0.001). Because variation between the two dry seasons was so great, CPUE across depth categories from the two dry seasons were analyzed separately using 1-way ANOSIM. In the 2002-2003 dry season, no variation in community structure was evident across depth categories (Global R = 0.023, P = 0.320). In the 2003-2004 dry season, however, significant variation in community structure was seen (Global R = 0.351, P = 0.001; **Figure 39**), and all pairwise comparisons of community structure were significant (shallow/medium: Global R = 0.185, P = 0.048; medium/deep: Global R = 0.237, P = 0.001; shallow/deep: Global R = 0.804, P = 0.001). We attribute these differences between the two dry seasons to be the result of the multiple drying reversals in the spring of 2003, which allowed fishes to recolonize the Rocky Glades solution holes, thereby homogenizing any previously existing differences among the hole-depth categories in that year. The spring of 2004 allowed those depth differences to become pronounced.

SIMPER indicated that the differences between solution holes in the 2002-2003 and 2003-2004 dry seasons were driven primarily by *H. letourneuxi*, *G. holbrooki*, *P. latipinna*, *C. bimaculatum*, *L. marginatus*, and *A. natalis* (cumulative dissimilarity = 68.8%). In the 2003-2004 dry season, shallow holes were characterized by *F. confluentus*, *G. holbrooki*, *J. floridae*, *L. marginatus*, *B. belizanus* (cumulative similarity = 93.9%), medium holes were characterized by *H. letourneuxi*, *C. bimaculatum*, *G. holbrooki*, *L. marginatus*, *B. belizanus*, and *F. confluentus* (cumulative similarity = 83.5%), and deep holes were characterized by *C. bimaculatum*, *H. letourneauxi*, *A. natalis*, *L. gulosus*, and *L. marginatus* (cumulative similarity = 92.8%)(**Figure 40**). Two-way crossed ANOVAs of common fish species indicated abundances of 6 species and total fish CPUE varied significantly with season and/or depth (**Table 14**). Abundances of *C. bimaculatum*, *F. confluentus*, *G. holbrooki*, *H. letourneuxi*, *J. floridae*, *L. gulosus*, and total fish abundance increased from the 2003-2003 dry season to the 2003-2004 dry season (**Tables 14 & 15**). While none of the common species' abundances varied among depth categories in the 2002-2003 dry season, several species' abundances varied among depth categories in the 2003-2004 dry season (**Figure 41**).

Shallow holes provide important habitat for the common small-fish species during the dry season, and should allow local colonization by these species as the marshes reflood. Under current water management, however, these holes never maintain water throughout the dry season. It is unclear whether historic water conditions in the Park allowed these holes to remain inundated throughout most dry seasons or if these holes have always been too shallow to provide high-quality, dry-season refuges for small fishes. In the absence of historical data, this question is very difficult to address, although future modeling may help provide insight. However, most medium and deep holes before regional drainage occurred likely maintained water during many average dry seasons.

*Impact of physicochemical conditions on non-indigenous fish species (NIS): T*he relative abundance of NIS in solution holes differed between sampling years ($F_{1, 693} = 6.3$, $p = 0.013$; **Figure 42**). In 2002-2003, an average of 19 % of minnow trap CPUE was composed of NIS. In contrast, in the 2003-2004 sampling year, NIS constituted an average of 52 % of CPUE. NIS relative abundance differed significantly between regions ($F_{3, 693} = 17.6$, $p = 0.0001$). The relative abundance of NIS averaged 16 % in Hidden Lake solution holes, whereas in solution holes in Wilderness Road, and the East and West Main Road regions relative abundance ranged from 44 to 65 % of CPUE (Bonferroni pairwise comparisons, all $p < 0.0001$) (**Figure 33**).

The relative abundance of NIS also differed between the depth categories of solution holes, but this effect varied between sampling years (significant year by depth interaction: $F_{2, 693} = 13.8$, $p = 0.0001$). In 2002-2003, we detected no difference between depth categories, again probably the result of the multiple reflooding events that spring. In 2003-2004, the relative abundance of NIS was only 3 % in shallow holes, compared to 47 % in medium holes and 61 % in deep holes (Bonferroni pairwise comparisons: $p = 0.001$ and $p = 0.0001$ respectively). Similar findings were reported in an earlier study of Rocky Glades solutions holes by Kobza et al. (2004). The relative abundance of NIS in medium and deep holes differed between sampling years. Relative abundance increased from 21 % to 47 % in medium holes, and from 16 % to 61 % in deep holes between 2002-2003 and 2003-2004 ($p = 0.0001$ in both comparisons).

We found little evidence that the relative abundance of non-indigenous species in solution holes was explained by physiochemical conditions. Inclusion of principal components 1 and 2 in the ANCOVA did not significantly improve the fit of our model ($R^2 = 0.51$ to $R^2 = 0.53$). Examination of the eigenvectors revealed that water depth was negatively correlated with principal component 1, whereas dissolved oxygen was positively correlated with principal component 2. Variation in the relative abundance of non-indigenous fishes was significantly affected by principal component 1 (water depth, $F_{1, 662} = 17.1$, $p = 0.0001$), but not principal component 2 (dissolved oxygen, $F_{1, 662} = 0.02$, $p = 0.88$). Regressing the relative abundance of non-indigenous species on factor 1 (water depth) revealed no meaningful relationship between the two (R^2 was very low and the slope was not significantly different from 0). Thus, we can conclude that variation in these correlates, including water depth, does not account for a large portion of the variation in the relative abundance of non-indigenous fishes in solution holes. Kobza et al. (2004) found that NIS comprised a high proportion of the fishes that survived in the deep holes that retained water through the dry season. Our data showed that those holes are often hypoxic and high in ammonia. Therefore, NIS must have the ability to tolerate both low dissolved-oxygen levels and high ammonia levels to be able to survive in those holes. All of the NIS species in the Rocky Glades are from tropical waters that experience dramatic wet-dry season changes. One of the most abundant NIS, the black acara, has the ability to survive in marginal aquatic situations in South America (Lowe-McConnell 1964).

IV. SURFACE WATER

METHODS

Physicochemical and Hydrological monitoring

We deployed YSI 600 devices to take continuous measurements of physico-chemical conditions for one-week periods during different seasons at the drift-fence array sites along the ENP main road (**Figure 43**) (units were calibrated prior to deployment; see Table 2 for summary of when and where units were deployed). After retrieving the units, we uploaded data to a PC, and used EcoWatch© to transform raw data onto a spreadsheet. We also used data from three ENP water-monitoring sites in the Rocky Glades (**Figure 3**).

Staff gauges to measure water depths were placed at each array and in each solution hole. In June 2002, we installed plastic rain gauges at arrays 2, 3, 4, and 5. Water depths and rain accumulation were recorded each time samples were collected. Because of the very uneven ground surface at the array sites, we adjusted staff guage measurements to average wetland surface as estimated by several dozen random measurements with a meter stick. Those adjusted measurements were used in all analyses.

Drift-fence sampling

In May 2000 we constructed four drift fence arrays in the marsh to measure the dispersal and relative abundance of fishes, invertebrates, amphibians, and reptiles with the arrival of the wet season. Sites were located along the Main Park Road, two east (Arrays) and two west (Arrays 3 & 4) of the Pineland Trail (Figure 43). Arrays were constructed using heavy black, nursery-greenhouse groundcloth, tied with plastic-coated wire to iron rebar driving into the limestone substrate. Each array had four arms that intersected at the center to form an X, creating four quadrants, which were oriented so that the central apex of each quadrant faced one of the four cardinal compass directions. Each arm of the array was 12 m long and 0.7 to 1.5-m high (depending on anticipated water depths). Where the arms intersected at the center of the array, we used additional cloth to form an approximately one- x one-m square area with a hole in each quadrant large enough to insert a minnow trap (Figure 44).

To sample fishes in drift-fence arrays, we inserted a three-mm, wire-mesh, Gee©minnow trap (mouth diameter = 2.5 cm) into each quadrant of the array. One trap mouth faced out into the quadrant, and the other (facing the center of the array) was plugged so that animals could enter the trap only from the quadrant it faced. Minnow traps remained set at the array for 24 h. An animal moving across the marsh would be intercepted by the array's arms and directed to the center of the array into the trap that faced the direction from which the animal was moving. The inverted funnel of the minnow trap opening prevented movement of animals out of the trap. Minnow-trap mouths were 8-cm high (from the substrate) which limited the depth of water at which we could begin collecting animals. Roads served as borders to the south end of arrays 1-4 (Main Park Road for arrays 1-3 and Pah-Hay-Okee Road for Array 4), so the south quadrant was not sampled for those arrays. When the initial rise in the water table inundated the arrays, we soaked the minnow traps for 24-hour periods every day for two weeks to gather data on early colonization patterns (**Table 16**). Later, as the wet season progressed, we reduced the frequency of sampling to two trap-days per week for the two weeks following the 14-day sampling period, then we reduced our efforts to one trap-day per week for the duration of the wetted period.

In 2001, we established nine additional drift-fence arrays **(Figure 33**). Three new arrays were added in the Rocky Glades, two in central Shark Slough, and two in intermediate areas between the slough and Rocky Glades habitats. Two new arrays were constructed near the park road but away from its direct influence, one north of Array 3, and one near Gate 11. Those sites (arrays 5 & 6, respectively) were sampled following the same protocol as the original four sites in. Farther north in the Rocky Glades, we constructed one array south of the Chekika Visitor Area (Array 9), one at the entrance to Context Road (Array 7), and one at the western end of Context Road (Array 8). By helicopter and airboat, we constructed two arrays in central and southern Shark River Slough (arrays 12 & 13, respectively). We also erected two arrays between arrays 11 and 12, and the Rocky Glades (arrays 10 & 11). The objective was to sample the entire suite of arrays at the beginning of the wet season to attempt to determine the sources and movement patterns of animal colonists for the Rocky Glades. The sites in Shark River Slough and its periphery were visited by either helicopter or airboat, so the sampling frequency was much lower than the sites accessible by road. In this report, we mainly report data from arrays 1-6, which had the most continuous and extensive data collections; however we do discuss findings from the other arrays.

Fishes and macroinvertebrates were either processed in the field (identified and enumerated) or processed in the lab (identified, enumerated, standard length (SL) or carapace length (CL) and total species mass). In 2000, most were preserved and processed in the lab for length and wet weight, gender, and in some cases, for stable-isotope signatures. After 2000, samples were preserved biweekly to obtain size and gender data, but the majority of samples were field-processed to avoid mortality. When releasing animals after field processing, we placed them far from the array to avoid recapturing the same animals. Vouchers for each species were preserved for deposition in the park museum. Reptiles, amphibians, and aquatic insects were identified and enumerated in the field, then released alive away from the arrays.

We performed a 24-hour catch study in October 2003. We collected fish at Arrays 1-3 during four 6-hour intervals (0600 h, 1200 h 1800 h, and 2400 h) to discern diel patterns in the catch related to fish activity.

Stable-isotope sampling

We analyzed samples of muscle from common fishes and invertebrates for stable isotopes of carbon and nitrogen. Our objective was to determine whether the signatures of those isotopes changed across the wet season. If that occurred, it might indicate that the fishes used different habitats before the wet season, and changed diets after colonizing the Rocky Glades. Small fishes were filleted to avoid including bone and scales. Tissues were dried at 55-60^o C and pulverized. Analyses were performed at the FIU stable-isotope lab of Dr. William Anderson, who provided data from the mass spectrometer to us for interpretation.

Fish-otolith microchemistry

To assess a relatively new technique of using otolith microchemistry in eastern mosquitofish for analysis of dispersal and use of distant refuges, we performed a pilot study to test the feasibility of the method to identify the past environmental history of the fishes in the arrays to determine their source refuges. Ototiths are ear bones that grow as a fish ages by daily deposition of calcium (and other minerals) bands that provide a day-by-day record of the fish's age and environments it experienced. Electron microprobe units have been developed that trace the elemental composition of rings sequentially from the center to the edge of the otolith. If we can identify spatially explicit mineral markers (for example the abundance of strontium (Sr) is correlated to salinity), it may be possible in the future to analyze otoliths to test hypotheses about movement, for example, the proposed role of creeks at the marsh-mangrove interface as refuges for fishes that colonize the Rocky Glades. For this technique to work, there has to be sufficient Sr available in the donor habitat for incorporation into the otolith for later detection in the recipient habitat. We were uncertain whether that is the case in these brackish-water, potential refuges.

We learned that the FIU Geology Department had an electron microprobe that might be used in this work. Therefore, in the dry season of 2004, we placed captive-raised easter mosquitofish from the Beard Center mesocosm facility into three pre-constructed 1-square-meter cages with 1-mm mesh set in the Hidden Lake canal along the Old Ingraham Highway east of Long Pine Key (freshwater Rocky Glades site), at Shark River Slough long-term fish-sampling site 06 (freshwater slough site), and in a Rookery Branch stream near P-35 (marine-influenced site). Five neonate fish were placed in each cage for 1.5 months to acquire the chemical signal from those locations before they were to be collected and analyzed. We had to access the sites by vehicle and by helicopter and airboat as the areas dried. A small number of wild eastern mosquitofish were collected from the field locations for matching analysis.

At the Beard Center mesocosm, we reared several remaining fish in well water, divided them into two groups, and dosed one group with Seachem® Strontium (Sr) product to artificially raise Sr levels in the tank to about one-half seawater concentration. The other group was kept in well water as a control. Once the fish were harvested, they were frozen. We extracted the otoliths, and processed them as described in Appendix 3, before submitting them to the FIU Geology lab for analysis.

Visual sampling

Because the arrays are activity traps, capturing animals when they are actively moving across the wetland, we wanted to use an alternate sampling method to estimate community patterns when dispersal was not so active. Frederick and Loftus (1993) used a visual sampling method in shallow, clear-water wetlands to estimate species composition and density of fishes. We established 24 visual-survey plots, six each flanking the four arrays. Each plot covered a 4-m square area that was marked at the corners by flagging. The survey consisted of a 1-minute visual search of each plot using binoculars. Generally, visual surveys were conducted every week, in conjunction with checking the array traps.

Radio-tracking of large piscivorous fish

In May 2003, we implanted radio transmitters into 15 Florida gar found taking refuge in the Taylor Slough Bridge pool. We wished to learn if those large, predatory fish move into the Rocky Glades during high water. We purchased 15 Holohil Systems® SB-2 transmitters, with frequencies in the 170-171 Mhz range, and a life span of about six months. For tracking, we used a scanning Telemetry receiver made by Communications Specialists Inc®, connected to a Yagi antenna. Transmitter range averaged about 1 km, depending on atmospheric conditions and the position of the fish in the water column and among vegetation.

We took the fish to the Beard Center lab after they were netted. After anaesthetizing the fish, we made an incision in the lower abdomen, inserted the transmitter, and sutured and glued the wound closed. We allowed the fish to recover for several hours, and returned them to the capture site for release. In outdoor tanks we retained five fish as controls for surgery (without transmitter implantation), and four as handling controls, to assess the effects of those stressors. On foot, we obtained weekly location and fish habitat fixes on the fish and, at the end of June, every other week from a fixed-wing aircraft. When we determined that a fish in the wild had died, we tried to recover the transmitters and re-implant them into other fish. In October 2003, we performed a 24-h radio-tracking program for the gar to document diel patterns in activity and habitat use.

Data analysis

Surface-water hydrology: Hydropatterns vary among arrays. The hydroperiods during each year of the study were plotted, and significant differences determined using ANOVA. To investigate potential relationships between water depth and CPUE, water depths and CPUEs were plotted for each array using sample dates chosen from the middle of each month during this study. ANOVAs of the CPUEs were run with event, direction, and array as factors and depth as a covariate. We also ran a linear regression to determine if there was a significant relationship between water depth and CPUE.

Community structure and size structure of marsh fishes: Array data were organized into initial, main, and subsequent event categories. An “event” refers to the duration of sampling occurring between drying events of the marsh surface. Initial events occurred early in each wet season and were those, usually spanning less than five weeks, that occurred before the most prolonged periods of flooding. The main events refer to those prolonged, more permanently flooded periods. Subsequent events were those caused by late wet-season rains that temporarily flooded the marsh surfaces for short durations after the main events. Depending on the location of the array and the annual hydrologic conditions, the three event-types (initial, main, and subsequent) might not have occurred in a particular year or location.

In some cases, particularly at Array 4, there was typically only one main sampling event in most years. At shorter-hydroperiod arrays, there were often multiple initial and subsequent events within the same year. Arrays in most years experienced very different flooding patterns (**Figure 45**). Coding the data in this manner allowed us to standardize differences between sites.

Catch-per-unit-effort (CPUE) and relative abundance (RA) were calculated for all species collected in the arrays during weekly samples from 2000 – 2003. Means, standard errors, relative abundances, and incidences of capture were calculated for the wet seasons of 2000 – 2003 for each array. We described fish recruitment to the arrays during the main flooding events by constructing species-richness accumulation curves in SigmaPlot 9.0® for each year at all array sites.

To examine temporal patterns in species composition during the wet seasons, we divided data from the "main event" into three categories: main–beginning, main–middle, and main–end. For each year, at each array site, we chose samples from the first three weeks, the middle three weeks, and the last three weeks from the main events. Those data were aggregated into a data matrix that included all array sites from 2000 – 2003, with the data from the beginning, middle, and end of the main events. Standardizing the data in this manner allowed us to analyze temporal patterns in species composition from all array sites together regardless of the differences in hydropattern at each site.

Relative abundances were displayed in pie charts to show differences between initial and subsequent events as well as differences between the three main event categories. We examined variation in the CPUEs of the six most abundant species in arrays using analyses of variance (ANOVA) to test the effects of time (initial, main-beginning, main-middle, main-end, and subsequent events), direction, and array location. Pairwise comparisons were calculated using Bonferroni post-hoc tests. All analyses were conducted in SYSTAT 10®.

Patterns in fish-community structure and abundance were examined for each array using multivariate methods. These analyses focused again on the "main events" and the data categories previously described. Two-way crossed ANOSIM (from standardized Bray-Curtis dissimilarity matrix) was used to compare temporal differences in fish-community structure across the main flooding events, and SIMPER (similarities percentage breakdown analyses) was used to determine which species were responsible for observed variation. Prior to running these tests, data were "standardized" and log (X+1) transformed. Non-metric multi-dimensional scaling (NMDS) plots were then constructed to visualize patterns in community structure. All multivariate analyses were conducted using PRIMER 5®.

Finally, to determine if there are temporal changes in size structures of aquatic communities throughout the flooded period, we plotted the frequency distributions of standard lengths of eastern mosquitofish, dollar sunfish, pike killifish, and Everglades crayfish during the beginning, middle, and end of the main flooding events. We used ANOVAs to determine if there were significant differences in the mean sizes of these species throughout the main flood events. Those four species were chosen on the basis of their abundance on the wetland during the wet season, and our ability to sample life stages of individuals with minnow traps.

Fish-catch dynamics of individual species: We focused on fish and invertebrate species that were abundant (≥ 5%) in the catches in the drift-fence arrays. Species typical of more permanent environments were taken in very low numbers, or were non-existent in the temporary aquatic environment of the Rocky Glades, and thus were not the focus of analyses. The study species were small (<8cm), omnivorous, cyprinodontiform fishes, centrarchid sunfish, and crayfish species that belong to five families: marsh killifish, flagfish, eastern mosquitofish, dollar sunfish, and Everglades crayfish (Cambaridae: *Procambarus alleni*). The marsh killifish can lay resting eggs that enable the species to persist in habitats with harsh drying conditions as experienced in parts of the Everglades (Harrington 1959). The flagfish is an egg-laying fish endemic to Florida, that is found throughout the Everglades, mainly in short-hydroperiod habitats where it constructs and guards nests (Loftus and Kushlan 1987; Loftus and Eklund 1994)). The eastern mosquitofish bears live young and is found in all aquatic habitats in the Everglades, where it is perhaps the most common fish (Loftus and Kushlan 1987). The dollar sunfish is a nest-building, egg-laying sunfish, and is typically found in short and intermediate hydroperiod environments. The Everglades crayfish typically inhabits short and intermediate hydroperiod areas, and burrows into the substrate to survive in drought conditions (Hendrix and Loftus 2000, Acosta and Perry 2001).

In the statistical analyses, the response variable was the number of individuals/trap (catch-per-unit-effort (CPUE) over 24 hours) of the study species. The data were non-normally distributed, so we log transformed (ln density+1) the data. We used a general linear model, based on ordinary least squares, to analyze the data. Because of the ubiquitous spatial and temporal variability among species, a base model was used for all species: Site + Direction(Site) + Year + Month(year). Parameters were then added to the base model, and the model fit was evaluated by an adjusted R-square to select the most parsimonious model and to avoid over-fitting. Parameters that increased the adjusted R-square by >0.005, were used to insure that the variation explained by the parameter was biologically meaningful. The parameters used in the models fell into three categories:

Spatial: Site- location of study site;
Direction(site)- direction of minnow trap (N, S, E, W) estimated directional movement by fish;
Flow-direction of water flow.

Temporal: Year- Corresponded to 12-month periods that encompassed the wet and dry seasons (May-April, for 5 seasons);
Month(year)- month nested within year.

Hydrological (covariates): Depth- water depth (cm) at the site;
DSD- the number of days since the last disturbance (water levels <5cm)

We found that both hydrological parameters fit best when a nonlinear term was added ($Depth^2$ and DSD^2). In addition to the adjusted R-square, we calculated the coefficient of determination (R-square=1-(SSE/SST)). To understand importance of temporal variation in directional fish movement, we estimated the R-square for a model with only the interaction term, direction*month(site*year). This was determined by dividing the amount of variation explained by the parameter by the amount of variation explained by the entire model (R-square). To interpret the effect of the interaction, we used a general linear model to calculate the least-square means (lsmeans) and plotted them on graphs.

Diel patterns in fish movement: In addition to our regular sampling of arrays in 2003, we conducted a 24-hour catch survey on 8-9 October to test for diel patterns in catch related to fish activity. Traps were set at 0600h, 1200h 1800h, and 2400h (6-h soak time). ANOSIM (standardized Bray-Curtis dissimilarity matrix) was used to compare fish-community structure across sampling events (1200 h, 1800 h, 2400 h, 0600 h), and SIMPER was used to determine which species were responsible for observed variation. We then used ANOVA to delineate patterns in common-fish species abundance (CPUE) and relative abundance. CPUE was $\sqrt{y}$-transformed and relative abundances were arcsine($\sqrt{y}$)-transformed to satisfy assumptions of normality.

Early colonization of marshes: As discussed earlier, the local source colonist hypothesis suggests that fishes are caught in arrays when solution holes flood and release surviving fishes onto the marsh surface. We examined variation in the community composition of early colonizers (days 1-14 of first flooding event) using Primer®. We used one-way analysis of similarity (ANOSIM), based on Bray-Curtis dissimilarity matrices, to test for effects of years (2003 vs. 2004), arrays (1 – 6) and days of the first flooding event of the season (1-14 days) (Clarke & Warwick, 2001). Dissimilarity matrices were constructed based on ln (observed value + 1)-transformed total CPUE from arrays. Catches from the three (or four) quadrants of arrays were added to obtain one total CPUE per array for each sampling day. We limited analyses to those species that had abundances greater than >1 % in samples: *G. holbrooki*, *P. latipinna*, *F. confluentus*, *J. floridae*, *Heterandria formosa* (least killifish), *Lucania goodei* (bluefin killifish), *F. chrysotus*, *L. marginatus*, and *Belonesox belizanus* (pike killifish). Preliminary analyses based on all 23 fish species taken in the first 14 days of sampling at the arrays yielded similar results. ANOSIM tests produce Global R statistics with values ranging between 1 and -1. Values closer to 1 indicate greater community dissimilarity among groups than within, while values closer to -1 indicate less dissimilarity among groups than within. We followed ANOSIM analyses with similarities percentage breakdown analyses (SIMPER) to determine which taxa contributed most to groupings observed among samples. We then constructed non-metric multi-dimensional scaling (NMDS) plots to illustrate dissimilarity among groups. In these plots, the distance between data points is proportional to the degree of similarity between samples. All community-structure analyses were conducted using Primer® Version 5.2.9.

Role of solution holes as sources or sinks for colonists: To examine whether colonists found on the marsh surface at the beginning of the wet season might have originated from solution holes, we compared community composition of solution holes at the end of the dry season with that from drift-fence arrays at the beginning of the wet season using ANOSIM in PRIMER©. In 2003, at the end of the dry season, 28 of the 40 solution holes in our monitoring remained flooded, and of those 28, only 14 had fish. We compared species composition in those 14 solution holes to species composition in six array samples (three corresponding to early samples-days 1-4, and three corresponding to late samples-days 13-14). Arrays 4 and 5 were excluded from the analysis because re-flooding of those arrays occurred much sooner in the wet season (29 March 2003). Data used in this comparison came from samples taken in solution holes between 11 April and 23 May 2003, and samples taken in arrays between 27 May and 24 June 2003. Only two solution holes remained wet at the end of the dry season in 2004, and those were used for comparison. In 2004, we compared species composition in those two solution holes to species composition in nine array samples (6 early and 3 late - the averages of days 1-4 and 13-14 of sampling, respectively). Data used in this comparison came from samples taken in solution holes between 11 June and 16 July 2004, and samples taken in arrays between 23 July and 10 August 2004. To better estimate abundance in solution holes, we averaged catches over the last four sampling dates of the dry season in both years. Prior to averaging, we compared the four sampling dates to insure CPUE was similar over this period of time prior to re-flooding. Dissimilarity matrices were constructed based on ln (observed value + 1)-transformed CPUE. For array data, CPUE was summed over all quadrants.

RESULTS & DISCUSSION

Surface-water hydrology

Ground-surface elevations between the westernmost and easternmost arrays (arrays 4 and 1) increase by about 80 cm, so that the westernmost array, Array 4, has the longest hydroperiod (**Figures 45 & 46**). Array 4 is on the eastern periphery of Shark River Slough and, during this study, appeared to be influenced by water-management in that basin. The higher elevations of the easternmost arrays, 1 and 2, resulted in the shortest flooding periods and frequent wetting and drying events during the wet season (**Figure 45**). In 2000, arrays 1 & 2, east of the Pineland Trail, did not flood until mid-July, and dried by November (**Figure 45**). Water flow was generally west to east at Arrays 1, towards Taylor Slough, while at Array 2, direction varied between east and west flow. Arrays 3 & 4, west of the Pineland Trail in ENP, flooded in early June 2000 (**Figure 45**). Array 3 had surface water until November, while Array 4 stayed wet until the end of December. Water flow at those arrays was generally east to west, towards Shark River Slough. In 2001, Flooding patterns differed from 2000, with rains arriving later in the wet season delaying the flooding of the marshes**.** Arrays 3 & 4, west of the Pineland Trail in ENP, which flooded in early June 2000, did not receive water until a month later in 2001 (**Figure 45**). However, a wet autumn kept water on the surface longer than in 2000. A large rain event brought rapid flooding to the marsh surface in early June, but rains were sporadic and all areas dried and re-flooded at least once. Continuous water appeared in most areas by mid-July, with a few remaining patchy until August. Array 3 had surface water until November, while Array 4 stayed wet until April 2002. Water flow at those arrays was generally east to west, towards Shark River Slough. Arrays 1 & 2, which did not flood until mid-July 2000, and dried by November 2000 (**Figure 45**), showed a pattern similar to that of 2001. Direction of water flows at Arrays 1 and 2 was similar to 2000. Arrays 7 and 9 along the eastern ENP boundary had very short hydroperiods in most years. In 2002, although rainfall in the winter and spring were near normal, groundwater levels in the spring fell well below the levels of 2001. Surface water returned to Array 4 in late May, and the remaining sites re-flooded by mid-June (**Figure 45**). There were no reversals during the summer so all sites were continuously flooding until August. There were no tropical-storm events in the late summer or fall to bring extra moisture to the region.

Coupled with pre-storm drawdowns from September to December in anticipation of heavy rains from tropical cyclones, all sites except Array 4 lost surface water several months earlier than in previous years (**Figure 45**). Early winter rains brought back surface water for a short period. Array 4, under the influence of Shark Slough releases, had continuous surface flooding until January 2003. A series of cold-front associated rain events in March and April, 2003, restored surface flooding to most arrays for several days to a week. Persistent summer flooding arrived at the usual time in late May to early June. Most arrays began drying in September-October, again as a result of no tropical systems but the use of pre-storm drawdowns. By early January 2004, all arrays had dried. 2004 brought a very late wet season onset, in late July. Arrays 1 and 2 had surface water only until late September and by late November, only Array 4 remained wet.

Physico-chemical water monitoring

Surface-water conditions at the arrays were the most variable of any habitat and showed the largest diel cycle in temperature, pH, and DO in mg/L (**Figures 47-50**). The wet-season temperatures were less variable but warmer, ranging from 25^o to 34^o C, than in the winter months when temperatures ranged from 11^o to 22^o C. The DO concentration was super-saturated in the wet season, with values reaching 11mg/L. Dry season DO concentration ranges were similar to the wet season ranges. The pH was more variable in the wet season and varied between 7.5-8.5, with the dry season being less variable and stabile between pH 7.5 and 8. The wetland surface is the site of intense photosynthetic activity by periphyton and emergent macrophytes that results in greater fluxes compared with ground water and solution-hole environments. These extremes in water chemistry, especially DO concentration, certainly influence fish and invertebrate behavior and should be considered in relation to future interpretations of faunal movement and survivorship.

Aquatic-animal catch, composition, community structure, and patterns

Temporal-catch narrative - A total of 38 fish species were taken from the surface of the Rocky Glades in the drift-fence arrays (**Table 1; Appendix 1**). Many species of aquatic insects, amphibians, and reptiles, particularly aquatic snakes, were also trapped in the arrays (**Table 17**). Many individuals of these bycatch (non-target) species were encountered at the beginning of events that re-flooded the wetlands, when they were dispersing across the surface. Catches of bycatch slowed considerably as the wet season progressed. At the six study sites, there were a total of 123,273 individuals of all species collected from 2000-2004 (sites 5 and 6 not included until 2001; 2004 only includes July and August). Overall, there were 72,970 eastern mosquitofish (59.2%) with a CPUE of 22.33, 18,959 flagfish (15.4%) with a CPUE of 5.80, 10,322 dollar sunfish (8.4%) with a CPUE of 3.16, 7,501 marsh killifish (6.1%) with a CPUE of 2.30, and 6,992 Everglades crayfish (5.7%) with a CPUE of 2.13. These data are presented by location and year in **Appendices 4-13**.

In 2000, we collected a total of 26,407 fishes and crustaceans in the four arrays (**Appendix 4**). Animals appeared rapidly on the surface as the wetlands around the arrays re-flooded. Fishes and crayfish reappeared in the traps on the same day that the wetlands re-flooded. Large catches of several species occurred within a few days of reflooding. The fishes exhibited mass directional dispersal as the wetlands flooded. Although flow velocities were relatively slow in these shallow wetlands (usually less than 1 cm/sec), animals appeared to orient to the flow. The majority of species appeared at each array within one week of flooding (**Figures 51-56**). Non-native and larger-bodied native fishes were slower to appear at the arrays, possibly indicating dispersal from distant refuges. The most abundant species in the arrays in 2000 were the eastern mosquitofish, flagfish, marsh killifish, dollar sunfish, and sailfin molly (**Appendix 5**). Hydroperiods were arranged from longest to shortest from arrays 4, 3, 2, to 1 (**Figure 46)**. The total number of fishes collected at each array was directly related to the length of flooding (Table 2). As seen in the example for Array 4, there seemed to be an inverse relationship between catch and water depth (Figure 4). Largest catches occurred when water depths were rising at the beginning of the wet season, and dropping at the end of the wet season. Catches were lowest at high water (**Figures 57 & 58**).

The total number of fishes collected at each array appeared to be directly related to the length of flooding in 2000. The catch of riverine grass shrimp was also directly related to the hydroperiod (**Appendices 4 & 5**). Even before the arrays flooded, we observed crayfish, aquatic insects, and juvenile mosquitofish in areas of the Rocky Glades near arrays 3, 4, and 5. Culvert pools at Pa-Hay-Okee also had schools of mosquitofish and marsh killifish present, probably having moved there from nearby wetlands with surface water or from the Pa-Hay-Okee solution-hole network.

In 2001, the number of animals caught increased to 54,139 fishes and crustaceans because of the larger network of 13 arrays that year (Appendices 6 &7). Similar to 2000, fishes and crayfish reappeared in the traps on the same day that the wetlands flooded. We collected large catches of several species in the first few days of re-flooding (Tables 18-23). Since the flooding of the marsh happened later than in 2000, the catch distribution and depth varied within an array. The maximum number of fishes and crayfish caught at any given time in 2001 was significantly less than at the onset of flooding in 2000. The fishes again exhibited mass directional dispersal as the wetlands flooded.

The species that appeared at the onset of flooding were distributed much in the same manner as those appearing first in 2000 (**Figures 51-56**). Despite the numbers being less, possibly due to such a long period of dry down and sporadic rain, there were still many fish moving about the marsh once it flooded.

In 2002, fishes appeared in the array traps immediately following site reflooding. Relative abundance of species varied by array (**Tables 18-23**). Unlike other years, least killifish had high catch rates in some arrays. This fish normally requires a predator-free refuge and long hydroperiods for survival. The eastern mosquitofish was numerically dominant at most sites. Despite the relatively short hydroperiods at arrays 1 to 3, total catch at each site was intermediate between 2000 and 2001 catches. Arrays 7 and 9 had the very shortest hydroperiods of any site sampled. Water levels there are usually high enough for fish sampling only in late summer, when heavy rains flood the area. In 2002, that situation did not occur and we were unable to collect samples there. Fishes in those areas are confined to solution holes for long periods and the populations are completely eliminated each year when the shallow holes dry. Until water levels are restored along the eastern boundary, it must be considered as a population sink for fishes.

2003 was the third year of full implementation of drift-fence array sampling for fishes on the marsh surface. The 2003 sampling began in early spring when unseasonable rains fell over the region in March (Figure 8). Some arrays also flooded for several days before drying. We began sampling the arrays two months earlier than usual (**Table 17**). However these heavy, but short-lived, rain events resulted in multiple reversals of flooding, causing us to alternate sampling between surface-water arrays and solution holes. This resulted in a situation like that of 2002, when sporadic drying and rewetting forced multiple starts for sampling at arrays. Another heavy rainfall in late April and early May again re-flooded the surface until mid-May (**Figure 45**). We collected samples at the arrays during those times. In late May, the summer rains completely inundated most arrays, and we began our normal sampling regime. Despite increased sampling this year, fewer fishes were collected in the arrays than in previous years. This may have been caused by the fluctuating water levels at the arrays in 2003.

In 2003, rainfall amounts in late summer and early fall were higher than in 2002, although, again, there were no tropical systems to flood the area at that time. As a result, surface waters receded at arrays earlier than in 2000 and 2001. Flooding of these sites is highly dependent upon ambient rainfall, and lag flows into the area from upstream are apparently not existent or are non-influential. Note that the order of arrays from east to west is: 1, 2, 5, 3 & 6, and 4. Generally, the pattern of array drying started east and moved west: 1, 2, 6, 3, 5, and 4. Sites at Context Road and Chekika were wet for such a short time that few samples were obtained.

Array 1, east of Long Pine Key had the most easterly water flows, followed by array 2, also located east of the pinelands (**Figure 43**). The flow patterns at all arrays west of Long Pine Key, arrays 3-6, were generally east to west, towards Shark River Slough, with west to east water movements being much less frequent. Water flows at all of the arrays appear to be non-existent for approximately 1/3 of the flooded periods.

We collected a total of 12,444 fishes in the six arrays in 2003 (other non-routinely sampled arrays produced only 358) (**Appendix 10**). This greatly decreased from 2002 when 40,607 fishes were collected in the 13 arrays (**Appendix 8**). The most abundant species in 2003 were dollar sunfish, eastern mosquitofish, marsh killifish, flagfish, and African jewelfish (*Hemichromis letourneuxi)* (**Tables 18-23**). This differed from 2002 in that jewel cichlids replaced least killifish (*Heterandria formosa*) in the top five most abundant species. We collected the first specimen of African jewelfish in the Rocky Glades on 24 June 2002 at Array 1. This species has been moving west into the Park from its probable source, the L-31W canal, and is now one of the most abundant fish species we collect.

Common invertebrates in the array catches are the riverine grass shrimp (*Palaemonetes paludosus*) and Everglades crayfish (*Procambarus alleni*). Array 4 consistently had the largest catches of grass shrimp and crayfish. At the other arrays, both species were present but did not appear in large numbers, perhaps reflecting their dispersion across the marsh. This result may also demonstrate the likelihood of these species being preyed upon if predatory species are captured in the same trap.

Our past field observations that fishes disperse en masse when the marshes re-flood were not as well supported by the 2003 data. This may have been the result of the strange hydrologic pattern observed this year, with multiple periods of flooding and drying (**Figure 45**). This repeated wetting and drying may not have provided suitable conditions for fishes to move in mass across the wetland, or may have resulted in increased mortality as the fish were exposed to repeated drying episodes. The results from Array 4 in 2003, with the highest CPUEs in the first and last months of flooding, supported the hypothesis that fishes move from Shark River Slough at the beginning of the wet season, and return as the Rocky Glades dry.

The first fishes to colonize the arrays in 2003 were generally small-bodied killifishes, topminnows, sunfishes, and livebearers (**Figures 51-56**). The numerically dominant and ubiquitous eastern mosquitofish was the first to be captured. Flagfish and dollar sunfish tended to follow, generally being captured in groups of 10-50 individuals. Least killifish and the bluefin killifish also colonized within two weeks. Other species followed in this approximate order of appearance: marsh killifish, pike killfish, golden topminnow, sailfin molly, Mayan cichlid (*Cichlasoma urophthalmus*), spotted sunfish (*Lepomis punctatus)*, black acara, Everglades pygmy sunfish (*Elassoma evergladei*), yellow bullhead (*Ameiurus natalis*), bluespotted sunfish (*Enneacanthus gloriosus*), African jewelfish, warmouth (*Lepomis gulosus*), sheepshead minnow (*Cyprinodon variegatus*), walking catfish (*Clarias batrachus*), bluegill (*Lepomis macrochirus*), pirate perch (*Apherododerus sayanus*), jaguar guapote cichlid (*Cichlasoma managuense*) and tadpole madtom (*Noturus gyrinus*).

Comparison of species succession at Arrays 1, 4, and 5, located in different areas throughout the Rocky Glades (Figures 51, 54, and 55), resulted in a large number of similar species and timing of their arrival. The majority of species appeared at each array within one week of flooding. Arrays 4 and 5 shared closer similarities in succession patterns than with Array 1. For example, Mayan cichlids appeared early in the wet seasons of arrays 4 and 5, but were collected much later at Array 1. Conversely, sheepshead minnows appeared in the first week of flooding at Array 1 but were the last species collected at Array 4 and were absent from collections at Array 5. Species richness was similar for all three arrays, although the richness at Array 1 was slightly lower. Despite this, Array 1 had the greatest species richness in the first two weeks of flooding in 2003 (10 species). The lower richness at arrays 4 and 5 may have resulted from dry-downs early in the wet season at those sites.

In 2004, we sampled the arrays only during the initial 14-day sampling period. This followed the lengthiest dry period during the study. Although the composition of species was not very different from previous years, we recorded the lowest CPUE for all fishes during this year.

Recruitment, composition, and size structure of animals during the flooded period: Over 1,700 minnow traps were sampled weekly from 2000 – 2003 (**Table 24**), following the 14-day sampling events (**Table 16**). Within all the weekly samples, the most abundant fish species were eastern mosquitofish (65%), flagfish (10%), dollar sunfish (7%), marsh killifish (6%), sailfin mollies (4%), and African jewelfish (2%) (**Tables 18-23; 25**). Means, relative abundances, and incidences of capture were calculated for fish species during initial, main, and subsequent events for each array (**Tables 18-23**). In some locations, such as Array 4, there was only one main sampling event in most years. At shorter hydroperiod arrays, there were often multiple initial and subsequent events within the same year. Most species were collected during the main events. However, common species collected during the main events also tended to be present in initial events, probably because of their ability to disperse rapidly. Eastern mosquitofish was usually the most abundant species in both initial and main events. Fewer species tended to be collected in events subsequent to the main events, although there tended to be larger catches of African jewelfish and pike killifish in the eastern-most arrays (arrays 1 and 2) at those times (**Tables 18 and 19**). Because the wetland surface dried between the main and subsequent events, we speculate that the lower number of species taken during subsequent events may have been the result of predation and mortality coincident with drying. The two non-native species were probably not affected to the same degree as the smaller natives.

Recruitment of species to the marsh changed from year to year at each array (**Figures 51-56)**. However, the most common species tended to be present early in the wet seasons, whereas larger-bodied sunfishes and non-indigenous cichlids were often collected later. Similarly, small native fishes had the greatest relative abundances early in the wet seasons during initial events, whereas jewel cichlids became most abundant during subsequent events (**Figure 59).** During the main events, eastern mosquitofish had the greatest relative abundances (**Figure 60).** Other common species such as flagfish and marsh killifish were most abundant during the beginning and end of the main events, indicating movement of those species with rising and falling water levels.

Univariate analyses of the six most abundant species indicated that eastern mosquitofish and dollar sunfish CPUEs varied significantly with the direction of capture (F-ratio: 5.135, $P = 0.002$ and F-ratio: 3.906, $P = 0.009$, respectively) (**Figures 61 & 62**). Bonferonni's pairwise comparisons demonstrated that CPUEs of both species differed significantly between north and east ($P < 0.05$), whereas eastern mosquitofish CPUE also differed between east and south ($P < 0.05$). Most mosquitofish moved either from east to west or west to east. Total CPUE for all fishes also varied significantly with direction (ANOVA, Direction: F-ratio: 7.451, $P <0.001$; Depth: F-ratio: 4.762, $P = 0.03$) when depth was a covariate (**Figures 63 & 64).** For all species, the directional movement was consistently biased towards the prevailing flow directions, E-W and W-E. The data showed that minnow traps facing east had the highest CPUE for all species, except the Everglades crayfish, which had its highest CPUE in minnow traps facing west (**Figure 64**). Both eastern mosquitofish and the Everglades crayfish had the greatest unidirectional biases (east and west, respectively). We had observed the crayfish to move against water flow at the arrays so that its overall movement pattern is consistent with the prevailing flows from E-W at these sites. The extreme unidirectional bias exhibited by eastern mosquitofish indicates it is extremely adept at orienting its movement with water flow, which moves east to west at most drift-fence array locations. This behavior has been noted before (Rehage and Sih 2004), and probably assists its rapid colonization of these wetlands.

In all of the final models, there was considerable variation across spatial and temporal scales (**Table 26**). The same models were fit for marsh killifish, eastern mosquitofish, and dollar sunfish (Full model minus DSD, DSD2). Those models explained 31.7%, 45.2%, and 47.6% of the variation in the data for the species, respectively (see adjusted R-square in **Table 26**). There was no significant spatial main effect (site) for eastern mosquitofish and marsh killifish, but there was for dollar sunfish. There was no difference among years for either dollar sunfish or marsh killifish, but there was for eastern mosquitofish. For the Everglades crayfish, none of the hydrological covariates improved the fit of the model, so were not included in the final model (adj. R-square .3717; see **Table 26**). The only effect that did not show a significant difference for the Everglades crayfish was the nested main effect of trap(year). Only for flagfish did all hydrological covariates help explain the variation in the data (adj. R-square .37; see **Table 26**). For the flagfish model, there were three effects that did not show significant differences: year, site, and direction(site).

The DSD and DSD^2 parameters did not improve the model fit for marsh killifish, eastern mosquitofish, or dollar sunfish. This indicates a nonlinear relationship between their densities and the number of days since a disturbance. Previous work with eastern mosquitofish demonstrated this lack of relationship for more permanent environments, but this relationship in more permanent environments has not been quantified for the other species (DeAngelis et al. 2005). These disturbance parameters did help to explain the variation in flagfish density, which had been described in longer hydroperiod environments, but over much longer timescales (DeAngelis et al. 2005). This relationship with disturbance in temporary environments may be explained by the high initial movement rates during initial colonization, followed by lower catches as the wet season progresses (**Figure 57**).

In the Everglades crayfish models, none of the hydrological covariates helped to explain variation in the data. This suggests that Everglades crayfish populations are not greatly affected by hydrology, at least at this lower end of the hydrological gradient. Hydrological parameters may not be important in explaining crayfish population dynamics because the majority of the crayfish appear to be colonizing from local refuges, not from outside these marshes. The Everglades crayfish has been shown to burrow very deep during drought conditions (Acosta and Perry 2001; Nate Dorn, FAU, unpublished data), so local survival in the dry season is the main factor driving its success.

Although we found significant main effects from spatial and temporal factors, the majority of the spatial and temporal variation was explained by the interaction between month(year) and direction(site). For all of these species, the most explanatory parameter was the direction*month(site*year) interaction. This term explained: 94.37%, 92.8%, 97.6%, 95.5%, and 98.2% of the overall variation in the model for eastern mosquitofish, flagfish, marsh killifish, dollar sunfish, and Everglades crayfish, respectively. When interpreting the interaction between month(year) and direction(site) in the model, the lsmeans for the interaction was taken from the model for each species. Consistent with the overall CPUE, we found that throughout in the first three study years, mosquitofish predominantly moved from the east direction over most arrays (**Figures 64 & 65**). At Array 1, where the flow is predominantly from W-E, in general, eastern mosquitofish moved from the west. These patterns support our contention that eastern mosquitofish orient their movement with flow.

Other species did not show as consistent directional biases as did eastern mosquitofish, thus were not as effective at orienting their movement to flow. Similarly to eastern mosquitofish, however, the Everglades crayfish showed a strong change in directionality at Array 1 where the flow direction changed (**Figure 66**). This agrees with the previous evidence exhibited on the response of the Everglades crayfish to water flow, but its consequences are unknown. As stated earlier, the majority of the recolonization is most likely from local burrows. One potential reason for its strong response to water flow could be to decrease the density-dependent, intraspecific interactions that are inevitable when organisms are in a highly concentrated area (i.e. limited available burrow areas).

The CPUEs of flagfish (F-ratio: 5.110, P = 0.001) **(Figure 67**), dollar sunfish (F-ratio: 3.439, P = 0.001), sailfin molly (F-ratio: P = 0.006) (**Figure 68**), and jewel cichlid (F-ratio: 3.106, P = 0.023) differed significantly with event, and, hence, time. Dollar sunfish CPUE also differed significantly with array location (F-ratio: 6.671, P = 0.001). These results indicate that various factors influence catches of abundant marsh fishes during the wet season. However, time (indicated by the prevalence of significant event results) was the greatest contributing factor.

In addition to analyzing catches of the most abundant species, we used multivariate techniques to investigate temporal patterns in fish-community structure and abundance at each array site during the main events. Only species with incidence percentages $\geq$10% were included in these analyses. Two-way crossed ANOSIM did not reveal significant variation in community structure through time at arrays 1 and 2. However, ANOSIM results were significant for arrays 3 (Global R: 0.097, P = 0.002), 4 (Global R: 0.28, P = 0.001), 5 (Global R: 0.091, P = 0.013) and 6 (Global R: 0.086, P = 0.012) (**Figure 69**). All pairwise comparisons for arrays 3-6 showed significant differences between the beginning and middle of the main event ($P \leq 0.05$). Differences indicated by SIMPER at these arrays were characterized by eastern mosquitofish, dollar sunfish, flagfish, marsh killifish, and sailfin molly (cumulative dissimilarities = 77% - 96%). Pairwise comparisons for arrays 3, 4 and 6 showed significant differences between the beginning and end of the main events ($P \leq 0.03$). The middle vs. the end of main events differed significantly for arrays 4 and 5 ($P \leq 0.003$). SIMPER analysis of Array 4 data indicated that the beginning of the main event was characterized by dollar sunfish, eastern mosquitofish, and flagfish (cumulative similarity = 93.75%). The middle of the main event was characterized by Mayan cichlids, dollar sunfish, and eastern mosquitofish (cumulative similarity = 92.86%), and the end of the main event was characterized by eastern mosquitofish, marsh killifish, flagfish, and golden topminnows (cumulative similarity = 91.49%). The absence of dollar sunfish toward the end of the wet season may have resulted from movement of that species away from short-hydroperiod wetlands towards more permanent waters. Similarly, the prevalence of small native species at the end of the flooding period might also mass movement westward toward Shark Slough because Array 4 had the longest hydroperiod (**Figure 58**) and is located farthest west in the Rocky Glades. Two distinct patterns were evident in these data. One group of fishes, the early colonizers such as eastern mosquitofish and flagfish, showed high CPUE in either the initial or early main events. Sometimes those species also had high CPUE at the end of the main event, probably indicating movement from these temporary wetlands to more permanent wetlands. Trexler et al. (2002a) did not find similar long-distance movements associated with drying in long-hydroperiod sloughs, so this may be a phenomenon of short-hydroperiod areas where the fishes must either move or die.

The length of hydroperiod may explain why we found no significant differences in catches during the main events at arrays 1 and 2. Those arrays, located farthest east, have significantly shorter hydroperiods than arrays 4 and 5 (**Figure 46 ; P <0.05**). By the time these sites flood, most of the surrounding region has been flooded for several weeks or more, giving fishes time to expand ranges and populations. Data at these sites may reflect colonization by established populations from nearby wetlands, rather than the community succession observed at other arrays.

Because hydroperiod influences the community composition of fishes, it is likely that water depth is also an important factor because the two are closely related. A linear regression of CPUE with water depth showed a significant, positive relationship (F-ratio: 39.767, $P<0.001$). The highest CPUEs of fishes usually matched with periods having the greatest water depths (**Figure 58).** However, this was not always the case, as in the anomalous year of 2003 when several reversals occurred, and overall catches at all arrays were lowest (**Figure 57**).

Lastly, we plotted changes in size distributions of common aquatic species during the main events of the wet seasons. We examined eastern mosquitofish, dollar sunfish, pike killifish, and Everglades crayfish in these analyses (**Figures 70-73**). Frequency distributions for all species except Everglades crayfish showed a pattern in which larger individuals were present early in the wet season, followed by a decrease in size distributions as summer progressed into autumn. This trend is shown clearly in the plots of eastern mosquitofish and dollar sunfish (**Figures 70 & 71**). Large individuals of eastern mosquitofish were collected in the beginning of the main event, whereas smaller individuals were collected toward the middle, as gravid females dropped young in the wetlands. By the end of the main event, larger individuals were again being collected as the new cohort grew to sexual maturity. This trend in the frequency distributions of eastern mosquitofish lengths was verified by significant ANOVA results of mean sizes (F-ratio: 133.773, $P < 0.001$), and all Bonferonni pairwise comparisons were significant ($P <0.001$). The trend was also seen independently in the visual-survey data (Section below). With dollar sunfish, sizes of individuals were greatest in the beginning of the main event as adults that had overwintered colonized these peripheral wetlands. Males quickly established nests on the wetland floor, which we observed within one to two weeks of re-flooding. They quickly reproduced, and as the adults died to be replaced by the new cohort, sizes of dollar sunfish in our catches significantly decreased through the wet season (F-ratio: 322.187, $P < 0.001$). Again, all pairwise comparisons were significant ($P < 0.001$). The young fishes persisted on the marsh surface until decreasing water levels in autumn and early winter forced them to either move away from the drying marsh or take refuge in solution holes.

Individual-species data: Overall, we collected 72,970 eastern mosquitofish (59.2%) with an average CPUE of 22.33, 18,959 flagfish (15.4%) with an average CPUE of 5.80, 10,322 dollar sunfish (8.4%) with an average CPUE of 3.16, 7,501 marsh killifish (6.1%) with an average CPUE of 2.30, and 6,992 Everglades crayfish (5.7%) with an average CPUE of 2.13. These data are presented by location and year in **Tables 18-23; Tables 27-32)**. Of these species, eastern mosquitofish, flagfish, and dollar sunfish had the highest abundances, indicating that they were the best adapted to exploiting these highly disturbed, temporary wetlands. The pattern of immediate appearance by flagfish and eastern mosquitofish in the Rocky Glades was similar to their responses to disturbance in long-hydroperiod areas (DeAngelis et al. 2005, Trexler et al. 2005). Rapid recolonization following a drying event by flagfish and eastern mosquitofish appears to be a consistent behavioral response by both species across both temporary and more permanent environments in the Everglades. Previous data on marsh killifish in temporary wetlands, and the data gathered in this study, showed that marsh killifish are common in temporary environments, but its relative abundance has been shown to decrease in more permanent environments (Loftus and Eklund 1994, Trexler et al. 2005). This pattern is opposite that of its congener *Fundulus chrysotus*, the golden topminnow, which was not common in the Rocky Glades samples (**Tables 18-23**).

The relatively high CPUE of Everglades crayfish (about 2/trap) demonstrates that this species is especially well adapted to highly disturbed environments. The only other crayfish species in the southern Everglades (slough crayfish, *P. fallax*), typically abundant in more permanent environments (Hendrix and Loftus 2000), was completely absent from these temporary environments. So, these exceptionally harsh environments effectively eliminate *P. fallax*, leaving the Everglades crayfish as the sole large crustacean there. The other macrocrustacean to inhabit the Everglades, the riverine grass shrimp (Palaemonidae: *Palaemonetes paludosus*), was present but rarely common in our samples. It is more abundant in long-hydroperiod wetlands.

We calculated the monthly CPUEs for the common fish species to examine pattern s of catch across locations and time (**Figure 74**). Monthly CPUE for eastern mosquitofish was relatively high throughout the wet season (usually May-November), with the highest CPUE towards the end of the wet season (Sept-Nov) and lowest at the end of the dry season (Feb-April) (**Figure 57**). The major contributor to the catch at the arrays made by this species is seen the change in CPUE pattern when mosquitofish data are removed from the data set (**Figure 75**). At the yearly scale, this species had high densities year-round, especially during re-flooding and the drying of the marsh (**Figure 76**). The high year-round densities are indicative of high local recruitment following recolonization and/or continual immigration from more permanent marshes. In Years four and five of the study, CPUE was extremely low, indicating that this species was especially sensitive to fluctuating water levels (year 4) and very harsh drying events (year 5). Monthly CPUE across all sites and years for flagfish was highest in the re-flooding periods initially following a disturbance (re-flooding periods ranged from May to July over the course of the study), then declined as the season progressed (**Figure 57**). These patterns are generally reflected at the within-year scale (**Figure 77**). In Year 4, similarly to mosquitofish, CPUE for flagfish was very low, indicating sensitivity to rapid drying and wetting typical of spring reversals. The overall monthly CPUE for marsh killfish indicated high densities occurred at both the beginning and the end of the wet season

(**ChuckFig. 1**). When we plotted the data at the yearly scale, we found that for all years, densities were high at both the beginning (May-Jul) and the end of the wet season (Dec-Feb), with the lowest densities occurring in the middle of the wet season (**Figure 78**). This seems to indicate that marsh killifish respond to reflooding by moving into these temporary habitats, then move away from them as they dry in the autumn. The overall monthly CPUE for dollar sunfish showed the highest densities in the beginning of the year (May-June) and at the end of the season (Feb.) (**Figure 79**). At the yearly timescale, we found typically that there was an increase in density during both rewetting and drying of the marsh. Contrary to the pattern seen with flagfish and eastern mosquitofish, dollar sunfish had a relatively high CPUE in Year 4. The Everglades crayfish CPUE data did not exhibit as extreme seasonal fluctuations as the fish species (**Figure 80**). The overall monthly CPUE indicates that there is a slight increase at the beginning of the wet season (July) and at the end of the wet season (Jan-March) (**Figure 57**). When the data are plotted at the yearly timescale, more dramatic seasonal patterns emerge, with high densities both during re-wetting and drying of the marsh.

Overall, eastern mosquitofish, marsh killifish, dollar sunfish, and Everglades crayfish respond strongly to changing water levels, with higher catches when the marshes are rewetting (May-July) and as they are drying (December-March). The responses suggest an ability to detect and to respond to subtly changing water levels, enabling them to exploit these temporary environments successfully. In general, flagfish seemed to be the least-responsive species to marsh drying. The low CPUE at the end of the year suggests that the surface wetlands of the Rocky Glades may function as sinks for flagfish (very little emigration, annual deaths> annual births), but may not be sinks for species that emigrate during drying. Additionally, we found that the two most abundant species, eastern mosquitofish and flagfish, may be dramatically affected by dry-season reversals. In the fourth year of the study, there were numerous reversal events, mainly from unseasonable rainfall in spring. Compared to the other species in this study, the reversals appeared to have had a disproportionately negative affect on both flagfish and eastern mosquitofish. It is possible that the rapid, dramatic changes in water levels created stressful conditions for these fishes by exposing them to predation and desiccation. When the marsh floods after having been dry, these species move into the newly available habitat rapidly. Once there, the rapid drying after a reversal can trap the fish on the surface or in solution holes where they are vulnerable to predation or to poor environmental conditions. This explanation seems plausible in light of the relatively high CPUE in Year 4 of dollar sunfish, a species that does not move into temporary wetlands as rapidly as the other two, and may have avoided the precarious conditions experienced by them. If these dominant, predator-vulnerable species exhibit a trade-off between competitive ability and predation resistance, then a decrease in their populations could lead to increase of competitively inferior species. In fact, for Year 4, marsh killifish (a potential competitor with flagfish and eastern mosquitofish) had exceptionally high CPUEs at both the beginning and the end of the season. The effect of competition is obviously confounded with myriad other effects, but could nonetheless be an important factor shaping the population dynamics of this species.

Diel patterns in fish movement: We collected 15 fish species in the four 6-h sampling events of this 24-h study (**Table 33**, **Figure 81**). Minnow traps also retained 20 riverine grass shrimp, six Everglades crayfish, two *Belostoma flumineum* and three dyticid beetles. Our analyses were focused on nine common fish species (incidence ≥ 10%). Two-way crossed ANOSIM revealed significant temporal patterns in community structure (Global R=0.314, P=0.003), but no significant inter-site variation (**Table 34**). Pairwise analysis of sampling events indicated temporal variation was driven by differences between 1200 h and 1800 h (R=0.542, P=0.060), 1200 h and 0600 h (R=0.322, P=0.060), 1800 h and 2400 h (R=0.461, P=0.015), and between 1800 h and 0600 h (R=0.469, P=0.035; **Figure 82**).

SIMPER revealed ≥ 80% of temporal variation was driven by *H. letourneuxi, L. goodei, killifish, L. marginatus, C. urophthalmus*, and *G. holbrooki*. ANOVA indicated temporal variation in abundances of *L. goodei* ($F_{3,32}$=3.386, P=0.030) and *H. letourneuxi* ($F_{3,32}$=2.845, P=0.053). *L. goodei* were more active in the late afternoon (0600 h) than at night (**Figure 83**), while *H. letourneuxi* were more active late at night (2400 h) than earlier in the day (**Figure 83**). No variation was observed in other fish species or in total fish abundance. *P. paludosus* were also more active late at night (2400 h) than earlier in the day ($F_{3,32}$=5.006, P=0.006; **Figure 83**). Analyses of the relative abundances of *L. goodei* and *H. letourneuxi* showed similar patterns to those seen in abundances (*L. goodei*: $F_{3,32}$=3.436, P=0.028; *H. letourneuxi*: $F_{3,32}$=4.373, P=0.011; **Figure 83**).

Our 24-h catch data revealed few consistent patterns in diurnal fish or large invertebrate movement. While some species were more active during certain times (*L. goodei* in the late afternoon, *H. letourneuxi* at night, *P. paludosus* at night), we could not discern any logical pattern to this movement. Surprisingly, *P. paludosus* were most active at the same time as *H. letourneuxi*, which are known to be predators that consume *P. paludosus* (S. E. Liston, personal observation). It is likely that the absence of patterns in fish movement may be, in part, attributed to lunar phase. The night sampling was conducted the moon was 98.8% full and waxing. Light from the moon and other lunar cues may have been responsible for the failure of fish to exhibit consistent patterns in diurnal activity.

Introduced Fishes: We took a total of seven introduced fish species in the arrays (**Tables 18-23**). Several of these were new species for the Rocky Glades and the park. A few species, mainly black acara, Mayan cichlid, and pike killifish were fairly common at all arrays and solution holes at some time during the sampling period. Only the Mayan cichlid reached 5% of the relative abundance of common species and that was at Array 4 in 2001. Catch rates for introduced species were highest at arrays 2 and 4.

We detected the presence of several newly invading species in the Rocky Glades in the drift-fence arrays. In 2000, we found the jaguar guapote cichlid at Array 1 and subsequently that year, we tracked its westward movement to Pa-Hay-Okee. That species was a regular in our catches but remained uncommon. Similarly, we took the African jewelfish at Array 1 in 2001, and followed its westward movement across the Rocky Glades over the next two years. Jeff Kline, ENP, had previously collected the African jewelfish in the park in the Chekika area, from which it presumably moved south in L-31 canal to enter the Main Park Road area. By 2004, that species had become one of the most abundant non-native fishes in our collections **(Tables 18-23)**. Most sites tended to show delayed colonization by introduced species **(Figures 51-56)**. The relative abundances of non-native fishes increased throughout the wet season. The shortest hydroperiod sites, such as arrays 1 and 2, were colonized by non-natives earlier in the flooding sequence than other sites, probably because they flood later in the wet season when introduced and native species have had the opportunity to disperse across the wetland surface. Introduced species captured in initial events included pike killifish, walking catfish, Mayan cichlid, and black acara. Those species were prevalent in local and regional solution holes, so were able to disperse onto the surface rapidly. In 2003, three drying reversals occurred in the spring and resulted in introduced fishes being collected earlier in the flooding sequence at some arrays. Pike killifish and Mayan cichlid had high capture incidences at most locations. The African jewelfish was more frequently captured in the easternmost arrays, especially during events subsequent to the main flooding event. In general, the capture frequency of non-native species increased as the study progressed **(Tables 18-23).** However, the overall catch of non-native individuals was very low compared with that of the native fishes **(Figure 84).**

Although the rate by which fishes have been introduced into area waters had not increased since the mid-1980s, our data show that five new species have colonized park waters the late 1990s. At the beginning of 2000, seven species of introduced fishes bred in ENP, and two species (including the butterfly peacock, *Cichla ocellaris*) had not yet established (Loftus 2000). In addition, Loftus (2000) noted several species of exotic fishes that occurred in bordering canals but had not yet been observed or collected in ENP. Prior to the summer of 2000, no new exotic species had been observed within ENP since the mid-1980s (Trexler et al. 2000, Loftus 2000). Coincident with the implementation of new water delivery schemes to ENP (ISOP and IOP), we have collected three new non-native species in ENP, and observed the butterfly peacock in a different area of the Park.

Jaguar cichlids (*Cichlasoma managuense*) were noted by Loftus (2000) as a species in the local canal system that had not yet been collected in ENP. With the implementation of ISOP beginning in 2000, water levels in the L31W canal were raised and overflowed over the canal bank to introduce sheetflow into Upper Taylor Slough. In August 2000, juvenile jaguar cichlids were first collected at an ENP monitoring site in upper Taylor Slough (J. Kline, pers. comm..). This site was first sampled in July 1999 and continued monthly through September 2000. Sampling associated with the February 2000 stranding event in upper Taylor Slough did not produce any jaguar cichlids (Kline 2000). Since the first collection in ENP, jaguar cichlids have been collected regularly and observed in highest numbers near the L31W canal and upper Taylor Slough. They are being collected in other areas of ENP and have been collected within the 332 retention areas (J. Kline, pers. comm.).

African jewelfish (*Hemichromis letourneuxi*) have been known from Miami, FL. since the mid 1960's. Loftus and Kushlan (1987) noted a southward and westward range expansion that included the Tamiami Canal and Coral Gables, FL. They were first collected in August 2000 in the Chekika area of ENP (J. Kline, pers. comm.). Sites in the Chekika area were subsequently added to the monthly sampling program from April 2001-present. No African jewelfish were collected in 2001 during the monthly sampling but were collected within a canal associated with 237th Ave in the Chekika area of ENP (J. Kline, personal observation). In 2002, African jewelfish became a major proportion of the catch in the Chekika area and were collected in other sites in the East Everglades, Northeast Shark River Slough, and the C111 panhandle region in ENP that suggested its range was expanding. Other work used to document fish dispersal patterns in ENP has also collected jewel cichlids. African jewelfish first appeared in drift-fence arrays along the Main Park Road in 2002 at Array 1E, but were absent in 2000 and 2001. Since then, they have also been taken it in large numbers at the easternmost arrays, with a few farther west along Main Park Road. African jewelfish have more recently been collected within the 332 retention areas (J. Kline unpublished data). Overall, this species has become a common component of catches in the Rocky Glades and a dominant component of catches in the East Everglades marshes of ENP.

The armored catfish (*Hoplosternum littorale*) is the most recent non-native species collected within ENP. They were first documented from the Indian River system in Brevard County, Florida in 1995 and have rapidly spread south. An adult male armored catfish was collected in August 2002 in the pinelands north of Main Park Road (J. Kline, pers. comm.). We took juvenile specimens during our sampling of solution holes and arrays that indicate this species is reproducing and established in the Rocky Glades.

Butterfly peacock bass had been observed in the late 1980s at a Shark Valley borrow pit but had not been recorded since in ENP until 2002 (Loftus 2000). In 2001, they had been observed in the L-31W canal and in culvert holes associated with the L-31W canal (J. Kline, personal observations). Several individuals were observed in the Anhinga Trail borrow pit area in November 2002 as Taylor Slough dried down. Similarly, Kline and ourselves have taken the peacock spiny eel (*Macrognathus siamensis*) from the Taylor Slough/C-111 area, but we did not collect this species or the butterfly peacock in our sampling.

We collected data during a hard freeze in January 2003, when air temperatures in the park fell below 0^{o} C. Thermograph data at one of the surface-water, drift-fence arrays used for sampling fishes had a minimum of less than 6^{o} C at a water depth of 12 cm. Temperatures in a 1-m deep Taylor Slough alligator pond fell to about 11^{o} C. Mortality of several non-native species including Mayan cichlid, butterfly peacock, black acara, and walking catfish in surface waters coincided in time and space with these cold spells. Non-native fishes survive cold winters in the Rocky Glades in part because they have access to thermal refuges provided by groundwater. Access to groundwater is through solution holes (See Shallow Sub-surface Refuge Section above). Shafland (1999) stated that the survival of the introduced butterfly peacock bass in southeast Florida is aided by warm groundwater refuges in deep canals in winter (Shafland 1999)

Some non-native species have known physiological and behavioral adaptations that allow them to exploit environments low in dissolved oxygen, and perhaps tolerate abrupt temperature changes. Because measurements of groundwater refuges can have extremely low dissolved-oxygen values and potentially fatal ammonia concentrations, species that survive in those refuges must tolerate those conditions (see Shallow Sub-surface Refuge Section). Selective mortality and dispersal ability may explain why some fishes take longer to colonize, because their ideal refuge may not be local groundwater habitats, or because their population density is low there. Further study of adaptations, behaviors, and dispersal ability would be helpful to recover fish populations in this region.

Translocated native fishes: Two species native to central Florida northward have been collected in ENP since the beginning of ISOP/IOP. Both the pirate perch (*Aphredoderus sayanus*) and the grass/redfin pickerel (*Esox americanus*) had not been known or collected from ENP prior to new water-management practices (ISOP/IOP) (Loftus and Kushlan 1987, Loftus 2000). The pirate perch was first collected in Northeast Shark River Slough in 2002 and have since been collected south to Main Park Road (J. Kline and W. Loftus, unpublished data). In 2003-2004, we collected this species regularly in array traps. Multiple individuals of grass/redfin pickerel were also collected in the array traps. This piscivorous species is a new predator in the Rocky Glades wetlands.

Early colonization of marshes: We found little variation in array CPUE among the early days of the first flooding event of the 2003 and 2004 wet seasons. Fish composition in the array catch did not differ between days 1-4 (Global R = 0.033, p = 0.12). We also found no difference between years (2003 vs. 2004 wet seasons) (Global R = 0.065, p = 0.009), nor between arrays (Global R = 0.033, p = 0.12). These results suggest that early colonization events are somewhat uniform in composition across space and in the very early stages of recolonization (**Figure 85**).

ANOSIM detected some differences between days when the all days in the first flooding event of the season were included in analyses (Global R = 0.12, p =0.001). Pairwise comparisons showed that this variation was due to differences between early days (1-4) and late days (13-14), although separation between these days was not large (see green vs. blue symbols in **Figure 85**). Preliminary analysis that included all species in a presence/absence matrix showed the same result.

SIMPER showed that this variation in species composition between early and late days of the first flooding event was primarily due to the following species: *L. marginatus*, *G. holbrooki*, *F. confluentus,* and *J. floridae.* These four species accounted for 65-70 % of the dissimilarity among days. Univariate analysis showed, however, statistical differences in only three of the four species. Abundances of *F. confluentus* and *J. floridae* were higher in early vs. late days ($F_{5,59}$ = 2.9, p = 0.045 and $F_{5,59}$ = 2.8, p = 0.053 respectively; see figure below). In contrast, abundances of *L. marginatus* were higher in later days of the flooding event ($F_{5,59}$ = 3.6, p = 0.022) (**Figure 86**).

Role of solution holes as sources or sinks for colonists: In 2003 and 2004, minnow trap CPUE in solution holes at the end of the dry season did not vary significantly over the course of the last month of sampling (ANOSIM on four sampling dates; 2003: Global R = 0.047, p =0.097, and 2004: Global R = 0.269, p =0.097, **Figure 87**), thus we averaged catches across the last four sampling dates for the comparison to the solution-hole data.

In 2003, species composition at the end of the dry season in solution holes was similar to that detected in arrays on the marsh surface at the beginning of the wet season (Global R = -0.229, p = 1.0, **Figure 88**). *F. confluentus, G. holbrooki, L. marginatus* and *P. latipinna* were dominant species in both habitats, although numbers were significantly lower in solution holes. *L. goodei* and *J. floridae* were present in arrays upon reflooding but absent from solution holes, whereas *C. bimaculatum* was present in solution holes but absent form arrays.

We suspect that an earlier reflooding event in March 2003 restocked these solution holes with fishes dispersing out of Taylor and/or Shark sloughs and these fishes took refuge in these solution holes and may have contributed to the pool of colonizers detected in the array samples later in May-June 2003. This was a different pattern than we had noted in 2001-2002, when few fish survived in holes at the end of the dry season (See ENP IOP report). Unfortunately, sample sizes were too small for meaningful statistical analyses in those years.

In 2004, the rainy season did not start until mid July, thus our sampling of arrays did not begin until 23 July. By this late in the season, the majority of the solution holes had dried. The only exceptions were two deep solution holes in the Wilderness-Road region. Species composition in these two holes at the end of the dry season differed drastically from species composition detected in array catch data upon reflooding (Global R = 1.0, p =0.018, **Figure 88**). Fish communities in these two solution holes at the end of the dry season comprised only three species, all of them non-indigenous: *C. bimaculatum*, *H. letourneuxi* and *C. bratrachus*. Colonizers detected in the marsh surface included *J. floridae, F. confluentus, L. marginatus* and *G. holbrooki*. The only species in common between solution holes and array catches was was *H. letourneuxi.*

These results suggest that during short dry-down periods, solution holes may constitute an important refuge for fish and thus act as a source of local colonists. We suspect that was the situation historically before groundwater levels were reduced. However, under today's drained conditions, with prolonged dry downs, most solution holes dry long before the wet season begins, particularly the shallow and medium-depth holes that are most suitable to small fishes. Most fishes in solution holes perish before the wet season begins. Comparisons of community composition show that first colonists detected upon re-flooding do not come from solution holes. Instead, evidence suggests that fishes are dispersing from Shark River Slough and the eastern boundary canals into the shorter hydroperiod marshes of the Rocky Glades as soon as these areas re-flood.

Although animals appeared at all arrays within the first week of flooding, the pattern of capture at each array may help indicate the importance of local vs. regional vs. distant colonization. A distant-source colonization hypothesis would mean that fishes are dispersing across long distances (kilometers) from long-hydroperiod areas such as sloughs, estuaries, or canals. The arrays are bordered by Shark River Slough to the west and Taylor Slough to the east. If animals are moving from the sloughs or estuaries to re-colonize the re-flooding Rocky Glades, CPUE at arrays 1 and 4 should rise first (with some differences due to later flooding at Array 1 because of its higher elevation). Alternatively, if local or regional source refugia act as a primary source of fish colonists, array sites within the interior of the Rocky Glades should display the largest first-week CPUE of fishes. This latter pattern seemed evident in this year's first-week fish CPUE, in which Array 2 had the largest capture nearly every day of the first week. In support of the distant-source hypothesis, however, Array 1 had the largest CPUE of fishes in the east trap on the second day of flooding. This could be indicative of mass fish movements out of Taylor Slough. The speed at which recolonization of the arrays by small fishes occurs is a point difficult to resolve with the distant-source hypothesis. Is it possible for these small-bodied fishes to move so rapidly across this vegetated and often discontinuously flooded wetland landscape and appear so quickly in the numbers we find during the first week of flooding? This is a very difficult question to address in this vast landscape when dealing with animals too small to mark and recapture. In the case of 2003 data, we can speculate that fish movements were concurrent with water level fluctuations, with fish traveling during the short flooding periods brought on by the unseasonable rains During subsequent drying, fishes on the marsh surface likely expired or sought refuge in solution holes (See Sub-Surface Refuge Section). During the first week of flooding this year, fishes may have both been locally available in solution holes and moving in from more distant refuges.

Previous studies have shown that mosquitofishes are excellent dispersers (Brown 1987; Rehage and Sih 2004). Their dispersal ability, coupled with their positive rheophilic behavior, probably explains their high abundance in the Rocky Glades. The water flow at the arrays is predominantly from east to west, giving the impression that the fish may be surviving in refuges to the east, then following the flow to the arrays where they are captured. Directly east of the study sites, there are canals that provide dry-season refuge for eastern mosquitofish (Loftus, personal observation –2005). While this might indicate that the source populations for eastern mosquitofish reside in the L-31N and L-31E canals, the explanation is more complicated. Fish, including eastern mosquitofish appear first in the arrays (particularly arrays 4 and 5) in the western section of the Rocky Glades every year because those lower-elevation wetlands flood earlier than the rest. When those areas flood, there are no aquatic connections to the eastern canals because of higher ridge of land between arrays 5 and 2 prevents waters from becoming continuous with the canals until later in the summer (**Figure 89**). Instead, our data indicate that the eastern mosquitofish and other species colonize the arrays from the western marshes of Shark River Slough and the headwaters of Squawk Creek and others, the only areas that remain wet through most dry seasons. In wetter dry seasons, many species also persist in regional solution refuges such as the large complex on the north face of the Pa-Hay-Okee rock ridge, from which they can quickly colonize the Rocky Glades. Samples taken in the peripheral wetlands between the Rocky Glades and the slough have similar species compositions to those of the array samples. The fact that many fishes are taken in the eastern-facing traps when we think they are dispersing from the west is probably the result of local topography and the influence of the park road, both of which direct flows from east to west at most arrays. We must question whether these array traps provide a reliable estimate of the direction of dispersal because one would expect that sites closer to deep-water refuges would have the greatest directional biases toward the direction of the refuge. Instead, we have shown that Array 4, closest to Shark River Slough, has the largest catches in the east-facing trap, while Array 1 (closest to the eastern canal) has its largest catches of fish in the western-facing traps. While these local topographic idiosyncrasies may be responsible for the easterly or westerly flows seen in our data, we also have little doubt that L-31N and L-31W canals on the east and Shark River Slough to the west, provide the majority of mosquitofish colonists to the Rocky Glades marshes. Local refuges seem of little importance to re-colonization under today’s conditions.

