



March, 2012

Jeff Kline
South Florida Natural Resources Center
Everglades National Park
40001 State Road 9336
Homestead, FL 33034-6733

re: Cooperative Agreement H5000060104, Task No. J5284060023

Dear Jeff:

I have enclosed the final report for the cooperative agreement task entitled, *Analyzing the Impact of the Interim Operating Plan (IOP) in the Eastern Everglades, Everglades National Park*. Data collection and processing were completed in a timely fashion with the project goals. All field data for study sites in Everglades National Park collected and are being posted to our growing database. I am simultaneously submitting an electronic version of this report to the FIU Department of Sponsored Research, who will be forwarding that to your accountants.

We met all of the expectations laid out in the Scope of Work for this time period, and obtained a significant amount of information that will be useful for evaluating IOP and related activities, and in the Everglades restoration effort.

Please feel free to contact me (voice 305-348-1966 or trexlerj@fiu.edu) should any questions arise regarding our efforts for this project or the attached report.

Sincerely,

Joel Trexler
Professor

Final Report

September 2, 2006 through August 30, 2011

Cooperative Agreement: *Cooperative Agreement H5000060104, Task No. J5284060023*

Analyzing the Impact of the Interim Operating Plan (IOP) in the Eastern Everglades, Everglades National Park

Joel Trexler

Submitted March, 2012

Joel Trexler, Principal Investigator

Table of Contents

I. Executive Summary	3
II. Project Overview	4
A. Project Objectives	5
B. Methods	5
C. Personnel	8
D. List of publications and presentations	8
III. Findings: Fish	10
IV. Findings: Invertebrates	92
V. Findings: Periphyton and nutrient gradients	112
VIA. Findings: Large fish moving from canals	141
VIB. Findings: Fish in canals	147
VII. Manuscripts	
1. Obaza, A., D. L. DeAngelis, and J. C. Trexler. 2011. Using data from an encounter sampler to model fish dispersal. <i>Journal of Fish Biology</i> 78:495-513.	
2. Hoch, J. M., E. R. Sokol, A. D. Parker, and J. C. Trexler. Interspecific variation of movement strategies of small fish in a complex, seasonally-fluctuating environment. Manuscript	
3. Sokol, E. R., J. M. Hoch, and J. C. Trexler. The influence of ecological context over continuum-based community assembly. Manuscript	
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VIII. Presentations and Poster (Files sent separately)	
1. Sokol, E. R. , J. M. Hoch, and J. C. Trexler. Inter-annual variation in hydroperiod affects periphyton standing crop and the associated macroinvertebrate community in the Everglades. Poster GEER 2010	
2. Hoch, J. M., E. R. Sokol and J. C. Trexler. Monitoring Fish Communities and Populations on the Eastern Boundary of Everglades National Park. Poster GEER 2010	
3. Banet, A. I., and J. C. Trexler. Space-for-time substitutions in predictive models. Presentation, American Fisheries Society, September 2011.	

II. Executive Summary

In 2003 we proposed that hydration of short-hydroperiod Everglades marshes as part of a restoration program presented an assessment challenge. We hypothesized that lengthening hydroperiod lengthens the growing season and increases primary and secondary production. Furthermore, introducing water flow may suspend or otherwise re-distribute organic matter and release previously biologically unavailable nutrients. Increasing connectivity between habitats should also increase ecological dynamics by adding more migration of animals passing through the formerly isolated edge habitats. Animals transiting from canals to ENP marshes may bring nutrient imports, collected in the canal and released in the recipient marsh. Taken together, these hypothesized restoration effects may look a lot like anthropogenic nutrient enrichment! Thus, an overarching goal of this project has been to develop a conceptual model for data analysis to discriminate a trajectory of ecological restoration from one of eutrophication. Ultimately, eutrophication is very different from restoration, but our goal was to use ecological monitoring to discern at the earliest possible stage which trajectory is being realized in order to permit early action if restoration is going in the wrong direction.

This report describes the results of several coupled analyses of fish, macroinvertebrates, and periphyton on the eastern border of Everglades National Park (ENP), in marshes adjacent to recent efforts to manage over-drying and retain water in the Rocky Glades. These studies document edge effects across a variety of biological data that indicate nutrient enrichment associated with efforts to hydrate marshes and active movement of fish across canal-marsh boundaries created when sheet-flow is recovered. This active movement has included expansion of non-native fishes from disturbed habitats outside of ENP, notably by invasion of jewelfish into the Rocky Glades in the early 2000's. Similar to other fish invasions, this fish appears to be following a pattern of explosive population growth followed by a drop in local density with the freeze of January 2010, and possibly increasing again since that time. Their numbers peaked in 2009 in collections for this project and have dropped to a lower but persistent level in more recent years. Nutrient dynamics have proven to be complex and troubling; early influx of nutrients (2003-2005) appeared to abate in later years (2007-2008), but may be increasing again at some sites. These patterns do NOT provide a strong impetus for concern about nutrient enrichment from new construction in the S332, Aerojet, and C-111 areas, but they do not remove concern either. As expected by our periphyton tissue phosphorus results, macroinvertebrates and fish display edge effects consistent with local nutrient enrichment at the canal-marsh interface. Continued monitoring is recommended. Future work will develop conceptual models for the role of fluxes of nutrients and animals across the canal marsh interface. We now have the data necessary to pursue the original question of this program.

II. Project Overview

This project provides long-term data for assessing the impacts, if present, of water management activities intended to lengthen hydroperiods along the eastern border of Everglades National Park and increase sheet flow from the L-31W canal and C-111 basin. These projects are part of the Interim Operating Plan (IOP). Early work for a previous cooperative agreement of this project suggested that phosphorus enrichment may be an unintended consequence of the new management under IOP. Thus, this cooperative agreement focused on two goals: 1) documenting any continued nutrient impacts from IOP management, if present, and 2) assessing impacts on aquatic fauna in wetlands of Everglades National Park (ENP) associated with these management actions. Briefly described, management actions for IOP included construction of a system of detention ponds along the eastern border of ENP operated to create a hydraulic head that would block eastward seepage of water from within ENP and encourage it to flow southward in the Rocky Glades toward Taylor Slough. A levee immediately north of the decommissioned S-332 structure was degraded to permit sheet flow from the L-31W canal to form a new ‘headwaters’ area for Taylor Slough. In 2009, the original detention ponds were connected along the ENP boundary north of State Road 9226, and additional ponds were created in the Frog Pond and Aero Jet Canal area to further increase the storage capacity of this region. All of this construction had the potential to make several major changes in hydrology of this area and created experiments in hydrological management with major possible impacts on aquatic ecology of the region. The desired impacts of this effort were to increase hydroperiod in the affected wetlands and add sheetflow from water inflow points, particularly at the new Taylor Slough headwaters. This project was designed to gather data necessary to evaluate the following Restoration Hypothesis: Adding sheetflow and lengthening hydroperiod in short-hydroperiod Everglades wetlands will increase system productivity by lengthening the growing season and diminishing seasonal mortality of aquatic animals. In addition, we propose that the hypothesized pattern of ecological restoration will look similar to the effects of nutrient enrichment. Thus, in addition to evaluating the Restoration Hypothesis, we sought to develop and evaluate a successional model of restoration that could be used to distinguish the desired effects of lengthening hydroperiod from the early effects of nutrient enrichment.

This project continued and expanded monitoring research along the eastern boundary of Everglades National Park (ENP) that was begun in 2003 with the goal of assessing ongoing efforts to hydrate habitats of the Rocky Glades, Taylor Slough headwaters. During this 5-year cooperative agreement, work was expanded to include sites in the C-111 basin, upstream from the ENP panhandle, and associated with the Aerojet Canal project. Water detention areas were constructed on the eastern boundary of ENP under the plan that water held there would enter the groundwater to the east, creating a hydrological head to the west, inside ENP. In addition, sheetflow was introduced at the headwater of ENP in the vicinity of the old S-332 pumpstation with the intent to restore hydrological sheetflow at the Taylor Slough headwaters. Recently, the detention basins have been expanded along the eastern boundary of ENP and connected to the Aerojet canal and C-111 basin.

Monitoring work under this and a previous agreement suggested the new water management associated with the C-111 Southern and Frogpond Detention Areas may be creating changes in the nutrient dynamics of adjacent marshes. It is hoped that this is a temporary flushing of nutrients from historical farm lands that now house the detention areas and these impacts will subside with use. Though recent data are encouraging, continued monitoring is warranted because it is critical to prevent or minimize the impacts of nutrient additions before they reach levels where ecosystem effects are produced.

Project Objectives:

- 1) Gather field data on fish in IOP and C-111 project and reference areas of ENP.
- 2) Measure tissue phosphorus in periphyton and vascular plants in transects abutting new and anticipated construction along the eastern boundary of ENP.
- 3) Use field monitoring data to assess the influence of water management structures and operations by interpreting performance measures of nutrient inputs and hydration of short-hydroperiod marshes, and colonization of ENP by non-native fishes.

Methods

Fish Monitoring- Monitoring of fishes has kept pace with expansion of the IOP/C-111 projects along the eastern boundary. We monitored fishes at the 332B, C, and D retention areas and the marshes associated with the L-31W canal south of S-175 structure, the Aerojet borrow canal, and the C-111 canal south of S-18C (Figure II.1). Monitoring sites were selected with the objectives of having control and impact sites, but also with the objective of detecting change before and after management changes occur.

Fish monitoring in these Everglades edge habitats required special methods because of the dense vegetation and uneven ground surface. Obaza et al. (2011) describe the drift net methodology developed to accommodate these challenges. The original drift fences used for this project were permanently installed and have been shown to have biases and also some visual impacts to visitors. During this cooperative agreement, we developed small portable drift fences as a replacement of the original large drift fences and these have been shown to provide similar samples to the original traps (Figure II.2). These smaller drift fences enable samples from randomly selected sites, reducing impact of returning the same site repeatedly (trail impacts for example). These fences are also less visible to Park visitors.

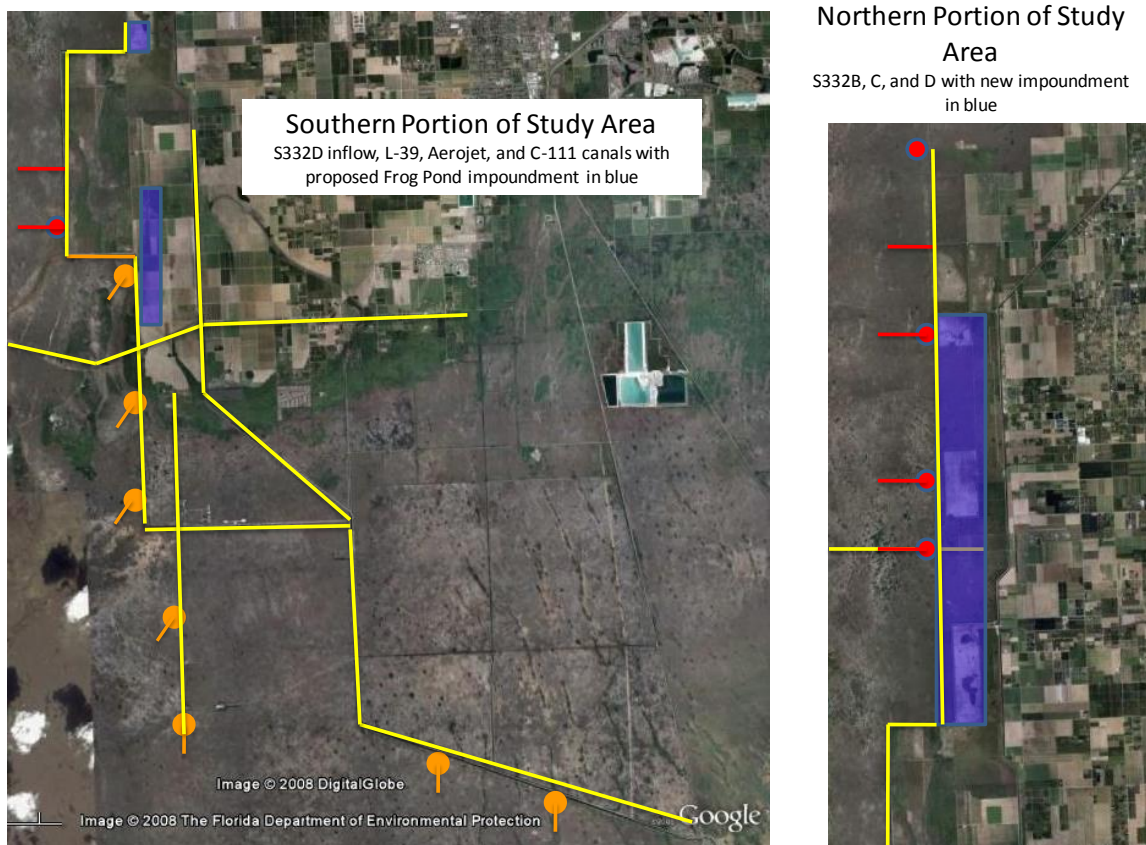


Figure II.1. Map of the study area. Right panel is the northern portion of the study area and left panel is the southern portion. Yellow lines indicate existing canals and roads; blue rectangles mark detention basins; red symbols indicate long-term monitoring sites; orange symbols new monitoring sites initiated in 2010; circles are sites of fish monitoring and short lines indicate transects for periphyton sampling.

Sampling was conducted bi-monthly while water is on the marsh surface, for a maximum of 8 sampling events. Past experience has indicated that we cannot predict the actual number of sampling events because it depends on the amount of rainfall and pump operations in the area. There is a tight relationship between canal management, marsh surface inundation, and fish movement in this area and our monitoring work must be adjusted to match water fluctuation as it occurs. We sample from three to six drift fences at each site on each sampling event. One fence is established adjacent to the canal, one is placed in the wetland 200 m into the wetland (perpendicular to the canal), and the third is placed 400 m into the wetland.

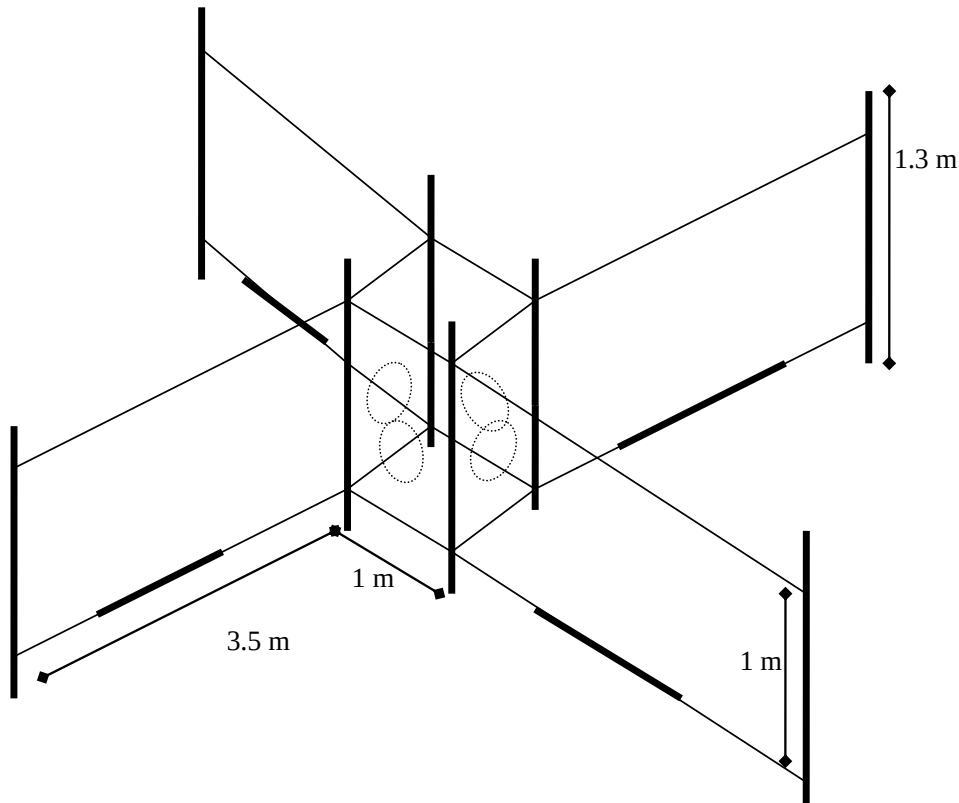


Fig II.2. Portable drift fence used to sample fishes as they move along the marsh surface in the Rocky Glades and similar short-hydroperiod marshes of the Everglades. Water depths must exceed 15cm to immerse the traps adequately to sample.

In addition to the fish collections on the marsh, we used a dual frequency identification sonar device (DIDSON) to document large fish in canals and to document behaviors at the canal-marsh boundary (e.g., Becker et al. 2011). The DIDSON was used to enumerate fish at the marsh-canal border of L-31W for this project, and at the L-67C canal for a different project that served for comparison and assisted in interpretation of the resulting data. These data complement radio tracking of fish moving between the L-31W canal system and adjacent marsh. Taken together, these data demonstrate the close linkage between canal dynamics and the marsh receiving fish and nutrients from the canals.

Invertebrate monitoring – Macroinvertebrates were sampled at drift fences in the S-332B, C, and D areas, as well as at long-term study sites in Shark River Slough, to evaluate impacts of re-hydrating marshes. Periphyton infauna (Liston and Trexler 2005) from periphyton core samples and larger macroinvertebrates from benthic sweep-net samples (Turner and Trexler 1997) were enumerated and their patterns assessed based on hydroperiod and proximity to canal inflows or

water detention areas.

Phosphorus monitoring- Phosphorus monitoring was expanded to all sites selected for the fish monitoring during this cooperative agreement, as well as some additional locations (Fig 1). Variables measured include periphyton biomass (AFDM), periphyton chlorophyll a, periphyton tissue total phosphorus, periphyton community structure, vascular plant tissue total phosphorus, and soil surface total phosphorus. Each transect was be sampled at 4 distances spaced 20 m apart from the canal border to a maximum of 80m from the edge following Gaiser et al. (2006).

The following sections discuss the results from these efforts.

Project Personnel:

Joel Trexler, PI; Evelyn Gaiser, co-PI

Post-docs: Alexander Fernandez, Eric Sokol, J. Matthew Hoch, Laura Belicka, Cristina Bruno

Technicians: Alani Taylor, Franco Tobias, Chuck Goss, Adam Obaza, Kristie Erickson, Jesenia Mejias, Angela Morino, Shawn Liston, Brooke Shamblin, and Raul Urgelles

Subcontracts: William Loftus, Jiangang Luo

List of Publications and Presentations:

Manuscripts

1. Obaza, A., D. L. DeAngelis, and J. C. Trexler. 2011. Using data from an encounter sampler to model fish dispersal. *Journal of Fish Biology* 78:495-513.
2. Hoch, J. M., E. R. Sokol, A. D. Parker, and J. C. Trexler. Interspecific variation of movement strategies of small fish in a complex, seasonally-fluctuating environment. Manuscript
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Presentations and Poster

1. Banet, A. I., and J. C. Trexler. Space-for-time substitutions in predictive models. Presentation, American Fisheries Society, September 2011.
2. Sokol, E. R., J. M. Hoch, and J. C. Trexler. Inter-annual variation in hydroperiod affects periphyton standing crop and the associated macroinvertebrate community in the Everglades. Poster GEER 2010
3. Hoch, J. M., E. R. Sokol and J. C. Trexler. Monitoring Fish Communities and Populations on the Eastern Boundary of Everglades National Park. Poster GEER 2010
4. Belicka, Trexler, Sokol, Hoch, and Jaffé. Biochemical Markers of the Effects of Canal-Induced Nutrient Gradients on Food-Webs in a Taylor Slough Freshwater Marsh. Poster GEER 2010

5. Obaza, A. K., and J. C. Trexler Application of a foraging model to estimate fish movement rates from trap data. Ecological Society of America, Aug 2009
6. Liston, Trexler, King, Hagerthey. Effects of Phosphorus Availability on Aquatic Food Webs and Community Structure in the Everglades. GEER 2008
7. Obaza and Trexler. Effectiveness of Drift Fences as a Method for Monitoring Fish Movement. (poster) GEER 2008
8. Goss and Trexler. Forecasting models and environmental impact assessment: The implications of ISOP/IOP for Everglades fish communities. (poster) GEER 2008
9. Trexler, Liston, and Gaiser Monitoring impacts of the S-332 structures on aquatic fauna of the Rocky Glades. (poster) GEER 2006

Meetings with So Florida Environmental Managers and Science Coordinators:

Trexler, J. C., C. Goss, E. E. Gaiser. Taylor Slough aquatic communities from the headwaters to Craighead Pond. South Florida Natural Resources Center (ENP), Sept 12, 2007

Fish Collected at IOP sites

J. Matthew Hoch and Joel Trexler

Introduction

The eastern boundary of Everglades National Park (ENP) is characterized by wetlands inundated for three months or less in many years. This short inundation time has led to sparse development of soil, leaving much exposed eroded limestone that inspired the region's name, Rocky Glades. Characterized by many solution holes and very short hydroperiod marshes, this is a harsh habitat for aquatic animals such as fishes (Kobza et al. 2004). Little is known about the ecology of aquatic animals in this area, which creates a challenge for ecological assessment of management of the area. We hypothesize that re-hydrating the area as part of ecosystem restoration will change these communities to be more similar to those of long-hydroperiod wetlands, though the time course for restoration and its predictability are unknown.

We monitored consumer communities (fish, invertebrates, reptiles and amphibians) on the eastern boundary of Everglades National Park from December 2003 through the present. Our sampling was carried out adjacent to the S332 water impoundments, the L-31W and C111 canals and the structures and activity adjacent to the Aerojet property. We also sampled in reference sites (Context Rd, abbreviated CXT and Chekika, abbreviated CKK) and sites in the long-hydroperiod portion of ENP (Shark River Slough). We used a passive sampler (a drift-fence) that captures moving animals, yielding multiple types of information: catch-per-unit-effort (CPUE) of individual species, their relative movement (direction and speed) and community structure (relative abundance). Our large-scale goal is to reveal any changes in these metrics as a result of varying hydroperiod, management or impacts from management structures (canals,

impoundments, etc).

Here we report our findings from the last several years, and test several hypotheses:

1. The abundance of native fish taxa varied among regions of the study;
2. The abundance of non-native fish taxa varied among regions of the study;
3. The community structure of fish varied among regions of the study and over the course of time;
4. The community structure of fish varies among the original regions and those added to the project in 2009;
5. Community structure and the abundance of key species varied with distance from the wetland edge; and
6. The new, smaller, temporary drift-fences perform similarly to the original, larger, permanent drift-fences.

Methods

Sites and sampling

Over the course of the Interim Operating Plan (IOP; December 2003-December 2011), we sampled two regions in limestone rocklands of the eastern Everglades (Chekika and Context Rd.; two sampling arrays within each), three sites adjacent to the S332 water control structures (S332B, S332C and S332D; from 2003-2009 we sampled six permanent drift-fence arrays at each, but in order to incorporate the new sites, reduced the number to three in 2009). We sampled five sites in Shark River slough (with two sampling arrays in each). Sites 6, 7 and 8 are in the long hydroperiod part of the main stream, and sites 23 and 50 are in the headwaters in the northern part of Everglades National Park. Site 50 is a short hydroperiod site (dry for a

significant portion of each year). We sampled 3 other regions in the regions west of the eastern park boundary and east of Shark River Slough (West Chekika, West Context Rd. and INT); these sites were only visited in 2004. We added the seven new sites (in three regions) in the final quarter of 2009 in the southern everglades (L-31W, AERO, C111). Each of these sites were adjacent to canals and had one drift-fence site in the wetland immediately adjacent to the canal, another one 200 m (perpendicular to the canal) into the wetland, and a third drift fence 400 m into the wetland. Three sites were located adjacent to the L-31W canal, one north (A) and two south (B and C) of State Road 9336. Two sites were located off of the canal parallel to the Aerojet road (AJM at a midpoint of the canal and AJE and the end). Finally we added two sites adjacent to the C-111 canal in the Eastern Everglades Panhandle. See table 1 for coordinates of all current sites, table 2 for former sites and table 3 for a list of sampling events and map 1 for a map showing all of our sampling points in Everglades National Park. The new portable drift-fence arrays that we began implementing in 2009 are removed after each sampling and re-installed at a random point near the site's GPS coordinates (See **table III.1** for geographic coordinates of our currently sampled sites, **table III.2** for sites that we no longer visit and **figure III.1** for a map showing the position of our current sites).

The original, permanent drift fences were constructed of lengths of ground-cloth from 0.7 to 1.5 m wide, supported by rebar posts. They were built around a central square fence, approximately 1.5 m per side, with each side facing one of the cardinal directions. Each had 12 m long arms extending from the corners of the central square at 45 degrees from the cardinal directions, forming an "X" shape. The new, temporary, portable drift-fences are constructed similarly to the permanent drift-fences. However, rather than ground cloth, they are built from

shade cloth (47%, woven; B & K Installations, Homestead FL), which is permeable to water, preventing a Venturi effect during times of flow. The central box is smaller, only one meter square. The arms are 3.5 m long, 0.914 m high and each is anchored along the bottom by fitting a 1.3 m piece of rebar into a sleeve at the bottom of the horizontal part of the fence (See **figure III.2** and attached drift-fence construction guide). These were rebuilt in the field for each sampling bout, and placed in a randomized position near the GPS coordinate for each sampling point (see attached drift-fence field instructions). We progressively used more of these drift-fences as they were constructed in the fall of 2009 and spring of 2010. By June 2010 we had transitioned to exclusively using the new, portable drift-fences.

Wire minnow traps (three-mm mesh) were placed in holes cut into the faces of the central square, so that its entrance was accessible to fish (2.5 cm entrance diameter; the inner opening was plugged). For the permanent drift-fences, we installed one trap per side in the shallower, short hydroperiod sites and used two traps per side in the deeper, long hydroperiod sites when depths exceeded 50 cm (one near the bottom, one high in the water column). The temporary fences always used only one trap per side. The traps are usable when water levels are between 15 cm (the shallowest water in which the openings of a minnow trap can be submerged) and the height of the fence. During periods when traps were usable, we attempted to sample monthly, but in some wet seasons (eg. 2008 and 2009) we sampled as often as twice a month at short-hydroperiod sites. At the time of deployment, we measured water depths at each of the traps, in the central box of the array and in the surrounding wetland. Minnow traps were deployed for 24-hour periods, after which fish and other animals were collected, anesthetized with FINQUEL MS-222 (Argent Chemical Laboratories, Inc., Redmond, WA, U.S.A.) and euthanized in 10%

formalin solution, following FIU humane animal care guidelines. In the laboratory, fish and other animals were washed and preserved with 70% ethanol, identified to species, counted, measured and weighed (see **table III.3** for a complete account of our sampling effort).

Statistical analysis

We compared the average abundance of the five most common native fish and average abundance of all fish pooled. We used drift fences as the unit of observation, and compared CPUE among regions and among years using factorial ANOVA (SAS, Proc GLM). When there was significant variation among regions, we used a Tukey post-hoc test to evaluate which regions were different from each other. We compared the abundance of non-native taxa in the regions and years covered by this study with factorial ANOVA (SAS, Proc GLM) using sites as the unit of observation. When there were significant differences among years or regions, we used a Tukey post-hoc test to distinguish which pairs of sites had different means from each other.