Because of these counterintuitive results, we conclude that the arrays are providing an indication of local water flow and fish response to that flow, rather than indicating regional movement patterns. To discern regional patterns, a much denser network of arrays would be needed. The array data also indicate the role of the park road in affecting local hydrology by blocking the flow of water and directing it either eastward or westward, depending on the local topography. Historically, water would have flowed southward towards Florida Bay in this region, but the roadbed without many culverts now redirects the flow (Stewart et al. 2002).

Stable-isotope work

Another method that we tested as a spatial marker for movements by fishes was the signatures of the spatial isotopes of carbon and nitrogen in fish tissues (**Figure 90**). We saw that, except for the Everglades crayfish, the signatures for carbon and nitrogen isotopes declined between the early re-flooding of the marsh, through the middle of the wet season, into the end of the wet season for the common species of fishes. This indicates that the early colonizers immigrated into the Rocky Glades from elsewhere where they had fed on diets with different carbon and nitrogen signatures. Then, as they inhabited the Rocky Glades, they assimilated the signatures of the prey from that region, which replaced the donor-site signatures over time. With further testing, this method may be a useful, indirect method of discerning movements by fishes too small to mark directly.

Otolith microchemistry

Of the nine cages set in the Hidden Lake ditch, Shark River Slough, and Rookery Branch creek, few survived the dry season. On 11-12 April 2004, a strong cold front with gusty winds hit Shark River Slough, blowing down the three cages. The cages at Rookery Branch had been damaged by alligators. All fish were lost. Cages at Hidden Lake were unharmed. With few captive fish remaining, we replaced one cage per site with five fish. We reserved a few for controls and for Sr dosing at the mesocosm. We performed the dosing at the Beard Center mesocosm from mid-April to mid-May. By 23 April 2004, the neonates in the dosing experiment had disappeared because of dragonfly predation. We introduced 5 additional neonates from the control tank to replace them.

By the end of May, water levels in the Hidden Lake canal had fallen drastically. In two cages, little free water remained and no eastern mosquitofish were found. In the other cage (1), we recovered two adult fish. We collected 10 wild mosquitofish from Hidden Lake for comparison. In early June, we recovered several captive-reared fish from the Strontium treatment and Control tanks in the mesocosm facility. Each group was placed in a plastic bag and frozen in the lab freezer after measuring. All fish from Rookery Branch were lost, and only a few were recovered from Shark River Slough.

After dissecting otoliths from the fish, we mounted samples in SPURR resin from five fish each from the Hidden Lake wild fish, the mesocosm Strontium-dosed tank, and the Strontium control tank. The otoliths were sectioned, sanded, and polished to the primordium. We glued the otoliths to a glass slide, and delivered them to the FIU Geology lab. Unfortunately, the electron microprobe malfunctioned for months while we awaited results. We did not obtain images of the otoliths (**Figure 91**) and data files until November 2005, too late to analyze them for this report. We plan to continue working with the data, and the otoliths that have yet to be examined, and will file a subsequent report on the results to ENP.

Visual sampling

We documented the onset of recruitment using the size-structure data and the visual-sampling data. All fishes emerging onto the surface were adults that began reproducing within one or two weeks. Small juveniles appeared in the wetlands within a month of reflooding (**Figure 92**). In the visual plots, eastern mosquitofish were most visible, probably because they are in constant motion. Sedentary, cryptic species were more difficult to observe. Over the course of the entire sampling period, the number of fish seen in visual plots showed an almost immediate response to periodic reversals and re-wettings (**Figure 92**). Likewise, fish and crustaceans captured in the arrays show a similar pattern of fluctuation. When we compared the density estimates from the visual samples with the CPUE data from the arrays, we found little correlation between those measurements. Therefore we stopped using this method in the Rocky Glades because we think that the vegetation cover in those wetlands affects our ability to observe the large numbers of fishes that the array samples demonstate are present.

Large-fish movement patterns

Two of five implant-control and one of four handling-control fish died in captivity; the remaining fish developed severe fungal infections, demonstrating that capture and handling stress could be a mortality factor. We began to track the fish weekly by foot on 21 May 2003 (**Appendix 14**). We collected environmental measurements at Anhinga Trail and Taylor Slough Bridge during each survey. Low, dry-season water levels confined the fish to the Taylor Slough Bridge pool, where we recorded most signals (**Figure 93**). We learned that a Great White Heron had preyed on one fish within two days of its release. When water levels rose in mid-June, but several signals remained beneath the bridge, we concluded that the stress of capture had resulted in the mortality of seven fish. We recovered those transmitters and implanted them into fish captured at the bridge or at Anhinga Trail. Those fish were released at their respective capture sites. Two transmitters were implanted into three different fish when the original recipients died. It appeared that cast netting of fish was less traumatic and resulted in fewer mortalities compared to gill netting.

The survivors from the initial and subsequent releases dispersed by moving north and south into the slough as the waters rose in the summer wet season (**Figure 93**). During flooding in August, we saw Great White Herons with gar along Taylor Slough; these large wading birds appear to take gar routinely. By late June, a few fish remained in the vicinity of the Main Park Road at Taylor Slough, but other gar could not be located. We suspected that they had either been preyed upon or had moved beyond the range of our road-based receiver. We initiated a fixed-wing aircraft survey on 26 June 2003; this continued every other week until December (**Appendix 14**). We continued to obtain location fixes by foot every week.

We located several of the gar in the area between Anhinga Trail and the Main Park Road. Others had moved south of Anhinga Trail, past Buzzard’s Roost in central Taylor Slough, where they remained for weeks before returning to the northern part of the slough (**Figure 93**). Many transmitters died within the expected life span of six months, but we were able to follow several gar for almost ten months. Other signals were lost after periods of weeks to a few months, and we do not know what became of those. During flights and by road, we also searched for missing fish in L-31W canal and at the S332 pump station pools, and west into the Rocky Glades without success. From November to December, with falling water levels, a few gar moved back to culvert pools on the Main Park Road, but before those pools became isolated, they moved south to Anhinga Trail, where they resided until the signals died. None of the gar we tracked ranged far from Taylor Slough, and none entered the Rocky Glades.

On 14-15 October 2003, we obtained positions and habitat-use information for gar every three hours during a 24-hr period, beginning around noon on the 14th. Four fish were initially located in Main Park Road culverts, and the fifth at Anhinga Trail. Most moved very little from noon until late evening, taking cover in dense vegetation or deep water. They began to move locally from shallow marsh or culvert edges to pool habitats and back again around midnight (**Figure 94**; **Appendix 15**). Some fish continued to move into the next morning. It is likely that these movements were associated with foraging (Snedden et al. 1999).

Based on the radio-tracking data and our collections and observations from the Rocky Glades, Florida gar are not a source of predation in that region. In fact, our data indicate that the shallow, temporary wetlands may actually serve as a predator refuge for the small fishes that utililize the wetlands for feeding and reproduction in the wet season.

PROJECT SYNTHESIS

The study of ecological interrelations between surface and sub-surface habitats will help determine how management has affected this region and what benefits can be anticipated by the restoration of natural hydrology. The temporal dynamics of the use of Rocky Glades habitats in relation to hydrology have just begun to be described. We are providing the first description of the aquatic fauna that inhabits this short-hydroperiod environment. This project will also provide data showing whether solution holes in the Rockland presently function as sources or sinks for fishes. These data will be important for use in simulation models that assist in planning management actions in Everglades National Park.

The environmental monitoring data contribute to our understanding of basic physiological tolerances of species that may be unique to the subterranean environment of south Florida. Interpretation of these data indicates that well and solution hole environments generally offer a very low DO habitat, while the habitat surrounding arrays is generally super-saturated with DO and varies diurnally with respect to temperature, and to a lesser degree, pH. It appears that fishes and other aquatic organisms inhabiting the Rocky Glades need several adaptations to successfully survive and reproduce in this region. The most challenging survival period may be during extreme drying of marsh surfaces, when organisms are forced below the ground surface. Although solution holes may be challenging because of their chemical variability, belowground chambers represent an even greater challenge as the absolute stability of DO is extremely low.

Although we did not find many species or individuals of aquatic species inhabiting groundwater, particularly beneath ENP, we were able to gather solid life-history and distributional data for the Miami cave crayfish, a poorly studied, endemic subterranean crustacean. We did not collect it beneath ENP, but we did locate the species at over a dozen new locations in southeastern Miami-Dade County. It is closely related to the surface-dwelling Everglades crayfish, and appears to be in the process of adapting to a truly subterranean life.

Survival of fishes in solution holes depends on the characteristics of the individual hole, the minimum groundwater depth in a particular year relative to hole depth, and the cohabiting fishes in the hole. Because groundwater levels remained higher in the spring of 2001, more holes held water and fishes than in 2002. The rapid drop in groundwater levels in 2002 killed fishes in many holes. Many introduced species have adaptations that enhance their survival in solution holes. Those species were most prevalent in the holes we sampled near the easternmost array sites, as well as in deeper holes. The physicochemical data demonstrate that the holes that retain water longest under today's drained conditions are also the most difficult habitats in terms of low dissolved oxygen. They also house the largest numbers of introduced predatory fishes, which are tolerant of those conditions, and also use the holes as a thermal refuge. Comparisons of fish species remaining in holes at the end of the dry season with those colonizing the surface at the start of the wet season reveals little correspondence, indicating that under today's drained conditions, solution holes are more likely sinks than refuges for small fishes.

Fish catches and relative abundances varied by year and by array. In general, arrays with the shortest hydroperiods had the lowest catches. Hydroperiods at arrays 1, 2, and 3 range from short to moderate, but are shorter than those predicted by the Natural Systems model for the area. Array 4 with the longest hydroperiod, usually had the highest catches. Most sites appeared to show an inverse relationship between catch and water depth. This was most pronounced at Array 4. During high-water periods in 2001 and 2002, catches at maximum water levels declined at Array 4, probably because of dispersal into shallower sites and because of a trapping problem.

Yearly rainfall patterns play a major role in determining the timing and duration of surface flooding, the number of reversals, and the extent to which groundwater levels fall in the spring. These patterns in turn affect the appearance and catch rates of fishes on the wetland surface, and probably also affect the interannual species composition. Our water depth data from each array, and the data from ENP continuous recorders, demonstrate that surface and ground water conditions in the Rocky Glades are dependent upon and highly responsive to rainfall. In addition to long-term reductions in water levels in the Rocky Glades, the data set for the easternmost arrays suggests that pumping and drainage operations during IOP affected hydropatterns and fish survival in those arrays. In 2002, average dry season rainfall kept the below-ground recession rate at a moderate level until pumping from L-31W ceased (S. Mitchell, Pers. Comm.). This dramatically increased the rate of recession, drying the solution-hole refuges, and causing fish mortality. Similarly, pre-storm drainage actions in September served to dry the wetlands earlier than normal, forcing fishes into solution holes where mortality occurred over time. Conversely, at Array 4, flooding in 2002 extended into 2003 at this site. We assume that hydrology at this site is responding to operations that affect Shark Slough rather than the Rocky Glades/Taylor Slough area.

At the beginning of 2000, seven species of introduced fishes bred in ENP, and two species (including the butterfly peacock bass, *Cichla ocellaris*) had not yet established (Loftus 2000). In addition, Loftus (2000) noted several species of exotic fishes that occurred in bordering canals but had not yet been observed or collected in ENP. Prior to the summer of 2000, no new exotic species had been observed within ENP. Since then, we have recorded three new species in the array and solution hole samples, and two additional species in Taylor Slough. Recent water-management changes may have directly contributed to the introduction of, or the redistribution of, new non-native fishes in ENP, as well as range expansions by two native species previously unrecorded from the southern Everglades.

The Rocky Glades region serves as a seasonal home to almost forty species of fishes, many invertebrates, amphibians, and aquatically associated reptiles. We conclude that, while some species like the Everglades crayfish, can survive in the wetlands by burrowing, the fishes must recolonize the region every wet season from permanent waters elsewhere. Some regional solution holes, such as those around Pa-Hay-Okee, offer dry-season refuge, but the majority of holes in the Rocky Glades are too shallow under today's conditions to maintain water through the dry season. If groundwater levels were higher, as they were in the past before drainage, then a higher percentage of holes would remain wet, providing more local recolonization of the surface when it re-floods.

POTENTIAL IMPACTS AND PRODUCTS:

This project has provided the first inventory, and baseline ecological data, for the aquatic fauna of the Rocky Glades region of Everglades National Park. Sampling at fixed sites that combined solution-hole complexes with surrounding wetlands was performed before restoration began so that a large amount of baseline data are now available. Future monitoring at those sites during the restoration process should be able to detect faunal changes. As this project ends, the study sites are available to the Everglades National Park monitoring staff for incorporation into the long-term monitoring program.

The benefits to restoration include more confidence in improved tools, like the ATLSS models, that are used to evaluate alternatives for ecological effects of the Central and Southern Florida Project Restudy, C-111 Project, and Modified Water Deliveries (Modwaters) Plan to Shark Slough. A number of Performance Measures and Success Criteria have been developed to assess Restudy actions that relate directly to the Rocky Glades. These Measures are referable to the Conceptual Models developed for the Restudy to illustrate the stressors and response variables in each major habitat that would be affected by restoration actions. Data from the present study will provide the information needed to examine the responses of aquatic communities to restored hydrological patterns and to an increase in the spatial extent of the system. The data, and the models that incorporate them, should also help define the reasons behind wading bird decline as relates to prey availability and abundance.

In addition to the application of these data to modeling, the data collected during these companion studies will represent new information about the composition and adaptations of the surface-water and groundwater communities. Preliminary collections have resulted in first records of some species for the United States, and potentially new species for science. The data are under review by USFWS, which is considering one species for candidacy for listing under the Endangered Species Act. The interactions of groundwater and surface-water habitats demonstrate the critical and delicate ecosystem linkages that occur on this karstic landscape. The relationships we describe, and the information we collect, may help managers of other karstic wetlands, as in Mexico, Belize and the Bahamas, better protect their resources.

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ACKNOWLEDGEMENTS

We greatly appreciate the help in field and laboratory of the technicians who built the arrays, tested the sampling gear, and processed the samples they collected: Victoria Foster, Robert Kobza, Delissa Padilla, Xavier Pagan, Diane Riggs, Hardin Waddle, Andrew Martin, Brooke Shamblin, Raul Urguelles, and Phil George. Paul Teague offered his willing services to produce the GIS maps, and Bob Zepp saw us through the ENP permit process. Daniel James of USGS and John Dennis of NPS provided oversight on the funding of the remote-sensing topographic work. We appreciate the permission and assistance given by Paul Radice to work with his captive population of Miami cave crayfish. Dr. Kevin Cunningham of USGS worked closely with us in the GPR survey and well drilling. Dieter Elswick and Christine Fadeley of USGS helped immensely with budget and personnel needs, and Dr. Tonya Howington of ENP was a great supporter of this work as NPS CESI coordinator and project administrator.

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Table 1. Scientific and common names of fishes and common macroinvertebrates taken during this study.

Common Name	Latin Name
American eel	*Anguilla rostrata*
African jewelfish*	*Hemichromis letourneuxi*
Black acara*	*Cichlasoma bimaculatum*
Blue tilapia*	*Oreochromis aureus*
Bluefin killifish	*Lucania goodei*
Bluegill	*Lepomis macrochirus*
Bluespotted sunfish	*Enneacanthus gloriosus*
Brook silverside	*Labidesthes sicculus*
Brown hoplo*	*Hoplosternum littorale*
Coastal shiner	*Notropis petersoni*
Dollar sunfish	*Lepomis marginatus*
Eastern mosquitofish	*Gambusia holbrooki*
Flagfish	*Jordanella floridae*
Florida gar	*Lepisosteus platyrhincus*
Everglades pygmy sunfish	*Elassoma evergladei*
Golden shiner	*Notemigonus crysoleucas*
Golden topminnow	*Fundulus chrysotus*
Grass pickerel	*Esox americanus*
Jaguar guapote cichlid*	*Cichlasoma managuense*
Lake chubsucker	*Erimyzon sucetta*
Largemouth bass	*Micropterus salmoides*
Least killifish	*Heterandria formosa*
Marsh killifish	*Fundulus confluentus*
Mayan cichlid*	*Cichlasoma urophthalmus*
Oscar*	*Astronotus ocellatus*
Pike killifish*	*Belonesox belizanus*
Pirate perch	*Aphrododerus sayanus*
Rainwater killifish	*Lucania parva*
Redear	*Lepomis microlophus*
Sailfin molly	*Poecilia latipinna*
Sheepshead minnow	*Cyprinodon variegatus*
Spotted sunfish	*Lepomis punctatus*
Spotted tilapia*	*Tilapia mariae*
Tadpole madtom	*Noturus gyrinus*
Taillight shiner	*Notropis maculatus*
Walking catfish*	*Clarias batrachus*
Warmouth	*Lepomis gulosus*
Yellow bullhead	*Ameiurus natalis*
Everglades crayfish	*Procambarus alleni*
Riverine Grass shrimp	*Palaemonetes paludosus*

* Introduced Species

Table 2. Dates and locations of samples collected with YSI 600s. Samples include measurements of water temperature, dissolved oxygen, specific conductance, and pH.

Surface Samples	**Deployment Dates**	**Solution-Hole Samples**	**Deployment Dates**	**Well Samples**	**Deployment Dates**
Array 4	9/12/02 – 9/19/02	3SB	10/1/02 – 10/8/02	MW5	8/19/02 – 8/26/02
Array 5	9/12/02 – 9/19/02	MR2	10/1/02 – 10/8/02	MW8	8/19/02 – 8/26/02
Array 3	9/12/02 – 9/19/02	Bluebag	10/1/02 – 10/8/02	MW8	8/19/02 – 8/26/02
Array 6	9/12/02 – 9/19/02	2MB	10/1/02 – 10/8/02	MW5	8/19/02 – 8/26/02
Array 4	10/23/02 – 10/30/02	MR4	10/1/02 – 10/8/02	MW8	10/11/02 – 10/18/02
Array 5	10/23/02 – 10/30/02	MR11	11/7/02 – 11/14/02	MW5	10/11/02 – 10/18/02
Array 3	10/23/02 – 10/30/02	2MB	11/7/02 – 11/14/02	MW8	10/11/02 – 10/18/02
Array 2	10/23/02 – 10/30/02	MR8	11/7/02 – 11/14/02	MW5	10/11/02 – 10/18/02
Array 4	1/10/03 – 1/16/03	Bluebag	11/7/02 – 11/14/02	Paul	11/2/02 – 11/10/02
Array 4	1/16/03 – 1/22/03	Bluebag	1/10/03 – 1/16/03	MW5	11/27/02 – 12/3/02
Array 4	1/23/03 – 1/30/03	Bluebag	1/16/03 – 1/22/03	MW5	2/20/03 – 3/6/03
Array 4	3/29/03 – 4/5/03	Bluebag	1/23/03 – 1/30/03	MW8	2/20/03 – 3/6/03
Array 3	6/5/03 – 6/19/03	PH01	2/6/03 – 2/13/03	PGL	2/20/03 – 3/6/03
Array 4	6/5/03 – 6/19/03	PH02	2/6/03 – 2/13/03	MW8	2/20/03 – 3/12/03
Array 4	7/11/03 – 7/14/03	PH01	2/6/03 – 2/13/03	MW5	2/20/03 – 3/12/03
Array 3	7/11/03 – 7/18/03	MR11	2/6/03 – 2/13/03	PPL9(B)	3/20/03 – 3/28/03
Array 6	7/11/03 – 7/18/03	MR7	3/29/03 – 3/30/03	PPL9(B)	3/20/03 – 3/28/03
Array 5	7/11/03 – 7/18/03	Bluebag	10/23/03 – 10/28/03	OHK	3/20/03 – 4/1/03
Array 6	8/1/03 – 8/2/03	MR11	10/23/03 – 10/28/03	OHK	3/20/03 – 4/3/03
Array 3	8/1/03 – 8/5/03	2MB	10/23/03 – 10/28/03	PGL	5/13/03 – 5/20/03
Array 4	8/1/03 – 8/8/03	MR8	10/23/03 – 10/28/03	PPL9(B)	5/13/03 – 5/20/03
Array 2	8/2/04 – 8/9/04	3SB	10/23/03 – 10/28/03	PPL9(B)	5/13/03 – 5/20/03
Array 4	8/2/04 – 8/9/04	Bluebag	12/17/03 – 12/24/03	PGL	5/13/03 – 5/20/03
Array 5	8/2/04 – 8/9/04	MR11	12/17/03 – 12/24/03	PGL	8/21/03 – 8/28/03
Array 3	8/2/04 – 8/9/04	2MB	12/17/03 – 12/24/03	PPL9(B)	8/21/03 – 8/28/03
Array 1	10/28/04 – 11/4/04	MR8	12/17/03 – 12/24/03	PPL9(B)	8/21/03 – 8/28/03
Array 4	10/28/04 – 11/4/04	3SB	12/17/03 – 12/24/03	PGL	3/25/04 – 4/1/04
		Bluebag	3/24/04 – 3/31/04	PGL	5/13/04 – 5/21/04
		MR11	3/25/04 – 4/1/04		
		3WR	3/25/04 – 4/1/04		
		PHO 1	5/13/04 – 5/20/04		
		1HL D	5/13/04 – 5/20/04		
		2WR D	5/13/04 – 5/20/04		
Total Samples	27		33		28

Table 3**:** Remotely sensed data types and their characteristics. Abbreviations for data types are provided within the text.

Data type	**Spectral coverage**	**Source**	**Ground Resolution**
DOQQ	Color-infrared	The National Map	1 meter
133_E	Color-infrared	Private Contract	~0.15 meter
HBDI	Color-infrared	USGS SWSC	~0.10 meter
LIDAR	Elevation and Intensity	Florida International University	~1 m

Table 4**:** Check of significant holes as forecasted by terrain analysis against existing fish solution-hole sample sites. Key: >20 cm – field site with a depth greater than 20 cm; >30 cm – terrain analysis forecasted to be greater than 30 cm in depth. Depth notations in the > 20 cm field were extracted for those sites from the terrain analysis forecast.

Site	**> 20 cm**	**> 30 cm**	**Latitude**	**Longitude**
5SA	Y - 27cm deep	N	25°26.146	-80°41.729
5SB	Y	Y	25°26.178	-80°41.730
7SA	Y – 23 cm deep	N	25°26.002	-80°44.089
MR1	Y	Y	25º26.18927	-80º42.88245
MR10	Y	Y	25º26.13745	-80º41.74788
MR11	Y	Y	25º26.01578	-80º44.09331
MR12	Y	Y	25º26.11814	-80º44.03988
MR13	Y	Y	25º26.09303	-80º43.96231
MR3	Y	Y	25º26.11267	-80º43.28285
MR4	Y – 21 cm deep	N	25º25.98746	-80º44.49821
MR5	Y – 24 cm deep	N	25º25.99454	-80º44.47407
MR6	Y – 16 cm deep	N	25º26.00098	-80º44.44028

Table 5**:** Comparison of significant (>30-cm deep) and insignificant (<20-cm deep) holes as derived from LIDAR-based terrain analysis or detected in the field. Key: Site – individual image-derived, solution-hole number; <20 – Field-located depression that is not a significant solution-hole habitat; Field? – determined in the field to be significant; Image? – forecasted as significant using terrain analysis; UTM X – UTM easting; UTM Y – UTM northing; Size – estimated size; Max/Ave/Stdev depth – estimated depth maximum, average, and standard deviation, respectively; NA – not applicable.

Hole #	Field?	Image?	UTM X	UTM Y	Size (m^2)	Max/Ave/Stdev Depth (m)
2301	Y	Y	530581	2813215	1	.33 / NA / NA
1086	Y	Y	530553	2813363	4	.35 / .32 / .03
2097	Y	Y	530742	2813209	30	.68 / .45 / .09
739	Y	Y	529797	2813418	28	.46 / .38 / .05
1468	Y	Y	529765	2813300	2	.40 / .38/ .04
1381	Y	Y	529841	2813311	27	.46 / .37 / .04
1084	Y	Y	527726	2813362	9	.38 / .35 / .02
934	Y	Y	529849	2813390	5	.37 / .34 / .03
NA	Y	N	529755	2813339	1	1.5 (field est.)
2182	Y	Y	527713	2813197	1	.33 / NA / NA
2066	Y	Y	527722	2813217	1	.34 / NA / NA
1589	Y	Y	527685	2813287	7	.42 / .37 / .05
2756	Y	Y	527665	2813125	1	.34 / NA / NA
2817	Y	Y	527648	2813318	6	.93 / .63 / .20
2677	Y	Y	527680	2813129	15	.50 / .38 / .07
< 20	N	N	530589	2813236	NA	NA
< 20	N	N	530588	2813372	NA	NA
< 20	N	N	530609	2813358	NA	NA

Table 6**:** Summary of the advantages and disadvantages of the various airborne remote-sensed data types or technologies evaluated through this research.

Data type	**Advantages**	**Disadvantages**	**Comments**
DOQQ	Availability	Spatial resolution	Resolution inadequate for all but broad habitat characterization
133_E	Spatial resolution Geometric fidelity Easy ortho creation	Lack of flexibility in collection date(s). High cost	Timing of collection is critical.
HBDI	Flexibility in deployment/data collection. Low cost	Difficult preprocessing (many images, no camera model). Image blur.	Easy to deploy during best water conditions. Imaging technology needs further development.
LIDAR	Best for identification when collected under proper conditions.	High cost. Lack of flexibility regarding collection date(s).	Required for consistent solution-hole identification.

Table 7. Specimens collected from well traps in the Rocky Glades

Well	Deployed	Retrieved	Device	Trap Depth (m)	Specimens Collected
WIO2B	6/18/01	6/19/01	Bottle Trap	-	0
3681	4/17/01	4/18/01	Bottle Trap	-	1 Coleoptera, 3 larval Coleoptera
3681	5/22/01	5/23/01	Bottle Trap	-	2 Ostracods
3686	5/22/01	5/23/01	Bottle Trap	-	0
3686	6/26/01	6/27/01	Bottle Trap	-	0
LPKPLB	2/6/01	2/7/01	Bottle Trap	-	36 Ostrascods
PGL	3/12/01	3/13/01	Bottle Trap	-	2 Coleoptera, 9 Ostracods, 1 *Physella*
PGL	4/17/01	4/18/01	Bottle Trap	-	5 Ostracods
PGL	5/21/01	5/22/01	Bottle Trap	-	23 Elmids, 3 Ostracods, 1 Oligochaete
PGL	6/17/01	6/18/01	Bottle Trap	-	2 Elmids, 40 Ostracods, 15 Copepods
PGL	1/23/02	1/24/01	Bottle Trap	-	5 *Palaemonetes paludosus*
Osteen	4/17/01	4/18/01	Bottle Trap	-	0
Osteen	5/21/01	5/22/01	Bottle Trap	-	1 Ostracod
Osteen	6/18/01	6/19/01	Bottle Trap	-	1 Ostracod
P-shal	2/2/99	2/3/99	Bottle Trap	-	0
P-deep	2/2/99	2/3/99	Bottle Trap	-	0
Deer	3/12/01	3/13/01	Bottle Trap	-	0
CH1	9/19/02	3/18/03	Substrate Trap	12.07	1 *Physa sp*, 1 *Acanthocyclops robustus*
CH2	9/19/02	3/18/03	Substrate Trap	16.23	0
MW4	9/19/02	3/18/03	Substrate Trap	3.57	1 *collembola*
MW5	9/19/02	3/18/03	Substrate Trap	3.14	1 *collembola*, *Orthocyclops modestus*
MW9	9/19/02	3/18/03	Substrate Trap	10.58	0
CH1	8/18/03	2/12/04	Substrate Trap	12.07	0
CH2	3/18/03	2/12/04	Substrate Trap	16.23	0
MW4	3/18/03	2/12/04	Substrate Trap	3.57	0
MW5	3/18/03	2/12/04	Substrate Trap	3.14	0
MW9	3/18/03	2/12/04	Substrate Trap	10.58	0

Table 8. Color ratio of captive-reared individuals of *P. milleri*.

	Normal	Orange	Pink	Blue	Albino	Red	Green	Beige	Brown
Females	795	140	2	3	0	16	25	45	4
Juveniles	550	16	2	1	0	0	1	16	2
Males	683	59	5	1	0	4	43	32	6
%	82.7	8.8	0.4	0.2	0	0.8	2.8	3.8	0.5

Table 9. Average, maximum, and minimum carapace lengths of Miami cave crayfish from a captive population.

	Non-gravid females	Gravid females	Form I males
Carapace Length			
average	1.88	2.22	2.07
max	2.93	2.72	2.93
min	1.00	1.72	1.04
n	943	80	450

Table 10. Solution holes and the months they were sampled during the 2002-2003 and 2003-2004 dry-seasons. Holes are classified and grouped by depth category: shallow (0-40 cm maximum depth), medium (41-80 cm maximum depth), deep (> 80 cm maximum depth). * indicates hole was not sampled during the corresponding time period.

Depth Category	Hole	Dry-Season	
		2002-2003	2003-2004
Shallow	1WRS	*	02/04
	2HLS	01/03 – 03/03	01/04 – 07/04
	3HLS	*	01/04 – 07/04
	5SAS1	10/02 – 05/03	10/03 – 02/04
	5SAS2	10/02 – 05/03	10/03 – 02/04
Medium	1HLM1	04/03 – 05/03	01/04 – 07/04
	1HLM2	01/03 – 05/03	01/04 – 07/04
	2MBM	01/03 – 05/03	10/03, 01/04 – 07/04
	2WRM	*	02/04 – 07/04
	3HLM	01/03 – 05/03	01/04 – 07/04
	3MBM1	01/03 – 05/03	10/03 – 07/04
	3MBM2	01/03 – 05/03	10/03 – 07/04
	3SBM	01/03 – 05/03	10/03 – 07/04
	4MAM1	10/02 – 05/03	10/03 – 07/04
	4MAM2	10/02 – 05/03	10/03 – 07/04
	4WRM	*	02/04 – 07/04
	5SBM	01/03 – 05/03	10/03 – 07/04
	BlueBagM	10/02 – 05/03	10/03 – 07/04
	MR10M	10/02 – 05/03	10/03 – 07/04
	MR11M	10/02 – 05/03	10/03 – 07/04
	MR7M	10/02 – 05/03	10/03 – 07/04
Deep	1WRD	*	02/04 – 07/04
	2MBD	01/03 – 05/03	10/03 – 07/04
	2WRD	*	02/04 – 07/04
	3HLD1	01/03 – 05/03	01/04 – 07/04
	3HLD2	01/03 – 05/03	01/04 – 07/04
	3WRD1	*	02/04 – 07/04
	3WRD2	*	02/04 – 07/04
	4MBD1	10/02 – 05/03	10/03 – 07/04
	4MBD2	10/02 – 05/03	10/03 – 07/04
	4WRD	*	02/04 – 07/04
	5SBD	10/02 – 05/03	10/03 – 07/04
	BlueBagD	10/02 – 05/03	10/03 – 07/04
	MR10D	10/02 – 05/03	10/03 – 07/04
	MR11D	10/02 – 05/03	10/03 – 07/04
	MR7D	10/02 – 05/03	10/03 – 07/04
	MR8D1	10/02 – 05/03	10/03 – 07/04
	MR8D2	10/02 – 05/03	10/03 – 07/04
	MR9D1	10/02 – 05/03	10/03 – 07/04
	MR9D2	10/02 – 05/03	10/03 – 07/04

Table 11. Sampling schedule of solution holes during 2001.

	March		April		May	
Sol. Hole	**Samples**	**Empty traps**	**Samples**	**Empty traps**	**Samples**	**Empty traps**
CR01					1	1
CR03					1	1
CR04	1		1		1	1
CR11					1	1
HL1	2	1	1		1	
HL2	1		1		1	
MR01	1		1	1	1	
MR04					1	1
MR07	5	5	2	2	1	1
MR08	5	3	1	1	1	1
MR09	5	5	2	2	1	1
MR10	5	2	1	1	1	1
MR11	2	1	2	2	1	1
PA01					1	1
PA02					1	1
PA03					1	
PA04					1	
PA05					1	
PA06					1	
PA07					1	
PA08					1	1
PA09					1	
PA10					1	
RP1			1	1	1	1
WR1					1	1
WR2					1	1
WR3	1		1		1	1
WR7	1		1		1	1

Table 12. Number of fishes caught during each month in traps that contained animals in 2001.

Sol. Hole	*Month*	*Livebearer*	*Killifish*	*Yellow bullhead*	*Crayfish*	*Shrimp*	*Dollar sunfish*	Black acara
CR04	March	1						11
	April							1
HL1	March	11	1				1	4
	April	13	3			1		
	May	2	2					
HL2	March	4	2					
	April	6	1					
	May	1						
MR01	March			1				
	May	1						
MR08	March			1	1			1
MR10	March				8			
MR11	March			1				
PA03	May					1		
PA04	May					1		

Table 12 – Cont.								
PA05	May					1		
PA06	May	1				1		
PA07	May		11					
PA09	May			2				
PA10	May			1				
WR3	March	2						
	April	1						
WR7	March	9						1
	April	2						

Table 13. Final dry-season 2001 sample results for traps set in solution holes.

	CR01	*CR02*	*CR03*	*CR04*	*CR07*	*HL1*	*HL2*	*MR01*	*MR07*	*MR08*	*MR09*	*MR10*	*MR11*	*RP1*	*WR1*	*WR2*	*WR3*	*WR4*	*WR6*	*WR7*
Empty Trap		1			1				1	1	1	1		1	1	1	1	1		
G. holbrooki						13	1													
J. floridae						1														
L. goodei						1	9													
P. alleni	2		2	5				2					1						2	
P. paludosus						1														2

Table **14**. Fish in shallow (0-40 cm maximum depth), medium (41-80 cm maximum depth), and deep (> 80 cm maximum depth) solution holes in the 2002-2003 dry-season. Average abundance (±standard error (SE)) per hole is based on minnow trap CPUE (24 h soak time). Incidence of presence (I_p) is percentage of site visits where species was observed and/or captured. Incidence of capture (I_c) is percentage of site visits where species was captured with minnow traps. Number of samples (N) is indicated for each depth category.

	Shallow (N = 24)			Medium (N = 197)			Deep (N = 261)		
Species	$\overline{X}$ (±SE)	I_p	I_c	$\overline{X}$ (±SE)	I_p	I_c	$\overline{X}$ (±SE)	I_p	I_c
Ameiurus natalis		4.0	0	0.05 (±0.02)	7.5	3.0	0.15 (±0.05)	9.2	5.4
Belonesox belizanus	0.21 (±0.10)	16.7	16.7	0.08 (±0.04)	13.0	4.1	0.03 (±0.02)	12.6	2.3
Cichlasoma bimaculatum		0	0	0.10 (±0.03)	16.4	7.1	0.07 (±0.02)	14.6	6.5
Cichlasoma managuense		0	0		0	0		0	0
Cichlasoma urophthalmus	0.25 (±0.18)	8.3	8.3	0.08 (±0.03)	10.6	5.6	0.04 (±0.01)	8.0	3.8
Clarius batrachus		0	0	0.01 (±0.01)	2.0	1.0	0.01 (±0.01)	4.2	1.1
Cyprinodon variegatus		0	0		0	0		0	0
Elassoma evergladei		0	0		0	0		0	0
Enneacanthus gloriosus		0	0		0	0		0	0
Fundulus chrysotus	0.08 (±0.06)	8.3	8.3	0.07 (±0.02)	5.6	4.6	0.01 (±0.01)	1.1	0.8
Fundulus confluentus	0.33 (±0.24)	8.3	8.3	0.09 (±0.03)	6.1	5.6	0.03 (±0.02)	1.9	1.9
Gambusia holbrooki	0.58 (±0.27)	48.0	25.0	0.24 (±0.09)	30.8	8.6	0.19 (±0.05)	27.6	7.3
Hemichromis letourneuxi		0	0		0	0		0	0
Heterandria formosa		0	0		0	0	0.01 (±0.01)	0.8	0.8
Hoplosternum littorale		0	0		0	0		0	0
Jordanella floridae	0.04 (±0.04)	4.2	4.2	0.11 (±0.04)	6.1	5.1	0.03 (±0.02)	3.1	1.9
Lepomis gulosus		0	0		0	0		0	0
Lepomis macrochirus		0	0	0.02 (±0.01)	2.5	2.0	0.02 (±0.01)	2.7	1.5
Lepomis marginatus	0.04 (±0.04)	4.2	4.2	0.43 (±0.10)	19.8	15.7	0.28 (±0.06)	18.8	13.0
Lepomis microlophus		0	0	0.05 (±0.02)	3.6	3.6	0.09 (±0.03)	4.2	4.2
Lepisosteus platyrhincus		0	0		1.5	0	<0.00(± <0.00)	0.4	0.4
Lepomis punctatus		0	0	0.08 (±0.03)	5.1	4.6	0.04 (±0.01)	4.2	3.4
Lepomis spp.		0	0		2.5	0		3.1	0
Lucania goodei		0	0	0.04 (±0.02)	1.5	1.5	0.01 (±0.01)	0.8	0.8
Micropterus salmoides		0	0		2.0	0		0.8	0
Noturus gyrinus		0	0		0	0		0	0
Oreochromis aureus		0	0		2.5	0		5.7	0
Poecilia latipinna		4.0	0	0.46 (±0.12)	20.1	12.7	0.90 (±0.16)	24.9	17.6
Tilapia mariae		0	0		0	0		1.1	0
Unidentified		0	0		0	0		0	0
Total Fish	0.61 (±0.38)			1.42 (±0.21)			1.93 (±0.19)		

Table **15** Fish in shallow (0-40 cm maximum depth), medium (41-80 cm maximum depth), and deep (> 80 cm maximum depth) solution holes in the 2003-2004 dry-season. Average abundance (±standard error (SE)) per hole is based on minnow trap CPUE (24 h soak time). Incidence of presence (I_p) is percentage of site visits where species was observed and/or captured. Incidence of capture (I_c) is percentage of site visits where species was captured with minnow traps. Number of samples (N) is indicated for each depth category.

	Shallow (N = 38)			Medium (N = 225)			Deep (N = 393)		
Species	$\overline{X}$ (±SE)	I_p	I_c	$\overline{X}$ (±SE)	I_p	I_c	$\overline{X}$ (±SE)	I_p	I_c
Ameiurus natalis		7.7	0	0.10 (±0.05)	8.7	4.0	0.53 (±0.18)	19.8	14.8
Belonesox belizanus	0.08 (±0.06)	12.5	5.3	0.28 (±0.09)	20.0	13.8	0.07 (±0.02)	13.5	5.3
Cichlasoma bimaculatum	0.05 (±0.04)	46.7	5.3	0.36 (±0.08)	34.2	17.3	0.70 (±0.08)	43.4	32.3
Cichlasoma managuense		0	0	0.01 (±0.01)	1.3	0.9	0.06 (±0.02)	4.1	4.1
Cichlasoma urophthalmus	0.05 (±0.04)	12.5	5.3	0.16 (±0.04)	13.1	8.9	0.07 (±0.02)	8.6	4.3
Clarius batrachus		2.6	0	0.01 (±0.01)	2.2	0.9	0.03 (±0.01)	2.5	1.8
Cyprinodon variegatus	0.03 (±0.03)	2.6	2.6		0	0		0	0
Elassoma evergladei	0.03 (±0.03)	2.6	2.6		0	0		0	0
Enneacanthus gloriosus		0	0	<0.00(± <0.00)	0.4	0.4	0.01 (±0.01)	1.3	1.3
Fundulus chrysotus	0.61 (±0.22)	21.1	21.1	0.15 (±0.05)	8.4	7.6	0.01 (±0.00)	2.3	0.5
Fundulus confluentus	3.82 (±0.76)	61.5	60.5	1.21 (±0.21)	24.3	23.1	0.13 (±0.05)	6.1	3.8
Gambusia holbrooki	6.24 (±1.99)	57.1	44.7	1.61 (±0.37)	38.5	26.2	0.04 (±0.01)	14.7	2.3
Hemichromis letourneuxi	0.05 (±0.05)	18.6	2.6	1.35 (±0.21)	37.2	32.4	1.22 (±0.19)	35.8	31.8
Heterandria formosa	0.24 (±0.12)	13.2	13.2		0	0		0.3	0
Hoplosternum littorale		0	0		0	0	<0.00(± <0.00)	0.3	0.3
Jordanella floridae	1.37 (±0.38)	42.1	42.1	0.91 (±0.27)	10.6	8.9	0.04 (±0.02)	2.3	1.8
Lepomis gulosus	0.13 (±0.06)	20.5	13.2	0.12 (±0.02)	13.9	10.2	0.27 (±0.05)	18.3	14.2
Lepomis macrochirus		0	0		0	0	<0.00(± <0.00)	0.3	0.3
Lepomis marginatus	0.61 (±0.24)	37.2	26.3	0.63 (±0.11)	29.6	22.2	0.36 (±0.06)	21.9	14.0
Lepomis microlophus		0	0		0.4	0		0	0
Lepisosteus platyrhincus		0	0		0	0		0	0
Lepomis punctatus	0.05 (±0.05)	5.3	2.6	0.07 (±0.02)	6.6	5.8	0.05 (±0.02)	3.8	3.8
Lepomis spp.	0.05 (±0.05)	2.6	2.6	0.02 (±0.01)	1.3	0.9	<0.00(± <0.00)	1.3	0.3
Lucania goodei	0.24 (±0.10)	15.8	15.8	0.13 (±0.07)	3.1	3.1		0	0
Micropterus salmoides		0	0		0	0		0	0
Noturus gyrinus		0	0	0.02 (±0.01)	1.8	1.8	0.03 (±0.02)	0.8	0.8
Oreochromis aureus		0	0		0.9	0		0	0
Poecilia latipinna	0.29 (±0.18)	21.4	10.5	0.54 (±0.13)	24.4	12.4	0.43 (±0.08)	22.5	12.5
Tilapia mariae		0	0	<0.00(± <0.00)	1.3	0.4	0.01 (±0.00)	1.3	0.5
Unidentified		0	0	<0.00(± <0.00)	0.4	0.4	<0.00(± <0.00)	0.3	0.3
Total Fish	3.04 (±1.69)			3.03 (±0.55)			2.43 (±0.31)		

Table 16. Daily drift fence array samples collected at the onset of flooding in each study year. Daily samples usually lasted for 14 consecutive days. Multiple dates indicate that dry-downs occurred at the arrays before the 14-day samples were completed and daily sampling re-commenced when the arrays re-flooded. (There are no subsequent events for the daily data because main events connect into the main event for the weekly data)

Array	**2000**	**2001**	**2002**	**2003**	**2004**
1	07/14 – 07/21	08/02 – 08/15	06/16 – 06/29	05/30 – 06/03 06/11 – 06/24	07/27 – 08/09
2	07/14 – 07/21	08/02 – 08/15	06/16 – 06/29	05/30 – 06/04 06/09 – 06/22	07/26 – 08/08
3	06/06 – 06/16	07/16 – 07/29	04/05 06/05 – 06/18	04/01 – 04/03 05/01 – 05/02 05/20 05/27 – 06/9	07/28 – 08/10
4	06/04 – 06/11	07/10 – 07/23	05/30 – 06/12	03/29 – 04/04 05/01 – 05/09 05/19	07/24 – 08/06
5	-	06/05 – 06/15 07/10 – 07/23	04/05 05/30 – 06/12	03/29 – 04/01 05/01 – 05/09 05/16 05/20 – 06/02	07/24 – 08/06
6	-	07/16 – 07/29	06/05 – 06/18	05/27 – 06/09	07/28 – 08/10
Total Samples	35	75	85	110	84

Table 17. Percent incidence of bycatch species greater than 0.1% collected within the drift-fence arrays from 2000-2004.

Group	Species		Incidence (%)
Amphibians	*Amphiuma means*	Amphiuma	5
	Siren lacertina	Greater siren	3
	Eumeces inexpectatus	Southern 5-lined skink	0.4
	Acris gryllus	Cricket frog	1
	Hyla cinerea	Green tree frog	0.3
	Rana sphenocephala	Southern leopard frog	0.1
	Rana grylio	Pig frog	0.3
	Bufo quercicus	Oak toad	2
	Gastrophryne carolinensis	Eastern narrow-mouthed toad	0.2
	Batrachian larvae	Tadpoles	35
Reptiles	*Nerodia taxispilota*	Brown water snake	0.1
	Nerodia fasciata pictiventis	Florida water snake	10
	Nerodia floridana	Florida green water snake	1
	Thamnophis sirtalis	Garter snake	3
	Thamnophis sauritus	Ribbon snake	2
	Coluber constrictor	Black racer	0.3
	Agkistrodon piscivorus	Cottonmouth	0.2
Invertebrates	Dytiscidae	Predaceous diving beetle	22
	Cybister sp .larva	Predaceous diving beetle	2
	Palemonetes paludosus	Grass shrimp	20
	Procambarus alleni	Everglades crayfish	45
	Procambarus fallax	Slough crayfish	1
	Pelocoris sp.	Alligator flea	4
	Belostoma sp.	Giant water bug	13
	Lethocerus sp.	Toe biter	12
	Dolomedes sp.	Fishing spider	2
	Anisopteran naiads	Dragonfly larvae	1
	Planorbella durii	Seminole snail	9
	Pomacea paludosus	Apple snail	2

Table 18. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 1. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis										
Aphredoderus sayanus										
Belonesox belizanus			1	<0.0	1	<0.0	3	0.5	1	0.2
Cichlasoma bimaculatum			3	0.1			4	0.7		
Cichlasoma managuense										
Cichlasoma urophthalmus							2	0.3		
Clarius batrachus					1	<0.0				
Cyprinodon variegatus			2	0.1			1	0.2	3	0.5
Elassoma evergladei					1	<0.0	2	0.3	3	0.5
Enneacanthus gloriosus							1	0.2		
Fundulus chrysotus	6	3.4	7	0.2	13	0.5			28	5.1
Fundulus confluentus	5	2.8	29	0.9	50	2.0	27	4.7	139	25.1
Gambusia holbrooki	63	35.8	2833	91.8	1726	68.8	351	61.1	91	16.4
Hemichromis letourneuxi					1	<0.0	3	0.5	1	0.2
Heterandria formosa	9	5.1	52	1.7	411	16.4	28	4.9	15	2.7
Jordanella floridae	80	45.5	135	4.4	150	6.0	15	2.6	89	16.1
Labidesthes sicculus			1	<0.0						
Lepomis gulosus			2	0.1						
Lepomis macrochirus										
Lepomis marginatus			3	0.1	86	3.4	92	16.0	171	30.9
Lepomis microlophus							1	0.2		
Lepomis punctatus							2	0.3		
Lepomis spp.			2	0.1			1	0.2		
Lucania goodei	5	2.8			32	1.3	17	3.0	3	0.5
Lucania parva										
Micropterus salmoides										
Notropsis petersoni										
Noturus gyrinus										
Oreochromis aureus										
Poecilia latipinna	8	4.5	15	0.5	38	1.5	24	4.2	10	
Total Fish	176		3085		2510		574		554	

Table 19. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 2. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis			1	<0.0			1	0.1	4	0.8
Aphredoderus sayanus										
Belonesox belizanus	1	0.1	10	0.4	10	0.3	24	1.8	6	1.1
Cichlasoma bimaculatum			54	2.0	2	0.1	4	0.3	1	0.2
Cichlasoma managuense			2	0.1						
Cichlasoma urophthalmus			3	0.1			7	0.5		
Clarius batrachus					4	0.1	1	0.1		
Cyprinodon variegatus			6	0.2	2	0.1	4	0.3	3	0.6
Elassoma evergladei			1	<0.0						
Enneacanthus gloriosus			1	<0.0						
Fundulus chrysotus	9	0.7	6	0.2	7	0.2	2	0.2	11	2.1
Fundulus confluentus	12	0.9	49	1.8	77	2.3	96	7.3	192	36.0
Gambusia holbrooki	301	21.9	1414	52.2	868	26.3	93	7.1	86	16.1
Hemichromis letourneuxi							2	0.2	4	0.8
Heterandria formosa	36	2.6	50	1.8	227	6.9	10	0.8	1	0.2
Jordanella floridae	929	67.6	818	30.2	1599	48.5	146	11.1	136	25.5
Labidesthes sicculus			3	0.1						
Lepomis gulosus			3	0.1						
Lepomis macrochirus			6	0.2	7	0.2				
Lepomis marginatus	6	0.4	93	3.4	428	13.0	882	67.1	63	11.8
Lepomis microlophus							14	1.1		
Lepomis punctatus							7	0.5		
Lepomis spp.			3	0.1						
Lucania goodei	72	5.2	15	0.6	23	0.7	14	1.1	4	0.8
Lucania parva										
Micropterus salmoides			1	<0.0						
Notropsis petersoni										
Noturus gyrinus							1	0.1		
Oreochromis aureus			1	<0.0						
Poecilia latipinna	9	0.7	168	6.2	45	1.4	6	0.5	22	4.1
Total Fish	1375		2708		3299		1314		533	

Table 20. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 3. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis							1	0.3		
Aphredoderus sayanus										
Belonesox belizanus			1	0.1	9	0.2	12	3.1	4	0.7
Cichlasoma bimaculatum										
Cichlasoma managuense										
Cichlasoma urophthalmus							1	0.3		
Clarius batrachus					4	0.1	1	0.3		
Cyprinodon variegatus			7	0.6	5	0.1	3	0.8	2	0.3
Elassoma evergladei			1	0.1	46	1.0	1	0.3	13	2.2
Enneacanthus gloriosus							1	0.3	7	1.2
Fundulus chrysotus	10	1.0	3	0.3	6	0.1			6	1.0
Fundulus confluentus	65	6.2	61	5.5	296	6.6	149	38.6	136	22.7
Gambusia holbrooki	584	55.6	782	70.6	2602	57.7	42	10.9	65	10.9
Hemichromis letourneuxi									2	0.3
Heterandria formosa			38	3.4	973	21.6	17	4.4	76	12.7
Jordanella floridae	365	35.1	198	17.9	491	10.9	46	11.9	139	23.2
Labidesthes sicculus										
Lepomis gulosus			1	0.1					1	0.2
Lepomis macrochirus										
Lepomis marginatus	2	0.2	3	0.3	11	0.2	41	10.6	97	16.2
Lepomis microlophus										
Lepomis punctatus							1	0.3		
Lepomis spp.										
Lucania goodei	2	0.2	2	0.2	37	0.8	54	14.0	26	4.3
Lucania parva			1	0.1					1	0.2
Micropterus salmoides										
Notropsis petersoni										
Noturus gyrinus										
Oreochromis aureus										
Poecilia latipinna	19	1.8	10	0.9	27	0.6	16	4.1	23	3.8
Total Fish	1051		1108		4507		386		598	

Table 21. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 4. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis							3	0.3		
Aphredoderus sayanus										
Belonesox belizanus	4	0.1	2	0.1	7	0.1	38	3.8	2	0.4
Cichlasoma bimaculatum			26	0.9						
Cichlasoma managuense										
Cichlasoma urophthalmus							7	0.7	3	0.6
Clarius batrachus										
Cyprinodon variegatus	2	<0.0	9	0.3	1	<0.0	2	0.2		
Elassoma evergladei							3	0.3		
Enneacanthus gloriosus									2	0.4
Fundulus chrysotus	9	0.2			19	0.4	1	0.1	1	0.2
Fundulus confluentus	41	0.8	24	0.9	228	4.8	34	3.4	77	16.5
Gambusia holbrooki	3763	77.0	675	24.4	3424	72.1	16	1.6	51	10.9
Hemichromis letourneuxi									11	2.4
Heterandria formosa	24	0.5	17	0.6	65	1.4			1	0.2
Jordanella floridae	600	12.3	1997	72.3	869	18.3	41	4.1	113	24.1
Labidesthes sicculus										
Lepomis gulosus										
Lepomis macrochirus										
Lepomis marginatus	318	6.5	8	0.3	120	2.5	839	83.6	203	43.4
Lepomis microlophus										
Lepomis punctatus			1	<0.0			13	1.3		
Lepomis spp.							1	0.1		
Lucania goodei	33	0.7			3	0.1	2	0.2	1	0.2
Lucania parva										
Micropterus salmoides										
Notropsis petersoni										
Noturus gyrinus										
Oreochromis aureus										
Poecilia latipinna	93	1.9	4	0.1	13	0.3	4	0.4	3	0.6
Total Fish	4887		2763		4749		1004		468	

Table 22. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 5. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis										
Aphredoderus sayanus										
Belonesox belizanus			1	<0.0	3	<0.0	6	0.6		
Cichlasoma bimaculatum			11	0.3						
Cichlasoma managuense										
Cichlasoma urophthalmus							2	0.2	1	0.4
Clarius batrachus							1	0.1		
Cyprinodon variegatus			22	0.5	1	<0.0				
Elassoma evergladei			1	<0.0						
Enneacanthus gloriosus									2	0.8
Fundulus chrysotus			14	0.3	10	0.1	9	0.9	1	0.4
Fundulus confluentus			757	18.1	262	2.6	160	16.1	33	13.7
Gambusia holbrooki			2022	48.4	8239	81.3	240	24.1	2	0.8
Hemichromis letourneuxi										
Heterandria formosa			24	0.6	66	0.7				
Jordanella floridae			1029	24.6	1520	15.0	164	16.5	52	21.6
Labidesthes sicculus										
Lepomis gulosus			4	0.1					1	0.4
Lepomis macrochirus										
Lepomis marginatus			59	1.4	19	0.2	404	40.6	148	61.4
Lepomis microlophus										
Lepomis punctatus			1	<0.0			1	0.1		
Lepomis spp.			48	1.1						
Lucania goodei			1	<0.0	3	<0.0	7	0.7		
Lucania parva										
Micropterus salmoides										
Notropsis petersoni										
Noturus gyrinus									1	0.4
Oreochromis aureus										
Poecilia latipinna			183	4.4	14	0.1				
Total Fish			4177		10137		994		241	

Table 23. Relative abundance (RA) and Catch per Unit Effort (CPUE) for the daily samples at Array 6. Upon flooding of the marsh, arrays were sampled daily for two weeks. Data presented here are for the full 14-day samples and do not include data from initial flooding events. Non-indigenous Species.

	2000		*2001*		*2002*		*2003*		*2004*	
Species	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)	CPUE	RA (%)
Ameiurus natalis					1	<0.0	2	0.3		
Aphredoderus sayanus							2	0.3		
Belonesox belizanus			2	0.1			53	8.8	1	0.1
Cichlasoma bimaculatum			1	0.1						
Cichlasoma managuense										
Cichlasoma urophthalmus										
Clarius batrachus			1	0.1						
Cyprinodon variegatus			3	0.2	1	<0.0	2	0.3	2	0.3
Elassoma evergladei			1	0.1					1	0.1
Enneacanthus gloriosus									4	0.6
Fundulus chrysotus			5	0.4	5	0.1	2	0.3	27	4.0
Fundulus confluentus			148	11.1	454	13.3	219	36.4	213	31.6
Gambusia holbrooki			717	53.6	1290	37.9	85	14.1	80	11.9
Hemichromis letourneuxi										
Heterandria formosa					114	3.3			2	0.3
Jordanella floridae			434	32.5	1442	42.4	185	30.7	235	34.8
Labidesthes sicculus										
Lepomis gulosus			3	0.2						
Lepomis macrochirus										
Lepomis marginatus			8	0.6	26	0.8	38	6.3	88	13.0
Lepomis microlophus										
Lepomis punctatus							2	0.3		
Lepomis spp.										
Lucania goodei			1	0.1	37	1.1	4	0.7	3	0.4
Lucania parva										
Micropterus salmoides										
Notropsis petersoni					1	<0.0				
Noturus gyrinus										
Oreochromis aureus										
Poecilia latipinna			13	1.0	35	1.0	8	1.3	19	2.8
Total Fish			1337		3407		602		675	

Table 24. Weekly drift fence array samples collected during each study year. Weekly samples were collected on Fridays during flooding. Multiple dates indicate that dry-downs occurred at the arrays, and weekly sampling re-commenced when the arrays re-flooded.

Array	2000	2001	2002	2003	2004
1	07/14 – 07/21 08/04 – 09/01 09/15 – 10/27	08/03 – 08/24 09/14 – 11/16	06/21 – 08/02	05/30 06/13 – 07/04 08/15 – 10/17 11/07 – 11/14	07/30 – 08/06
2	07/14 – 07/21 08/04 – 09/01 9/15 – 10/27	08/03 – 08/24 09/14 – 11/09	06/21 – 08/02 09/06 12/13	05/30 06/13 – 07/04 08/08 – 10/17 11/07 – 11/14	07/30 – 08/06
3	06/09 – 06/16 06/30 / 11/03	07/20 – 11/23 12/14 – 12/21 01/04 – 01/11	04/05 06/07 – 09/13 11/22 12/13 – 12/20	05/02 05/30 – 11/28	07/30 – 08/06
4	06/09 – 12/29	07/13 – 04/12	05/31 – 01/24	04/04 05/02 – 03/19	07/30 – 08/06
5	-	06/08 – 06/15 07/13 01/25	04/05 05/31 – 11/01 11/22 12/13 – 12/20	05/02 – 12/26	07/30 – 08/06
6	-	07/20 – 11/23 12/14 – 12/21 01/04 – 01/11	06/07 – 08/02 08/16 – 09/13 11/22 12/13 – 12/20	05/30 – 07/18 08/01 – 11/28	07/30 – 08/06
Total Samples	74	143	112	171	12

Table 25. Catch per unit effort (CPUE) and relative abundance (%) of fish species collected in the weekly drift-fence array samples.

Species	CPUE	RA (%)
Mosquitofish	22,271	64.8
Flagfish	3,542	10.3
Dollar sunfish	2,423	7.0
Marsh killifish	1,978	5.8
Sailfin molly	1,259	3.7
African jewelfish	681	2.0
Least killifish	570	1.7
Pike killifish	441	1.3
Bluefin killifish	310	0.9
Mayan cichlid	265	0.8
Black acara	140	0.4
Golden topminnow	132	0.4
Warmouth	75	0.2
Sunfish sp.	59	0.2
Spotted sunfish	53	0.2
Bluespotted sunfish	39	0.1
Yellow bullhead	31	0.1
Sheepshead minnow	27	0.1
Walking catfish	24	0.1
Largemouth bass	17	0.0
Bluegill	12	0.0
Everglades pygmy sunfish	9	0.0
Spotted tilapia	9	0.0
Jaguar guapote cichlid	8	0.0
Brook silverside	8	0.0
Tadpole madtom	6	0.0
Redear sunfish	3	0.0
Taillight shiner	1	0.0
	34,393	100.0

Table 26. Model results for statistical analysis of study species catch. A general linear model was used to analyze these data. ---- indicates that this parameter was not used in the model. Values <=.01 are significant.

Model	ERROR DF	MOSQUITOFISH	FLAGFISH	MARSH KILLIFISH	DOLLAR SUNFISH	EVERGLADES CRAYFISH
YEAR	33	0.0106	0.3003	0.4976	0.0213	<.0001
MONTH(YEAR)	1850	<.0001	<.0001	<.0001	<.0001	<.0001
SITE	14	0.8837	0.0903	0.8863	0.0109	<.0001
DIRECTION(SITE)	1850	<.0001	0.0319	<.0001	<.0001	0.6634
FLOW DIRECTION	1850	0.0005	<.0001	0.0007	0.0032	<.0001
DIRECTION*MONTH(SITE*YEAR)	1850	<.0001	<.0001	<.0001	<.0001	<.0001
DEPTH	1850	<.0001	<.0001	0.0016	<.0001	------
DEPTH2	1850	<.0001	<.0001	<.0001	<.0001	------
DSLDD	1850	------	<.0001	------	------	------
DSLDD2	1850	------	<.0001	------	------	------
Goodness-Of-Fit Statistics						
R-Square		0.572	0.506	0.4659	0.5896	0.5077
Adjusted R-Square		0.452	0.37	0.31745	0.476	0.3717
R-Square of interaction parameter						
DIRECTION*MONTH(SITE*YEAR)		0.9437	0.928	0.976	0.955	0.982

Table 27. Mean fish numbers from Array 1 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) is based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N = 45)			Main (N = 105)			Subsequent (N = 6)		
Species	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I
Ameiurus natalis		0	0	0.05 (±0.02)	0.1	4.8		0	0
Belonesox belizanus	0.11 (±0.05)	0.6	11.1	0.38 (±0.09)	0.9	21.9	0.50 (±0.34)	4.9	33.3
Cichlasoma bimaculatum	0.69 (±0.48)	3.9	15.6	0.12 (±0.04)	0.3	8.6		0	0
Cichlasoma managuense		0	0	0.08 (±0.03)	0.2	5.7		0	0
Cichlasoma urophthalmus	0.04 (±0.04)	0.3	2.2	0.42 (±0.17)	1.0	13.3		0	0
Clarius batrachus		0	0	0.05 (±0.04)	0.1	1.9		0	0
Cyprinodon variegatus	0.04 (±0.03)	0.3	4.4		0	0		0	0
Elassoma evergladei	0.02 (±0.02)	0.1	2.2		0	0		0	0
Enneacanthus gloriosus		0	0	0.08 (±0.03)	0.2	7.6	0.33 (±0.33)	3.3	16.7
Fundulus chrysotus	0.13 (±0.11)	0.8	4.4	0.18 (±0.07)	0.4	8.6		0	0
Fundulus confluentus	0.67 (±0.28)	3.8	17.8	1.72 (±0.25)	4.3	56.2	6.17 (±4.80)	60.7	66.7
Gambusia holbrooki	7.44 (±2.73)	42.7	51.1	29.04 (±8.73)	72.2	73.3		0	0
Hemichromis letourneuxi		0	0	1.23 (±0.64)	3.1	14.3	2.17 (±1.19)	21.3	83.3
Heterandria formosa	0.40 (±0.19)	2.3	15.6	0.62 (±0.41)	1.5	8.6		0	0
Jordanella floridae	3.04 (±1.68)	17.5	24.4	2.47 (±0.67)	6.1	36.2	0.33 (±0.33)	3.3	16.7
Lepomis gulosus		0	0	0.04 (±0.02)	0.1	3.8	0.17 (±0.17)	1.6	16.7
Lepomis macrochirus		0	0	0.02 (±0.01)	<0.0	1.9		0	0
Lepomis marginatus	0.87 (±0.47)	5.0	20.0	1.75 (±0.44)	4.4	35.2	0.17 (±0.17)	1.6	16.7
Lepomis microlophus		0	0		0	0		0	0
Lepomis punctatus	0.04 (±0.04)	0.3	2.2	0.04 (±0.02)	0.1	2.9	0.17 (±0.17)	1.6	16.7
Lepomis spp.		0	0		0	0		0	0
Lucania goodei	0.42 (±0.26)	2.4	13.3	0.39 (±0.16)	1.0	8.6		0	0
Lucania parva		0	0		0	0		0	0
Micropterus salmoides		0	0		0	0		0	0
Notropsis maculatus		0	0		0	0		0	0
Notropsis petersoni		0	0		0	0		0	0
Noturus gyrinus		0	0		0	0		0	0
Poecilia latipinna	3.49 (±2.67)	20.0	24.4	1.55 (±0.69)	3.9	31.4		0	0
Tilapia mariae	0.02 (±0.02)	0	2.2	0.01 (±0.01)	<0.0	1.0	0.17 (±0.17)	1.6	16.7
Unidentified		0	0		0	0		0	0
Total Fish	785			4224			61		

Table 28. Mean fish numbers from Array 2 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) is based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N = 45)			Main (N = 108)			Subsequent (N = 12)		
Species	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I
Ameiurus natalis		0	0	0.14 (±0.09)	0.3	6.5		0	0
Belonesox belizanus	0.96 (±0.50)	2.1	20.0	1.23 (±0.29)	2.2	33.3	0.75 (±0.41)	3.7	25.0
Cichlasoma bimaculatum	0.89 (±0.27)	1.0	31.1	0.24 (±0.09)	0.4	9.3		0	0
Cichlasoma managuense	0.02 (±0.02)	<0.0	2.2	0.03 (±0.02)	0.1	2.8		0	0
Cichlasoma urophthalmus	0.24 (±0.13)	0.5	8.9	1.31 (±0.22)	2.4	41.7	0.25 (±0.25)	1.2	8.3
Clarius batrachus		0	0	0.05 (±0.02)	0.1	4.6		0	0
Cyprinodon variegatus	0.11 (±0.07)	0.2	6.7	0.02 (±0.01)	<0.0	1.9		0	0
Elassoma evergladei	0.02 (±0.02)	<0.0	2.2		0	0		0	0
Enneacanthus gloriosus		0	0	0.12 (±0.06)	0.2	6.5	0.08 (±0.08)	0.4	8.3
Fundulus chrysotus	0.07 (±0.04)	0.1	6.7	0.09 (±0.04)	0.2	7.4		0	0
Fundulus confluentus	3.78 (±1.69)	8.3	44.4	2.27 (±0.46)	4.1	41.7	1.33 (±0.48)	6.6	58.3
Gambusia holbrooki	16.02 (±5.67)	35.3	55.6	32.6 (±10.18)	58.9	56.5	0.92 (±0.53)	4.5	33.3
Hemichromis letourneuxi	0.09 (±0.07)	0.2	4.4	3.19 (±1.73)	5.8	19.4	16.42 (±12.04)	80.7	25.0
Heterandria formosa	0.58 (±0.17)	1.3	22.2	1.11 (±1.05)	2.0	4.6		0	0
Jordanella floridae	10.91 (±3.53)	24.0	51.1	4.80 (±1.22)	8.7	43.5	0.50 (±0.34)	2.5	25.0
Lepomis gulosus	0.02 (±0.02)	<0.0	2.2	0.21 (±0.06)	0.4	13.0		0	0
Lepomis macrochirus		0	0	0.02 (±0.01)	<0.0	1.9		0	0
Lepomis marginatus	8.76 (±3.00)	19.3	40	6.00 (±1.27)	10.8	53.7	0.08 (±0.08)	0.4	8.3
Lepomis microlophus	0.04 (±0.04)	0.1	2.2	0.01 (±0.01)	<0.0	0.9		0	0
Lepomis punctatus	0.42 (±0.34)	0.9	8.9	0.09 (±0.04)	0.2	6.5		0	0
Lepomis spp.	0.44 (±0.45)	1.0	2.2	0.31 (±0.30)	0.6	2.8		0	0
Lucania goodei	0.60 (±0.36)	1.3	13.3	0.23 (±0.10)	0.4	10.2		0	0
Lucania parva		0	0		0	0		0	0
Micropterus salmoides		0	0	0.16 (±0.12)	0.3	3.7		0	0
Notropsis maculatus		0	0		0	0		0	0
Notropsis petersoni	0.02 (±0.02)	<0.0	2.2		0	0		0	0
Noturus gyrinus		0	0		0	0		0	0
Poecilia latipinna	1.42 (±0.70)	3.1	22.2	1.06 (±0.33)	1.9	24.1		0	0
Tilapia mariae		0	0	0.08 (±0.04)	0.2	4.6		0	0
Unidentified		0	0		0	0		0	0
Total Fish	2044			5982			244		

Table 29. Mean fish numbers from Array 3 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) is based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N = 12)			Main (N = 240)			Subsequent (N = 21)		
Species	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I
Ameiurus natalis		0	0	0.05 (<±0.00)	0.1	4.2		0	0
Belonesox belizanus		0	0	0.47 (±0.01)	0.8	21.3	1.14 (±0.47)	7.7	28.6
Cichlasoma bimaculatum		0	0	0.07 (<±0.00)	0.1	3.3		0	0
Cichlasoma managuense		0	0		0	0		0	0
Cichlasoma urophthalmus		0	0	0.06 (<±0.00)	0.1	5.0		0	0
Clarius batrachus		0	0	0.04 (<±0.00)	0.1	1.3		0	0
Cyprinodon variegatus		0	0	0.01 (<±0.00)	<0.0	0.8		0	0
Elassoma evergladei		0	0	<0.0 (<±0.00)	<0.0	0.4	0.05 (±0.05)	0.3	4.8
Enneacanthus gloriosus		0	0	0.04 (<±0.00)	0.1	3.8		0	0
Fundulus chrysotus	0.17 (±0.17)	0.7	8.3	0.08 (<±0.00)	0.1	5.0		0	0
Fundulus confluentus	2.42 (±1.75)	10.2	25.0	2.44 (±0.02)	4.1	43.8	0.57 (±0.34)	3.9	23.8
Gambusia holbrooki	18.17 (±17.5)	76.5	33.3	46.83 (±0.71)	78.7	52.5	10.81 (±8.82)	73.2	38.1
Hemichromis letourneuxi		0	0	0.10 (<±0.00)	0.2	4.2		0	0
Heterandria formosa		0	0	0.74 (±0.02)	1.2	10.0	1.05 (±0.60)	7.1	19.0
Jordanella floridae	3.00 (±2.42)	12.6	25.0	1.76 (±0.02)	3.0	27.9	0.81 (±0.42)	5.5	19.0
Lepomis gulosus		0	0	0.08 (<±0.00)	0.1	4.6		0	0
Lepomis macrochirus		0	0	0.03 (<±0.00)	<0.0	1.3		0	0
Lepomis marginatus		0	0	3.15 (±0.04)	5.3	35.8	0.14 (±0.14)	1.0	4.8
Lepomis microlophus		0	0	<0.0 (<±0.00)	<0.0	0.4		0	0
Lepomis punctatus		0	0	0.02 (<±0.00)	<0.0	1.7	0.10 (±0.10)	0.6	4.8
Lepomis spp.		0	0	0.15 (±0.01)	0.2	2.1		0	0
Lucania goodei		0	0	1.05 (±0.05)	1.8	12.5	0.05 (±0.05)	0.3	4.8
Lucania parva		0	0	<0.0 (<±0.00)	<0.0	0.4		0	0
Micropterus salmoides		0	0		0	0		0	0
Notropsis maculatus		0	0		0	0		0	0
Notropsis petersoni		0	0	0.03 (<±0.00)	<0.0	0.4		0	0
Noturus gyrinus		0	0	0.01 (<±0.00)	<0.0	1.3	0.05 (±0.05)	0.3	4.8
Poecilia latipinna		0	0	2.30 (±0.04)	3.9	23.8		0	0
Tilapia mariae		0	0		0	0		0	0
Unidentified		0	0		0	0		0	0
Total Fish	285			14281			310		

Table 30. Mean fish numbers from Array 4 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N =12)			Main (N = 444)			Subsequent (N = 0)		
Species	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I
Ameiurus natalis	0.08 (±0.08)	0.6	8.3	<0.0 (<±0.00)	<0.0	0.4			
Belonesox belizanus	0.17 (±0.74)	8.0	41.7	0.19 (±0.03)	0.5	10.1			
Cichlasoma bimaculatum		0	0	0.27 (±0.07)	0.7	6.3			
Cichlasoma managuense		0	0	<0.0 (<±0.00)	<0.0	0.2			
Cichlasoma urophthalmus	0.08 (±0.08)	0.6	8.3	1.16 (±0.18)	3.2	36.7			
Clarius batrachus		0	0		0	0			
Cyprinodon variegatus		0	0	0.03 (±0.01)	0.1	1.8			
Elassoma evergladei		0	0	0.03 (±0.01)	0.1	1.4			
Enneacanthus gloriosus		0	0	0.09 (±0.02)	0.2	5.6			
Fundulus chrysotus	0.17 (±0.11)	1.1	16.7	0.20 (±0.05)	0.5	9.0			
Fundulus confluentus	0.83 (±0.42)	5.7	41.7	1.89 (±0.28)	5.2	30.4			
Gambusia holbrooki	2.0 (±1.18)	13.8	41.7	21.75 (±6.03)	60.2	38.1			
Hemichromis letourneuxi		0	0	0.11 (±0.03)	0.3	4.7			
Heterandria formosa	0.83 (±0.51)	5.7	25	0.21 (±0.08)	0.6	5.2			
Jordanella floridae	1.17 (±0.44)	8.0	50	2.30 (±0.46)	6.4	28.2			
Lepomis gulosus	0.08 (±0.08)	0.6	8.3	0.04 (±0.02)	0.1	2.0			
Lepomis macrochirus		0	0	0.02 (±0.01)	<0.0	1.6			
Lepomis marginatus	5.17 (±2.84)	35.6	33.3	5.27 (±0.55)	14.6	47.1			
Lepomis microlophus		0	0		0	0			
Lepomis punctatus		0	0	0.30 (±0.12)	0.8	9.2			
Lepomis spp.		0	0	0.05 (±0.04)	0.1	1.6			
Lucania goodei	2.75 (±1.73)	19.0	25	0.22 (±0.05)	0.6	8.3			
Lucania parva		0	0		0	0			
Micropterus salmoides		0	0	0.11 (±0.10)	0.3	0.5			
Notropis maculatus		0	0	0.01 (±0.01)	<0.0	0.2			
Notropis petersoni		0	0	<0.0 (<±0.00)	<0.0	0.2			
Noturus gyrinus		0	0	0.01 (±0.01)	<0.0	1.1			
Poecilia latipinna	0.17 (±0.17)	1.1	8.3	1.87 (±0.50)	5.2	19.1			
Tilapia mariae		0	0	<0.0 (<±0.00)	<0.0	0.2			
Unidentified		0	0		0	0			
Total Fish	174			16037					

Table 31. Mean fish numbers from Array 5 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) is based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N = 28)			Main (N = 344)			Subsequent (N = 12)		
Species	$\bar{X}$ (±SE)	RA	I	$\bar{X}$ (±SE)	RA	I	$\bar{X}$ (±SE)	RA	I
Ameiurus natalis		0	0	0.01 (±0.01)	<0.0	1.2		0	0
Belonesox belizanus	0.11 (±0.11)	0.8	3.6	0.19 (±0.04)	0.7	11.3	0.17 (±0.11)	10.5	16.7
Cichlasoma bimaculatum		0	0	0.15 (±0.10)	0.5	4.9		0	0
Cichlasoma managuense		0	0	<0.0 (<±0.00)	<0.0	0.3		0	0
Cichlasoma urophthalmus	0.43 (±0.30)	3.1	10.7	0.13 (±0.04)	0.5	7.0		0	0
Clarius batrachus		0	0	<0.0 (<±0.00)	<0.0	0.3		0	0
Cyprinodon variegatus		0	0	0.06 (±0.02)	0.2	2.3		0	0
Elassoma evergladei		0	0	<0.0 (<±0.00)	<0.0	0.3		0	0
Enneacanthus gloriosus		0	0	0.12 (±0.05)	0.4	3.2		0	0
Fundulus chrysotus	0.25 (±0.13)	1.8	14.3	0.09 (±0.03)	0.3	5.2		0	0
Fundulus confluentus	2.29 (±0.73)	16.5	39.3	1.50 (±0.26)	5.3	26.7	0.08 (±0.08)	5.3	8.3
Gambusia holbrooki	2.54 (±0.99)	18.3	46.4	19.48 (±3.76)	69.2	43.5		0	0
Hemichromis letourneuxi		0	0	0.18 (±0.05)	0.7	6.4		0	0
Heterandria formosa	1.04 (±0.59)	7.5	21.4	0.42 (±0.12)	1.5	9.9	0.08 (±0.08)	5.3	8.3
Jordanella floridae	2.61 (±0.98)	18.9	39.3	3.01 (±0.42)	10.7	36.5		0	0
Lepomis gulosus	0.04 (±0.04)	0.3	3.6	0.14 (±0.04)	0.5	7.0		0	0
Lepomis macrochirus		0	0	0.01 (±0.01)	<0.0	0.3	0.08 (±0.08)	5.3	8.3
Lepomis marginatus	1.46 (±0.61)	10.6	35.7	1.96 (±0.36)	6.9	42.9	0.42 (±0.40)	26.3	8.3
Lepomis microlophus		0	0		0	0		0	0
Lepomis punctatus		0	0	0.03 (±0.01)	0.1	2.6		0	0
Lepomis spp.		0	0	0.01 (±0.01)	<0.0	0.9		0	0
Lucania goodei	2.71 (±1.27)	19.6	35.7	0.04 (±0.01)	0.2	3.5	0.67 (±0.34)	42.1	33.3
Lucania parva		0	0	0.01 (±0.01)	<0.0	0.3		0	0
Micropterus salmoides		0	0		0	0		0	0
Notropis maculatus		0	0		0	0		0	0
Notropis petersoni		0	0	<0.0 (<±0.00)	<0.0	0.3		0	0
Noturus gyrinus		0	0	0.02 (±0.01)	0.1	2.0		0	0
Poecilia latipinna	0.36 (±0.36)	2.6	3.6	0.59 (±0.13)	2.1	12.2	0.08 (±0.08)	5.3	8.3
Tilapia mariae		0	0		0	0		0	0
Unidentified		0	0		0	0		0	0
Total Fish	387			9686				19	

Table 32. Mean fish numbers from Array 6 during the initial, main, and subsequent flooding events from 2000 – 2003. Average abundance (±standard error (SE)) is based on minnow trap CPUE (24-h soak time). RA = relative abundance. Incidence (I) = percentage of weekly samples in which the species was captured. Number of samples (N) indicated for each event category. Species in red are non-native.