We classified the S332 sites as “impact” (reflecting the impoundments to their east), the Context Road and Chekika sites as “reference” sites, and L-31W, C111 and AERO sites as “new”. The SRS sites were labeled as “slough”. We compared community structure (two-way ANOSIM, primer 5.2.9) for the impact, reference and slough sites for all years of the study (2003-2009, using sites within regions and months within years as the units of replication; there were 44 species of fish represented here). We completed this analysis using a Bray-Curtis dissimilarity matrix using the $\text{Ln}(x + 1)$ transformation and standardized data. Because rare species may become overly influential, we re-ran the analysis using only the fish taxa for which we had greater than 80 total ($N = 20$ species). The results of both of these analyses were illustrated using MDS plots (but reducing all data to region and year only, for ease of

presentation). We performed ANOSIM using the same criteria to compare regions for samples collected from 2009-2011 (including the newly added regions). Again, to ensure that the results were not biased by rare species, we ran the analysis twice: once with all fish and once with fish of which we caught 40 or more ($N = 17$ species). We used MDS to visually display the results. For both of these analyses we identified the fish taxa that contribute most to similarity within sites and dissimilarity among sites by using similarity percentage breakdown analysis (SIMPER, Primer 5.2.9).

The drift fences were set at three distances from the edge of the wetland, which we classified as “Edge,” “Mid” and “Far.” To compare whether there were greater differences in community structure among sites within a region, or at distances within a site, we conducted two-way analysis of similarity (ANOSIM, Primer 5.2.9) testing the factors of site and distance (CKK and CXT were treated as sites within the “reference” region). We created a Bray-Curtis dissimilarity matrix using $\ln(X + 1)$ transformed data. We built MDS plots to visualize the data by averaging communities by year. We used similarity percentage breakdown analysis (SIMPER, Primer 5.2.9) to identify the fish taxa that contributed most to similarity within distances and dissimilarity among distances. We then compared CPUE of the fishes identified as contributing to greater than 10% of the dissimilarity among distances using ANOVA (Proc GLM, SAS 9.2); when differences were significant at $p < 0.05$, we used Tukey post-hoc tests to identify which distances had more of that species of fish.

We compared the original permanent drift fences and the new portable drift fences, and any potential differences in their yield by comparing the assemblages of fish caught in each for all periods where they were simultaneously deployed in the same site. We excluded species

which yielded only a single individual, $\ln(x + 1)$ transformed abundances and standardized all values. We created a Bray-Curtis dissimilarity matrix (Primer 5.2.9) and used two-way analysis of similarity (ANOSIM) to compare drift-fence types (old and new) and regions (S332 and SRS). We used similarity percentage breakdown analysis (SIMPER) to identify the species that contributed most to differences between drift-fence types and which contributed most to similarity within a drift-fence type. To more closely assess differences in catch, we used the same methods to compare catch within regions; we compared catch in the new drift-fences with the old in the S332 sites. In the SRS sites, we compared catch from the new drift-fences with catch from the top minnow traps and bottom minnow traps separately. Results were illustrated with MDS. For the fish identified as contributing the most to differences between the old and new drift-fence types, we performed model II (RMA) regressions (Bohonak and Van der Linde 2004) on $\ln(x + 1)$ transformed data to elucidate the differences (separately for SRS and S332).

Results

During this study, we captured 80,963 fish and 6,726 other animals (see **table III.4** for total fish catch, by year; **table III.5** for total invertebrate, amphibian and reptile catch, by year; **table III.6** for fish catch-per-unit-effort, that is catch standardized by effort; **table III.7** for invertebrate, amphibian and reptile catch-per-unit-effort; **tables III.8 and III.9** for total fish catch, divided by region for the years 2010 and 2011; **tables III.10 and III.11** for fish catch-per-unit-effort divided by regions for the years 2010 and 2011; **tables III.12 and III.13** for total invertebrate, reptile and amphibian catch, divided by regions for the years 2010 and 2011; **tables III.14 and III.15** for invertebrate, reptile and amphibian catch-per-unit-effort, divided by regions

for 2010 and 2011). We captured 44 total fish species. The most abundant native fish taxa that we yielded include the eastern mosquitofish (*Gambusia holbrooki*), marsh killifish (*Fundulus confluentus*), sailfin molly (*Poecilia latipinna*), bluefin killifish (*Lucania goodei*), flagfish (*Jordanella floridae*) and dollar sunfish (*Lepomis marginatus*). Non-native taxa that we captured include: pike killifish (*Belonesox belizanus*), jaguar guapote (*Cichlasoma managuanense*), Mayan cichlid (*Cichlasoma urophthalmus*), jewelfish (*Hemichromis letourneuxi*), and several others (see **table III.4**).

The CPUE of all fish varied among regions, years and with the interaction between regions and years (**table III.16, figure III.3A**). The CPUE of each of the five most common individual native fishes in the study (eastern mosquitofish, marsh killifish, flagfish, bluefin killifish and sailfin molly) varied among years (**table III.16, figures III.3A, 3B**). All but sailfin molly varied in CPUE among regions, and all species varied in CPUE with the year-by-region interaction. The Tukey post-hoc tests revealed that total fish CPUE was greatest in the sites of the eastern fringe of ENP, especially the S332 regions and Context Road. See **figures III.3A and III.3B** for visual representation of the results of the Tukey tests.

Abundance of non-native taxa varied among region and years (**table III.17, figure III.4**). For pike killifish, jaguar guapote, Mayan cichlid, jewelfish and all non-native taxa pooled, there were more non-native fish in the short hydroperiod sites in the eastern Everglades, including the S332 sites and Context Rd. For blue tilapia, spotted tilapia, brown hoplo, walking catfish, sailfin catfish and asian swamp eel, we did not detect any difference, either because their CPUE were invariant among regions or because we collected too few to make any inference. There were also differences in CPUE among years for most of the non-native taxa; the general pattern is that they

were more abundant in wetter years. Jaguar guapote, unidentified cichlids (juveniles), and jewelfish all showed significant variation in abundance with the interaction of year and region. See **figure III.4** for visual representation of the results of the Tukey tests.

For the impact, reference and slough regions from 2003-2011, both analyses of community structure (the complete set of fish and the fish for which we caught 80 or more fish in the impact sites, reference sites and slough sites) yielded similar results to each other (see **tables III.18A, III.18B, figure III.5**). There were significant differences in the assemblages of fish across regions (each region was distinct from the others) and across years. For specific pairwise comparisons of treatment regions and the identity of the fish that contributed most to similarity and dissimilarity, see **tables III.18A and III.18B**. In the comparison of all current regions (using the 2009-2011 data from the new regions and the original regions) there were significant differences among years and regions. In fact, most pairwise comparisons suggested different assemblages (see **tables III.19A, III.19B, figure III.6**). The following pairs *were not* different: SRS and AERO, S332 and L-31W, CXT and CKK, L-31W and CKK. When the sample was reduced to only common fish, only SRS and AERO and CXT and CKK remained not different from each other, suggesting that the presence of a few rare species decreased power to detect differences in community similarity, probably by elevating the error variance. For specific pairwise comparisons of regions and the identity of the fish that contributed most to similarity and dissimilarity, see **tables III.19A and III.19B**.

For our comparison of community structure within regions and among distances from the marsh edge, the only region that had any difference in community structure among its sites was S332 ($p = 0.001$). C111, CKK/CXT and S332 each showed differences in community structure

among distances (**tables III.20A, III.20B, III.20C, III.20D and III.20E, figures III.7A and III.7B**). In C111, mosquitofish, sailfin mollies, bluefin killifish and marsh killifish were identified as contributing the most to dissimilarity among distances. Of these, mosquitofish, sailfin mollies and bluefin killifish had greatest abundances at the edge sites (**table III.21, figure III.7A**). In CKK and CXT, mosquitofish, jewelfish and dollar sunfish were identified as contributing the most to dissimilarity among distances. Of these, only dollar sunfish varied in abundance among distances (but not importantly so, since the edge adjacent sites almost never had enough water to sample **table III.21, figure III.7A**). At S332, mosquitofish, dollar sunfish and flagfish were identified as contributing the most to dissimilarity among distances. Of these, mosquitofish and flagfish had greatest abundances at the edge sites (**table III.21, figure III.7B**). See **figures III.7A and III.7B** for Tukey comparisons of abundances of fishes identified as contributing to dissimilarity of differences.

Our analysis of community structure captured by the old, permanent, and new, portable, drift fences in the S332 sites supported the hypothesis that the two types of fence yielded similar results ($p = 0.1440$; **table III.22, figure III.8**). Similarity within both drift-fence types was driven most by eastern mosquitofish, flagfish, dollar sunfish, sailfin mollies and jewelfish. Dissimilarity was most influenced by dollar sunfish, flagfish and jewelfish (**table III.22, figures III.8 and III.9**). The drift-fences at the Shark River Slough sites also supported the hypothesis that overall catch was similar between types. There was no difference between the new drift fences and either the top ($p = 0.679$) or bottom ($p = 0.183$) minnow traps from the old drift fences (but top and bottom traps were different from each other; $p = 0.021$; **table III.22, figure III.8**). Similarity within the bottom trap was driven by eastern mosquitofish, dollar sunfish, and

sailfin mollies. In top traps, similarity was driven by eastern mosquitofish and sailfin mollies. In the new drift-fences, similarity was driven by eastern mosquitofish, bluefin killifish and sailfin mollies. Dissimilarity between the bottom and top traps was driven by eastern mosquitofish, dollar sunfish, and sailfin mollies. These differences between top and bottom traps are likely driven by differences in lifestyle. For example, dollar sunfish, a benthic feeder, is much more often caught in the lower traps of the permanent fence, and sailfin molly, a surface feeder, is more often caught in top traps. Dissimilarity between the bottom and new type were driven by eastern mosquitofish, dollar sunfish and bluefin killifish. Differences between the top and new type were driven by sailfin molly, bluefin killifish, flagfish, marsh killifish and eastern mosquitofish (**table III.22, figures III.8 and III.9**).

We repeated the comparison of old and new drift-fence types in SRS, but pooling the catch from top and bottom minnow traps. We still did not detect a difference in catch between the two fence types ($p = 0.37$). In this comparison, eastern mosquitofish, flagfish and dollar sunfish contributed most to similarity within the new drift-fences. In the old drift-fences, eastern mosquitofish, dollar sunfish, and sailfin molly contributed the most to similarity. Dollar sunfish, flagfish, eastern mosquitofish, marsh killifish, sailfin molly and bluefin killifish contributed the most to differences between old and new drift-fences.

RMA regression showed that for most of the species that contribute to dissimilarity there was not a strong difference in catch between the two drift-fence types (**table III.9, figure III.23**). The slope of the regressions were near one (which would indicate equal catch on average), but the regression explained little of the variance (very low R^2 values). These fish were likely identified as strong contributors to dissimilarity because of their patchy populations. That is,

these fish might move over the landscape in groups that encounter one drift-fence type or the other by chance. Differences in catch over any given 24-hour period does not reflect difference in performance of the fence types. The exceptions to this were flagfish (flagfish), which was consistently captured in greater numbers by the new drift-fences (seen clearly by the relatively high slope of the RMA regressions) and sailfin mollies (sailfin molly) which in SRS were caught in greater numbers in the old, permanent drift-fences (relatively low slope). These differences must be a result of avoidance (flagfish) or attraction (sailfin mollies) to the permanent structure provided by the permanent drift-fences (or vice versa). It is possible that the old, permanent drift-fences over-estimate sailfin molly abundance and under-estimate flagfish abundance.

Conclusions

We have shown that the abundance of native fish varies among the regions covered by this study. Within our samples, we consistently captured the most fish in the eastern Everglades in the short-hydroperiod regions. This is likely a result of many fish migrating into these sites to exploit newly available resources in the wet season. Non-native fish were also most abundant in samples from the short-hydroperiod regions. This is probably a result of the vicinity of these sites to point sources of introduction and dry-season refuges such as the water impoundments and canals.

From 2003-2011, the community structures of the impact, reference and slough sites were all distinct from each other. Community structure at the “impact” sites was intermediate between the reference and slough sites (**figure III.5**). This appears to be largely driven by hydroperiod at the sites, since the “impact” sites are also intermediate in hydroperiod. The differences among

all of our regions appear to also be driven largely by hydroperiod, but also by geographic distance and potential points of introduction and migration, such as canals.

For several of the sites, there appeared to be a strong effect of proximity to the wetland edge, especially for the S332 sites and the C111 sites. The character of the edge sites in these regions is clearly different from the mid and far sites. They are characterized by greater diversity of plants, different qualities of periphyton, and different sediment thickness (see later sections of this report). This may be a result of general ‘disturbance’ because these they are located on the ecotone between wetlands and water management structures (like the canals and water impoundments), but these sites appear to be impacted by nutrient additions. We observed greater CPUE of eastern mosquitofish, sailfin molly and bluefin killifish at the edge sites in S332 and greater CPUE of eastern mosquitofish and flagfish at the edge sites in C111. It is possible that these fish are taking advantage of the higher resource quality that could result from nutrient impacts (or greater access to invertebrate prey in the deteriorating periphyton mats). Belicka et al (2012, appended to this report) and our samples of periphyton tissue TP (Gaiser section in this report) demonstrate that these edges experience nutrient enrichment. Belicka et al. (2012) also provides molecular evidenc that canal edge sites are active zones of fish mixing among habitats. Future work should seek to determine if these edge habitats are simply active intersections with fish moving through, or sites of productivity with fish remaining and producing offspring.

Our new portable drift fences return qualitatively similar results to the original permanent drift fences. The assemblages of fish captured by the drift fences were affected by both the region and the drift-fence type, though overall there was little difference between the fence types. There are several potential reasons for this, discussed below.

The older, permanent fences covered a much larger expanse than the new, temporary fences (the area bounded by the old, permanent fences is approximately 300 m², compared to about 50 m² for the new, temporary fences). The subset of fish that move over great enough distances to both enter the domain of the fences and make it all the way to the traps in the center may be different for the differently-sized fences, especially since we see a general pattern of less activity-density in Shark River Slough (for example, the *shortest* distance a fish must travel to enter the fence and get to the trap is about 8 m for the permanent fences, compared to about 3.5 m for the new, temporary fences). This may not be an issue at the S332 sites, since activity-density is so much greater.

The greater water depth in long-hydroperiod marshes required that the permanent fences in SRS be slightly different in structure than those at S332 and the new fences. The long-hydroperiod fences had two minnow traps in each face, at different heights from the bottom. Because the new fences only have a single minnow trap placed at the middle of the water column, they may capture fewer surface-feeding fish or benthic specialists. This is well-illustrated by the greater CPUE of dollar sunfish in the bottom traps (and low CPUE in the top traps), and is most likely a result of their benthic-feeding lifestyle. In the new drift fences, the minnow traps are suspended at an intermediate depth, which we believe resulted in the intermediate CPUE of dollar sunfish. Flagfish were captured far more often by the temporary fences. This may result from avoidance of the permanent structures (or organisms/disturbance associated with the permanent structures), movement patterns that lead to a greater likelihood of them moving to the center of the smaller, temporary fences or some other factor.

Another potential source of difference in fish assemblages trapped in the old and new

drift fences is the different types of disturbances associated with their presence. The old fences were sampled monthly for several years. This led to changes in the sediment profile around the fences; for example, along the length of each wing, a path formed as a result of trampling during repeated visits. This increased both depth at the sites and topographical complexity. The permanent presence of the fences also may provide habitat and refuge for organisms, or provide hiding places. Disturbances associated with the new drift fences may include trampling, though much less severe because they were re-positioned for each sampling bout. The material from which the permanent drift fences were constructed may also influence water-flow patterns. Directional flow may create a funneling effect on one side of the array and diminished flow on the other. This is less of a problem for the new drift fences owing to their smaller size, and the use of porous shade-cloth instead of solid ground-cloth.

Finally, passive sampling resulted in idiosyncratic results. A great amount of variation was present among arrays within sites, sites within regions and between regions. As our sampling continues and sample sizes increase, the total catch that is yielded may swamp out the variation that we currently see between the fence types and reveal more similar patterns of catch.

Our nine-year dataset has yielded many findings. We have discovered basic properties of fish abundance and community structure, as discussed in this document, and much important data on animal movement (discussed in the attached manuscript). With continued support, we hope to continue our analyses of animal movement, begin projects on the movement of other organisms (like grass shrimp and crayfish) and build large-scale metacommunity models that will be of specific use to Everglades ecologists and specific use to animal ecologists. These models will be used to evaluate how canal and impoundment construction and connectivity affects the

ecology of adjacent wetlands.

Table III.1. Currently used sites: The following sites are currently being visited and will continue to be used in the next phase of the project. Easting and Northing columns contain UTM coordinates (Datum: NAD 83, Zone: 17).

<u>Region and site</u>	<u>Drift fence array</u>	<u>Easting</u>	<u>Northing</u>	<u>Latitude</u>	<u>Longitude</u>
S332B	A9	542623	2825204	25.54355	-80.5757294
S332B	B1	542474	2824939	25.54116	-80.57722091
S332B	C1	542291	2825351	25.54488	-80.57902943
S332C	A1	542593	2821865	25.51339	-80.57613398
S332C	B1	542328	2821690	25.51182	-80.5787766
S332C	C1	542060	2821560	25.51066	-80.58144759
S332D	A5	541187	2811880	25.42327	-80.590431
S332D	B4	541026	2812084	25.42511	-80.59202577
S332D	C1	540982	2812007	25.42442	-80.59246565
SRS 50	50N	524178	2841345	25.68972	-80.75903756
SRS 50	50S	523961	2840645	25.6834	-80.76121281
SRS 23	23N	538436	2840505	25.68183	-80.61696599
SRS 23	23S	538334	2839761	25.67511	-80.61800388
SRS 6	6N	526824	2835470	25.63662	-80.73278551
SRS 6	6S	527824	2835090	25.63317	-80.72283175
SRS 7	7N	524165	2829481	25.58258	-80.75938195
SRS 7	7S	524008	2829481	25.58259	-80.76094524
SRS 8	8N	517034	2819524	25.49277	-80.83051356
SRS 8	8S	516702	2818798	25.48622	-80.83382593
EAST CONTEXT RD	CXTE A	542611	2820358	25.49979	-80.57600265
EAST CONTEXT RD	CXTE B	542483	2820357	25.49978	-80.5772763
EAST CHEKIKA	CKK EA	542423	2828885	25.57679	-80.57760362
EAST CHEKIKA	CKK EB	542351	2828985	25.5777	-80.57831733
L31wA (12/2011)	0M	541223	2811370	25.41866	-80.59008859
L31wA (12/2011)	200M	541073	2811259	25.41766	-80.5915835
L31wA (12/2011)	400M	540931	2811173	25.41689	-80.59299808
L31wB	0M	542849.9	2807502.2	25.38369	-80.574034
L31wB	200M	542612	2807500	25.38367	-80.57639905
L31wB	400M	542453	2807513	25.3838	-80.57797921
L31wC	0M	542840	2805730	25.36768	-80.57418862
L31wC	200M	542660	2805726	25.36765	-80.57597783
L31wC	400M	542500	2805724	25.36764	-80.57756819
AERO AJM	0M	543636	28000860	252.1393	-82.27478205
AERO AJM	200M	543436	28000860	252.1393	-82.26894108
AERO AJM	400M	543236	28000860	252.1394	-82.26310008
AERO AJE	0M	543711	2800262	25.31828	-80.56570778
AERO AJE	200M	543701	2800088	25.31671	-80.56581273

AERO AJE	400M	543684	2799922	25.31521	-80.56598697
C111A	0M	548314	2799794	25.31391	-80.51999237
C111A	200M	548258	2799620	25.31234	-80.52055491
C111A	400M	548259	2799424	25.31057	-80.52055194
C111B	0M	551826	2798457	25.30172	-80.48515217
C111B	200M	551812	2798256	25.29991	-80.48529891
C111B	400M	551804	2798034	25.2979	-80.48538684

Table III.2. Sites no longer being used: We are no longer sampling at the following sites, owing to lack of access (INT, CXT W and CKK W), persistent lack of water deep enough to sample (L-31W-A) or to redistribute effort between older and newer sites (S332). Easting and Northing columns contain UTM coordinates (Datum: NAD 83, Zone: 17).

<u>Region and site</u>	<u>Drift fence array</u>	<u>Easting</u>	<u>Northing</u>	<u>Latitude</u>	<u>Longitude</u>
S332B	A8	542660	2825446	25.54573	-80.57535341
S332B	B3	542464	2825308	25.54449	-80.57730877
S332B	D5	542275	2824870	25.54054	-80.57920386
S332C	A2	542601	2822162	25.51608	-80.57604495
S332C	B2	542327	2822000	25.51462	-80.57877678
S332C	C2	542086	2821822	25.51302	-80.58118065
S332D	A0	541174	2811983	25.4242	-80.59055713
S332D	B8	540974	2811915	25.42359	-80.59254799
S332D	D2	540803	2811719	25.42182	-80.59425434
INTERMEDIATE	INT N	526032	2820552	25.50192	-80.74096514
INTERMEDIATE	INT S	525839	2820421	25.50074	-80.74288812
WEST CONTEXT RD	CXT W	533847	2820119	25.49785	-80.6632128
WEST CHEKIKA	CKK W	533967	2828936	25.57747	-80.66179553
L31w-A (2010)	0M	542556	2811298	25.41797	-80.57683612
L31w-A (2010)	200M	542498	2811156	25.41669	-80.57741731
L31w-A (2010)	400M	542518	2811055	25.41578	-80.57722162

Table III.3. Sampling dates and total effort in each region. Effort refers to the number of drift-fences that were set (with 4 or 8 minnow traps each).

Year	Month	Day	Region	Effort
2003	Dec.	4	S332	6
		5	S332	6
2003 Total				12
2004	May	19	SRS	6
	Jul.	14	SRS	3
		15	SRS	3
	Aug.	5	S332	6
		12	SRS	1
		18	SRS	2
		31	S332	6
	Sep.		SRS	6
		1	SRS	2
		21	CKK	2
			INT	2
			S332	6
			SRS	4
		23	SRS	6
		13	CKK	2
	Oct.		CXT	1
			INT	2
			S332	5
			SRS	4
		15	S332	1
			SRS	6
		2	S332	6
			SRS	4
		4	CKK	2
			CXT	1
			INT	2
			S332	4
Nov.		SRS	6	
		16	CKK	2
			CXT	2
			INT	2
			S332	6
			SRS	4

Year	Month	Day	Region	Effort
	Dec.	18	S332	4
			SRS	6
		1	CXT	1
			S332	4
			SRS	6
		3	CKK	2
			CXT	1
			INT	2
			S332	6
			SRS	4
2004 Total				153
2005	Jun.	17	S332	10
	Aug.	4	S332	6
			SRS	2
		6	S332	4
			SRS	4
	Sep.	10	SRS	4
		1	CKK	2
			CXT	2
			SRS	4
		2	S332	5
		3	S332	1
			SRS	4
		8	S332	4
		9	S332	2
		11	SRS	2
		24	CKK	2
			CXT	2
			S332	12
			SRS	2
		28	SRS	6
		30	SRS	2
	Oct.	12	SRS	8
		14	SRS	2
		15	CKK	2
			CXT	1
		19	S332	6
		20	S332	5
	Nov.	9	S332	6
			SRS	4

Year	Month	Day	Region	Effort
	Dec.	10	SRS	4
		11	S332	6
			SRS	2
		16	CXT	1
		9	S332	4
		14	CXT	1
			SRS	8
		15	SRS	2
		17	S332	6
2005 Total			150	
2006	Sep.	6	CXT	1
		7	S332	6
			SRS	5
		8	SRS	5
		25	SRS	6
		26	CXT	1
			SRS	2
		27	S332	2
		28	S332	6
		SRS	1	
	Oct.	29	SRS	2
		26	SRS	2
		27	SRS	7
	Nov.	30	SRS	2
	Dec.	1	SRS	9
2006 Total			57	
2007	Jan.	5	SRS	8
	Feb.	16	SRS	6
	Aug.	14	S332	5
			SRS	2
		16	SRS	7
		23	S332	1
		28	SRS	1
	Oct.	6	S332	1
		9	S332	10
		11	SRS	3
		23	S332	6
			SRS	1
		25	SRS	6
	Nov.	6	S332	6

Year	Month	Day	Region	Effort
		8	SRS	8
		9	S332	2
		20	SRS	1
	Dec.	6	SRS	3
2007 Total				77
2008	Jul.	8	SRS	6
		9	SRS	2
		17	SRS	1
	Aug.	28	S332	11
	Sep.	3	S332	7
		10	S332	3
		11	S332	3
		16	SRS	5
	Oct.	1	S332	11
		8	CXT	2
		15	S332	6
		16	S332	5
		21	CXT	1
		29	S332	11
	Nov.	6	SRS	4
		13	S332	10
		26	S332	10
	Dec.	10	S332	10
		17	SRS	6
2008 Total				114
2009	Feb.	5	SRS	8
	Jun.	24	S332	6
		25	S332	6
	Jul.	16	SRS	9
		21	CXT	2
			S332	5
			SRS	1
		23	S332	6
	Aug.	7	CXT	1
			S332	10
		18	SRS	10
		20	S332	6
		25	CXT	1
			S332	6
	Sep.	4	S332	3

Year	Month	Day	Region	Effort
		9	S332	3
		11	CXT	2
			S332	7
		15	S332	4
		25	S332	7
			SRS	10
		29	CXT	1
			S332	3
	Oct.	1	S332	6
		15	AERO	3
		20	S332	1
			SRS	10
		22	CXT	1
			S332	7
		23	S332	7
			SRS	4
		29	SRS	1
	Nov.	6	S332	7
		10	AERO	1
			L-31W	1
			S332	9
		11	AERO	3
			L-31W	1
		12	AERO	2
		17	L-31W	4
		18	C111	6
		24	SRS	14
	Dec.	8	AERO	3
			L-31W	1
		9	AERO	1
			S332	15
		14	SRS	1
		15	C111	6
			L-31W	8
		17	SRS	12
		18	SRS	3
2009 Total				255
2010	Jan.	13	SRS	10
		15	C111	6
			L-31W	2

Year	Month	Day	Region	Effort
	Feb.	9	C111	3
		16	SRS	11
		19	C111	3
			SRS	2
	Mar.	4	C111	6
		16	SRS	2
		25	SRS	12
	May	13	CXT	2
			S332	6
		20	C111	6
		26	SRS	8
		27	SRS	2
	Jun.	9	CXT	2
			S332	9
		11	C111	6
		15	SRS	8
		17	SRS	2
	Jul.	21	CXT	2
			S332	9
			SRS	2
		27	SRS	8
		29	L-31W	3
	Aug.	18	SRS	2
		20	SRS	8
		24	CXT	2
			L-31W	1
			S332	9
		26	L-31W	6
	Sep.	8	SRS	2
		10	SRS	8
		14	CKK	2
			CXT	2
			L-31W	3
			S332	9
		16	L-31W	3
	Oct.	13	SRS	9
		15	CKK	2
			S332	6
		18	CXT	1
		26	L-31W	5

Year	Month	Day	Region	Effort
			SRS	1
		28	L-31W	1
			S332	3
	Nov.	10	S332	2
		11	S332	2
		12	L-31W	4
		19	SRS	2
		23	SRS	8
	Dec.	9	C111	1
			L-31W	1
		15	SRS	2
		21	SRS	8
2010 Total				247
2011	Jan.	11	SRS	8
		12	SRS	1
	Jul.	19	AERO	3
			SRS	2
		26	C111	6
			L-31W	2
	Aug.	17	AERO	6
			SRS	2
		23	C111	6
			L-31W	2
	Sep.	13	AERO	3
			CXT	2
			S332	5
		20	C111	6
			L-31W	2
		27	SRS	10
	Oct.	20	S332	8
		21	AERO	6
			CXT	2
			S332	1
		24	L-31W	3
		25	C111	6
			L-31W	3
		28	SRS	10
		.	L-31W	1
	Nov.	8	CXT	2
			S332	6

Year	Month	Day	Region	Effort
		10	AERO	6
			L-31W	1
			S332	3
		14	C111	3
		15	C111	3
			L-31W	6
		18	SRS	10
	Dec.	6	AERO	6
			CXT	2
			S332	9
		14	C111	6
			L-31W	9
		16	SRS	10
2011 Total				188
Grand Total				1,253

Table III.4. Catch per year for each fish species. Non-native taxa are indicated with an asterisk on the common name.

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>Adinia xenica</i>	Diamond killifish								1	44	45
<i>Ameiurus natalis</i>	Yellow bullhead		6	2		1	2	8	1		20
<i>Ameiurus nebulosus</i>	Brown bullhead							1			1
<i>Amia calva</i>	Bowfin								1		1
<i>Anguilla rostrata</i>	American eel							1			1
<i>Aphredoderus sayanus</i>	Pirate perch		51	1	2	2		1			57
<i>Belonesox belizanus</i>	Pike killifish*	4	15	24	10	25	74	48	24	19	243
<i>Cichlasoma bimaculatum</i>	Black acara*		21	2	6	1	2	19	5		56
<i>Cichlasoma managuanense</i>	Jaguar guapote*				14	4	4	73	9	1	105
<i>Cichlasoma spp.</i>	Unidentified <i>Cichlasoma</i> *							1		14	15
<i>Cichlasoma urophthalmus</i>	Mayan cichlid*	3	150	170	26	13	28	163	11	43	607
<i>Clarias batrachus</i>	Walking catfish*		1	2				6			9
<i>Cyprinodon variegatus</i>	Sheepshead minnow		7	8	3	9	42	176	265	125	635
<i>Elassoma evergladei</i>	Everglades pygmy sunfish		13	6	3		48	5	4	2	81
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish		27	32	24	21	3	3	1	1	112
<i>Erimyzon succetta</i>	Lake Chubsucker		1	15	2						18
<i>Esox americanus</i>	Redfin pickerel		3	1	2						6
<i>Fundulus chrysotus</i>	Golden topminnow		196	114	29	71	40	107	286	132	975
<i>Fundulus confluentus</i>	Marsh killifish		238	151	77	84	261	706	758	465	2740
<i>Fundulus grandis</i>	Gulf killifish							1			1
<i>Fundulus seminolis</i>	Seminole killifish			29		3	1	4	1		38
<i>Fundulus spp.</i>	Unidentified <i>Fundulus</i>							6			6
<i>Gambusia holbrooki</i>	Mosquitofish	17	2587	2192	1976	2212	2698	13561	10033	7089	42365

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>Hemichromis letourneuxi</i>	Jewelfish*	49	454	1065	44	26	52	564	490	21	2765
<i>Hemichromis spp.</i>	Unidentified <i>Hemichromis</i> *					2				1	3
<i>Heterandria formosa</i>	Least killifish	1	14	48	20	42	90	78	218	42	553
<i>Hoplosternum littorale</i>	Brown Hoplo*		35	1			3	4		1	44
<i>Jordanella floridae</i>	Flagfish		361	258	214	185	1535	2029	1660	2154	8396
<i>Labidesthes sicculus</i>	Brook silverside		41	12			1	2			56
<i>Lepomis gulosus</i>	Warmouth	1	79	36	11	14	56	121	14	4	336
<i>Lepomis macrochirus</i>	Bluegill		17		8	2	2	11		7	47
<i>Lepomis marginatus</i>	Dollar sunfish	21	2033	1727	571	504	598	2751	573	66	8844
<i>Lepomis microlophus</i>	Redear		8	4	16	16		15	4		63
<i>Lepisosteus platyrhincus</i>	Florida gar			1	1	1				5	8
<i>Lepomis punctatus</i>	Spotted sunfish	4	43	27	90	12	24	76	79	11	366
<i>Lepomis spp.</i>	Sunfishes		23	2			2	14	1	1	43
<i>Lucania goodei</i>	Bluefin killifish	4	264	288	97	134	720	138	1705	528	3878
<i>Lucania parva</i>	Rainwater killifish								1		1
<i>Micropterus salmoides</i>	Largemouth bass			4	1			2	1	2	10
<i>Monopterus albus</i>	Asian swamp eel*							2			2
<i>Noturus gyrinus</i>	Tadpole madtom		42	12	8	9	10	2		1	84
<i>Notropis petersoni</i>	Coastal shiner		27	7	10	10	1	8	17	1	81
<i>Oreochromis aureus</i>	Blue tilapia*		309	100	4	1	9	220		11	654
<i>Poecilia latipinna</i>	Sailfin molly	2	205	204	235	244	354	958	1646	2467	6315
<i>Pterygoplichthys multiradiatus</i>	Orinoco sailfin catfish*				1		2		1		4
<i>Tilapia mariae</i>	Spotted tilapia*		20	48	12		11	13	1	3	108
	Unidentified fish	8	66	4	6	10	7	32	21	11	165
Total		114	7357	6597	3523	3658	6680	21930	17832	13272	80963

Table III.5. Catch per year for amphibians, reptiles and invertebrates (including crayfish).

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>Acris gryllus</i>	cricket frog adult		3	2				1	1		7
<i>Acris gryllus</i> tadpole	cricket frog tadpole			4	2	3	2	2	1	2	16
<i>Amphiuma means</i>	two-toed amphiuma			3	1			8	1		13
<i>Anax junius</i>	common green darner			3						1	4
<i>Aphylla williamsoni</i>	two-striped forceptail							2	2		4
<i>Arigomphus pallidus</i>	gray-green clubtail		1								1
<i>Belostoma spp.</i>	giant water bug	1	36	29	11	6	20	26	46	26	201
<i>Brachymesia gravida</i>	four-spotted pennant		1	3			3				7
<i>Bufo</i> tadpole	Toad tadpole		3								3
Caudata species	salamander species							1			1
<i>Celithemis eponina</i>	halloween pennant		17	7	4		7	4	2	1	42
<i>Celithemis</i> species	pennant									1	1
family Coenagrionidae	damselfly larvae		4					2	2	2	10
order Coleoptera	aquatic beetle adults		14	7		5	2	9	6	19	62
<i>Coryphaeschna ingens</i>	regal darner		1		1		2	2			6
<i>Cybister fimbriolatus</i>	predaceous diving beetle				4	1	51	36	53	16	161
<i>Cybister</i> spp.	predaceous diving beetle		8	33			7	12	24	5	89
order Diptera	unidentified fly larva									2	2
<i>Epitheca stella/sepia</i>	Florida baskettail		7		1						8
<i>Erythemis simplicicollis</i>	eastern pondhawk		2	2					2		6
<i>Eumeces inexpectatus</i>	southeastern five-lined skink (non-aquatic)						1				1
<i>Gastrophryne carolinensis</i> tadpole	Eastern narrowmouth toad tadpole		15								15
family Gerridae	water striders		2					1	1	2	6
<i>Haitia bermudezi</i>	low-dome physa		12	4	3		8	13	5		45
suborder Heteroptera	aquatic bugs		1						1	1	3

class Hirudinea	Leeches				1	10	2	1	1	15
<i>Hyla cineria</i> tadpole	green tree frog tadpole	5	1	1		6	6	2	2	23
<i>Hyla cineria</i>	green tree frog adult	9					4	4		17
<i>Laevapex spp.</i>	ancylid							1		1
<i>Lethocerus griseus</i>	giant water bug			1						1
<i>Lethocerus spp.</i>	giant water bug	2	23		1		8	19	17	70
<i>Lethocerus uhleri</i>	giant water bug					10	50	8	1	69
<i>Libellula needhami</i>	Needham's skimmer	10	4	5		5	3	4	1	32
<i>Littoridinops monroensis</i>	cockscorb hydrobe							1		1
<i>Marisa cornuarietis</i>	giant rams horn	3	1							4
<i>Nerodia floridana</i>	Florida green water snake						1	6		7
<i>Nerodia spp.</i>	water snake	13	4	8			1			26
<i>Nerodia taxispilota</i>	Brown water snake							1		1
<i>Notophthalmus viridescens</i>	peninsula newt	1	2	1			5	6	2	17
class Oligochaeta	oligochaetes						2			2
<i>Pachydiplax longipennis</i>	blue dasher	4	2				1	1		8
<i>Palaemonetes paludosus</i>	grass shrimp	12	181	97	115	15	223	254	538	1696
<i>Pelocoris femoratus</i>	alligator flea	32	9	2	2	13	5	23	29	115
<i>Planorbella spp.</i>	unidentified planorbid snail	25	12	8		8	17	12	4	86
<i>Pomacea paludosa</i>	apple snail	1	23	13	8	1	8	10	2	66
<i>Pseudosuccinea columella</i>	mimic lymnaea								1	1
<i>Pyralidae spp.</i>	aquatic caterpillar						1			1
<i>Rana spp.</i> tadpole	pig frog tadpole/ leopard frog tadpole	1	34	29	7	19	67	24	13	194
<i>Rana grylio</i>	pig frog adult	1					3	5		9
<i>Regina alleni</i>	striped crayfish snake	3	1							4
<i>Siren lacertina</i>	greater siren	5	4				3	4	1	17
<i>Spongilla lacustris</i>	sponge						1			1

family Stratiomyidae	soldier fly larvae							2	1	3	
	unidentified tadpole		16	7		2	4	2	2	33	
<i>Procambarus alleni</i> (male)	Everglades Crayfish	2		72	241	22	205	497	213	171	1423
<i>Procambarus alleni</i> (female)	Everglades Crayfish	5		53	240	33	191	688	233	168	1611
<i>Procambarus alleni</i> (immature)	Everglades Crayfish				2	1		1		1	5
<i>Procambarus fallax</i> (male)	Slough Crayfish		7	15	57		31	30	11	15	166
<i>Procambarus fallax</i> (female)	Slough Crayfish		10	29	63	1	34	25	18	16	196
<i>Procambarus spp.</i> (male)	Unidentified Crayfish			3			4	25	1	3	36
<i>Procambarus spp.</i> (female)	Unidentified Crayfish			4			1	28	2	11	46
<i>Procambarus spp.</i> (immature)	Unidentified Crayfish				2	1		4	1	1	9
	Grand Total	22	511	482	789	91	866	1863	1300	802	6726

Table III.6. Catch-per-unit-effort for fish. Each value represents the average number of that species captured per minnow trap. The grand total for each species represents the total probability of that species presence in a minnow trap. The grand total for years represents the average number of fish captured in one minnow trap.

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>Adinia xenica</i>	Diamond killifish								0.0010	0.0590	0.0078
<i>Ameiurus natalis</i>	Yellow bullhead		0.0080	0.0024		0.0035	0.0038	0.0065	0.0010		0.0034
<i>Ameiurus nebulosus</i>	Brown bullhead							0.0008			0.0002
<i>Amia calva</i>	Bowfin								0.0010		0.0002
<i>Anguilla rostrata</i>	American eel							0.0008			0.0002
<i>Aphredoderus sayanus</i>	Pirate perch		0.0678	0.0012	0.0060	0.0070		0.0008			0.0098
<i>Belonesox belizanus</i>	Pike killifish	0.0833	0.0199	0.0287	0.0302	0.0871	0.1402	0.0389	0.0231	0.0255	0.0419
<i>Cichlasoma bimaculatum</i>	Black acara		0.0279	0.0024	0.0181	0.0035	0.0038	0.0154	0.0048		0.0097
<i>Cichlasoma managuense</i>	Jaguar guapote				0.0423	0.0139	0.0076	0.0591	0.0087	0.0013	0.0181
<i>Cichlasoma spp.</i>	Unidentified <i>Cichlasoma</i>							0.0008		0.0188	0.0026
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	0.0625	0.1995	0.2031	0.0785	0.0453	0.0530	0.1320	0.0106	0.0576	0.1046
<i>Clarias batrachus</i>	Walking catfish		0.0013	0.0024				0.0049			0.0016
<i>Cyprinodon variegatus</i>	Sheepshead minnow		0.0093	0.0096	0.0091	0.0314	0.0795	0.1425	0.2555	0.1676	0.1095
<i>Elassoma evergladei</i>	Everglades pygmy sunfish		0.0173	0.0072	0.0091		0.0909	0.0040	0.0039	0.0027	0.0140
<i>Enneacanthus</i>	Bluespotted		0.0359	0.0382	0.0725	0.0732	0.0057	0.0024	0.0010	0.0013	0.0193

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>gloriosus</i>	sunfish										
<i>Erimyzon succetta</i>	Lake Chubsucker		0.0013	0.0179	0.0060						0.0031
<i>Esox americanus</i>	Redfin pickerel		0.0040	0.0012	0.0060						0.0010
<i>Fundulus chrysotus</i>	Golden topminnow		0.2606	0.1362	0.0876	0.2474	0.0758	0.0866	0.2758	0.1769	0.1681
<i>Fundulus confluentus</i>	Marsh killifish		0.3165	0.1804	0.2326	0.2927	0.4943	0.5717	0.7310	0.6233	0.4723
<i>Fundulus grandis</i>	Gulf killifish							0.0008			0.0002
<i>Fundulus seminolis</i>	Seminole killifish			0.0346		0.0105	0.0019	0.0032	0.0010		0.0066
<i>Fundulus spp.</i>	Unidentified <i>Fundulus</i>							0.0049			0.0010
<i>Gambusia holbrooki</i>	Mosquitofish	0.3542	3.4402	2.6189	5.9698	7.7073	5.1098	10.9806	9.6750	9.5027	7.3031
<i>Hemichromis letourneuxi</i>	Jewelfish	1.0208	0.6037	1.2724	0.1329	0.0906	0.0985	0.4567	0.4725	0.0282	0.4766
<i>Hemichromis spp.</i>	Unidentified <i>Hemichromis</i>					0.0070				0.0013	0.0005
<i>Heterandria formosa</i>	Least killifish	0.0208	0.0186	0.0573	0.0604	0.1463	0.1705	0.0632	0.2102	0.0563	0.0953
<i>Hoplosternum littorale</i>	Brown Hoplo		0.0465	0.0012			0.0057	0.0032		0.0013	0.0076
<i>Jordanella floridae</i>	Flagfish		0.4801	0.3082	0.6465	0.6446	2.9072	1.6429	1.6008	2.8874	1.4473
<i>Labidesthes sicculus</i>	Brook silverside		0.0545	0.0143			0.0019	0.0016			0.0097
<i>Lepomis gulosus</i>	Warmouth	0.0208	0.1051	0.0430	0.0332	0.0488	0.1061	0.0980	0.0135	0.0054	0.0579
<i>Lepomis</i>	Bluegill		0.0226		0.0242	0.0070	0.0038	0.0089		0.0094	0.0081

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>macrochirus</i>											
<i>Lepomis marginatus</i>	Dollar sunfish	0.4375	2.7035	2.0633	1.7251	1.7561	1.1326	2.2275	0.5526	0.0885	1.5246
<i>Lepomis microlophus</i>	Redear		0.0106	0.0048	0.0483	0.0557		0.0121	0.0039		0.0109
<i>Lepisosteus platyrhincus</i>	Florida gar			0.0012	0.0030	0.0035				0.0067	0.0014
<i>Lepomis punctatus</i>	Spotted sunfish	0.0833	0.0572	0.0323	0.2719	0.0418	0.0455	0.0615	0.0762	0.0147	0.0631
<i>Lepomis spp.</i>	Sunfishes		0.0306	0.0024			0.0038	0.0113	0.0010	0.0013	0.0074
<i>Lucania goodei</i>	Bluefin killifish	0.0833	0.3511	0.3441	0.2931	0.4669	1.3636	0.1117	1.6442	0.7078	0.6685
<i>Lucania parva</i>	Rainwater killifish								0.0010		0.0002
<i>Micropterus salmoides</i>	Largemouth bass			0.0048	0.0030			0.0016	0.0010	0.0027	0.0017
<i>Monopterus albus</i>	Asian swamp eel							0.0016			0.0003
<i>Noturus gyrinus</i>	Tadpole madtom		0.0559	0.0143	0.0242	0.0314	0.0189	0.0016		0.0013	0.0145
<i>Notropis petersoni</i>	Coastal shiner		0.0359	0.0084	0.0302	0.0348	0.0019	0.0065	0.0164	0.0013	0.0140
<i>Oreochromis aureus</i>	Blue tilapia		0.4109	0.1195	0.0121	0.0035	0.0170	0.1781		0.0147	0.1127
<i>Poecilia latipinna</i>	Sailfin molly	0.0417	0.2726	0.2437	0.7100	0.8502	0.6705	0.7757	1.5873	3.3070	1.0886
<i>Pterygoplichthys multiradiatus</i>	Orinoco sailfin catfish				0.0030		0.0038		0.0010		0.0007
<i>Tilapia mariae</i>	Spotted tilapia		0.0266	0.0573	0.0363		0.0208	0.0105	0.0010	0.0040	0.0186
	Unidentified fish	0.1667	0.0878	0.0048	0.0181	0.0348	0.0133	0.0259	0.0203	0.0147	0.0284

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
	Total	2.3750	9.7832	7.8817	10.6435	12.7456	12.6515	17.7571	17.1958	17.7909	13.9567

Table III.7. Catch-per-unit-effort for amphibians, reptiles and invertebrates (including crayfish). Each value represents the average number of that species captured per minnow trap. The grand total for each species represents the total probability of that species presence in a minnow trap. The grand total for years represents the average number of invertebrates, amphibians and reptiles captured in one minnow trap.

Species name	Common name	2003	2004	2005	2006	2007	2008	2009	2010	2011	Grand Total
<i>Acris gryllus</i>	cricket frog adult		0.0040	0.0024				0.0008	0.0010		0.0012
<i>Acris gryllus</i> tadpole	cricket frog tadpole			0.0048	0.0060	0.0105	0.0038	0.0016	0.0010	0.0027	0.0028
<i>Amphiuma means</i>	two-toed amphiuma			0.0036	0.0030			0.0065	0.0010		0.0022
<i>Anax junius</i>	common green darner			0.0036						0.0013	0.0007
<i>Aphylla williamsoni</i>	two-striped forceptail							0.0016	0.0019		0.0007
<i>Arigomphus pallidus</i>	gray-green clubtail		0.0013								0.0002
<i>Belostoma spp.</i>	giant water bug	0.0208	0.0479	0.0346	0.0332	0.0209	0.0379	0.0211	0.0444	0.0349	0.0346
<i>Brachymesia gravida</i>	four-spotted pennant		0.0013	0.0036			0.0057				0.0012
<i>Bufo</i> tadpole	Toad tadpole		0.0040								0.0005
Caudata species	salamander species							0.0008			0.0002
<i>Celithemis eponina</i>	halloween pennant		0.0226	0.0084	0.0121		0.0133	0.0032	0.0019	0.0013	0.0072
<i>Celithemis</i> species	pennant									0.0013	0.0002
family	damselfly larvae		0.0053					0.0016	0.0019	0.0027	0.0017
Coenagrionidae											
order Coleoptera	aquatic beetle adults		0.0186	0.0084		0.0174	0.0038	0.0073	0.0058	0.0255	0.0107
<i>Coryphaeschna ingens</i>	regal darner		0.0013		0.0030		0.0038	0.0016			0.0010
<i>Cybister fimbriolatus</i>	predaceous diving beetle				0.0121	0.0035	0.0966	0.0291	0.0511	0.0214	0.0278
<i>Cybister</i> spp.	predaceous diving beetle		0.0106	0.0394			0.0133	0.0097	0.0231	0.0067	0.0153
order Diptera	unidentified fly larva									0.0027	0.0003
<i>Epitheca stella/sepia</i>	Florida baskettail		0.0093		0.0030						0.0014
<i>Erythemis simplicicollis</i>	eastern pondhawk		0.0027	0.0024					0.0019		0.0010

<i>Eumeces inexpectatus</i>	southeastern five-lined skink (non-aquatic)					0.0019					0.0002
<i>Gastrophryne carolinensis</i> tadpole	Eastern narrowmouth toad tadpole	0.0199									0.0026
family Gerridae	water striders	0.0027						0.0008	0.0010	0.0027	0.0010
<i>Haitia bermudezi</i>	low-dome physa	0.0160	0.0048	0.0091		0.0152	0.0105	0.0048			0.0078
suborder Heteroptera	aquatic bugs	0.0013							0.0010	0.0013	0.0005
class Hirudinea	Leeches			0.0030		0.0189	0.0016	0.0010	0.0013		0.0026
<i>Hyla cineria</i> tadpole	green tree frog tadpole	0.0066	0.0012	0.0030		0.0114	0.0049	0.0019	0.0027		0.0040
<i>Hyla cineria</i>	green tree frog adult	0.0120					0.0032	0.0039			0.0029
<i>Laevapex spp.</i>	ancylid							0.0010			0.0002
<i>Lethocerus griseus</i>	giant water bug			0.0030							0.0002
<i>Lethocerus spp.</i>	giant water bug	0.0027	0.0275		0.0035		0.0065	0.0183	0.0228		0.0121
<i>Lethocerus uhleri</i>	giant water bug					0.0189	0.0405	0.0077	0.0013		0.0119
<i>Libellula needhami</i>	Needham's skimmer	0.0133	0.0048	0.0151		0.0095	0.0024	0.0039	0.0013		0.0055
<i>Littoridinops monroensis</i>	cockscorn hydrobe							0.0010			0.0002
<i>Marisa cornuarietis</i>	giant rams horn	0.0040	0.0012								0.0007
<i>Nerodia floridana</i>	Florida green water snake						0.0008	0.0058			0.0012
<i>Nerodia spp.</i>	water snake	0.0173	0.0048	0.0242			0.0008				0.0045
<i>Nerodia taxispilota</i>	Brown water snake							0.0010			0.0002
<i>Notophthalmus viridescens</i>	peninsula newt	0.0013	0.0024	0.0030			0.0040	0.0058	0.0027		0.0029
class Oligochaeta	oligochaetes							0.0016			0.0003
<i>Pachydiplax longipennis</i>	blue dasher	0.0053	0.0024				0.0008	0.0010			0.0014
<i>Palaemonetes paludosus</i>	grass shrimp	0.2500	0.2407	0.1159	0.3474	0.0523	0.4223	0.2057	0.5188	0.3499	0.2924
<i>Pelocoris femoratus</i>	alligator flea	0.0426	0.0108	0.0060	0.0070	0.0246	0.0040	0.0222	0.0389		0.0198
<i>Planorbella spp.</i>	unidentified planorbid	0.0332	0.0143	0.0242		0.0152	0.0138	0.0116	0.0054		0.0148

	snail									
<i>Pomacea paludosa</i>	apple snail	0.0208	0.0306	0.0155	0.0242	0.0019	0.0065	0.0096	0.0027	0.0114
<i>Pseudosuccinea columella</i>	mimic lymnaea								0.0013	0.0002
<i>Pyralidae spp.</i>	aquatic caterpillar						0.0008			0.0002
<i>Rana spp.</i> tadpole	pig frog tadpole/ leopard frog tadpole	0.0208	0.0452	0.0346	0.0211	0.0360	0.0543	0.0231	0.0174	0.0334
<i>Rana grylio</i>	pig frog adult		0.0013				0.0024	0.0048		0.0016
<i>Regina alleni</i>	striped crayfish snake		0.0040	0.0012						0.0007
<i>Siren lacertina</i>	greater siren		0.0066	0.0048			0.0024	0.0039	0.0013	0.0029
<i>Spongilla lacustris</i>	sponge						0.0008			0.0002
family Stratiomyidae	soldier fly larvae							0.0019	0.0013	0.0005
	unidentified tadpole		0.0213	0.0084		0.0038	0.0032	0.0019	0.0027	0.0057
<i>Procambarus alleni</i> (male)	Everglades Crayfish	0.0417		0.0860	0.7281	0.0767	0.3883	0.4024	0.2054	0.2453
<i>Procambarus alleni</i> (female)	Everglades Crayfish	0.1042		0.0633	0.7251	0.1150	0.3617	0.5571	0.2247	0.2777
<i>Procambarus alleni</i> (immature)	Everglades Crayfish				0.0060	0.0035		0.0008	0.0013	0.0009
<i>Procambarus fallax</i> (male)	Slough Crayfish		0.0093	0.0179	0.1722		0.0587	0.0243	0.0106	0.0286
<i>Procambarus fallax</i> (female)	Slough Crayfish		0.0133	0.0346	0.1903	0.0035	0.0644	0.0202	0.0174	0.0338
<i>Procambarus spp.</i> (male)	Unidentified Crayfish			0.0036			0.0076	0.0202	0.0010	0.0062
<i>Procambarus spp.</i> (female)	Unidentified Crayfish			0.0048			0.0019	0.0227	0.0019	0.0079
<i>Procambarus spp.</i> (immature)	Unidentified Crayfish				0.0060	0.0035		0.0032	0.0010	0.0016
	Grand Total	0.4583	0.6795	0.5759	2.3837	0.3171	1.6402	1.5085	1.2536	1.0751
										1.1595

Table III.8. Gross fish totals 2010: Total catch for each species, divided by regions.

<u>Species</u>	<u>Common name</u>	AERO	C111	CKK	CXT	L31W	S332	SRS	Grand Total
<i>Adinia xenica</i>	Diamond killifish							1	1
<i>Ameiurus natalis</i>	Yellow bullhead						1		1
<i>Amia calva</i>	Bowfin							1	1
<i>Belonesox belizanus</i>	Pike killifish	8	21		1	6	11		47
<i>Cichlasoma bimaculatum</i>	Black acara		7				3		10
<i>Cichlasoma managuanense</i>	Jaguar guapote		1			1	8		10
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	7	46			1	8		62
<i>Cyprinodon variegatus</i>	Sheepshead minnow	63	5		5	3	40	214	330
<i>Elassoma evergladei</i>	Everglades pygmy sunfish	1				2		2	5
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish	1	1						2
<i>Fundulus chrysotus</i>	Golden topminnow	88	101		1	42	70	142	444
<i>Fundulus confluentus</i>	Marsh killifish	62	31		53	96	256	338	836
<i>Fundulus grandis</i>	Gulf killifish	1	1						2
<i>Fundulus seminolis</i>	Seminole killifish							1	1
<i>Gambusia holbrooki</i>	Mosquitofish	688	2321	10	70	579	2213	5863	11744
<i>Hemichromis letourneuxi</i>	Jewelfish	2	1	34	64	108	280	4	493
<i>Heterandria formosa</i>	Least killifish	9	81			13	48	86	237
<i>Jordanella floridae</i>	Flagfish	28	8		14	74	645	924	1693
<i>Lepomis gulosus</i>	Warmouth		4			3	4	6	17
<i>Lepomis macrochirus</i>	Bluegill	1							1
<i>Lepomis marginatus</i>	Dollar sunfish	6	76		31	23	130	344	610
<i>Lepomis microlophus</i>	Redear		1					4	5
<i>Lepomis punctatus</i>	Spotted sunfish	1	35		1	13	3	34	87
<i>Lepomis spp.</i>	Sunfishes					1			1
<i>Lucania goodei</i>	Bluefin killifish	68	642	1	3	48	159	1146	2067
<i>Lucania parva</i>	Rainwater killifish							1	1
<i>Micropterus salmoides</i>	Largemouth bass		1						1
<i>Notropis petersoni</i>	Coastal shiner							17	17
<i>Poecilia latipinna</i>	Sailfin molly	152	288			250	556	782	2028
<i>Pterygoplichthys multiradiatus</i>	Orinoco sailfin catfish						1		1
<i>Tilapia mariae</i>	Spotted tilapia						1		1
	unidentified fish	1	2			5	9	7	24
	Total	1187	3674	45	243	1268	4446	9917	20780

Table III.9. Gross fish totals 2011: Total catch for each species, divided by regions.