	Initial (N = 32)			Main (N = 192)			Subsequent (N = 48)		
Species	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I	$\overline{X}$ (±SE)	RA	I
Ameiurus natalis		0	0	0.02 (±0.01)	0.1	2.1	0.02 (±0.02)	0.1	2.1
Belonesox belizanus	0.41 (±0.13)	8.1	28.1	0.24 (±0.06)	0.7	13.0	0.58 (±0.22)	2.9	25.0
Cichlasoma bimaculatum		0	0	0.03 (±0.02)	0.1	1.6		0	0
Cichlasoma managuense		0	0		0	0		0	0
Cichlasoma urophthalmus		0	0	0.13 (±0.04)	0.3	7.3	0.08 (±0.05)	0.4	6.3
Clarius batrachus		0	0	0.02 (±0.01)	<0.0	1.6	0.02 (±0.02)	0.1	2.1
Cyprinodon variegatus		0	0	0.01 (±0.01)	<0.0	0.5		0	0
Elassoma evergladei		0	0	0.01 (±0.01)	<0.0	0.5	0.02 (±0.02)	0.1	2.1
Enneacanthus gloriosus		0	0	0.02 (±0.01)	0.1	1.6		0	0
Fundulus chrysotus		0	0	0.10 (±0.04)	0.3	6.8		0	0
Fundulus confluentus	1.22 (±0.53)	24.2	25.0	2.26 (±0.36)	6.1	45.8	1.02 (±0.38)	5.1	33.3
Gambusia holbrooki	1.03 (±0.50)	20.5	28.1	27.33 (±8.05)	73.8	54.2	15.17 (±8.43)	75.8	33.3
Hemichromis letourneuxi		0	0	0.15 (±0.05)	0.4	7.3		0	0
Heterandria formosa		0	0	0.10 (±0.04)	0.3	5.2	0.15 (±0.08)	0.7	8.3
Jordanella floridae	1.50 (±0.99)	29.8	21.9	3.79 (±0.74)	10.2	41.1	1.46 (±0.96)	7.3	14.6
Lepomis gulosus		0	0	0.16 (±0.07)	0.4	8.3	0.02 (±0.02)	0.1	2.1
Lepomis macrochirus		0	0	0.01 (±0.01)	<0.0	0.5		0	0
Lepomis marginatus	0.59 (±0.26)	11.8	21.9	0.65 (±0.15)	1.7	26.0	0.71 (±0.62)	3.5	10.4
Lepomis microlophus		0	0		0	0		0	0
Lepomis punctatus	0.06 (±0.04)	1.2	6.3	0.02 (±0.01)	<0.0	1.6	0.02 (±0.02)	0.1	2.1
Lepomis spp.		0	0		0	0		0	0
Lucania goodei	0.03 (±0.03)	0.6	3.1	0.07 (±0.04)	0.2	4.2	0.02 (±0.02)	0.1	2.1
Lucania parva		0	0		0	0		0	0
Micropterus salmoides		0	0		0	0		0	0
Notropis maculatus		0	0		0	0	0.17 (±0.10)	0.8	6.3
Notropis petersoni		0	0		0	0		0	0
Noturus gyrinus	0.03 (±0.03)	0.6	3.1		0	0		0	0
Poecilia latipinna	0.16 (±0.10)	3.1	9.4	1.93 (±0.49)	5.2	24.0	0.56 (±0.31)	2.8	10.4
Tilapia mariae		0	0		0	0		0	0
Unidentified		0	0		0	0		0	0
Total Fish	161			7105			961		

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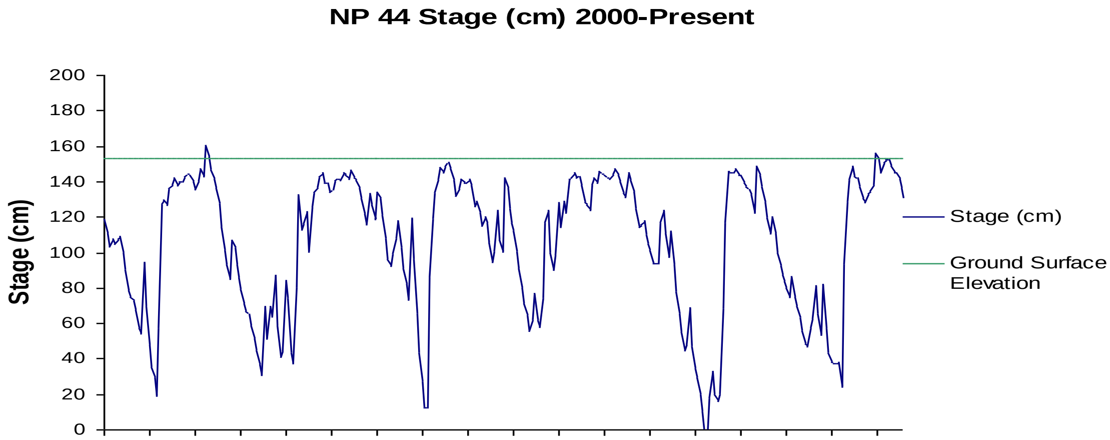
Table 33. Percent relative abundance (RA), percent incidence (I), and number (N) of fish collected in 24-hour drift-fence sampling (08-09 October 2003) – sum of 36 samples (3 directions * arrays * 4 sampling events).

Species	Common name	RA	(I)	N
Astronotus ocellatus	Oscar	1.2	(8.3)	3
Belonesox belizanus	Pike killifish	3.6	(13.9)	9
Cichlasoma bimaculatum	Black acara	0.4	(2.8)	1
Cichlasoma urophthalmus	Mayan cichlid	3.2	(13.9)	8
Enneacanthus gloriosus	Bluespotted sunfish	5.2	(19.4)	13
Esox americanus	Grass pickerel	1.6	(8.3)	4
Fundulus chrysotus	Golden topminnow	0.8	(5.6)	2
Fundulus confluentus	Marsh killifish	4.4	(19.4)	11
Gambusia holbrooki	Eastern mosquitofish	5.2	(16.7)	13
Hemichromis letourneuxi	African jewelfish	43.4	(63.9)	109
Jordanella floridae	Flagfish	3.2	(13.9)	8
Lepomis gulosus	Warmouth	1.2	(5.6)	3
Lepomis marginatus	Dollar sunfish	15.9	(27.8)	40
Lucania goodei	Bluefin killifish	10.4	(22.2)	26
Poecilia latipinna	Sailfin molly	0.4	(2.8)	1
Total				251

Table 34. Statistical information for 2-way crossed ANOVA for season * depth factors – only significant effects are shown ($P \leq 0.05$).

	Factor			
Species	**Season ($F_{1,60}$)**	**Depth ($F_{2,60}$)**	**Season x Depth ($F_{2,60}$)**	**R^2**
Cichlasoma bimaculatum	9.36	3.84	4.24	0.455
Fundulus confluentus	14.85	9.20	4.60	0.443
Gambusia holbrooki	5.55	5.42	3.39	0.302
Hemichromis letourneuxi	7.99			0.332
Jordanella floridae	5.61			0.198
Lepomis gulosus	10.98			0.364
Total fish	19.19			0.317


Water Conservation Areas
MAIN EVERGLADES
MIAMI
ROCKLAND
COASTAL RIDGE
S-196A
HOMESTEAD
N
PARK BOUNDARY
0
9
18
KM
STUDY AREA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Stage (cm)
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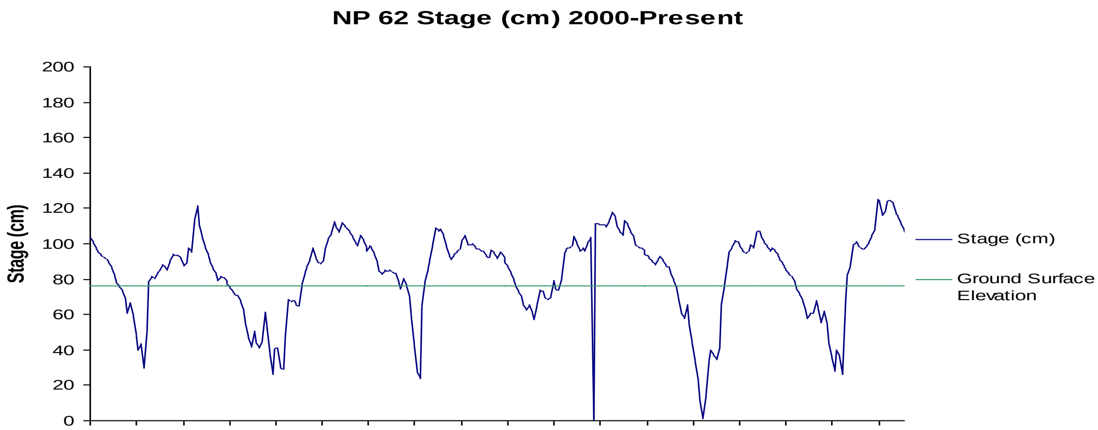
180
160
140
120
100
80
60
40
20
0
Stage (cm)
Ground Surface Elevation


NP 62 Stage (cm) 2000-Present
Stage (cm)
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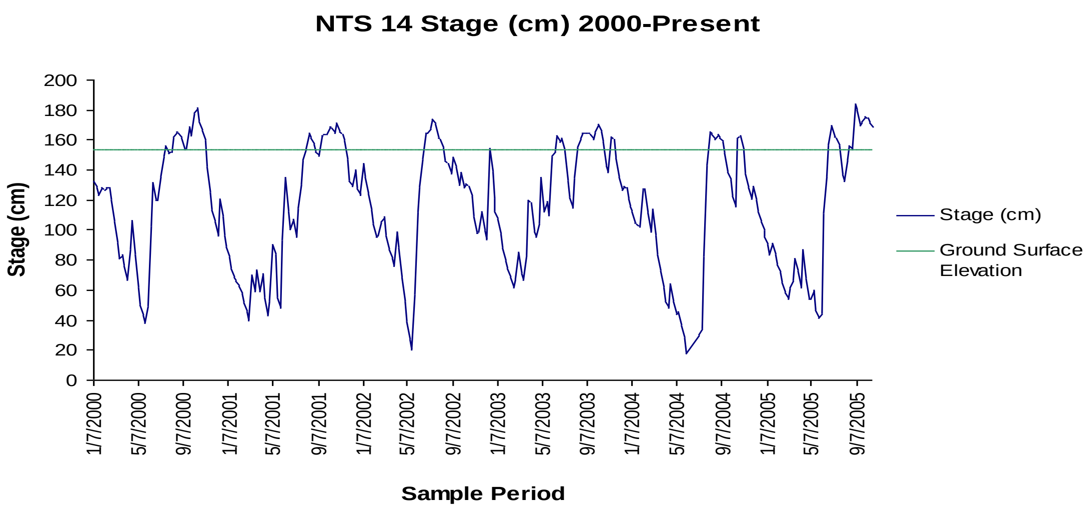
180
160
140
120
100
80
60
40
20
0
Stage (cm)
Ground Surface Elevation


NTS 14 Stage (cm) 2000-Present
Stage (cm)
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180
160
140
120
100
80
60
40
20
0
1/7/2000
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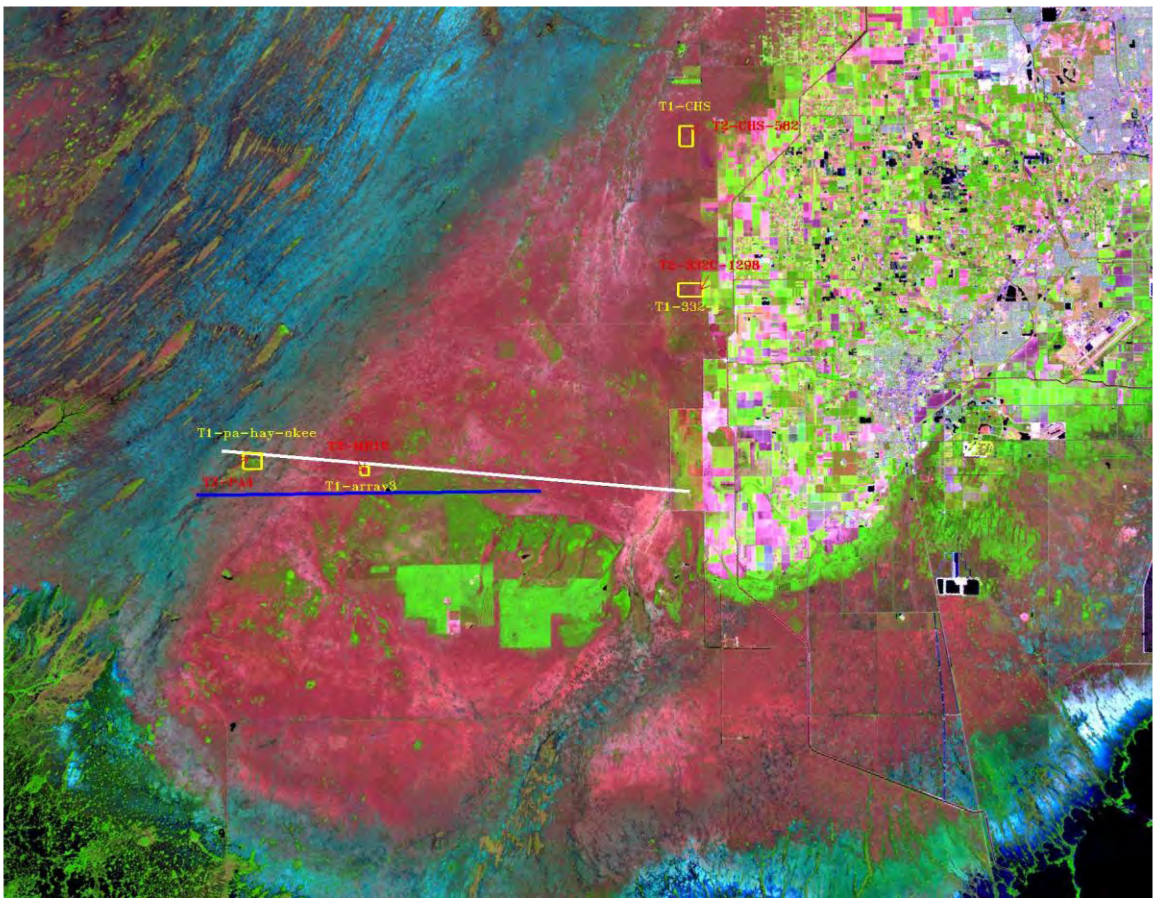
9/7/2000
1/7/2001
5/7/2001
9/7/2001
1/7/2002
5/7/2002
9/7/2002
1/7/2003
5/7/2003
9/7/2003
1/7/2004
5/7/2004
9/7/2004
1/7/2005
5/7/2005
9/7/2005
Sample Period
Stage (cm)
Ground Surface Elevation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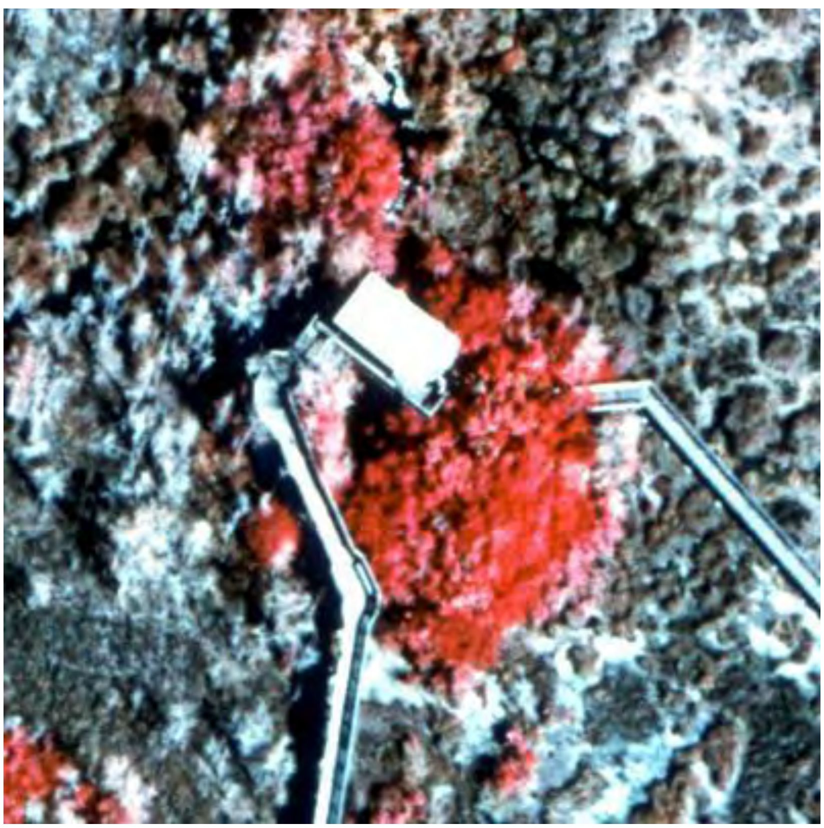
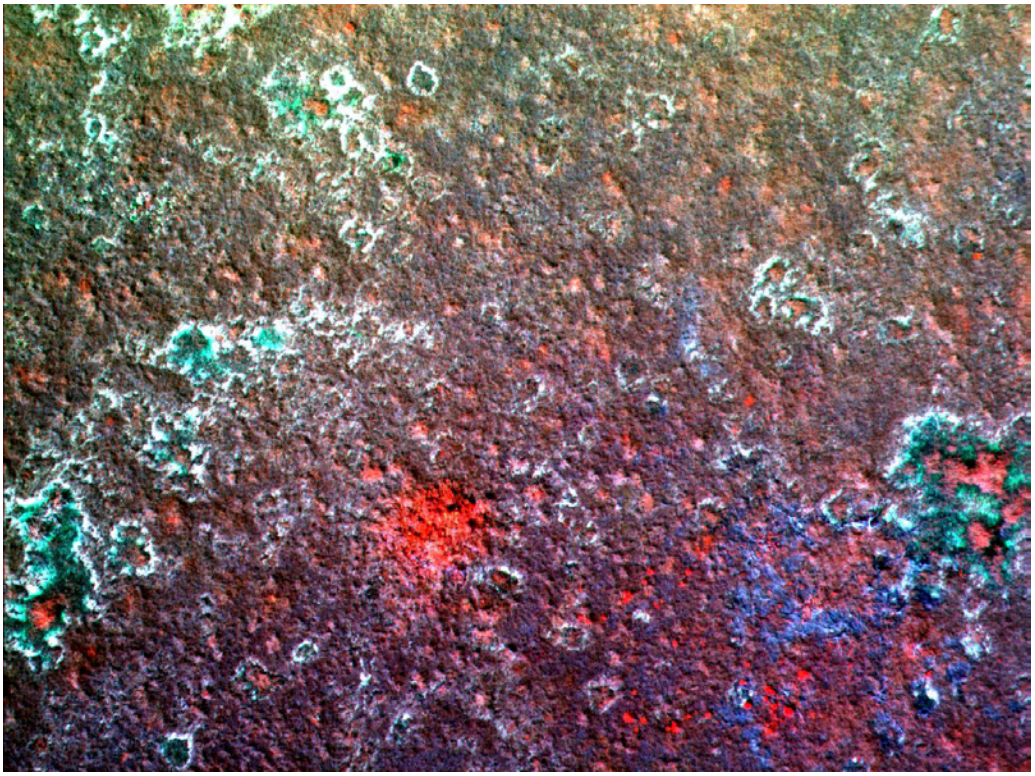
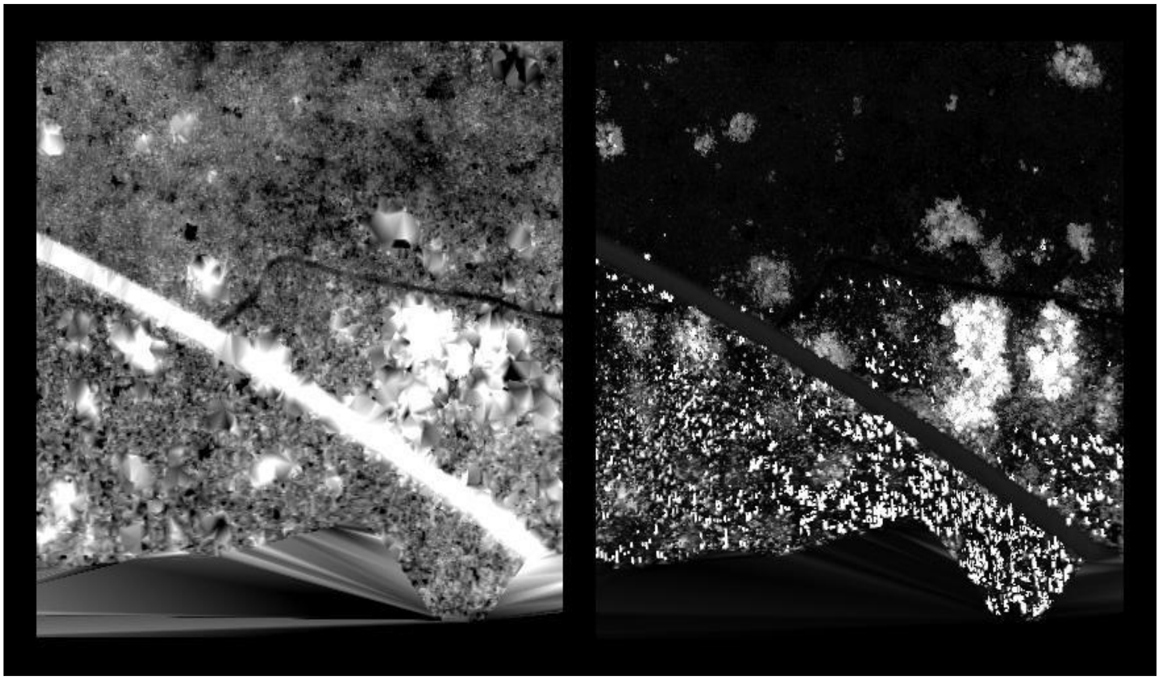
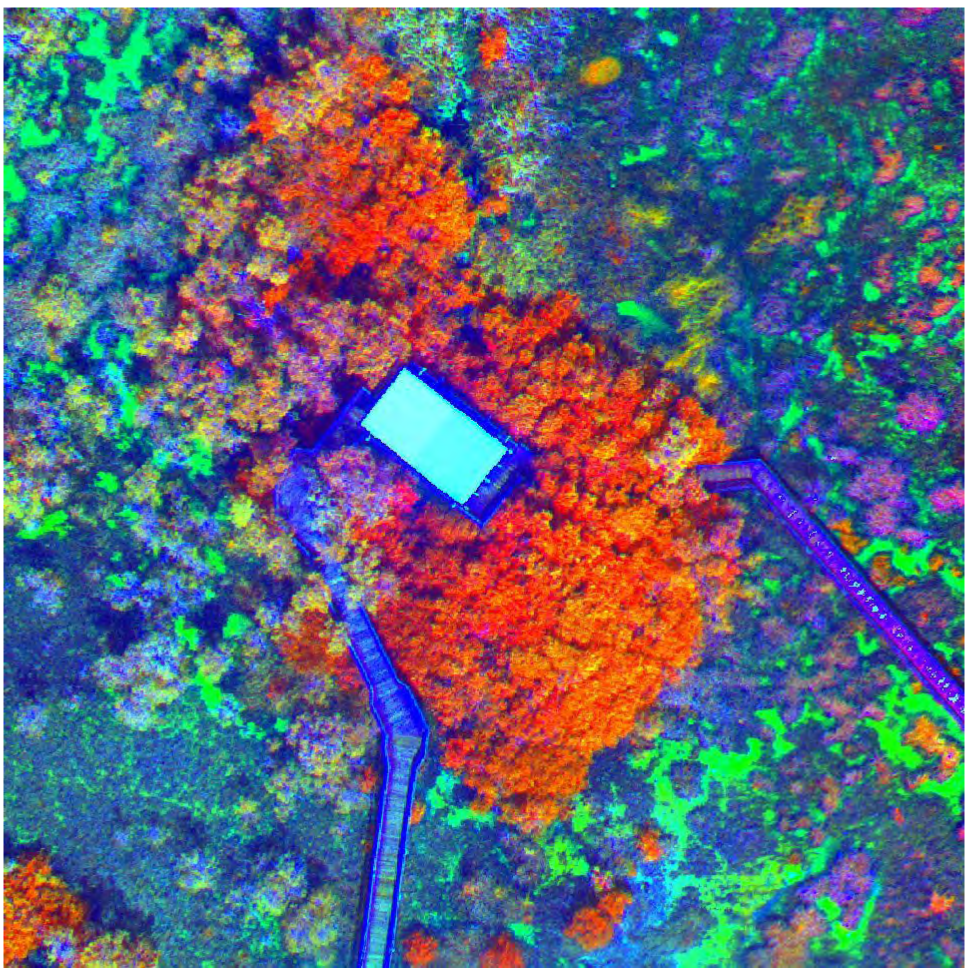
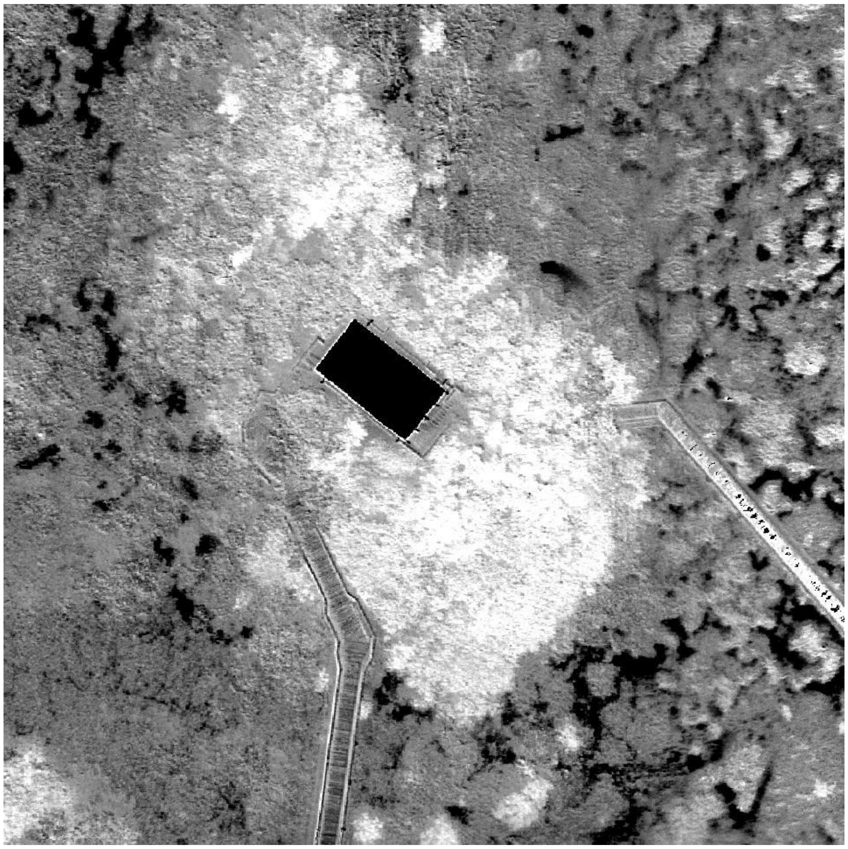
T2-CHS-582
T1-pa-hay-okee
T1-array3

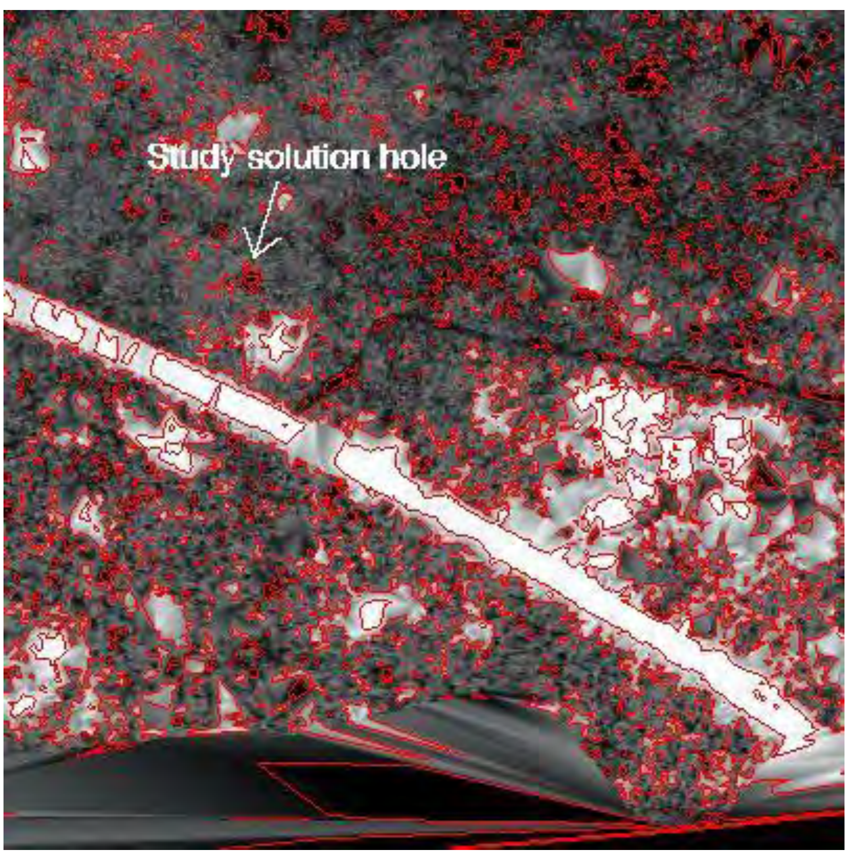


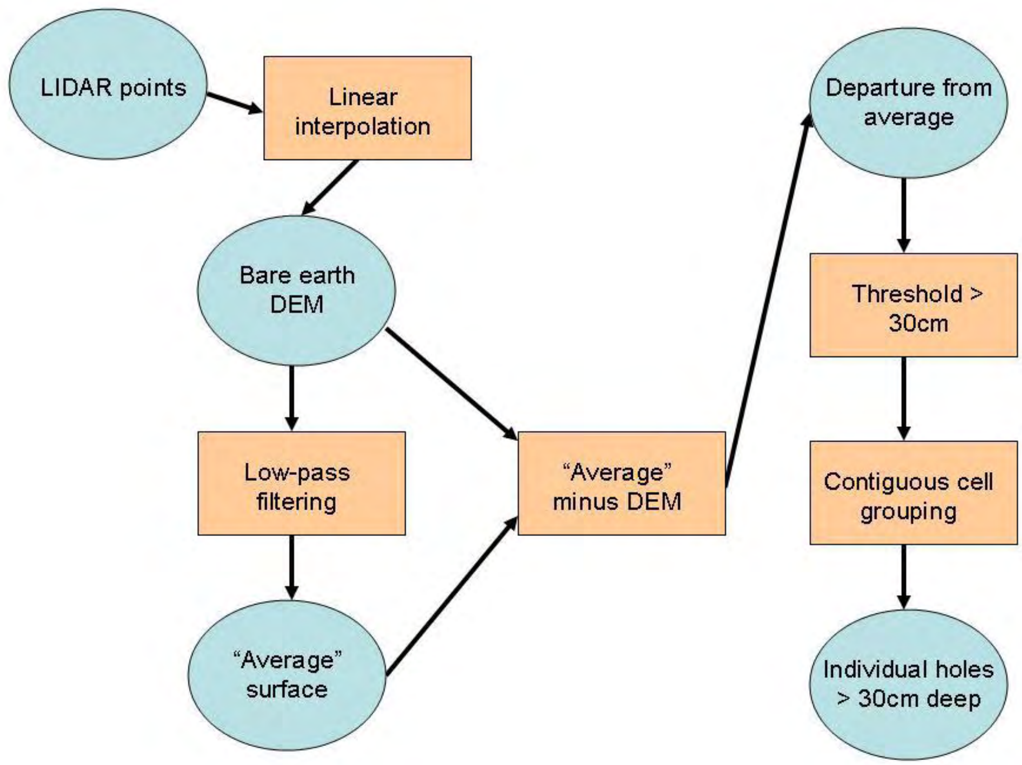


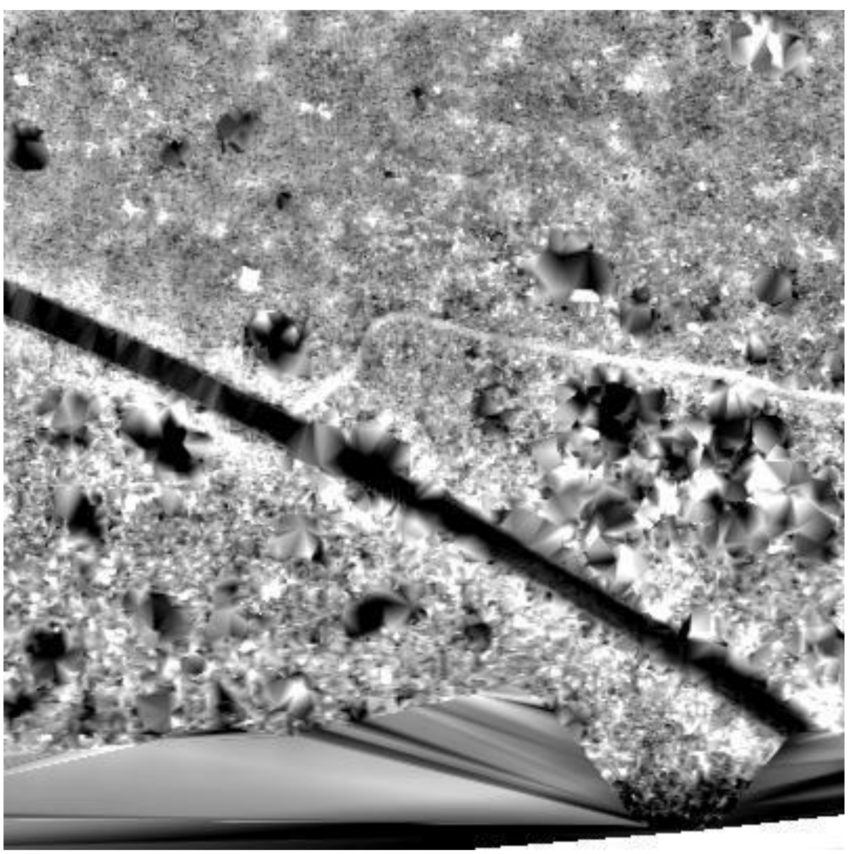


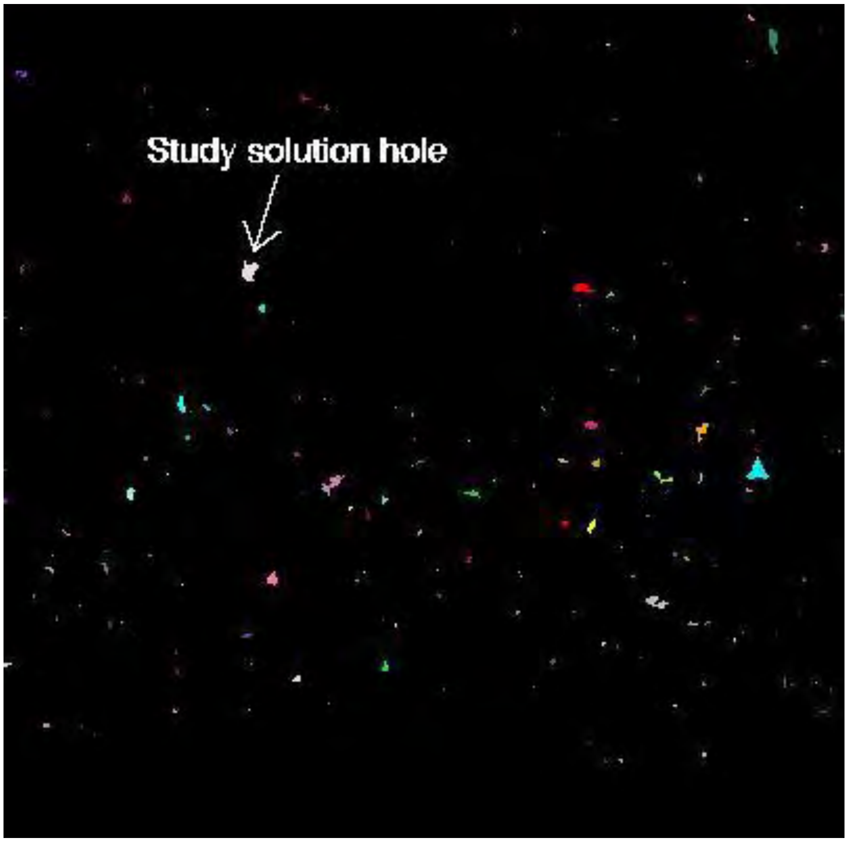


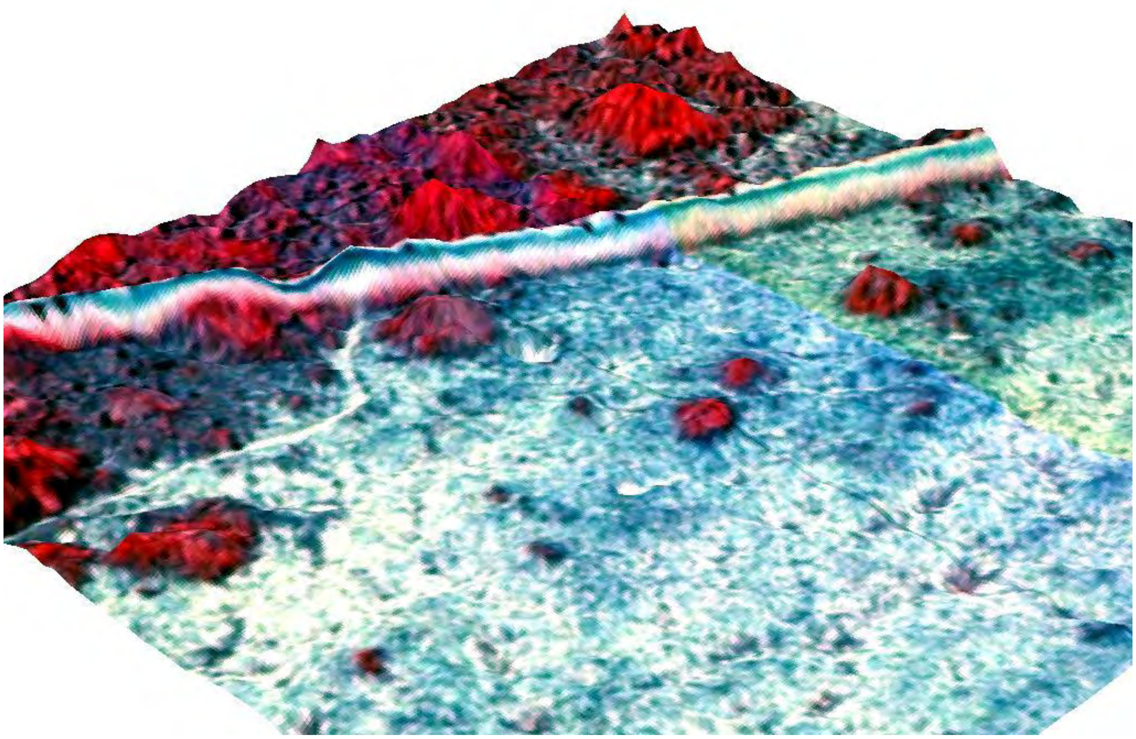


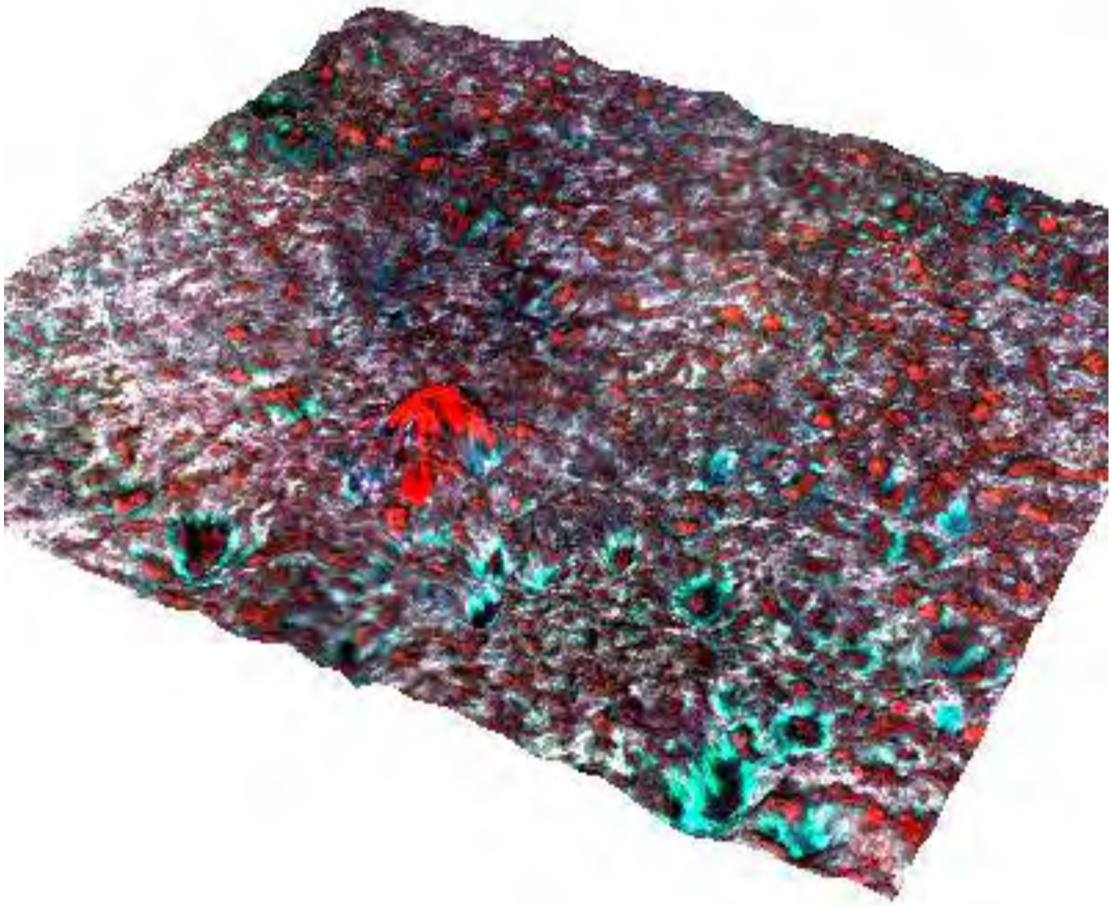

Study solution hole

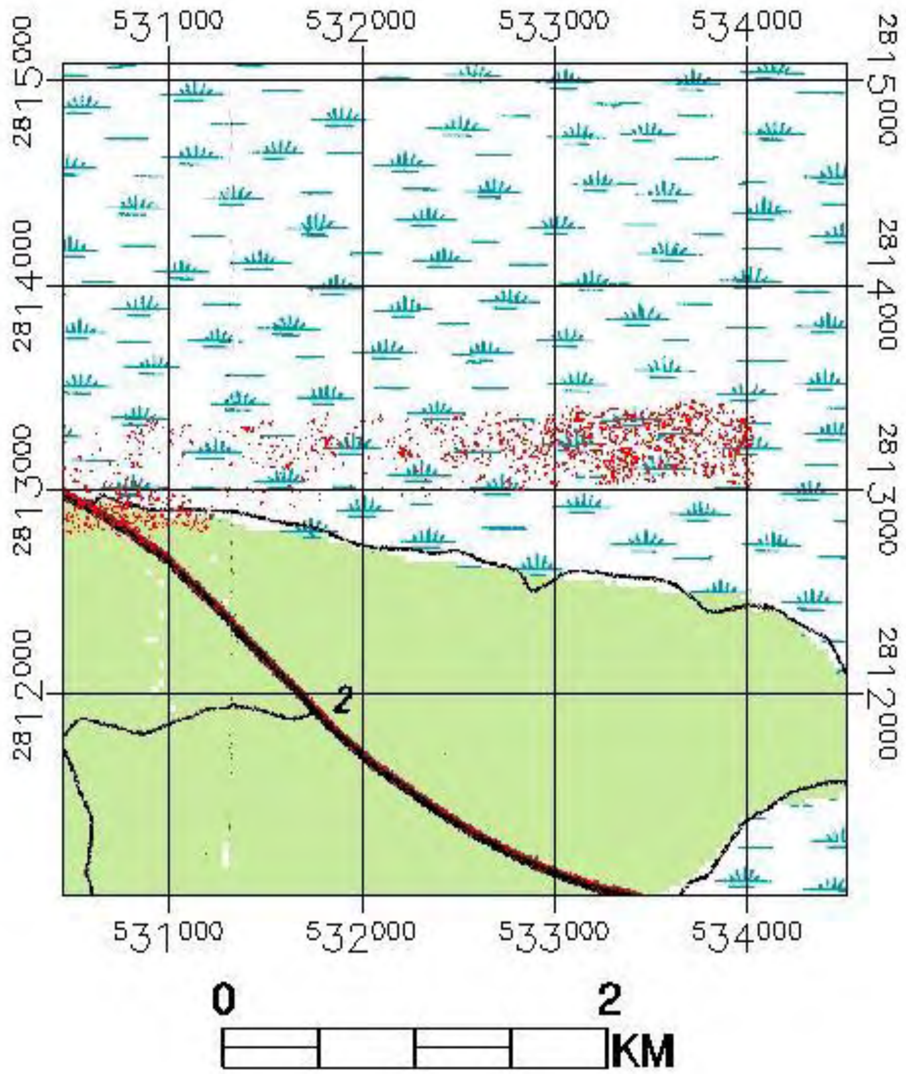

LIDAR points
Linear interpolation
Bare earth DEM
Low-pass filtering
"Average" surface
"Average" minus DEM
Departure from average
Threshold > 30cm
Contiguous cell grouping
Individual holes > 30cm deep



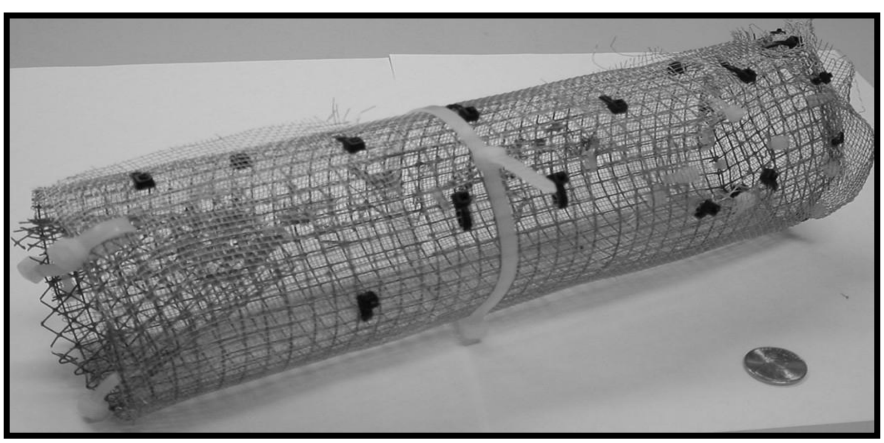

Study solution hole

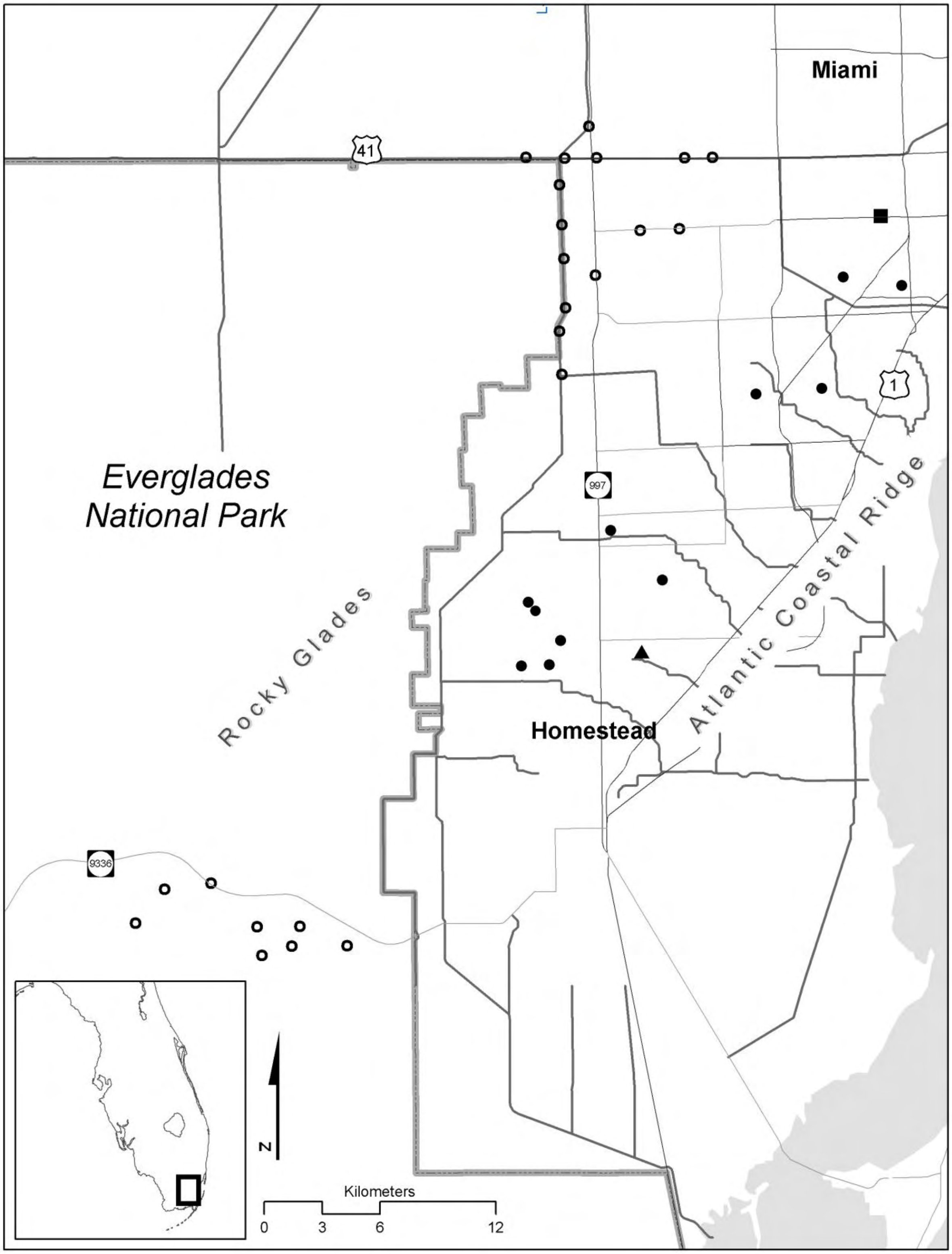




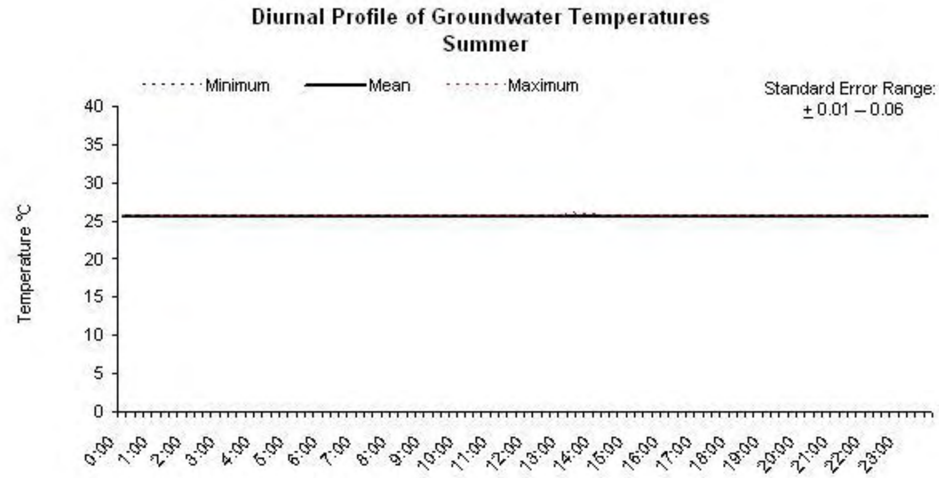


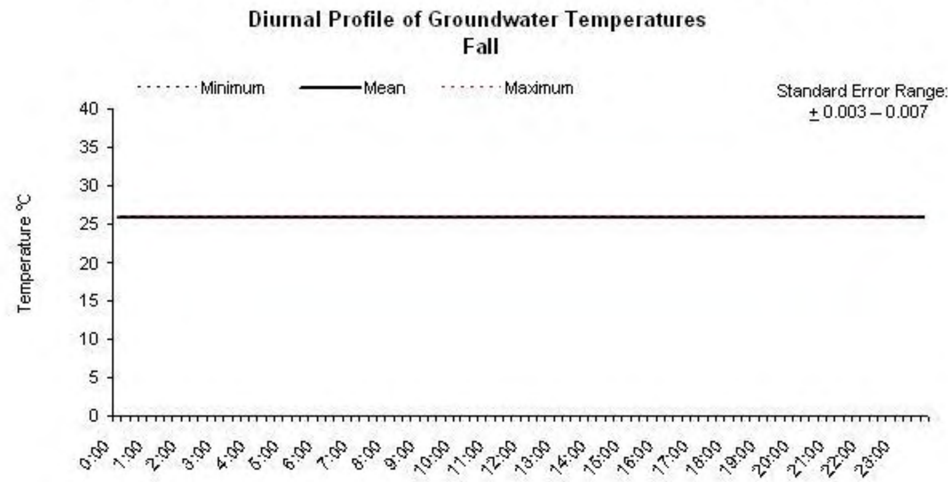
531000
532000
533000
534000
2815000
2814000
2813000
2812000
2
0
2
KM

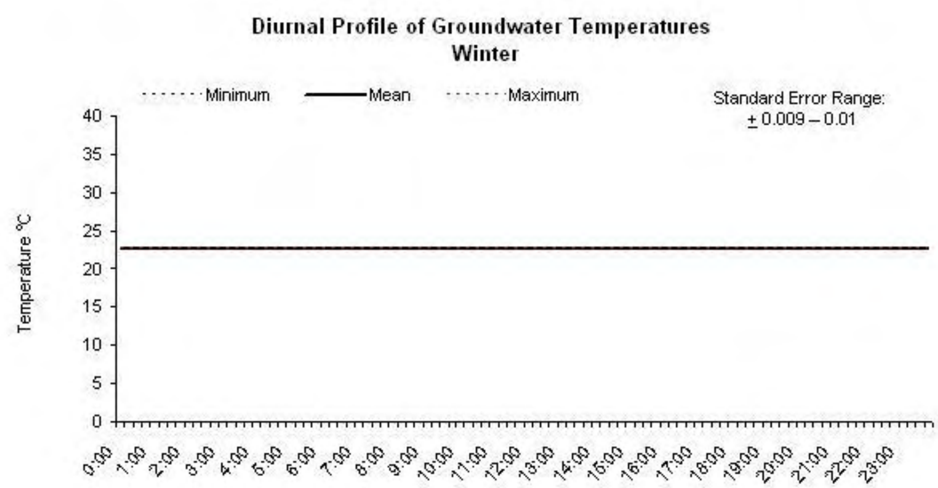




Miami
41
1
997
Everglades
National Park
Rocky Glades
Atlantic Coastal Ridge
Homestead
9336
N
Kilometers
0
3
6
12


Diurnal Profile of Groundwater Temperatures
Summer
Minimum
Mean
Maximum
Standard Error Range:
± 0.01 – 0.06
Temperature °C
40
35
30
25
20
15
10
5
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Temperatures
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 0.003 – 0.007
Temperature °C
40
35
30
25
20
15
10
5
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Temperatures
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.009 – 0.01
Temperature °C
40
35
30
25
20
15
10
5
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
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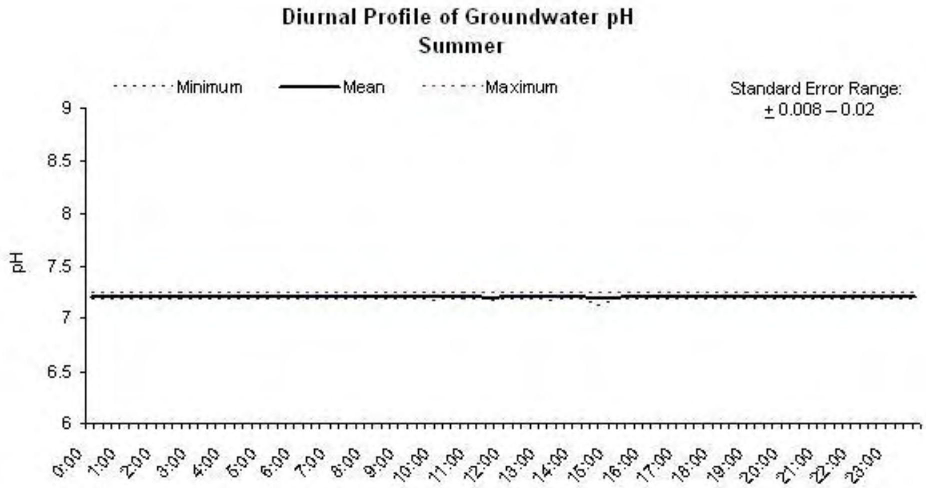
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater pH
Summer
Minimum
Mean
Maximum
Standard Error Range:
± 0.008 – 0.02
pH
9
8.5
8
7.5
7
6.5
6
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
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15:00
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18:00
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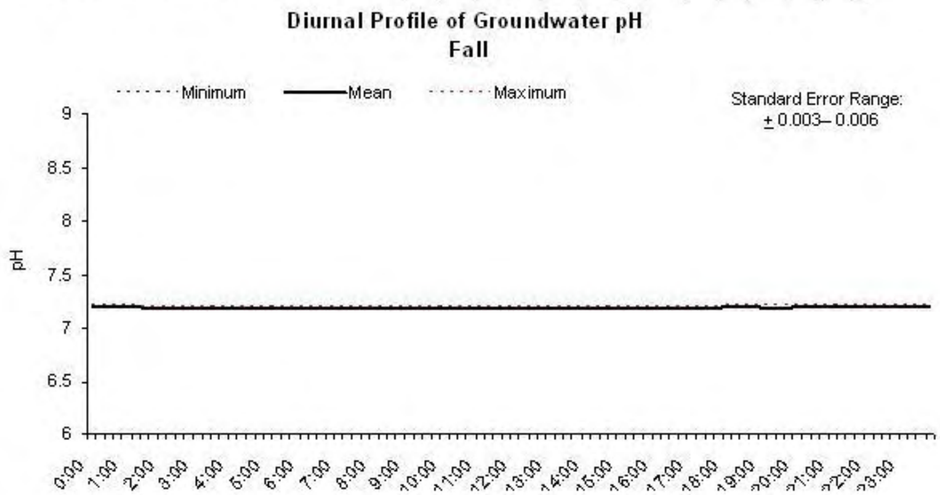
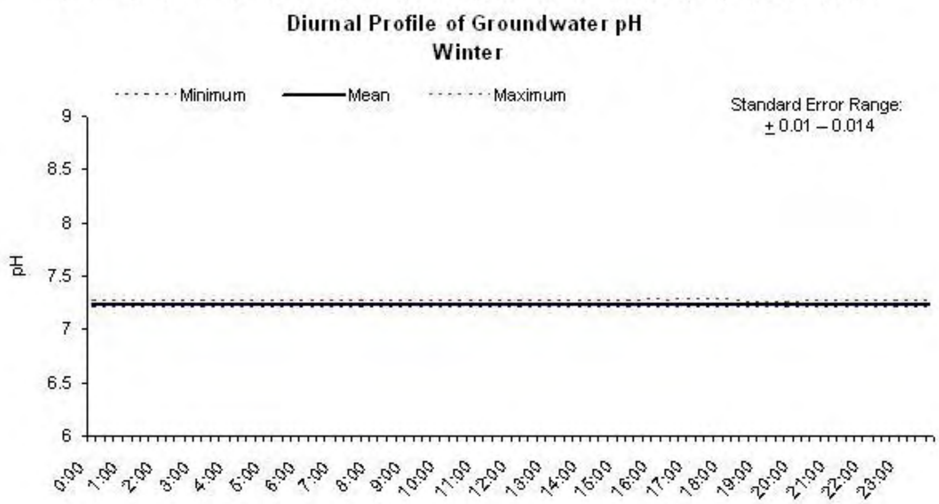
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater pH
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 0.003– 0.006
pH
9
8.5
8
7.5
7
6.5
6
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater pH
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.01 – 0.014
pH
9
8.5
8
7.5
7
6.5
6
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
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17:00
18:00
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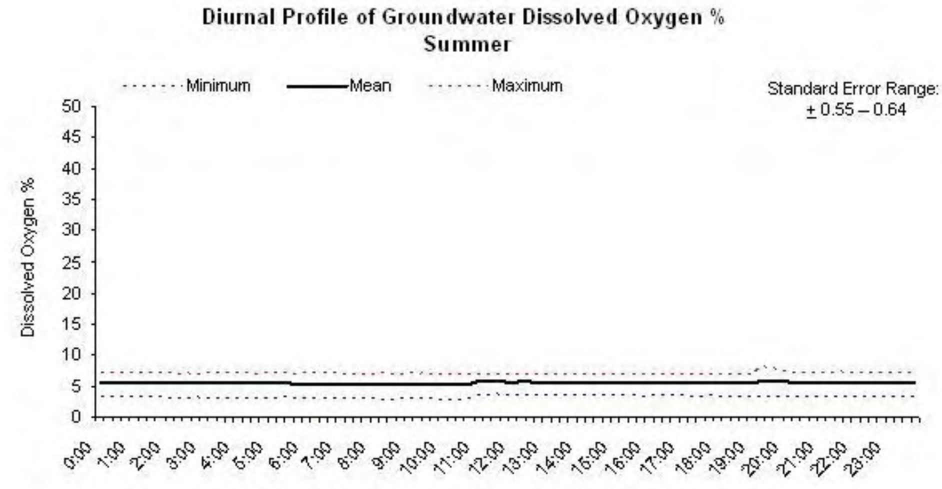
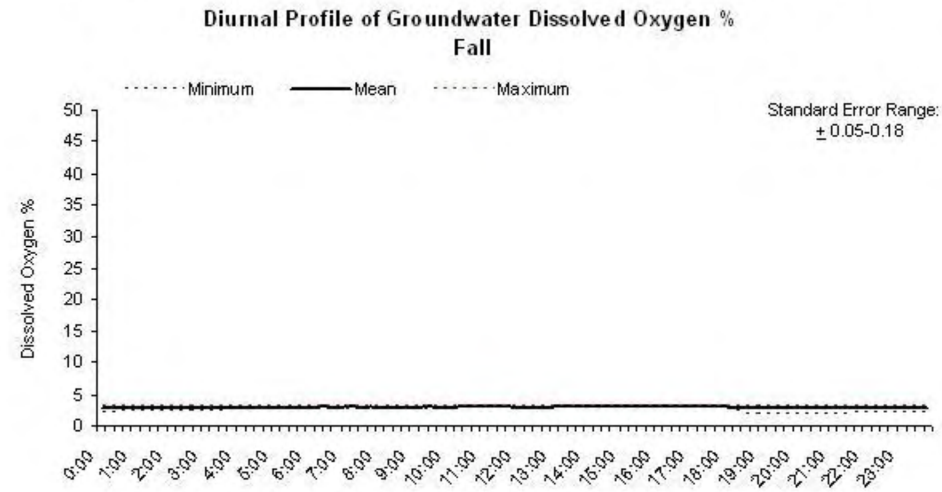
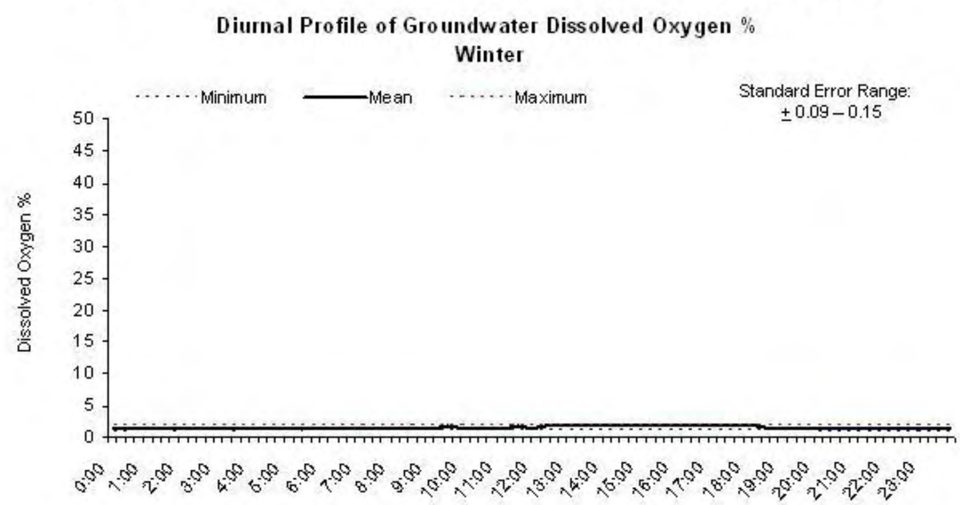
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Dissolved Oxygen %
Summer
Minimum
Mean
Maximum
Standard Error Range:
± 0.55 – 0.64
Dissolved Oxygen %
0
5
10
15
20
25
30
35
40
45
50
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Dissolved Oxygen %
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 0.05-0.18
Dissolved Oxygen %
0
5
10
15
20
25
30
35
40
45
50
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Dissolved Oxygen %
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.09 – 0.15
Dissolved Oxygen %
0
5
10
15
20
25
30
35
40
45
50
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
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13:00
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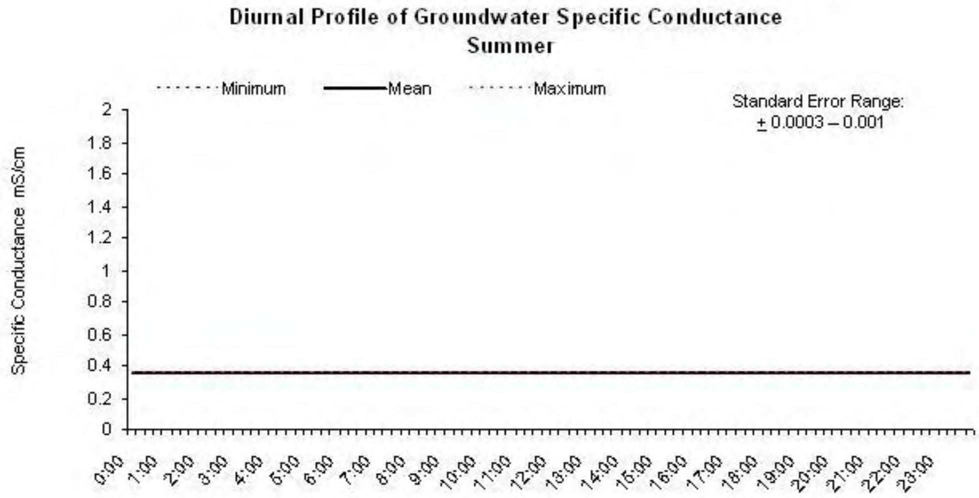
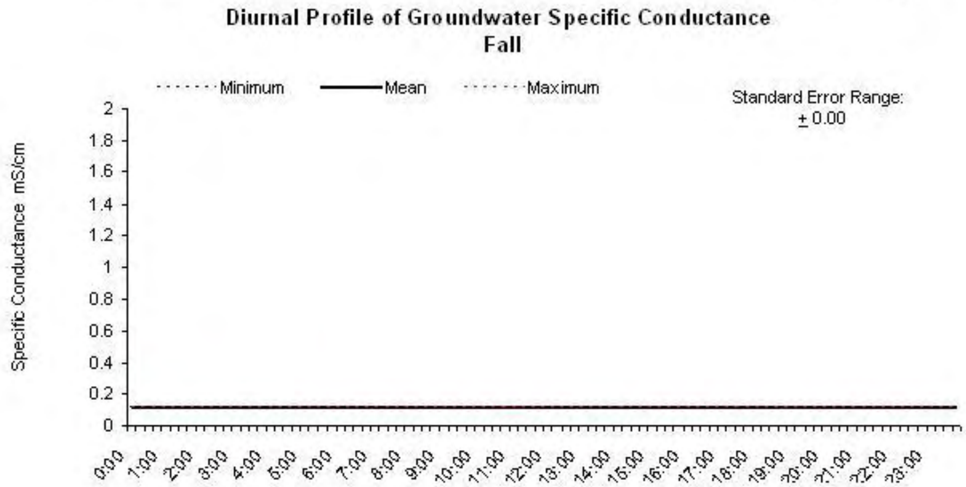
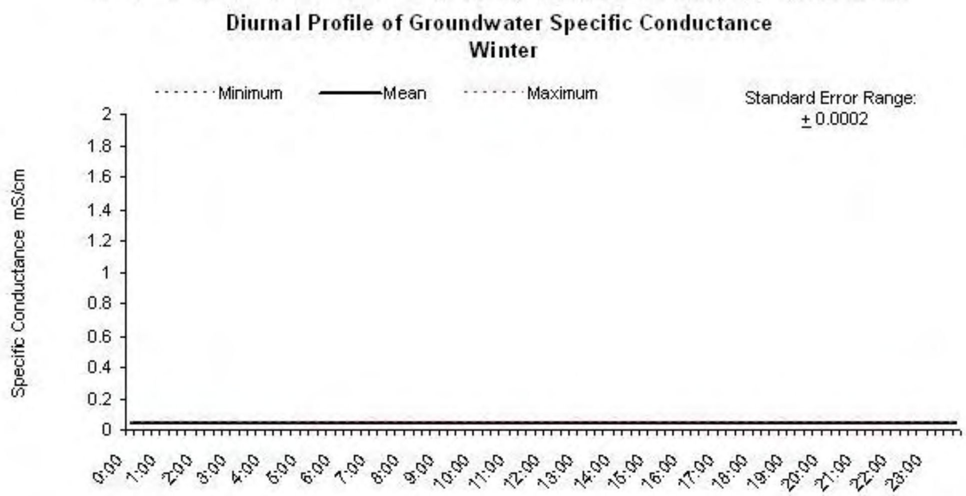
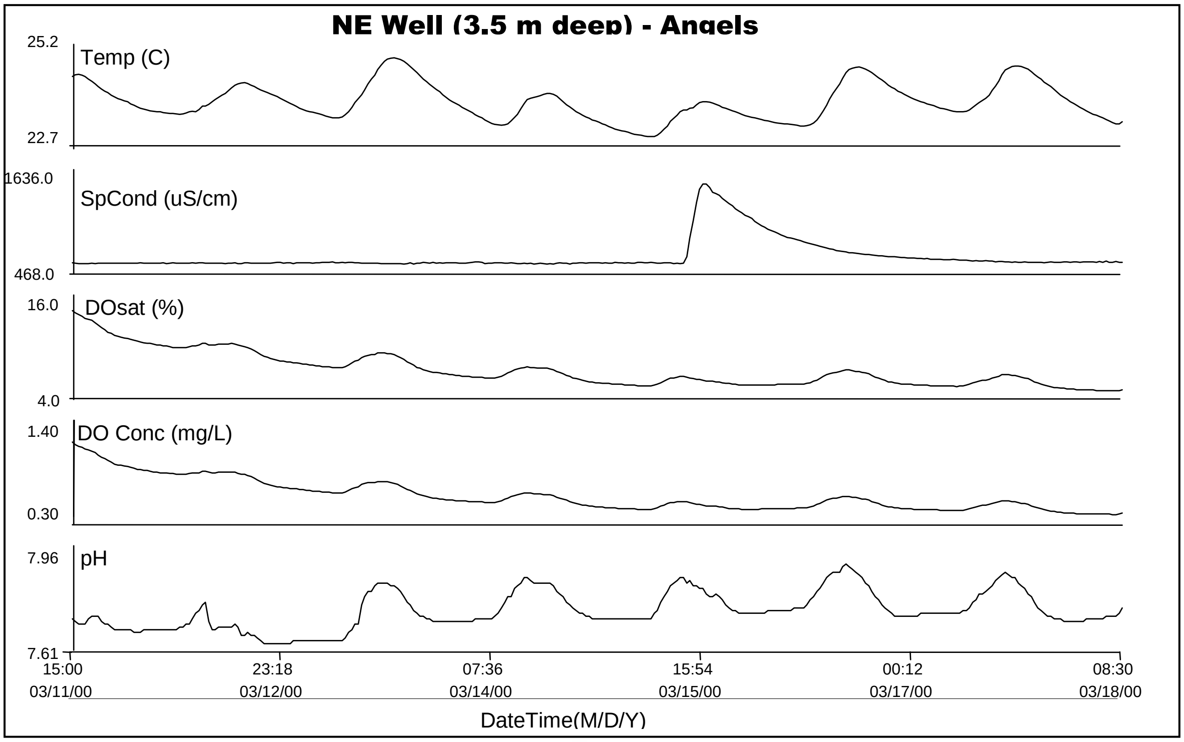
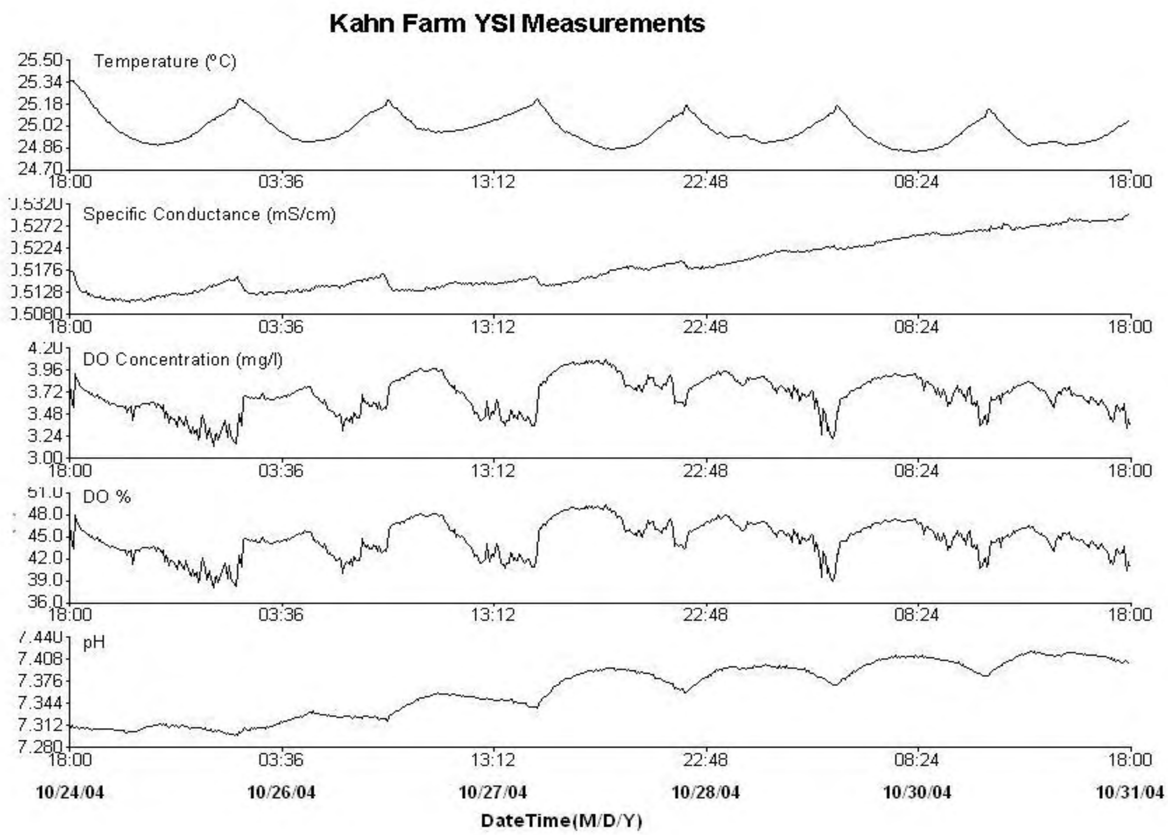
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Groundwater Specific Conductance
Summer
Minimum
Mean
Maximum
Standard Error Range:
± 0.0003 – 0.001
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00