<u>Species</u>	<u>Common name</u>	<u>AERO</u>	<u>C111</u>	<u>CXT</u>	<u>L31W</u>	<u>S332</u>	<u>SRS</u>	<u>Grand Total</u>
<i>Adinia xenica</i>	Diamond killifish	9	34				1	44
<i>Belonesox belizanus</i>	Pike killifish	4	4	2	5	4		19
<i>Cichlasoma managuanense</i>	Jaguar guapote		1					1
<i>Cichlasoma spp.</i>	Unidentified <i>Cichlasoma</i>		5		1		8	14
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	18	22		2	1		43
<i>Cyprinodon variegatus</i>	Sheepshead minnow	22	80	1	1		21	125
<i>Elassoma evergladei</i>	Everglades pygmy sunfish	1				1		2
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish		1					1
<i>Fundulus chrysotus</i>	Golden topminnow	2	7		22	5	96	132
<i>Fundulus confluentus</i>	Marsh killifish	61	102	11	87	78	126	465
<i>Gambusia holbrooki</i>	Mosquitofish	448	1039	626	930	2125	1921	7089
<i>Hemichromis letourneuxi</i>	Jewelfish	1	1		14	5		21
<i>Hemichromis spp.</i>	Unidentified <i>Hemichromis</i>					1		1
<i>Heterandria formosa</i>	Least killifish	1	2		3	21	15	42
<i>Hoplosternum littorale</i>	Brown Hoplo						1	1
<i>Jordanella floridae</i>	Flagfish	476	40	99	250	771	517	2153
<i>Lepomis gulosus</i>	Warmouth	1				2	1	4
<i>Lepomis macrochirus</i>	Bluegill					4	3	7
<i>Lepomis marginatus</i>	Dollar sunfish	1	8	1	6	1	50	67
<i>Lepisosteus platyrhincus</i>	Florida gar	3	1		1			5
<i>Lepomis punctatus</i>	Spotted sunfish	1	6		1		3	11
<i>Lepomis spp.</i>	Sunfishes						1	1
<i>Lucania goodei</i>	Bluefin killifish	13	90		23	4	398	528
<i>Micropterus salmoides</i>	Largemouth bass	2						2
<i>Noturus gyrinus</i>	Tadpole madtom						1	1
<i>Notropis petersoni</i>	Coastal shiner	1						1
<i>Oreochromis aureus</i>	Blue tilapia		2		1	4	4	11
<i>Poecilia latipinna</i>	Sailfin molly	464	989	29	187	250	548	2467
<i>Tilapia mariae</i>	Spotted tilapia		3					3
	unidentified fish	1			3	3	4	11
	Total	1530	2437	769	1537	3280	3719	13272

Table III.10A. Fish catch-per-unit-effort in 2010: Catch of fish, standardized by sampling effort, divided into regions. The numbers reflect the average number of fish caught for each minnow trap (that soaked for 24 h).

Species	Common name	AERO	C111	CKK	CXT	L31W	S332	SRS	Average
<i>Adinia xenica</i>	Diamond killifish	0	0	0	0	0	0	0.0021	0.0003
<i>Ameiurus natalis</i>	Yellow bullhead	0	0	0	0	0	0.0046	0	0.0007
<i>Amia calva</i>	Bowfin	0	0	0	0	0	0	0.0021	0.0003
<i>Belonesox belizanus</i>	Pike killifish	0.0714	0.0847	0	0.0227	0.0536	0.0509	0	0.0405
<i>Cichlasoma bimaculatum</i>	Black acara	0	0.0282	0	0	0	0.0139	0	0.0060
<i>Cichlasoma managuanense</i>	Jaguar guapote	0	0.0040	0	0	0.0089	0.0370	0	0.0071
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	0.0625	0.1855	0	0	0.0089	0.0370	0	0.0420
<i>Cyprinodon variegatus</i>	Sheepshead minnow	0.5625	0.0202	0	0.1136	0.0268	0.1852	0.4534	0.1945
<i>Elassoma evergladei</i>	Everglades pygmy sunfish	0.0089	0	0	0	0.0179	0	0.0042	0.0044
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish	0.0089	0.0040	0	0	0	0	0	0.0019
<i>Fundulus chrysotus</i>	Golden topminnow	0.7857	0.4073	0	0.0227	0.3750	0.3241	0.3008	0.3165
<i>Fundulus confluentus</i>	Marsh killifish	0.5536	0.1250	0	1.2045	0.8571	1.1852	0.7161	0.6631
<i>Fundulus grandis</i>	Gulf killifish	0.0089	0.0040	0	0	0	0	0	0.0019
<i>Fundulus seminolis</i>	Seminole killifish	0	0	0	0	0	0	0.0021	0.0003
<i>Gambusia holbrooki</i>	Mosquitofish	6.1429	9.3589	0.625	1.5909	5.1696	10.2454	12.4216	6.5078
<i>Hemichromis letourneuxi</i>	Jewelfish	0.0179	0.0040	2.125	1.4545	0.9643	1.2963	0.0085	0.8386
<i>Heterandria formosa</i>	Least killifish	0.0804	0.3266	0	0	0.1161	0.2222	0.1822	0.1325
<i>Jordanella floridae</i>	Flagfish	0.2500	0.0323	0	0.3182	0.6607	2.9861	1.9576	0.8864
<i>Lepomis gulosus</i>	Warmouth	0	0.0161	0	0	0.0268	0.0185	0.0127	0.0106
<i>Lepomis macrochirus</i>	Bluegill	0.0089	0	0	0	0	0	0	0.0013
<i>Lepomis marginatus</i>	Dollar sunfish	0.0536	0.3065	0	0.7045	0.2054	0.6019	0.7288	0.3715
<i>Lepomis microlophus</i>	Redear	0	0.0040	0	0	0	0	0.0085	0.0018
<i>Lepomis punctatus</i>	Spotted sunfish	0.0089	0.1411	0	0.0227	0.1161	0.0139	0.0720	0.0535
<i>Lepomis spp.</i>	Sunfishes	0	0	0	0	0.0089	0	0	0.0013
<i>Lucania goodei</i>	Bluefin killifish	0.6071	2.5887	0.0625	0.0682	0.4286	0.7361	2.4280	0.9885
<i>Lucania parva</i>	Rainwater killifish	0	0	0	0	0	0	0.0021	0.0003
<i>Micropterus salmoides</i>	Largemouth bass	0	0.0040	0	0	0	0	0	0.0006
<i>Notropis petersoni</i>	Coastal shiner	0	0	0	0	0	0	0.0360	0.0051
<i>Poecilia latipinna</i>	Sailfin molly	1.3571	1.1613	0	0	2.2321	2.5741	1.6568	1.2831
<i>Pterygoplichthys multiradiatus</i>	Orinoco sailfin catfish	0	0	0	0	0	0.0046	0	0.0007
<i>Tilapia mariae</i>	Spotted tilapia	0	0	0	0	0	0.0046	0	0.0007
	unidentified fish	0.0089	0.0081	0	0	0.0446	0.0417	0.0148	0.0169

Average total	10.59	14.81	2.81	5.52	11.32	20.58	21.01	12.38
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Table III.11. Fish catch-per-unit-effort in 2011: Catch of fish, standardized by sampling effort, divided into regions. The numbers reflect the average number of fish caught for each minnow trap (that soaked for 24 h).

Species	Common name	AERO	C111	CXT	L31W	S332	SRS	Average
<i>Adinia xenica</i>	Diamond killifish	0.0750	0.2361	0	0	0	0.0050	0.0527
<i>Belonesox belizanus</i>	Pike killifish	0.0333	0.0278	0.0714	0.0500	0.0323	0	0.0358
<i>Cichlasoma managuanense</i>	Jaguar guapote	0	0.0069	0	0	0	0	0.0012
<i>Cichlasoma spp.</i>	Unidentified <i>Cichlasoma</i>	0	0.0347	0	0.0100	0	0.0400	0.0141
<i>Cichlasoma urophthalmus</i>	Mayan cichlid	0.1500	0.1528	0	0.0200	0.0081	0	0.0551
<i>Cyprinodon variegatus</i>	Sheepshead minnow	0.1833	0.5556	0.0357	0.0100	0	0.1050	0.1483
<i>Elassoma evergladei</i>	Everglades pygmy sunfish	0.0083	0	0	0	0.0081	0	0.0027
<i>Enneacanthus gloriosus</i>	Bluespotted sunfish	0	0.0069	0	0	0	0	0.0012
<i>Fundulus chrysotus</i>	Golden topminnow	0.0167	0.0486	0	0.2200	0.0403	0.4800	0.1343
<i>Fundulus confluentus</i>	Marsh killifish	0.5083	0.7083	0.3929	0.8700	0.6290	0.6300	0.6231
<i>Gambusia holbrooki</i>	Mosquitofish	3.7333	7.2153	22.3571	9.3000	17.1371	9.6050	11.5580
<i>Hemichromis letourneuxi</i>	Jewelfish	0.0083	0.0069	0	0.1400	0.0403	0	0.0326
<i>Hemichromis spp.</i>	Unidentified <i>Hemichromis</i>	0	0	0	0	0.0081	0	0.0013
<i>Heterandria formosa</i>	Least killifish	0.0083	0.0139	0	0.0300	0.1694	0.0750	0.0494
<i>Hoplosternum littorale</i>	Brown Hoplo	0	0	0	0	0	0.0050	0.0008
<i>Jordanella floridae</i>	Flagfish	3.9667	0.2778	3.5357	2.5000	6.2177	2.5850	3.1805
<i>Lepomis gulosus</i>	Warmouth	0.0083	0	0	0	0.0161	0.0050	0.0049
<i>Lepomis macrochirus</i>	Bluegill	0	0	0	0	0.0323	0.0150	0.0079
<i>Lepomis marginatus</i>	Dollar sunfish	0.0083	0.0556	0.0357	0.0600	0.0081	0.2500	0.0696
<i>Lepisosteus platyrhincus</i>	Florida gar	0.0250	0.0069	0	0.0100	0	0	0.0070
<i>Lepomis punctatus</i>	Spotted sunfish	0.0083	0.0417	0	0.0100	0	0.0150	0.0125
<i>Lepomis spp.</i>	Sunfishes	0	0	0	0	0	0.0050	0.0008
<i>Lucania goodei</i>	Bluefin killifish	0.1083	0.6250	0	0.2300	0.0323	1.9900	0.4976
<i>Micropterus salmoides</i>	Largemouth bass	0.0167	0	0	0	0	0	0.0028
<i>Noturus gyrinus</i>	Tadpole madtom	0	0	0	0	0	0.0050	0.0008
<i>Notropis petersoni</i>	Coastal shiner	0.0083	0	0	0	0	0	0.0014
<i>Oreochromis aureus</i>	Blue tilapia	0	0.0139	0	0.0100	0.0323	0.0200	0.0127
<i>Poecilia latipinna</i>	Sailfin molly	3.8667	6.8681	1.0357	1.8700	2.0161	2.7400	3.0661
<i>Tilapia mariae</i>	Spotted tilapia	0	0.0208	0	0	0	0	0.0035
	unidentified fish	0.0083	0	0	0.0300	0.0242	0.0200	0.0138
	Average total	12.75	16.924	27.46	15.37	26.45	18.56	

Table III.12. Invertebrate, reptile and amphibian catch in 2010: Total catch for invertebrates and amphibians, divided by regions.

Species	Common name	AERO	C111	CKK	CXT	L31W	S332	SRS	Total
<i>Procambarus alleni</i>	Everglades crayfish	33	40	1	26	53	78	215	446
<i>Procambarus fallax</i>	slough Crayfish	1	7			2		19	29
<i>Procambarus</i> spp.	Unidentified crayfish	1				1	1	1	4
<i>Acris gryllus</i> tadpole	cricket frog tadpole						1	1	2
<i>Amphiuma means</i>	two-toed amphiuma							1	1
<i>Aphylla williamsoni</i>	two-striped forceptail							2	2
<i>Belostoma</i> spp.	giant water bug	10	14		1	2	10	11	48
<i>Celithemis eponina</i>	halloween pennant		1					1	2
family Coenagrionidae	damselfly larvae		1					1	2
order Coleoptera	aquatic beetle adults		4					3	7
<i>Cybister fimbriolatus</i>	predaceous diving beetle	4	7		4	6	27	25	73
<i>Cybister</i> spp.	predaceous diving beetle	1	3			2	8	15	29
<i>Erythemis simplicicollis</i>	eastern pondhawk		2						2
family Gerridae	water striders		1						1
<i>Haitia bermudezi</i>	low-dome physa						2	3	5
suborder Heteroptera	aquatic bugs							1	1
class Hirudinea	Leeches							1	1
<i>Hyla cineria</i> tadpole	green tree frog tadpole					1	1		2
<i>Hyla cineria</i>	green tree frog adult							6	6
<i>Laevapex</i> species	ancylid		1						1
<i>Lethocerus</i> spp.	giant water bug	2	7		4	2	9	6	30
<i>Libellula needhami</i>	Needham's skimmer		1					3	4
<i>Littoridinops monroensis</i>	cockscorb hydrobe						1		1
<i>Nerodia floridana</i>	Florida green water snake					1	2	3	6
<i>Nerodia taxispilots</i>	brown water snake							1	1
<i>Notophthalmus viridescens</i>	peninsula newt							6	6
<i>Pachydiplax longipennis</i>	blue dasher			1					1
<i>Palaemonetes paludosus</i>	grass shrimp	150	672	3	19	80	83	1921	2928
<i>Pelocoris femoratus</i>	alligator flea		7		1		7	10	25
<i>Planorbella</i> spp.	unidentified planorbid snail	1	4				2	6	13
<i>Pomacea paludosa</i>	apple snail		1			1	2	6	10
<i>Rana</i> spp. tp.	Pig or leopard frog tadpole				1	1	13	15	30
<i>Rana grylio</i>	pig frog adult							5	5
<i>Siren lacertina</i>	greater siren							5	5
family Stratiomyidae	soldier fly larvae	1						1	2
	unidentified tadpole							2	2
Grand Total		204	773	5	56	152	247	2296	3733

Table III.13. Invertebrate and amphibian catch in 2011: Total catch for invertebrates and amphibians, divided by regions.

Species	Common name	AERO	C111	CXT	L31W	S332	SRS	Total
<i>Procambarus alleni</i>	Everglades crayfish	47	39	32	42	52	128	340
<i>Procambarus fallax</i>	slough crayfish	5	2				24	31
<i>Procambarus</i> spp.	unidentified crayfish	4	1				10	15
<i>Acris gryllus</i> tadpole	cricket frog tadpole						2	2
<i>Anax junius</i>	common green darner					1		1
<i>Belostoma</i> spp.	giant water bug	2	11		4	3	6	26
<i>Celithemis eponina</i>	halloween pennant						1	1
<i>Celithemis</i> species	pennant		1					1
family Coenagrionidae	damselfly larvae		1				1	2
order Coleoptera	aquatic beetle adults	3	1		4	5	7	20
<i>Cybister fimbriolatus</i>	predaceous diving beetle	1	3		4	4	6	18
<i>Cybister</i> spp.	predaceous diving beetle			1	1		3	5
order Diptera	unidentified fly larva		1				1	2
family Gerridae	water striders		2					2
suborder Heteroptera	aquatic bugs					1		1
class Hirudinea	Leeches						1	1
<i>Hyla cineria</i> tadpole	green tree frog tadpole					1	1	2
<i>Lethocerus</i> spp.	giant water bug	5	9		1	2	3	20
<i>Libellula needhami</i>	Needham's skimmer						1	1
<i>Notophthalmus viridescens</i>	peninsula newt						3	3
<i>Palaemonetes paludosus</i>	grass shrimp	32	142	9	64	131	833	1211
<i>Pelocoris femoratus</i>	alligator flea	5	9		1	1	21	37
<i>Planorbella</i> spp.	unidentified planorbid snail	1	2			1		4
<i>Pomacea paludosa</i>	apple snail	1			1			2
<i>Pseudosuccinea columella</i>	mimic lymnaea						1	1
<i>Rana</i> spp. tadpole	pig frog tadpole/leopard frog tadpole					4	11	15
<i>Siren lacertina</i>	greater siren	1						1
family Stratiomyidae	soldier fly larvae						1	1
	unidentified tadpole	1		1				2
	Grand Total	108	224	43	122	206	1065	1768

Table III.14. Invertebrate and amphibian catch-per-unit-effort in 2010: Catch of invertebrates and amphibians, standardized by sampling effort, divided into regions. The numbers reflect the average number of animals caught for each minnow trap (that soaked for 24 h).

Species	Common name	AERO	C111	CKK	CXT	L31W	S332	SRS	Total
<i>Procambarus alleni</i>	Everglades crayfish	0.2946	0.1613	0.0625	0.5909	0.4732	0.3611	0.4555	0.3427
<i>Procambarus fallax</i>	slough Crayfish	0.0089	0.0282	0	0	0.0179	0	0.0403	0.0136
<i>Procambarus</i> spp.	Unidentified crayfish	0.0089	0	0	0	0.0089	0.0046	0.0021	0.0035
<i>Acris gryllus</i> tadpole	cricket frog tadpole	0	0	0	0	0	0.0046	0.0021	0.0010
<i>Amphiuma means</i>	two-toed amphiuma	0	0	0	0	0	0	0.0021	0.0003
<i>Aphylla williamsoni</i>	two-striped forceptail	0	0	0	0	0	0	0.0042	0.0006
<i>Belostoma</i> spp.	giant water bug	0.0893	0.0565	0	0.0227	0.0179	0.0463	0.0233	0.0366
<i>Celithemis eponina</i>	halloween pennant	0	0.0040	0	0	0	0	0.0021	0.0009
family Coenagrionidae	damselfly larvae	0	0.0040	0	0	0	0	0.0021	0.0009
order Coleoptera	aquatic beetle adults	0	0.0161	0	0	0	0	0.0064	0.0032
<i>Cybister fimbriolatus</i>	predaceous diving beetle	0.0357	0.0282	0	0.0909	0.0536	0.1250	0.0530	0.0552
<i>Cybister</i> spp.	predaceous diving beetle	0.0089	0.0121	0	0	0.0179	0.0370	0.0318	0.0154
<i>Erythemis simplicicollis</i>	eastern pondhawk	0	0.0081	0	0	0	0	0	0.0012
family Gerridae	water striders	0	0.0040	0	0	0	0	0	0.0006
<i>Haitia bermudezi</i>	low-dome physa	0	0	0	0	0	0.0093	0.0064	0.0022
suborder Heteroptera	aquatic bugs	0	0	0	0	0	0	0.0021	0.0003
class Hirudinea	Leeches	0	0	0	0	0	0	0.0021	0.0003
<i>Hyla cineria</i> tadpole	green tree frog tadpole	0	0	0	0	0.0089	0.0046	0	0.0019
<i>Hyla cineria</i>	green tree frog adult	0	0	0	0	0	0	0.0127	0.0018
<i>Laevapex</i> species	ancylid	0	0.0040	0	0	0	0	0	0.0006
<i>Lethocerus</i> spp.	giant water bug	0.0179	0.0282	0	0.0909	0.0179	0.0417	0.0127	0.0299
<i>Libellula needhami</i>	Needham's skimmer	0	0.0040	0	0	0	0	0.0064	0.0015
<i>Littoridinops monroensis</i>	cockscorb hydrobe	0	0	0	0	0	0.0046	0	0.0007
<i>Nerodia floridana</i>	Florida green water snake	0	0	0	0	0.0089	0.0093	0.0064	0.0035
<i>Nerodia taxispilots</i>	brown water snake	0	0	0	0	0	0	0.0021	0.0003
<i>Notophthalmus viridescens</i>	peninsula newt	0	0	0	0	0	0	0.0127	0.0018

Species	Common name	AERO	C111	CKK	CXT	L31W	S332	SRS	Total
<i>Pachydiplax longipennis</i>	blue dasher	0	0	0.0625	0	0	0	0	0.0089
<i>Palaemonetes paludosus</i>	grass shrimp	1.3393	2.7097	0.1875	0.4318	0.7143	0.3843	4.0699	1.4052
<i>Pelocoris femoratus</i>	alligator flea	0	0.0282	0	0.0227	0	0.0324	0.0212	0.0149
<i>Planorbella</i> spp.	unidentified planorbid snail	0.0089	0.0161	0	0	0	0.0093	0.0127	0.0067
<i>Pomacea paludosa</i>	apple snail	0	0.0040	0	0	0.0089	0.0093	0.0127	0.0050
<i>Rana</i> spp. tp.	pig frog tadpole/leopard frog tadpole	0	0	0	0.0227	0.0089	0.0602	0.0318	0.0177
<i>Rana grylio</i>	pig frog adult	0	0	0	0	0	0	0.0106	0.0015
<i>Siren lacertina</i>	greater siren	0	0	0	0	0	0	0.0106	0.0015
family Stratiomyidae	soldier fly larvae	0.0089	0	0	0	0	0	0.0021	0.0016
	unidentified tadpole	0	0	0	0	0	0	0.0042	0.0006
	Grand Total	1.821	3.117	0.313	1.273	1.357	1.144	4.864	

Table III.15. Invertebrate and amphibian catch-per-unit-effort in 2011: Catch of invertebrates and amphibians, standardized by sampling effort, divided into regions. The numbers reflect the average number of animals caught for each minnow trap (that soaked for 24 h).

<u>Species</u>	<u>Common name</u>	<u>AERO</u>	<u>C111</u>	<u>CXT</u>	<u>L31W</u>	<u>S332</u>	<u>SRS</u>	<u>Grand Total</u>
<i>Procambarus alleni</i>	Everglades crayfish	0.3917	0.2708	1.1429	0.42	0.4194	0.64	0.5475
<i>Procambarus fallax</i>	slough crayfish	0.0417	0.0139	0	0	0	0.12	0.0293
<i>Procambarus</i> spp.	unidentified crayfish	0.0333	0.0069	0	0	0	0.05	0.0150
<i>Acris gryllus</i> tadpole	cricket frog tadpole	0	0	0	0	0	0.01	0.0017
<i>Anax junius</i>	common green darner	0	0	0	0	0.0081	0	0.0013
<i>Belostoma</i> spp.	giant water bug	0.0167	0.0764	0	0.04	0.0242	0.03	0.0312
<i>Celithemis eponina</i>	halloween pennant	0	0	0	0	0	0.005	0.0008
<i>Celithemis</i> species	pennant	0	0.0069	0	0	0	0	0.0012
family Coenagrionidae	damselfly larvae	0	0.0069	0	0	0	0.005	0.0020
order Coleoptera	aquatic beetle adults	0.0250	0.0069	0	0.04	0.0403	0.035	0.0245
<i>Cybister fimbriolatus</i>	predaceous diving beetle	0.0083	0.0208	0	0.04	0.0323	0.03	0.0219
<i>Cybister</i> spp.	predaceous diving beetle	0	0	0.0357	0.01	0	0.015	0.0101
order Diptera	unidentified fly larva	0	0.0069	0	0	0	0.005	0.0020
family Gerridae	water striders	0	0.0139	0	0	0	0	0.0023
suborder Heteroptera	aquatic bugs	0	0	0	0	0.0081	0	0.0013
class Hirudinea	Leeches	0	0	0	0	0	0.005	0.0008
<i>Hyla cineria</i> tadpole	green tree frog tadpole	0	0	0	0	0.0081	0.005	0.0022
<i>Lethocerus</i> spp.	giant water bug	0.0417	0.0625	0	0.01	0.0161	0.015	0.0242
<i>Libellula needhami</i>	Needham's skimmer	0	0	0	0	0	0.005	0.0008
<i>Notophthalmus viridescens</i>	peninsula newt	0	0	0	0	0	0.015	0.0025
<i>Palaemonetes paludosus</i>	grass shrimp	0.2667	0.9861	0.3214	0.64	1.0565	4.165	1.2393
<i>Pelocoris femoratus</i>	alligator flea	0.0417	0.0625	0	0.01	0.0081	0.105	0.0379
<i>Planorbella</i> spp.	unidentified planorbid snail	0.0083	0.0139	0	0	0.0081	0	0.0050
<i>Pomacea paludosa</i>	apple snail	0.0083	0	0	0.01	0	0	0.0031
<i>Pseudosuccinea columella</i>	mimic lymnaea	0	0	0	0	0	0.005	0.0008
<i>Rana</i> spp. tadpole	pig frog tadpole/leopard frog tadpole	0	0	0	0	0.0323	0.055	0.0145
<i>Siren lacertina</i>	greater siren	0.0083	0	0	0	0	0	0.0014
family Stratiomyidae	soldier fly larvae	0	0	0	0	0	0.005	0.0008
	unidentified tadpole	0.0083	0	0.0357	0	0	0	0.0073
Grand Total		0.9	1.5556	1.535714	1.22	1.6613	5.325	

Table III.16. Statistical results of ANOVA comparing abundances of native fish. See figure X for results of Tukey post-hoc test.

Fish	Source	DF	F	p
Marsh killifish <i>(fundulus confluentus)</i>	Year	7	2.67	0.0096
	Region	5	18.43	<.0001
	Year x Reg.	18	3.1	<.0001
Eastern mosquitofish <i>(Gambusia holbrooki)</i>	Year	7	4.19	0.0001
	Region	5	6.92	<.0001
	Year x Reg.	18	5.49	<.0001
Flagfish <i>(Jordanella floridae)</i>	Year	7	9.82	<.0001
	Region	5	26.25	<.0001
	Year x Reg.	18	2.52	0.0005
Bluefin killifish <i>(Lucania goodei)</i>	Year	7	5.47	<.0001
	Region	5	7.82	<.0001
	Year x Reg.	18	4.7	<.0001
Sailfin molly <i>(Poecilia latipinna)</i>	Year	7	8.09	<.0001
	Region	5	2.18	0.0545
	Year x Reg.	18	3.98	<.0001
All fish total	Year	7	1.75	0.0949
	Region	5	16.96	<.0001
	Year x Reg.	18	5.66	<.0001

Table III.17. Statistical results of ANOVA comparing abundances of non-native fish. See figure X for results of Tukey post-hoc test.

Fish	Source	DF	F	p
Pike killifish <i>(Belonesox belizanus)</i>	Year	8	1.33	0.2506
	Region	5	10.06	< 0.0001
	Year x Reg.	17	1.25	0.2636
Black Acara <i>(Cichlasoma bimaculatum)</i>	Year	8	2.1	0.0515
	Region	5	2.29	0.0583
	Year x Reg.	17	1.34	0.2054
Jaguar guapote <i>(Cichlasoma managuanense)</i>	Year	8	1.96	0.0698
	Region	5	5.98	0.0002
	Year x Reg.	17	2.19	0.0152
Ciclosoma spp.	Year	8	5.84	<.0001
	Region	5	6.1	0.0002
	Year x Reg.	17	4.94	<.0001
Mayan cichlid <i>(Cichlasoma urophthalmus)</i>	Year	8	2.56	0.0193
	Region	5	4.73	0.0012
	Year x Reg.	17	1.54	0.1156
Walking catfish <i>(Clarias batrachus)</i>	Year	8	1.62	0.1421
	Region	5	2.21	0.0672
	Year x Reg.	17	1.3	0.2281
Jewelfish <i>(Hemichromis letourneuxi)</i>	Year	8	17.76	<.0001
	Region	5	62.66	<.0001
	Year x Reg.	17	5.78	<.0001
Brown Hoplo <i>(Hoplosternum littorale)</i>	Year	8	1.92	0.0763
	Region	5	1.82	0.1241
	Year x Reg.	17	1.49	0.1337
Blue tilapia <i>(Oreochromis aureus)</i>	Year	8	1.68	0.1258
	Region	5	4.08	0.0033
	Year x Reg.	17	1.5	0.131
Sailfin catfish <i>(Pterygoplichthys multiradiatus)</i>	Year	8	1.49	0.1817
	Region	5	2.24	0.0642
	Year x Reg.	17	1.3	0.2304
Spotted tilapia <i>(Tilapia mariae)</i>	Year	8	1.14	0.3557
	Region	5	2.77	0.0269
	Year x Reg.	17	0.63	0.8559

Table III.18A. Results of ANOSIM comparing impact, reference and slough sites from 2004-2011. This table includes results generated using all fish species.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences between Impact, reference and slough sites		
Global test	0.216	0.001
Pairwise comparisons		
Impact-reference	0.259	0.001
Impact-Slough	0.123	0.001
Reference-Slough	0.485	0.001
ANOSIM differences among years		
Global test	0.319	0.001
SIMPER: Individual species contribution to dis/similarity among impact, reference and slough sites		
	<u>Species contribution</u>	
Similarity within impact sites:		
<i>Gambusia holbrooki</i>	33.2%	
<i>Jordanella floridae</i>	15.6%	
<i>Lepomis marginatus</i>	12.9%	
<i>Poecilia latipinna</i>	10.43%	
Similarity within reference sites:		
<i>Gambusia holbrooki</i>	29.1%	
<i>Lepomis marginatus</i>	26.3%	
<i>Hemichromis letourneauxi</i>	23.1%	
Similarity within slough sites		
<i>Gambusia holbrooki</i>	43.8%	
<i>Poecilia latipinna</i>	13.1%	
<i>Lucania goodei</i>	11.2%	
<i>Lepomis marginatus</i>	10.9%	
<i>Jordanella floridae</i>	10.8%	
Dissimilarity between Impact and reference:		
<i>Lepomis marginatus</i>	12.7%	
<i>Hemichromis letourneauxi</i>	12.2%	
<i>Gambusia holbrooki</i>	11.4%	
<i>Jordanella floridae</i>	11.3%	
Dissimilarity between Impact and slough		
<i>Lepomis marginatus</i>	11.4%	
Dissimilarity between reference and slough		
<i>Hemichromis letourneauxi</i>	13.7%	
<i>Lepomis marginatus</i>	12.2%	

Table III.18B. Results of ANOSIM comparing impact, reference and slough sites from 2004-2011. This table includes results generated using fish species of which we caught 80 or more.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences between Impact, reference and slough sites		
Global test	0.231	0.001
Pairwise comparisons		
Impact-reference	0.272	0.002
Impact-Slough	0.136	0.001
Reference-Slough	0.505	0.001
ANOSIM differences among years		
Global test	0.311	0.001
SIMPER: Individual species contribution to dis/similarity among impact, reference and slough sites		
	<u>Species contribution</u>	
Similarity within impact sites:		
<i>Gambusia holbrooki</i>	33.2%	
<i>Jordanella floridae</i>	15.6%	
<i>Lepomis marginatus</i>	12.9%	
<i>Poecilia latipinna</i>	10.4%	
Similarity within reference sites:		
<i>Gambusia holbrooki</i>	29.1%	
<i>Lepomis marginatus</i>	27.0%	
<i>Hemichromis letourneauxi</i>	23.3%	
Similarity within slough sites		
<i>Gambusia holbrooki</i>	44.0%	
<i>Poecilia latipinna</i>	13.1%	
<i>Lucania goodei</i>	11.2%	
<i>Lepomis marginatus</i>	11.9%	
<i>Jordanella floridae</i>	10.8%	
Dissimilarity between Impact and reference:		
<i>Lepomis marginatus</i>	13.4%	
<i>Hemichromis letourneauxi</i>	12.8%	
<i>Gambusia holbrooki</i>	11.9%	
<i>Jordanella floridae</i>	11.9%	
Dissimilarity between Impact and slough		
<i>Lepomis marginatus</i>	11.4%	
<i>Jordanella floridae</i>	10.6%	
Dissimilarity between reference and slough		
<i>Hemichhromis letourneauxi</i>	14.6%	
<i>Lepomis marginatus</i>	13.1%	
<i>Gambusia holbrooki</i>	11.2%	

Table III.19A. Results of ANOSIM comparing all regions from 2009-2011. This tables include results generated using all fish species.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences between regions		
Global test	0.271	0.001
Pairwise comparisons		
SRS-S332	0.164	0.001
SRS-CXT	0.546	0.001
SRS-AERO	-0.02	0.539
SRS-C111	0.241	0.003
SRS-L31W	0.224	0.001
SRS-CKK	0.863	0.002
S332-CXT	0.299	0.002
S332-AERO	0.239	0.023
S332-C111	0.572	0.001
S332-L31W	0.072	0.082
S332-CKK	0.701	0.01
CXT-AERO	0.365	0.011
CXT-C111	0.65	0.001
CXT-L31W	0.281	0.006
CXT-CKK	0.177	0.286
AERO-C111	0.257	0.002
AERO-L31W	0.149	0.009
C111-L31W	0.413	0.001
C111-CKK	0.779	0.026
ANOSIM differences among years		
Global test	0.23	0.001
SIMPER: Individual species contribution to dis/similarity among impact, reference and slough sites		
	<u>Species</u>	<u>contribution</u>
Similarity within AERO:		
<i>Gambusia holbrooki</i>		36.73%
<i>Jordanella floridae</i>		19.98%
<i>Poecilia latipinna</i>		18.84%
<i>Fundulus confluentus</i>		12.9%
Similarity within C111:		
<i>Gambusia holbrooki</i>		44.59%
<i>Poecilia latipinna</i>		19.31%
<i>Lucania goodei</i>		13.34%
Similarity within CKK		
<i>Hemichromis letourneauxi</i>		55.78%
Similarity within CXT:		
		33.99%
		18.28%

<i>Gambusia holbrooki</i>	14.66%
<i>Hemichromis letourneauxi</i>	14.35%
<i>Jordanella floridae</i>	13.28%
<i>Fundulus confluentus</i>	
<i>Lepomis marginatus</i>	
Similarity within L-31W:	
<i>Gambusia holbrooki</i>	39.67%
<i>Poecilia latipinna</i>	17.8%
<i>Jordanella floridae</i>	14.23%
<i>Fundulus confluentus</i>	10.77%
Similarity within S332	
<i>Gambusia holbrooki</i>	37.89%
<i>Jordanella floridae</i>	20.47%
<i>Poecilia latipinna</i>	12.18%
Similarity within SRS	
<i>Gambusia holbrooki</i>	41.35%
<i>Jordanella floridae</i>	17.88%
<i>Poecilia latipinna</i>	14.16%
Dissimilarity between SRS and S332	
<i>Lepomis marginatus</i>	12.22
<i>Lucania goodei</i>	10.72
<i>Poecilia latipinna</i>	10.45
<i>Jordanella floridae</i>	10.29
Dissimilarity between SRS and CXT	
<i>Hemichromis letourneauxi</i>	14.86
<i>Lepomis marginatus</i>	11.92
<i>Gambusia holbrooki</i>	11.6
<i>Poecilia latipinna</i>	11.11
<i>Lucania goodei</i>	10.36
<i>Jordanella floridae</i>	10.02
Dissimilarity between S332 and CXT	
<i>Hemichromis letourneauxi</i>	14.49
<i>Lepomis marginatus</i>	13.29
<i>Gambusia holbrooki</i>	12.62
<i>Jordanella floridae</i>	12.08
<i>Poecilia latipinna</i>	10.4
Dissimilarity between SRS and AERO	
<i>Poecilia latipinna</i>	12.43
<i>Jordanella floridae</i>	11.6
<i>Lucania goodei</i>	11.39
<i>Lepomis marginatus</i>	11.04
Dissimilarity between S332 and AERO	
<i>Poecilia latipinna</i>	11.87

<i>Lepomis marginatus</i>	11.73
<i>Jordanella floridae</i>	10.94
Dissimilarity between CXT and AERO	
<i>Hemichromis letourneauxi</i>	14.58
<i>Poecilia latipinna</i>	14.46
<i>Jordanella floridae</i>	11.96
<i>Lepomis marginatus</i>	11.48
<i>Gambusia holbrooki</i>	11.15
Dissimilarity between SRS and C111	
<i>Jordanella floridae</i>	13.56
<i>Poecilia latipinna</i>	13.01
<i>Lucania goodei</i>	11.8
Dissimilarity between S332 and c11	
<i>Jordanella floridae</i>	14.26
<i>Poecilia latipinna</i>	11.35
<i>Lucania goodei</i>	10.36
Dissimilarity between CXT and C111	
<i>Hemichromis letourneauxi</i>	13.33
<i>Poecilia latipinna</i>	12.67
<i>Lucania goodei</i>	10.78
<i>Gambusia holbrooki</i>	10.7
<i>Lepomis marginatus</i>	10.16
Dissimilarity between AERO and c111	
<i>Jordanella floridae</i>	16.87
<i>Poecilia latipinna</i>	12.12
<i>Lucania goodei</i>	11.27
Dissimilarity between SRS and L-31W	
<i>Hemichromis letourneauxi</i>	11.11
<i>Lucania goodei</i>	11.1
<i>Poecilia latipinna</i>	10.83
<i>Lepomis marginatus</i>	10.44
<i>Jordanella floridae</i>	10.21
Dissimilarity between S332 and L-31W	
<i>Lepomis marginatus</i>	11.82
<i>Hemichromis letourneauxi</i>	11.53
<i>Jordanella floridae</i>	11.43
<i>Poecilia latipinna</i>	10.89
Dissimilarity between CXT and L-31W	
<i>Hemichromis letourneauxi</i>	14.69
<i>Poecilia latipinna</i>	13.38
<i>Gambusia holbrooki</i>	12.48

<i>Lepomis marginatus</i>	12.31
<i>Jordanella floridae</i>	10.59
Dissimilarity between AERO and L-31W	
<i>Jordanella floridae</i>	12.27
<i>Poecilia latipinna</i>	11.33
<i>Hemichromis letourneauxi</i>	11.27
Dissimilarity between C111 and L-31W	
<i>Poecilia latipinna</i>	11.99
<i>Jordanella floridae</i>	11.53
<i>Lucania goodei</i>	11.2
<i>Hemichromis letourneauxi</i>	10.11
Dissimilarity between SRS and CKK	
<i>Hemichromis letourneauxi</i>	25.95
<i>Gambusia holbrooki</i>	14.2
<i>Jordanella floridae</i>	12.31
<i>Poecilia latipinna</i>	11.08
Dissimilarity between S332 and CKK	
<i>Hemichromis letourneauxi</i>	20.73
<i>Jordanella floridae</i>	15.69
<i>Gambusia holbrooki</i>	14.94
<i>Poecilia latipinna</i>	10.66
Dissimilarity between CXT and CKK	
<i>Hemichromis letourneauxi</i>	20.86
<i>Gambusia holbrooki</i>	20.11
<i>Lepomis marginatus</i>	14.19
<i>Jordanella floridae</i>	13.34
<i>Fundulus confluentus</i>	12.39
Dissimilarity between AERO and CKK	
<i>Hemichromis letourneauxi</i>	23.58
<i>Jordanella floridae</i>	14.92
<i>Poecilia latipinna</i>	14.26
<i>Gambusia holbrooki</i>	12.69
Dissimilarity between C111 and CKK	
<i>Hemichromis letourneauxi</i>	27.41
<i>Gambusia holbrooki</i>	14.8
<i>Poecilia latipinna</i>	14.68
Dissimilarity between L-31W and CKK	
<i>Hemichromis letourneauxi</i>	20.77
<i>Gambusia holbrooki</i>	15.99
<i>Poecilia latipinna</i>	14.46
<i>Jordanella floridae</i>	12.52
<i>Fundulus confluentus</i>	10.57

Table III.19B. Results of ANOSIM comparing all regions from 2009-2011. This tables include results generated using only fish species of which we caught 40 or more individuals.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences between regions		
Global test	0.287	0.001
Pairwise comparisons		
SRS-S332	0.164	0.001
SRS-CXT	0.563	0.001
SRS-AERO	-0.021	0.543
SRS-C111	0.296	0.001
SRS-L31W	0.23	0.003
SRS-CKK	0.91	0.001
S332-CXT	0.343	0.003
S332-AERO	0.283	0.004
S332-C111	0.627	0.001
S332-L31W	0.094	0.029
S332-CKK	0.802	0.01
CXT-AERO	0.413	0.001
CXT-C111	0.682	0.001
CXT-L31W	0.29	0.005
CXT-CKK	0.365	0.071
AERO-C111	0.24	0.003
AERO-L31W	0.174	0.004
C111-L31W	0.423	0.001
C111-CKK	0.805	0.026
L31W-CKK	0.505	0.044
ANOSIM differences among years		
Global test	0.246	0.001
SIMPER: Individual species contribution to dis/similarity among impact, reference and slough sites		
		<u>Species contribution</u>
Similarity within AERO:		
<i>Gambusia holbrooki</i>		36.74
<i>Jordanella floridae</i>		19.95
<i>Poecilia latipinna</i>		18.84
<i>Fundulus confluentus</i>		12.9
Similarity within C111:		
<i>Gambusia holbrooki</i>		44.72
<i>Poecilia latipinna</i>		19.45
<i>Lucania goodei</i>		13.28
Similarity within CKK		
<i>Hemichromis letourneauxi</i>		55.78%

Similarity within CXT:	
<i>Gambusia holbrooki</i>	33.98
<i>Hemichromis letourneauxi</i>	18.28
<i>Jordanella floridae</i>	14.66
<i>Fundulus confluentus</i>	14.35
<i>Lepomis marginatus</i>	13.29
Similarity within L-31W:	
<i>Gambusia holbrooki</i>	40.12
<i>Poecilia latipinna</i>	17.64
<i>Jordanella floridae</i>	14.14
<i>Fundulus confluentus</i>	10.68
Similarity within S332	
<i>Gambusia holbrooki</i>	37.87
<i>Jordanella floridae</i>	20.44
<i>Poecilia latipinna</i>	12.11
Similarity within SRS	
<i>Gambusia holbrooki</i>	41.49
<i>Jordanella floridae</i>	17.84
<i>Poecilia latipinna</i>	14.14
Dissimilarity between SRS and S332	
<i>Lepomis marginatus</i>	13.02
<i>Lucania goodei</i>	11.35
<i>Poecilia latipinna</i>	11.11
<i>Jordanella floridae</i>	10.92
Dissimilarity between SRS and CXT	
<i>Hemichromis letourneauxi</i>	15.34
<i>Lepomis marginatus</i>	12.36
<i>Gambusia holbrooki</i>	11.95
<i>Poecilia latipinna</i>	11.53
<i>Lucania goodei</i>	10.72
<i>Jordanella floridae</i>	10.38
Dissimilarity between S332 and CXT	
<i>Hemichromis letourneauxi</i>	14.94
<i>Lepomis marginatus</i>	13.74
<i>Gambusia holbrooki</i>	13
<i>Jordanella floridae</i>	12.46
<i>Poecilia latipinna</i>	10.71
Dissimilarity between SRS and AERO	
<i>Poecilia latipinna</i>	13.28
<i>Jordanella floridae</i>	12.37
<i>Lucania goodei</i>	12.18
<i>Lepomis marginatus</i>	11.84
Dissimilarity between S332 and AERO	
<i>Poecilia latipinna</i>	12.56

<i>Lepomis marginatus</i>	12.46
<i>Jordanella floridae</i>	11.55
<i>Hemichromis letourneauxi</i>	10
Dissimilarity between CXT and AERO	
<i>Hemichromis letourneauxi</i>	15.02
<i>Poecilia latipinna</i>	14.9
<i>Jordanella floridae</i>	12.29
<i>Lepomis marginatus</i>	11.82
<i>Gambusia holbrooki</i>	11.48
Dissimilarity between SRS and C111	
<i>Jordanella floridae</i>	14.39
<i>Poecilia latipinna</i>	13.81
<i>Lucania goodei</i>	12.51
<i>Lepomis marginatus</i>	10.36
Dissimilarity between S332 and c111	
<i>Jordanella floridae</i>	14.95
<i>Poecilia latipinna</i>	11.92
<i>Lucania goodei</i>	10.81
<i>Lepomis marginatus</i>	10.14
Dissimilarity between CXT and C111	
<i>Hemichromis letourneauxi</i>	13.69
<i>Poecilia latipinna</i>	13.05
<i>Lucania goodei</i>	11.04
<i>Gambusia holbrooki</i>	10.97
<i>Lepomis marginatus</i>	10.45
Dissimilarity between AERO and c111	
<i>Jordanella floridae</i>	17.79
<i>Poecilia latipinna</i>	12.79
<i>Lucania goodei</i>	11.86
Dissimilarity between SRS and L-31W	
<i>Hemichromis letourneauxi</i>	11.75
<i>Lucania goodei</i>	11.65
<i>Poecilia latipinna</i>	11.52
<i>Lepomis marginatus</i>	11.11
<i>Jordanella floridae</i>	10.85
<i>Fundulus confluentus</i>	10.44
Dissimilarity between S332 and L-31W	
<i>Lepomis marginatus</i>	12.49
<i>Hemichromis letourneauxi</i>	12.12
<i>Jordanella floridae</i>	12.07
<i>Poecilia latipinna</i>	11.47

<i>Fundulus confluentus</i>	10.16
Dissimilarity between CXT and L-31W	
<i>Hemichromis letourneauxi</i>	15.13
<i>Poecilia latipinna</i>	13.7
<i>Gambusia holbrooki</i>	12.93
<i>Lepomis marginatus</i>	12.68
<i>Jordanella floridae</i>	10.9
<i>Fundulus confluentus</i>	10.26
Dissimilarity between AERO and L-31W	
<i>Jordanella floridae</i>	12.94
<i>Poecilia latipinna</i>	12
<i>Hemichromis letourneauxi</i>	11.79
Dissimilarity between C111 and L-31W	
<i>Poecilia latipinna</i>	12.64
<i>Jordanella floridae</i>	12.04
<i>Lucania goodei</i>	11.73
<i>Hemichromis letourneauxi</i>	10.54
Dissimilarity between SRS and CKK	
<i>Hemichromis letourneauxi</i>	26.5
<i>Gambusia holbrooki</i>	14.55
<i>Jordanella floridae</i>	12.59
<i>Poecilia latipinna</i>	11.37
Dissimilarity between S332 and CKK	
<i>Hemichromis letourneauxi</i>	21.07
<i>Jordanella floridae</i>	16.02
<i>Gambusia holbrooki</i>	15.25
<i>Poecilia latipinna</i>	10.86
Dissimilarity between CXT and CKK	
<i>Hemichromis letourneauxi</i>	20.93
<i>Gambusia holbrooki</i>	20.21
<i>Lepomis marginatus</i>	14.27
<i>Jordanella floridae</i>	13.41
<i>Fundulus confluentus</i>	12.47
Dissimilarity between AERO and CKK	
<i>Hemichromis letourneauxi</i>	24.05
<i>Jordanella floridae</i>	15.19
<i>Poecilia latipinna</i>	14.54
<i>Gambusia holbrooki</i>	12.99
Dissimilarity between C111 and CKK	
<i>Hemichromis letourneauxi</i>	28
<i>Gambusia holbrooki</i>	15.17

<i>Poecilia latipinna</i>	15.06
Dissimilarity between L-31W and CKK	
<i>Hemichromis letourneauxi</i>	21.37
<i>Gambusia holbrooki</i>	16.69
<i>Poecilia latipinna</i>	14.62
<i>Jordanella floridae</i>	12.68
<i>Fundulus confluentus</i>	10.69

Table III.20A. Results of ANOSIM comparing edge, mid and far arrays within a site for region AERO.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences among distances		
Global test	0.057	0.099
Pairwise comparisons		
Edge-Far	-0.024	0.646
Edge-Mid	0.049	0.049
Mid-Far	0.154	0.024
ANOSIM differences among sites in this region		
Global test	0.081	0.083
SIMPER: Individual species contribution to dis/similarity among distances from the wetland edge		<u>Species contribution</u>
Similarity within edge sites		
<i>Gambusia holbrooki</i>		45.55
<i>Poecilia latipinna</i>		19.57
<i>Jordanella floridae</i>		14.33
Similarity within mid sites		
<i>Gambusia holbrooki</i>		62.5
<i>Jordanella floridae</i>		16.64
Similarity within far sites		
<i>Gambusia holbrooki</i>		39.5
<i>Poecilia latipinna</i>		21.73
<i>Jordanella floridae</i>		19.01
<i>Fundulus confluentus</i>		16.35
Dissimilarity between edge and far sites		
<i>Jordanella floridae</i>		18.67
<i>Poecilia latipinna</i>		17.28
<i>Gambusia holbrooki</i>		10.4
Dissimilarity between edge and mid sites		
<i>Poecilia latipinna</i>		17.84
<i>Jordanella floridae</i>		16.7
<i>Gambusia holbrooki</i>		10.87
Dissimilarity between mid and far sites		
<i>Poecilia latipinna</i>		21.96
<i>Jordanella floridae</i>		19.66
<i>Gambusia holbrooki</i>		11.42

Table III.20B. Results of ANOSIM comparing edge, mid and far arrays within a site for region C111.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences among distances		
Global test	0.132	0.002
Pairwise comparisons		
Edge-Far	0.187	0.001
Edge-Mid	0.246	0.001
Mid-Far	-0.056	0.062
ANOSIM differences among sites in this region		
Global test	0.004	0.366
SIMPER: Individual species contribution to dis/similarity among distances from the wetland edge		<u>% Species contribution</u>
Similarity within edge sites		
<i>Gambusia holbrooki</i>		42.82
<i>Poecilia latipinna</i>		21.52
<i>Lucania goodei</i>		20.33
Similarity within mid sites		
<i>Gambusia holbrooki</i>		75.02
Similarity within far sites		
<i>Gambusia holbrooki</i>		70.57
Dissimilarity between edge and far sites		
<i>Poecilia latipinna</i>		18.13
<i>Gambusia holbrooki</i>		17.79
<i>Lucania goodei</i>		16.44
Dissimilarity between edge and mid sites		
<i>Poecilia latipinna</i>		18.29
<i>Gambusia holbrooki</i>		17.61
<i>Lucania goodei</i>		16.45
Dissimilarity between mid and far sites		
<i>Gambusia holbrooki</i>		18.72
<i>Poecilia latipinna</i>		17.62
<i>Fundulus confluentus</i>		11.37

Table III.20C. Results of ANOSIM comparing edge, mid and far arrays within a site for region Context Rd. and Chekika.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences among distances		
Global test	0.151	0.015
ANOSIM differences among sites in this region		
Global test	-0.012	0.517
SIMPER: Individual species contribution to dis/similarity among distances from the wetland edge		<u>Species contribution</u>
Similarity within mid sites		
<i>Gambusia holbrooki</i>		36.01
<i>Hemichromis letourneauxi</i>		31.68
<i>Lepomis marginatus</i>		23.88
Similarity within far sites		
<i>Gambusia holbrooki</i>		69.55
<i>Hemichromis letourneauxi</i>		13.69
Dissimilarity between mid and far sites		
<i>Gambusia holbrooki</i>		49.31
<i>Hemichromis letourneauxi</i>		16.3
<i>Lepomis marginatus</i>		14.88

Table III.20D. Results of ANOSIM comparing edge, mid and far arrays within a site for region L-31W.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences among distances		
Global test	-0.006	0.494
Pairwise comparisons		
Edge-Mid	0.041	0.127
Edge-Far	0.046	0.295
Mid-Far	-0.154	0.946
ANOSIM differences among sites in this region		
Global test	0.064	0.115
Pairwise comparisons		
A-B	0.204	0.021
A-C	-0.007	0.493
B-C	0.065	0.143
SIMPER: Individual species contribution to dis/similarity among distances from the wetland edge		
		<u>% Species contribution</u>
Similarity within edge sites		
<i>Gambusia holbrooki</i>		39.04
<i>Poecilia latipinna</i>		21.9
<i>Jordanella floridae</i>		13.64
Similarity within mid sites		
<i>Gambusia holbrooki</i>		49.89
<i>Hemichromis letourneauxi</i>		13.01
Similarity within far sites		
<i>Gambusia holbrooki</i>		51.95
<i>Fundulus confluentus</i>		18.73
<i>Jordanella floridae</i>		14.15
Dissimilarity between edge and mid sites		
<i>Poecilia latipinna</i>		15.77
<i>Gambusia holbrooki</i>		15.16
<i>Jordanella floridae</i>		13.29
<i>Hemichromis letourneauxi</i>		10.53
Dissimilarity between edge and far sites		
<i>Poecilia latipinna</i>		16.32
<i>Jordanella floridae</i>		14.26
<i>Fundulus confluentus</i>		13.57
<i>Gambusia holbrooki</i>		12.25
<i>Hemichromis letourneauxi</i>		10.47

Dissimilarity between mid and far sites

<i>Gambusia holbrooki</i>	17.87
<i>Fundulus confluentus</i>	15.6
<i>Jordanella floridae</i>	15.49
<i>Poecilia latipinna</i>	12.99
<i>Hemichromis letourneauxi</i>	12.12

Table III.20E. Results of ANOSIM comparing edge, mid and far arrays within a site for region S332.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences among distances		
Global test	0.034	0.002
Pairwise comparisons		
Edge-Far	0.058	0.001
Edge-Mid	0.017	0.077
Mid-Far	0.026	0.057
ANOSIM differences among sites in this region		
Global test	0.107	0.001
Pairwise comparisons		
B-D	0.063	0.001
B-C	0.157	0.012
D-C	0.248	0.001
SIMPER: Individual species contribution to dis/similarity among distances from the wetland edge		<u>% Species contribution</u>
Similarity within edge sites		
<i>Gambusia holbrooki</i>		58.59
<i>Jordanella floridae</i>		16.68
<i>Lepomis marginatus</i>		10.3
Similarity within mid sites		
<i>Gambusia holbrooki</i>		48.4
<i>Lepomis marginatus</i>		18.04
<i>Jordanella floridae</i>		10
Similarity within far sites		
<i>Gambusia holbrooki</i>		46.33
<i>Lepomis marginatus</i>		21.97
<i>Hemichromis letourneauxi</i>		11.73
Dissimilarity between edge and mid sites		
<i>Gambusia holbrooki</i>		39.36
<i>Jordanella floridae</i>		14.58
<i>Lepomis marginatus</i>		14.37
Dissimilarity between edge and far sites		
<i>Gambusia holbrooki</i>		39
<i>Lepomis marginatus</i>		17.15
<i>Jordanella floridae</i>		14.19
Dissimilarity between mid and far sites		
<i>Gambusia holbrooki</i>		37.67
<i>Lepomis marginatus</i>		19.18

Table III.21. Results from ANOVAs comparing abundance of fish species at different distances from the wetland edge, separated by region. In each case, the main effect being tested is distance (edge, mid or far)

Region	Species	DF	F	p
AERO	<i>Gambusia holbrooki</i>	2	0.41	0.6653
	<i>Poecilia latipinna</i>	2	2.79	0.0737
	<i>Jordanella floridae</i>	2	0.74	0.484
C111	<i>Gambusia holbrooki</i>	2	6.59	0.0023
	<i>Poecilia latipinna</i>	2	5.08	0.0086
	<i>Lucania goodei</i>	2		<
			22.03	0.0001
	<i>Fundulus confluentus</i>	2	2.53	0.0867
CXT and CKK	<i>Gambusia holbrooki</i>	2	0.91	0.3462
	<i>Hemichromis</i>	2		
	<i>letourneauxi</i>		1.79	0.188
	<i>Lepomis marginatus</i>	2	10.05	0.0027
L-31W	<i>Gambusia holbrooki</i>	2	2.47	0.0927
	<i>Poecilia latipinna</i>	2	6.09	0.0037
	<i>Jordanella floridae</i>	2	1.4	0.2549
	<i>Hemichromis</i>	2		
	<i>letourneauxi</i>		0.61	0.5464
	<i>Fundulus confluentus</i>	2	3.35	0.0411
S332	<i>Gambusia holbrooki</i>	2	6.44	0.0017
	<i>Lepomis marginatus</i>	2	1.3	0.2745
	<i>Jordanella floridae</i>	2		<
			15.43	0.0001

Table III.22. Analysis of similarity (ANOSIM) and similarity percentage breakdown analysis (SIMPER) of fish caught in permanent (old) drift-fences and in new, portable drift-fences for sites in S332 and SRS. Data includes only points that were sampled with both types of drift-fence and fish present in more than one sample. Data was $\ln(x + 1)$ transformed and relativized.