Diurnal Profile of Groundwater Specific Conductance
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 0.00
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

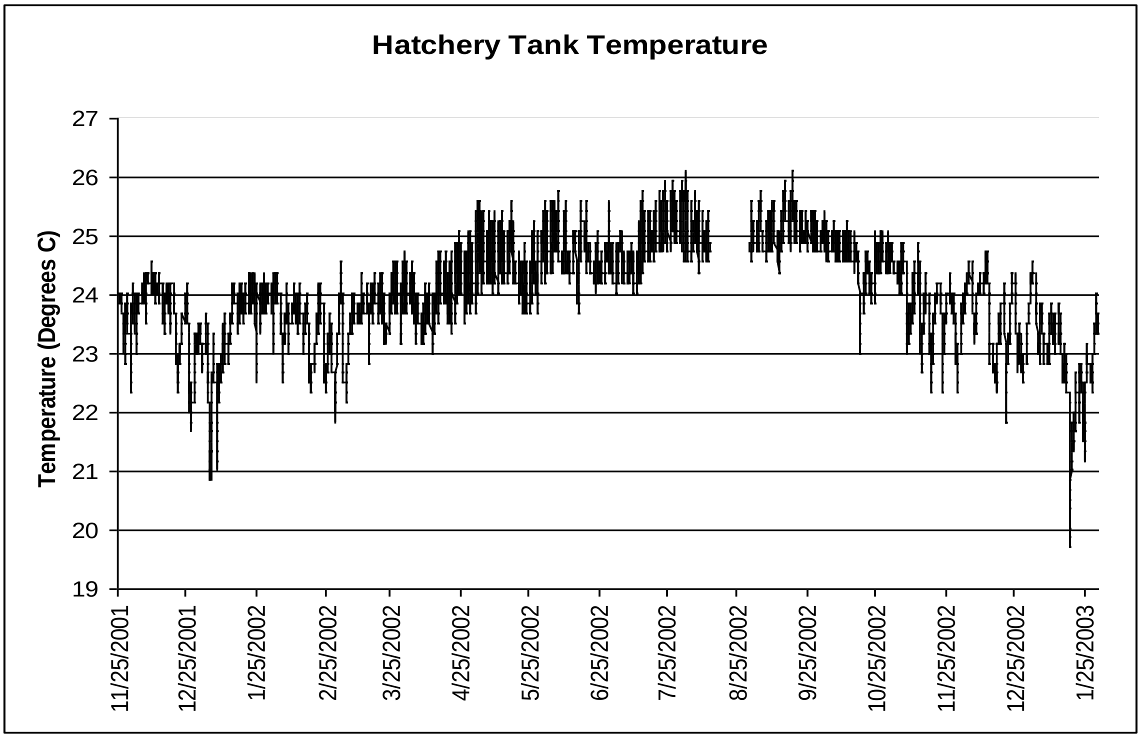

Diurnal Profile of Groundwater Specific Conductance
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.0002
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00


NE Well (3.5 m deep) - Angels
Temp (C)
25.2
22.7
SpCond (uS/cm)
1636.0
468.0
DOsat (%)
16.0
4.0
DO Conc (mg/L)
1.40
0.30
pH
7.96
7.61
15:00
03/11/00
23:18
03/12/00
07:36
03/14/00
15:54
03/15/00
00:12
03/17/00
08:30
03/18/00
DateTime(M/D/Y)

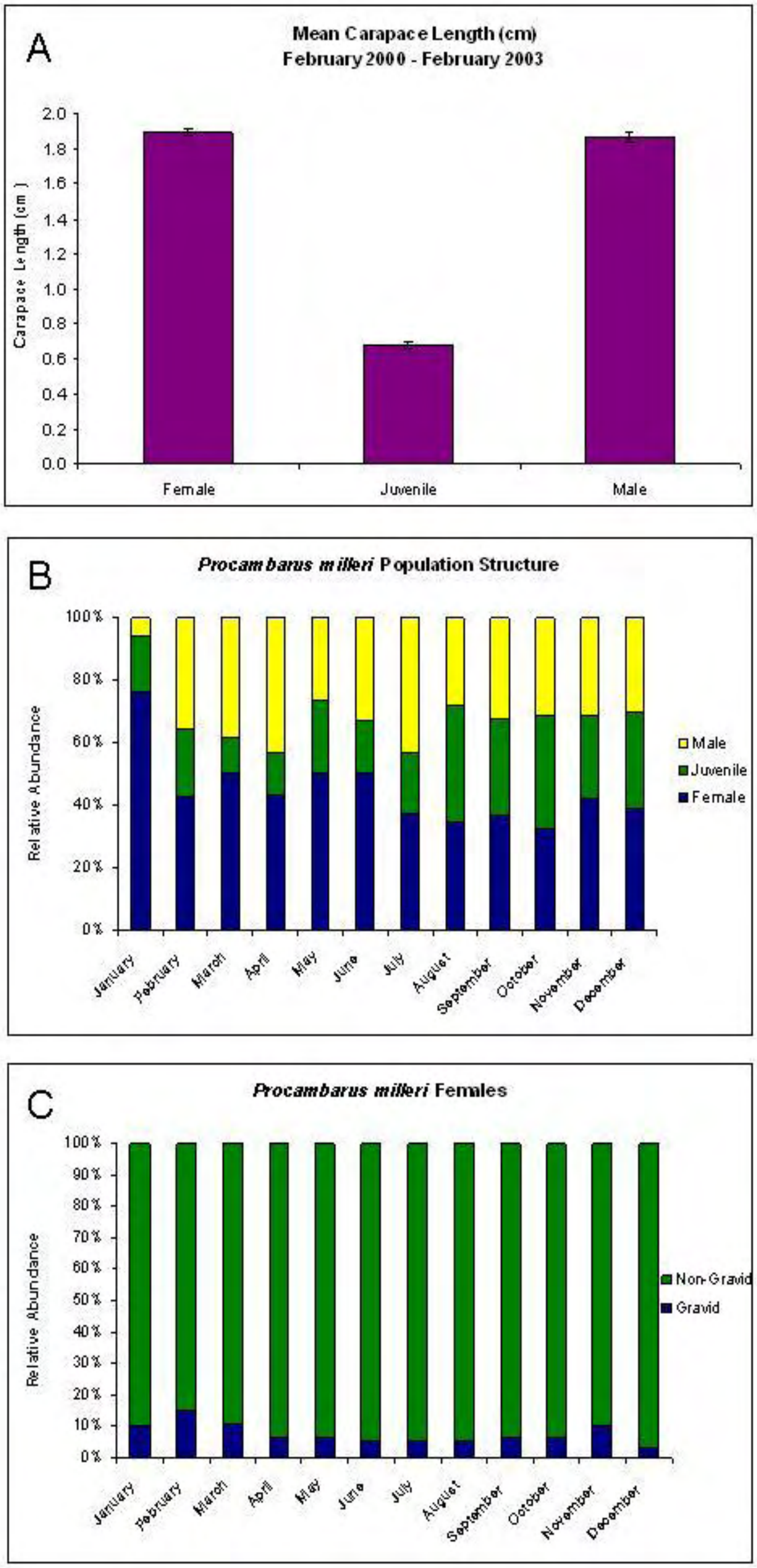

Kahn Farm YSI Measurements
Temperature (°C)
25.50
25.34
25.18
25.02
24.86
24.70
Specific Conductance (mS/cm)
DO Concentration (mg/l)
4.20
3.96
3.72
3.48
3.24
3.00
DO %
48.0
45.0
42.0
39.0
36.0
pH
7.408
7.376
7.344
7.312
7.280
18:00
03:36
13:12
22:48
08:24
18:00
10/24/04
10/26/04
10/27/04
10/28/04
10/30/04
10/31/04
DateTime(M/D/Y)

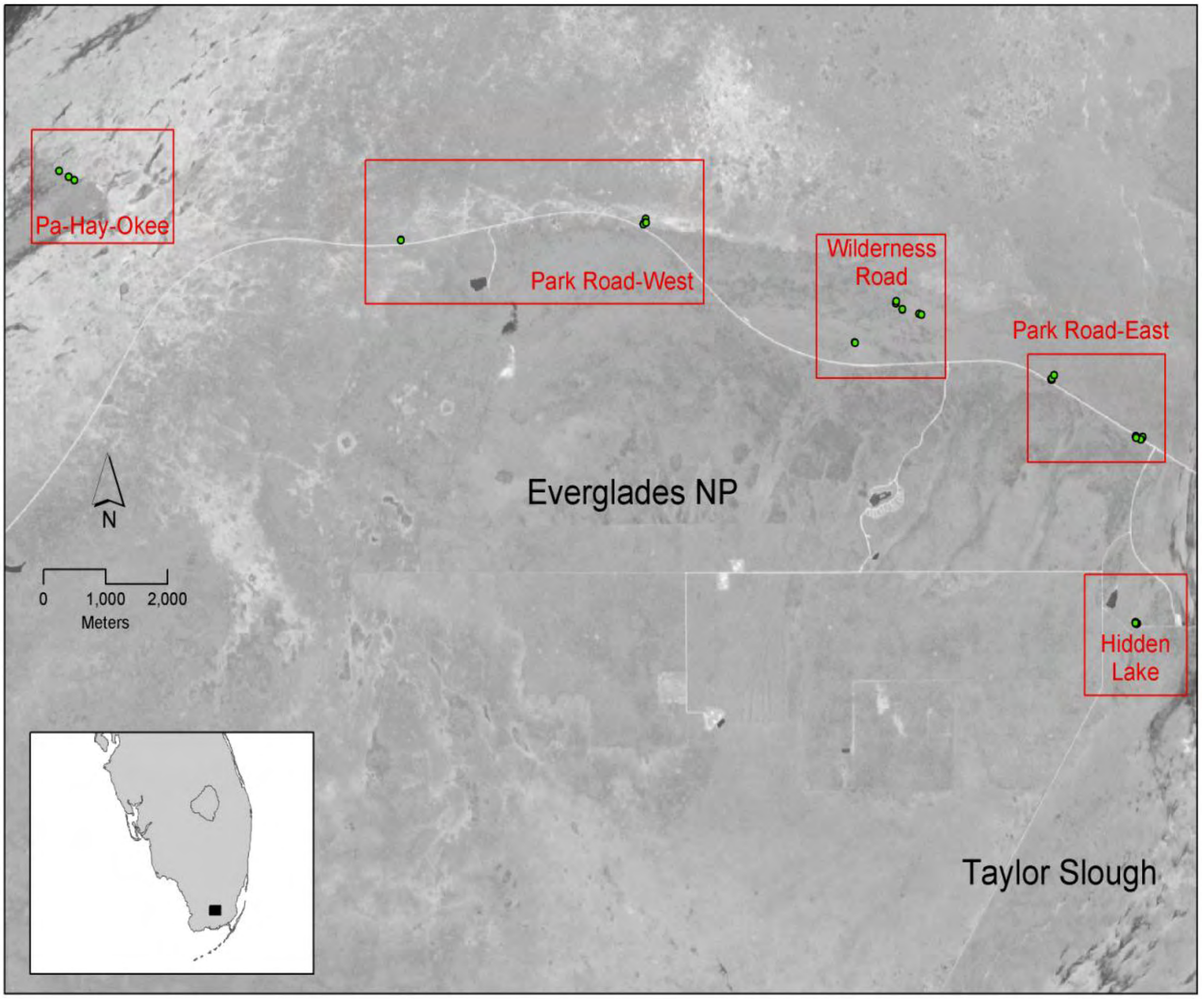
A. B.

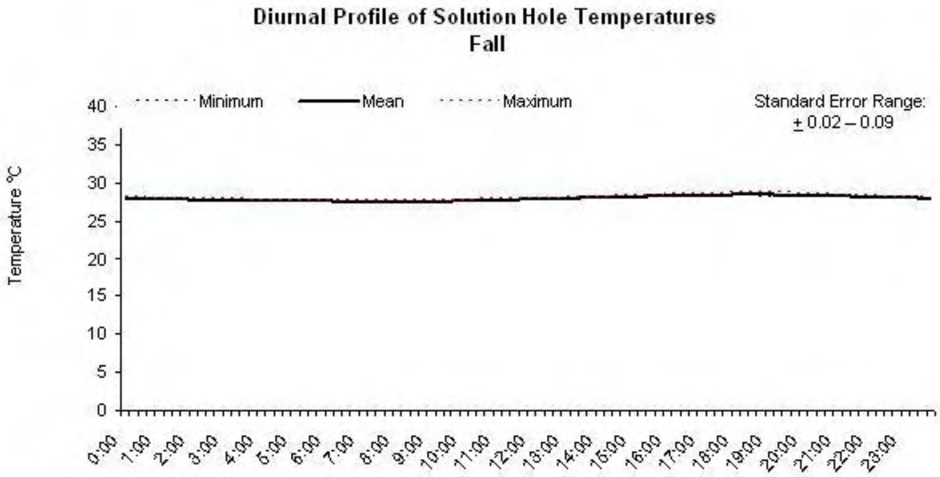
C.

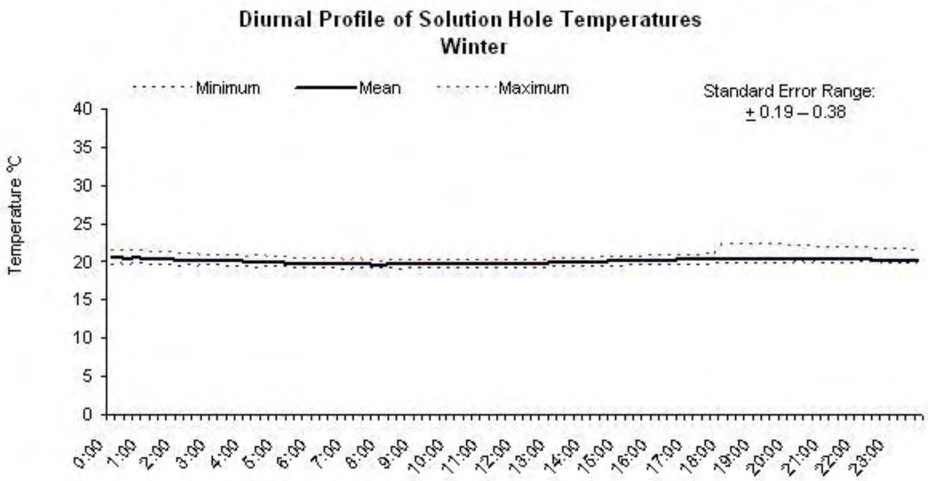


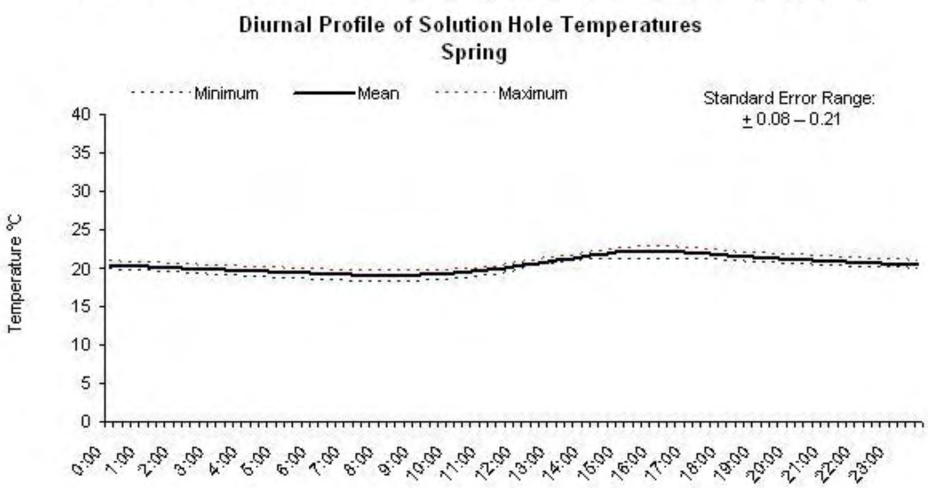
Hatchery Tank Temperature
Temperature (Degrees C)
27
26
25
24
23
22
21
20
19
11/25/2001
12/25/2001
1/25/2002
2/25/2002
3/25/2002
4/25/2002
5/25/2002
6/25/2002
7/25/2002
8/25/2002
9/25/2002
10/25/2002
11/25/2002
12/25/2002
1/25/2003


A
Mean Carapace Length (cm)
February 2000 - February 2003
Carapace Length (cm)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Female
Juvenile
Male
B
Procambarus milleri Population Structure
Relative Abundance
100%
80%
60%
40%
20%
0%
January
February
March
April
May
June
July
August
September
October
November
December
Male
Juvenile
Female
C
Procambarus milleri Females
Relative Abundance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
January
February
March
April
May
June
July
August
September
October
November
December
Non-Gravid
Gravid

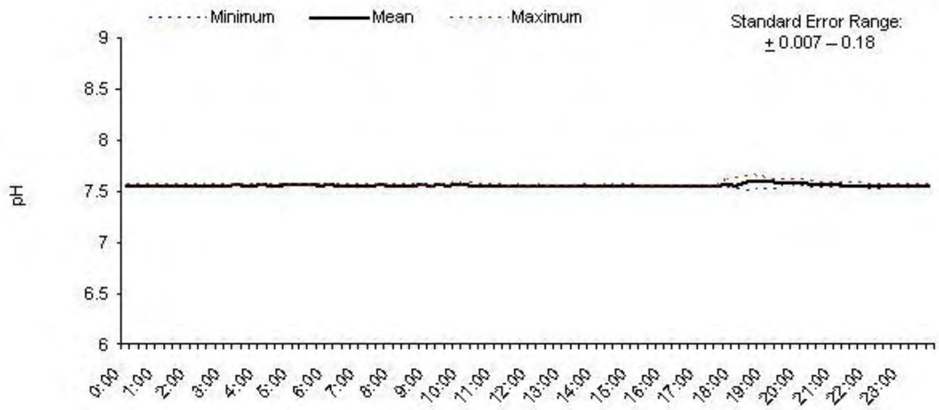

Pa-Hay-Okee
Park Road-West
Wilderness Road
Park Road-East
Everglades NP
N
0 1,000 2,000
Meters
Hidden Lake
Taylor Slough


Diurnal Profile of Solution Hole Temperatures
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 0.02 – 0.09
Temperature °C
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

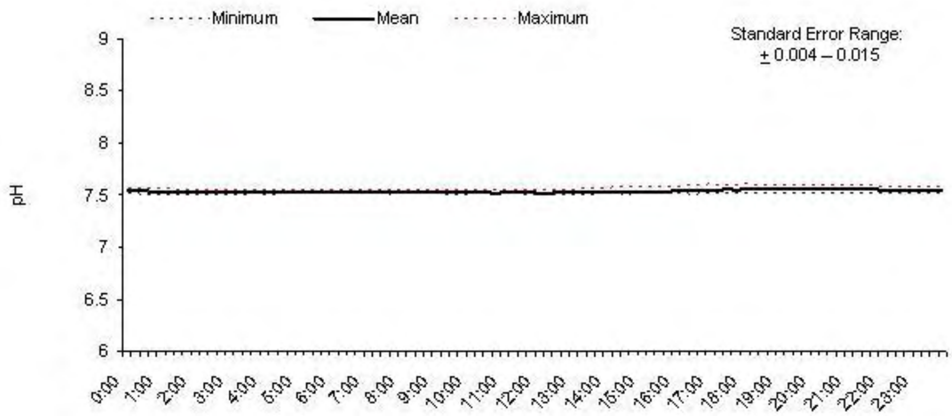

Diurnal Profile of Solution Hole Temperatures
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.19 – 0.38
Temperature °C
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00


Diurnal Profile of Solution Hole Temperatures
Spring
Minimum
Mean
Maximum
Standard Error Range:
± 0.08 – 0.21
Temperature °C
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

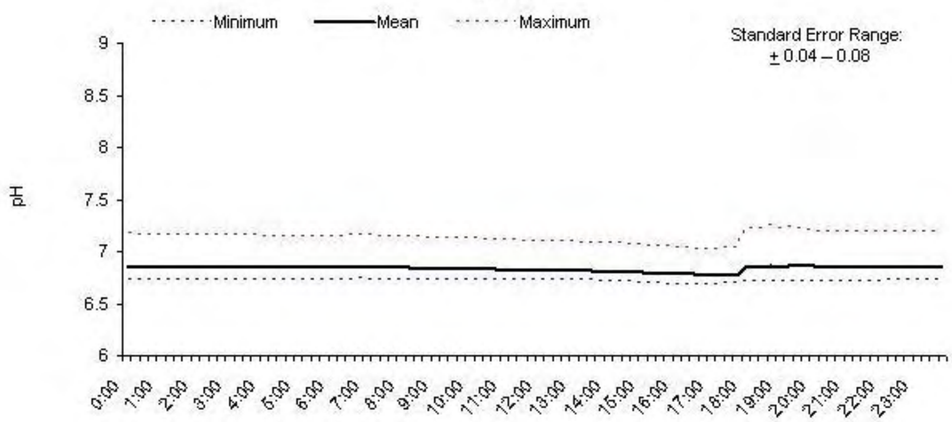
Diurnal Profile of Solution Hole pH
Fall

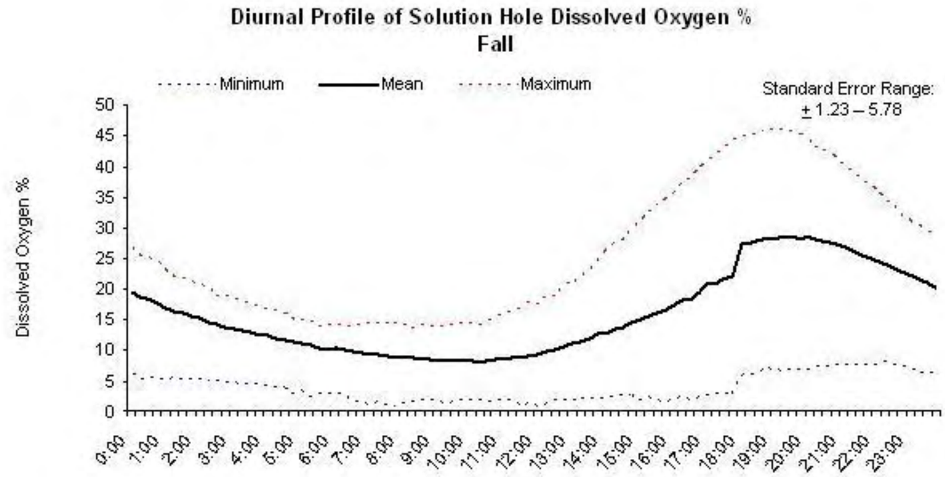


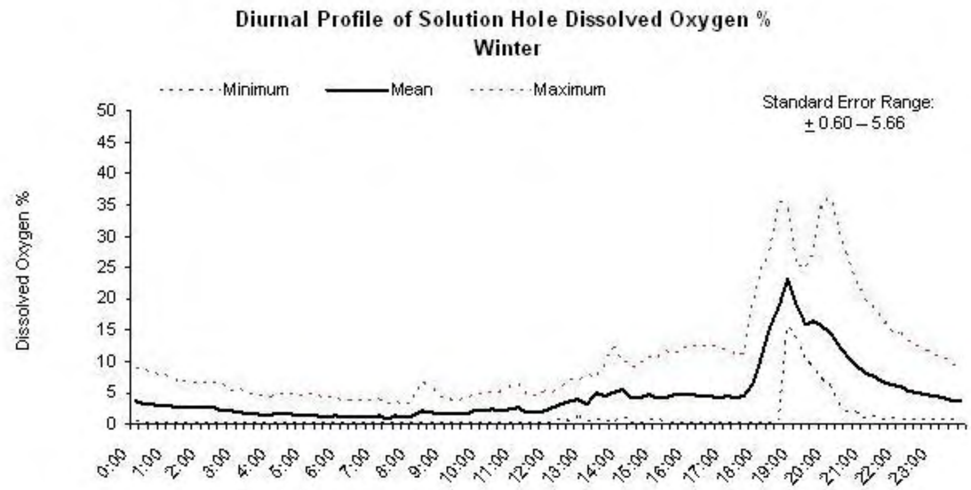
Diurnal Profile of Solution Hole pH
Winter

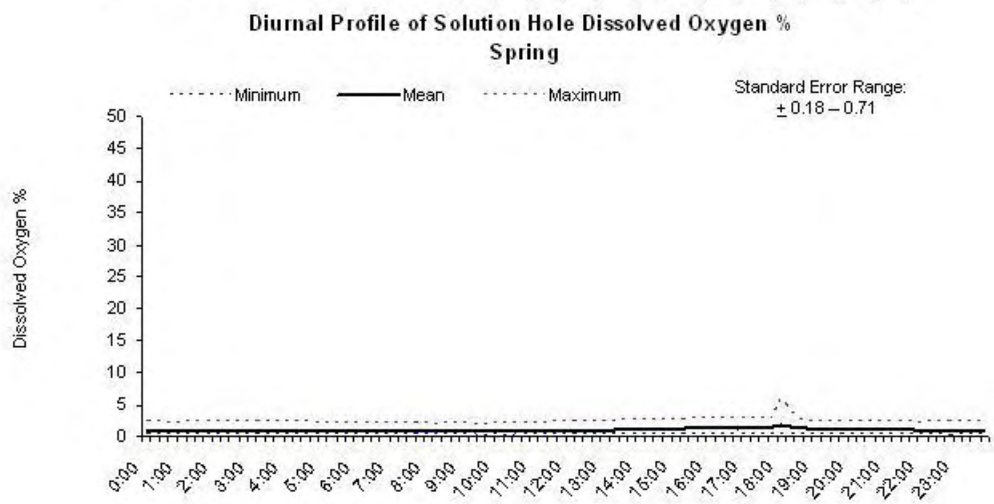


Diurnal Profile of Solution Hole pH
Spring

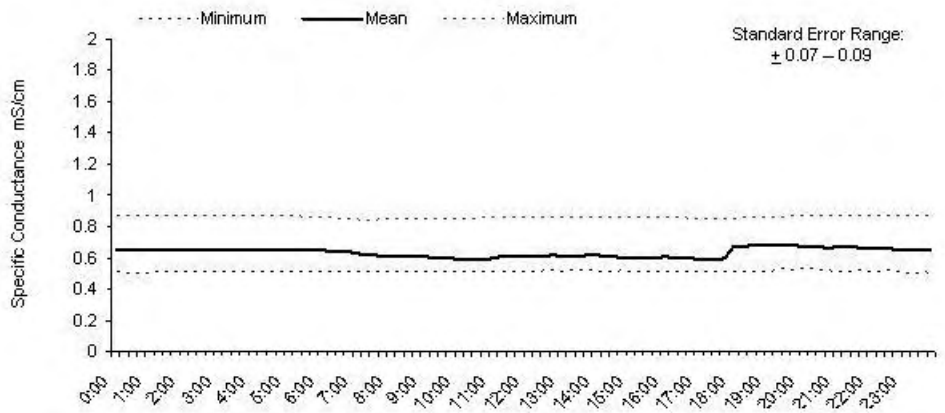



Diurnal Profile of Solution Hole Dissolved Oxygen %
Fall
Minimum
Mean
Maximum
Standard Error Range:
± 1.23 – 5.78
Dissolved Oxygen %
50
45
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

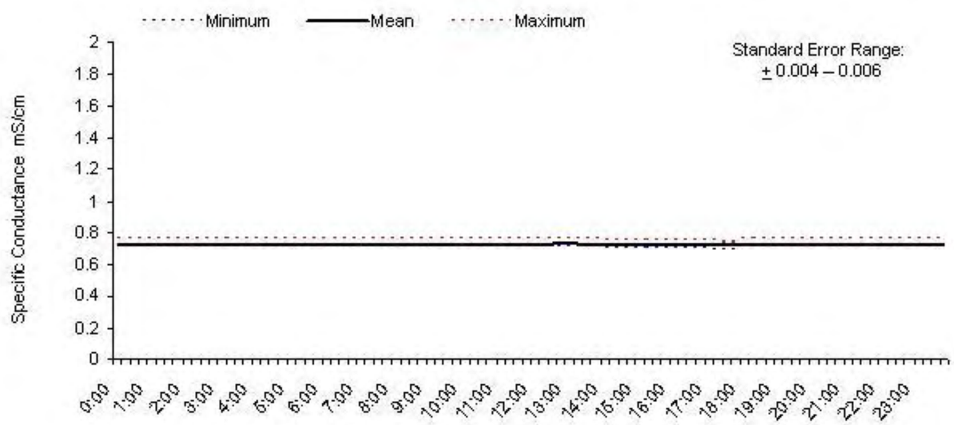

Diurnal Profile of Solution Hole Dissolved Oxygen %
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.60 – 5.66
Dissolved Oxygen %
50
45
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00


Diurnal Profile of Solution Hole Dissolved Oxygen %
Spring
Minimum
Mean
Maximum
Standard Error Range:
± 0.18 – 0.71
Dissolved Oxygen %
50
45
40
35
30
25
20
15
10
5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

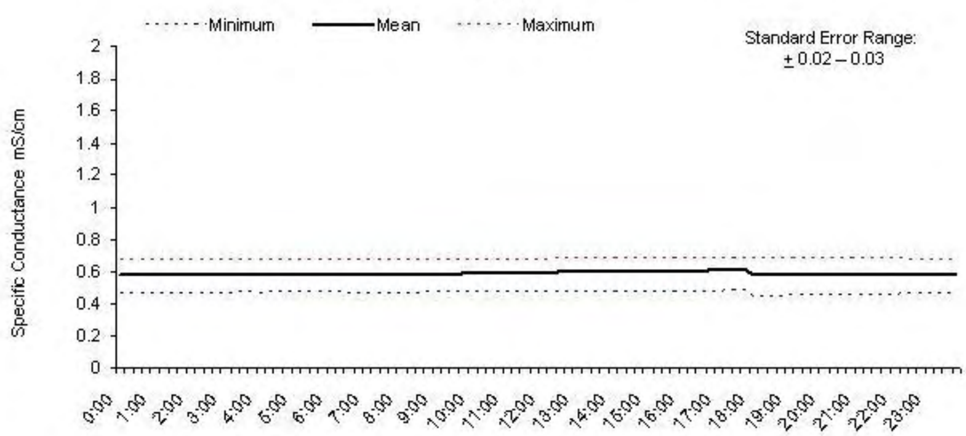
Diurnal Profile of Solution Hole Specific Conductance
Fall

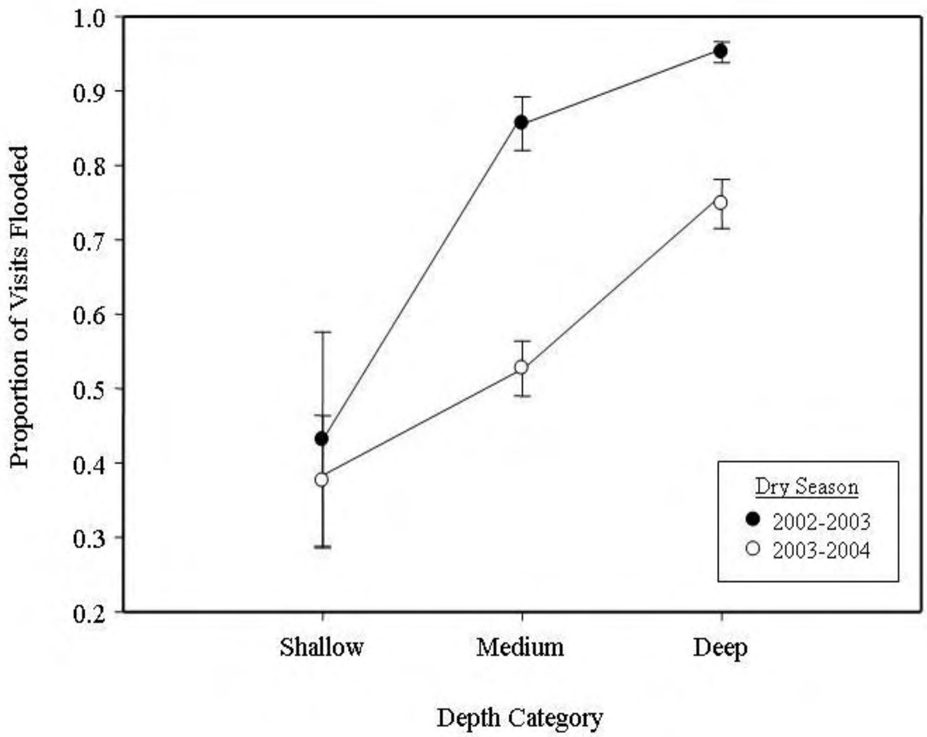


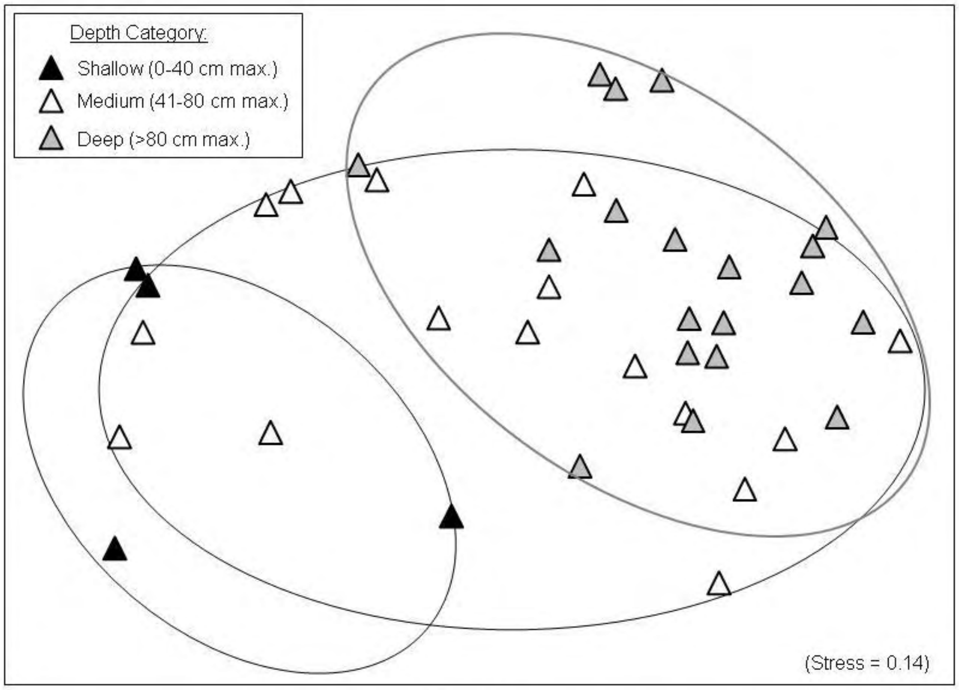
Diurnal Profile of Solution Hole Specific Conductance
Winter



Diurnal Profile of Solution Hole Specific Conductance
Spring



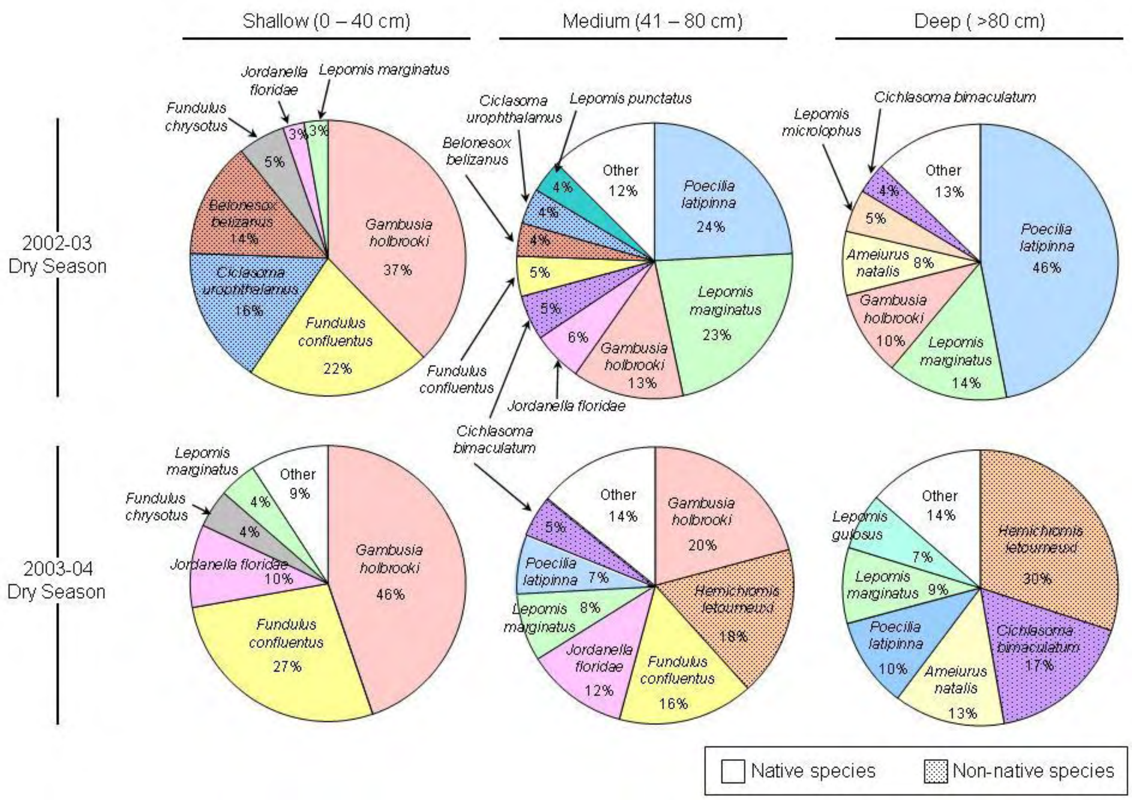

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Proportion of Visits Flooded
Dry Season
2002-2003
2003-2004
Shallow
Medium
Deep
Depth Category



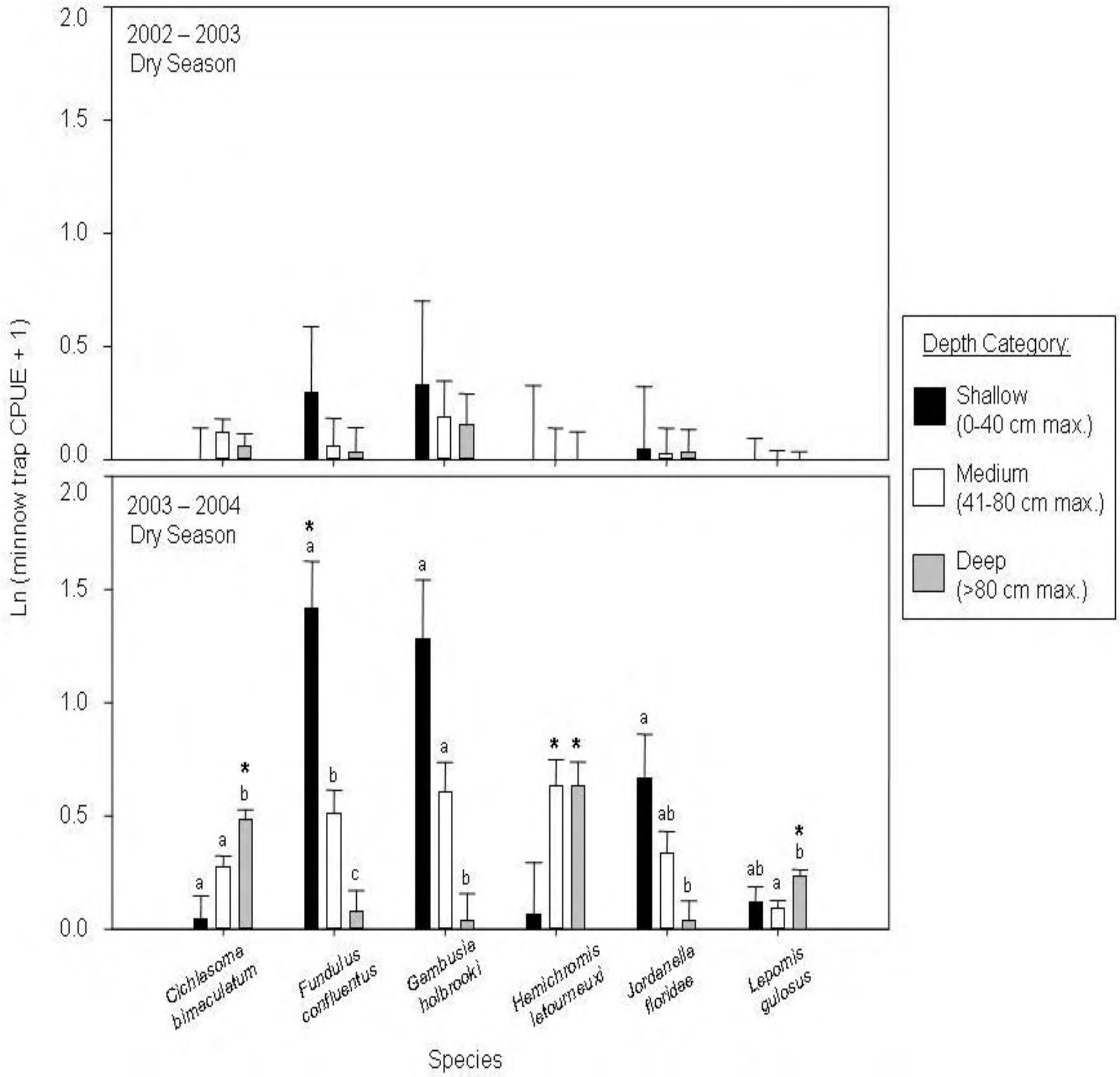
Global Test
Sample statistic (Global R): 0.351
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

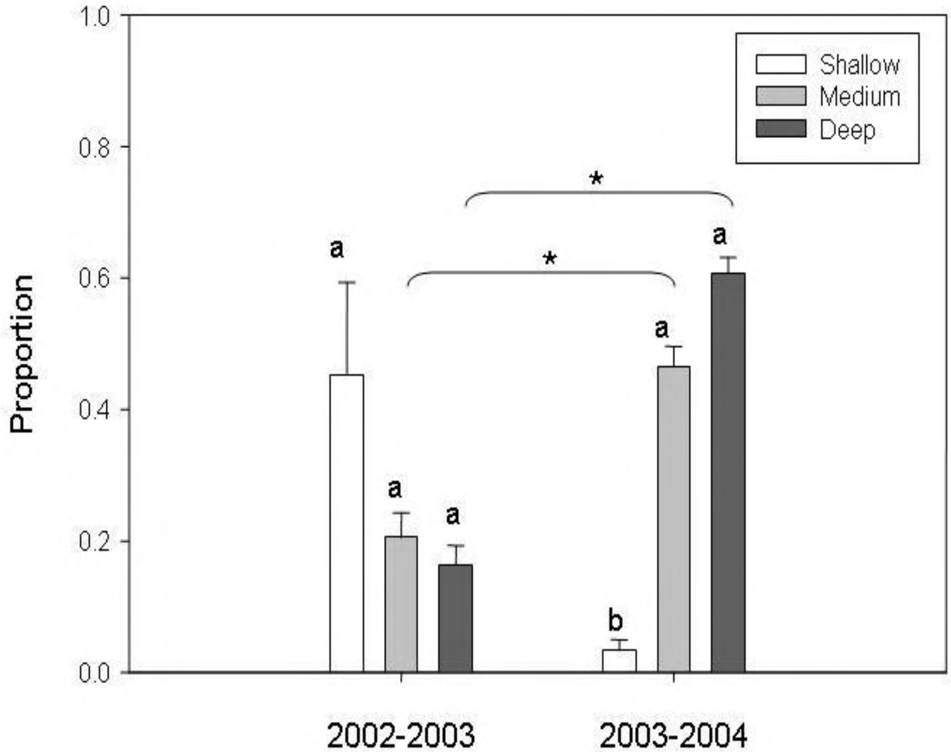
Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
M, D	0.237	0.1	Too Many	999	0
M, S	0.185	4.9	4845	999	48
D, S	0.884	0.3	8855	999	2

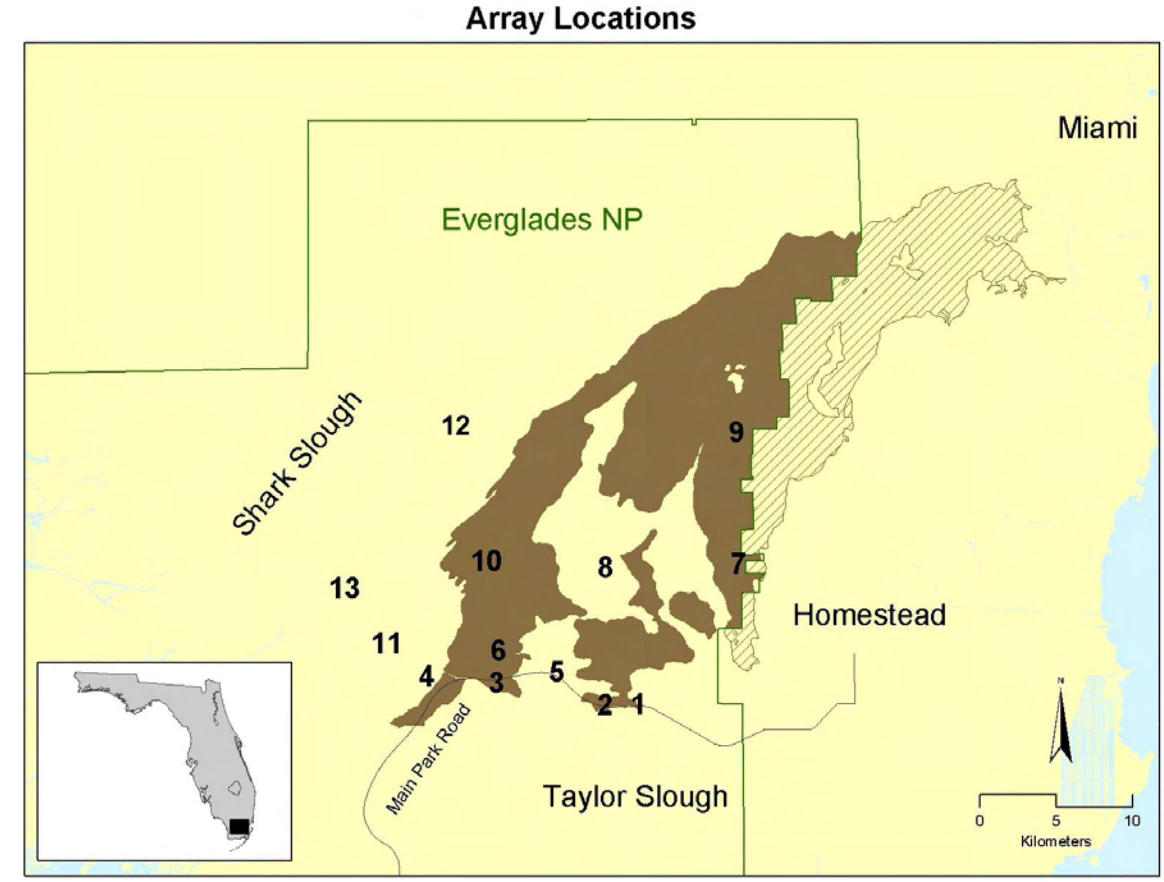


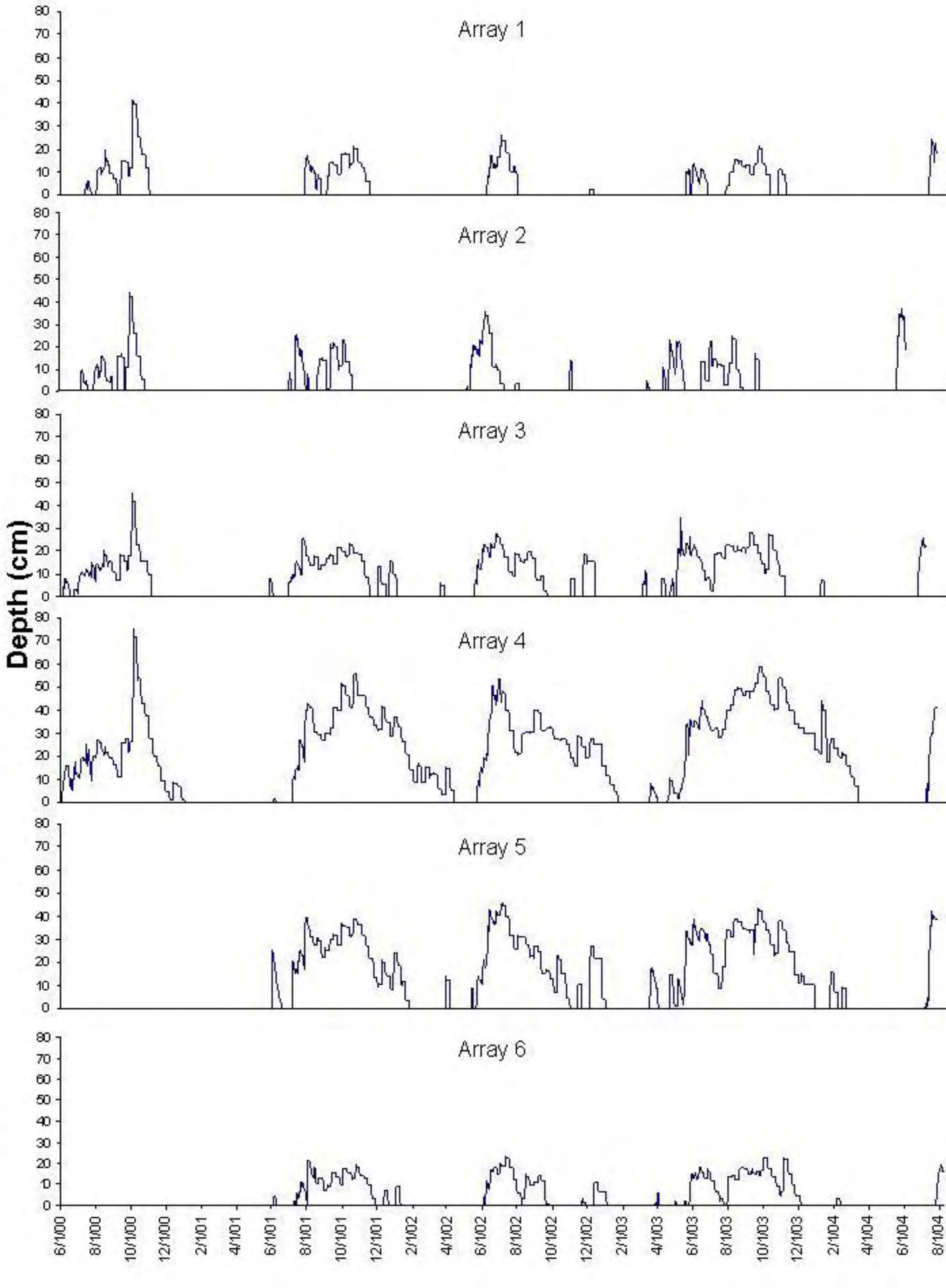
Shallow (0 – 40 cm)
Medium (41 – 80 cm)
Deep (>80 cm)
2002-03 Dry Season
2003-04 Dry Season
Gambusia holbrooki 37%
Fundulus confluentus 22%
Ciclasoma urophthalamus 16%
Belonesox belizanus 14%
Fundulus chrysotus 5%
Jordanella floridae 3%
Lepomis marginatus 3%
Poecilia latipinna 24%
Lepomis marginatus 23%
Gambusia holbrooki 13%
Other 12%
Lepomis punctatus
Cichlasoma bimaculatum
Poecilia latipinna 46%
Lepomis marginatus 14%
Gambusia holbrooki 10%
Ameiurus natalis 8%
Lepomis microlophus
Other 13%
Gambusia holbrooki 46%
Fundulus confluentus 27%
Jordanella floridae 10%
Other 9%
Gambusia holbrooki 20%
Hemichromis letourneuxi 18%
Fundulus confluentus 16%
Jordanella floridae 12%
Lepomis marginatus 8%
Poecilia latipinna 7%
Other 14%
Hemichromis letourneuxi 30%
Cichlasoma bimaculatum 17%
Ameiurus natalis 13%
Poecilia latipinna 10%
Lepomis marginatus 9%
Lepomis gulosus 7%
Native species
Non-native species



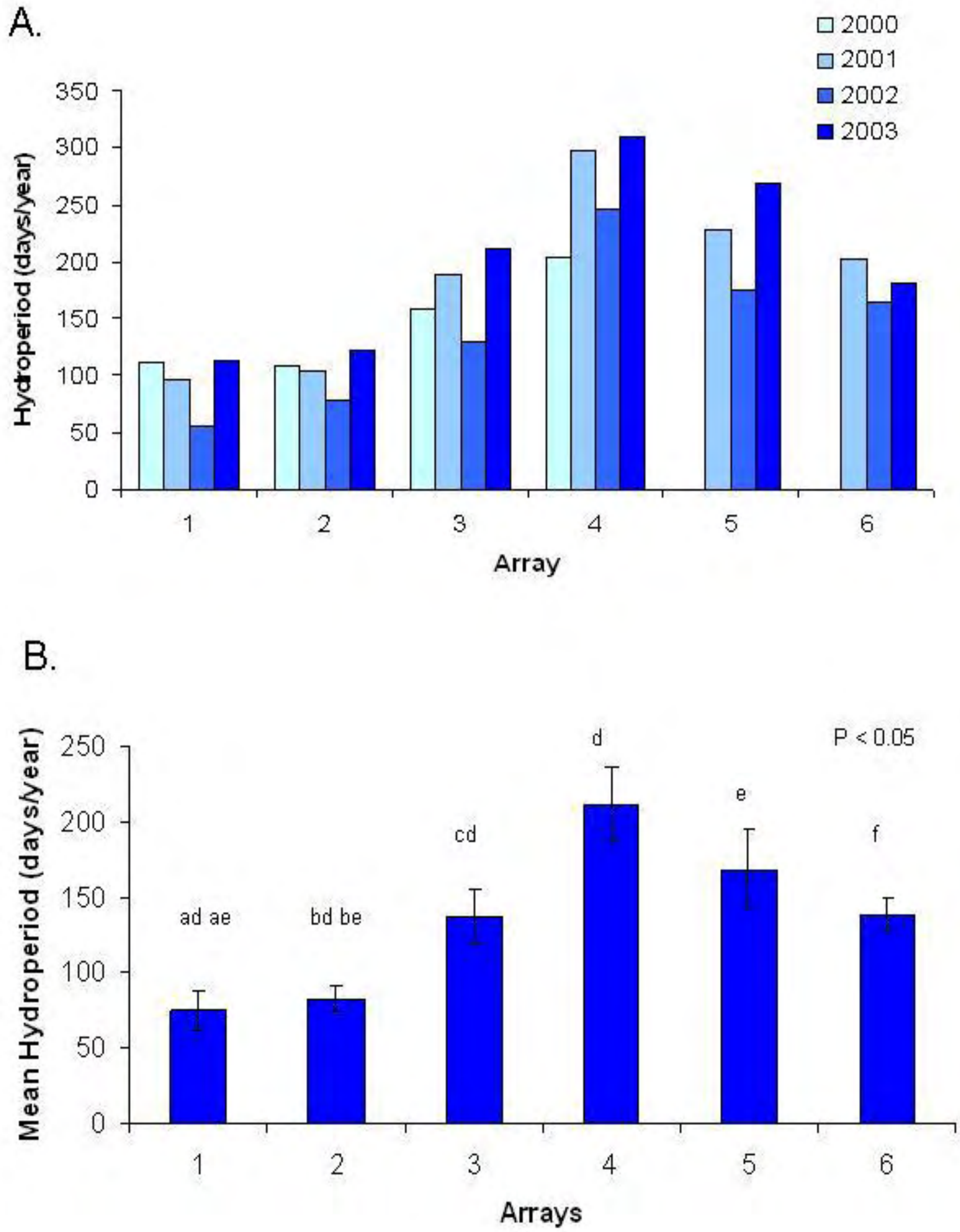
2002 – 2003
Dry Season
2003 – 2004
Dry Season
Ln (minnow trap CPUE + 1)
2.0
1.5
1.0
0.5
0.0
Depth Category:
Shallow
(0-40 cm max.)
Medium
(41-80 cm max.)
Deep
(>80 cm max.)
Cichlasoma bimaculatum
Fundulus confluentus
Gambusia holbrooki
Hemichromis letourneuxi
Jordanella floridae
Lepomis gulosus
Species


1.0
0.8
0.6
0.4
0.2
0.0
Proportion
Shallow
Medium
Deep
*
*
a
a
a
a
a
b
2002-2003
2003-2004

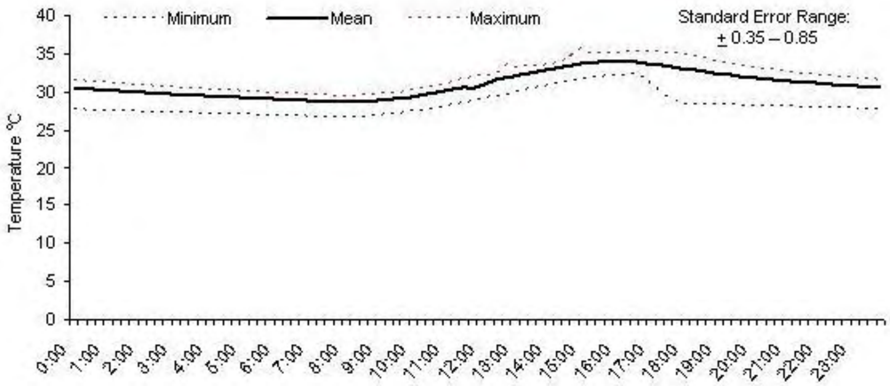

Array Locations
Miami
Everglades NP
Shark Slough
12
9
10
8
7
13
Homestead
11
6
4
5
3
2
1
Main Park Road
Taylor Slough
0
5
10
Kilometers



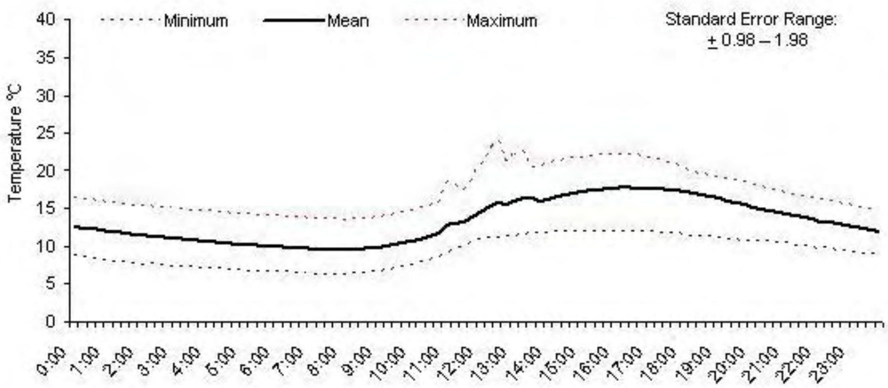
Array 1
Array 2
Array 3
Array 4
Array 5
Array 6
Depth (cm)
0
10
20
30
40
50
60
70
80
6/1/00
8/1/00
10/1/00
12/1/00
2/1/01
4/1/01
6/1/01
8/1/01
10/1/01
12/1/01
2/1/02
4/1/02
6/1/02
8/1/02
10/1/02
12/1/02
2/1/03
4/1/03
6/1/03
8/1/03
10/1/03
12/1/03
2/1/04
4/1/04
6/1/04
8/1/04


A.
2000
2001
2002
2003
350
300
250
200
150
100
50
0
Hydroperiod (days/year)
1
2
3
4
5
6
Array
B.
250
200
150
100
50
0
Mean Hydroperiod (days/year)
P < 0.05
ad ae
bd be
cd
d
e
f
1
2
3
4
5
6
Arrays

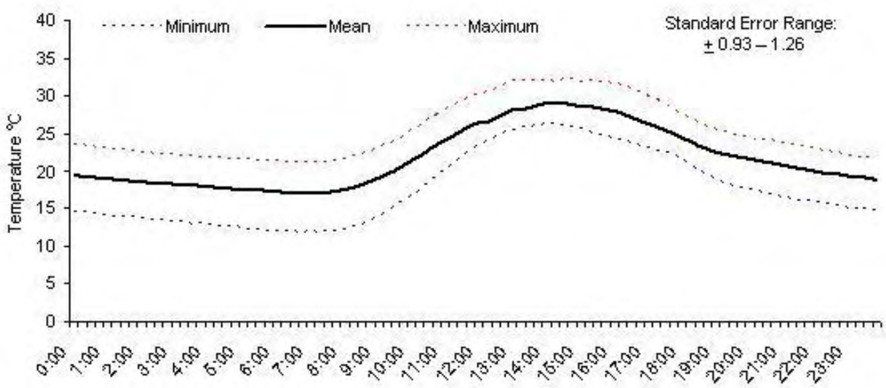
Diurnal Profile of Marsh Surface Temperatures
Summer



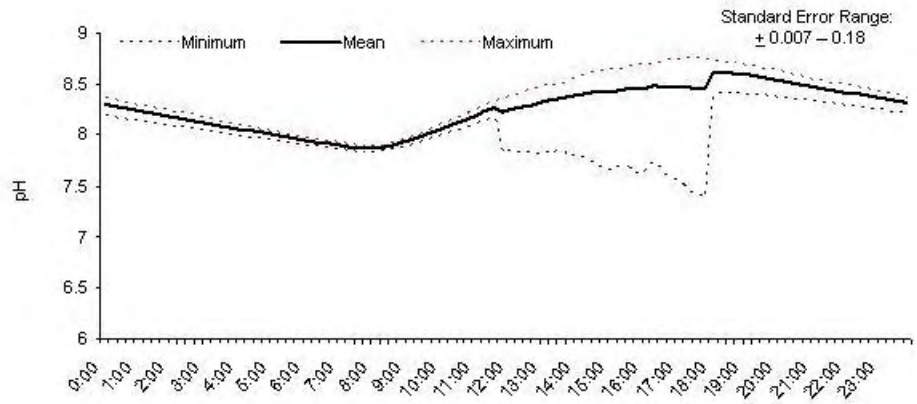
Diurnal Profile of Marsh Surface Temperatures
Winter



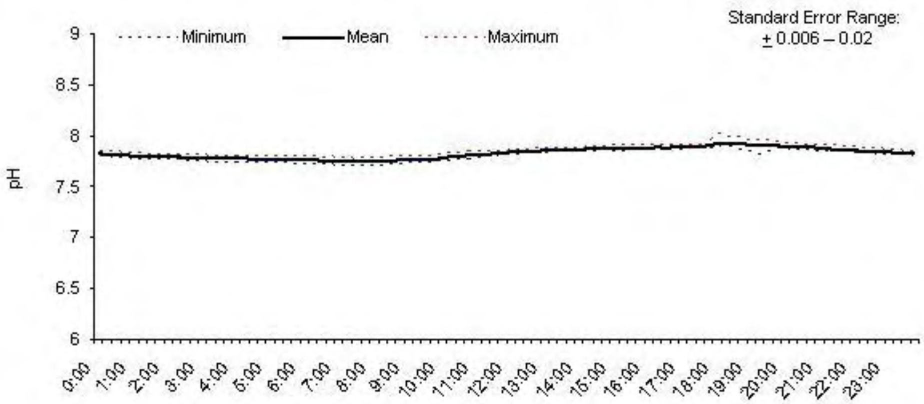
Diurnal Profile of Marsh Surface Temperatures
Spring



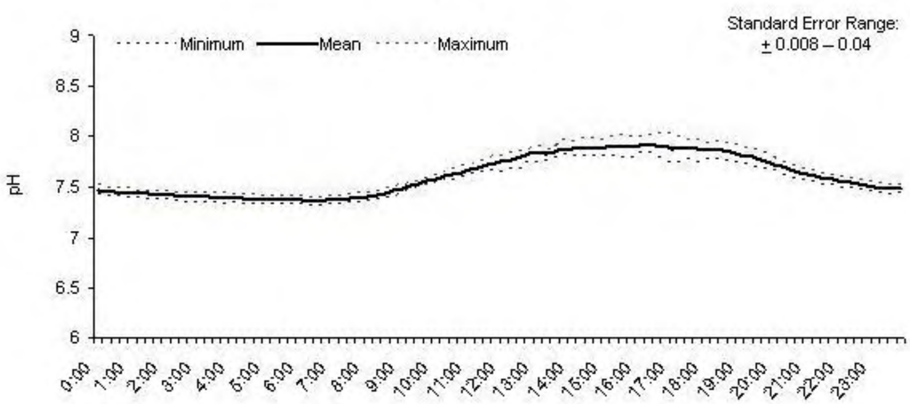
Diurnal Profile of Marsh Surface pH
Summer



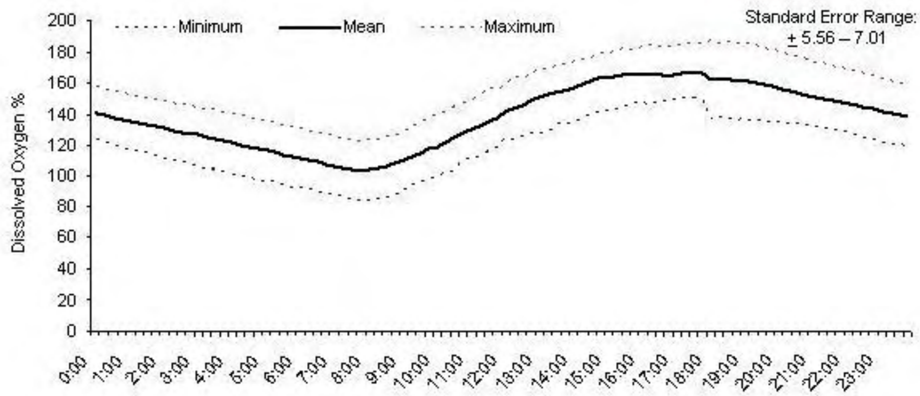
Diurnal Profile of Marsh Surface pH
Winter



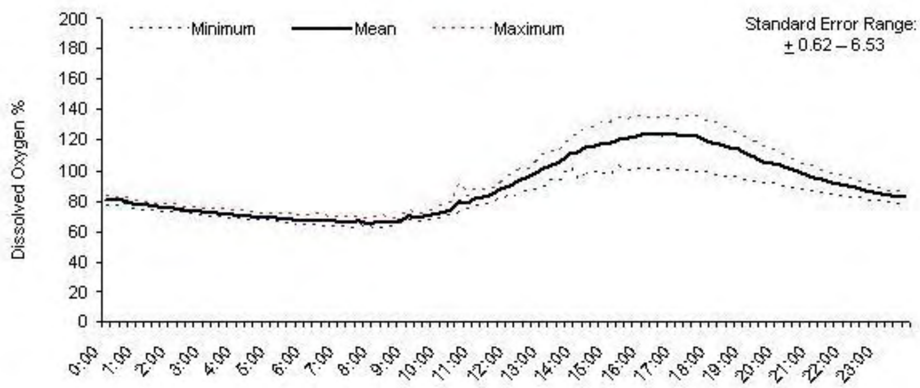
Diurnal Profile of Marsh Surface pH
Spring



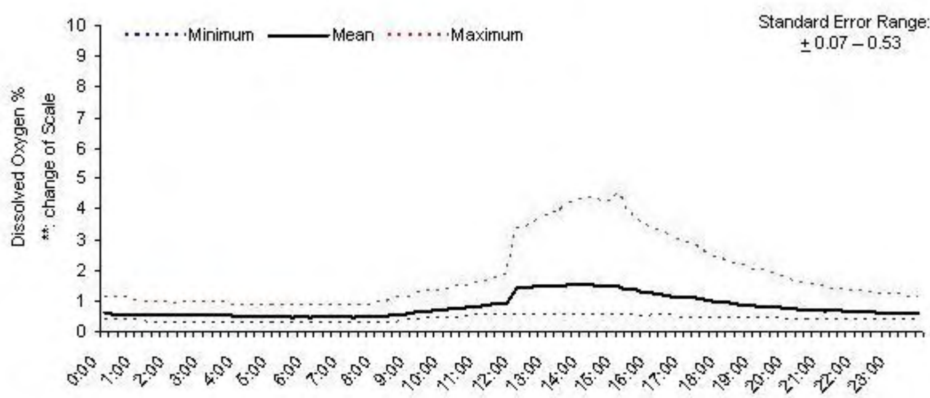
Diurnal Profile of Marsh Surface Dissolved Oxygen %
Summer

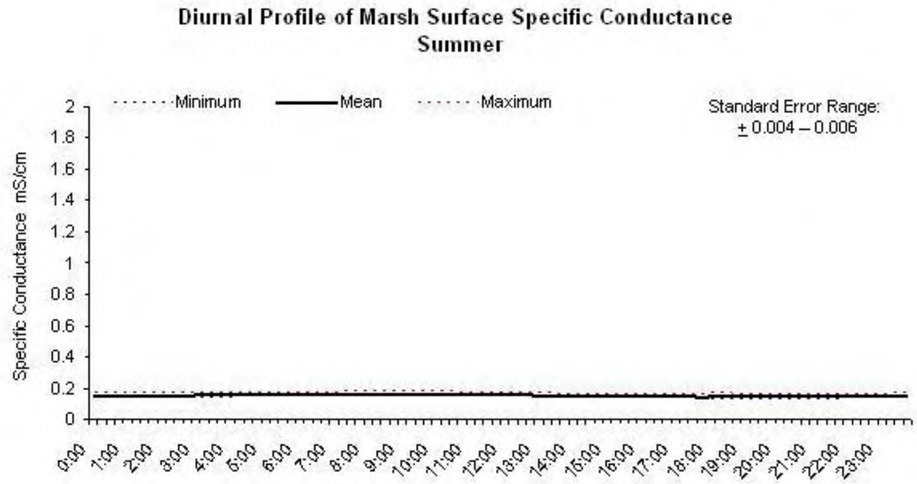


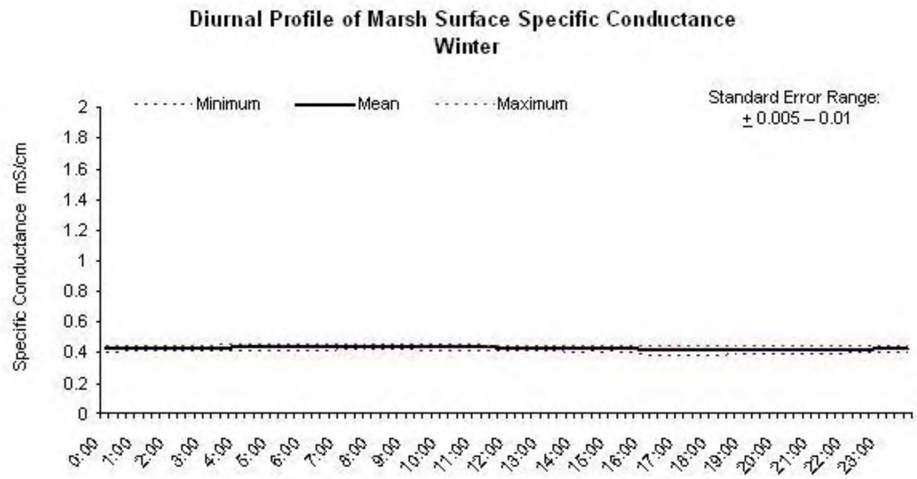
Diurnal Profile of Marsh Surface Dissolved Oxygen %
Winter

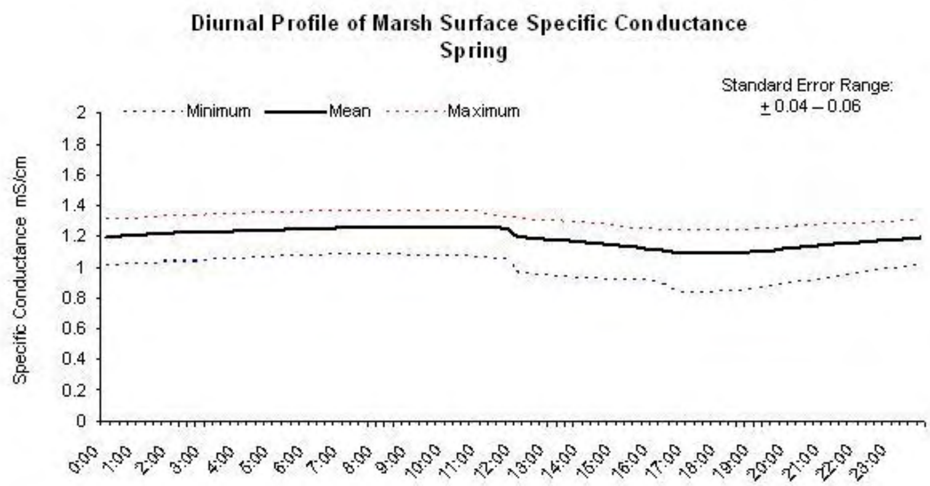


Diurnal Profile of Marsh Surface Dissolved Oxygen %
Spring

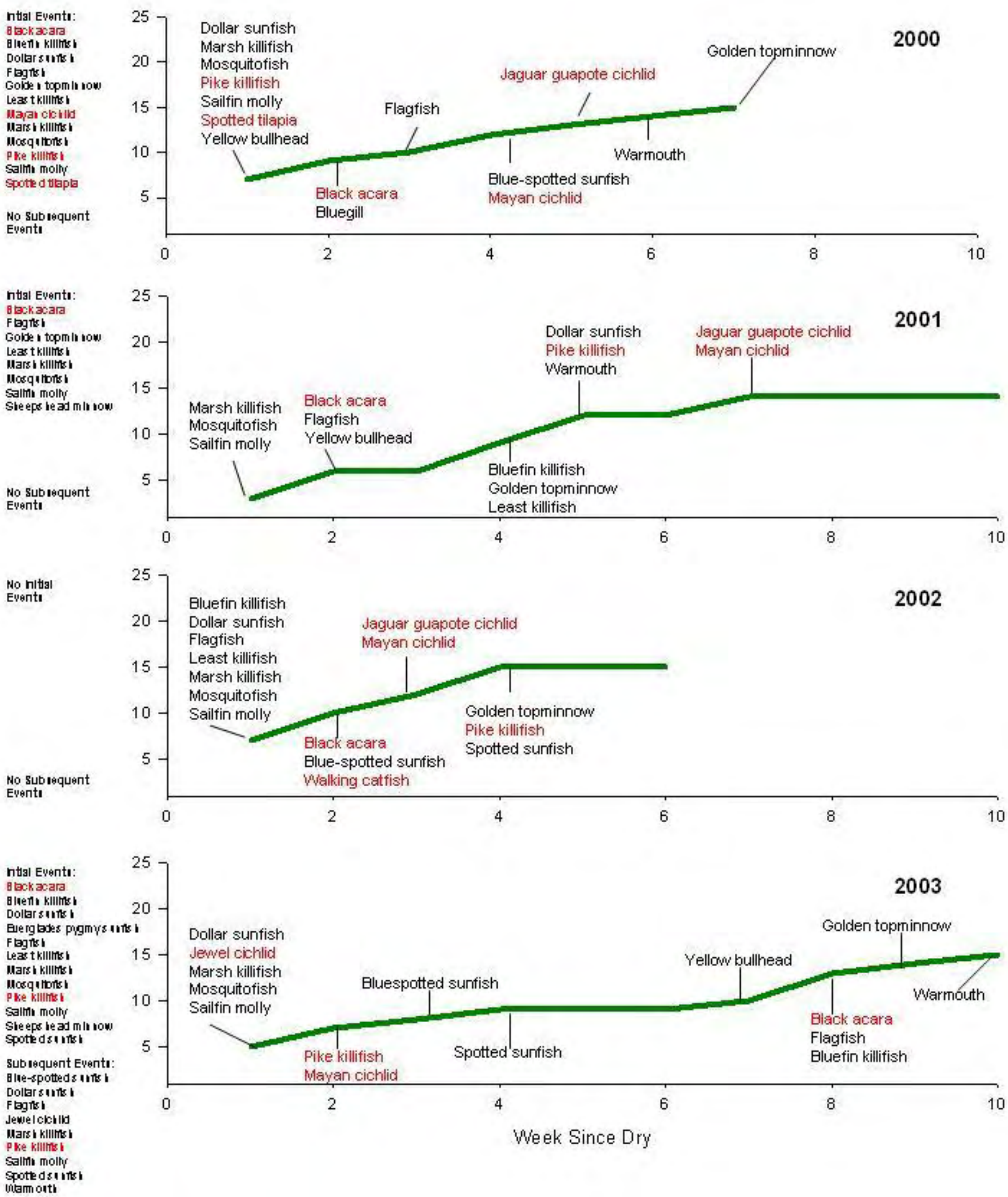


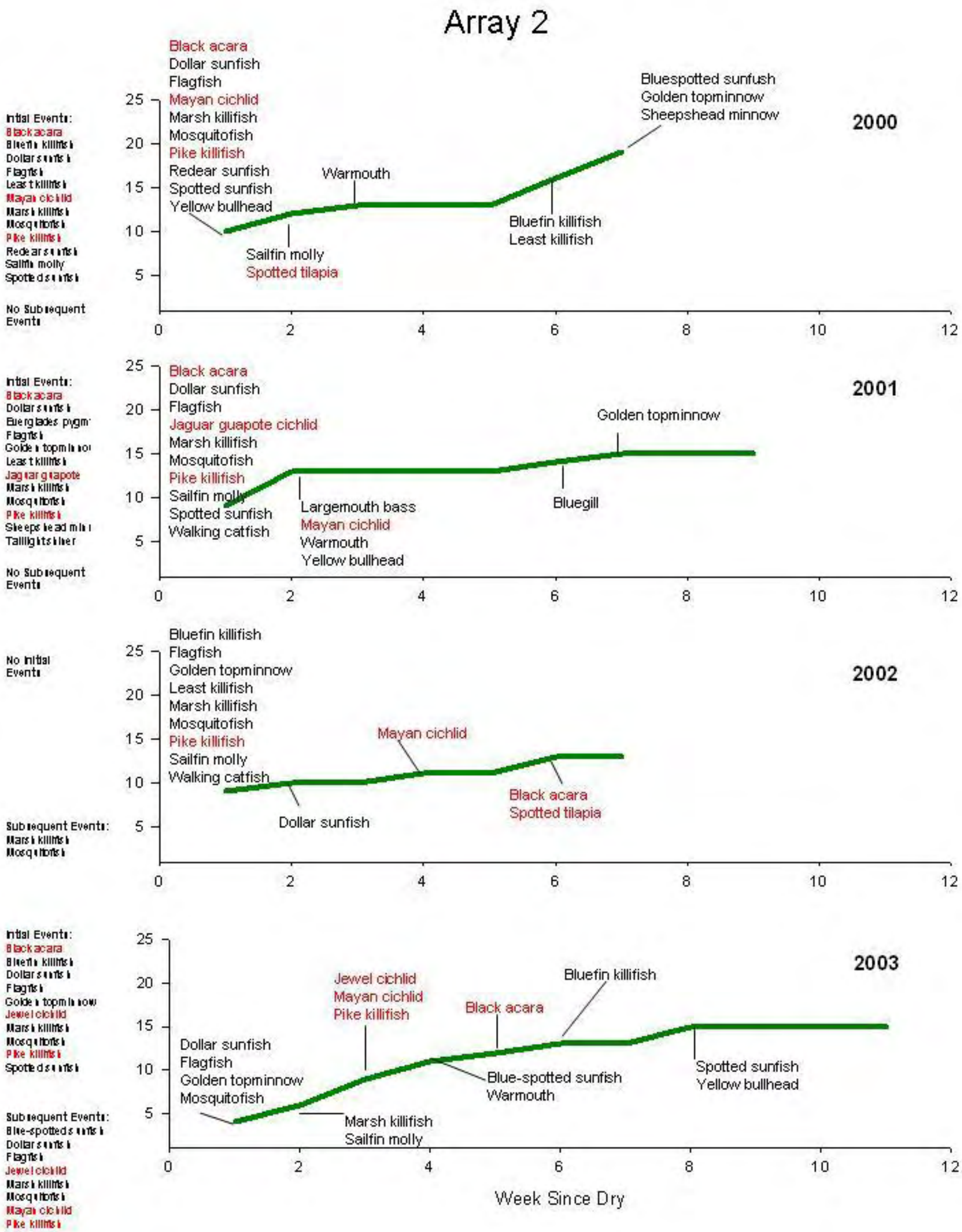

Diurnal Profile of Marsh Surface Specific Conductance
Summer
Minimum
Mean
Maximum
Standard Error Range:
± 0.004 – 0.006
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Diurnal Profile of Marsh Surface Specific Conductance
Winter
Minimum
Mean
Maximum
Standard Error Range:
± 0.005 – 0.01
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

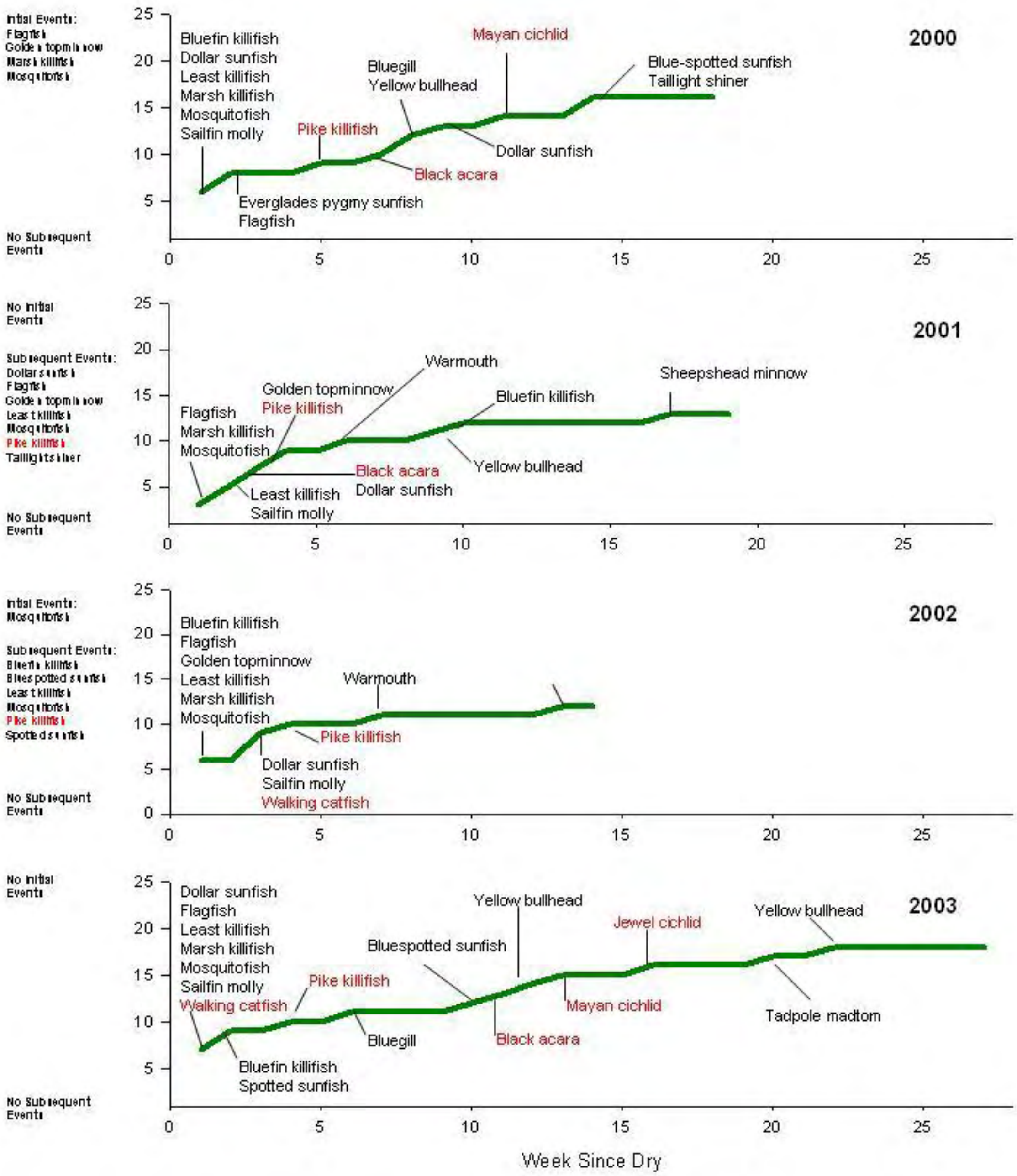

Diurnal Profile of Marsh Surface Specific Conductance
Spring
Standard Error Range:
± 0.04 – 0.06
Minimum
Mean
Maximum
Specific Conductance mS/cm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

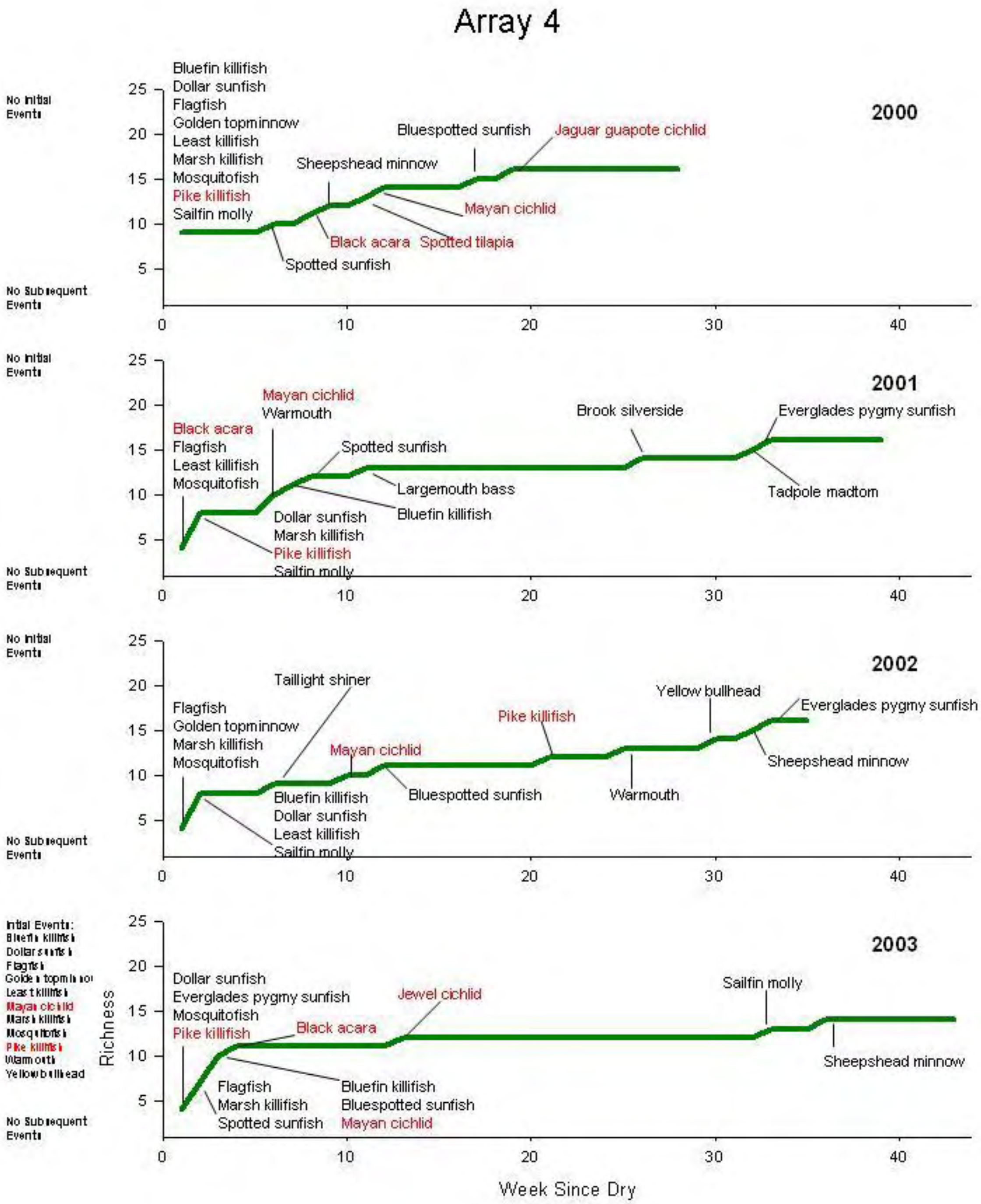
Array 1


Initial Events:
Black acara
Bluefin killifish
Dollar sunfish
Flagfish
Golden topminnow
Least killifish
Mayan cichlid
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Spotted tilapia
No Subsequent Events
2000
Dollar sunfish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Spotted tilapia
Yellow bullhead
Black acara
Bluegill
Flagfish
Jaguar guapote cichlid
Blue-spotted sunfish
Mayan cichlid
Warmouth
Golden topminnow
Initial Events:
Black acara
Flagfish
Golden topminnow
Least killifish
Marsh killifish
Mosquitofish
Sailfin molly
Sheepshead minnow
No Subsequent Events
2001
Marsh killifish
Mosquitofish
Sailfin molly
Black acara
Flagfish
Yellow bullhead
Bluefin killifish
Golden topminnow
Least killifish
Dollar sunfish
Pike killifish
Warmouth
Jaguar guapote cichlid
Mayan cichlid
No Initial Events
No Subsequent Events
2002
Bluefin killifish
Dollar sunfish
Flagfish
Least killifish
Marsh killifish
Mosquitofish
Sailfin molly
Black acara
Blue-spotted sunfish
Walking catfish
Jaguar guapote cichlid
Mayan cichlid
Golden topminnow
Pike killifish
Spotted sunfish
Initial Events:
Black acara
Bluefin killifish
Dollar sunfish
Everglades pygmy sunfish
Flagfish
Least killifish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Sheepshead minnow
Spotted sunfish
Subsequent Events:
Blue-spotted sunfish
Dollar sunfish
Flagfish
Jewel cichlid
Marsh killifish
Pike killifish
Sailfin molly
Spotted sunfish
Warmouth
2003
Dollar sunfish
Jewel cichlid
Marsh killifish
Mosquitofish
Sailfin molly
Pike killifish
Mayan cichlid
Bluespotted sunfish
Spotted sunfish
Yellow bullhead
Black acara
Flagfish
Bluefin killifish
Golden topminnow
Warmouth
25
20
15
10
5
0
2
4
6
8
10
Week Since Dry

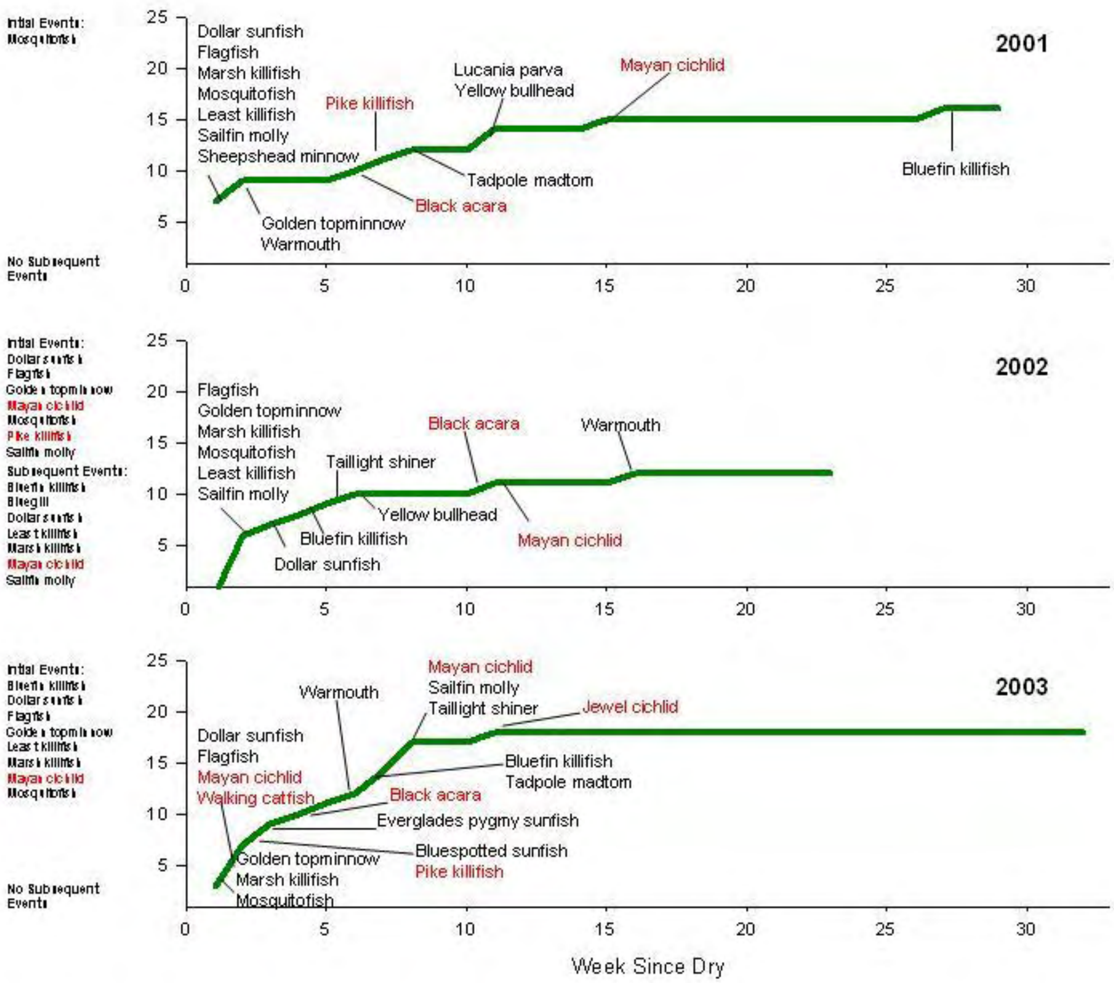

Array 2
2000
Black acara
Dollar sunfish
Flagfish
Mayan cichlid
Marsh killifish
Mosquitofish
Pike killifish
Redear sunfish
Spotted sunfish
Yellow bullhead
Sailfin molly
Spotted tilapia
Warmouth
Bluefin killifish
Least killifish
Bluespotted sunfush
Golden topminnow
Sheepshead minnow
2001
Black acara
Dollar sunfish
Flagfish
Jaguar guapote cichlid
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Spotted sunfish
Walking catfish
Largemouth bass
Mayan cichlid
Warmouth
Yellow bullhead
Bluegill
Golden topminnow
2002
Bluefin killifish
Flagfish
Golden topminnow
Least killifish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Walking catfish
Dollar sunfish
Mayan cichlid
Black acara
Spotted tilapia
2003
Dollar sunfish
Flagfish
Golden topminnow
Mosquitofish
Marsh killifish
Sailfin molly
Jewel cichlid
Mayan cichlid
Pike killifish
Blue-spotted sunfish
Warmouth
Black acara
Bluefin killifish
Spotted sunfish
Yellow bullhead
Week Since Dry

Array 3

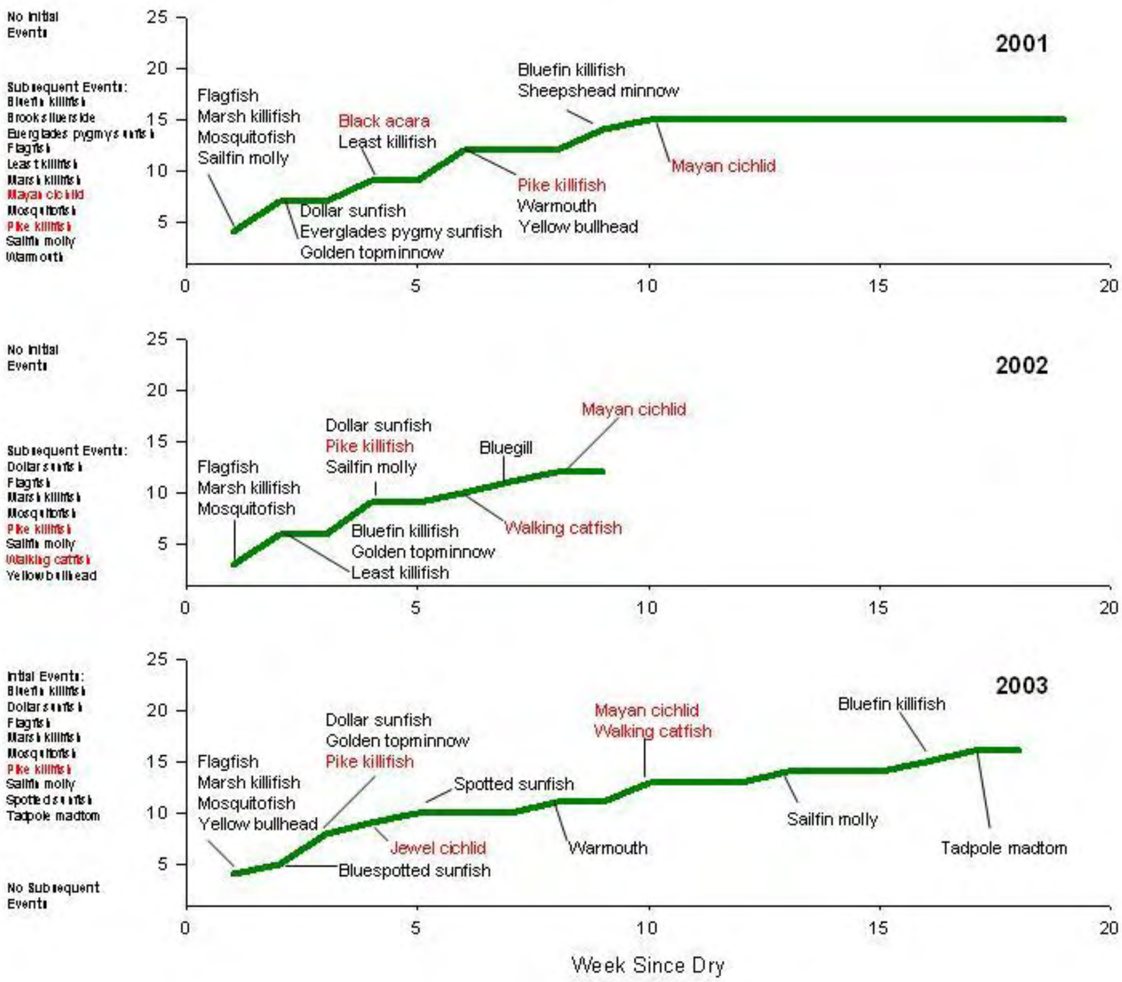

Initial Events:
Flagfish
Golden topminnow
Marsh killifish
Mosquitofish
No Subsequent Events
2000
Bluefin killifish
Dollar sunfish
Least killifish
Marsh killifish
Mosquitofish
Sailfin molly
Pike killifish
Bluegill
Yellow bullhead
Mayan cichlid
Blue-spotted sunfish
Taillight shiner
Dollar sunfish
Black acara
Everglades pygmy sunfish
Flagfish
No Initial Events
Subsequent Events:
Dollar sunfish
Flagfish
Golden topminnow
Least killifish
Mosquitofish
Pike killifish
Taillight shiner
No Subsequent Events
2001
Warmouth
Golden topminnow
Pike killifish
Bluefin killifish
Sheepshead minnow
Flagfish
Marsh killifish
Mosquitofish
Black acara
Dollar sunfish
Yellow bullhead
Least killifish
Sailfin molly
Initial Events:
Mosquitofish
Subsequent Events:
Bluefin killifish
Bluespotted sunfish
Least killifish
Mosquitofish
Pike killifish
Spotted sunfish
No Subsequent Events
2002
Bluefin killifish
Flagfish
Golden topminnow
Least killifish
Marsh killifish
Mosquitofish
Warmouth
Pike killifish
Dollar sunfish
Sailfin molly
Walking catfish
No Initial Events
No Subsequent Events
2003
Dollar sunfish
Flagfish
Least killifish
Marsh killifish
Mosquitofish
Sailfin molly
Walking catfish
Pike killifish
Bluespotted sunfish
Yellow bullhead
Jewel cichlid
Yellow bullhead
Bluegill
Black acara
Mayan cichlid
Tadpole madtom
Bluefin killifish
Spotted sunfish
Week Since Dry


Array 4
2000
No Initial Events
No Subsequent Events
Bluefin killifish
Dollar sunfish
Flagfish
Golden topminnow
Least killifish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Sheepshead minnow
Bluespotted sunfish
Jaguar guapote cichlid
Mayan cichlid
Black acara
Spotted tilapia
Spotted sunfish
2001
No Initial Events
No Subsequent Events
Mayan cichlid
Warmouth
Black acara
Flagfish
Least killifish
Mosquitofish
Spotted sunfish
Largemouth bass
Bluefin killifish
Dollar sunfish
Marsh killifish
Pike killifish
Sailfin molly
Brook silverside
Everglades pygmy sunfish
Tadpole madtom
2002
No Initial Events
No Subsequent Events
Taillight shiner
Flagfish
Golden topminnow
Marsh killifish
Mosquitofish
Mayan cichlid
Pike killifish
Yellow bullhead
Everglades pygmy sunfish
Sheepshead minnow
Bluefin killifish
Dollar sunfish
Least killifish
Sailfin molly
Bluespotted sunfish
Warmouth
2003
Initial Events:
Bluefin killifish
Dollar sunfish
Flagfish
Golden topminnow
Least killifish
Mayan cichlid
Marsh killifish
Mosquitofish
Pike killifish
Warmouth
Yellow bullhead
No Subsequent Events
Dollar sunfish
Everglades pygmy sunfish
Mosquitofish
Pike killifish
Black acara
Jewel cichlid
Sailfin molly
Sheepshead minnow
Flagfish
Marsh killifish
Spotted sunfish
Bluefin killifish
Bluespotted sunfish
Mayan cichlid
Richness
Week Since Dry
0
10
20
30
40
5
10
15
20
25

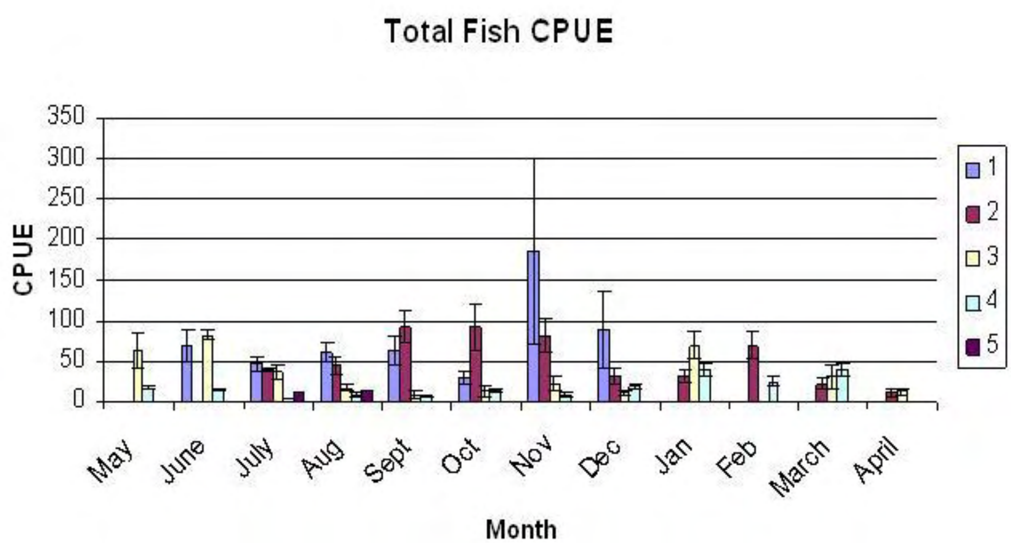
Array 5

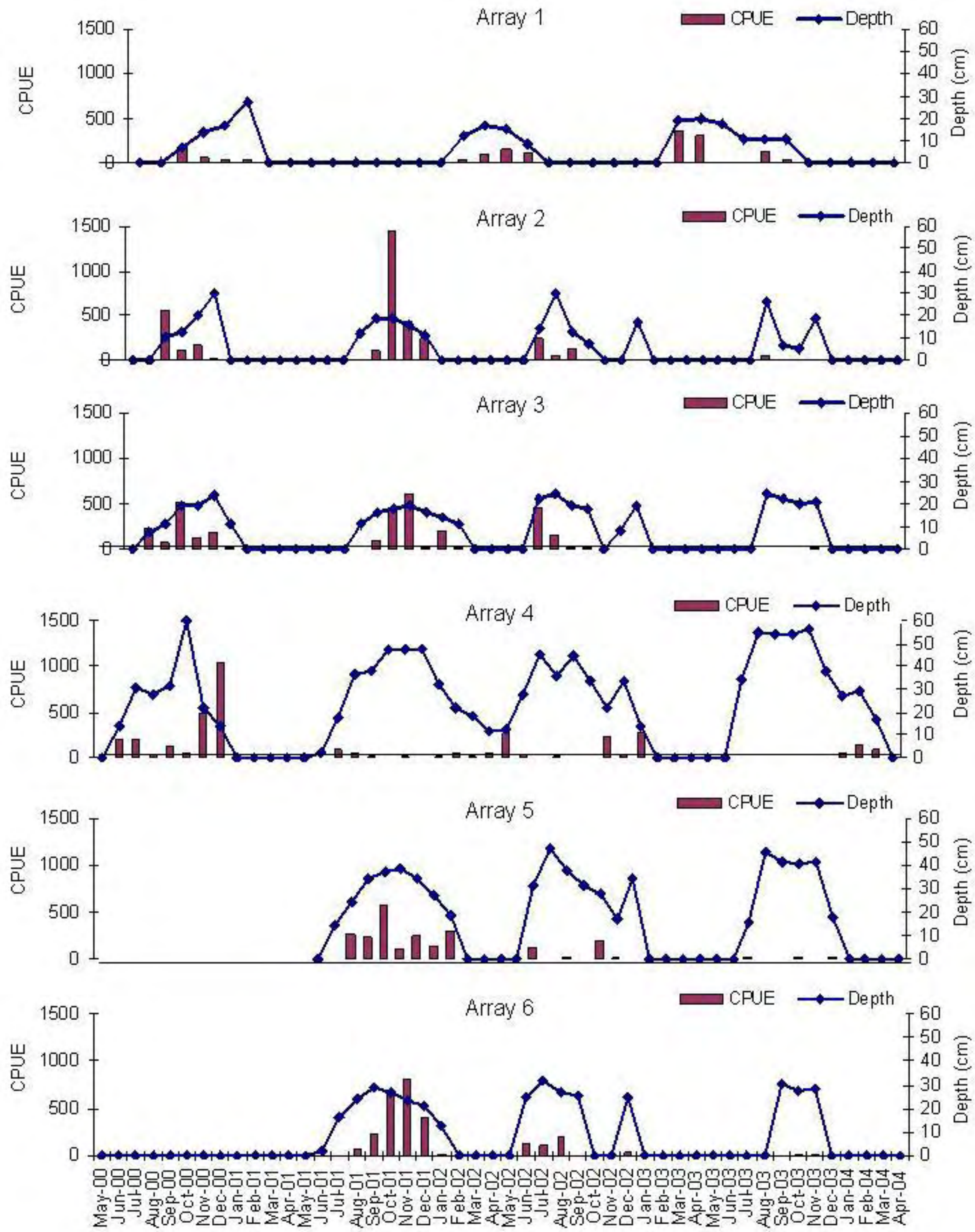

2001
Dollar sunfish
Flagfish
Marsh killifish
Mosquitofish
Least killifish
Sailfin molly
Sheepshead minnow
Pike killifish
Lucania parva
Yellow bullhead
Mayan cichlid
Tadpole madtom
Black acara
Golden topminnow
Warmouth
Bluefin killifish
2002
Flagfish
Golden topminnow
Marsh killifish
Mosquitofish
Least killifish
Sailfin molly
Taillight shiner
Black acara
Warmouth
Yellow bullhead
Bluefin killifish
Dollar sunfish
Mayan cichlid
2003
Mayan cichlid
Sailfin molly
Taillight shiner
Jewel cichlid
Warmouth
Dollar sunfish
Flagfish
Mayan cichlid
Walking catfish
Bluefin killifish
Tadpole madtom
Black acara
Everglades pygmy sunfish
Bluespotted sunfish
Pike killifish
Golden topminnow
Marsh killifish
Mosquitofish
Week Since Dry

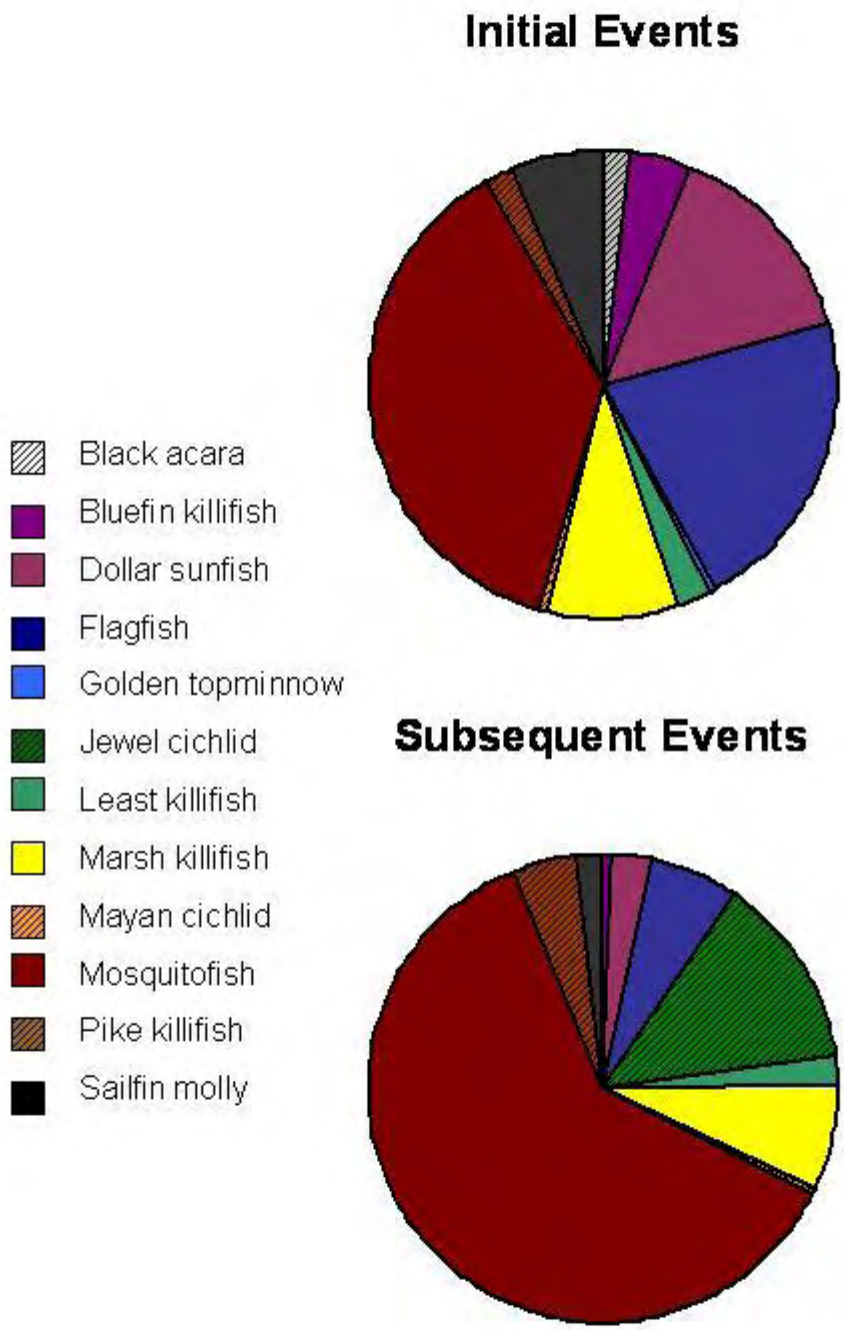
Array 6

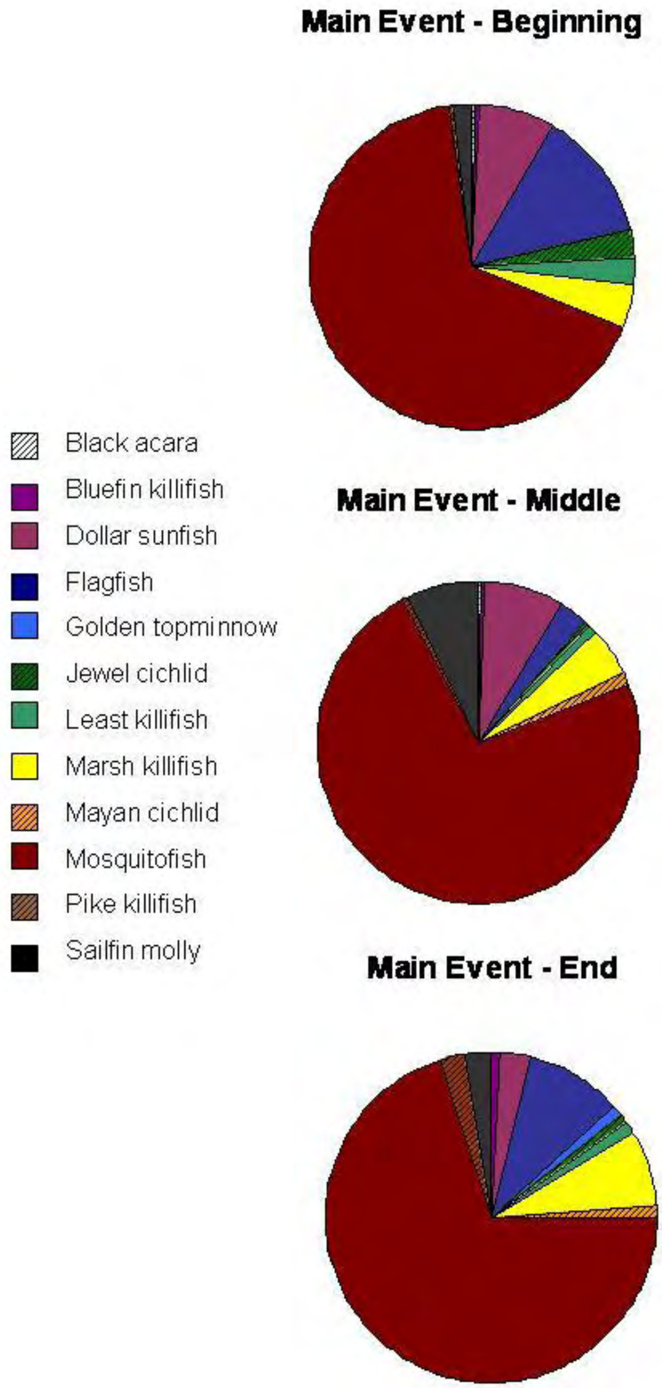


No Initial Events
Subsequent Events:
Bluefin killifish
Brook silverside
Everglades pygmy sunfish
Flagfish
Least killifish
Marsh killifish
Mayan cichlid
Mosquitofish
Pike killifish
Sailfin molly
Warmouth
2001
Flagfish
Marsh killifish
Mosquitofish
Sailfin molly
Dollar sunfish
Everglades pygmy sunfish
Golden topminnow
Black acara
Least killifish
Pike killifish
Warmouth
Yellow bullhead
Bluefin killifish
Sheepshead minnow
Mayan cichlid
No Initial Events
Subsequent Events:
Dollar sunfish
Flagfish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Walking catfish
Yellow bullhead
2002
Flagfish
Marsh killifish
Mosquitofish
Dollar sunfish
Pike killifish
Sailfin molly
Bluefin killifish
Golden topminnow
Least killifish
Bluegill
Walking catfish
Mayan cichlid
Initial Events:
Bluefin killifish
Dollar sunfish
Flagfish
Marsh killifish
Mosquitofish
Pike killifish
Sailfin molly
Spotted sunfish
Tadpole madtom
No Subsequent Events
2003
Flagfish
Marsh killifish
Mosquitofish
Yellow bullhead
Bluespotted sunfish
Dollar sunfish
Golden topminnow
Pike killifish
Jewel cichlid
Spotted sunfish
Warmouth
Mayan cichlid
Walking catfish
Sailfin molly
Bluefin killifish
Tadpole madtom
Week Since Dry

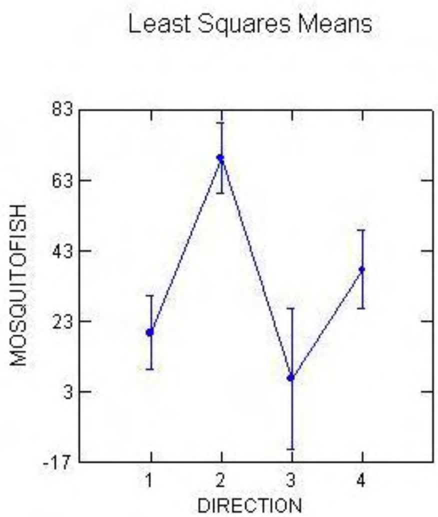

Total Fish CPUE
350
300
250
200
150
100
50
0
CPUE
1
2
3
4
5
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month


Array 1
Array 2
Array 3
Array 4
Array 5
Array 6
CPUE
Depth
Depth (cm)
0
500
1000
1500
0
10
20
30
40
50
60
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04


Initial Events
Black acara
Bluefin killifish
Dollar sunfish
Flagfish
Golden topminnow
Jewel cichlid
Least killifish
Marsh killifish
Mayan cichlid
Mosquitofish
Pike killifish
Sailfin molly
Subsequent Events


Main Event - Beginning
Black acara
Bluefin killifish
Dollar sunfish
Flagfish
Golden topminnow
Jewel cichlid
Least killifish
Marsh killifish
Mayan cichlid
Mosquitofish
Pike killifish
Sailfin molly
Main Event - Middle
Main Event - End

ANOVA: Mosquitofish CPUE and Direction



Direction :

1 – North
2 - East
3 – South
4 – West

ANOVA Results:

N: 462
Multiple R: 0.180
Squared Multiple R: 0.033

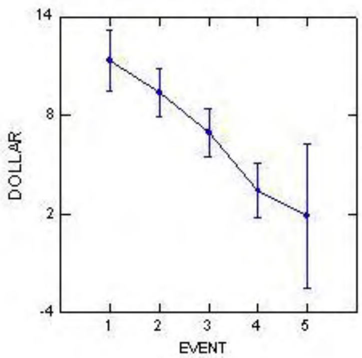
F-ratio: 5.135
P: 0.002

Pairwise Comparisons
(Significant Results):

North – East, P: 0.004
East – South, P: 0.032

ANOVA: Dollar Sunfish CPUE and Direction

Least Squares Means



Even:

1 – Initial
2 - Main – Beginning
3 – Main – Middle
4 – Main – End
5 - Subsequent

ANOVA Results:

N: 287
Multiple R: 0.216
Squared Multiple R: 0.047

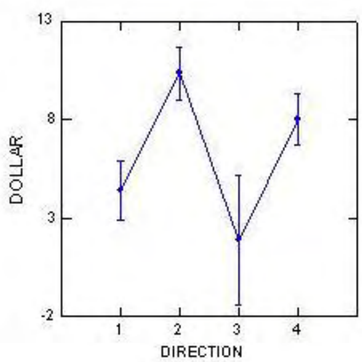
F-ratio: 3.439
P: 0.001

Pairwise Comparisons
(Significant Results):

Initial – Main End, P: 0.018
Main-Beginning – Main End, *P: 0.069*

ANOVA: Dollar Sunfish CPUE and Direction

Least Squares Means



Direction:

1 – North
2 - East
3 – South
4 – East

ANOVA Results:

N: 287
Multiple R: 0.199
Squared Multiple R: 0.040

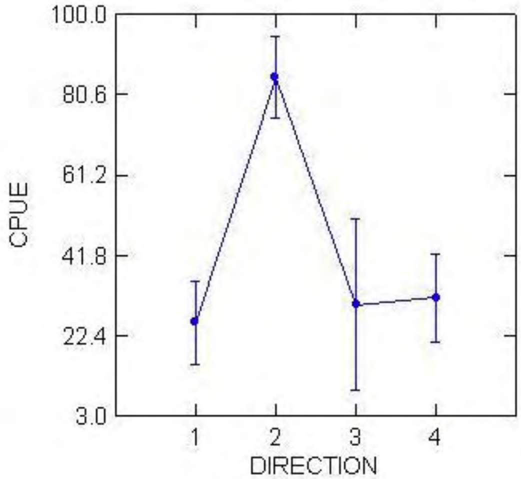
F-ratio: 3.906
P: 0.009

Pairwise Comparisons
(Significant Results):

North - East, P: 0.022

ANOVA: CPUE and Direction, with Depth as Covariate

Least Squares Means



Direction:

1 – North
2 - East
3 – South
4 – East

ANOVA Results: Direction with Depth as a Covariate

N: 325
Multiple R: 0.280
Squared Multiple R: 0.078

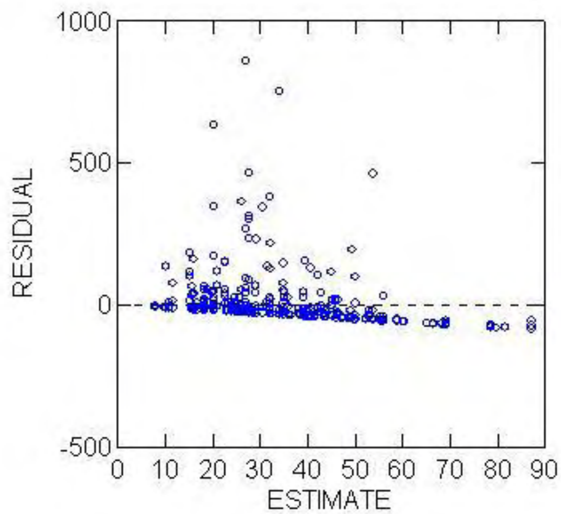
Direction:
F-ratio: 7.451
P: <0.001

Depth:
F-ratio: 4.762
P: 0.030

Pairwise Comparisons for Direction (Significant Results):

North - East, P: <0.001
East – West, *P: 0.063*
East – South, P: 0.002

Plot of Residuals against Predicted Values



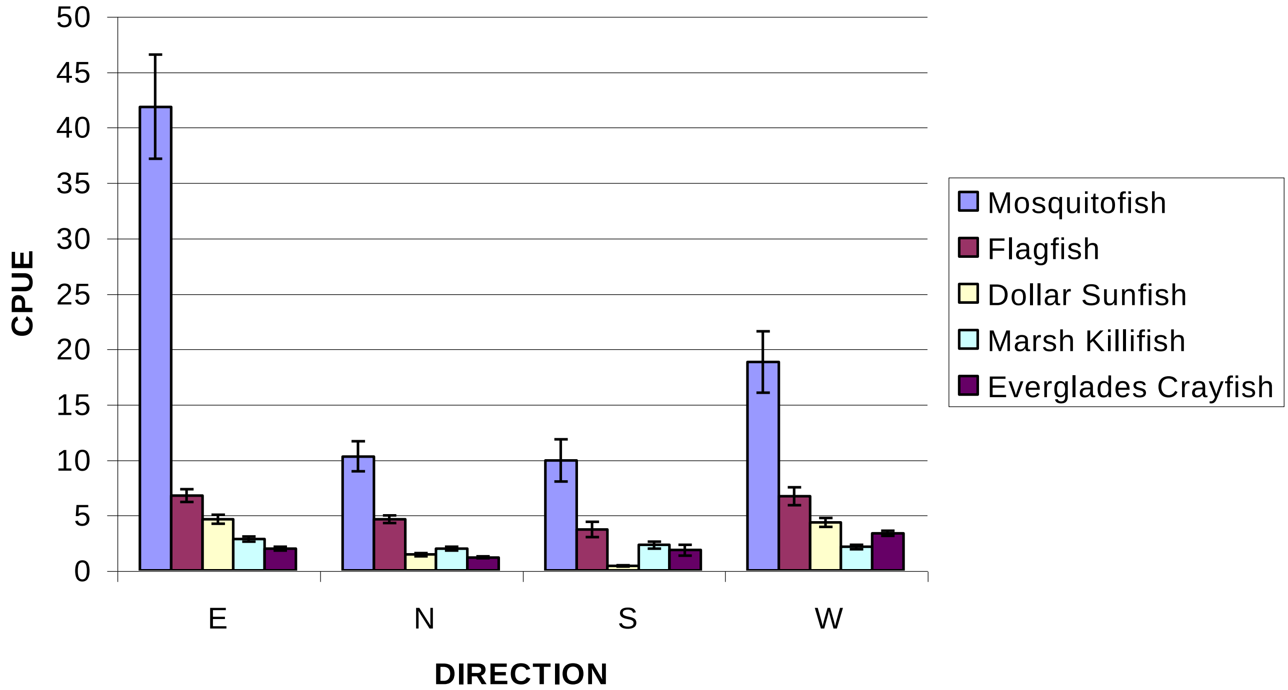
Linear Regression of CPUE and Depth

ANOVA Results:

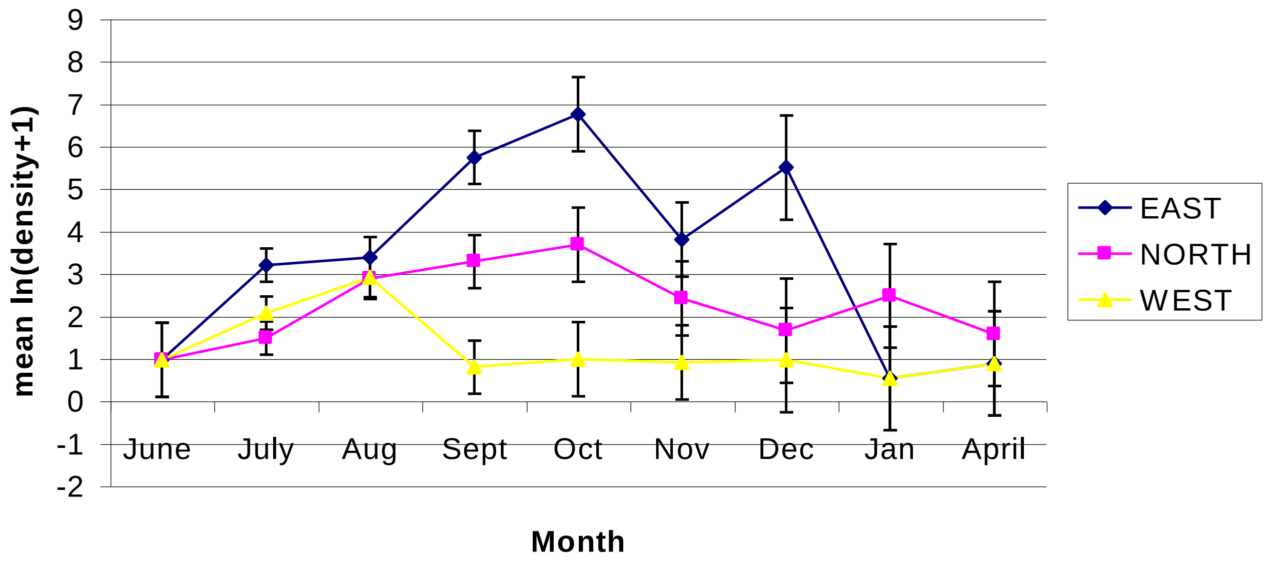
N: 325
Multiple R: 0.331
Squared Multiple R: 0.109

F-ratio: 39.767
P: <0.001

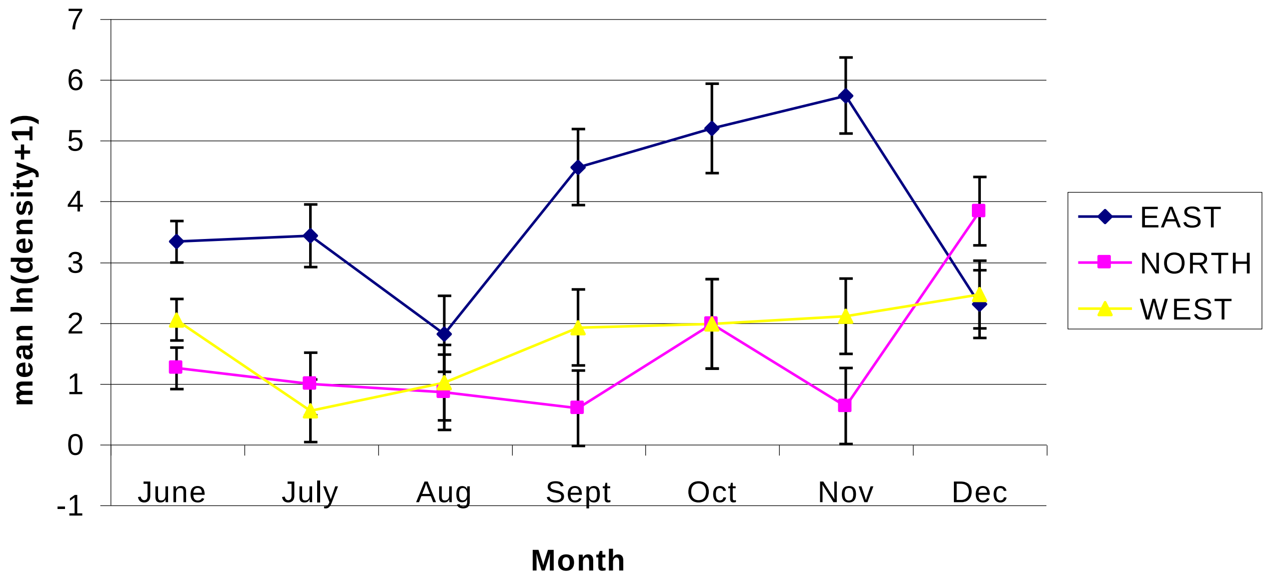
DIRECTION CPUE

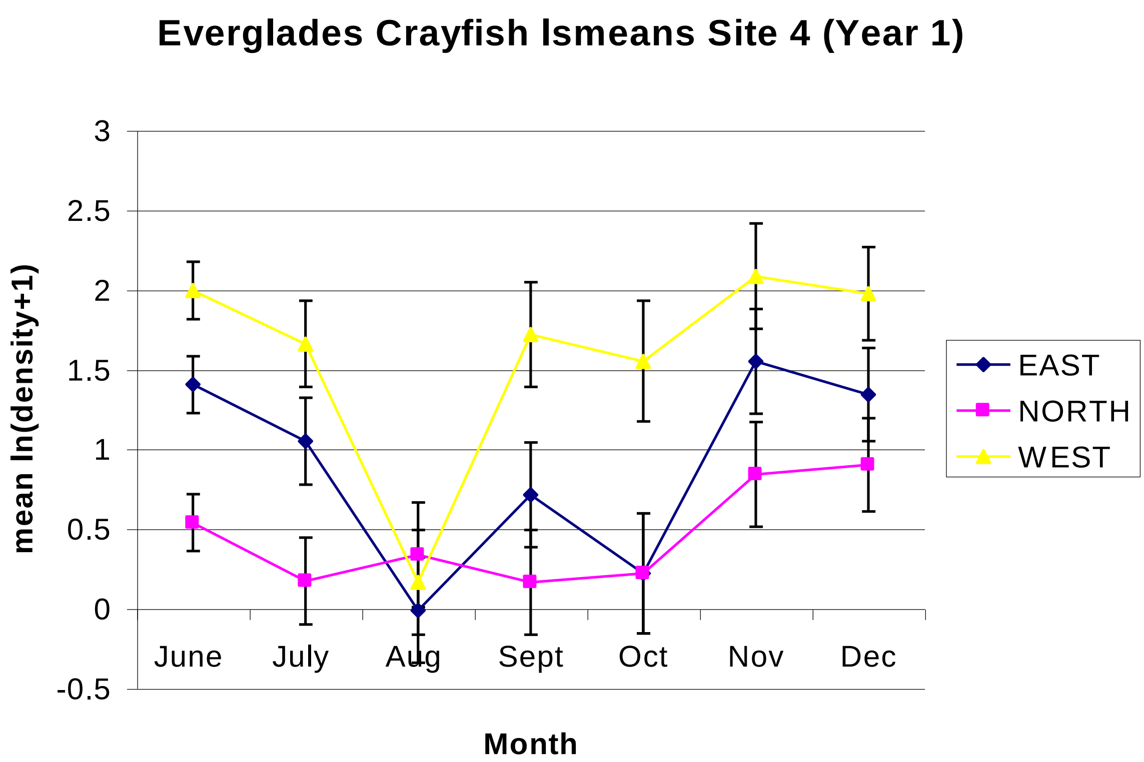


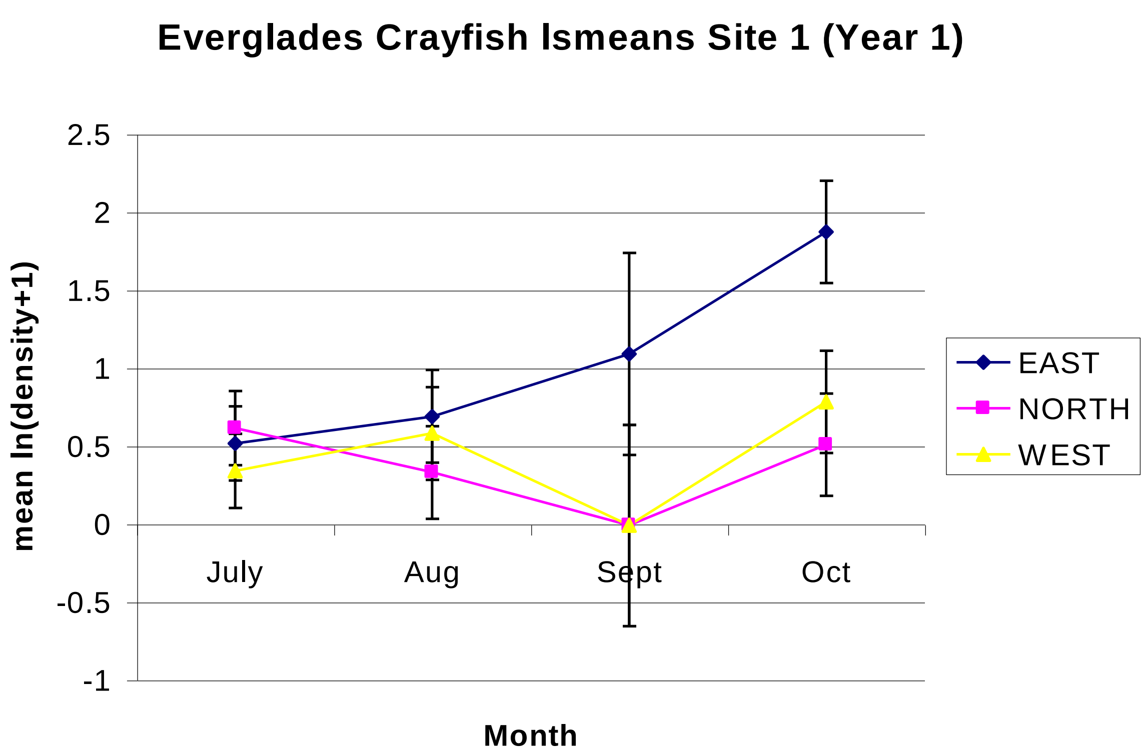
Mosquitofish lsmeans Site 3 (Year 2)



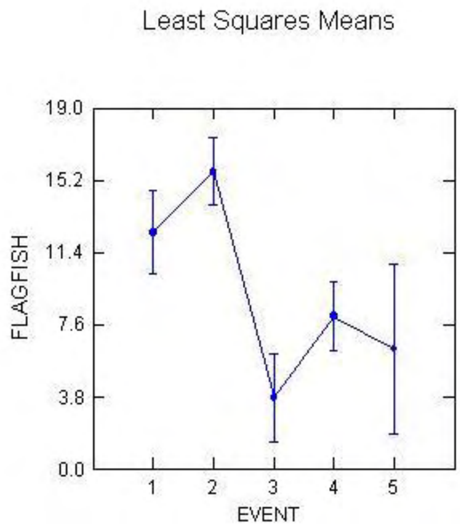
Mosquitofish lsmeans Site 4 (Year 1)




Everglades Crayfish lsmeans Site 4 (Year 1)
3
2.5
2
1.5
1
0.5
0
-0.5
mean ln(density+1)
June
July
Aug
Sept
Oct
Nov
Dec
Month
EAST
NORTH
WEST


Everglades Crayfish lsmeans Site 1 (Year 1)
2.5
2
1.5
1
0.5
0
-0.5
-1
mean ln(density+1)
July
Aug
Sept
Oct
Month
EAST
NORTH
WEST

ANOVA: Flagfish CPUE with Event Timing



Event:

1 – Initial
2 - Main – Beginning
3 – Main – Middle
4 – Main – End
5 - Subsequent

ANOVA Results:

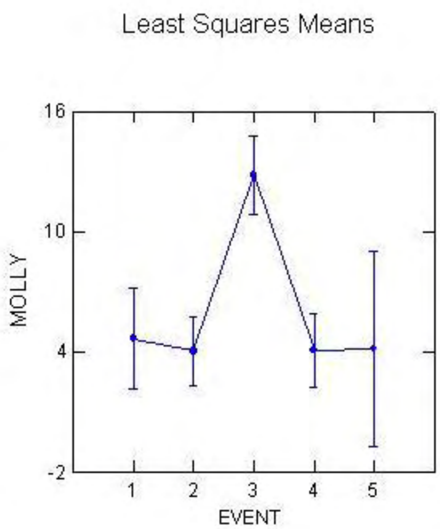
N: 322
Multiple R: 0.246
Squared Multiple R: 0.061

F-ratio: 5.110
P: 0.001

Pairwise Comparisons
(Significant Results):

Main-Beginning – Main Middle, P: 0.001
Main-Beginning – Main End, P: 0.029

ANOVA: Sailfin Molly CPUE with Event Timing



ANOVA Results:

N: 180
Multiple R: 0.282
Squared Multiple R: 0.080

F-ratio: 3.784
P: 0.006

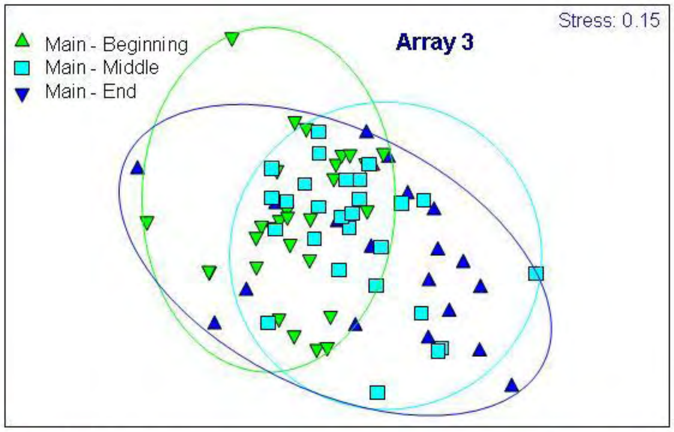
Pairwise Comparisons
(Significant Results):

Main-Beginning – Main Middle, P: 0.009
Main-Middle – Main End, P: 0.013

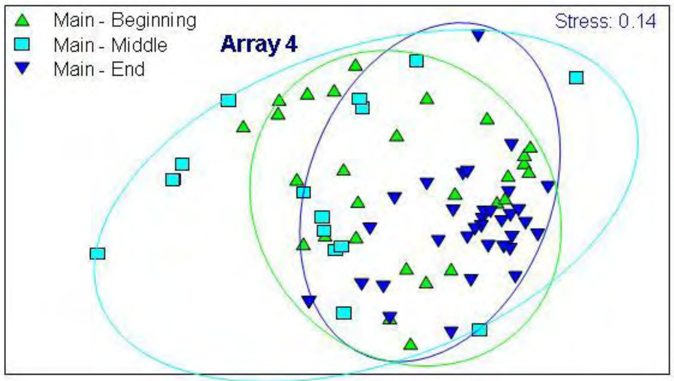
Event:

1 – Initial
2 - Main – Beginning
3 – Main – Middle
4 – Main – End
5 - Subsequent

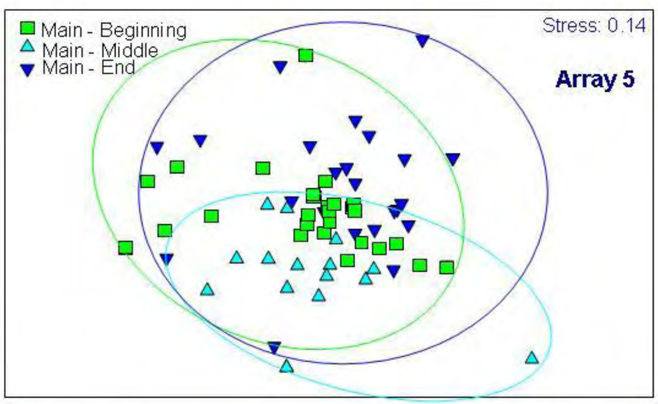
a.


Main - Beginning
Main - Middle
Main - End
Array 3
Stress: 0.15

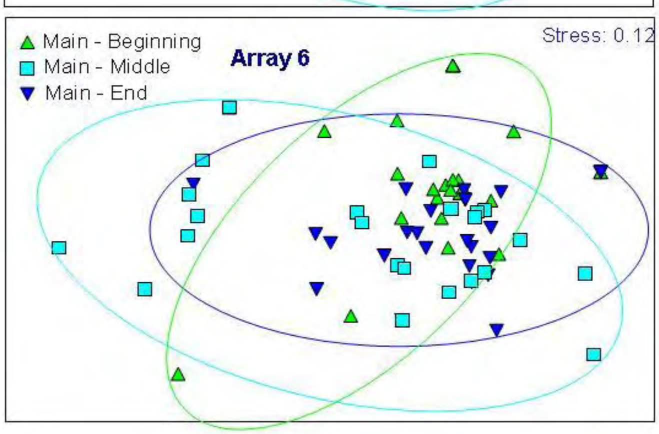
b.


Main - Beginning
Main - Middle
Main - End
Array 4
Stress: 0.14

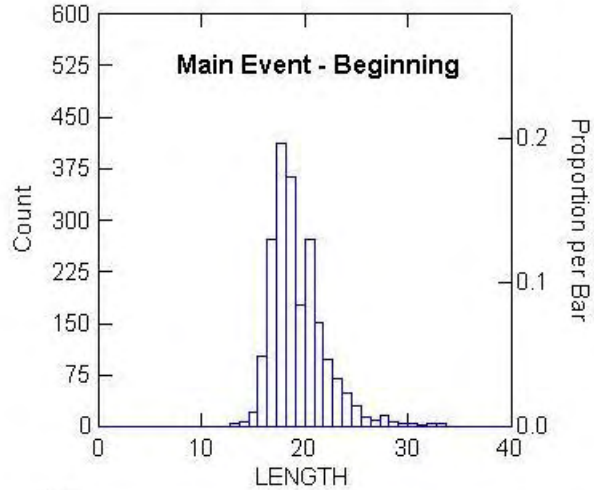
c.


Main - Beginning
Main - Middle
Main - End
Array 5
Stress: 0.14

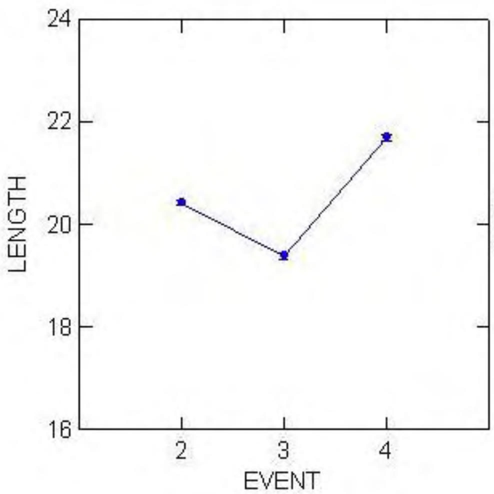
d.