<u>Test and Comparison</u>	<u>Rho</u>	<u>P</u>
ANOSIM differences between new and old drift-fences in S332		
Differences between old and new drift-fences	0.079	0.1440
ANOSIM for differences between new drift-fences and top and bottom minnow traps from old drift-fences in SRS		
Bottom-Top	0.15	0.021**
Bottom-New	0.101	0.183
Top-New	-0.074	0.679
ANOSIM differences between new and old drift-fences in SRS, pooling top and bottom minnow traps		
Differences between old and new drift-fences	0.016	0.370
SIMPER: Individual species contribution to dis/similarity for old and new drift-fences in S332 (showing only those > 10%, plus <i>Gambusia holbrooki</i>)	<u>Species contribution</u>	
Similarity within new drift-fences:		
<i>Gambusia holbrooki</i>	33.27%	
<i>Lepomis marginatus</i>	18.15%	
<i>Jordanella floridae</i>	15.14%	
Similarity within old drift-fences:		
<i>Gambusia holbrooki</i>	33.54%	
<i>Lepomis marginatus</i>	22.51%	
<i>Jordanella floridae</i>	12.91%	
<i>Hemichromis letourneauxi</i>	11.64%	
Dissimilarity between drift-fence types:		
<i>Lepomis marginatus</i>	17.84%	
<i>Jordanella floridae</i>	12.17%	
<i>Hemichromis letourneauxi</i>	10.68%	
<i>Gambusia holbrooki</i>	8.68%	
SIMPER: Individual species contribution to dis/similarity for old and new drift-fences in SRS (showing only those > 10%)	<u>Species contribution</u>	
Similarity within new drift-fences:	53.92%	
<i>Gambusia holbrooki</i>	17.9%	

<i>Jordanella floridae</i>	10.44%
<i>Lepomis marginatus</i>	
Similarity within old drift-fences:	
<i>Gambusia holbrooki</i>	70.63%
<i>Poecilia latipinna</i>	10.82%
<i>Lepomis marginatus</i>	10.37%
Dissimilarity between drift-fence types:	
<i>Lepomis marginatus</i>	16.42%
<i>Jordanella floridae</i>	15.31%
<i>Gambusia holbrooki</i>	12.21%
<i>Fundulus confluentus</i>	12.2%
<i>Poecilia latipinna</i>	11.52%
<i>Lucania goodei</i>	10.37%

Figure III.23. Results of RMA regressions for fish species between new and old drift fences.

Region/Species	Intercept	Slope (95% CI)	R²
<u>S332</u>			
<i>Gambusia holbrooki</i>	0.6925	0.8505 (0.40-1.30)	0.0566
<i>Hemichromis letourneauxi</i>	2.754	-1.066 (-1.65- -0.48)	0.0111
<i>Jordanella floridae</i>	0.4552	1.205 (0.56-1.85)	0.0439
<i>Lepomis marginatus</i>	-0.161	0.9254 (0.53-1.32)	0.3865
<u>SRS</u>			
<i>Fundulus confluentus</i>	0.3606	0.7396 (0.50-0.98)	0.3368
<i>Gambusia holbrooki</i>	-0.0782	0.8692 (0.54-1.20)	0.1156
<i>Lucania goodei</i>	0.7142	0.9303 (0.56-1.31)	0.0042
<i>Lepomis marginatus</i>	0.1501	0.8647 (0.58-1.15)	0.3364
<i>Poecilia latipinna</i>	-0.1619	0.3536 (0.22-0.49)	0.1129
<i>Jordanella floridae</i>	0.0814	2.138 (1.50-2.78)	0.4467

Figure III.1. Map of sample region in South Florida. Sites 50, 23, 6, 7 and 8 comprise the Shark River Slough region (SRS). Airboat access is required for the SRS region (sites 6, 7, 8, 23 and 50). The rest can all be accessed from roads and levies.

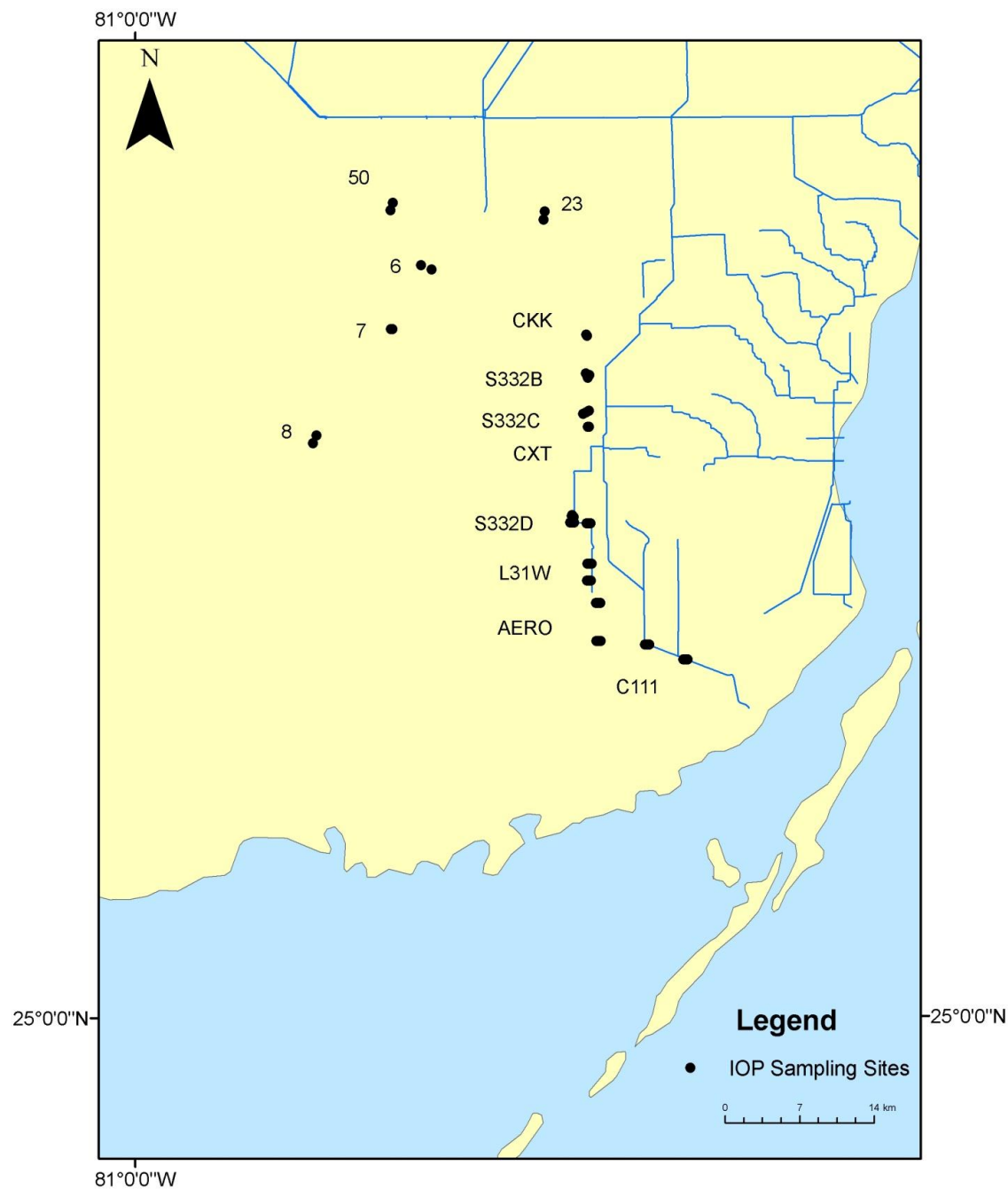


Figure III.2. Schematic diagrams of drift fences. On the left, the thicker lines represent rebar posts. The thin lines show edges of shade or ground cloth. Thin dotted circles show openings cut for installing minnow traps. On the right, viewed from above, showing minnow trap placement.

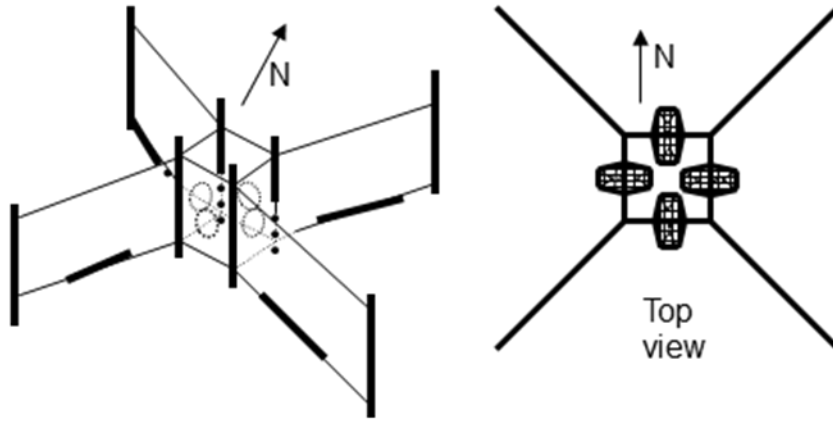


Figure III.3A. Total catch for all fish species (pooled), marsh killifish and eastern mosquitofish. Error bars show standard error. Groups of bars labeled with different letters are significantly different at $p < 0.05$ according to Tukey post-hoc tests. The graphs show raw means, but analyses were completed on $\ln(x + 1)$ transformed data.

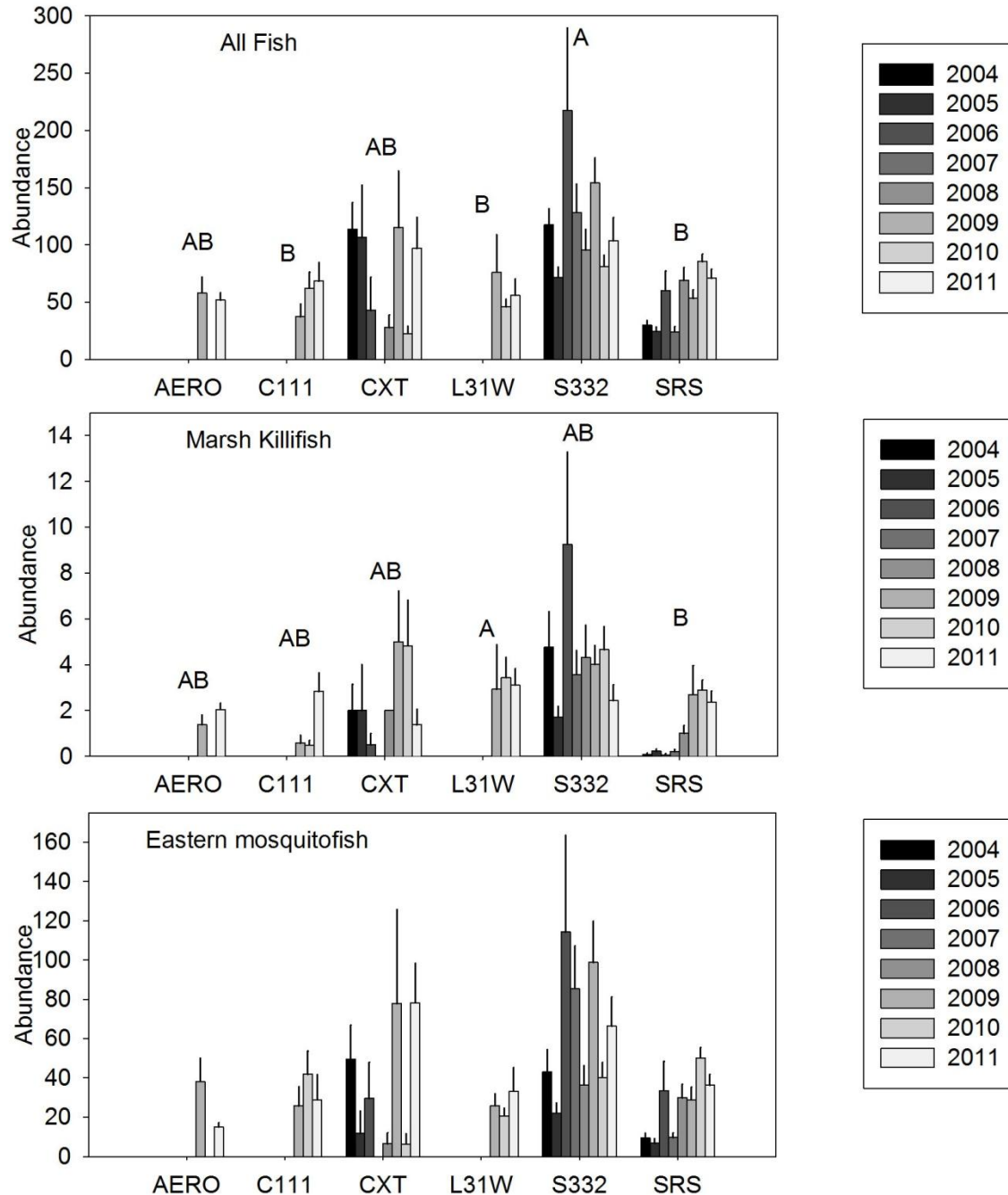


Figure III.3B. Total catch for flagfish, bluefin killifish and sailfin molly. Error bars show standard error. Groups of bars labeled with different letters are significantly different at $p < 0.05$ according to Tukey post-hoc tests. The graphs show raw means, but analyses were completed on $\ln(x + 1)$ transformed data.

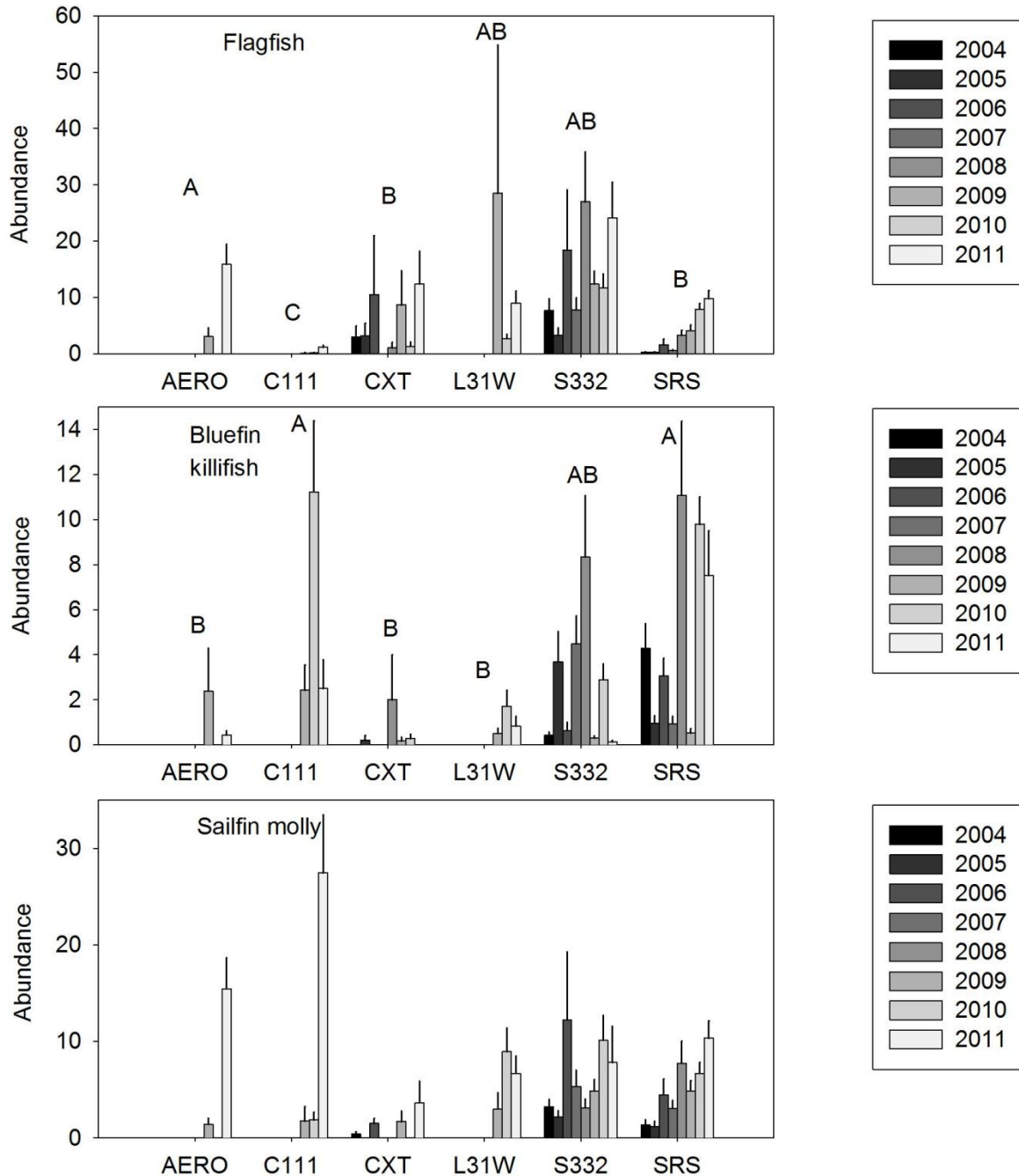


Figure III.4. Total catch for non-native fish, including pike killifish, jaguar guapote, Mayan cichlid, jewelfish and all non-native fish pooled. Error bars show standard error. Groups of bars labeled with different letters are significantly different at $p < 0.05$ according to post-hoc Tukey tests. These plots show log-transformed raw data, but analyses were completed on $\text{Ln}(X + 1)$ data.

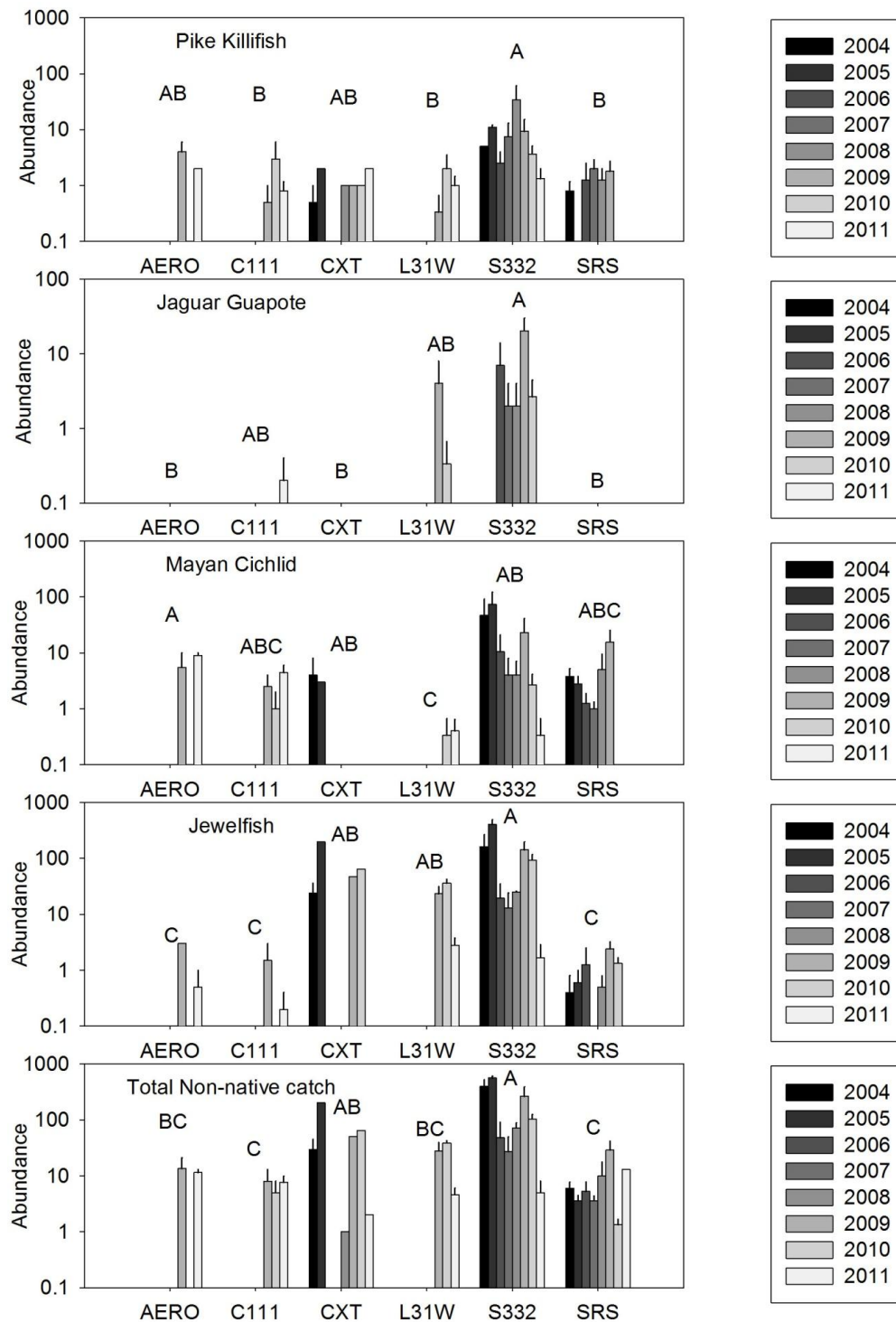


Figure III.5. Multi-dimensional scaling plots showing community structure (based on Bray-Curtis dissimilarity) for impact (S332), Reference (CKK, CXT) and Slough (SRS, INT) sites. The first plot shows community structure including all fish species. The second shows community structure calculated only using the most abundant fish. For both, each points represents total community captured in a year.

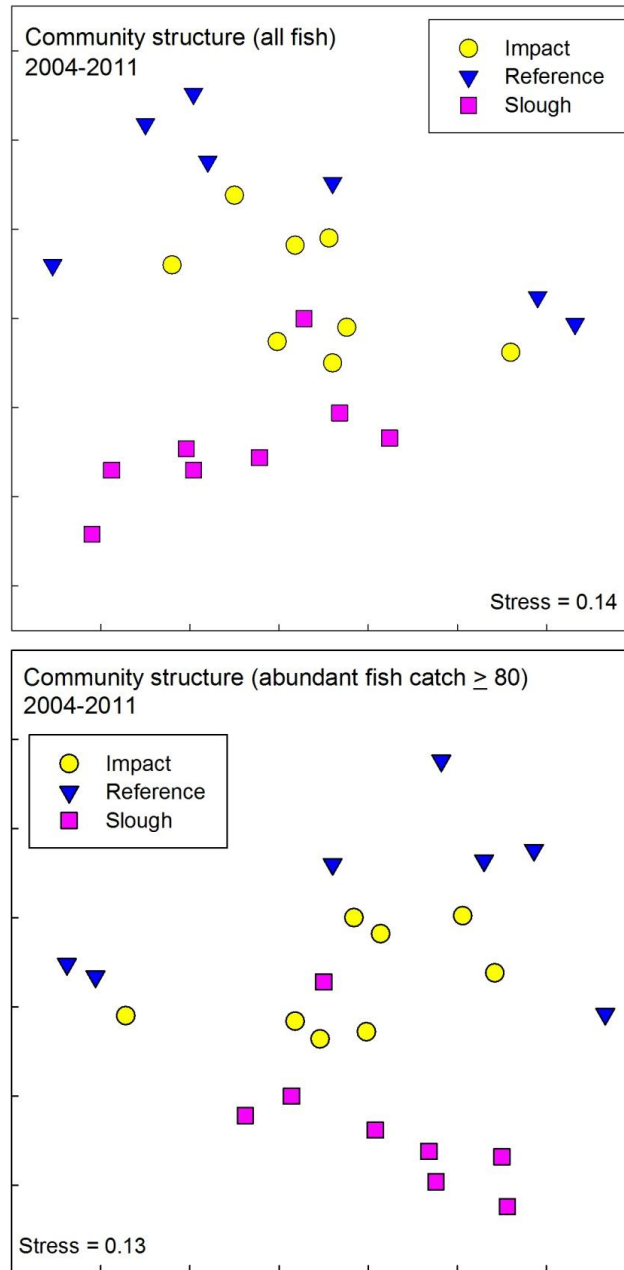


Figure III.6. Multi-dimensional scaling plots showing community structure (based on Bray-Curtis dissimilarity) for each region from 2009 to 2011. The first plot shows community structure including all fish species. The second shows community structure calculated only using the most abundant fish. For both, each points represents total community captured in a year.

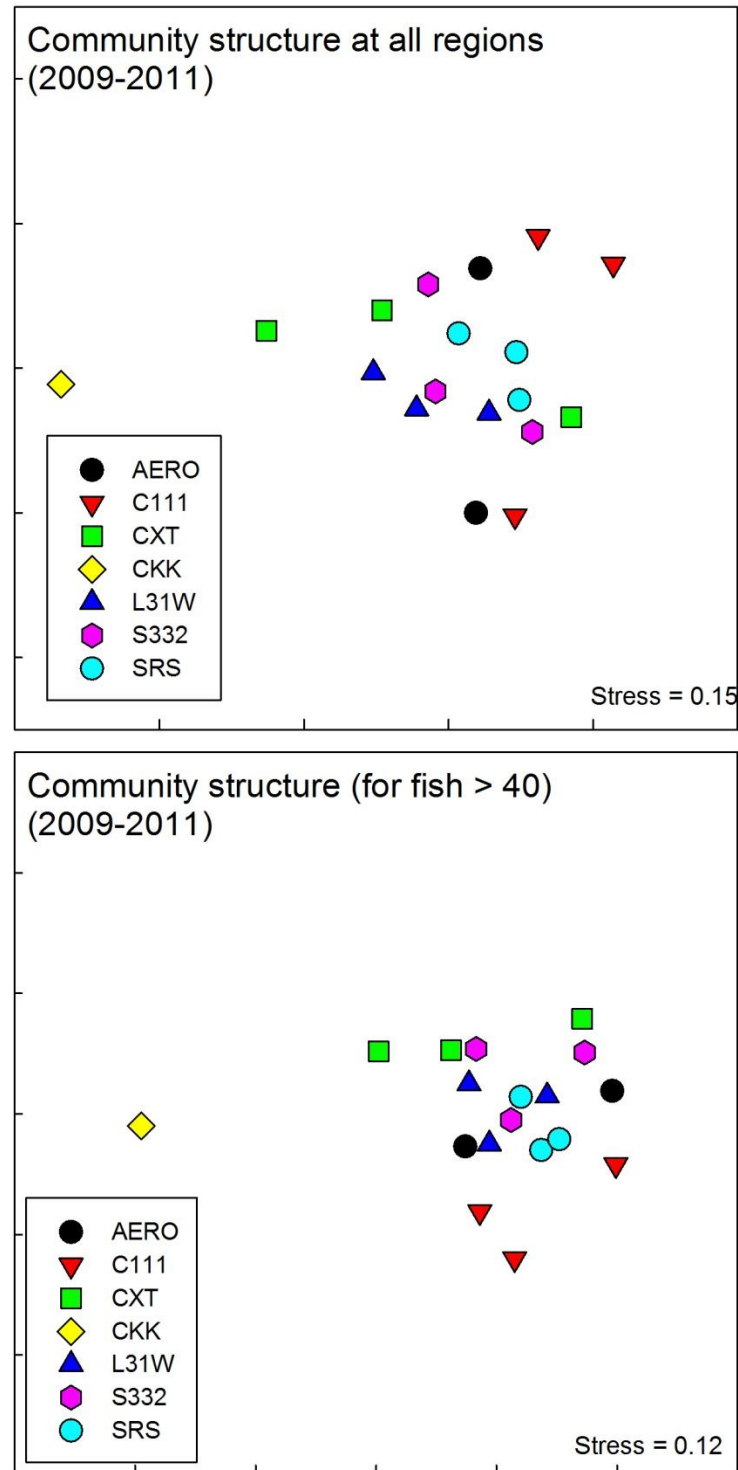


Figure III.7A. Left plots: Multidimensional scaling plots showing community similarity for arrays at difference distances from the wetland edge. Right plots: Mean abundance of the fish identified as contributing most to dissimilarity among distances. Asterisks identify means that are significantly different from the others. These plots show regions AERO, C111 and CXT/CKK.