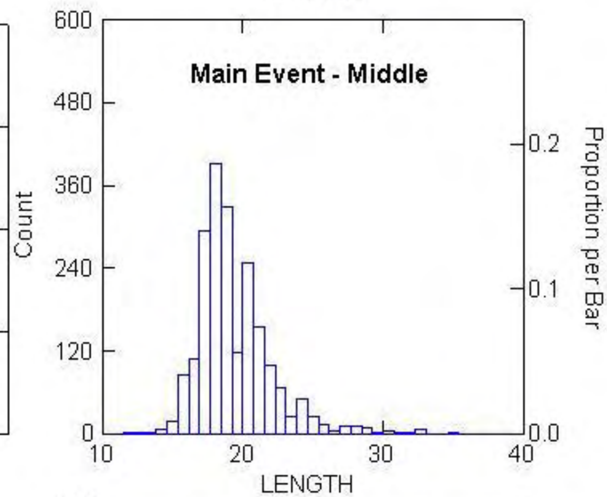

Main - Beginning
Main - Middle
Main - End
Array 6
Stress: 0.12

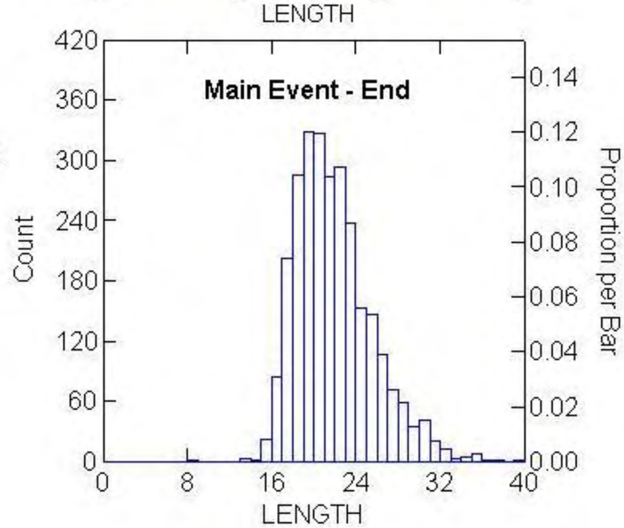
Frequency Distributions for Eastern mosquitofish Lengths



Least Squares Means







ANOVA Results:

N: 1253
Multiple R: 0.392
Squared Multiple R: 0.154

F-ratio: 133.773
P: <0.001

Pairwise Comparisons
(Significant Results):

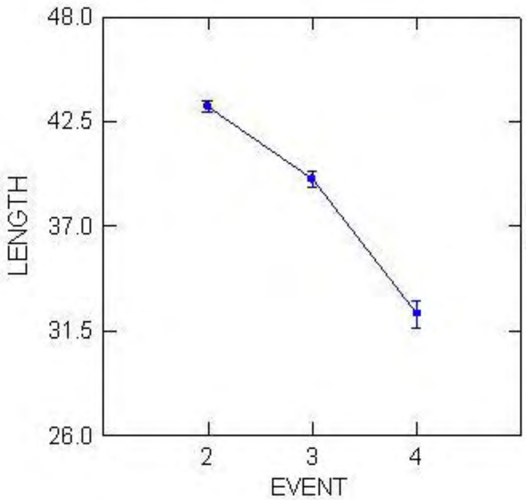
Beginning - Middle, P: <0.001
Beginning - End, P: <0.001
Middle – End, P: <0.001

Event:

2 - Main – Beginning
3 - Main – Middle
4 - Main – End

Frequency Distributions for Dollar sunfish Lengths

Least Squares Means



ANOVA Results:

N: 9098
Multiple R: 0.257
Squared Multiple R: 0.066

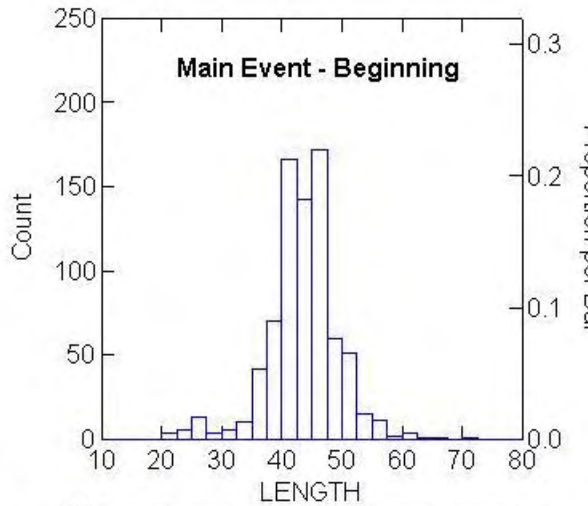
F-ratio: 322.187
P: <0.001

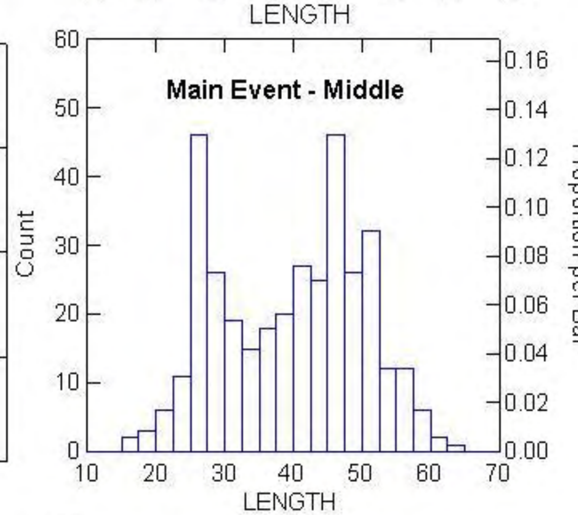
Pairwise Comparisons
(Significant Results):

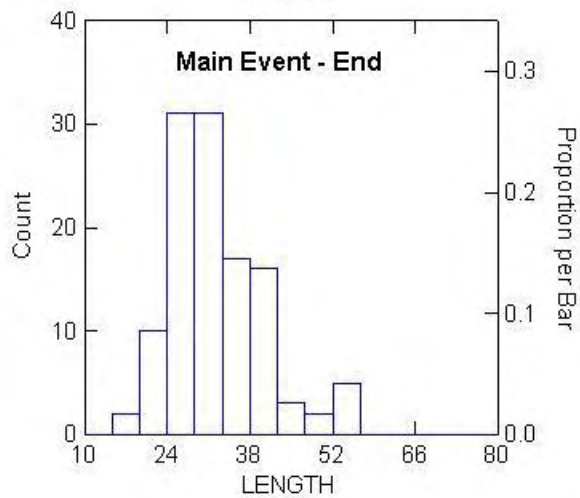
Beginning - Middle, P: <0.001
Beginning - End, P: <0.001
Middle – End, P: <0.001

Event:

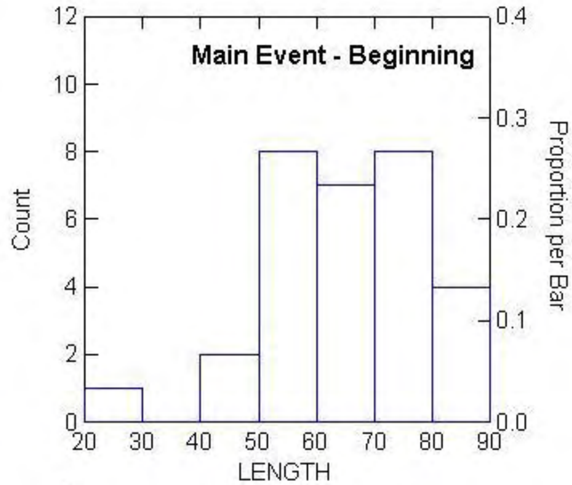
2 - Main – Beginning
3 - Main – Middle
4 - Main – End



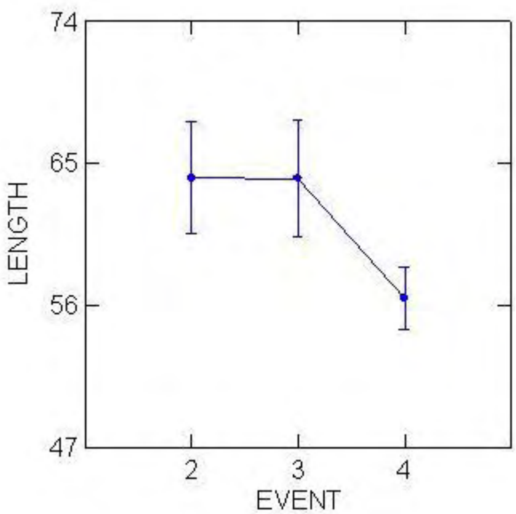


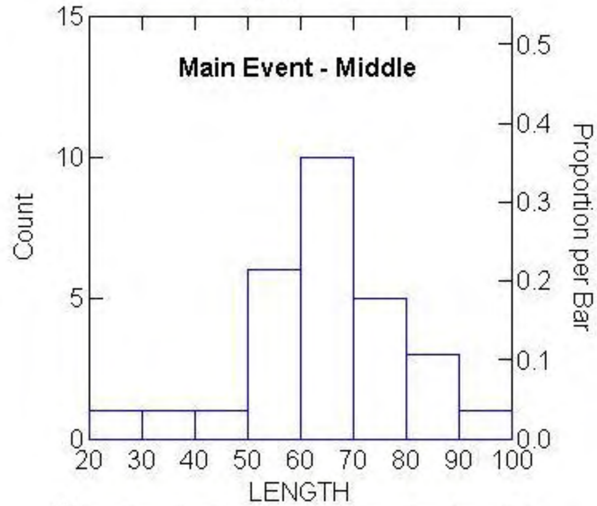


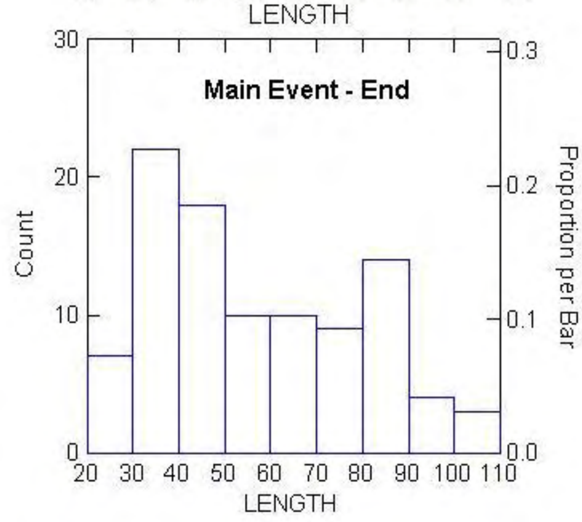
Frequency Distributions for Pike killifish Lengths



Least Squares Means







ANOVA Results:

N: 155
Multiple R: 0.187
Squared Multiple R: 0.035

F-ratio: 2.756
P: 0.067

Pairwise Comparisons
(No Significant Results):

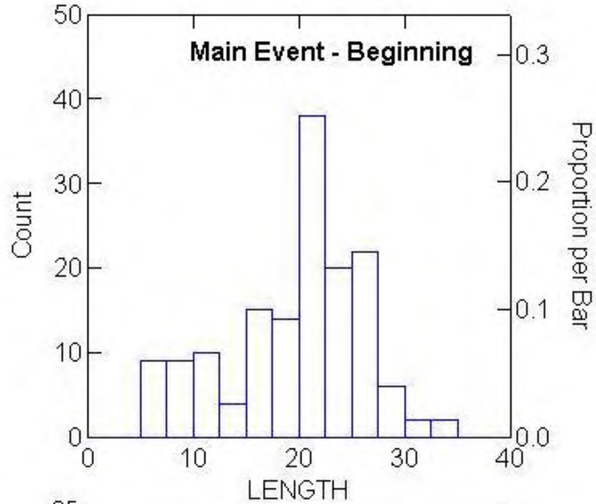
Kolgomorov-Smirnov Two Sample Test Results:

Beginning - End, P: 0.002
Middle – End, P: <0.001

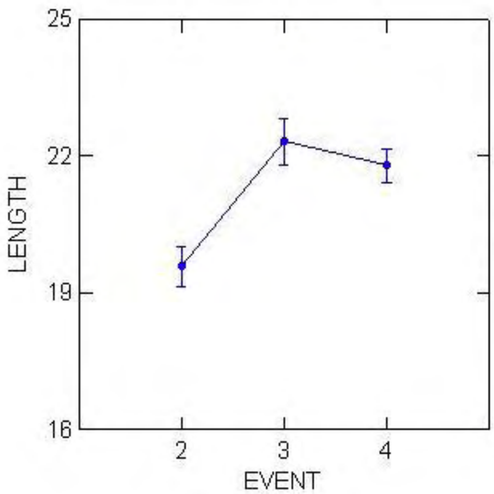
Event:

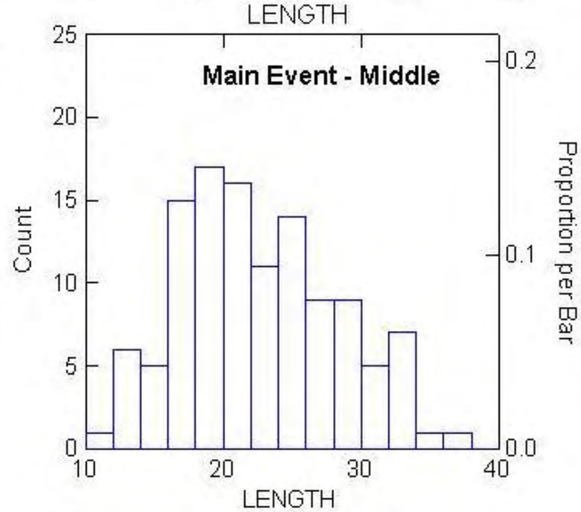
2 - Main – Beginning
3 - Main – Middle
4 - Main – End

Frequency Distributions for Everglades crayfish Carapace Lengths



Least Squares Means





ANOVA Results:

N: 502
Multiple R: 0.199
Squared Multiple R: 0.040

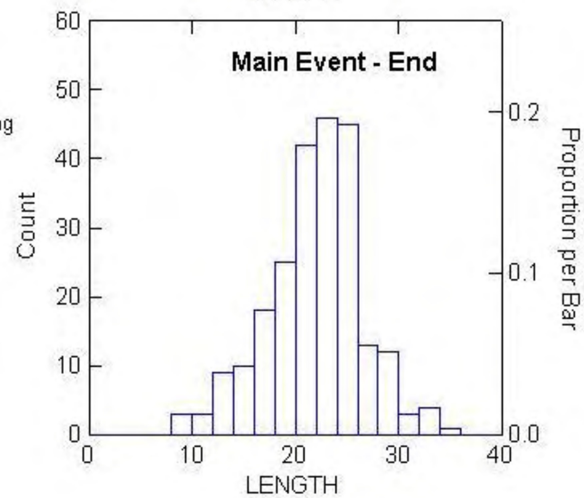
F-ratio: 10.267
P: <0.001

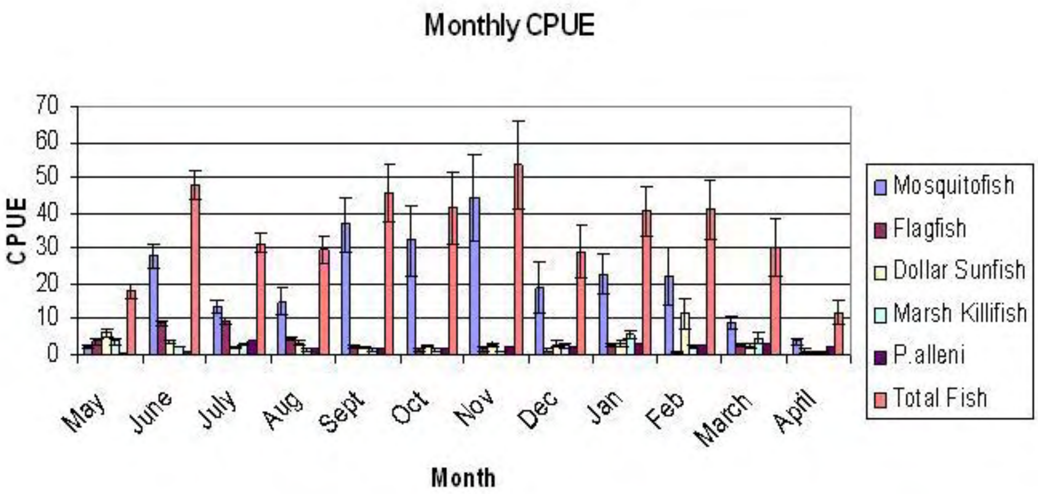
Pairwise Comparisons
(Significant Results):

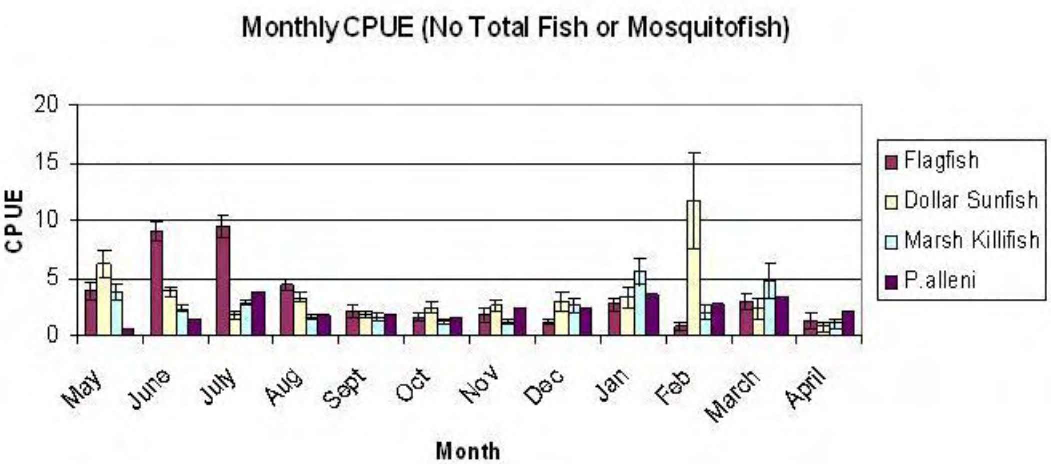
Beginning - Middle, P: <0.001
Beginning - End, P: <0.001

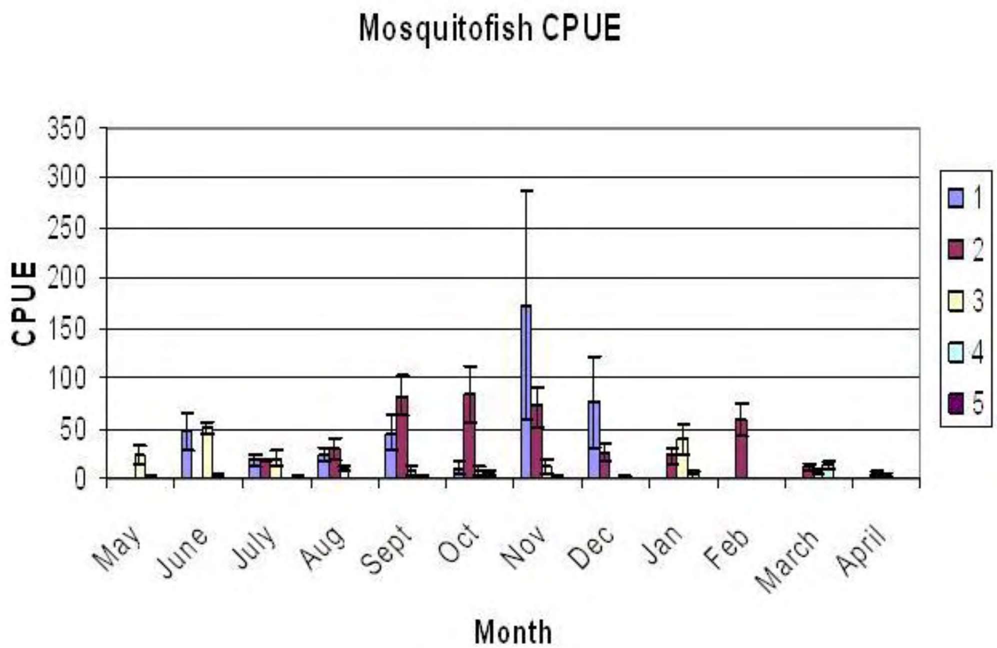
Event:

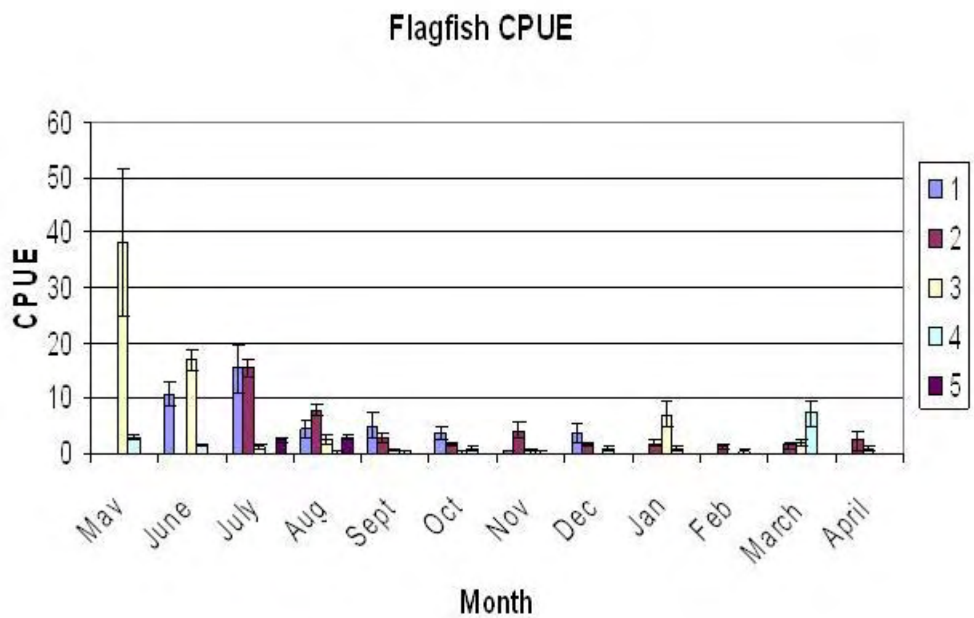
2 - Main – Beginning
3 - Main – Middle
4 - Main – End

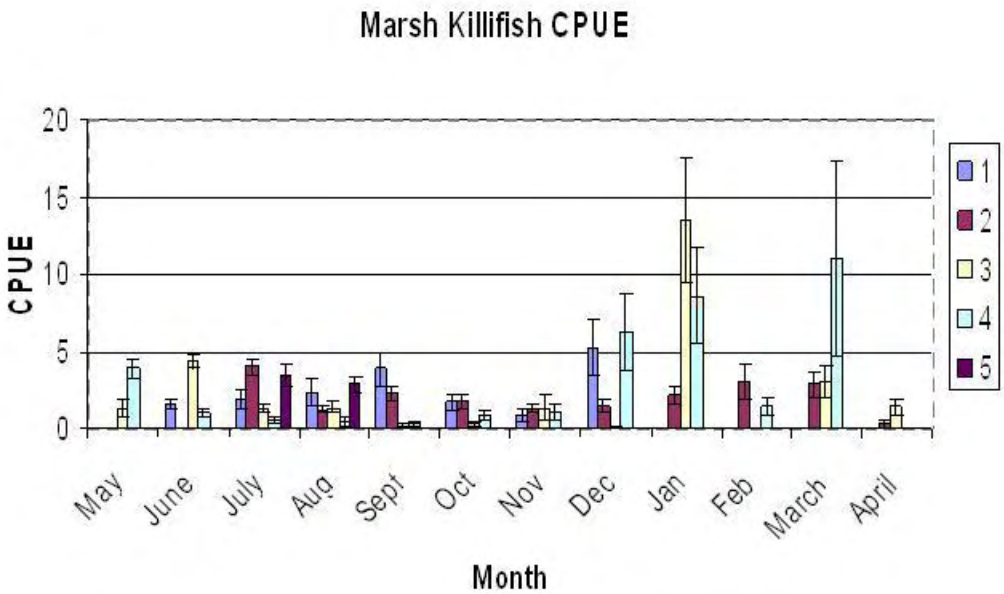


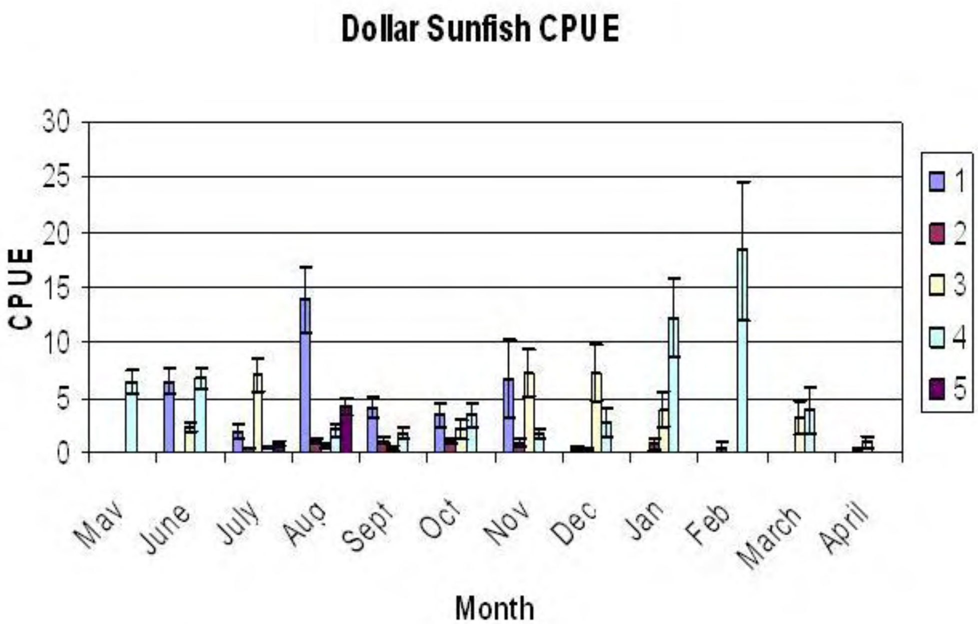

Monthly CPUE
70
60
50
40
30
20
10
0
CPUE
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
Mosquitofish
Flagfish
Dollar Sunfish
Marsh Killifish
P.alleni
Total Fish

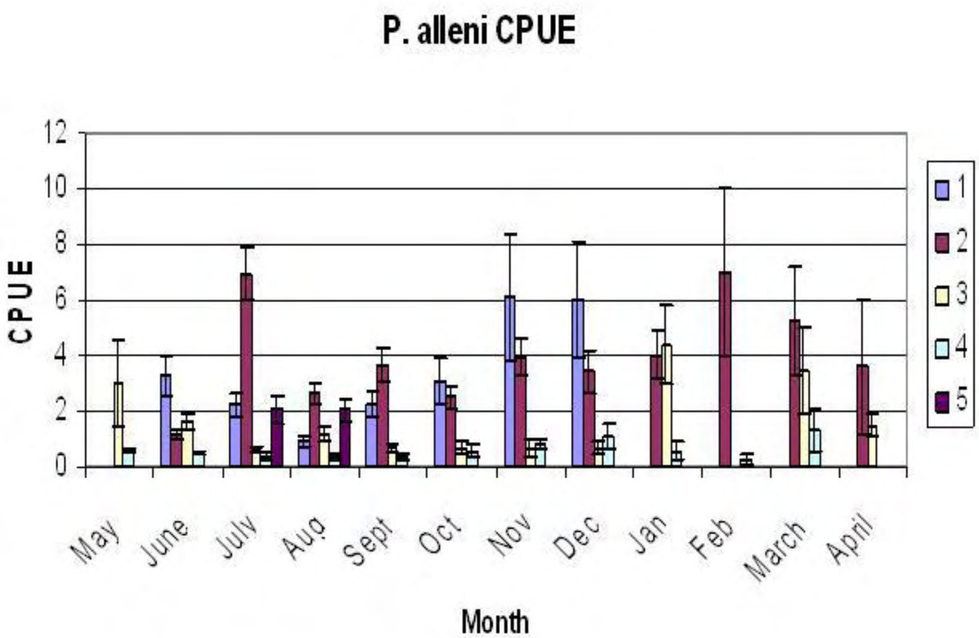

Monthly CPUE (No Total Fish or Mosquitofish)
20
15
10
5
0
CPUE
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
Flagfish
Dollar Sunfish
Marsh Killifish
P.alleni

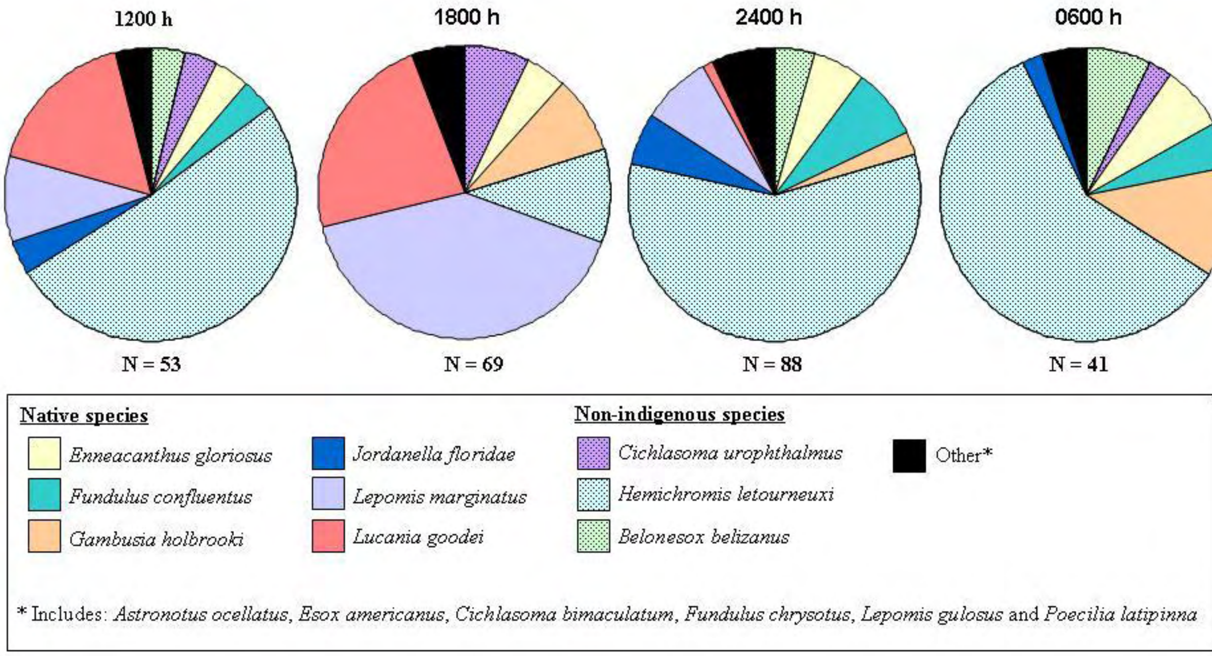

Mosquitofish CPUE
350
300
250
200
150
100
50
0
CPUE
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
1
2
3
4
5

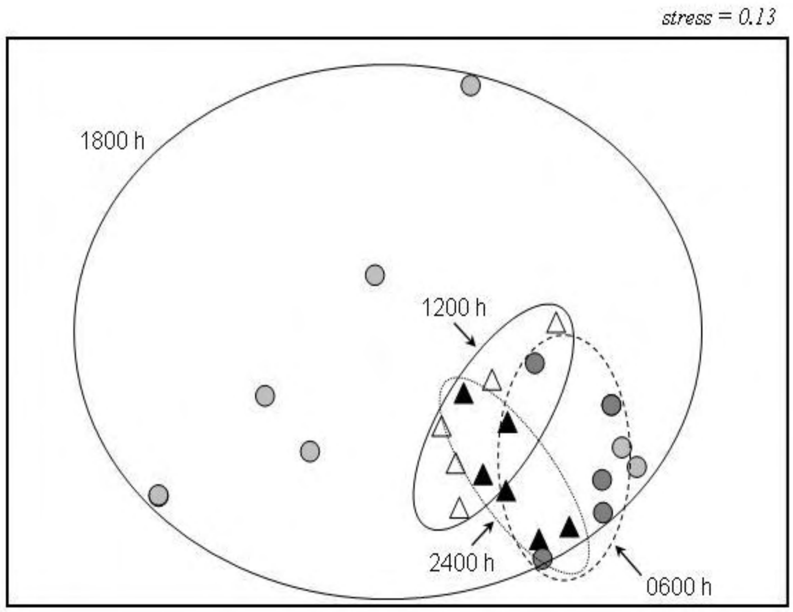

Flagfish CPUE
60
50
40
30
20
10
0
CPUE
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
1
2
3
4
5

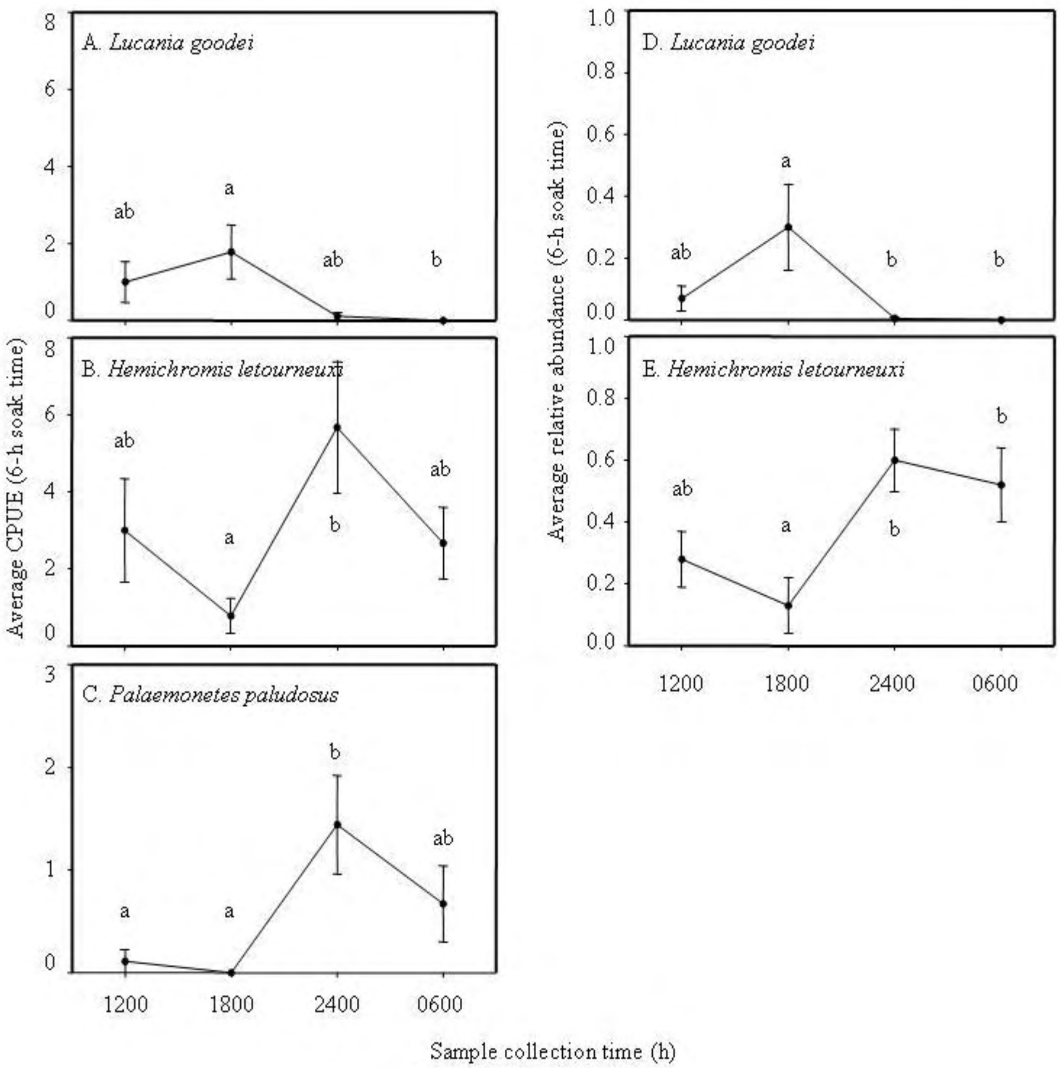

Marsh Killifish CPUE
CPUE
20
15
10
5
0
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
1
2
3
4
5

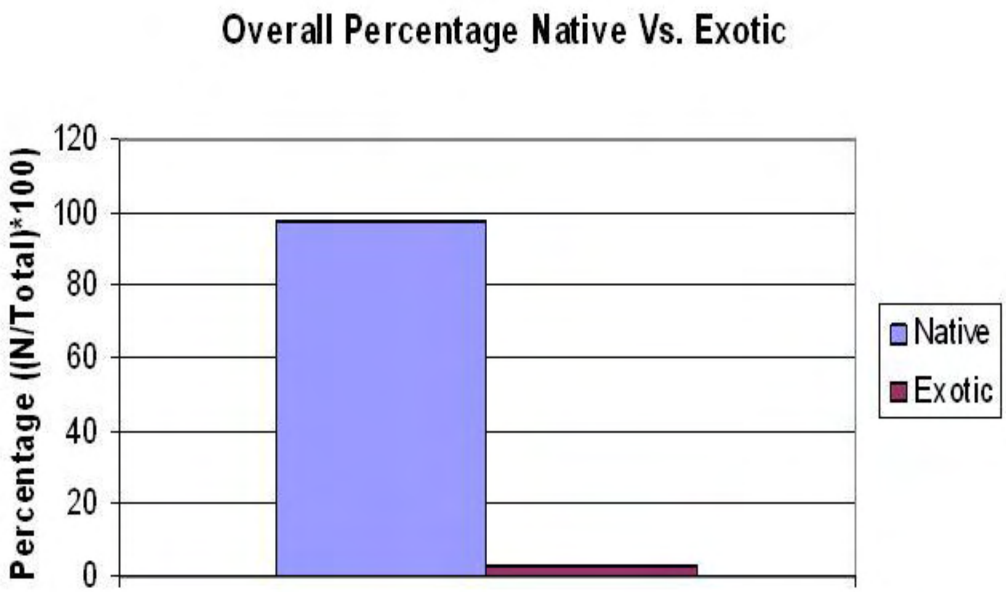

Dollar Sunfish CPUE
CPUE
30
25
20
15
10
5
0
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
1
2
3
4
5

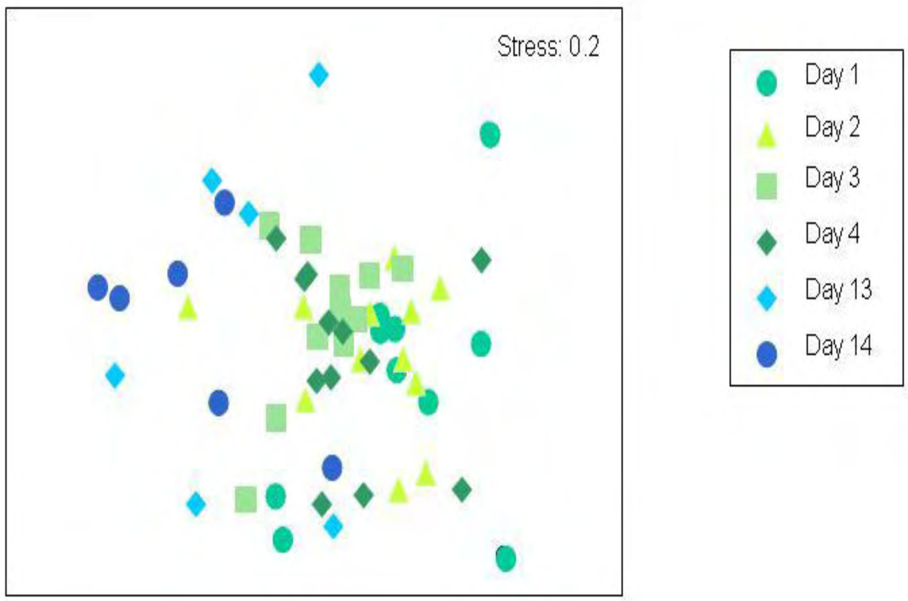

P. alleni CPUE
12
10
8
6
4
2
0
CPUE
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Month
1
2
3
4
5

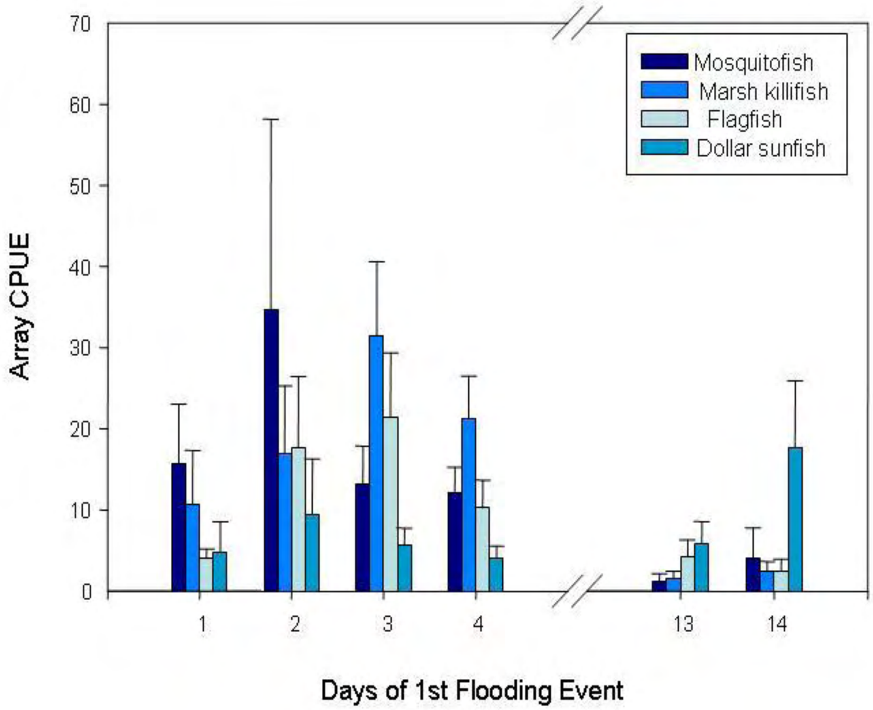

1200 h
1800 h
2400 h
0600 h
N = 53
N = 69
N = 88
N = 41
Native species
Enneacanthus gloriosus
Fundulus confluentus
Gambusia holbrooki
Jordanella floridae
Lepomis marginatus
Lucania goodei
Non-indigenous species
Cichlasoma urophthalmus
Hemichromis letourneuxi
Belonesox belizanus
Other*
* Includes: Astronotus ocellatus, Esox americanus, Cichlasoma bimaculatum, Fundulus chrysotus, Lepomis gulosus and Poecilia latipinna


stress = 0.13
1800 h
1200 h
2400 h
0600 h


A. Lucania goodei
B. Hemichromis letourneuxi
C. Palaemonetes paludosus
D. Lucania goodei
E. Hemichromis letourneuxi
Average CPUE (6-h soak time)
Average relative abundance (6-h soak time)
Sample collection time (h)
1200
1800
2400
0600
ab
a
b

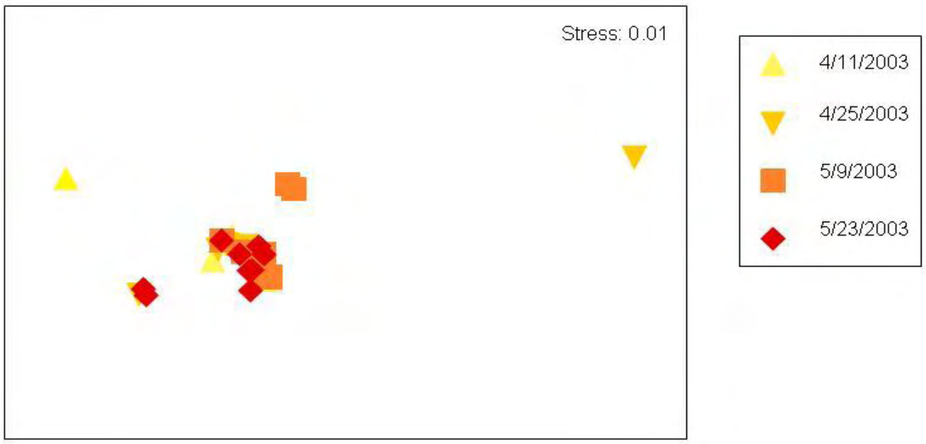

Overall Percentage Native Vs. Exotic
Percentage ((N/Total)*100)
120
100
80
60
40
20
0
Native
Exotic


Stress: 0.2
Day 1
Day 2
Day 3
Day 4
Day 13
Day 14

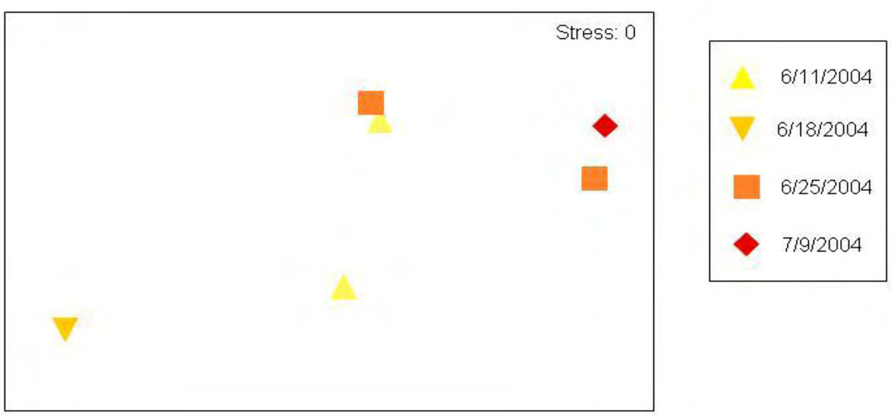


70
60
50
40
30
20
10
0
Array CPUE
Mosquitofish
Marsh killifish
Flagfish
Dollar sunfish
1
2
3
4
13
14
Days of 1st Flooding Event

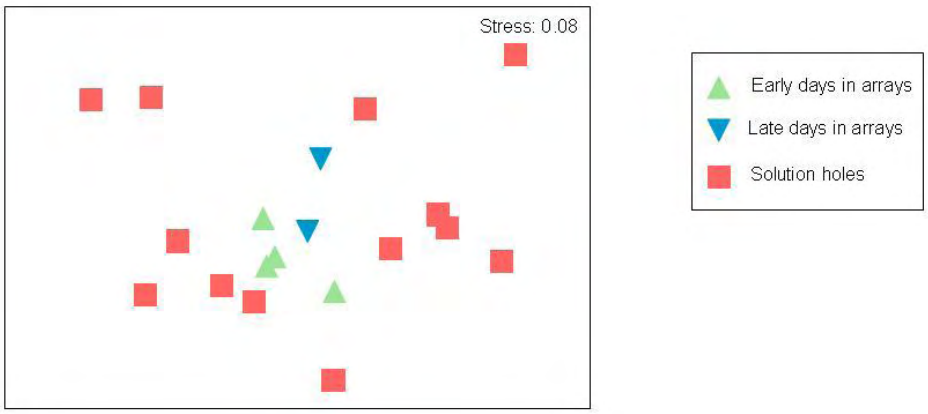
A.


Stress: 0.01
4/11/2003
4/25/2003
5/9/2003
5/23/2003

B.


Stress: 0
6/11/2004
6/18/2004
6/25/2004
7/9/2004

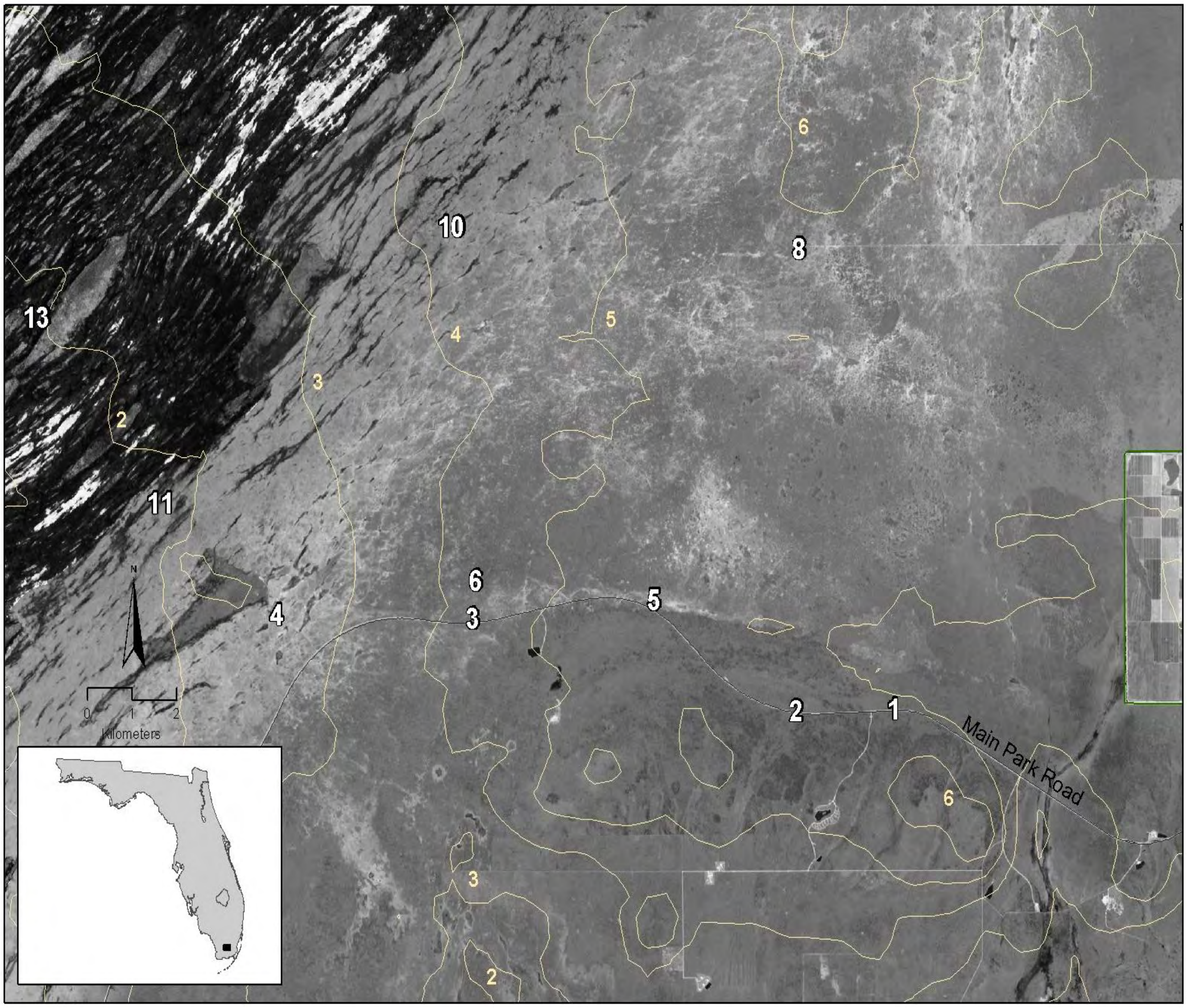
A.


Stress: 0.08
Early days in arrays
Late days in arrays
Solution holes

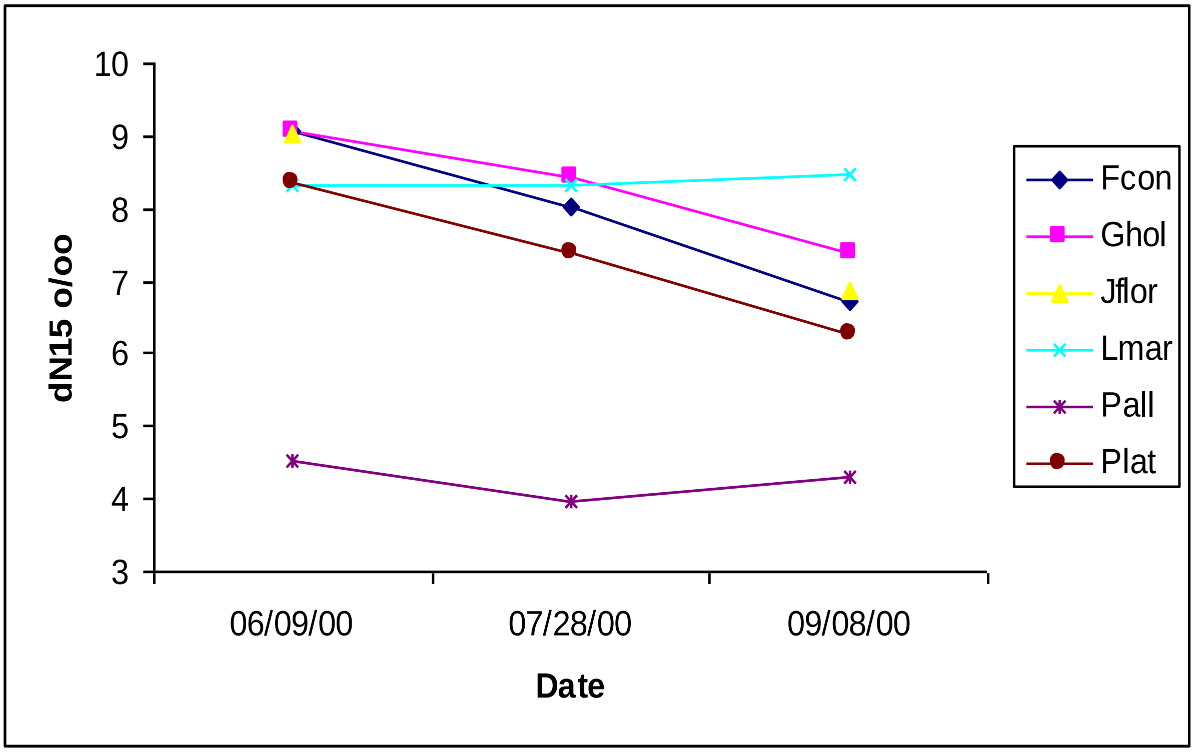
B.

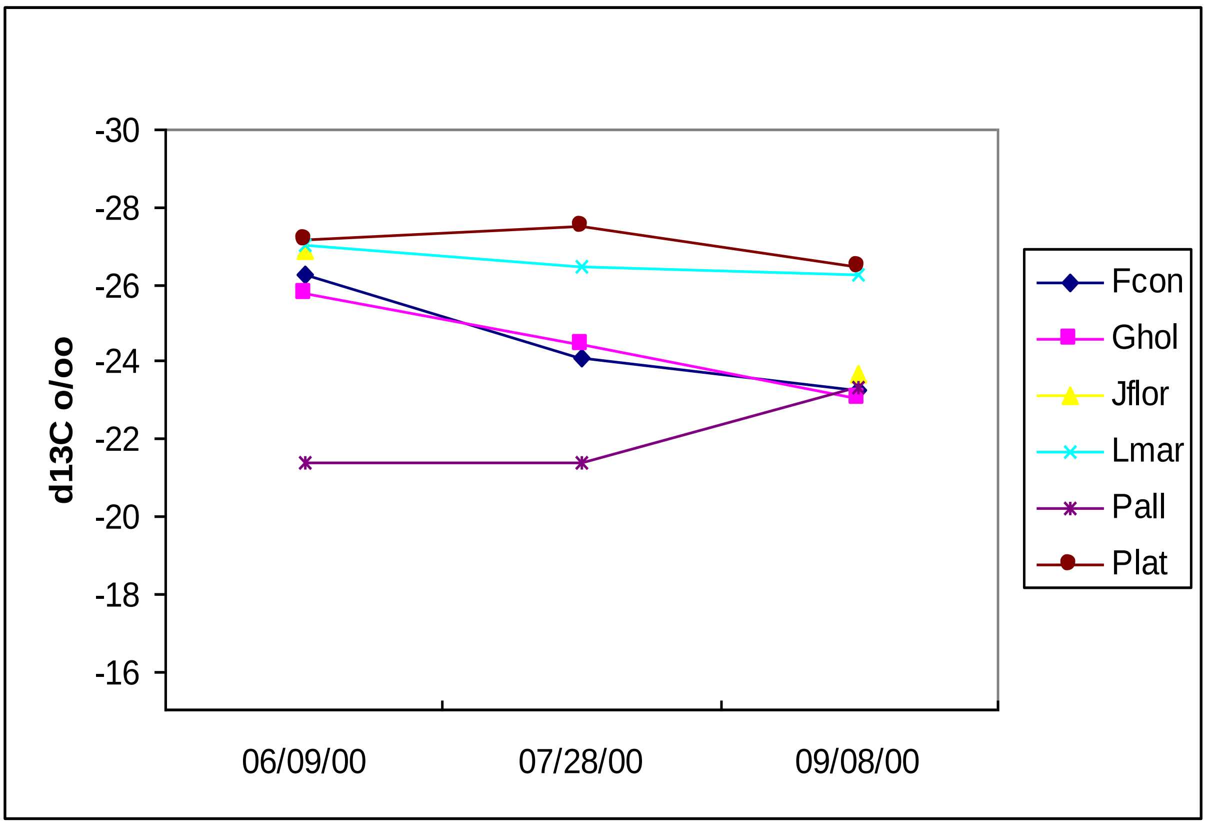

Stress: 0.01
Early days in arrays
Late days in arrays
Solution holes

Array Locations

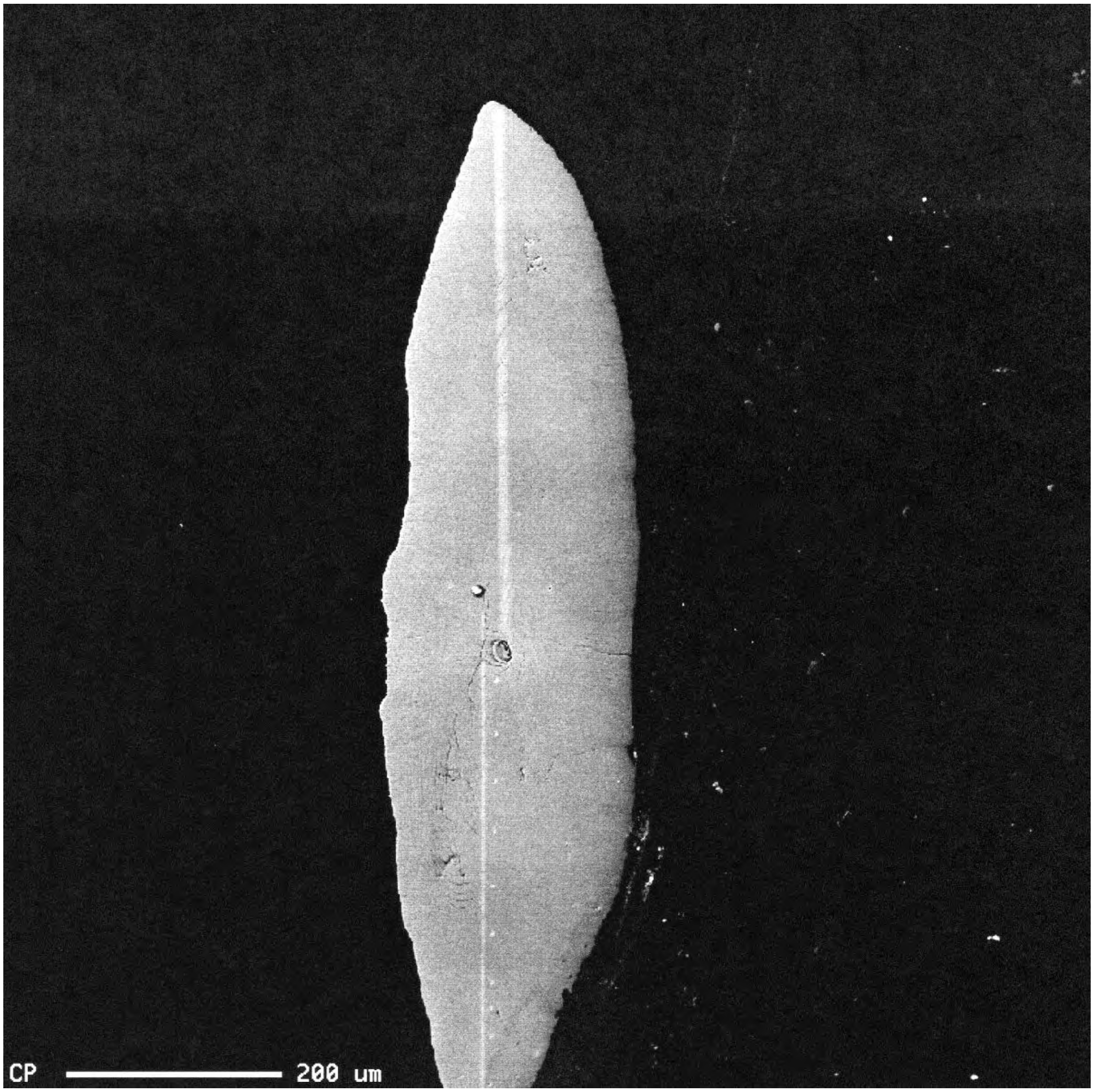


A.

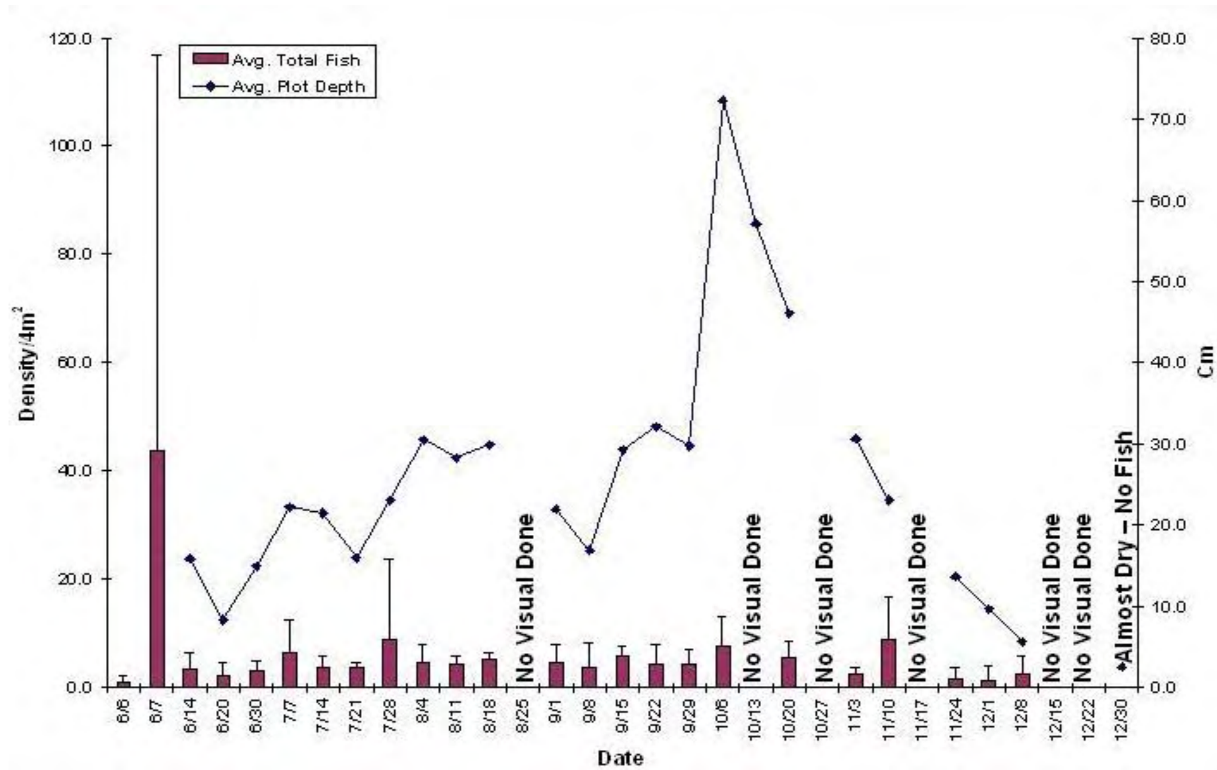

10
9
8
7
6
5
4
3
dN15 o/oo
06/09/00
07/28/00
09/08/00
Date
Fcon
Ghol
Jflor
Lmar
Pall
Plat

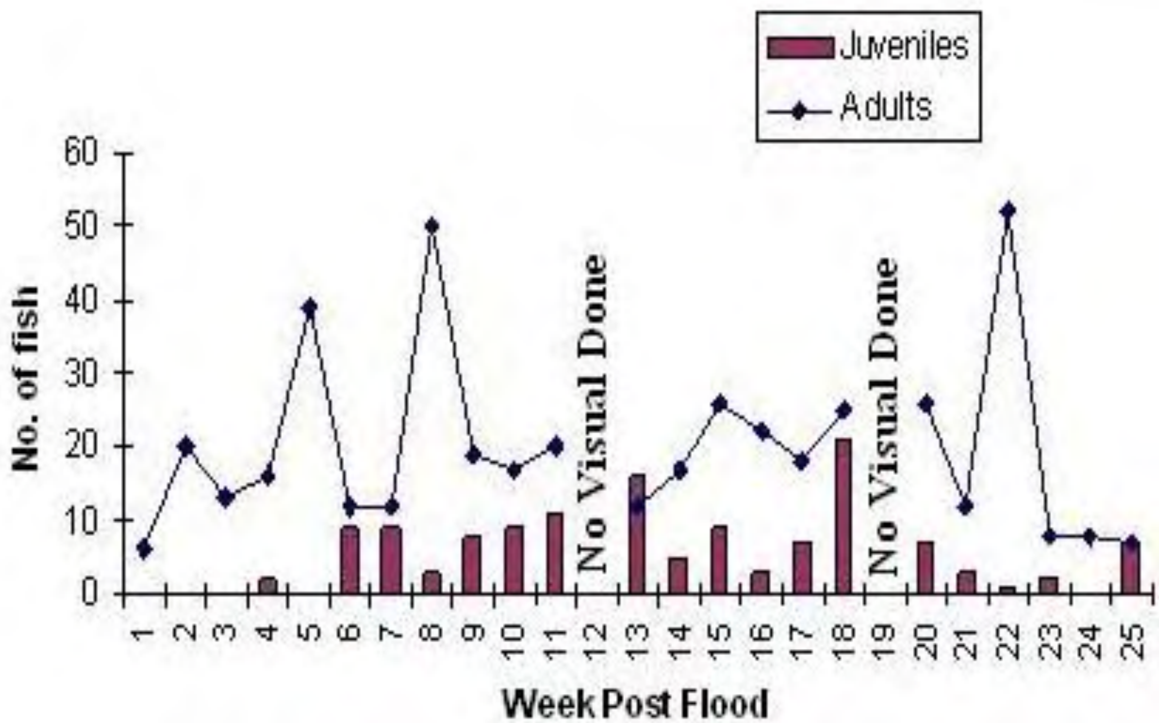

-30
-28
-26
-24
-22
-20
-18
-16
d13C o/oo
06/09/00
07/28/00
09/08/00
Fcon
Ghol
Jflor
Lmar
Pall
Plat

B

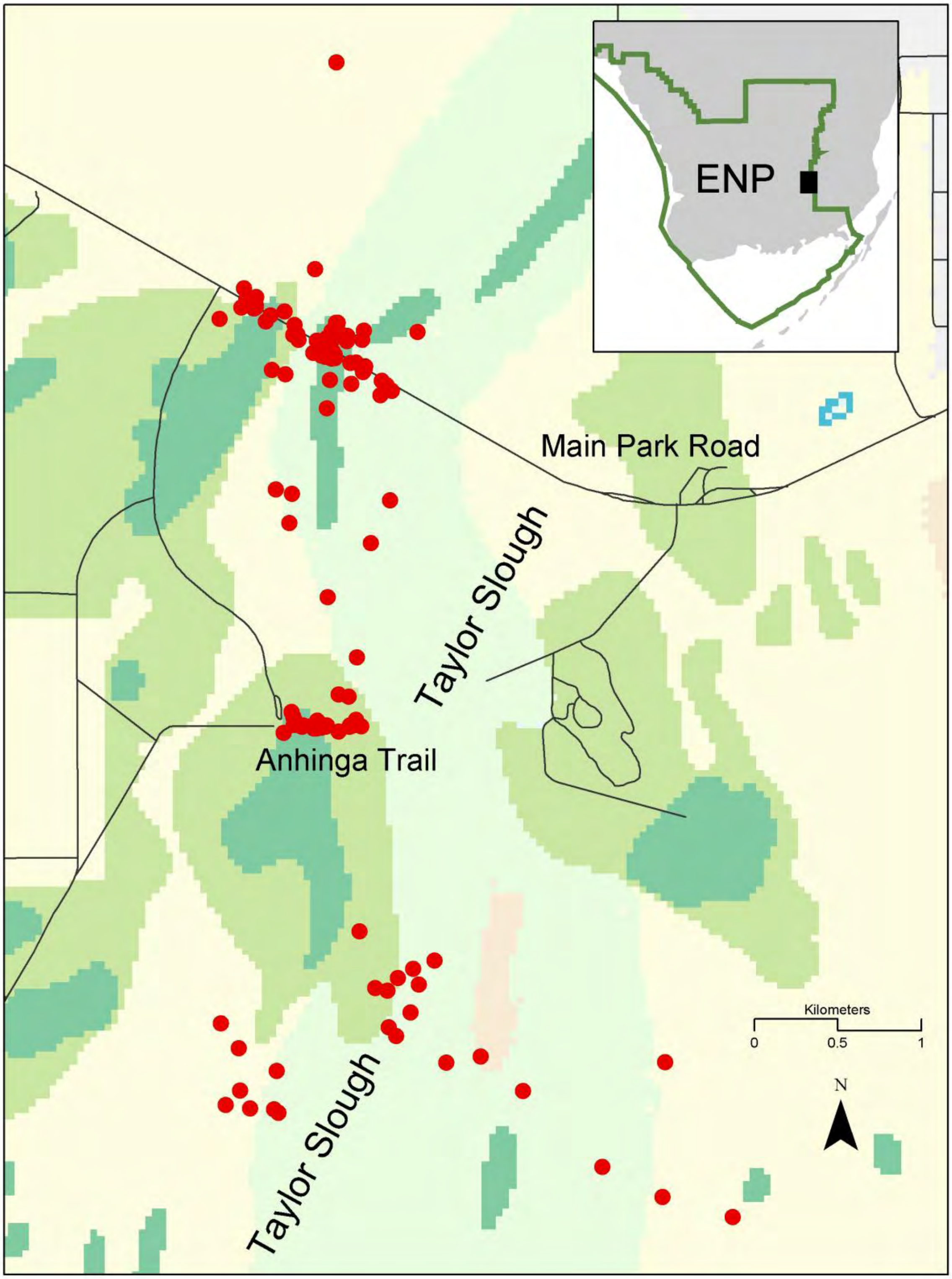

CP
200 um

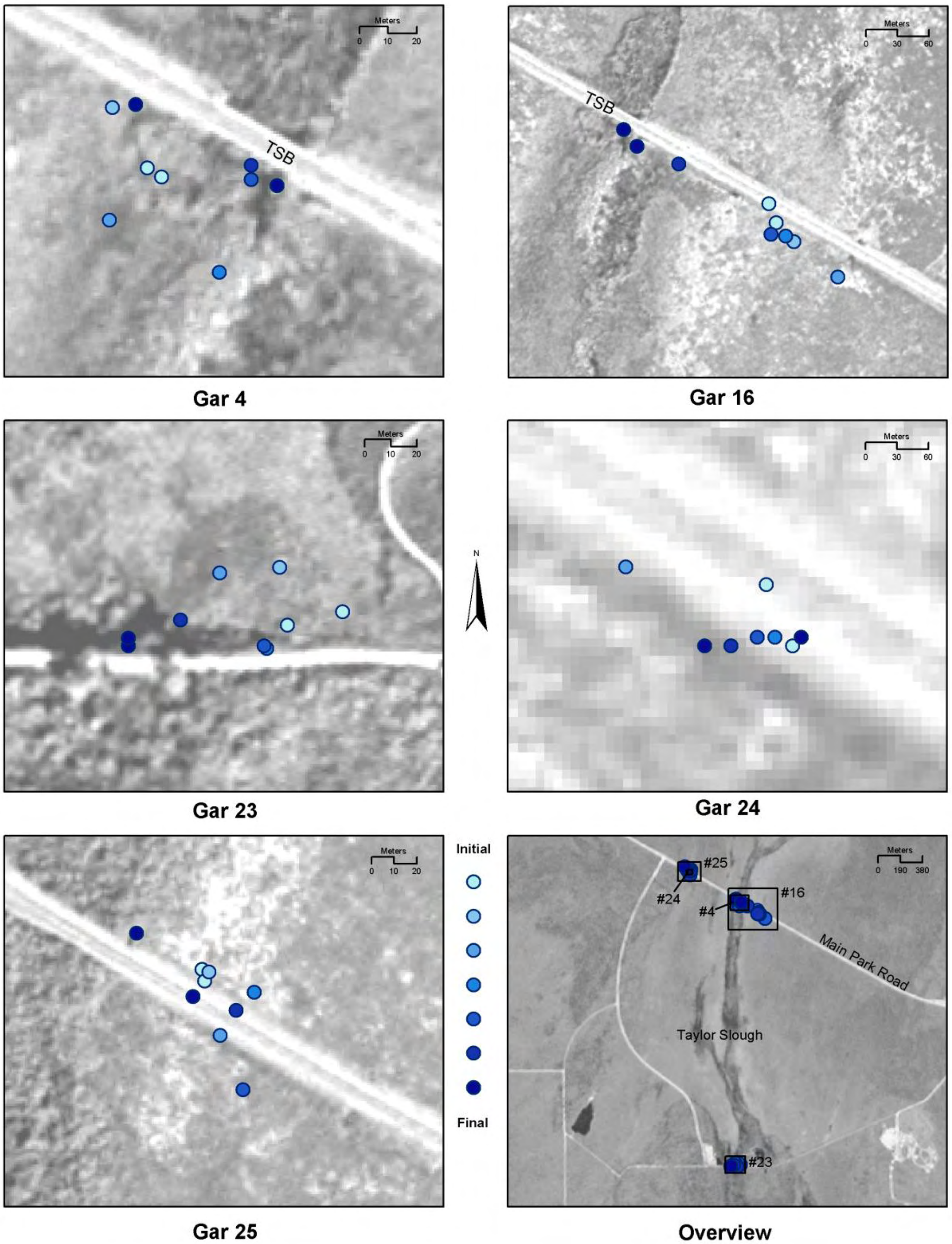
A.


Avg. Total Fish
Avg. Plot Depth
Density/4m²
Cm
Date
No Visual Done
No Visual Done
No Visual Done
No Visual Done
No Visual Done
No Visual Done
*Almost Dry – No Fish
6/6
6/7
6/14
6/20
6/30
7/7
7/14
7/21
7/28
8/4
8/11
8/18
8/25
9/1
9/8
9/15
9/22
9/29
10/6
10/13
10/20
10/27
11/3
11/10
11/17
11/24
12/1
12/8
12/15
12/22
12/30


Juveniles
Adults
No. of fish
No Visual Done
No Visual Done
Week Post Flood

B.


ENP
Main Park Road
Taylor Slough
Anhinga Trail
Taylor Slough
Kilometers
0
0.5
1
N


Meters
0 10 20
TSB
Gar 4
Meters
0 30 60
TSB
Gar 16
Meters
0 10 20
Gar 23
N
Meters
0 30 60
Gar 24
Meters
0 10 20
Gar 25
Initial
Final
Meters
0 190 380
#25
#24
#16
#4
Main Park Road
Taylor Slough
#23
Overview

APPENDIX 1. Fish species sampled in the Rocky Glades, ENP. ▲Non-indigenous fish species.

LEPISOSTEIDAE	GARS
Lepisosteus platyrhincus	Florida gar
CYPRINIDAE	CARPS AND MINNOWS
Notemigonus crysoleucas	Golden shiner
Notropis petersoni	Coastal shiner
CATOSTOMIDAE	SUCKERS
Erimyzon sucetta	Lake chubsucker
ICTALURIDAE	NORTH AMERICAN CATFISHES
Ameiurus natalis	Yellow bullhead
Ameiurus nebulosus	Brown bullhead
Noturus gyrinus	Tadpole madtom
CLARIIDAE	LABYRINTH CATFISHES
▲*Clarias batrachus*	Walking Catfish
CALLICHTHYIDAE	CALLICHTHYID ARMORED CATFISHES
▲*Hoplosterum littorale*	Brown hoplo
ESOCIDAE	PIKES
Esox americanus	Redfin Pickerel
ATHERINIDAE	NEW WORLD SILVERSIDES
Labidesthes sicculus	Brook silverside
FUNDULIDAE	TOPMINNOWS
Fundulus chrysotus	Golden topminnow
Fundulus confluentus	Marsh killifish
Lucania parva	Rainwater killifish
Lucania goodei	Bluefin killifish
POECILIIDAE	LIVEBEARERS
▲*Belonesox belizanus*	Pike killifish
Gambusia holbrooki	Mosquitofish
Heterandria formosa	Least killifish
Poecilia latipinna	Sailfin molly
CYPRINODONTIDAE	PUPFISHES
Cyprinodon variegatus	Sheepshead minnow
Jordanella floridae	Flagfish
APHREDODERIDAE	PIRATE PERCHES
Aphredoderus sayanus	Pirate Perch
CENTRARCHIDAE	SUNFISHES
Enneacanthus gloriosus	Bluespotted sunfish
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis marginatus	Dollar sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Micropterus salmoides	Largemouth bass
PERCIDAE	PERCHES
Etheostoma fusiforme	Swamp darter
ELASSOMATIDAE	PYGMY SUNFISHES
Elassoma evergladei	Everglades pygmy sunfish
CICHLIDAE	CICHLIDS
▲*Astronotus ocellatus*	Oscar
▲*Cichlasoma bimaculatum*	Black acara
▲*Cichlasoma urophthalmus*	Mayan cichlid
▲*Oreochromis aureus*	Blue tilapia
▲*Cichlasoma managuense*	Jaguar guapote
▲*Hemichormis letourneuxi*	African jewelfish
▲*Tilapia mariae*	Spotted tilapia

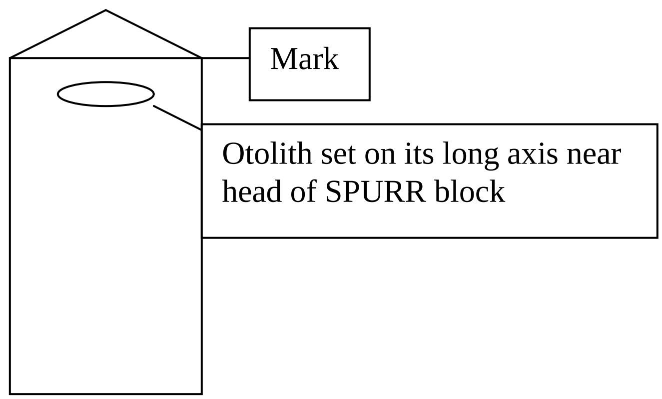
Appendix 2. Solution-hole physical characteristics.

Complex	Solution Hole	Vegetation Cover (%)	Dominant Vegetation Species	Complexity Score (1-3)	Length (cm)	Width (cm)	Maximum Depth (cm)
1HL	M1	90	*Bacopa caroliniana*	1	130	70	63
1HL	M2	25	*Bacopa caroliniana*	2	500	400	77
2HL	S	15	*Cladium jamaicense, Bacopa caroliniana, Pluchea sp.*	1	230	170	32
3HL	S	> 90	*Crinum americanum, Bacopa caroliniana*	1	300	270	38
3HL	D2	< 10	*Bacopa caroliniana*	2	320	300	80
3HL	M	10	*Ludwigia repens, Utricularia foliosa*	2	300	140	58
3HL	D1	< 10	*Ludwigia repens*	1	330	230	82
2MB	D	85	*Salix caroliniana, Pontedaria cordata, Bacopa caroliniana, Cladium jamaicense*	3	270	400	85
2MB	M	> 90	*Bacopa caroliniana, Panicum sp., Cladium jamaicense*	2	265	295	50
Blue Bag	M	60	*Ludwigia repens, Sagitarria lancifolia, Prosperpinaca palustris*	2	170	165	64
Blue Bag	D	30	*Chara sp.*	2	410	200	105
MR8	D1	0		2	120	110	110
MR8	D2	80	*Chara sp.*	3	190	110	105
MR7	D	< 10	*Chara sp.*	1	160	160	100
MR7	M	15	*Sagitarria lancifolia*	2	100	100	49
3SB	M	> 90	*Sagitarria lancifolia, Prosperpinaca palustris*	2	320	270	42
3MB	M1	15	*Cladium jamaicense*	1	240	145	43
3MB	M2	> 90	*Sagitarria lancifolia, Polygonum densiflorum, Salix caroliniana*	2	820	680	48
MR9	D1	0		2	140	70	92
MR9	D2	0		2	150	140	107
4MB	D1	70	*Prosperpinaca palustris, Salix caroliniana, Polygonum densiflorum, Cephalanthus occidentalis, Sagitarria lancifolia*	3	850	540	82
4MB	D2	80	*Sagitarria lancifolia, Cladium jamaicense, Polygonum densiflorum, Ludwigia repens*	3	650	650	86
4MA	M1	40	*Sagitarria lancifolia, Cladium jamaicense, Mikania scandens, Prosperpinaca palustris*	3	340	100	71
4MA	M2	> 90	*Cladium jamaicense, Sagitarria lancifolia*	3	300	380	64
1WR	D	0		1	290	270	145
1WR	S	< 10	*Cladium jamaicense*	1	190	240	38
3WR	D1	20	*Panicum sp., Cladium jamaicense*	2	240	190	110
3WR	D2	0		3	250	200	145
4WR	M	> 90	*Sagitarria lancifolia, Cladium jamaicense, Prosperpinaca palustris*	3	450	350	48
4WR	D	0		2	260	220	163
2WR	D	< 10	*Sagittaria lancifolia*	3	760	680	142
2WR	M	< 10	*Polygonum densiflorum, Panicum sp.*	2	330	159	79
MR10	M	15	*Prosperpinaca palustris*	2	290	240	68
MR10	D	20	*Salix caroliniana, Cladium jamaicense, Sagitarria lancifolia Ludwigia repens*	2	350	200	82
5SB	D	< 10	*Pluchea sp., Eupatorium leptophyllum*	1	260	260	81
5SB	M	35	*Cladium jamaicense, Rhynchospora sp.*	2	440	190	61
5SA	S1	> 90	*Cladium jamaicense, Mikania scandens, Pluchea sp., Eupatorium leptophyllum*	2	450	200	27
5SA	S2	80	*Cladium jamaicense, Prosperpinaca palustris*	2	430	360	27
MR11	D	< 10	*Cladium jamaicense, Alternanthera philoxeroides*	1	370	300	104
MR11	M	40	*Prosperpinaca palustris*	2	87	61	55

Appendix 3. Otolith Preparation Procedure

Extract sagittal otoliths from target fish with forceps and clean of any attached tissues.

Imbed otolith in SPURR resin in the rubberized mounting block after properly orienting it. Sometimes setting the otolith in a tiny drop of Superglue in the mounting chamber before adding the SPURR will help maintain its orientation.



Bake in drying oven at 50-60 C.

Remove block from rubberized mold and make a mark for cutting on the resin block.

First Sawing

Use Isomet saw to cut along mark on resin block. Be sure that there is Isomet oil in the saw reservoir. Pinch resin block in saw vise, tighten vise, lower and position saw blade, and cut while holding finger under the saw arm to prevent it from falling once block has been cut through. Remove resin block and dry of oil residue. When finished, remove saw blade and dry before storing.

Sanding and Polishing

Start with 400-grit wet sandpaper, and proceed to 600-grit wet sandpaper. Mount paper and polishing cloth on board with adhesive. Move resin block with otolith back and forth. Check progress with dissecting microscope. When nearing the primordium (nucleus) of the otolith, use alumina powder on polishing cloth to remove grooves caused by sanding.

Attaching to Petrographic Slide

Attach resin block to numbered glass, 24x44-mm, petrographic slide (Fisher Scientific) by placing 8-mm disk of Crystal Bond cement on center of slide on a hot plate until melted. Remove from hot plate and quickly place sawed side of resin block into cement until it hardens.

Second Sawing

Using slide adapter for Isomet saw, with lubricant to create good suction after depressing side button on mount adapter, attach to cutting saw with screws and washers. Keep ledge on mounting slide facing upwards. Cut close to otolith. Wipe off oil residue and remove slide.

Polishing Second Side

Use the 100x lens on a compound microscope to look for the primordium. Hold slide in fingernails and sand lightly with 400-grit wet sandpaper. Move on to 600-grit until primordium comes into view. Polish with alumina powder and polishing cloth.

A. **For Microchemical Analysis**: Stop at this stage. Be sure otolith is sanded and polished to a flat plane without large bumps or grooves. Record data for each slide and deliver to lab for analysis with Electron Microprobe.
B. **For Aging**: The otolith must be etched to bring out the ring pattern for counting. Place a drop of 0.1N HCl onto the otolith surface for about 30 seconds. Wash with deionized water. Examine with compound microscope. If rings are well-defined, stop; otherwise, repeat etching for 30 seconds more. Count rings with compound microscope. Often a drop of water under cover slip will help define rings better.

SPURR recipe (Electron Microscopy Services, Inc.)

1. DER 736 Epoxy Resin (Polyglycol di-eposides)
2. NSA (Nonenyl succinic anhydride)
3. ERL-4206 (VCD – Vinyl cyclohexane dioxide)
4. DMAE (2-Dimethylamino) Ethanol

Add together first: 10g VCD, 26g NSA, and 6g DER 736 by weighing each in a plastic weigh boat on balance under fume hood. Add 0.4g of DMAE catalyst last, then mix well. Place resultant SPURR in labeled glass vials and keep frozen until use.

Appendix 4. Sampling data showing the number of fishes, Everglades crayfish (*Procambarus alleni*), and the riverine grass shrimp (*Palaemonetes paludosus*) by collection date, array, and directional trap during 2000.

	1			2			3			4			Grand Total
Date	E	N	W	E	N	W	E	N	W	E	N	W	
6/4/00							Dry	Dry	Dry	25	14	17	59
6/5/00							2	Dry	1	72	8	28	112
6/6/00							30	8	31	100	56	136	361
6/7/00							87	49	5	226	5	203	575
6/8/00							0	67	0	450	98	840	1457
6/9/00							240	34	12	1733	54	53	2126
6/10/00							24	39	0	740	18	30	851
6/11/00							40	19	Dry	168	10	40	278
6/12/00							2	57	76				135
6/13/00							1	19	208				228
6/14/00							0	21	0				23
6/15/00							4	8	1	49	80	91	233
6/16/00							0	3	0				5
6/19/00							Dry	Dry	Dry	20	16	17	56
6/20/00							Dry	Dry	Dry	18	8	11	40
6/22/00							Dry	Dry	Dry	95	18	22	138
6/23/00							Dry	Dry	Dry	34	14	29	80
6/26/00							31	13	33	71	15	54	217
6/27/00							3	54	29				86
6/28/00							11	34	53				98
6/29/00							61	57	21				139
6/30/00							Dry	4	9	43	3	30	90
7/1/00							8	3	11				22
7/2/00							1	9	Dry				11
7/3/00							113	14	80				207
7/4/00							41	1	158	90	1	1	292
7/5/00							51	8	305				364
7/6/00							37	10	137				184
7/7/00							78	Lost	591	35	11	42	757
7/11/00							13	21	55	65	4	11	169
7/14/00	0	2	154	125	131	207							620
7/15/00	0	0	0	106	60	104	53	23	42	228	49	17	685
7/16/00	Dry	4	Dry	52	12	8							78
7/17/00	0	3	1	121	74	120							320
7/18/00	Dry	7	Dry	2	15	17							43
7/19/00	0	2	0	4	21	236							265
7/20/00	11	5	0	0	11	15							44
7/21/00	Dry	Dry	Dry	4	3	3	17	7	12	168	32	20	269
7/25/00	Dry	Dry	Dry	3	Dry	1							8
7/28/00	Dry	Dry	Dry	Dry	Dry	Dry	92	4	20	453	0	20	596
8/1/00	17	17	Dry	65	7	185	171	15	19	30	2	23	552
8/4/00	36	50	Dry	110	40	144	226	4	24	58	5	42	740
8/8/00	19	35	173	558	14	92							891
8/11/00	3	12	236	52	22	32	151	6	13	59	5	7	598
8/15/00	13	11	40	97	15	49							225
8/18/00	35	10	41	17	1	58	504	11	21	42	8	3	751
8/22/00	50	13	127	38	3	71							302
9/1/00	0	9	0	58	64	32	59	4	19	16	0	18	282
9/8/00	Dry	Dry	Dry	Dry	Dry	Dry	34	16	1	24	4	25	110
9/15/00	15	19	4	82	99	42	122	12	12	78	5	67	557
9/22/00	15	27	512	30	117	30	439	18	17	111	1	11	1328
9/29/00	45	44	0	11	4	72	295	16	16	742	4	42	1292
10/6/00	12	11	15	26	0	23	58	7	17				170
10/13/00	4	7	30	5	0	17	31	6	226	22	34	11	394
10/20/00	28	5	22	13	52	24	84	1	41	244	3	5	522
10/27/00	45	34	0	19	9	26	94	8	19	140	7	13	415
11/3/00							15	8	2	404	5	4	438
11/10/00										1730	22	24	1776
11/17/00										461	28	75	564
11/24/00										55	12	133	200
12/1/00										23	118	69	210
12/8/00										0	11	7	19
12/15/00										1145	460	35	1640
12/22/00										8	50	21	79
12/30/00										5	43	33	81
Grand Total	359	332	1369	1601	779	1610	3332	724	2347	10281	1343	2380	26457

Appendix 5. On each sample date in 2000, from each array, the percentage of the total catch comprised by the five most abundant fishes, the Everglades crayfish (*Procambarus alleni*), and the riverine grass shrimp (*Palaemonetes paludosus*).

	ARRAY 1							ARRAY 2						
Date	*G. holbrooki*	*P. latipinna*	*F. confluentus*	*J. floridae*	*L. marginatus*	*P. alleni*	*P. paludosus*	*G. holbrooki*	*P. latipinna*	*F. confluentus*	*J. floridae*	*L. marginatus*	*P. alleni*	*P. paludosus*
07/14/00	37.2	5.1	3.2	42.9	0.0	0.0	0.0	28.3	0.9	1.7	60.0	0.6	2.2	0.0
07/15/00								27.4	1.1	0.4	42.2	0.4	3.3	0.0
07/16/00	50.0	0.0	0.0	0.0	0.0	50.0	0.0	12.5	2.8	4.2	66.7	1.4	11.1	0.0
07/17/00	25.0	0.0	0.0	25.0	0.0	50.0	0.0	15.2	0.0	0.0	78.7	0.0	2.2	0.0
07/18/00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
07/19/00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	13.0	0.0	0.0	77.0	0.4	6.9	0.0
07/20/00	12.5	0.0	0.0	18.8	0.0	56.3	0.0	15.4	0.0	0.0	19.2	0.0	61.5	0.0
07/21/00								10.0	0.0	0.0	10.0	0.0	80.0	0.0
07/25/00								0.0	0.0	0.0	0.0	0.0	100.0	0.0
08/01/00	11.8	17.6	8.8	41.2	2.9	8.8	0.0	21.8	32.3	1.9	29.2	1.2	3.9	0.4
08/04/00	44.2	3.5	2.3	41.9	1.2	3.5	0.0	31.6	0.3	0.7	10.5	52.4	0.3	0.0
08/08/00	40.1	49.8	4.4	0.9	1.3	0.0	0.0	36.7	43.2	0.9	0.2	12.7	0.3	0.0
08/11/00	35.5	48.2	4.0	5.6	1.2	2.8	0.0	8.5	0.9	4.7	8.5	32.1	5.7	0.0
08/15/00	59.4	14.1	0.0	9.4	4.7	3.1	0.0	3.7	0.0	0.6	0.0	68.9	1.2	0.0
08/18/00	34.9	17.4	5.8	0.0	5.8	0.0	3.5	3.9	0.0	1.3	0.0	67.1	0.0	0.0
08/22/00	22.1	14.2	2.6	44.7	5.3	1.1	1.6	2.7	0.0	0.0	0.9	78.6	0.0	0.0
09/01/00	11.1	11.1	66.7	0.0	0.0	11.1	0.0	16.2	16.2	28.6	14.3	0.0	7.1	0.0
09/15/00	57.9	2.6	10.5	0.0	15.8	5.3	0.0	40.4	0.0	3.1	28.7	4.5	1.3	0.0
09/22/00	85.9	1.1	2.2	9.4	0.4	0.4	0.0	15.3	1.1	8.5	49.7	12.4	2.3	0.0
09/29/00	49.4	7.9	9.0	13.5	1.1	16.9	0.0	40.2	4.6	10.3	3.4	11.5	20.7	0.0
10/06/00	0.0	15.8	39.5	7.9	7.9	10.5	5.3	0.0	0.0	22.4	2.0	24.5	16.3	0.0
10/13/00	0.0	2.4	0.0	51.2	22.0	0.0	0.0	0.0	4.5	0.0	0.0	68.2	0.0	0.0
10/20/00	14.5	0.0	0.0	5.5	3.6	52.7	7.3	3.4	0.0	15.7	51.7	7.9	0.0	0.0
10/27/00	44.3	0.0	1.3	25.3	0.0	15.2	0.0	11.1	0.0	7.4	0.0	5.6	16.7	5.6

Appendix 5. Continued

	ARRAY 3							ARRAY 4						
Date	*G. holbrooki*	*P. latipinna*	*F. confluentus*	*J. floridae*	*L. marginatus*	*P. alleni*	*P. paludosus*	*G. holbrooki*	*P. latipinna*	*F. confluentus*	*J. floridae*	*L. marginatus*	*P. alleni*	*P. paludosus*
06/04/00								12.5	0.0	0.0	17.9	0.0	69.6	0.0
06/05/00	0.0	0.0	0.0	0.0	0.0	100.0	0.0	5.6	0.0	0.0	7.4	0.0	86.1	0.0
06/06/00	11.6	0.0	2.9	52.2	0.0	31.9	0.0	23.3	1.0	6.8	49.7	9.2	6.8	2.4
06/07/00	4.3	0.0	7.1	87.9	0.0	0.7	0.0	41.0	2.1	1.2	49.1	3.7	2.8	0.0
06/08/00	40.3	1.5	6.0	50.7	0.0	0.0	0.0	81.8	0.8	0.5	11.8	4.1	0.5	0.0
06/09/00	75.5	0.0	10.1	12.6	0.0	1.7	0.0	89.0	2.3	0.1	2.7	4.3	1.1	0.1
06/10/00	25.4	0.0	9.5	63.5	0.0	1.6	0.0	86.7	1.0	0.3	0.3	6.2	2.3	0.0
06/11/00	11.9	6.8	8.5	61.0	0.0	0.0	0.0	21.6	8.7	2.3	4.1	40.8	8.7	0.0
06/12/00	60.0	0.0	0.7	36.3	0.7	2.2	0.0	44.1	9.1	1.8	1.4	26.8	5.5	0.0
06/13/00	89.9	5.7	1.8	2.2	0.0	0.0	0.0	35.8	0.0	0.0	5.7	30.2	5.7	0.0
06/14/00	47.6	0.0	14.3	33.3	4.8	0.0	0.0	27.0	0.0	5.4	2.7	48.6	0.0	13.5
06/15/00	53.8	7.7	7.7	15.4	0.0	15.4	0.0	63.0	3.7	4.4	0.0	15.6	8.1	0.0
06/16/00	33.3	0.0	0.0	0.0	0.0	0.0	0.0	11.7	1.3	2.6	1.3	79.2	3.9	0.0
06/26/00	19.5	0.0	9.1	37.7	5.2	20.8	0.0	12.1	2.1	1.4	0.7	77.9	3.6	0.7
06/27/00	31.4	7.0	3.5	14.0	9.3	0.0	0.0							
06/28/00	48.0	4.1	10.2	14.3	9.2	2.0	2.0							
06/29/00	21.6	5.0	9.4	33.1	0.7	3.6	0.0							
06/30/00	7.7	23.1	7.7	0.0	7.7	30.8	0.0	19.7	22.4	0.0	0.0	50.0	6.6	0.0
07/01/00	18.2	50.0	0.0	13.6	0.0	0.0	0.0							
07/02/00	0.0	20.0	20.0	60.0	0.0	0.0	0.0							
07/03/00	57.0	3.9	12.1	17.4	0.0	4.8	0.0							
07/04/00	68.0	0.0	16.0	4.0	3.5	3.5	0.0	20.7	0.0	3.3	33.7	27.2	8.7	0.0
07/05/00	0.0	0.0	0.0	100.0	0.0	0.0	0.0							
07/06/00	50.5	0.5	7.1	4.3	2.2	16.3	0.5							
07/07/00	74.9	3.0	7.0	2.4	0.3	0.3	0.0	0.0	0.0	3.4	6.8	75.0	14.8	0.0
07/11/00	25.8	12.4	1.1	1.1	19.1	2.2	0.0	46.3	16.3	5.0	12.5	8.8	1.3	0.0
07/15/00	25.4	15.3	7.6	3.4	17.8	3.4	23.7	28.6	31.6	1.7	3.1	3.4	5.1	13.3
07/21/00	36.1	8.3	36.1	0.0	0.0	11.1	8.3	21.4	59.1	4.5	4.5	0.0	4.5	2.3
07/28/00	59.5	0.0	0.0	0.0	22.4	7.8	0.9	59.2	33.8	0.0	0.0	0.8	3.6	0.8
08/01/00	56.1	4.9	28.8	1.0	2.4	4.9	0.0	27.3	3.6	0.0	0.0	60.0	1.8	0.0
08/04/00	43.3	2.4	2.0	0.0	46.9	1.6	1.2	19.0	21.0	0.0	1.0	54.3	1.0	0.0
08/11/00	42.4	27.1	3.5	0.6	16.5	1.8	4.7	52.1	2.8	2.8	0.0	33.8	0.0	1.4
08/18/00	75.7	10.8	3.4	0.9	5.2	0.2	0.4	5.7	0.0	3.8	0.0	56.6	1.9	5.7
09/01/00	70.7	7.3	9.8	2.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	67.6	5.9	0.0
09/08/00	37.3	7.8	35.3	5.9	0.0	9.8	0.0	52.8	22.6	0.0	0.0	7.5	7.5	0.0
09/15/00	69.9	2.7	4.1	0.0	17.8	2.1	0.0	22.7	0.7	29.3	2.0	30.0	7.3	3.3
09/22/00	84.0	3.4	2.5	3.0	1.9	0.4	1.7	72.4	4.1	0.0	0.0	17.1	4.1	0.8
09/29/00	72.2	2.1	4.6	2.4	8.6	7.3	0.3	94.0	1.9	0.0	0.1	1.8	1.3	0.6
10/06/00	6.1	1.2	9.8	0.0	51.2	12.2	4.9							
10/13/00	0.4	0.0	0.4	0.0	0.4	3.8	24.8	0.0	0.0	4.5	32.8	35.8	4.5	1.5
10/20/00	51.6	0.8	0.8	1.6	5.6	24.6	0.0	91.7	0.0	0.8	0.8	0.0	1.6	0.4
10/27/00	28.9	0.0	13.2	30.6	2.5	9.9	3.3	41.9	0.0	0.0	3.8	18.8	5.0	0.0
11/03/00	20.0	0.0	8.0	0.0	4.0	28.0	4.0	96.4	0.5	0.0	0.2	0.0	0.5	1.0
11/10/00								96.5	0.2	0.1	0.1	1.0	0.5	0.3
11/17/00								73.6	0.0	0.4	0.4	12.9	2.7	6.2
11/24/00								28.5	0.0	3.5	1.0	5.0	29.0	25.5
12/01/00								44.3	0.0	18.1	7.6	0.5	22.9	4.8
12/08/00								16.7	0.0	22.2	11.1	0.0	27.8	0.0
12/15/00								60.2	0.7	0.7	1.2	0.3	1.8	34.3
12/22/00								50.6	1.3	3.8	15.2	0.0	6.3	15.2
12/30/00								22.2	7.4	27.2	3.7	0.0	2.5	30.9

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Appendix 6. Sampling data showing the number of fishes, Everglades crayfish (*Procambarus alleni*), and riverine grass shrimp (*Palaemonetes paludosus*) by collection date, array, and directional trap during 2001.

ARRAY	1			2			3			4			5				6				Grand Total
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	S	W	E	N	S	W	
06/05/01				2	0	2	0	3	6	0	0	1	4	8	1	6	2	8	0	0	43
06/07/01				1	0	1	1	2	0	0	0	0	1	1	0	1	0	1	0	2	11
06/08/01				0	0	0	0	0	0	0	0	0	1	3	1	3	0	1	0	0	9
06/09/01													1	5	2	2					10
06/10/01													3	5	3	14					25
06/11/01				0	0	0	0	0	0	0	0	0	6	7	1	5	0	0	1	0	20
06/12/01				0	0	0	0	0	0	0	0	0	2	1	0	5	0	1	0	0	9
06/13/01				0	0	0	0	0	0	0	0	0	4	0	1	4	0	0	0	0	9
06/14/01				0	0	0	0	0	0				2	2	5	0					9
06/15/01				0	0	0	0	0	0	0	0	0	1	1	2	3	0	0	0	0	7
06/16/01				0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	5
06/17/01				0	0	0	0	0	0	0	1	0	0	0	3	2	0	0	0	0	6
06/18/01				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06/19/01				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06/20/01				0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0	6
07/10/01										0	2	28	29	50	2	28					139
07/11/01										53	101	128	133	21	12	22	1	0	0	3	474
07/12/01										62	47	150	32		49	54	1	0	0	0	395
07/13/01										111	20	146	45	109	23	63					517
07/14/01							0	0	0	68	25	13	62	324	74	107	0	0	0	2	675
07/15/01							0	0	0	29	29	141	91	126	30	55	0	0	0	1	502
07/16/01							7	9	2	45	23	295	160	111	33	47	0	2	0	13	747
07/17/01							0	0	1	171	12	158	81	265	38	82	0	1	0	3	812
07/18/01							0	16	1	68	5	110	79	252	53	143	0	0	1	3	731
07/19/01							6	12	122	87	10	119	126	93	95	66	17	6	0	17	776
07/20/01							19	9	58	125	5	125	124	135	16	80	8	5	0	20	729
07/21/01							65	21	95	260	28	177	95	62	30	43	43	46	92	28	1085
07/22/01							212	64	80	61	8	184	56	135	12	125	248	78	209	34	1506
07/23/01				1	1	6	138	17	9	127	8	99	45	114	6	159	316	31	12	106	1195
07/24/01				1	2	0	67	9	15	14	2	45	39	90	8	128	91	20	30	12	573
07/26/01				0	1	0	25	1	26								58	5	0	11	127
07/27/01				0	0	0	105	0	3	143	2	13	174	40	56	28	53	8	2	4	631
07/28/01							57	3	11								19	8	5	6	109
07/29/01							43	0	0								7	4	3	7	64
07/30/01							9	3	0								1	4	1	5	23
07/31/01							1	1	0	83	37	44	77	61	27	36	3	1	0	1	372
08/01/01							12	11	32								3	1	0	4	63
08/02/01	8	0	0	88	3	15															114
08/03/01	80	11	2	245	82	206	172	7	335	17	9	12	26	47	45	34	19	49	17	15	1430
08/04/01	55	10	1980	118	14	199															2376
08/05/01	88	1	194	144	31	103															561
08/06/01	43	1	346	83	31	77															581
08/07/01	7	0	78	1	16	121	46	30	83	27	3	12	11	13	23	91	34	58	61	62	777

08/08/01	6	1	14	2	6	66															95
Appendix 6 continued																					
ARRAY	**1**			**2**			**3**			**4**			**5**				**6**				**Grand**
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**Total**
08/11/01	15	1	0	68	16	53															153
08/12/01	22	2	117	248	14	28															431
08/13/01	3	1	0	119	13	40															176
08/14/01	0	0	0	45	4	30	32	31	32								35	12	2	10	233
08/15/01	11	7	10	47	13	75															163
08/16/01	32	4	13	73	35	19															176
08/17/01	10	6	7	36	7	28	73	34	3	35	39	44	163	59	21	20	29	11	16	16	657
08/21/01	1	0	0	0	0	0															1
08/24/01	5	2	0	0	6	12	142	28	59	21	4	12	58	80	7	39	12	52	42	16	597
08/28/01	0	0	2	0	0	0															2
08/31/01	0	0	0	0	0	0	8	17	24	18	6	13	159	49	24	20	54	5	2	10	409
09/07/01	0	0	0	0	0	0	174	24	7	9	5	31	126	53	19	42	182	18	38	12	740
09/11/01	25	5	31	191	86	221															559
09/14/01	44	27	31	895	261	307	395	82	4	24	4	20	518	12	38	27	152	21	35	41	2938
09/21/01	20	8	257	98	25	163	600	17	13	49	0	45	767	31	5	29	719	35	51	23	2955
09/28/01	0	11	32	0	0	1	121	37	5	2	1	20	76	4	3	32	118	13	16	6	498
10/05/01	35	63	15	111	70	471	1837	7	9	21	11	12	37	6	9	17	590	14	11	15	3361
10/12/01	17	0	26	29	15	40	236	0	20	7	9	13	1	5	1	14	53	9	0	8	503
10/19/01	66	55	27	82	177	184	342	268	2	7	1	7	89	22	9	22	10	668	6	10	2054
10/26/01	10	13	253	4	8	12	1091	50	20	3	2	7	2	9	6	9	5	13	63	6	1586
11/02/01	40	34	22	37	51	58	993	9	16	34	0	23	4	1	0	13	483	7	46	16	1887
11/09/01	24	59	67	181	79	36	331	14	7	40	7	9	512	8	215	22	828	12	62	9	2522
11/16/01	1	93	25				33	11	11	17	3	21	18	18	244	15	792	13	19	9	1343
11/23/01							102	10	0	9	12	15	16	30	125	20	17	2	2	9	369
11/30/01										1	2	17	101	237	152	100					610
12/07/01										2	3	18	50	70	15	61					219
12/14/01							222	21	2	1	3	8	96	31	27	23	382	7	32	11	866
12/21/01							0	1	0	5	0	6	54	72	119	55	1	1	0	1	315
12/31/01										22	7	14	2	1	5	4					55
01/04/02				0	0	1	144	14	25	5	1	23	155	22	209	20	134	8	16	12	789
01/11/02							0	19	0	1	7	32	268	39	44	61	11	0	2	3	487
01/18/02										11	6	12	110	72	131	34					376
01/25/02										47	17	29	0	0	7	0					100
02/01/02										185	65	106									356
02/08/02										25	58	132									215
02/15/02										59	22	46									127
02/22/02										41	164	139									344
03/01/02										30	25	19									74
03/08/02										151	53	63									267
03/15/02										39	104	31									174
03/22/02										19	11	53									83
04/05/02							0	1	1	56	52	37	5	72	5	2					231
04/12/02										13	83	109									205
Grand Total	**694**	**419**	**3551**	**3123**	**1099**	**2678**	**7952**	**943**	**1174**	**2574**	**1184**	**3192**	**4906**	**3147**	**2101**	**2147**	**5616**	**1351**	**961**	**638**	**49450**

Appendix 6 continued.

ARRAYS	7				8				9				10				Grand
Date	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	Total
06/07/01													0	3	1	2	6
06/08/01					20	0	27	14									61
06/22/01					35	19	25	22					24	5	27	28	185
07/14/01					34	20	16	17					2	3	20	7	119
08/04/01	0	0	0	0					0	0	0	0					0
08/14/01					24	25	16	21					31	47	10	34	208
09/20/01	0	0	0	0					0	1	1	0					2
09/27/01					15	11	38	11					3	11	36	13	138
10/03/01	0	24	62	83					44	71	36	38					358
10/19/01	0	0	0	0					0	0	0	0					0
10/23/01	33	43	0	336	13	14	14	13	59	111	21	0	5	9	10	5	686
10/26/01	0	4	0	7					17	0	4	0					32
11/28/01					12	274	7	20					3	3	9	22	350
Grand Total	**33**	**71**	**62**	**426**	**153**	**363**	**143**	**118**	**120**	**183**	**62**	**38**	**68**	**81**	**113**	**111**	**2145**

	11				12				13				Grand
Date	E	N	S	W	E	N	S	W	E	N	S	W	Total
06/07/01	17	8	47	103									175
06/08/01	7	4	139	4					0	106	46	0	306
06/22/01	3	6	33	8					8	173	74	69	374
07/14/01	84	14	116	224	37	124	52	11	27	242	7	74	1012
08/14/01	20	23	44	14	9	37	60	8	18	4	8	33	278
09/11/01					6	6	20	18	11	2	0	14	77
09/27/01	7	1	8	1	1	10	20	17	1	5	4	6	81
10/23/01	2	0	9	6	7	12	27	10	12	8	6	8	107
11/28/01	2	1	26	17	7	1	8	8	10	19	1	34	134
Grand Total	**142**	**57**	**422**	**377**	**67**	**190**	**187**	**72**	**87**	**559**	**146**	**238**	**2544**

Appendix 7. On each sample date from each array by direction in 2001, the percentage of the total catch comprised by the five most abundant fish species, and the Everglades crayfish (*Procambarus alleni*), and riverine grass shrimp (*Palaemonetes paludosus*).

Array1	*G. holbrooki*			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
08/02/01	75.0																		25.0					
08/03/01	79.6	4.3	1.1							5.4	3.2	1.1							1.1	1.1			3.2	
08/04/01	2.2	0.4	95.0			0.0	0.0		0.2	0.1		1.1	0.0		0.4							0.2	0.0	
08/05/01	14.8		45.6			0.4			1.1	15.2	0.4	8.8	0.4		10.2			0.4	0.4					1.8
08/06/01	9.0	0.3	87.4						0.5	1.0						0.3			0.5		0.3	0.3		0.5
08/07/01	1.2		77.6						5.9	2.4					5.9				1.2			3.5		
08/08/01	14.3	4.8	9.5			9.5			38.1	9.5														4.8
08/09/01			25.0						25.0														25.0	
08/10/01	21.4			3.6						25.0	3.6		3.6						35.7				3.6	
08/11/01	37.5	6.3		6.3						18.8														
08/12/01	7.1	1.4	65.2			4.3			2.8	5.7					3.5			0.7	2.8		0.7			5.7
08/13/01										25.0			25.0						25.0	25.0				
08/14/01																								
08/15/01	7.1	17.9	14.3	10.7					3.6	7.1		7.1							10.7	7.1				
08/16/01	51.0	8.2	2.0	2.0			2.0		2.0	4.1		10.2						2.0	6.1		10.2			
08/17/01	17.4	26.1	13.0						4.3	8.7									13.0		8.7			
08/21/01																								
08/24/01	71.4																			28.6				
08/28/01			100.0																					
08/31/01																								
09/11/01	39.3	6.6	45.9			1.6													1.6	1.6	3.3			
09/14/01	35.3	22.5	24.5	1.0	1.0			1.0	1.0										5.9	2.0	4.9	1.0		
09/21/01	1.4	1.1	83.2			0.7		0.4	1.8			3.9							5.6	1.1	0.4			
09/28/01		18.6	48.8					4.7	16.3		2.3										9.3			
10/05/01	23.0	50.4	6.2	1.8	0.9	0.9	0.9		1.8	0.9		0.9			0.9				3.5		0.9		4.4	0.9
10/12/01	7.0		37.2			2.3	2.3		2.3	2.3		14.0				7.0			18.6					
10/19/01	35.1	27.7	12.2				7.4	7.4	4.1		0.7	2.0							1.4	0.7				
10/26/01	1.4	1.4	85.9			0.4		2.9	0.4						0.4		0.4	0.7	0.4		1.1			1.4
11/02/01	20.8	31.3	8.3	1.0			1.0	2.1	1.0	6.3	1.0								2.1		2.1	9.4		7.3
11/09/01	4.0	10.0	36.7				4.0	4.0	2.0	7.3	24.0	1.3			0.7					0.7	0.7			0.7
11/16/01	0.8	69.7	17.6					2.5			2.5												2.5	

Appendix 7, Continued

Array2	*G. holbrooki*			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/05/01																			50.0		50.0			
06/07/01																			50.0		50.0			
06/08/01																								
06/11/01																								
06/15/01																								
06/16/01																								
06/17/01																								
06/18/01																								
06/19/01																								
06/20/01																								
07/23/01																			12.5	12.5	75.0			
07/24/01																			33.3	66.7				
07/25/01																					100.0			
07/26/01																				100.0				
07/27/01																								
08/02/01	69.8	0.9	9.4							12.3									0.9	1.9	4.7			
08/03/01	34.0	10.3	29.1						3.6	11.6	4.1	5.6	0.4	0.6	0.2					0.4				
08/04/01	15.1		27.5							16.9	3.9	31.1	2.4		0.9				1.2	0.3				
08/05/01	23.7	3.6					0.4	1.1	0.7	22.7	5.8	34.2				4.3	0.4	1.8	0.7	0.4				
08/06/01	22.5	5.2	19.4			1.0		1.0	0.5	8.9	5.2	15.2			2.1	4.2	3.7	0.5	0.5		1.6			
08/07/01	0.7	1.4	42.8		0.7				0.7		8.0	34.8			4.3		1.4	1.4			1.4			
08/08/01			59.5			4.1	1.4	1.4			5.4	4.1			8.1				1.4		2.7			
08/09/01	48.8	0.5	3.9	0.5	1.5		0.5		0.5	3.4	2.9	29.3					0.5	0.5	0.5					
08/10/01	9.8	2.0	3.9	27.5	2.9	1.0				2.0	7.8	4.9	2.9		2.0	2.9	2.9	6.9	2.9		4.9			
08/11/01	21.2	2.9	21.9	19.7	1.5	4.4		0.7		5.8	2.9	2.9	0.7		2.2		2.2	1.5						
08/12/01	39.3		2.1	15.5	1.4					23.1	2.4	2.8	0.3		0.3	3.8	0.7	0.7	0.3		3.8	0.3		
08/13/01	47.1	1.7	12.8	14.5				1.7		1.2	2.9		2.3		0.6	1.7		6.4		0.6	0.6	0.6		
08/14/01	22.8		20.3	6.3	2.5	3.8	2.5			5.1	1.3	2.5	1.3			3.8		2.5			5.1			
08/15/01	15.6	4.4	37.0	2.2		3.0	4.4	1.5	1.5	4.4	2.2	10.4						0.7			0.7	4.4		
08/16/01	23.6	15.0	0.8	8.7	1.6	0.8	7.1	1.6		4.7	3.1	3.9				1.6			0.8	1.6	9.4		0.8	
08/17/01	12.7		7.0	1.4			2.8			15.5									4.2	1.4	32.4	1.4		
08/21/01																								
08/24/01			55.6					5.6	11.1											22.2				
08/28/01																								
08/31/01																								
09/07/01																								
09/11/01	36.9	13.9	40.2			0.2		2.0	0.4	0.4	0.8	1.6	0.2		0.2				0.6	0.4	1.0			
09/14/01	60.5	17.5	19.5	0.1	0.1	0.1		0.1	0.3		0.1					0.1		0.1			0.1			
09/21/01	16.4	7.3	48.3	0.3			8.0		0.7	2.8						2.1		0.3						
09/28/01			100.0																					
10/05/01	10.7	3.7	71.2	4.0	0.3		0.2	4.1			2.6					0.8								
10/12/01	15.5	14.3	35.7				6.0				2.4	1.2				8.3			1.2		4.8			
10/19/01	14.0	35.9	39.5	0.9	0.7		1.6	1.1		1.1	1.1								0.5		1.6			
10/26/01		12.5						16.7								8.3		25.0			8.3			
11/02/01	11.6	26.7	32.2				1.4		2.1	3.4	3.4							0.7	0.7		2.1		2.1	
11/09/01	57.4	11.1	3.0				0.3	1.0		1.7	8.4								0.7	1.0	8.1	1.0	5.1	0.3
01/04/02																					100.0			

Appendix 7 Continued

Array3	*G. holbrooki*			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/05/01																				33.3	66.7			

06/07/01		66.7																	33.3					
06/08/01																								
06/11/01																								
06/12/01																								
06/13/01																								
06/14/01																								
06/15/01																								
06/16/01																								
06/17/01																								
06/18/01																								
06/19/01																								
06/20/01																								
07/14/01																								
07/15/01																								
07/16/01										5.6	11.1								33.3	38.9	11.1			
07/17/01																					100.0			
07/18/01		5.9						35.3			47.1										5.9			
07/19/01	0.7	0.7	82.9				1.4		1.4	1.4	3.6	1.4							0.7	4.3	0.7			
07/20/01	10.5	3.5	62.8				4.7	4.7	1.2	5.8	2.3	2.3							1.2		1.2			
07/21/01	16.0	5.0	39.2				2.8	1.7	1.1	2.2	2.2	6.1			1.7			0.6	14.9	2.2	2.8			0.6
07/22/01	28.7	9.8	16.3			0.3	1.7	1.7		8.1	5.3	2.8			2.0				21.1	0.8	0.8			
07/23/01	37.8	3.7	1.8				2.4			8.5	3.7	1.8			0.6				34.1	3.0	0.6			
07/24/01	7.7	4.4	2.2	2.2						19.8	3.3	13.2	23.1			1.1			18.7	2.2	1.1			
07/25/01	8.6	2.9	5.7							5.7	11.4	2.9	5.7						2.9		31.4	14.3		5.7
07/26/01	7.7		34.6	5.8		3.8	15.4	1.9		11.5		3.8			3.8				1.9			5.8		
07/27/01	89.8			0.9						4.6		0.9							1.9		1.9			
07/28/01	63.4	4.2	1.4				2.8			9.9		8.5	1.4		1.4	1.4					1.4			
07/29/01	81.4			2.3			11.6			4.7														
07/30/01	25.0	8.3								33.3									8.3	16.7				
07/31/01																				50.0				
08/01/01	18.2	16.4	58.2				3.6	3.6																
08/03/01	24.3		59.7				0.2		0.2	0.2		1.9		0.4	2.9	1.4			6.6	1.0	0.4			
08/07/01	21.4	5.7	38.4		2.5			0.6		5.0	8.8	10.1		0.6	2.5		0.6	0.6	1.3			1.3		
08/10/01	23.1	9.1	9.9	13.2	3.3	0.8	9.1	3.3		12.4	4.1				1.7	1.7			3.3		2.5	0.8		
08/14/01	29.5	29.5	12.6		2.1		3.2			1.1		17.9			1.1					1.1				
08/17/01	26.4	21.8	0.9	22.7	6.4		6.4			4.5	2.7					2.7			0.9		1.8	0.9		
08/24/01	51.5	4.8	7.9	2.6	2.2		1.7	3.1		3.1	1.3	17.0				0.4	0.4		0.4	0.4	0.9	1.7		
08/31/01	6.1	26.5	26.5		4.1	4.1	2.0	2.0	2.0	8.2	2.0	14.3									2.0			
09/07/01	83.9	5.4	0.5				1.0	0.5			2.9						0.5	0.5		2.0	2.4			
09/14/01	81.1	13.7	0.2		0.4	0.2	0.2	2.1									0.2		0.2	0.4	0.4	0.4		
09/21/01	93.8	1.6	0.3	0.5			0.3	0.2		0.6	0.3						0.2	0.3		0.5	0.6			0.3
09/28/01	68.7	16.6		0.6	3.1		2.5	1.2			0.6										3.1			
10/05/01	98.7	0.2	0.3	0.1			0.1			0.1	0.1					0.1					0.1	0.2	0.1	0.1
10/12/01	86.7		1.6	1.2			2.7		0.4	0.4		0.8						0.4			0.8	0.8		2.3
Array3	*G. holbrooki*			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
10/19/01	55.6	42.8					0.2													1.0	0.3			
10/26/01	93.2	1.8	0.3					0.3			2.2	1.2									0.2	0.6		
11/02/01	96.8	0.4						0.3			0.1			0.1							1.5	0.4		0.1
11/09/01	89.5			0.3	1.7			0.9		0.3	0.9						0.3				2.0	2.0		
11/16/01	16.4	16.4	3.6										14.5	3.6							9.1	29.1		7.3
11/23/01	84.8	4.5						0.9		1.8	1.8		3.6	1.8										

12/14/01	75.9	1.2	0.4				0.4	2.9		2.0	2.4		4.5				1.2				0.4	5.7	0.8	
12/21/01																							100.0	
01/04/02	10.9	3.3					0.5	1.1		0.5			2.7						0.5	2.7	10.9	60.7		
01/11/02		31.6						5.3			26.3			26.3									10.5	
04/05/02		50.0																			50.0			

Appendix 7 Continued

Array4	*G. holbrooki*			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/05/01																					1.0			
06/07/01																								
06/08/01																								
06/11/01																								
06/12/01																								
06/13/01																								
06/15/01																								
06/16/01																								
06/17/01																				1.0				
06/18/01																								
06/19/01																								
06/02/01																				1.0				
07/01/01		3.3							6.7		3.3	23.3			3.3						6.0			
07/11/01	14.5	25.2	6.4				0.8		0.8	2.1	7.4	5.7	1.6	0.8	0.8					1.6	3.1	0.4	1.4	1.4
07/12/21	0.4	8.9	9.3	0.8			0.4	0.4		21.2	6.9	44.4		0.8	1.2				0.4	0.8	1.2	0.8	0.4	1.5
07/13/01			4.3							17.7	5.8	28.9			0.4				16.2	1.4	18.8			0.4
07/14/01	35.8	14.2	0.9							26.4	8.5	0.9							0.9	0.9	1.4			
07/15/01	5.5	3.5	11.6							6.5	4.2	15.8							2.5	7.4	44.7			
07/16/01	0.6		5.0							6.7	3.6	52.9			0.3				5.8	2.8	23.1			
07/17/01	4.7		2.9		0.3					3.8	1.8	34.2							14.4	1.2	7.9			
07/18/01	17.5		8.7						0.5	18.6	2.2	46.4			0.5			0.5	0.5	0.5	1.6	0.5		0.5
07/19/01	14.4		12.5						0.5	21.3	2.8	4.3				0.9		0.5	3.2	1.4	1.4			
07/02/01	13.3	0.4	1.2	0.4			0.4		1.6	32.9	1.2	46.0	0.4					0.8	0.8	0.4	0.4	0.4		
07/21/01	16.3		15.7				0.4	0.2	0.4	28.6	1.9	19.8				0.2	0.2		1.3	3.7	2.2			
07/22/01	0.4	0.4	2.4						0.4	2.9	1.6	64.3							2.4	1.2	5.9			
07/23/01	15.8		2.6						1.3	3.3		35.4							6.0	3.4	3.4			
07/24/01			3.3				1.6					6.7						1.6	9.8	3.3	8.2			
07/27/01	36.8		1.3	3.8			1.3			43.4		5.7				1.3			1.9	1.3	1.3	1.9		
07/31/01	9.1	7.0	9.1		1.8					27.4	6.8	15.2				1.8	0.7	0.7	6.8	2.4	0.7	1.2	4.3	1.2
08/03/01	7.9		2.6							2.6						2.6		13.2	5.3	7.9	13.2	26.3	15.8	
08/07/01			4.8			2.4				14.3		9.5				4.8		2.4	19.5	4.8	9.5		2.4	
Array4																								
	G. holbrooki			*P. latipinna*			*F. confluentus*			*J. floridae*			*H. formosa*			*L. marginatus*			*P. alleni*			*P. paludosus*		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
08/01/01		2.6	2.6		31.6				2.6	7.9	5.3	2.6				2.6		2.6	2.6	5.3	5.3	1.5		
08/17/01	2.5	21.2	11.2		4.2					4.2	2.5	2.5				4.2			5.8	0.8	23.7	2.5	4.2	
08/24/01	2.7											2.7				13.5		2.7	1.8		21.6		1.8	
08/31/01	2.7	2.7	8.2				5.5				2.7					18.9			16.2	1.8	21.6			
09/07/01			4.4				2.2									2.2		13.3	13.3	6.7	48.9			
09/14/01	8.3		6.3							2.8						22.9	4.2	6.3	4.2	4.2	29.2			
09/21/01									2.1							1.6								
09/2801																			4.3		87.0			
01/05/01	2.3	4.5	4.5													6.8	2.3			18.2	2.5			

01/1201																1.3	6.9		6.9	17.2	41.4			
01/19/01	33.3						6.7										6.7				46.7			
01/26/01																			8.3	16.7	58.3			
11/0201			1.8							1.8						36.8			1.8		38.6			
11/09/01	1.8								5.4							1.8			7.1		5.4			
11/16/01	34.1																		4.9		48.8			
11/23/01																	5.6		11.1	13.9	33.3			
11/03/01									5.0			5.0						5.0	5.0		6.0		1.0	
12/07/01		8.7															4.3		8.7		69.6			
12/1401																			8.3		41.7			16.7
12/21/01																			45.5		27.3			27.3
12/03/01				4.7			14.0		11.6	7.0						4.7	2.3	11.6	11.6	11.6	9.3			
01/0402						3.4			1.3			13.8							3.4		27.6	13.8		
01/11/02					1.0				5.0		2.5						2.5	55.0			1.0			
01/18/02								3.4	1.3							17.2	3.4	3.4	6.9		27.6			
01/25/02		1.8	3.2	1.8				3.2	2.2			1.8				3.2	2.2	1.8	1.8		21.6			
02/01/02	49.2	9.6	21.9	0.6	0.3	0.6			0.6		0.3										3.7	0.6	7.9	0.6
02/08/02	4.2	19.7	4.5		0.5			3.7	0.5	1.9	0.9	1.9							3.3	0.9	4.2	1.9	0.9	12.9
02/15/02	5.5	8.7	7.9	7.9			9.4	3.1								4.7			0.8		28.3	17.3	2.4	
02/22/02	0.9	41.3	28.5					2.3	0.3		0.6	0.9			3.8				0.9		3.8	9.9	2.3	
03/01/02	14.9	6.8	1.4	2.7	14.9			2.7			6.8										23.0	23.0		
03/08/02	12.7	2.6	12.4	15.7	2.6		3.0	1.5	1.5	1.5	0.4	1.1							0.7		6.7	22.8	12.0	0.7
03/15/02	0.6	0.6	2.9	1.7				0.6	1.7										0.6	1.7	6.3	18.4	56.9	5.7
03/2202	8.4	7.2	25.0			2.5	2.5	3.6	8.4	2.5	1.2	2.5							2.5		1.8	7.2	1.2	14.5
04/05/02	1.4	1.4																2.7		0.7	22.7	35.9	33.1	
04/12/02	2.9	1.2	5.4	0.5	1.0		1.5	0.5			1.5				0.5						2.4	1.5	27.3	44.9

Appendix 8. Sampling data showing the CPUE of fishes by collection date, array, and directional trap during 2002.

2002	1			2			3			4			5				6				TOTALS
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	S	W	E	N	S	W	
05/30/02	-	-	-	-	-	-	-	-	-	84	39	150	-	-	-	-	-	-	-	-	273
05/31/02	-	-	-	-	-	-	-	-	-	50	52	4	-	-	-	-	-	-	-	-	106
06/01/02	-	-	-	-	-	-	-	-	-	90	127	364	40	195	13	7	-	-	-	-	836
06/02/02	-	-	-	-	-	-	-	-	-	77	68	125	788	573	231	213	-	-	-	-	2075
06/03/02	-	-	-	-	-	-	-	-	-	53	78	161	275	339	106	157	-	-	-	-	1169
06/04/02	-	-	-	-	-	-	-	-	-	219	36	109	374	353	447	673	-	-	-	-	2211
06/05/02	-	-	-	-	-	-	0	92	0	350	66	119	513	234	139	136	26	0	1	0	1676
06/06/02	-	-	-	-	-	-	0	35	0	919	29	268	59	99	11	42	0	0	1	0	1463
06/07/02	-	-	-	-	-	-	612	34	0	194	18	20	86	493	64	228	0	47	29	0	1825
06/08/02	-	-	-	-	-	-	6	66	155	9	10	98	116	196	67	84	144	159	70	198	1378
06/09/02	-	-	-	0	0	0	142	5	106	19	21	19	767	237	97	149	145	70	102	35	1914
06/10/02	-	-	-	0	0	0	209	24	87	20	15	16	691	137	109	89	356	21	135	20	1929
06/11/02	-	-	-	0	0	0	393	36	204	401	29	45	203	57	21	42	233	21	71	28	1784
06/12/02	-	-	-	0	0	0	32	54	71	88	61	29	95	40	15	37	132	21	31	41	747
06/13/02	-	-	-	0	0	0	29	11	0	8	13	18	52	63	21	46	104	20	8	38	431
06/14/02	-	-	-	0	0	0	54	0	0	3	146	5	45	114	24	73	106	18	28	57	673
06/15/02	-	-	-	0	0	0	20	10	0	2	24	23	11	42	8	63	63	27	1	34	328
06/16/02	17	1	0	10	0	0	167	52	260	7	29	0	2	76	2	74	63	75	48	50	933
06/17/02	4	35	0	141	16	91	221	29	778	-	-	-	-	-	-	-	75	57	84	120	1651
06/18/02	6	14	1	118	64	183	83	21	409	14	36	15	38	52	11	50	54	29	43	68	1309
06/19/02	326	0	0	168	37	504	53	16	145	-	-	-	-	-	-	-	42	25	31	71	1418
06/20/02	150	0	1	365	58	14	49	16	124	-	-	-	-	-	-	-	13	28	3	79	900
06/21/02	332	22	2	50	1	325	11	15	83	14	2	16	1	13	3	46	3	21	1	0	961
06/22/02	124	27	618	57	25	171	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1022
06/23/02	246	0	47	105	79	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	525
06/24/02	156	3	36	84	32	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	333
06/25/02	23	3	64	27	18	42	3	8	80	32	0	1	4	20	0	18	3	5	0	18	369
06/26/02	8	2	19	40	10	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	119
06/27/02	34	0	2	46	11	61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	154
06/28/02	68	9	29	84	7	29	4	5	47	1	0	0	5	4	0	29	0	22	8	0	351
06/29/02	29	4	47	48	0	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	196
06/30/02	24	4	17	46	6	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	115
07/01/02	17	5	1	62	8	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	136
07/02/02	37	12	130	60	1	26	34	0	42	-	-	-	-	-	-	-	4	12	0	3	361
07/03/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
07/05/02	11	8	45	85	2	54	38	1	22	2	3	1	2	1	1	9	6	17	2	0	310
07/09/02	34	1	58	28	6	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	133
07/12/02	23	3	832	23	3	58	7	0	69	2	7	2	0	13	0	5	4	82	0	0	1133
07/19/02	286	10	28	6	23	32	61	4	84	2	1	2	0	5	0	2	66	21	15	12	660
07/26/02	6	6	9	62	15	61	457	32	7	42	5	5	0	21	0	3	225	4	49	24	1033
08/02/02	32	37	50	87	34	35	57	9	0	9	17	5	96	41	2	1	10	0	1	36	559
08/09/02	-	-	-	-	-	-	-	-	-	0	4	7	17	5	1	1	-	-	-	-	35
08/16/02	-	-	-	-	-	-	8	7	2	6	4	11	5	4	1	0	4	1	6	205	264
08/23/02	-	-	-	-	-	-	131	7	0	1	0	3	7	3	9	0	90	1	1	2	255
08/25/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
08/30/02	-	-	-	-	-	-	11	2	2	1	4	0	3	1	0	3	0	2	0	2	31
09/06/02	0	0	0	0	0	4	250	0	3	1	3	0	5	3	0	0	42	1	0	1	313
09/13/02	-	-	-	-	-	-	17	0	0	0	4	4	0	0	1	3	1	1	0	0	31
09/20/02	-	-	-	-	-	-	-	-	-	0	0	0	4	19	0	6	-	-	-	-	29
09/27/02	-	-	-	-	-	-	-	-	-	0	1	3	5	0	2	0	-	-	-	-	11
10/04/02	-	-	-	-	-	-	-	-	-	0	0	4	22	34	4	6	-	-	-	-	70
10/11/02	-	-	-	-	-	-	-	-	-	0	1	2	1	0	0	1	-	-	-	-	5
10/18/02	-	-	-	-	-	-	-	-	-	5	3	3	181	1	7	22	-	-	-	-	222
10/25/02	-	-	-	-	-	-	-	-	-	1	2	20	14	0	7	4	-	-	-	-	48
11/01/02	-	-	-	-	-	-	-	-	-	0	1	17	0	4	2	1	-	-	-	-	25
11/08/02	-	-	-	-	-	-	-	-	-	218	12	15	-	-	-	-	-	-	-	-	245
11/15/02	-	-	-	-	-	-	-	-	-	170	47	26	-	-	-	-	-	-	-	-	243
11/22/02	-	-	-	-	-	-	0	0	0	45	24	44	1	9	0	0	0	0	0	0	123
11/29/02	-	-	-	-	-	-	-	-	-	15	2	0	-	-	-	-	-	-	-	-	17
12/06/02	-	-	-	-	-	-	-	-	-	30	22	33	-	-	-	-	-	-	-	-	85
12/13/02	-	-	-	2	7	0	10	0	1	10	4	35	1	0	0	0	33	1	2	0	106
12/20/02	-	-	-	-	-	-	6	2	0	77	3	40	7	1	0	0	2	1	0	0	139
01/03/03	-	-	-	-	-	-	-	-	-	31	40	200	-	-	-	-	-	-	-	-	271
01/10/03	-	-	-	-	-	-	-	-	-	216	62	47	-	-	-	-	-	-	-	-	325
01/17/03	-	-	-	-	-	-	-	-	-	72	66	141	-	-	-	-	-	-	-	-	279
01/24/03	-	-	-	-	-	-	-	-	-	23	34	22	-	-	-	-	-	-	-	-	79
01/31/03	-	-	-	-	-	-	-	-	-	37	3	44	-	-	-	-	-	-	-	-	84
Grand Total	**1993**	**206**	**2036**	**1804**	**463**	**1935**	**3175**	**593**	**2781**	**3670**	**1278**	**2341**	**4536**	**3502**	**1426**	**2323**	**2049**	**810**	**771**	**1142**	**38834**

(-) = No samples taken

.

Appendix 9. The percentages of total catch comprised by the five most abundant fishes in 2002 by date from each array.

Array 1	Mosquitofish			Flagfish			Dollar sunfish			Least killifish			Marsh killifish			Crayfish			Shrimp		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/16/02	15	-	-	2	1	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
06/17/02	-	32	-	3	2	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-
06/18/02	-	9	-	4	4	-	-	-	-	-	-	-	2	1	1	-	1	-	-	-	-
06/19/02	236	-	-	85	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
06/20/02	33	-	-	-	-	-	-	-	-	104	-	-	1	-	1	-	-	-	-	-	-
06/21/02	322	5	1	6	9	-	-	-	-	3	-	-	1	7	-	2	1	-	-	-	2
06/22/02	75	22	576	1	2	1	12	-	-	33	-	37	2	2	-	1	-	-	-	-	4
06/23/02	173	-	24	1	-	5	-	-	-	67	-	-	1	-	2	1	1	3	-	-	2
06/24/02	12	-	13	1	-	2	4	-	-	132	-	6	3	3	8	-	-	-	-	-	2
06/25/02	10	1	55	3	2	-	5	-	-	1	-	7	-	-	-	1	-	-	-	1	25
06/26/02	-	-	4	-	1	1	8	-	11	-	-	3	-	1	-	1	-	-	-	-	7
06/27/02	13	-	-	11	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1
06/28/02	34	8	15	3	-	-	27	1	-	1	-	3	3	-	1	4	1	-	-	-	36
06/29/02	12	2	24	-	-	-	15	-	2	2	-	5	-	-	8	1	-	-	-	-	37
06/30/02	4	1	5	5	-	-	5	-	-	1	-	-	4	1	4	4	1	-	-	-	6
07/01/02	6	3	1	2	1	-	9	-	-	-	1	-	-	-	-	3	-	-	-	1	-
07/02/02	13	7	94	2	2	-	20	-	2	2	-	12	-	2	-	1	-	1	-	-	50
07/05/02	1	6	10	-	-	-	7	-	21	-	-	-	2	1	1	4	1	-	-	-	18
07/09/02	-	1	19	-	-	-	34	-	23	-	-	-	-	-	-	-	1	-	-	1	-
07/12/02	3	-	728	-	-	-	17	-	12	-	-	40	1	1	-	-	-	1	-	-	16
07/19/02	199	1	21	-	2	-	-	6	1	16	-	-	-	-	-	-	-	-	4	-	51
07/26/02	-	2	5	2	1	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-
08/02/02	16	23	37	-	8	4	-	-	-	-	-	-	-	4	9	-	1	2	-	-	-
09/06/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1177	123	1632	131	35	14	163	7	73	368	2	113	23	24	35	27	9	7	4	3	257

(-) = No specimens taken.

Appendix 9. Continued.

Array 2	Mosquitofish			Flagfish			Dollar sunfish			Least killifish			Marsh killifish			Crayfish			Shrimp		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/09/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-
06/10/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06/11/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
06/12/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06/13/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06/14/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	3	7	-	-	-
06/15/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
06/16/02	6	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-
06/17/02	9	2	4	132	11	68	-	-	-	-	-	-	-	3	12	3	3	-	-	-	-
06/18/02	11	3	15	95	58	161	2	-	4	2	1	-	3	-	1	-	1	-	-	-	-
06/19/02	18	4	80	145	32	418	-	-	-	-	-	-	2	1	5	1	-	-	-	-	-
06/20/02	220	8	5	125	49	4	-	-	-	15	-	-	2	1	4	-	-	1	-	-	-
06/21/02	3	-	179	43	-	16	-	-	-	1	-	113	2	-	1	-	-	-	-	-	-
06/22/02	15	-	116	27	23	34	-	-	-	10	1	13	2	1	1	5	-	-	-	-	1
06/23/02	69	47	6	9	28	34	5	1	2	15	3	-	-	-	3	1	-	-	-	-	-
06/24/02	4	17	5	2	5	5	28	-	4	40	3	3	2	-	4	-	-	-	-	-	3
06/25/02	1	-	9	3	13	17	22	3	11	-	-	2	-	2	2	-	1	4	-	-	-
06/26/02	-	-	2	5	4	4	34	-	29	-	-	-	-	4	5	-	-	4	-	-	-
06/27/02	-	3	1	-	5	10	36	-	43	-	-	1	9	2	2	1	1	1	-	-	-
06/28/02	-	2	4	3	5	-	77	-	20	-	-	4	-	-	-	1	2	1	-	-	-
06/29/02	-	-	-	2	-	2	46	-	61	-	-	-	-	-	1	-	-	-	-	-	-
06/30/02	13	-	1	1	-	1	24	2	13	-	-	-	-	-	-	-	-	6	-	-	-
07/01/02	3	2	1	10	1	4	49	-	29	-	-	-	-	4	3	1	-	-	-	-	-
07/02/02	-	-	4	-	-	-	59	-	20	-	-	-	1	-	1	-	-	3	-	-	-
07/05/02	9	1	-	2	-	1	71	-	52	-	-	-	2	1	1	-	1	-	-	-	-
07/09/02	-	2	-	-	-	-	27	-	3	-	-	-	-	-	-	-	-	-	-	-	1
07/12/02	-	-	-	-	3	1	19	-	55	-	-	-	1	-	1	-	-	-	-	-	-
07/19/02	-	9	2	1	6	-	5	-	24	-	-	-	-	-	1	-	-	1	-	-	-
07/26/02	26	-	24	3	2	5	-	-	-	-	-	-	20	9	3	-	1	6	-	1	-
08/02/02	48	3	11	20	2	11	4	7	6	-	-	-	-	14	-	1	2	5	-	2	-
09/06/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	2	-	-	-
12/13/02	1	6	-	-	-	-	-	-	-	-	-	-	1	1	-	4	2	3	-	-	-
TOTAL	456	109	469	630	247	796	508	13	376	83	8	136	47	43	55	32	21	47	0	3	5

(-) = No specimens taken.

Appendix 9. Continued.

Array 3	Mosquitofish			Flagfish			Dollar sunfish			Least killifish			Marsh killifish			Crayfish			Shrimp		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
06/05/02	-	51	-	-	35	-	-	-	-	-	-	-	-	6	-	-	2	-	-	-	-
06/06/02	-	32	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
06/07/02	605	8	-	3	19	-	-	-	-	1	-	-	2	4	-	4	-	2	-	-	-
06/08/02	3	1	70	1	57	19	-	-	-	-	-	63	2	8	3	-	2	-	-	-	-
06/09/02	100	-	1	14	1	-	-	-	-	-	3	103	26	1	1	-	1	-	-	-	-
06/10/02	167	1	24	1	15	-	-	-	-	28	-	58	3	7	-	4	-	-	1	-	-
06/11/02	287	14	197	2	18	-	-	1	-	98	-	5	2	3	2	-	-	-	-	-	-
06/12/02	4	6	61	3	44	-	2	1	1	-	-	-	22	3	6	-	1	-	-	-	-
06/13/02	-	1	-	21	8	-	-	-	-	-	1	-	8	1	-	-	-	-	-	-	-
06/14/02	33	-	-	12	-	-	-	-	-	-	-	-	9	-	-	-	1	-	-	-	-
06/15/02	15	2	-	3	-	-	-	-	-	-	-	-	2	7	-	-	1	-	-	-	-
06/16/02	48	8	235	56	28	-	5	-	1	-	-	7	53	16	14	1	-	11	-	-	-
06/17/02	131	-	355	65	22	1	-	-	-	-	-	368	24	7	22	-	1	2	-	-	2
06/18/02	38	2	102	29	13	-	-	-	-	-	4	234	11	2	17	-	-	2	2	-	1
06/19/02	22	1	126	13	8	1	1	-	-	-	-	7	13	6	9	-	1	2	-	-	-
06/20/02	20	7	42	13	4	-	1	-	1	-	-	63	11	1	13	2	1	1	-	-	1
06/21/02	3	8	36	-	1	-	-	-	2	-	-	32	-	5	12	-	-	1	11	-	3
06/25/02	1	1	19	-	4	-	1	-	3	-	-	41	-	2	1	-	-	2	-	-	24
06/28/02	3	-	24	-	-	-	-	1	19	-	-	-	1	4	-	-	-	1	-	-	-
07/02/02	16	-	7	2	-	-	5	-	34	-	-	-	6	-	-	1	-	-	-	-	-
07/05/02	7	-	16	-	-	-	28	-	-	-	-	-	1	1	-	-	1	-	1	3	24
07/12/02	-	-	-	-	-	-	1	-	69	-	-	-	5	-	-	-	-	-	2	-	-
07/19/02	37	-	26	-	-	6	1	-	-	-	-	3	3	2	2	-	1	2	38	-	-
07/26/02	337	30	5	1	-	-	-	1	2	-	-	-	3	-	-	1	2	2	3	-	-
08/02/02	22	2	-	2	5	-	-	-	-	-	-	-	15	1	-	-	1	-	-	-	-
08/16/02	-	2	1	-	-	-	-	-	-	-	-	-	4	4	1	-	1	3	-	-	-
08/23/02	76	4	-	22	-	-	-	1	-	-	-	-	-	-	-	1	-	9	-	-	-
08/30/02	10	1	1	-	-	-	-	-	1	-	-	-	-	-	-	1	-	2	-	-	-
09/06/02	228	-	-	12	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
09/13/02	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
11/22/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12/13/02	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	15	-	7
12/20/02	3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	7	1	-
TOTAL	2228	182	1348	275	283	27	45	5	134	128	8	984	227	93	103	15	18	43	80	4	62
(-) = No specimens taken.																					

Appendix 9. Continued

Array 4	Mosquitofish			Flagfish			Dollar sunfish			Least killifish			Marsh killifish			Crayfish			Shrimp		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
05/30/02	47	10	50	36	29	98	-	-	-	-	-	-	1	-	1	1	-	3	-	-	-
05/31/02	22	6	4	24	42	-	-	-	-	-	-	-	3	3	-	4	-	10	-	-	-
06/01/02	29	34	303	47	88	52	2	1	-	-	-	4	8	2	1	2	-	8	-	-	-
06/02/02	15	27	75	44	31	38	2	-	-	1	2	-	10	7	10	1	-	4	-	-	-
06/03/02	28	58	101	8	18	52	12	-	-	-	-	-	3	2	8	1	1	4	-	-	-
06/04/02	191	6	10	22	27	88	3	-	-	-	-	-	3	3	10	2	-	6	-	-	-
06/05/02	321	59	84	9	3	30	9	1	1	8	2	-	3	-	4	3	-	7	-	-	-
06/06/02	888	22	256	-	-	2	-	1	1	28	-	-	3	6	9	-	-	5	-	-	-
06/07/02	150	-	8	-	4	4	24	2	-	13	-	-	4	12	8	2	1	9	-	-	-
06/08/02	5	-	46	-	-	5	-	2	1	-	-	-	3	8	46	1	1	4	-	-	-
06/09/02	9	1	11	2	10	4	6	1	2	-	-	2	2	8	-	1	-	4	-	-	-
06/10/02	3	4	8	1	10	-	12	-	5	-	1	-	3	-	1	-	-	9	-	1	-
06/11/02	377	17	14	5	2	14	6	1	13	3	-	-	9	9	2	-	1	5	-	-	-
06/12/02	65	54	6	11	-	9	7	1	4	-	1	-	5	1	7	-	-	8	-	-	-
06/13/02	-	12	1	1	-	10	6	-	4	-	-	-	1	1	3	-	-	8	-	1	-
06/14/02	-	142	4	-	1	-	3	-	1	-	-	-	-	2	-	-	-	6	1	1	-
06/15/02	2	15	14	-	-	4	-	-	-	-	7	-	-	2	5	4	-	9	1	-	-
06/16/02	5	11	-	-	7	-	2	-	-	-	-	-	-	4	-	8	3	94	1	-	-
06/18/02	1	10	6	2	-	1	11	-	5	-	9	2	-	7	-	-	-	8	-	4	-
06/21/02	6	-	2	1	-	-	-	-	14	3	1	-	2	-	-	-	-	6	8	3	-
06/25/02	-	-	-	-	-	-	32	-	1	-	-	-	-	-	-	-	-	5	-	-	-
06/28/02	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-	-
07/05/02	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	1	40	7	22
07/12/02	-	-	-	-	3	1	-	4	-	-	-	-	-	-	-	-	-	4	2	-	1
07/19/02	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	1	-	4
07/26/02	1	2	-	34	1	-	3	2	5	-	-	-	2	-	-	-	-	-	-	-	-
08/02/02	1	5	-	-	5	-	-	2	-	-	-	-	-	2	2	-	-	2	-	-	-
08/09/02	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1	2	4	-	-	-
08/16/02	1	-	-	1	-	1	-	-	1	-	-	-	3	3	5	-	-	2	-	-	-
08/23/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
08/30/02	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
09/06/02	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	3	2	-	-	-	-
09/13/02	-	-	-	-	3	-	-	-	1	-	-	-	-	-	-	2	1	2	-	-	-
09/20/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09/27/02	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	1	-	-	-
10/04/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
10/11/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/18/02	-	2	-	2	-	-	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-
10/25/02	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
11/01/02	-	-	-	-	-	-	-	1	14	-	-	-	-	-	-	-	1	-	2	4	-
11/08/02	175	-	1	-	-	-	33	10	10	-	-	-	4	-	-	-	-	-	-	-	-
11/15/02	125	13	4	8	3	2	21	5	10	-	-	-	10	19	7	1	-	10	5	-	-
11/22/02	2	1	-	-	-	-	33	22	42	-	-	-	-	-	-	-	-	1	-	-	-
11/29/02	-	-	-	-	-	-	11	1	-	-	-	-	-	-	-	1	1	2	1	5	1
12/06/02	1	-	-	-	-	-	27	17	27	-	-	-	-	-	1	-	-	-	-	5	-
12/13/02	1	-	-	-	-	-	7	3	29	-	-	-	-	-	-	-	1	2	24	-	-
12/20/02	-	-	-	-	-	-	65	3	39	-	-	-	-	-	-	-	1	5	-	-	-
01/03/03	6	21	187	-	-	1	23	7	9	-	-	-	-	11	-	14	-	-	-	-	53
01/10/03	135	17	23	1	7	2	9	-	7	3	-	-	62	33	11	-	2	13	27	-	-
01/17/03	44	9	106	5	16	20	-	3	-	3	-	-	8	19	9	1	-	9	71	1	2
01/24/03	6	14	7	7	3	3	-	1	-	-	-	-	6	12	10	3	1	14	2	12	1
01/31/03	8	2	2	9	-	31	-	-	-	-	-	-	16	-	5	5	1	3	-	1	2
TOTAL	2671	575	1333	281	317	472	372	92	267	62	23	8	177	180	167	61	21	302	192	45	86

(-) = No specimens taken.

Appendix 9. Continued

Array 5	Mosquitofish				Flagfish				Dollar sunfish				Least killifish				Marsh killifish				Crayfish				Shrimp			
Date	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W
06/01/02	22	159	6	5	17	33	7	2	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-
06/02/02	626	507	79	85	153	65	148	128	-	-	-	-	-	-	-	-	4	-	4	-	1	-	5	4	-	-	-	-
06/03/02	219	314	47	125	56	25	57	31	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-
06/04/02	332	314	355	647	41	29	91	23	-	-	-	-	1	3	-	-	-	7	-	1	1	-	1	-	-	-	-	-
06/05/02	430	218	62	80	72	5	68	51	-	-	-	-	4	-	-	-	6	10	9	4	-	1	3	-	-	-	-	-
06/06/02	42	86	8	35	10	6	-	6	-	-	-	-	1	-	-	-	6	6	3	1	-	-	3	1	-	-	-	-
06/07/02	77	464	35	197	6	13	15	27	-	-	-	-	2	15	-	-	1	-	13	3	-	1	3	-	-	-	-	-
06/08/02	95	160	56	37	10	20	7	41	-	-	-	-	-	11	2	-	10	3	2	6	1	5	1	9	-	-	-	-
06/09/02	709	214	28	124	39	6	46	16	3	2	-	-	1	6	-	2	13	9	23	7	-	1	-	1	-	-	-	-
06/10/02	685	112	88	57	-	7	14	22	1	-	1	-	2	9	1	5	2	9	5	5	-	3	2	2	-	-	-	-
06/11/02	194	37	2	3	1	11	16	31	1	1	-	2	-	1	-	-	6	6	3	5	1	2	1	1	-	-	-	-
06/12/02	60	-	1	1	15	10	2	21	2	5	1	-	-	-	-	-	16	25	11	14	-	1	3	2	-	-	-	-
06/13/02	14	36	5	7	10	13	7	26	3	5	-	1	-	1	-	-	24	8	9	12	1	3	1	3	-	-	-	-
06/14/02	16	65	4	31	14	32	9	34	4	3	1	2	-	1	-	-	11	13	9	4	1	4	1	4	-	-	-	-
06/15/02	9	22	2	31	1	10	-	14	-	3	1	-	-	-	-	-	1	7	5	18	-	3	-	5	-	-	-	-
06/16/02	-	1	-	43	-	72	-	13	2	-	1	5	-	-	-	-	-	1	-	13	2	2	2	5	-	-	-	-
06/18/02	5	3	2	10	33	48	9	5	-	-	-	28	-	-	-	5	-	1	-	-	2	3	4	-	1	-	-	-
06/21/02	-	-	-	5	-	13	3	-	-	-	-	-	-	-	-	22	1	-	-	-	4	5	2	7	1	-	-	-
06/25/02	2	-	-	6	1	17	-	1	-	-	-	2	-	-	-	2	1	2	-	-	-	1	-	1	2	-	1	-
06/28/02	-	-	-	7	-	2	-	-	5	1	-	2	-	-	-	1	-	1	-	2	1	-	-	8	-	-	-	-
07/05/02	1	1	-	3	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	3	7	17	2	-
07/12/02	-	1	-	-	-	11	-	-	-	-	-	4	-	-	-	-	-	-	-	1	-	-	1	4	-	-	9	8
07/19/02	-	3	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	3	3	-	-
07/26/02	-	13	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	1	1	-	1	1
08/02/02	76	28	1	-	8	3	1	-	6	1	-	-	-	-	-	-	-	2	-	-	-	-	1	3	-	-	-	-
08/09/02	-	2	-	-	17	-	-	-	-	2	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	1	-
08/16/02	1	3	-	-	2	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-
08/23/02	-	1	6	-	7	-	1	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
08/30/02	-	-	-	-	-	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	2	-	1	1	-	-	-
09/06/02	2	-	-	-	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-
09/13/02	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
09/20/02	4	9	-	2	-	1	-	2	-	8	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
09/27/02	4	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/04/02	13	21	-	5	-	1	-	-	3	-	-	-	-	2	-	-	-	-	-	-	1	-	2	2	-	-	-	-
10/11/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	4	1	-	-	-	-
10/18/02	143	-	-	-	4	-	-	1	3	1	6	20	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
10/25/02	10	-	-	-	-	-	-	-	2	-	2	2	-	-	-	-	2	-	-	1	-	-	2	2	-	-	-	-
11/01/02	-	2	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11/22/02	-	-	-	-	-	-	-	-	-	5	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-
12/13/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	1	9	11
12/20/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	11	-	-	-
TOTAL	3791	2796	789	1550	520	457	502	496	37	43	17	78	11	50	3	37	109	117	98	98	21	41	46	80	33	21	24	21

(-) = No specimens taken.