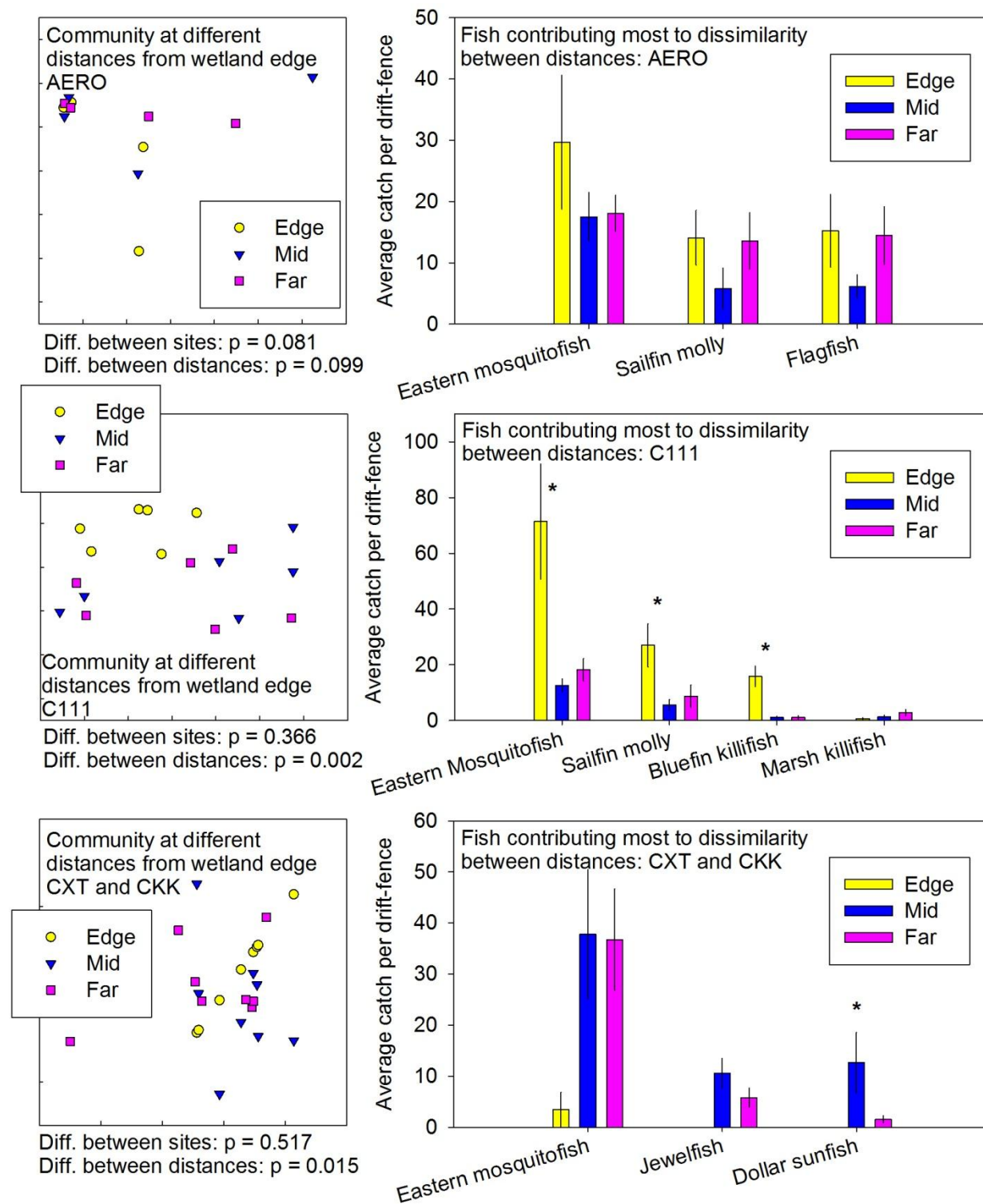


Figure III.7B. Left plots: Multidimensional scaling plots showing community similarity for arrays at difference distances from the wetland edge. Right plots: Mean abundance of the fish identified as contributing most to dissimilarity among distances. Asterisks identify means that are significantly different from the others. These plots show regions L-31W and S332.

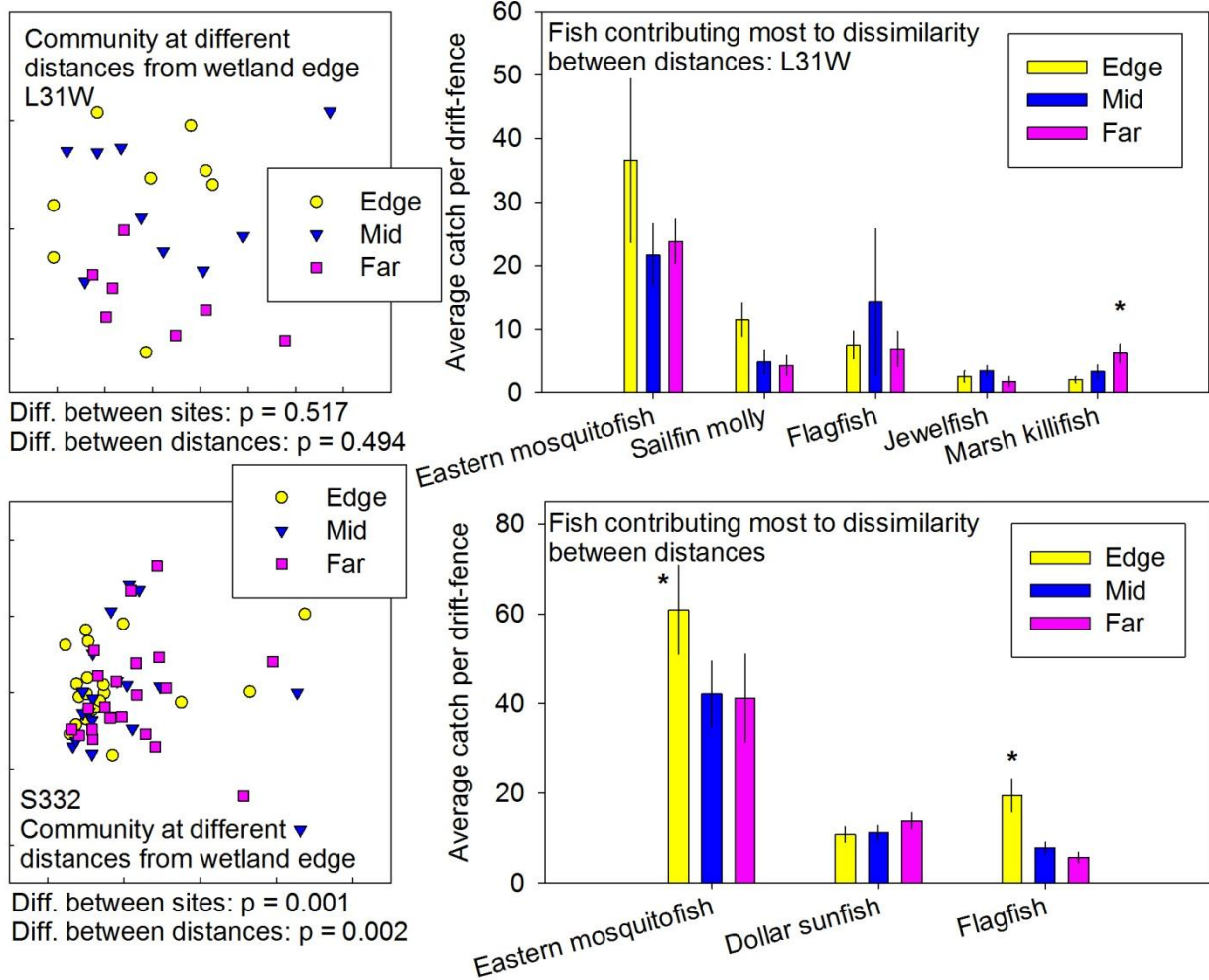


Figure III.8. Multi-dimensional scaling plots (MDS) showing differences in community structure (Bray-Curtis) between old and new drift-fence types. A) Compares communities caught in new and old drift-fences at the S332 sites. B) Compares community structure of new drift-fences with those of the top and bottom minnow traps in the SRS sites.

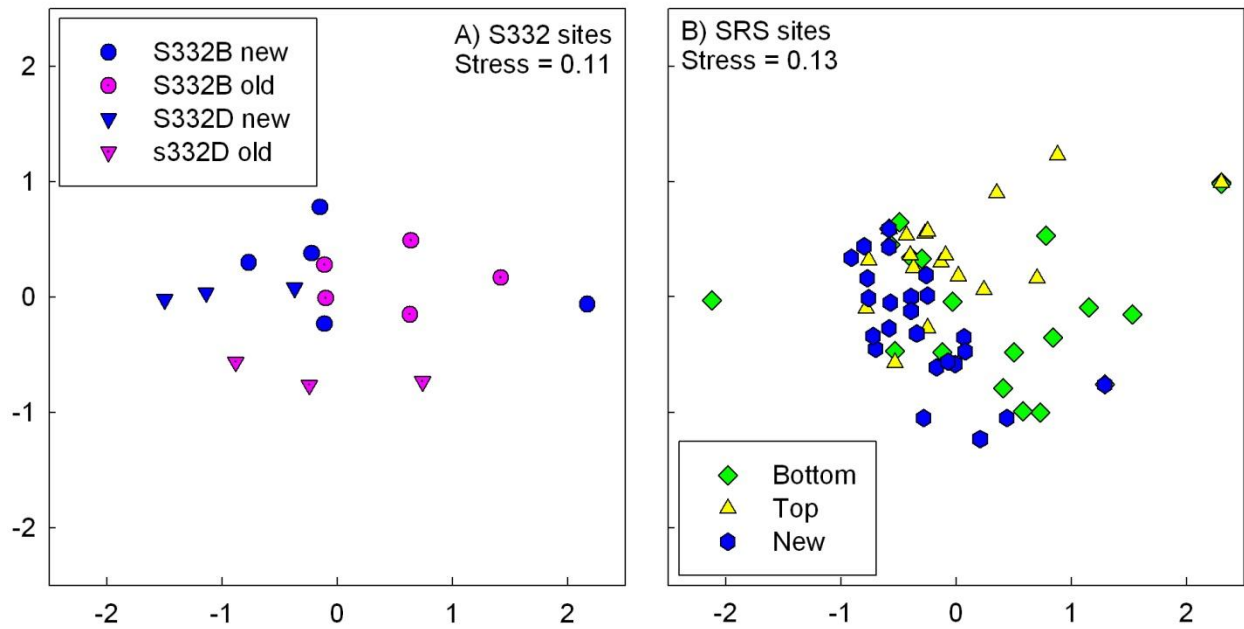
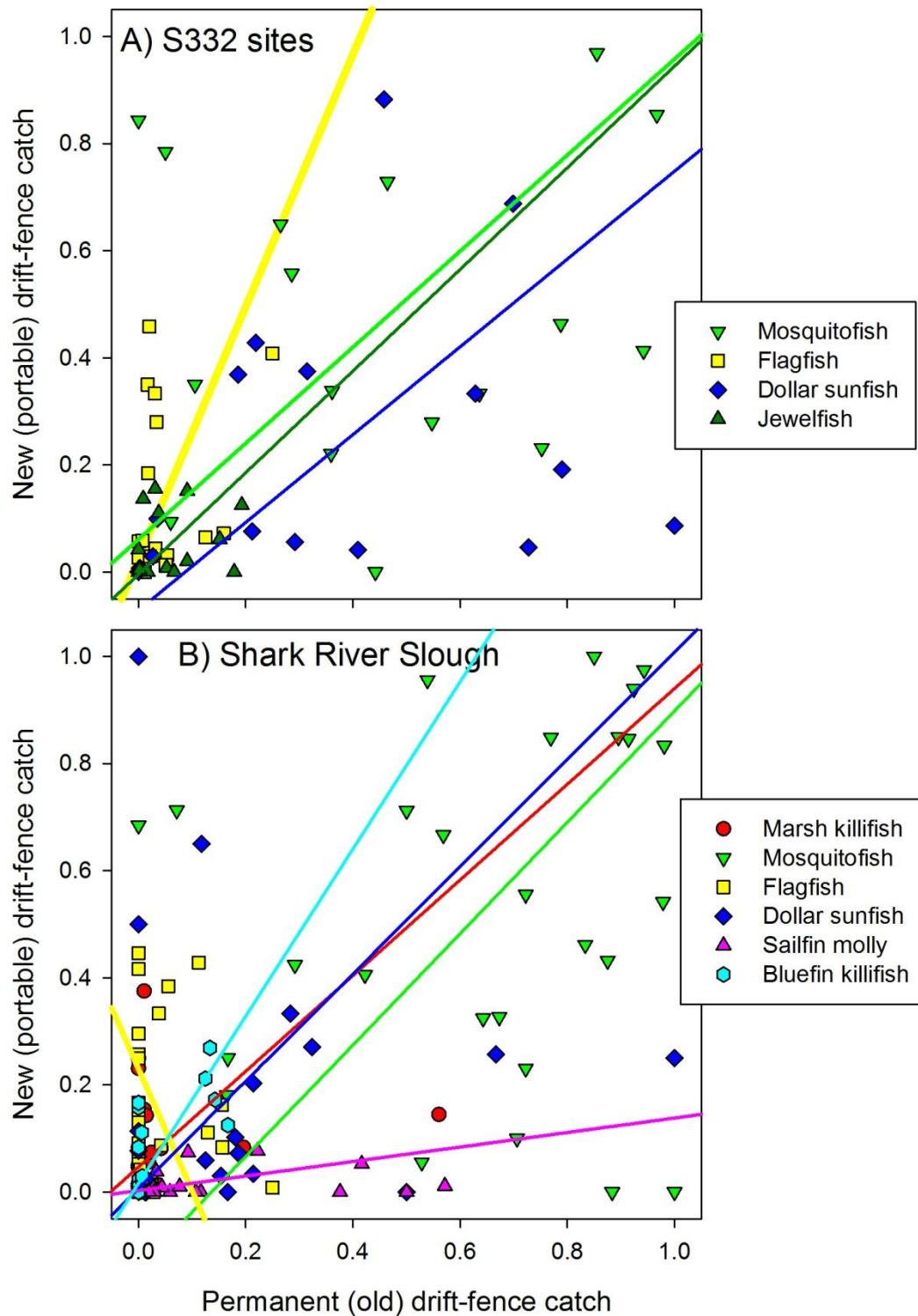


Figure III.9. Model II (RMA) regressions of catch in the new drift-fences against that of the old fence type for several species. The color of each regression line matches the fill color in each species' symbol.



VI. IOP macroinvertebrates for 2009 and 2010 hydrologic years

Eric Sokol and Joel Trexler

Introduction

Aquatic macroinvertebrate consumers have proven to be closely tied to hydrology and primary productivity in the Everglades ecosystem (Liston 2006, Liston et al. 2008), and community composition can be used to make inferences about processes organizing the ecosystem (Chase 2003). We have continued to monitor macroinvertebrate community composition to use as a tool to assess changes at the base of the aquatic food web in the Everglades at sites near the eastern edge of the park, near the S332 impoundments. These sites are likely influenced by changes in water management associated with the Intermediate Operating Plan (IOP). During the 2009 and 2010 hydrologic years, we expanded the spatial coverage of our monitoring effort of aquatic macroinvertebrates near the eastern edge of Everglades National Park (ENP) to include sites located in Taylor Slough and the Everglades Panhandle (see Table 1), and we continued to include sites in the interior of the park in Shark River Slough (SRS) as reference, long-hydroperiod sites.

Methods

Sampling design

The aquatic macroinvertebrate community was sampled at short and long hydroperiod sites in Everglades National Park (ENP) during the 2009 and 2010 hydrologic years. Sampling plots were arranged in a stratified design. Groups of plots located along the eastern edge of ENP were arranged at 0 m, 200 m, and 400 m along a transect perpendicular to the park boundary.

Duplicate plots (N = North, S = South) were located in Shark River Slough (SRS) in the interior of the park. Triplicate samples were collected during each sampling event at each plot. We attempted to collect samples from all sites once during the wet season (September-November) and once during the dry season (December-January) during each hydrologic year. Results here are only reported for three sampling events: wet season during the 2009 hydrologic year, dry season during the 2009 hydrologic year, and wet season during the 2010 hydrologic year.

Sample collection and processing

Periphyton core samples were collected using a 5 cm diameter coring device and stored in 75% ethanol in polyethylene sample cups. Periphyton cores were used to estimate periphyton standing crop and the standing stock of the infaunal macroinvertebrate community. Animals were removed from periphyton cores under 10× magnification and identified using the taxonomic groups listed in Table IV.A1 in Appendix IV.A. Periphyton was dried for 24 h, and combusted at 500 °C for 2 h to estimate ash free dry mass (AFDM) (APHA et al. 1998). Periphyton AFDM was standardized to core area to calculate an areal estimate of periphyton standing crop. Macroinvertebrate abundances were standardized to the AFDM of the periphyton core from which they were collected to estimated “crowding”, which is a standardized measure of infaunal standing crop.

Sweep samples were collected using a 10” D-frame net with 1 mm mesh. The D-frame net was swept in a 1 m long “U” shape motion through the water column. Sweep samples targeted macroinvertebrates in periphyton mats, free-swimming animals, and animals on emergent and submerged vegetation. Samples were preserved in 10% formalin in the field. Animals were removed without the aid of magnification in the lab and identified using the

taxonomic groups listed in Table A1 in Appendix A. Abundances were standardized to unit effort (a 1 m sweep = 1 unit effort) to yield catch per unit effort (CPUE).

Statistical Analysis

Standing crop and standing stocks were compared among short hydroperiod sites adjacent to S332 impoundments (S332), other short-hydroperiod sites not adjacent to the S332 impoundments (Short), and long-hydroperiod sites (Long). Standing stock and crop estimates were averaged among replicate samples for sampling plot level estimate. Observational units for all statistical analyses were plot level estimates. Plot level estimates of standing crop and stocks were log transformed prior to analysis. All analyses were conducted using the R statistical environment (R Development Core Team 2009).

We used a two-way ANOVA for comparisons among groups, and among sampling events, and to test for interactions. We treated observations collected during different sampling events as independent samples because we assume community composition varies substantially in both space and time (Trexler et al. 2002).

We used the vegan package (Oksanen et al. 2009) for R to calculate non-metric multidimensional scaling ordinations of plot level observations of community composition for periphyton core and sweep samples. We used plot-average relative abundances (RAs). RAs were $\log ([100 \times \text{RA}] + 1)$ transformed (McCune and Grace 2002), and used to calculate Bray-Curtis dissimilarity matrices. The BC dissimilarity matrices were used to calculate the ordinations for the periphyton core macroinvertebrate community and the sweep sample macroinvertebrate community separately. Observations were pooled over all sampling events for the assessment of differences in community composition among groups (S332, Short, Long).

The BC dissimilarities were also used to assess among-observation differences in community composition (beta-diversity). Within group beta-diversity was calculated for Short, S332, and Long groups of observations using the betadisper function in the vegan package. Among-group differences in beta-diversity were compared using a permutational analysis of multivariate dispersion (Anderson et al. 2006, Chase 2007, 2010, Babak and He 2009).

Results

Standing crop and stocks

We observed differences in periphyton standing crops among groups ($F_{2,83} = 18.0$, $P < 0.001$), but not sampling events ($F_{2,83} = 1.1$, $P = 0.35$), and there was no interaction between group and sampling effect ($F_{2,83} = 2.0$, $P = 0.10$) (Figure IV.2A). A Tukey's HSD test indicated no differences in standing crop between S332 and Short groups, but both had higher periphyton standing crops than estimates from cores in the Long group.

Estimates of standing stocks (crowding = no. animals g^{-1} AFDM periphyton) for infaunal macroinvertebrates in cores (Figure IV.2B) were higher for long-hydroperiod observations ($F_{2,83} = 6.9$, $P = 0.002$), and also decreased through out the study period ($F_{2,83} = 6.3$, $P = 0.003$), but there was no interaction ($F_{4,83} = 1.1$, $P = 0.34$). Estimates of standing stocks (CPUE) for macroinvertebrates collected in sweep samples (Figure IV.2C) showed no difference among groups, but did show differences among sampling events ($F_{2,90} = 4.0$, $P = 0.02$).

Community composition

NMDS ordinations of community composition for the infaunal community in periphyton cores (Figure IV.3) shows the community composition at short-hydroperiod sites is more variable than long-hydroperiod sites. The convex hull for long hydroperiod observations is completely contained within the convex hull for short hydroperiod sites, which indicates long-hydroperiod infaunal communities are a subset of the taxonomic groups observed at short-hydroperiod sites. A similar pattern is represented in the macroinvertebrate community collected using sweep samples (Figure IV.4). Taxonomic loading in Figure IV.5 shows long-hydroperiod core samples are characterized by beetle and true fly larvae, and short-hydroperiod samples have more adult beetles and mites; however, many short-hydroperiod sites have similar composition to long hydroperiod sites. A similar pattern is present in sweep samples.

Estimates of multivariate dispersion of the community composition for macroinvertebrate communities in periphyton core samples and sweep samples show beta-diversity differed among groups (Figure IV.6). The community composition was less variable (lower beta-diversity) among long-hydroperiod observations than among short-hydroperiod observations not collected near the S332 impoundments. This pattern was present in both periphyton cores and sweep samples. The beta-diversity of the macroinvertebrate community in periphyton cores at short-hydroperiod sites near the S332 impoundments was reduced, and no different than the beta-diversity measures observed for the short or long hydroperiod groups (Figure IV.6A). A similar pattern was qualitatively present in the sweep samples (Figure IV.6B), but not detectable using a $p = 0.05$ cutoff.

Discussion

Samples were collected in a monitoring effort to assess macroinvertebrate community composition during the 2009 and 2010 hydrologic years. The sampling effort during this study was expanded compared to previous years to increase spatial coverage. New sites included in this monitoring effort were located in Taylor Slough (TS) and the Everglades Panhandle (EPH, see Table IV.1 and Figure IV.1). The increased spatial coverage will provide a dataset more appropriate for assessing the influence of spatial autocorrelation over diversity patterns (Borcard et al. 1992, Nekola and White 1999, Tuomisto and Ruokolainen 2006). The added sites also proved useful as a short-hydroperiod reference against which the S332 sites can be compared as water management decisions lead to changes in the hydroperiod.

Periphyton is the base of the aquatic food web in the Everglades ecosystem (Ewe et al. 2006, Gaiser 2009). During the 2009 and 2010 hydrologic year, Periphyton standing crops were consistently higher at short-hydroperiod sites. While there is overlap in the types of animals collected in periphyton cores and sweep samples, the processing methods are biased toward infaunal animals that are primary consumers in periphyton core samples, and biased toward larger secondary consumers in sweep samples. Standing stocks in core samples, like periphyton samples, were consistently different between short and long-hydroperiod sites. This pattern of high periphyton standing crops and low crowding at short-hydroperiod sites is a common pattern in ENP. Both the infaunal standing stock, measured as crowding, and the standing stock estimated in sweep samples decreased during the course of the study; however, a lack of significant interactions indicates seasonal changes in standing stocks occurred regardless of hydrologic status.

Beta-diversity patterns are important indicators of the types of processes that shape aquatic communities along water permanence gradients, productivity gradients, and predation gradients (Chase 2003, 2007, 2010, Chase et al. 2009). Beta-diversity for the S332 group of observations was intermediate between short and long hydroperiod groups. Data collected in 2004-2008 shows beta-diversity is high among short hydroperiod sites, and decreases as hydroperiod increases. The 2004-2008 dataset also shows community composition converges toward a characteristic long-hydroperiod community. The intermediate beta-diversity measure for the S332 sites during this study period (2009-2010) indicates that the S332 sites are likely intermediate between other short and long hydroperiod-sites in ENP. This likely coincides with the increased hydroperiod that has resulted from changes in water management associated with the operation of water management structures near the S332 impoundments.

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Table IV.1. Sampling plots. Regions are EPH (Everglades panhandle), RG (Rocky Glades), SRS (Shark River Slough) and TS (Taylor Slough). Sample plots were grouped for statistical analysis (Short = short hydroperiod sites that are not adjacent to S332 water management structures, DSD < 300; S332 = short hydroperiod sites affected by changes in water management near S332 impoundments; Long = long hydroperiod sites, DSD > 200). See Figure 1 for a map.