Appendix 9. Continued

Array 6	Mosquitofish				Flagfish				Dollar sunfish				Least killifish				Marsh killifish				Crayfish				Shrimp			
Date	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W	E	N	S	W
06/05/02	5	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	4	-	1	-	1	1	-	-	-	-	-	-
06/06/02	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
06/07/02	-	10	10	-	-	29	10	-	-	-	-	-	-	-	-	-	-	8	9	-	-	2	1	-	-	-	-	-
06/08/02	39	83	25	70	53	62	16	114	-	-	-	4	-	6	-	-	52	8	29	4	1	6	1	1	-	-	-	-
06/09/02	66	19	72	21	52	47	23	5	-	-	-	2	-	1	-	3	27	3	7	4	1	2	-	2	-	-	-	-
06/10/02	161	6	63	12	134	7	48	8	5	-	-	-	1	-	1	-	53	7	20	-	1	1	-	1	-	-	-	-
06/11/02	80	9	50	11	127	5	13	11	1	-	-	-	-	-	3	-	24	6	5	5	1	1	-	-	-	-	-	-
06/12/02	39	5	18	3	73	9	6	26	-	-	-	-	-	-	1	-	18	5	3	11	-	4	-	-	-	-	-	-
06/13/02	23	-	3	1	60	17	5	19	1	-	-	-	-	-	-	-	19	3	-	18	-	3	1	3	-	-	-	-
06/14/02	40	6	20	14	53	6	5	36	-	-	-	-	1	-	-	1	12	5	2	6	-	1	-	2	-	-	-	-
06/15/02	30	2	-	6	19	14	-	20	-	-	-	2	2	-	-	2	9	11	-	3	-	-	1	5	-	-	-	-
06/16/02	5	25	21	24	52	32	17	15	-	-	-	7	-	5	-	3	6	13	10	-	1	1	1	-	-	-	-	1
06/17/02	27	13	45	63	40	31	35	-	-	-	-	2	-	8	-	28	8	3	4	1	1	1	3	2	-	-	-	-
06/18/02	17	1	11	15	27	21	24	-	-	2	-	-	-	1	-	47	-	1	7	-	1	4	-	1	-	-	-	1
06/19/02	5	12	17	23	30	9	11	-	-	-	-	-	-	3	1	39	6	1	1	2	-	6	-	2	-	-	-	-
06/20/02	3	16	1	5	7	8	-	-	-	-	-	-	-	2	2	69	2	2	-	2	-	1	-	2	-	2	1	6
06/21/02	1	8	-	-	1	8	-	-	-	-	-	-	-	4	-	-	1	1	1	-	1	-	1	3	-	3	-	-
06/25/02	-	3	-	7	3	-	-	-	-	-	-	-	-	-	-	1	-	1	-	5	1	8	-	-	-	-	-	24
06/28/02	-	7	5	-	-	7	-	-	-	-	1	-	-	-	-	-	-	3	1	-	-	3	1	-	-	-	19	1
07/02/02	2	6	-	1	-	2	-	-	1	-	-	-	-	1	-	-	-	1	-	-	-	6	-	-	-	-	2	4
07/05/02	-	3	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	-	7	-
07/12/02	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	15	-	-	-	1	-	-	-	-	2	-
07/19/02	14	5	9	1	3	2	-	4	1	-	-	-	-	-	-	-	2	3	2	2	-	-	-	-	6	-	-	-
07/26/02	188	1	40	14	12	-	-	1	1	-	-	-	-	-	-	-	8	-	4	3	-	-	-	3	-	-	-	-
08/02/02	4	-	1	25	2	-	-	2	-	-	-	-	-	-	-	-	4	-	-	5	10	-	3	-	-	-	-	-
08/16/02	1	-	-	187	-	-	-	2	-	-	1	1	-	-	-	-	2	1	-	-	1	1	-	-	-	-	-	-
08/23/02	28	-	-	-	44	1	-	-	-	-	-	-	-	-	-	-	4	-	1	2	2	-	-	9	-	-	-	-
08/30/02	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-
09/06/02	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	1	3	-	-	-	-
09/13/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
11/22/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
12/13/02	-	-	-	-	-	-	-	-	30	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
12/20/02	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
TOTAL	815	242	414	505	809	317	213	263	40	5	3	18	4	32	8	193	261	102	107	73	29	61	15	39	6	6	32	39

(-) = No specimens taken.

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Appendix 10a. CPUE of the five most abundant fish species collected in each sample at Array 1 in 2003.

	Mosquitofish			Sailfin Molly			Marsh Killifish			Dollar Sunfish			Jewel Cichlid		
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**
5/30/2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5/31/2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6/1/2003	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
6/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/11/2003	0	19	0	0	0	0	0	0	0	5	0	7	0	0	0
6/12/2003	274	9	7	12	1	0	12	0	0	11	0	0	0	0	0
6/13/2003	0	0	6	0	0	5	0	0	0	0	0	9	0	0	0
6/14/2003	0	1	1	0	0	1	0	0	2	0	0	0	1	0	0
6/15/2003	1	3	7	0	0	0	0	0	1	1	4	0	0	0	0
6/16/2003	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/17/2003	0	0	2	1	0	2	2	0	1	0	1	0	0	0	0
6/18/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/19/2003	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0
6/20/2003	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
6/21/2003	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6/22/2003	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
6/23/2003	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0
6/24/2003	0	0	0	2	0	0	1	2	2	1	16	22	0	1	1
6/25/2003	2	4	129	0	0	77	0	0	0	2	3	0	0	0	0
6/26/2003	0	0	1	0	0	4	0	0	1	0	0	0	0	0	0
6/27/2003	0	2	4	0	0	3	0	0	0	1	1	19	0	0	0
7/1/2003	2	1	0	1	0	0	3	0	0	0	0	0	0	0	0
7/4/2003	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8/15/2003	1	1	1	1	0	0	1	0	0	2	0	0	6	2	0
8/22/2003	1	0	0	0	0	0	0	0	1	3	3	1	8	13	65
8/29/2003	0	2	0	0	1	0	0	0	0	0	0	5	0	0	1
9/5/2003	15	0	32	5	0	0	0	0	8	0	13	0	0	0	0
9/12/2003	4	23	0	0	0	0	0	1	0	0	0	1	2	0	0
9/19/2003	1	1	1	0	0	0	1	0	1	0	0	1	0	0	1
9/26/2003	0	0	0	0	0	0	0	1	0	2	0	0	1	0	9
10/3/2003	0	3	12	0	0	1	0	0	2	0	0	19	8	0	3
10/10/2003	58	0	2	1	1	3	1	1	1	3	3	4	4	4	2
10/17/2003	47	3	72	0	0	1	0	0	7	0	0	1	0	0	0
11/7/2003	0	0	0	1	0	0	3	3	1	0	0	1	1	1	8
11/14/2003	0	0	0	0	0	0	0	0	30	0	0	0	1	0	2

Appendix 10b. CPUE of the five most abundant fish species collected in each sample at Array 2 in 2003.

	Mosquitofish			Marsh Killifish			Flagfish			Dollar Sunfish			Jewel Cichlid		
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**
5/30/2003	19	3	0	3	11	66	2	3	3	0	0	0	0	0	0
5/31/2003	0	2	33	6	0	91	40	5	65	14	41	29	0	0	0
6/1/2003	22	2	15	1	1	13	27	13	49	23	0	4	0	0	0
6/2/2003	0	0	5	4	10	0	8	1	2	2	0	2	0	0	0
6/3/2003	6	1	0	0	0	0	0	2	0	0	2	1	0	0	0
6/4/2003	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
6/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/6/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/8/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/9/2003	25	5	16	11	1	59	44	5	31	20	11	4	0	0	0
6/10/2003	0	8	4	3	0	5	5	9	11	56	38	71	0	0	0
6/11/2003	0	0	0	1	1	1	6	0	1	108	7	48	0	0	0
6/12/2003	0	0	0	0	0	0	13	0	0	55	0	44	0	0	0
6/13/2003	0	0	0	0	0	0	0	0	0	85	7	0	1	0	0
6/14/2003	0	0	0	1	0	1	0	0	0	33	12	80	0	0	0
6/15/2003	0	0	0	0	0	0	0	0	0	53	14	44	0	0	0
6/16/2003	0	0	0	0	0	1	0	0	0	20	11	5	0	0	0
6/17/2003	0	1	6	0	0	1	0	0	0	23	8	16	0	0	1
6/18/2003	6	0	0	3	0	2	2	0	1	5	0	4	0	0	0
6/19/2003	4	0	0	1	1	0	1	0	1	0	0	0	0	0	0
6/20/2003	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
6/21/2003	0	0	1	1	0	0	3	0	2	0	0	0	0	0	0
6/22/2003	16	0	0	0	0	2	1	6	3	0	0	0	0	0	0
6/24/2003	0	0	0	1	0	3	7	0	0	71	0	13	1	0	3
6/25/2003	0	0	2	0	0	0	0	0	0	43	14	33	0	1	0
6/26/2003	18	28	7	1	2	1	2	6	0	6	2	7	1	0	0
6/27/2003	0	2	0	1	1	3	0	1	0	27	6	14	3	0	0
7/1/2003	0	1	1	2	1	1	3	0	1	0	0	0	0	0	0
7/4/2003	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0
8/8/2003	0	1	1	0	0	0	3	2	4	6	1	2	0	0	0
8/15/2003	3	0	4	9	0	4	0	0	1	0	0	0	0	0	0
8/22/2003	0	0	0	0	0	0	0	0	0	25	7	25	180	29	39
8/29/2003	0	0	0	0	0	0	0	0	0	13	0	11	13	3	4
9/5/2003	0	1	0	0	0	0	0	0	0	3	19	1	2	0	4
9/12/2003	7	2	0	5	0	0	19	4	0	17	5	3	3	2	4
9/19/2003	2	1	0	0	1	0	1	0	0	0	0	0	0	0	0
9/26/2003	0	0	0	0	1	0	0	0	0	6	0	0	12	9	0
10/3/2003	0	0	0	0	0	0	0	0	0	33	5	2	10	1	1
10/10/2003	0	0	0	0	0	0	0	0	0	3	2	1	13	3	8
10/17/2003	2	0	0	0	0	0	0	0	0	3	0	0	4	1	0
11/7/2003	0	1	3	1	2	0	4	1	1	0	1	0	42	12	143
11/14/2003	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0

Appendix 10c. CPUE of the five most abundant fish species collected in each sample at Array 3 in 2003.

	Mosquitofish			Marsh Killifish			Flagfish			Bluefin Killifish			Jewel Cichlid		
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**
4/1/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4/2/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/1/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/20/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2003	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
5/28/2003	0	5	1	1	2	2	0	2	0	0	0	0	0	1	0
5/29/2003	0	5	1	7	36	4	3	10	1	0	0	1	0	0	2
5/30/2003	1	0	22	24	1	15	5	1	7	0	0	0	1	2	9
5/31/2003	0	1	0	7	2	3	2	3	1	0	4	0	0	1	0
6/1/2003	0	0	0	1	8	2	0	2	0	0	0	0	0	0	0
6/2/2003	0	1	2	5	0	3	0	0	0	0	0	0	0	0	1
6/3/2003	0	0	0	3	0	3	1	0	0	0	1	14	0	0	0
6/4/2003	3	0	0	1	0	1	0	0	0	0	0	2	1	0	0
6/5/2003	0	0	0	4	0	0	0	0	0	0	0	14	0	0	2
6/6/2003	0	0	0	0	2	2	0	1	0	0	0	2	0	0	9
6/7/2003	0	0	0	1	0	2	0	0	0	0	0	10	0	0	0
6/8/2003	0	0	0	6	0	0	0	0	0	0	3	3	0	0	0
6/9/2003	0	0	0	0	1	0	0	0	0	0	0	0	7	0	5
6/10/2003	0	0	0	1	0	0	0	0	0	0	0	0	35	4	6
6/13/2003	0	0	1	9	1	3	5	0	0	0	0	2	0	2	15
6/17/2003	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
6/20/2003	0	0	0	0	0	0	0	0	0	0	1	3	3	0	0
6/27/2003	0	0	0	42	0	2	0	0	0	0	0	1	13	1	0
7/4/2003	0	0	0	8	0	0	0	0	0	0	0	1	6	0	0
7/11/2003	0	2	2	8	0	0	0	0	0	0	0	0	0	0	0
7/18/2003	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0
7/25/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/1/2003	0	0	0	24	0	0	0	0	0	0	0	0	6	0	0
8/8/2003	7	0	0	0	0	0	0	0	0	0	0	0	15	1	0
8/15/2003	3	0	0	0	0	0	0	0	0	1	0	0	2	0	0
8/22/2003	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3
8/29/2003	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
9/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/12/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
9/19/2003	0	0	3	2	0	0	0	0	0	0	0	0	2	0	1
9/26/2003	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
10/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	78	0	0
10/10/2003	0	0	0	0	0	0	0	0	0	3	0	0	11	1	0
10/17/2003	0	0	0	0	0	0	0	0	0	0	0	0	7	0	1
10/24/2003	16	0	1	2	0	1	0	0	0	0	0	0	0	9	0
10/31/2003	31	15	0	14	12	0	9	10	0	0	0	0	0	0	0
11/7/2003	0	0	0	5	0	0	0	0	0	0	0	0	2	13	13
11/14/2003	0	0	0	1	0	0	0	0	0	7	0	0	15	0	0
11/21/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/28/2003	0	15	0	5	1	0	0	0	0	0	1	0	0	0	0

Appendix 10d. CPUE of the five most abundant fish species collected in each sample at Array 4 in 2003/2004.

	Mosquitofish			**Marsh Killifish**			**Flagfish**			**Bluefin Killifish**			**Dollar Sunfish**		
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**
1/3/2003	6	21	187	0	11	0	0	0	1	0	0	0	23	7	9
1/10/2003	135	17	23	62	33	11	1	7	2	0	0	0	9	0	7
1/17/2003	44	9	106	8	19	9	5	16	20	3	0	1	0	3	0
1/24/2003	6	14	7	6	12	10	7	3	3	0	0	0	0	1	0
1/31/2003	8	2	2	16	0	5	9	0	31	0	0	0	0	0	0
3/29/2003	51	20	17	6	5	3	3	7	1	154	11	15	26	19	0
3/30/2003	23	0	5	10	0	11	4	10	6	4	0	10	2	8	0
3/31/2003	0	1	3	0	0	0	1	0	1	0	0	0	1	2	0
4/1/2003	2	2	15	0	0	2	0	0	0	0	0	0	0	0	0
4/2/2003	9	0	14	0	1	2	0	0	1	0	0	0	0	0	0
4/3/2003	0	0	7	0	0	4	0	0	0	0	1	1	0	0	1
4/4/2003	1	0	14	0	0	0	0	0	0	0	0	0	0	0	2
5/1/2003	1	5	4	2	1	2	3	15	0	0	0	7	7	0	1
5/2/2003	1	0	5	1	5	2	2	0	4	20	6	7	26	9	25
5/6/2003	1	0	0	1	4	0	2	1	0	0	0	0	1	3	2
5/7/2003	2	1	0	4	0	0	0	0	0	0	0	0	1	2	1
5/8/2003	1	0	1	3	2	1	0	1	0	0	0	0	0	0	0
5/9/2003	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0
5/16/2003	0	0	0	0	1	0	4	1	2	0	0	0	0	0	0
5/20/2003	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
5/21/2003	0	0	0	1	0	1	2	1	0	0	0	0	0	0	2
5/22/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
5/23/2003	4	1	0	0	0	0	0	0	0	0	0	0	0	5	9
5/24/2003	0	2	5	1	6	1	0	1	6	0	2	0	69	11	21
5/25/2003	1	2	0	7	9	2	1	17	0	0	0	0	17	5	10
5/26/2003	0	1	0	0	0	0	5	0	0	0	0	0	47	11	36
5/27/2003	0	0	0	0	2	0	0	0	0	0	0	0	44	16	35
5/28/2003	0	0	0	0	0	0	0	1	0	0	0	0	41	20	101
5/29/2003	0	0	0	0	1	0	0	0	0	0	0	0	0	28	17
5/30/2003	0	0	0	2	0	0	0	2	1	0	0	0	24	9	55
5/31/2003	0	0	0	0	0	0	0	1	0	0	0	0	24	3	28
6/1/2003	0	0	0	0	0	0	2	0	0	0	0	0	6	27	14
6/2/2003	0	0	0	0	1	0	0	0	0	0	0	0	75	6	19
6/3/2003	0	0	0	0	0	0	0	1	0	1	0	0	37	4	3
6/6/2003	0	0	0	0	0	0	0	1	0	0	2	0	22	3	57
6/10/2003	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5
6/13/2003	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
6/20/2003	0	0	0	1	0	0	0	0	0	0	0	0	2	1	2
6/27/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7/4/2003	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
7/11/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/18/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/25/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8/1/2003	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1
8/8/2003	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
8/15/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0

APPENDIX 10d.-Cont.	Mosquitofish			Marsh killifish			Flagfish			Bluefin killifish			Dollar sunfish		
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	W
8/22/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
8/29/2003	0	0	0	0	0	0	0	0	0	2	0	0	8	1	0
9/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/12/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1
9/19/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
9/26/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
10/10/2003	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
10/17/2003	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0
10/24/2003	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10/31/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
11/3/2003	0	21	0	0	12	0	0	0	0	0	0	0	0	7	0
11/7/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0
11/14/2003	0	0	0	1	0	0	3	0	0	0	0	0	1	0	0
11/21/2003	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
11/28/2003	0	0	0	0	0	0	0	0	0	5	0	0	0	2	0
12/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	8	4	20
12/12/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12/19/2003	0	0	0	1	0	0	0	0	0	0	0	0	0	7	29
12/26/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1/9/2004	0	0	0	1	1	1	0	0	0	0	0	0	23	6	45
1/16/2004	0	0	0	4	1	0	0	0	0	0	0	0	20	5	6
1/23/2004	1	1	0	14	5	21	3	0	2	0	0	0	5	5	7
1/30/2004	31	1	10	36	6	13	1	4	1	0	0	3	14	2	9

Appendix 10e. CPUE of the five most abundant fish species collected in each sample at Array 5 in 2003.

	Mosquitofish				Marsh Killifish				Flagfish				Bluefisn Killifish				Dollar Sunfish			
Date	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**
3/29/2003	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3/30/2003	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	6	0	0
3/31/2003	0	14	0	0	4	17	3	4	1	5	0	2	0	1	0	1	0	2	0	0
4/1/2003	1	9	2	4	5	8	0	3	0	12	1	2	2	82	4	6	0	0	0	0
4/4/2003	3	10	2	0	9	7	1	0	4	4	1	0	15	11	3	4	13	11	0	1
5/1/2003	5	1	0	0	0	2	0	0	0	8	0	0	5	0	0	0	0	1	0	0
5/2/2003	0	6	1	7	4	1	3	13	8	7	4	0	3	32	3	2	2	4	1	5
5/6/2003	0	2	0	0	2	0	0	0	0	0	3	3	3	2	0	1	0	0	0	0
5/7/2003	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5/8/2003	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0
5/9/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/16/2003	9	2	1	2	8	6	11	1	6	9	0	4	1	2	0	0	1	2	0	1
5/20/2003	3	1	2	3	0	12	10	3	3	0	3	0	1	0	0	0	0	0	0	1
5/21/2003	2	1	2	0	1	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0
5/22/2003	0	1	0	0	1	1	0	2	0	0	0	2	0	0	0	0	0	0	0	0
5/23/2003	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/24/2003	0	1	0	2	0	2	5	5	0	0	0	0	0	0	0	0	0	0	0	0
5/25/2003	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/26/2003	43	0	1	0	11	7	13	8	17	4	6	18	0	0	0	0	1	1	1	0
5/27/2003	14	0	0	1	12	9	1	6	4	2	4	6	0	0	0	1	2	16	1	1
5/28/2003	1	0	0	1	4	2	11	6	13	7	1	5	0	0	0	0	0	29	3	2
5/29/2003	0	0	0	0	1	3	7	1	0	0	0	4	0	0	0	0	4	5	1	60
5/30/2003	0	0	0	0	0	1	0	1	0	2	0	2	0	0	0	0	0	9	0	109
5/31/2003	0	0	1	0	0	1	0	0	0	20	0	0	0	1	3	0	1	8	0	79
6/1/2003	0	156	0	0	0	5	2	0	0	33	0	0	0	0	1	0	0	5	0	44
6/2/2003	0	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	1	0	20
6/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
6/6/2003	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	4	6	0	13
6/10/2003	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0	9
6/13/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	1	1
6/20/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	6
6/27/2003	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0
7/4/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	5	3
7/11/2003	6	1	0	0	3	0	0	0	11	7	0	0	0	1	0	0	5	0	0	0
7/18/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
7/25/2003	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
8/1/2003	3	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	2	0
8/8/2003	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	11	1	4	2
8/15/2003	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0
8/22/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
8/29/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	3
9/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/12/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	1	1
9/19/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
9/26/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	0

Appendix 10e-Cont.	Mosquitofish				Marsh killifish				Flagfish				Bluefin killifish				Dollar sunfish			
Date	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**
10/10/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
10/17/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	9
10/24/2003	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12	22
10/31/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
11/7/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
11/14/2003	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
11/21/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	15
11/28/2003	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	13
12/5/2003	9	5	1	8	39	10	57	5	6	2	6	0	1	1	2	0	0	3	2	4
12/12/2003	0	0	0	0	7	2	7	0	0	0	0	1	0	0	0	0	0	0	0	0
12/19/2003	2	3	8	6	5	3	19	11	0	0	7	0	0	0	0	0	0	0	0	1
12/26/2003	1	0	2	2	0	0	1	7	0	0	0	4	0	0	0	0	0	0	0	0

Appendix 10f. CPUE of the five most abundant fish species collected in each sample at Array 6 in 2003.

	Mosquitofish				**Marsh Killifish**				**Flagfish**				**Dollar Sunfish**				**Pike Killifish**			
Date	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**
4/1/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/2/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/1/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/2/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/20/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/21/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/23/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/27/2003	1	0	3	0	8	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
5/28/2003	7	4	5	4	21	13	12	2	10	12	1	1	0	1	0	0	0	0	1	0
5/29/2003	13	0	2	1	21	26	33	14	26	2	2	3	1	1	1	6	0	0	0	1
5/30/2003	2	1	13	10	13	2	10	5	8	31	2	0	1	7	2	0	0	0	0	0
5/31/2003	3	8	0	0	3	0	10	3	13	1	4	13	1	1	3	0	0	4	1	0
6/1/2003	1	0	0	3	2	4	0	0	5	15	0	1	0	1	0	4	1	0	4	0
6/2/2003	0	0	1	0	0	5	3	0	1	4	3	0	0	0	0	0	1	0	9	1
6/3/2003	0	0	0	0	1	0	0	1	1	6	0	0	0	0	0	1	6	0	0	3
6/4/2003	0	0	0	0	0	1	0	0	0	6	0	0	1	0	0	0	0	1	3	0
6/5/2003	0	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	4	2
6/6/2003	0	0	2	0	0	0	0	0	1	0	4	0	4	0	0	0	0	0	0	3
6/7/2003	0	0	0	0	1	1	1	0	1	2	0	0	0	0	0	0	2	1	1	0
6/8/2003	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
6/9/2003	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	1
6/10/2003	0	0	0	0	0	0	1	0	0	0	0	0	15	0	0	0	3	0	1	1
6/13/2003	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0
6/17/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	1	0	0
6/20/2003	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
6/27/2003	0	0	1	0	2	0	0	1	0	0	0	0	2	0	0	2	0	0	0	0
7/4/2003	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2	1	0
7/11/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
7/18/2003	2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/25/2003	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
8/1/2003	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
8/6/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/8/2003	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
8/15/2003	0	0	3	0	1	0	0	0	0	0	0	0	1	1	0	0	1	0	1	3
8/22/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0
8/29/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	2	0	1
9/5/2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
9/12/2003	0	1	0	0	0	0	0	0	0	0	0	0	10	0	1	0	0	0	0	0
9/19/2003	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
9/26/2003	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	1
10/3/2003	0	0	0	0	0	0	0	0	0	0	0	0	6	1	2	1	0	1	0	0
10/10/2003	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10/17/2003	0	0	0	0	2	0	0	0	0	2	0	0	15	0	1	0	4	0	0	2
10/24/2003	99	4	4	1	11	9	1	7	15	0	0	0	3	0	0	1	4	0	1	0
10/31/2003	7	1	6	0	3	0	2	2	4	0	0	0	0	0	0	0	0	0	1	0

Appendix 11. Fish CPUE by trap direction for Arrays 1 – 6 in 2003.

	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**Totals**
3/29/03	-	-	-	-	-	-	-	-	-	316	72	47	1	1	0	0	-	-	-	-	437
3/30/03	-	-	-	-	-	-	-	-	-	49	25	50	0	11	0	0	-	-	-	-	135
3/31/03	-	-	-	-	-	-	-	-	-	4	4	4	5	42	3	7	-	-	-	-	69
4/1/03	-	-	-	-	-	-	0	1	0	2	4	17	9	119	8	18	-	-	-	-	178
4/2/03	-	-	-	-	-	-	0	0	0	11	1	30	-	-	-	-	0	0	0	0	42
4/3/03	-	-	-	-	-	-	-	-	-	2	3	18	-	-	-	-	-	-	-	-	23
4/4/03	-	-	-	-	-	-	-	-	-	1	0	21	50	45	9	9	-	-	-	-	135
5/1/03	-	-	-	-	-	-	0	0	0	14	27	17	11	13	0	1	0	0	0	0	83
5/2/03	-	-	-	-	-	-	0	0	0	56	24	53	17	69	12	28	0	0	0	0	259
5/6/03	-	-	-	-	-	-	-	-	-	7	10	3	5	7	3	4	-	-	-	-	39
5/7/03	-	-	-	-	-	-	-	-	-	7	4	1	3	0	0	0	-	-	-	-	15
5/8/03	-	-	-	-	-	-	-	-	-	6	3	6	1	0	0	6	-	-	-	-	22
5/9/03	-	-	-	-	-	-	-	-	-	6	1	0	-	-	-	-	-	-	-	-	7
5/16/03	-	-	-	-	-	-	-	-	-	4	6	2	26	21	15	9	-	-	-	-	83
5/20/03	-	-	-	-	-	-	-	-	-	0	1	7	7	16	15	7	-	-	-	-	53
5/21/03	-	-	-	-	-	-	-	-	-	5	2	6	6	1	3	2	0	0	0	0	25
5/22/03	-	-	-	-	-	-	-	-	-	1	4	6	1	2	0	4	-	-	-	-	18
5/23/03	-	-	-	-	-	-	-	-	-	6	7	14	0	2	1	2	0	0	0	0	32
5/24/03	-	-	-	-	-	-	-	-	-	70	22	35	0	3	5	7	-	-	-	-	142
5/25/03	-	-	-	-	-	-	-	-	-	28	43	17	0	0	1	1	-	-	-	-	90
5/26/03	-	-	-	-	-	-	-	-	-	54	14	38	72	12	21	27	-	-	-	-	238
5/27/03	-	-	-	-	-	-	0	7	0	45	20	35	32	27	8	17	13	0	4	0	208
5/28/03	-	-	-	-	-	-	1	10	3	41	22	103	18	38	15	15	38	30	19	7	360
5/29/03	-	-	-	-	-	-	11	52	10	0	29	17	5	8	8	65	62	29	39	25	360
5/30/03	0	1	0	24	19	69	34	4	71	26	12	56	1	12	0	113	24	41	27	19	553
5/31/03	0	2	0	63	48	242	9	21	4	24	6	29	1	30	4	80	21	16	19	16	635
6/1/03	0	1	0	75	19	87	2	10	2	10	29	16	0	201	3	44	9	20	4	11	543
6/2/03	-	-	-	14	13	10	5	1	8	75	9	20	1	8	1	21	3	9	16	1	215
6/3/03	0	0	0	6	6	2	4	1	18	39	5	4	0	0	1	0	10	6	0	5	107
6/4/03	-	-	-	2	2	0	6	2	5	-	-	-	-	-	-	-	2	8	3	0	30
6/5/03	-	-	-	0	0	0	4	1	16	-	-	-	-	-	-	-	1	2	6	2	32
6/6/03	-	-	-	0	0	0	0	4	13	23	8	58	4	7	1	21	5	0	6	3	153
6/7/03	-	-	-	-	-	-	3	1	13	-	-	-	-	-	-	-	4	4	2	0	27
6/8/03	-	-	-	0	0	0	8	3	3	-	-	-	-	-	-	-	3	0	0	0	17
6/9/03	-	-	-	106	25	119	10	1	5	-	-	-	-	-	-	-	2	1	2	1	272
6/10/03	-	-	-	65	55	97	38	4	6	2	1	5	0	7	0	10	18	0	2	2	312
6/11/03	6	37	7	117	11	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	229
6/12/03	321	10	10	69	1	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	458
6/13/03	0	1	40	87	8	2	14	3	22	17	1	1	11	0	1	1	3	1	1	1	215
6/14/03	2	1	7	38	12	81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	141
6/15/03	5	8	8	54	15	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135
6/16/03	6	0	0	21	15	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58
6/17/03	8	1	8	29	15	31	1	0	2	-	-	-	-	-	-	-	4	1	0	0	100

Appendix 11-Cont.	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	S	W	E	N	S	W	Total
6/18/03	0	0	0	22	1	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34
6/19/03	0	4	0	6	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
6/20/03	0	2	0	0	0	2	5	2	3	9	2	5	12	1	2	6	1	1	1	2	56
6/21/03	0	1	0	4	0	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
6/22/03	0	11	0	20	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42
6/23/03	0	16	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
6/24/03	6	21	27	81	0	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	157
6/25/03	4	11	208	44	15	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	326
6/26/03	0	0	7	39	46	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120
6/27/03	1	3	31	34	12	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113
7/1/03	6	2	0	11	2	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28
7/4/03	0	4	0	1	0	5	17	0	2	14	0	2	1	3	9	4	4	2	1	0	69
7/18/03	-	-	-	-	-	-	0	3	0	0	1	0	0	0	8	2	7	0	0	0	21
7/25/03	-	-	-	-	-	-	-	-	-	0	0	1	7	2	11	4	-	-	-	-	25
8/1/03	-	-	-	-	-	-	31	0	0	4	3	3	7	1	3	0	2	1	2	0	57
8/6/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	1	1
8/8/03	-	-	-	9	4	8	55	4	1	12	0	3	15	3	4	4	1	0	2	0	125
8/15/03	11	3	1	13	0	25	11	1	3	10	4	0	3	0	1	0	3	2	4	3	98
8/22/03	15	16	68	207	37	64	8	3	14	2	0	1	0	2	0	0	4	0	1	0	442
8/29/03	0	3	8	36	3	16	6	1	0	10	1	1	0	6	0	3	4	2	1	3	104
9/5/03	20	14	41	14	21	16	5	1	1	1	0	1	1	1	0	0	0	1	1	1	140
9/12/03	6	24	2	67	17	17	0	2	3	0	16	2	14	1	1	2	10	1	1	0	186
9/19/03	2	1	4	3	3	0	7	0	5	0	8	0	0	4	0	0	3	0	0	0	40
9/26/03	4	1	9	20	13	1	2	0	0	0	1	2	-	-	-	-	4	0	1	2	60
10/3/03	11	3	61	43	6	11	79	0	1	0	10	0	5	5	0	1	7	12	2	4	261
10/10/03	84	24	17	19	6	17	18	1	1	3	0	1	0	1	1	0	2	1	0	0	196
10/17/03	53	5	84	27	4	8	7	0	2	1	4	0	0	4	5	11	23	0	2	4	244
10/24/03	-	-	-	-	-	-	20	11	2	1	2	0	0	6	13	27	144	16	6	10	258
10/31/03	-	-	-	-	-	-	58	38	0	2	8	1	1	0	1	3	14	1	10	2	139
11/3/03	-	-	-	-	-	-	-	-	-	0	41	0	-	-	-	-	-	-	-	-	41
11/7/03	6	4	12	48	17	147	9	13	14	1	18	0	1	2	0	5	0	4	6	3	310
11/14/03	3	2	34	6	9	4	24	0	1	6	0	3	1	0	0	1	10	2	2	1	109
11/21/03	-	-	-	-	-	-	2	0	3	0	1	2	4	1	3	17	32	0	2	1	68
11/28/03	-	-	-	-	-	-	5	21	0	5	6	1	10	4	9	22	3	0	1	0	87
12/5/03	-	-	-	-	-	-	-	-	-	14	9	23	66	23	84	23	-	-	-	-	242
12/12/03	-	-	-	-	-	-	-	-	-	24	51	15	7	2	12	4	-	-	-	-	115
12/18/03	-	-	-	-	-	-	-	-	-	1	9	32	10	8	39	21	-	-	-	-	120
12/23/03	-	-	-	-	-	-	-	-	-	4	9	2	2	1	4	13	-	-	-	-	35
1/9/04	-	-	-	-	-	-	-	-	-	35	18	56	-	-	-	-	-	-	-	-	109
1/16/04	-	-	-	-	-	-	-	-	-	31	12	13	-	-	-	-	-	-	-	-	56
1/23/04	-	-	-	-	-	-	-	-	-	40	22	46	-	-	-	-	-	-	-	-	108
1/30/04	-	-	-	-	-	-	-	-	-	104	22	69	-	-	-	-	-	-	-	-	195

Appendix 12. Grass shrimp CPUE by trap direction for Arrays 1 – 6 in 2003.

	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**Totals**
1/3/2003	-	-	-	-	-	-	-	-	-	-	-	53	-	-	-	-	-	-	-	-	53
1/10/2003	-	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	-	-	-	27
1/17/2003	-	-	-	-	-	-	-	-	-	71	1	2	-	-	-	-	-	-	-	-	74
1/24/2003	-	-	-	-	-	-	-	-	-	2	12	1	-	-	-	-	-	-	-	-	15
1/31/2003	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	3
3/29/2003	-	-	-	-	-	-	-	-	-	1	1	1	-	-	1	-	-	-	-	-	4
3/30/2003	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	-	-	-	4
3/31/2003	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	3
4/1/2003	-	-	-	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	4
4/2/2003	-	-	-	-	-	-	-	-	-	10	3	3	-	-	-	-	-	-	-	-	16
4/3/2003	-	-	-	-	-	-	-	-	-	1	6	10	-	-	-	-	-	-	-	-	17
4/4/2003	-	-	-	-	-	-	-	-	-	-	10	8	7	-	-	1	-	-	-	-	26
5/1/2003	-	-	-	-	-	-	-	-	-	9	1	11	-	-	-	-	-	-	-	-	21
5/2/2003	-	-	-	-	-	-	-	-	-	10	10	10	-	2	-	-	-	-	-	-	32
5/6/2003	-	-	-	-	-	-	-	-	-	10	10	10	-	1	-	-	-	-	-	-	31
5/7/2003	-	-	-	-	-	-	-	-	-	-	10	10	-	-	-	-	-	-	-	-	20
5/8/2003	-	-	-	-	-	-	-	-	-	4	10	10	-	-	-	-	-	-	-	-	24
5/9/2003	-	-	-	-	-	-	-	-	-	8	3	2	-	-	-	-	-	-	-	-	13
5/16/2003	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	2
5/20/2003	-	-	-	-	-	-	-	-	-	10	4	10	-	-	-	-	-	-	-	-	24
5/21/2003	-	-	-	-	-	-	-	-	-	10	10	10	-	-	-	-	-	-	-	-	30
5/22/2003	-	-	-	-	-	-	-	-	-	11	7	10	-	-	-	-	-	-	-	-	28
5/23/2003	-	-	-	-	-	-	-	-	-	10	10	10	-	-	-	-	-	-	-	-	30
5/24/2003	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	6
5/25/2003	-	-	-	-	-	-	-	-	-	11	10	-	-	-	-	-	-	-	-	-	21
5/26/2003	-	-	-	-	-	-	-	-	-	4	6	-	-	-	-	-	-	-	-	-	10
5/27/2003	-	-	-	-	-	-	-	-	-	10	10	-	-	-	-	-	-	-	-	-	20
5/28/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
5/29/2003	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-	-	-	-	-	-	7
5/30/2003	-	-	-	-	-	-	-	-	10	-	10	-	8	-	-	-	-	-	-	8	36
5/31/2003	-	-	-	-	-	-	-	11	-	-	-	2	-	1	1	-	-	9	-	-	24
6/1/2003	-	-	-	-	-	-	-	2	10	10	-	1	6	-	-	-	-	-	-	-	29
6/2/2003	-	-	-	-	-	-	5	-	10	-	9	-	4	2	2	-	-	-	-	9	41
6/3/2003	-	-	-	-	-	-	-	5	10	-	8	10	2	-	-	-	2	-	6	-	43
6/4/2003	-	-	-	-	-	-	1	6	1	-	-	-	-	-	-	-	-	3	4	-	15
6/5/2003	-	-	-	-	-	-	1	9	1	-	-	-	-	-	-	-	3	1	-	2	17
6/6/2003	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	4	2	9
6/7/2003	-	-	-	-	-	-	1	6	5	-	-	-	-	-	-	-	-	-	-	-	12
6/8/2003	-	-	-	-	-	-	8	1	1	-	-	-	-	-	-	-	-	-	-	5	15
6/9/2003	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	7	-	-	-	12
6/10/2003	-	-	-	-	-	-	-	-	1	1	5	-	2	-	1	-	-	-	-	2	12
6/11/2003	1	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
6/12/2003	1	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
6/13/2003	-	-	1	-	-	-	7	-	7	-	8	3	-	2	-	1	-	1	-	4	34
6/14/2003	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
6/15/2003	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3

Appendix 12-Cont.	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	S	W	E	N	S	W	Total
6/16/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6/17/2003	-	-	1	-	-	-	3	-	9	-	-	-	-	-	-	-	4	7	-	-	24
6/18/2003	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
6/19/2003	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
6/20/2003	-	1	-	2	2	-	1	1	1	-	1	1	-	1	1	-	1	1	-	1	15
6/21/2003	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
6/22/2003	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
6/23/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6/24/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6/25/2003	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
6/26/2003	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
6/27/2003	-	3	3	-	-	-	2	-	8	-	4	20	-	-	-	7	-	-	-	7	54
7/1/2003	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
7/4/2003	-	-	-	-	-	-	1	-	1	-	1	-	1	1	1	-	-	-	-	1	7
7/11/2003	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
7/18/2003	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
7/25/2003	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
8/1/2003	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	2
8/6/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8/8/2003	-	-	-	-	1	-	-	-	-	-	-	-	-	3	2	-	-	-	-	1	7
8/15/2003	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	3
8/22/2003	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	2	5
8/29/2003	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	2
9/5/2003	1	-	-	-	-	-	-	-	-	-	1	-	-	8	-	-	-	-	-	-	10
9/12/2003	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	3
9/19/2003	-	-	-	-	-	-	-	-	1	5	-	2	-	-	1	-	-	-	2	-	11
9/26/2003	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
10/3/2003	-	-	6	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	-	12
10/10/2003	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	1	4
10/17/2003	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2
10/24/2003	-	-	-	-	-	-	-	1	1	1	-	1	1	1	-	-	-	-	-	-	6
10/31/2003	-	-	-	-	-	-	-	-	-	-	-	2	-	6	-	-	-	-	-	-	8
11/3/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11/7/2003	1	-	1	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	5
11/14/2003	51	7	-	23	16	13	-	-	4	-	1	-	6	-	-	1	2	-	-	1	125
11/21/2003	-	-	-	-	-	-	1	-	1	-	-	1	1	1	1	-	1	-	-	-	7
11/28/2003	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	11
12/5/2003	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	-	-	-	4
12/12/2003	-	-	-	-	-	-	-	-	-	-	-	-	5	3	2	12	-	-	-	-	22
12/19/2003	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	1	-	-	-	-	5
12/26/2003	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	3
1/9/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
1/16/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
1/23/2004	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
1/30/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Appendix 13. Crayfish CPUE by trap direction for Arrays 1 – 6 in 2003.

	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**S**	**W**	**E**	**N**	**S**	**W**	**Total**
1/3/2003	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	14
1/10/2003	-	-	-	-	-	-	-	-	-	-	2	13	-	-	-	-	-	-	-	-	15
1/17/2003	-	-	-	-	-	-	-	-	-	1	-	9	-	-	-	-	-	-	-	-	10
1/24/2003	-	-	-	-	-	-	-	-	-	3	1	14	-	-	-	-	-	-	-	-	18
1/31/2003	-	-	-	-	-	-	-	-	-	5	1	3	-	-	-	-	-	-	-	-	9
3/29/2003	-	-	-	-	-	-	-	-	-	3	1	12	-	-	1	2	-	-	-	-	19
3/30/2003	-	-	-	-	-	-	-	-	-	1	-	9	2	-	-	2	-	-	-	-	14
3/31/2003	-	-	-	-	-	-	-	-	-	3	3	31	-	-	1	1	-	-	-	-	39
4/1/2003	-	-	-	-	-	-	-	1	-	7	-	8	-	-	2	-	-	-	-	-	18
4/2/2003	-	-	-	-	-	-	-	2	-	2	-	7	-	-	-	-	1	-	-	1	13
4/3/2003	-	-	-	-	-	-	-	-	-	2	-	4	-	-	-	-	1	-	-	-	7
4/4/2003	-	-	-	-	-	-	-	-	-	1	-	3	1	-	1	1	-	-	-	-	7
5/1/2003	-	-	-	-	-	-	-	1	-	2	1	3	3	-	-	1	-	-	-	-	11
5/2/2003	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	4
5/6/2003	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2
5/7/2003	-	-	-	-	-	-	-	-	-	3	-	2	1	-	1	-	-	-	-	-	7
5/8/2003	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
5/9/2003	-	-	-	-	-	-	-	-	-	1	-	4	-	-	-	-	-	-	-	-	5
5/16/2003	-	-	-	-	-	-	-	-	-	2	-	3	-	-	1	1	-	-	-	-	7
5/20/2003	-	-	-	-	-	-	-	-	-	1	1	2	1	-	-	-	-	-	-	-	5
5/21/2003	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	3
5/22/2003	-	-	-	-	-	-	-	-	-	1	1	3	-	-	-	-	-	-	-	-	5
5/23/2003	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2
5/24/2003	-	-	-	-	-	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	4
5/25/2003	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2
5/26/2003	-	-	-	-	-	-	-	-	-	-	1	-	6	-	1	-	-	-	-	-	8
5/27/2003	-	-	-	-	-	-	-	-	-	-	-	2	-	1	2	2	-	-	-	-	7
5/28/2003	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	2	-	1	6
5/29/2003	-	-	-	-	-	-	-	-	1	-	-	-	-	3	-	-	-	-	-	-	4
5/30/2003	-	-	-	-	-	3	2	-	-	2	-	-	1	-	-	-	-	1	1	1	11
5/31/2003	-	-	-	1	-	1	4	2	2	-	-	-	3	2	1	-	-	-	-	5	21
6/1/2003	-	-	-	-	-	-	2	-	-	-	-	1	1	3	-	-	-	3	-	-	10
6/2/2003	-	-	-	-	-	-	4	1	-	-	1	1	1	1	-	1	-	-	2	-	12
6/3/2003	-	-	-	-	-	-	-	1	1	-	-	3	-	-	-	-	-	2	-	1	8
6/4/2003	-	-	-	-	1	-	2	2	2	-	-	-	-	-	-	-	-	1	1	-	9
6/5/2003	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	4	-	-	7
6/6/2003	-	-	-	-	-	-	-	-	-	-	2	1	1	1	1	-	-	-	3	-	9
6/7/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	3
6/8/2003	-	-	-	-	-	-	1	7	-	-	-	-	-	-	-	-	-	2	-	-	10
6/9/2003	-	-	-	-	6	1	-	1	2	-	-	-	-	-	-	-	-	1	-	-	11
6/10/2003	-	-	-	-	-	-	-	-	1	-	1	1	1	-	-	-	-	1	-	-	5
6/11/2003	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
6/12/2003	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
6/13/2003	-	1	-	-	-	1	2	-	-	-	-	2	-	2	2	-	1	1	1	-	13
6/14/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

[redacted]

Appendix 13-Cont.	Array 1			Array 2			Array 3			Array 4			Array 5				Array 6				
Date	E	N	W	E	N	W	E	N	W	E	N	W	E	N	S	W	E	N	S	W	Total
6/15/2003	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
6/16/2003	4	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
6/17/2003	1	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	4
6/18/2003	-	-	-	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
6/19/2003	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
6/20/2003	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	4
6/21/2003	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
6/22/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6/23/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6/24/2003	1	2	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
6/25/2003	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
6/26/2003	3	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
6/27/2003	-	-	-	-	-	1	-	1	-	-	2	-	-	1	1	-	-	-	2	-	8
7/1/2003	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
7/4/2003	-	2	-	1	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	6
7/11/2003	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	3
7/18/2003	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	4	-	-	-	7
7/25/2003	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	3
8/1/2003	-	-	-	-	-	-	2	4	-	2	1	1	-	1	2	-	-	2	-	-	15
8/6/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
8/8/2003	-	-	-	-	-	1	-	-	1	2	-	3	1	-	-	1	-	2	-	-	11
8/15/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8/22/2003	-	-	-	-	-	6	1	-	-	-	-	1	-	-	-	-	-	1	1	-	10
8/29/2003	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
9/5/2003	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
9/12/2003	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
9/19/2003	-	1	-	2	2	4	-	-	-	-	-	-	-	-	-	-	1	-	-	1	11
9/26/2003	3	-	-	2	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	1	13
10/3/2003	6	-	-	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	10
10/10/2003	-	-	-	-	1	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
10/17/2003	-	-	2	4	1	16	-	-	2	-	-	-	-	-	-	-	-	-	-	-	25
10/24/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2
10/31/2003	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	3
11/3/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11/7/2003	2	1	2	7	10	2	1	1	1	-	-	-	1	-	-	-	-	5	-	-	33
11/14/2003	-	-	2	3	1	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	11
11/21/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	2
11/28/2003	-	-	-	-	-	-	1	1	-	-	-	3	-	2	1	4	2	-	-	-	14
12/5/2003	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	1	-	-	-	-	4
12/12/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	6
12/19/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2
12/26/2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2
1/9/2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
1/16/2004	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
1/23/2004	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
1/30/2004	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	5

Appendix 14. Radio-implanted Florida gar observation records.

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
1	170.2	77095	539529	2809627	Deep water	10:00	5/15/03	Foot	95	None
2	170.2	77094	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
3	170.2	77093	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
4	170.1	77092	539506	2809621	Deep water	10:00	5/15/03	Foot	100	None
5	170.1	77091	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
6	170.1	77090	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
7	170.1	77089	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
8	170.1	77088	539440	2809627	Deep water	10:00	5/15/03	Foot	100	None
9	170.1	77087	539440	2809627	Deep water	10:00	5/19/03	Foot	100	*Eleocharis*
10	170.1	77086	539440	2809627	Deep water	10:00	5/19/03	Foot	100	*Eleocharis*
11	170.1	77085	539440	2809627	Deep water	10:00	5/19/03	Foot	100	*Eleocharis Typha*
12	170	77084	539440	2809627	Deep water	10:00	5/19/03	Foot	100	*Eleocharis*
13	170	77083	539440	2809627	Deep water	10:00	5/19/03	Foot	100	*Eleocharis*
1	170.2	77095	539529	2809684		11:50	5/21/03	Foot	125	*Nymphea Phragmites*
2	170.2	77094	539506	2809577		10:50	5/21/03	Foot	100	None
3	170.2	77093	539511	2809555		10:45	5/21/03	Foot	125	*Nymphea Phragmites*
4	170.1	77092	539507	2809553		10:37	5/21/03	Foot	125	*Typha Phragmites Nymphaea*
5	170.1	77091	539499	2809586		10:55	5/21/03	Foot	100	None
6	170.1	77090	539507	2809557		11:15	5/21/03	Foot	125	*Nymphaea Phragmites*
7	170.1	77089	539557	2809732	Open Marsh	11:15	5/21/03	Foot	25	*Panicum Eleocharis Sagittaria*
8	170.1	77088	539479	2809586		11:25	5/21/03	Foot	100	*Typha Ludwigia Eleocharis*
9	170.1	77087	539511	2809559		10:15	5/21/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539454	2809595		10:05	5/21/03	Foot	100	None
11	170.1	77085	539467	2809536		9:50	5/21/03	Foot	100	*Typha*
12	170	77084	539518	2809570		9:35	5/21/03	Foot	100	None
14	170	77082	539440	2809627	Deep water	10:00	5/21/03	Foot	100	*Eleocharis*
15	170	77081	539440	2809627	Deep water	10:00	5/21/03	Foot	100	*Eleocharis*
1	170.2	77095	540045	2809677		13:20	5/28/03	Foot	125	*Phragmites*
2	170.2	77094	539507	2809570		12:35	5/28/03	Foot	100	None
3	170.2	77093	539497	2809570		12:27	5/28/03	Foot	100	*Phragmites*
4	170.1	77092	539513	2809553		12:20	5/28/03	Foot	125	*Nymphaea Phragmites*
5	170.1	77091	539506	2809577		12:15	5/28/03	Foot	100	*Sagittaria Phragmites*
6	170.1	77090	539508	2809549		12:07	5/28/03	Foot	100	*Nymphaea Phragmites*
7	170.1	77089	539557	2809725	Open Marsh	13:15	5/28/03	Foot	25	*Panicum Eleocharis Sagittaria*
8	170.1	77088	539477	2809581		12:00	5/28/03	Foot	100	*Typha Ludwigia Eleocharis*
9	170.1	77087	539501	2809557		11:45	5/28/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539465	2809590		11:35	5/28/03	Foot	100	*Cladium Eleocharis*
11	170.1	77085	539487	2809627		12:50	5/28/03	Foot	70	*Ludwigia Sagittaria*
12	170	77084	539524	2809559		11:24	5/28/03	Foot	55	*Eleocharis Phragmites*
14	170	77082	539491	2809577		11:12	5/28/03	Foot	100	*Eleocharis Phragmites*
15	170	77081	539497	2809537		11:01	5/28/03	Foot	60	*Eleocharis Phragmites*
2	170.2	77094	539496	2809597		14:30	6/4/03	Foot	100	*Pontedaria Cladium*
5	170.1	77091	539507	2809579		14:20	6/4/03	Foot	100	None
6	170.1	77090	539529	2809518	Open Marsh	14:10	6/4/03	Foot	125	*Cladium Salix*
7	170.1	77089	539566	2809734	Open Marsh	15:05	6/4/03	Foot	60	*Panicum Eleocharis Sagittaria*
8	170.1	77088	539476	2809586		14:00	6/4/03	Foot	100	*Typha Ludwigia*
9	170.1	77087	539501	2809557		14:15	6/4/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539464	2809592		13:55	6/4/03	Foot	100	None
11	170.1	77085	539487	2809627		14:50	6/4/03	Foot	70	*Ludwigia Sagittaria*

Appendix 14, continued

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
12	170	77084	539524	2809559		14:00	6/4/03	Foot	93	*Eleocharis Phragmites*
14	170	77082	539331	2809630		10:07	6/4/03	Foot	60	*Salix Typha*
15	170	77081	539501	2809553		9:50	6/4/03	Foot	125	*Phragmites Salix*
2	170.2	77094	539497	2809585		11:00	6/11/03	Foot	100	None
5	170.1	77091	539499	2809577		10:45	6/11/03	Foot	100	None
8	170.1	77088	539477	2809583		10:30	6/11/03	Foot	100	*Typha Ludwigia*
9	170.1	77087	539507	2809559		10:25	6/11/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539460	2809588		10:25	6/11/03	Foot	100	*Cladium Eleocharis*
11	170.1	77085	539487	2809627		11:10	6/11/03	Foot	70	*Ludwigia Sagittaria*
12	170	77084	539524	2809553		10:15	6/11/03	Foot	100	None
14	170	77082	539331	2809630	Gator Hole	14:00	6/11/03	Foot	80	*Salix Typha*
17	170.1	77089	539440	2809627		10:00	6/13/03	Foot		
5	170.1	77091	539502	2809575		13:05	6/18/03	Foot	125	None
8	170.1	77088	539482	2809583		12:30	6/18/03	Foot	100	*Typha Ludwigia*
9	170.1	77087	539509	2809553		12:54	6/18/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539471	2809590		12:51	6/18/03	Foot	100	*Cladium Eleocharis*
12	170	77084	539531	2809564		12:48	6/18/03	Foot	100	None
14	170	77082	539326	2809656	Gator Hole	13:30	6/18/03	Foot	80	*Salix Typha*
17	170.1	77089	539499	2809590		13:00	6/18/03	Foot		*Pontedaria Sagittaria*
5	170.1	77091	539504	2809579		13:10	6/25/03	Foot	125	None
8	170.1	77088	539481	2809583		13:00	6/25/03	Foot	100	*Typha Ludwigia*
9	170.1	77087	539511	2809555		12:55	6/25/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539454	2809607		12:54	6/25/03	Foot	100	*Cladium Eleocharis*
11	170.1	77085	539487	2809627		13:25	6/25/03	Foot	70	*Ludwigia Sagittaria*
12	170	77084	539531	2809557		12:45	6/25/03	Foot	100	None
14	170	77082	539316	2809673	Gator Hole	13:35	6/25/03	Foot	35	*Salix Typha*
17	170.1	77089	539548	2809542		13:05	6/25/03	Foot	100	*Eleocharis Ludwigia*
1	170.2	77095	539559	2811290	Gator Hole	10:40	6/26/03	Aircraft	125	*Cladium Salix Eleocharis*
2	170.2	77094	539185	2805029	Gator Hole	11:10	6/26/03	Aircraft	100	*Eleocharis Cladium Salix*
3	170.2	77093	541931	2804384	Gator Hole	11:00	6/26/03	Aircraft	100	*Cladium Eleocharis Salix*
5	170.1	77091	539507	2809579		13:03	7/8/03	Foot		
8	170.1	77088	539479	2809583		12:53	7/8/03	Foot	100	*Typha Ludwigia*
9	170.1	77087	539507	2809557		12:50	7/8/03	Foot	125	*Nymphaea Phragmites*
10	170.1	77086	539469	2809590		12:45	7/8/03	Foot	100	*Cladium Eleocharis*
11	170.1	77085	539487	2809627		13:40	7/8/03	Foot		*Ludwigia Sagittaria*
12	170	77084	539531	2809555		12:35	7/8/03	Foot		None
14	170	77082	539323	2809665	Gator Hole	13:10	7/8/03	Foot	35	*Typha Cladium*
17	170.1	77089	539534	2809551		12:56	7/8/03	Foot	100	
2	170.2	77094	538897	2805055	Gator Hole	10:45	7/9/03	Aircraft	100	*Cladium Salix Nymphaea*
3	170.2	77093	541511	2804504	Gator Hole	11:05	7/9/03	Aircraft	100	*Cladium Salix Nymphaea*
16	170.1	77091	539716	2809454	Culvert	14:00	7/18/03	Foot		
18	170.1	77089	539716	2809454	Culvert	10:00	7/18/03	Foot	100	*Nuphar Nymphaea Eleocharis*
19	170.1	77088	539440	2809627		14:33	7/18/03	Foot	100	None
22	170.1	77085	539716	2809454	Culvert	14:00	7/18/03	Foot	120	*Eleocharis Nuphar Nymphaea*
21	170.1	77086	539440	2809627		16:45	7/21/03	Foot		
14	170	77082	539301	2809661		11:51	7/22/03	Foot		
16	170.1	77091	539677	2809496	Culvert	12:07	7/22/03	Foot		*Nymphaea*
18	170.1	77089	539719	2809456	Culvert	10:00	7/22/03	Foot		*Nuphar Nymphaea Eleocharis*
19	170.1	77088	539504	2809561		11:40	7/22/03	Foot	150	*Nymphaea*
21	170.1	77086	539534	2809564		11:30	7/22/03	Foot		*Typha Ludwigia*
22	170.1	77085	539719	2809469	Culvert	12:15	7/22/03	Foot	120	*Eleocharis Nuphar Nymphaea*

Appendix 14, continued

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
2	170.2	77094	539212	2805006	Gator Hole	10:30	7/23/03	Aircraft	100	*Cladium Eleocharis Salix*
3	170.2	77093	541150	2804682	Gator Hole	11:00	7/23/03	Aircraft	100	
14	170	77082	539529	2809531		10:59	7/30/03	Foot		
16	170.1	77091	539677	2809496	Culvert	10:15	7/30/03	Foot		
18	170.1	77089	539719	2809449	Culvert	10:00	7/30/03	Foot		*Nuphar Nymphaea Eleocharis*
19	170.1	77088	539485	2809629		11:47	7/30/03	Foot	150	*Nymphaea Salix*
21	170.1	77086	539536	2809651		11:30	7/30/03	Foot	70	*Cladium Salix*
22	170.1	77085	539719	2809469	Culvert	10:15	7/30/03	Foot	120	*Eleocharis Nuphar Nymphaea*
20	170.1	77087	539439	2807307	Anhinga Trail	10:00	7/31/03	Foot	100	*Eleocharis Nymphaea Nuphar*
23	170	77084	539439	2807307	Anhinga Trail	10:00	7/31/03	Foot	100	*Eleocharis Nuphar Nymphaea*
16	170.1	77091	539719	2809450	Culvert	14:32	8/5/03	Foot		
22	170.1	77085	539727	2809456	Culvert	14:35	8/5/03	Foot		*Sagittaria*
2	170.2	77094	539041	2805034	Marsh	10:00	8/6/03	Aircraft	100	
3	170.2	77093	541525	2805310	Tree Island	10:00	8/6/03	Aircraft	100	
16	170.1	77091	539723	2809685	Culvert	10:40	8/6/03	Aircraft	150	
19	170.1	77088	539569	2809684		10:50	8/6/03	Aircraft	100	
20	170.1	77087	539681	2807732	Anhinga Trail	11:00	8/6/03	Aircraft	100	
21	170.1	77086	539624	2809655		10:30	8/6/03	Aircraft	150	
22	170.1	77085	539712	2809632	East Culvert	10:15	8/6/03	Aircraft	150	
23	170	77084	539571	2807287	Anhinga Trail	10:30	8/6/03	Aircraft	100	None
16	170.1	77091	539725	2809456	East Culvert	15:32	8/7/03	Foot		
19	170.1	77088	539509	2809566	Gator Hole	16:00	8/7/03	Foot	100	*Eleocharis Ludwigia*
20	170.1	77087	539639	2807325	Anhinga Trail	16:30	8/7/03	Foot	100	None
21	170.1	77086	539624	2809655		15:44	8/7/03	Foot	70	*Cladium Salix*
22	170.1	77085	539727	2809457	East Culvert	15:37	8/7/03	Foot	150	*Eleocharis Sagittaria*
23	170	77084	539359	2807323	Anhinga Trail	16:13	8/7/03	Foot		
4	170.1	77092	539487	2809578		11:43	8/13/03	Foot	60	
21	170.1	77086	539500	2809622		11:33	8/13/03	Foot	100	None
22	170.1	77085	539720	2809455	East Culvert	11:10	8/13/03	Foot	150	
23	170	77084	539409	2807321	Anhinga Trail	12:39	8/13/03	Foot	150	*Nymphaea Phragmites*
4	170.1	77092	539493	2809577		15:17	8/21/03	Foot		
21	170.1	77086	539500	2809622		15:04	8/21/03	Foot		*Cladium Salix*
22	170.1	77085	539730	2809472	East Culvert	15:04	8/21/03	Foot	150	
23	170	77084	539649	2807321	Anhinga Trail	15:55	8/21/03	Foot	150	*Nymphaea Phragmites*
2	170.2	77094	539200	2805257	Marsh	10:00	8/26/03	Aircraft		
3	170.2	77093	540676	2805138	Tree Island	10:00	8/26/03	Aircraft		
4	170.1	77092	539172	2809451		10:00	8/26/03	Aircraft	150	
4	170.1	77092	539507	2809570		13:00	8/26/03	Aircraft		
18	170.1	77089	539519	2809564		13:39	8/26/03	Aircraft		
20	170.1	77087	539864	2805738	Marsh	10:00	8/26/03	Aircraft		
21	170.1	77086	539504	2809643		10:00	8/26/03	Aircraft		
22	170.1	77085	539507	2809542		10:00	8/26/03	Foot	150	*Sagittaria*
23	170	77084	539872	2805519	Anhinga Trail	10:00	8/26/03	Aircraft	150	
16	170.1	77091	539723	2809445	East Culvert	12:02	8/27/03	Foot	150	
18	170.1	77089	539539	2809677	Pond	11:21	8/27/03	Foot	225	*Cladium Nymphaea Phragmites*
21	170.1	77086	539544	2809648		10:38	8/27/03	Foot		
24	170.1	77086	539075	2809831	West Culvert	17:00	8/27/03	Foot	150	None
25	170	77082	539075	2809831	West Culvert	17:00	8/27/03	Foot	150	None
2	170.2	77094	538868	2805543	Tree Island	9:00	9/3/03	Aircraft		
3	170.2	77093	540215	2805306	Tree Island	9:00	9/3/03	Aircraft		
20	170.1	77087	540145	2805917	Pond	9:00	9/3/03	Aircraft		

Appendix 14, continued

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
22	170.1	77085	539542	2809523		9:00	9/3/03	Aircraft		None
23	170	77084	539916	2805466	Marsh	9:00	9/3/03	Aircraft		
24	170.1	77086	539005	2809938	West Culvert	9:00	9/3/03	Aircraft	150	None
25	170	77082	539249	2809801	West Culvert	9:00	9/3/03	Aircraft		None
4	170.1	77092	539487	2809568		13:21	9/5/03	Foot		*Typha Cladium Eleocharis*
16	170.1	77091	539719	2809446	East Culvert	13:09	9/5/03	Foot	150	*Nuphar Sagittaria Eleocharis*
22	170.1	77085	539538	2809558		13:13	9/5/03	Foot	150	None
24	170.1	77086	539078	2809888	Marsh	13:58	9/5/03	Foot	70	*Cladium*
25	170	77082	539018	2809864	West Culvert	13:45	9/5/03	Foot	100	*Pontedaria Cladium*
4	170.1	77092	539507	2809571		13:45	9/11/03	Foot		
22	170.1	77085	539505	2809556		13:37	9/11/03	Foot	200	None
24	170.1	77086	539063	2809819	West Culvert	14:04	9/11/03	Foot	200	*Cladium*
25	170	77082	539038	2809863	West Culvert	14:13	9/11/03	Foot	40	*Cladium*
4	170.1	77092	539506	2809560		10:23	9/16/03	Foot		
16	170.1	77091	539724	2809455	East Culvert	9:48	9/16/03	Foot	150	*Thalia*
22	170.1	77085	539509	2809561		10:32	9/16/03	Foot	225	None
24	170.1	77086	539137	2809741	Gator Hole	11:00	9/16/03	Foot		*Cladium Salix*
25	170	77082	539019	2809872	West Culvert	10:48	9/16/03	Foot	30	*Cladium*
2	170.2	77094	538981	2805140	Tree Island	8:40	9/18/03	Aircraft		
3	170.2	77093	540423	2805343	Tree Island	9:00	9/18/03	Aircraft		
20	170.1	77087	539926	2805812	Gator Hole	9:20	9/18/03	Aircraft		
23	170	77084	540001	2805607	Marsh	8:14	9/18/03	Aircraft		
6	170.1	77090	539889	2809326		11:51	9/25/03	Foot	20	*Cladium*
16	170.1	77091	539831	2809385	East Bridge	11:32	9/25/03	Foot	60	*Sagittaria Eleocharis Bacopa*
22	170.1	77085	539509	2809546	West Culvert	12:45	9/25/03	Foot	60	*Typha Nymphaea Phragmites*
24	170.1	77086	539066	2809818	West Culvert	13:45	9/25/03	Foot	200	
25	170	77082	539028	2809864	West Culvert	13:39	9/25/03	Foot	40	*Cladium*
18	170.1	77089	539860	2809361	East Culvert	12:26	9/26/03	Foot	25	
3	170.2	77093	539880	2808671	Anhinga Trail	12:30	10/2/03	Foot	25	*Eleocharis Rhynchospora*
4	170.1	77092	539463	2809563	West Bridge	13:41	10/2/03	Foot		*Typha Eleocharis*
6	170.1	77090	539821	2809299	East Culvert	13:05	10/2/03	Foot	25	*Cladium* Periphyton
23	170	77084	539708	2807319	Anhinga Trail	10:25	10/2/03	Foot	100	*Typha Phragmites Panicum*
24	170.1	77086	539065	2809829	West Culvert	14:00	10/2/03	Foot	40	*Ludwigia*
25	170	77082	539065	2809829	West Culvert	14:02	10/2/03	Foot	40	*Cladium Ludwigia* Periphyton
2	170.2	77094	538974	2805393	Tree Island	12:02	10/7/03	Aircraft		
16	170.1	77091	539648	2809368	East Culvert	11:47	10/7/03	Aircraft		
20	170.1	77087	540052	2805775	Tree Island	12:06	10/7/03	Aircraft		
4	170.1	77092	539465	2809565	West Bridge	13:10	10/14/03	Foot	40	*Typha Eleocharis*
16	170.1	77091	539643	2809492	East Bridge	12:40	10/14/03	Foot	25	*Typha Eleocharis*
23	170	77084	539500	2807325	Anhinga Trail	14:25	10/14/03	Foot	50	*Eleocharis Panicum Pontedaria*
24	170.1	77086	539068	2809820	West Culvert	13:45	10/14/03	Foot	35	Periphyton
25	170	77082	539052	2809846	West Culvert	13:35	10/14/03	Foot	30	*Cladium Spartina Eleocharis*
4	170.1	77092	539490	2809529	West Culvert	0:12	10/15/03	Foot	40	*Typha Phragmites Nymphaea*
23	170	77084	539471	2807311	Anhinga Trail	0:54	10/15/03	Foot		
4	170.1	77092	539494	2809569		11:13	10/21/03	Foot	50	
16	170.1	77091	539518	2809535	Pond	11:04	10/21/03	Foot	60	*Salix*
23	170	77084	539425	2807326	Anhinga Trail	12:55	10/21/03	Foot	60	*Eleocharis Sagittaria Nymphaea*
24	170.1	77086	539254	2809426	Open Marsh	12:05	10/21/03	Foot	55	*Eleocharis*
2	170.2	77094	539698	2806092	Tree Island	11:53	10/22/03	Aircraft		
3	170.2	77093	539506	2808091	Anhinga Trail	11:38	10/22/03	Aircraft	50	
20	170.1	77087	539792	2805752	Tree Island	12:00	10/22/03	Aircraft		

Appendix 14, continued

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
25	170	77082	539277	2808536	Anhinga Trail	11:48	10/22/03	Aircraft	50	None
2	170.2	77094	539502	2809583		12:24	10/28/03	Foot		
4	170.1	77092	539494	2809595		12:20	10/28/03	Foot	45	
23	170	77084	539438	2807313	Anhinga Trail	13:02	10/28/03	Foot	100	*Eleocharis Nymphaea*
2	170.2	77094	539533	2809560	West Culvert	11:00	11/5/03	Aircraft	150	
4	170.1	77092	539489	2809568	West Culvert	11:10	11/5/03	Aircraft	60	
23	170	77084	539428	2807309	Anhinga Trail	11:46	11/5/03	Aircraft	100	
3	170.2	77093	539293	2808711	Central TS	10:20	11/10/03	Aircraft		
16	170.1	77091	539519	2809392	West Culvert	10:00	11/10/03	Aircraft		
20	170.1	77087	540017	2805869	Pond	10:25	11/10/03	Aircraft		
23	170	77084	539243	2807280	Anhinga Trail	10:10	11/10/03	Aircraft	100	
24	170.1	77086	539308	2809721	West Culvert	10:40	11/10/03	Aircraft		
25	170	77082	538990	2809825	West Culvert	10:50	11/10/03	Aircraft		None
4	170.1	77092	539460	2809599		13:20	11/18/03	Foot	100	
16	170.1	77091	539725	2809453	Culvert	13:23	11/18/03	Foot		
23	170	77084	539443	2807354	Open Marsh	13:57	11/18/03	Foot	40	*Cladium*
24	170.1	77086	539076	2809825	West Culvert	13:10	11/18/03	Foot	150	*Sagittaria Eleocharis Ludwigia*
25	170	77082	539077	2809831	West Culvert	13:07	11/18/03	Foot	150	*Sagittaria Eleocharis Ludwigia*
3	170.2	77093	539764	2808415	Central TS	10:20	11/18/03	Foot		
3	170.2	77093	539195	2808735	West Bridge	10:20	11/24/03	Aircraft		
4	170.1	77092	539500	2809222	West Bridge	13:20	11/24/03	Aircraft		
16	170.1	77091	539620	2809622	West Bridge		11/24/03	Aircraft		
23	170	77084	539571	2807510	Anhinga Trail	13:57	11/24/03	Aircraft		
24	170.1	77086	538859	2809756	West Culvert	13:10	11/24/03	Aircraft		None
25	170	77082	539165	2809776	West Culvert	13:07	11/24/03	Aircraft		None
23	170	77084	539289	2807404	Open Marsh	12:02	12/3/03	Foot		Salix
24	170.1	77086	539420	2809552	open marsh	13:00	12/3/03	Foot		*Cladium Eleocharis*
25	170	77082	539077	2809841	West Culvert	12:52	12/3/03	Foot	100	*Sagittaria Eleocharis Ludwigia*
2	170.2	77094	539495	2809580		14:02	12/12/03	Foot		
16	170.1	77091	539719	2809438	East Bridge	13:52	12/12/03	Foot	150	*Nymphaea Sagittaria*
23	170	77084	539343	2807321	Pond	14:42	12/12/03	Foot	225	None
25	170	77082	539308	2809667	West Bridge	14:23	12/12/03	Foot	50	*Typha Salix Conocarpus*
3	170.2	77093	539525	2809554	Central TS	10:20	12/18/03	Aircraft		
16	170.1	77091	539551	2809522		15:07	12/18/03	Aircraft	40	*Typha Sagittaria*
23	170	77084	539449	2807321	Ditch	15:44	12/18/03	Aircraft	100	*Eleocharis*
23	170	77084	539438	2807311	Anhinga Trail	9:49	1/8/04	Foot	50	None
24	170.1	77086	539352	2807317	Pond	9:56	1/8/04	Foot	150	None
25	170	77082	539638	2807317	Culvert	10:05	1/8/04	Foot	50	*Nymphaea Phragmites*
23	170	77084	539439	2807309	Anhinga Trail	9:40	1/16/04	Foot	30	None
25	170	77082	539678	2807336	Anhinga Trail	9:58	1/16/04	Foot	125	None
23	170	77084	539437	2807311	Anhinga Trail	13:48	1/23/04	Foot	40	*Eleocharis*
25	170	77082	539677	2807336	Anhinga Trail	14:14	1/23/04	Foot	125	None
23	170	77084	539437	2807311	Anhinga Trail	10:00	1/30/04	Foot	30	*Eleocharis*
25	170	77082	539306	2807356	Anhinga Trail	10:10	1/30/04	Foot	225	None
23	170	77084	539437	2807311	Anhinga Trail	9:37	2/2/04	Foot	125	*Eleocharis*
25	170	77082	539306	2807356	Anhinga Trail	10:30	2/2/04	Foot	225	None
23	170	77084	539494	2807317	Anhinga Trail	9:44	2/6/04	Foot	75	*Eleocharis*
25	170	77082	539632	2807497	Anhinga Trail	10:02	2/6/04	Foot	225	*Salix*
23	170	77084	539449	2807309	Anhinga Trail	10:17	2/12/04	Foot	200	*Eleocharis*
25	170	77082	539632	2807497	Anhinga Trail	10:40	2/12/04	Foot	225	*Salix*
23	170	77084	539461	2807328	Open Marsh	15:29	2/19/04	Foot		

Appendix 14, continued

Gar	Freq	Trans.	Eastnad83	Northnad83	Habitat	Time	Date	Method	Depth	Vegetation
25	170	77082	539675	2807357	Anhinga Trail	15:49	2/19/04	Foot	225	None
23	170	77084	539337	2807326	Pond	8:16	2/26/04	Foot	225	None
25	170	77082	539427	2807307	Anhinga Trail	8:20	2/26/04	Foot	150	None
23	170	77084	539422	2807305	Anhinga Trail	9:02	3/3/04	Foot	100	*Eleocharis*
25	170	77082	539686	2807328	Anhinga Trail	9:13	3/3/04	Foot	100	None
23	170	77084	539437	2807307	Anhinga Trail	9:22	3/12/04	Foot	40	None
25	170	77082	539673	2807329	Anhinga Trail	9:31	3/12/04	Foot	75	None
25	170	77082	539299	2807377	Anhinga Trail	9:30	3/19/04	Foot	100	None
25	170	77082	539338	2807327	Anhinga Trail	9:59	3/26/04	Foot	50	None
25	170	77082	539304	2807327	Anhinga Trail	9:06	4/2/04	Foot	100	None
25	170	77082	539317	2807345	Anhinga Trail	9:40	4/9/04	Foot		None

Appendix 15. Diel movements by Florida gar over a 24-hour period.

Gar	Freq	Transmitter	Eastnad83	Northnad83	Habitat	Time	Date	Method
4	170.14	77092	539465	2809565	West Bridge	13:10	10/14/03	Foot
4	170.14	77092	539470	2809562	West Bridge	15:30	10/14/03	Foot
4	170.14	77092	539453	2809586	West Bridge	18:25	10/14/03	Foot
4	170.14	77092	539452	2809547	TSB West	21:32	10/14/03	Foot
4	170.14	77092	539490	2809529	TSB West	0:12	10/15/03	Foot
4	170.14	77092	539501	2809561	TSB West	3:54	10/15/03	Foot
4	170.14	77092	539501	2809566	TSB West	6:42	10/15/03	Foot
4	170.14	77092	539461	2809587	TSB West	9:29	10/15/03	Foot
4	170.14	77092	539510	2809559	TSB West	12:37	10/15/03	Foot
16	170.132	77091	539643	2809492	East Bridge	12:40	10/14/03	Foot
16	170.132	77091	539650	2809474	Open Marsh	15:20	10/14/03	Foot
16	170.132	77091	539667	2809456	Open Marsh	18:05	10/14/03	Foot
16	170.132	77091	539709	2809422	Open Marsh	21:26	10/14/03	Foot
16	170.132	77091	539659	2809461	Open Marsh	0:06	10/15/03	Foot
16	170.132	77091	539645	2809463	Open Marsh	4:02	10/15/03	Foot
16	170.132	77091	539557	2809530	Open Marsh	6:35	10/15/03	Foot
16	170.132	77091	539517	2809547	TSB Pond	9:10	10/15/03	Foot
16	170.132	77091	539504	2809563	TSB Pond	12:21	10/15/03	Foot
23	170.047	77084	539500	2807325	Anhinga	14:25	10/14/03	Foot
23	170.047	77084	539479	2807320	Anhinga	16:00	10/14/03	Foot
23	170.047	77084	539476	2807342	Anhinga	19:00	10/14/03	Foot
23	170.047	77084	539453	2807340	Anhinga	22:30	10/14/03	Foot
23	170.047	77084	539471	2807311	Anhinga	0:54	10/15/03	Foot
23	170.047	77084	539470	2807312	Anhinga	3:30	10/15/03	Foot
23	170.047	77084	539438	2807322	Anhinga	7:17	10/15/03	Foot
23	170.047	77084	539418	2807312	Anhinga	10:21	10/15/03	Foot
23	170.047	77084	539418	2807315	Anhinga	13:10	10/15/03	Foot
24	170.073	77086	539068	2809820	West Culvert	13:45	10/14/03	Foot
24	170.073	77086	539071	2809813	West Culvert	15:45	10/14/03	Foot
24	170.073	77086	539052	2809822	Open Marsh	22:05	10/14/03	Foot
24	170.073	77086	539069	2809814	West Culvert	0:41	10/15/03	Foot
24	170.073	77086	539067	2809814	West Culvert	3:46	10/15/03	Foot
24	170.073	77086	539064	2809813	West Culvert	7:00	10/15/03	Foot
24	170.073	77086	539061	2809813	West Culvert	9:55	10/15/03	Foot
24	170.073	77086	539072	2809814	West Culvert	12:54	10/15/03	Foot
25	170.021	77082	539052	2809846	TSB West	13:35	10/14/03	Foot
25	170.021	77082	539053	2809841	TSB West	15:40	10/14/03	Foot
25	170.021	77082	539055	2809845	TSB West	18:35	10/14/03	Foot
25	170.021	77082	539060	2809817	TSB West	22:01	10/14/03	Foot
25	170.021	77082	539075	2809836	TSB West	0:33	10/15/03	Foot
25	170.021	77082	539070	2809793	TSB West	3:43	10/15/03	Foot
25	170.021	77082	539067	2809828	TSB West	6:55	10/15/03	Foot
25	170.021	77082	539048	2809834	TSB West	9:48	10/15/03	Foot
25	170.021	77082	539023	2809862	TSB West	12:48	10/15/03	Foot