Region	Site	Sampling Plot	Group	UTMZone	Easting	Northing
EPH	C111A	0m	Short	17N	548275	2799924
EPH	C111A	200m	Short	17N	548275	2799724
EPH	C111A	400m	Short	17N	548275	2799524
EPH	C111B	0m	Short	17N	551862	2798528
EPH	C111B	200m	Short	17N	551862	2798328
EPH	C111B	400m	Short	17N	551862	2798128
RG	CKKE	0m	Short	17N	542663.05	2828935.04
RG	CKKE	200m	Short	17N	542422.24	2828886.6
RG	CKKE	400m	Short	17N	542352.18	2828984.82
RG	CXTE	0m	Short	17N	542783	2820353
RG	CXTE	200m	Short	17N	542611	2820358
RG	CXTE	400m	Short	17N	542483	2820357
RG	S332B	0m	S332	17N	542660	2825446
RG	S332B	200m	S332	17N	542464	2825308
RG	S332B	400m	S332	17N	542291	2825351
RG	S332C	0m	S332	17N	542593	2821865
RG	S332C	200m	S332	17N	542393	2821865
RG	S332C	400m	S332	17N	542193	2821865
RG	S332D	0m	S332	17N	541174	2811983
RG	S332D	200m	S332	17N	541026	2812084
RG	S332D	400m	S332	17N	540982	2812007
SRS	SRS23	N	Long	17N	538436	2840505
SRS	SRS23	S	Long	17N	538334	2839761
SRS	SRS50	N	Long	17N	524178	2841345
SRS	SRS50	S	Long	17N	523961	2840645
SRS	SRS6	N	Long	17N	526824	2835470
SRS	SRS6	S	Long	17N	527824	2835090
SRS	SRS7	N	Long	17N	524165	2829481
SRS	SRS7	S	Long	17N	524008	2829481
SRS	SRS8	N	Long	17N	517034	2819524
SRS	SRS8	S	Long	17N	516702	2818798
TS	AJE	0m	Short	17N	543711	2800262

TS	AJE	200m	Short	17N	543711	2800062
TS	AJE	400m	Short	17N	543711	2799862
TS	AJM	0m	Short	17N	543675	2803823
TS	AJM	200m	Short	17N	543475	2803823
TS	AJM	400m	Short	17N	543275	2803823
TS	L31WA	0m	Short	17N	542766	2811290
TS	L31WA	200m	Short	17N	542766	2811090
TS	L31WA	400m	Short	17N	542766	2810890
TS	L31WB	0m	Short	17N	542850	2807502
TS	L31WB	200m	Short	17N	542650	2807502
TS	L31WB	400m	Short	17N	542450	2807502
TS	L31WC	0m	Short	17N	542802	2805928
TS	L31WC	200m	Short	17N	542602	2805928
TS	L31WC	400m	Short	17N	542402	2805928

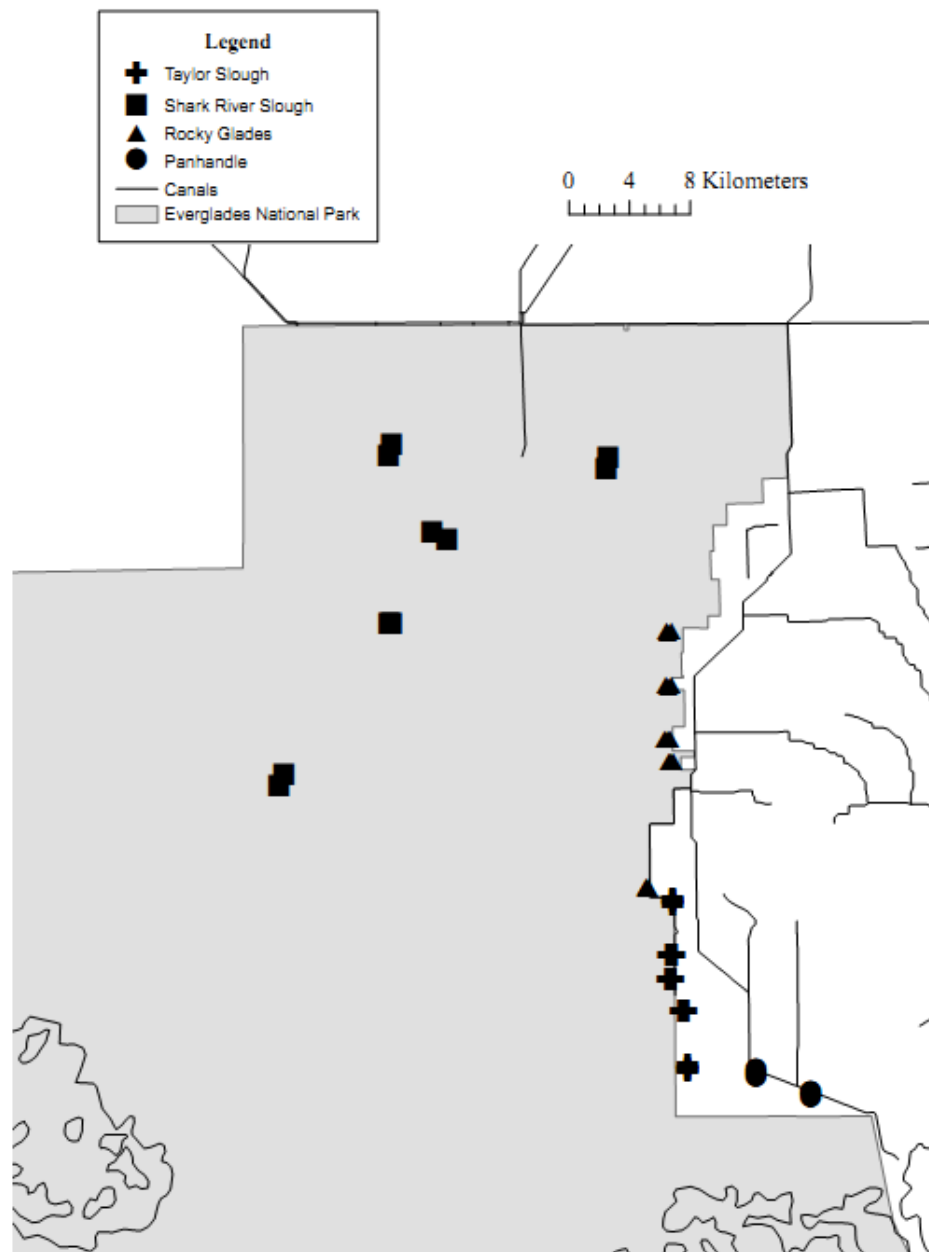


Figure IV.1. Location of sampling plots used in the 2009 and 2010 hydrologic year sampling events. See Table 1 for details.

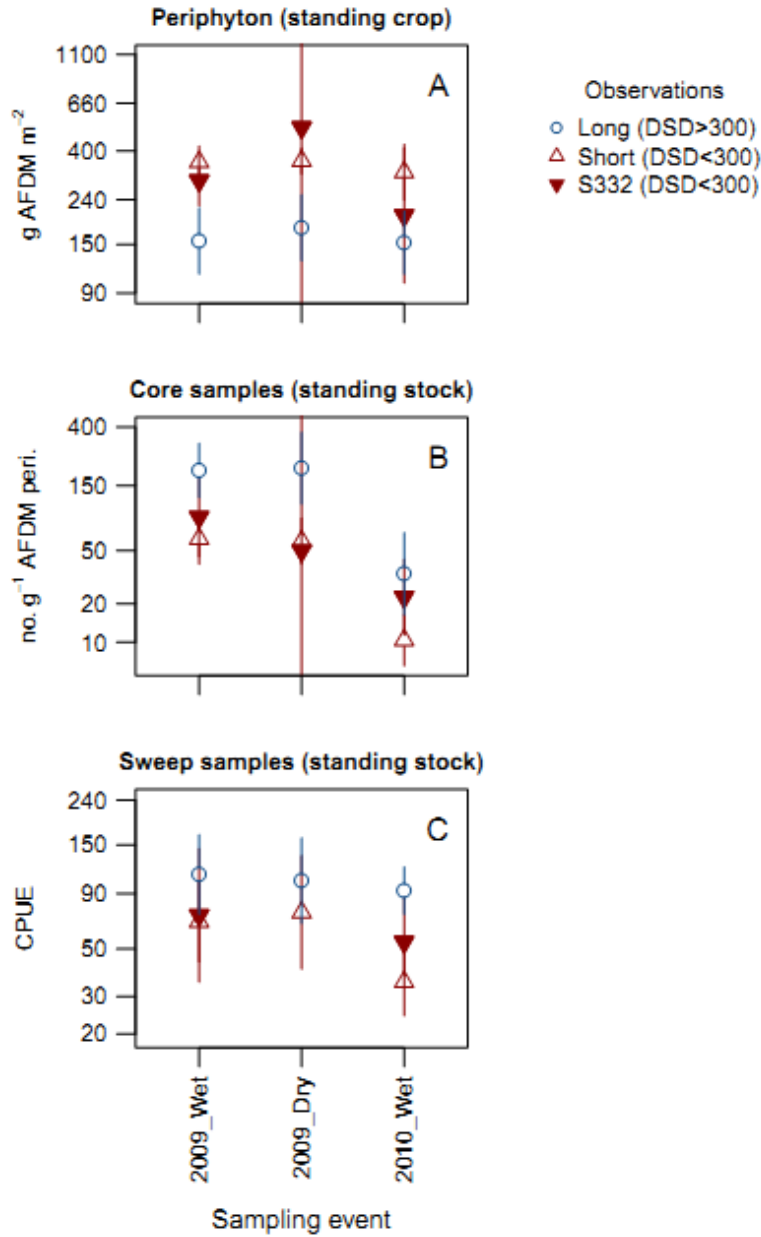


Figure IV.2. Periphyton standing crop and macroinvertebrate standing crops estimated for sites in ENP sampled in the 2009 and 2010 hydrologic years. (A) Areal standing crop of periphyton mats sampled with a coring device. (B) Standing stock of infaunal macroinvertebrates in core samples, standardized to periphyton AFDM (crowding). (C) Macroinvertebrate standing crop estimated from sweep samples (CPUE = catch per unit effort, where effort is a 1 m sweep sample). Means are plotted for long hydroperiod sites, short hydroperiod sites, and S332 sites (also short hydroperiod, see Table 1) for three sampling events (wet season 2009 hydrologic year, dry season 2009 hydrologic year, wet season 2010 hydrologic year). Error bars indicate 95% CIs.

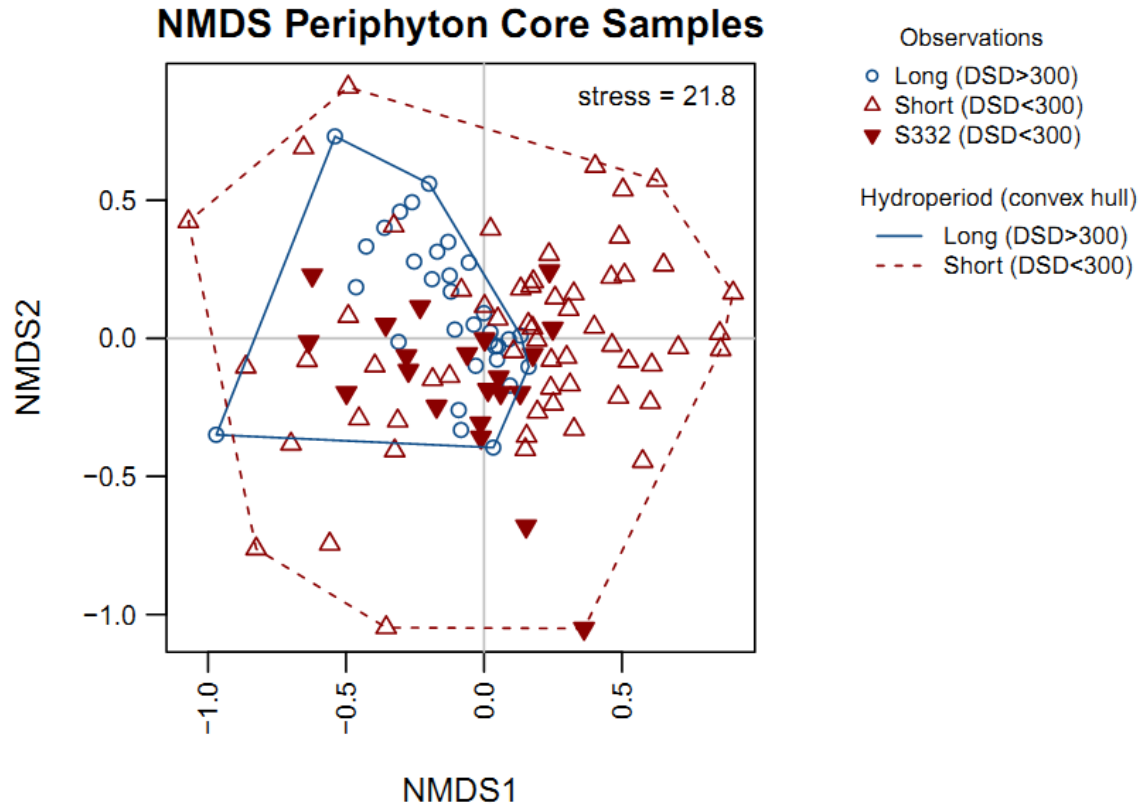


Figure IV.3. NMDS ordination of macroinvertebrate communities in periphyton cores in taxonomic space. Each point represents the average community composition of the infaunal macroinvertebrate community from replicate periphyton core samples at each sampling location, during each sampling event (wet season 2009 hydrologic year, dry season 2009 hydrologic year, wet season 2010 hydrologic year). Different symbols represent observations from S332 (short hydroperiod) sites, other short hydroperiod sites (see Table 1), and long hydroperiod sites (located in SRS, see Table 1). Convex hulls are outlined for all short hydroperiod observations (S332 and other sites, maroon dotted line), and for long hydroperiod observations (blue solid line).

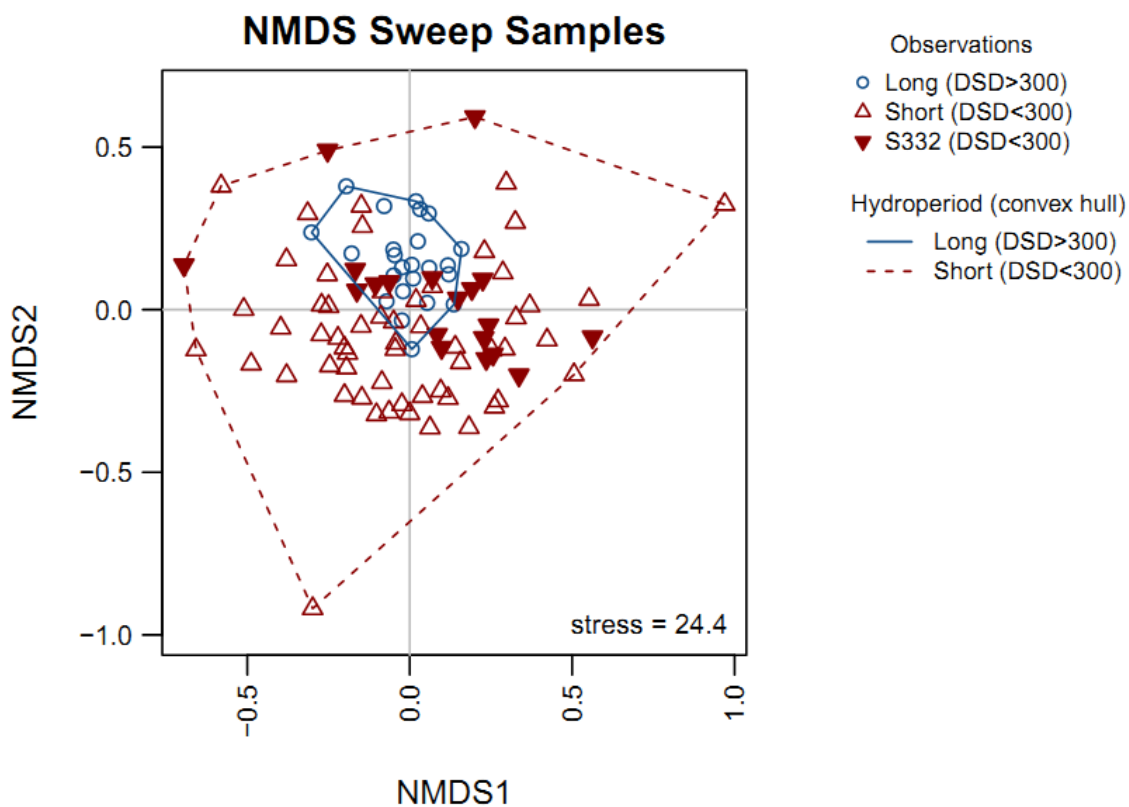


Figure IV.4. NMDS ordination of macroinvertebrate communities in sweep samples in taxonomic space. Each point represents the average community composition of the macroinvertebrate community from replicate sweep samples at each sampling location, during each sampling event (see Figure 2 for a description of symbols).

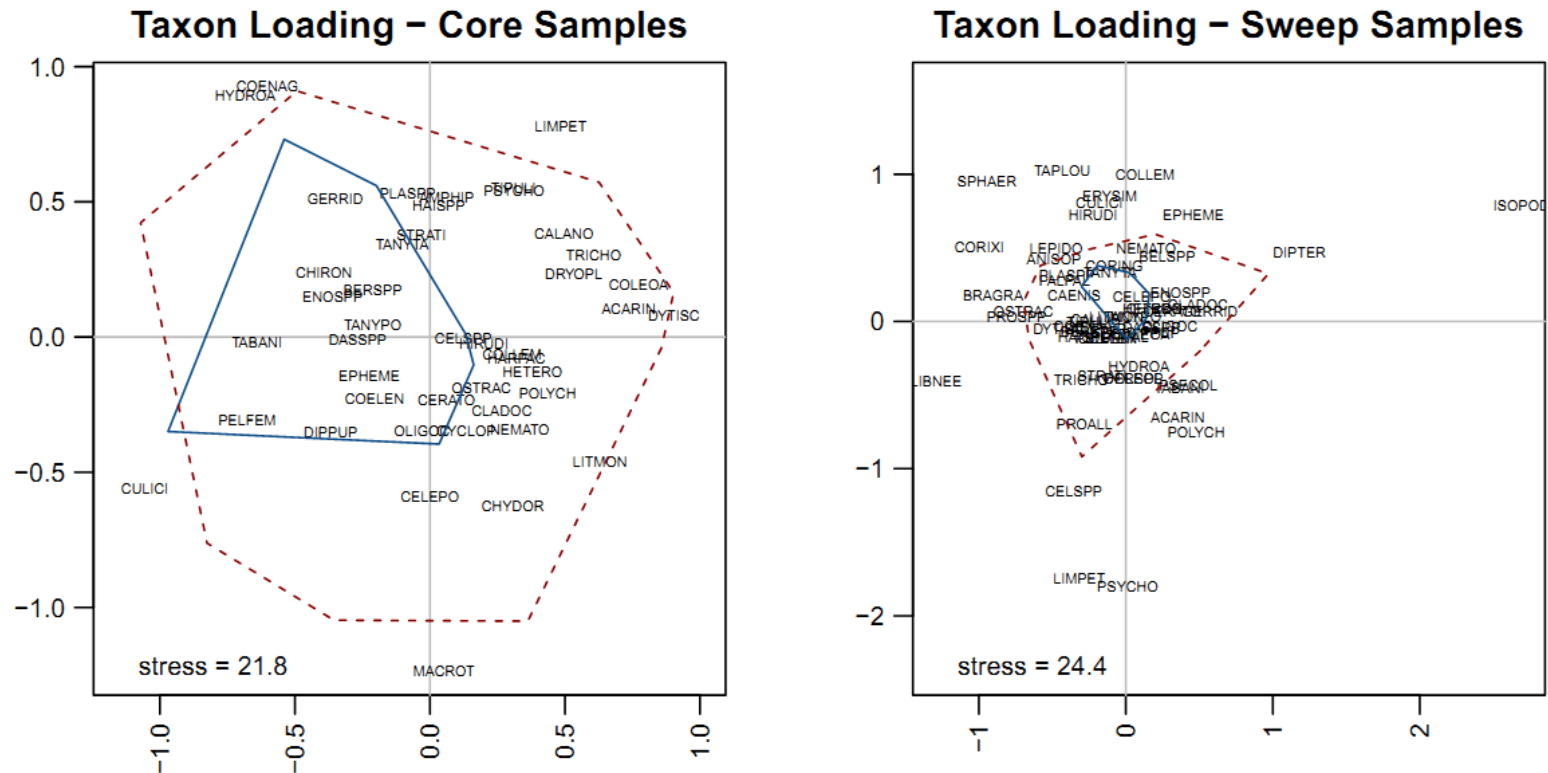


Figure IV.5. Loading for taxonomic groups for NMDS plots calculated for core samples (Figure 3) and sweep samples (Figure 4). Convex hulls for hydroperiod groups are plotted for reference. See Table A1 in Appendix A for a description of taxonomic codes.

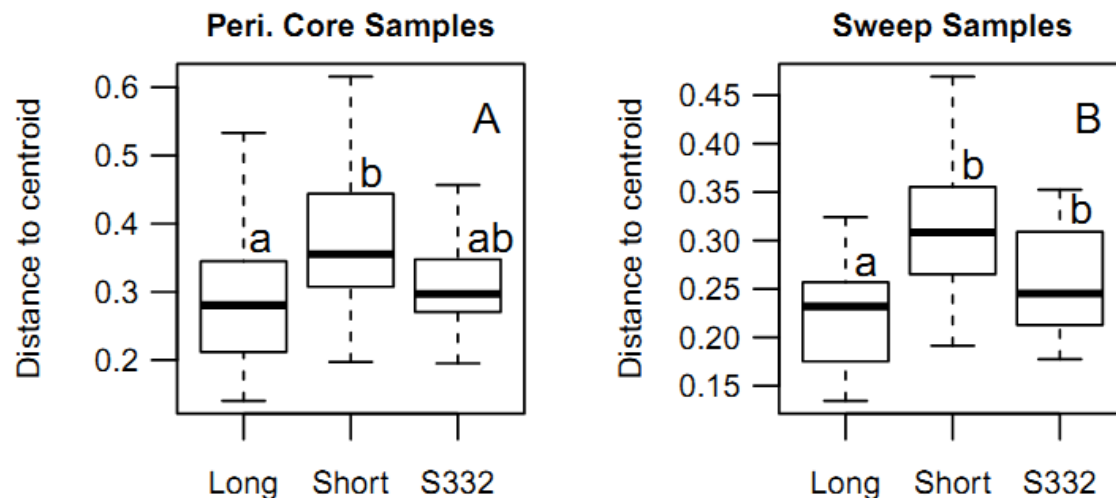


Figure IV.6. Comparison of beta-diversities among three groups of observations (Long hydroperiod, Short hydroperiod not adjacent to S332 impoundments, and short hydroperiod observations located near S332 impoundments). Beta-diversity was estimated among observations within groups using a permutational analysis of multivariate dispersion (Anderson et al. 2006, Chase 2007, 2010, Chase et al. 2009). A group with a higher mean distance to the centroid has a higher dispersion of observations in multivariate space, and thus higher within-group beta-diversity. (A) Comparison of beta-diversities for the infaunal macroinvertebrate community in periphyton cores. (B) Comparison of beta-diversities for the macroinvertebrate community represented in sweeps. Different lower case letters indicate significant among group differences in multivariate dispersion using a cut off of $p = 0.05$, where p -values are calculated using 1000 permutations.

Appendix IV.A

Table IV.A1. Description of taxonomic codes.

CODE	Class/Phylum	Order/Subclass	Family/Suborder	Genus/Subfamily	Species/Tribe	Common name
ACARIN	Arachnida	Acari				Water mite
SPHAER	Bivalvia	Veneroida	Sphaeriidae			Fingernail clam
CLADOC	Branchiopoda	Cladocera				
HIRUDI	Clitellata	Hirudinea				Leech
CALANO	Copepoda	Calanoida				
CYCLOP	Copepoda	Cyclopoida				
HARPAC	Copepoda	Harpacticoida				
NAUPLI	Copepoda					Nauplius is a term for Copepod larvae
SPOLAC	Demospongiae	Haplusclenida	Spongillidae	<i>Spongilla</i>	<i>lacustris</i>	Sponge
POMPAL	Gastropoda	Caenogastropoda	Ampullariidae	<i>Pomacea</i>	<i>paludosa</i>	Apple snail
LITMON	Gastropoda	Caenogastropoda	Hydrobiidae	<i>Littoridinops</i>	<i>monroensis</i>	Cockscomb hydrobe snail
LIMPET	Gastropoda	Heterobranchia	Ancylidae	<i>Laevapex</i>	<i>peninsulas</i>	Limpet
PSECOL	Gastropoda	Heterobranchia	Lymnaeidae	<i>Pseudosuccinea</i>	<i>columella</i>	Mimi pondsnail
HAISPP	Gastropoda	Heterobranchia	Physidae	<i>Hatia</i>		Bladder snail
PLASPP	Gastropoda	Heterobranchia	Planorbidae	<i>Planorbella</i>		Planorbid snail
COELEN	Hydrozoa	Anthomedusae	Hydridae	<i>Hydra</i>		Hydra
CURCUL	Insecta	Coleoptera	Curculionidae			
DRYOPI	Insecta	Coleoptera	Dryopidae or Elmidae			
DYTISC	Insecta	Coleoptera	Dytiscidae			
GYRINI	Insecta	Coleoptera	Gyrinidae			Whirligig beetles
BERSPP	Insecta	Coleoptera	Hydrophilidae	<i>Berosus</i>		Water scavenger beetle family
DESPSP	Insecta	Coleoptera	Hydrophilidae	<i>Derallus</i>		
ENOSPP	Insecta	Coleoptera	Hydrophilidae	<i>Enochrus</i>		
HYDROA	Insecta	Coleoptera	Hydrophilidae			Adult scavenger beetle
COLLEM	Insecta	Collembola				

CODE	Class/Phylum	Order/Subclass	Family/Suborder	Genus/Subfamily	Species/Tribe	Common name
DASSPP	Insecta	Diptera	Ceratopogonidae	<i>Dasyhelea</i>		Biting midge
CERATO	Insecta	Diptera	Ceratopogonidae			Biting midge
TANYTA	Insecta	Diptera	Chironomidae	<i>Chironominae</i>	<i>Tanytarsini</i>	Midge
TANYPO	Insecta	Diptera	Chironomidae	<i>Tanypodinae</i>		Midge
CHIRON	Insecta	Diptera	Chironomidae			Midge
STRATI	Insecta	Diptera	Stratiomyidae			Soldier fly
TABANI	Insecta	Diptera	Tabanidae			Horse/deer fly
TIPULI	Insecta	Diptera	Tipulidae			Crane fly
CALLIB	Insecta	Ephemeroptera	Baetidae	<i>Callibaetis</i>		
CAENIS	Insecta	Ephemeroptera	Caenidae	<i>Caenis</i>		
EPHEME	Insecta	Ephemeroptera				
BELSPP	Insecta	Hemiptera	Belostomatidae	<i>Belostoma</i>		Giant water bugs
LETSPP	Insecta	Hemiptera	Belostomatidae	<i>Lethocerus</i>		Giant water bugs
CORIXI	Insecta	Hemiptera	Corixidae			Water boatman
GERRID	Insecta	Hemiptera	Gerridae			Water strider
PELFEM	Insecta	Hemiptera	Naucoridae	<i>Pelocoris</i>	<i>femoratus</i>	Alligator flea
HETERO	Insecta	Hemiptera				True Bug
CORING	Insecta	Odonata	Aeshnidae	<i>Coryphaeschna</i>	<i>ingens</i>	Regal Darner
COENAG	Insecta	Odonata	Coenagrionidae			
BRAGRA	Insecta	Odonata	Libellulidae	<i>Brachymesia</i>	<i>gravida</i>	Four-spotted Pennant, Skimmer family
CELEPO	Insecta	Odonata	Libellulidae	<i>Celithemis</i>		Halloween Pennant, Ornate Pennant, Skimmer family
ERYSIM	Insecta	Odonata	Libellulidae	<i>Erythemis</i>	<i>simplicicollis</i>	Eastern Pondhawk, Skimmer family
LIBNEE	Insecta	Odonata	Libellulidae	<i>Libellula</i>	<i>needhami</i>	Needham's Skimmer
PACLON	Insecta	Odonata	Libellulidae	<i>Pachydiplax</i>	<i>longipennis</i>	Blue dasher, Skimmer
LIBELL	Insecta	Odonata	Libellulidae			
TRICHO	Insecta	Trichoptera				Caddisfly

CODE	Class/Phylum	Order/Subclass	Family/Suborder	Genus/Subfamily	Species/Tribe	Common name
AMPHIP	Malacostraca	Amphipoda				
PROSPP	Malacostraca	Decapoda	Cambaridae	<i>Procambarus</i>		Crayfish
PALPAL	Malacostraca	Decapoda	Palaemonidae	<i>Palaemonetes</i>	<i>paludosus</i>	Grass shrimp
TAPLOU	Malacostraca	Mysida	Mysidae	<i>Taphromysis</i>	<i>louisianae</i>	Mysid shrimp
NEMATO	Nematoda					
OLIGOC	Oligochaeta					
OSTRAC	Ostracoda					
PLATYH	Platyhelminthes					Flatworm
ROTIFE	Rotifera					Rotifer

V. Periphyton and Macrophytes

Evelyn Gaiser and Joel Trexler

Overview: Water flow into Taylor Slough within the Everglades National Park (ENP) and subsequently to downstream estuaries has been significantly modified by water control projects along the eastern boundary of the park. Significant alterations in the mechanisms of water delivery have occurred along the L-31W canal, including creation of the S-332 detention ponds, and further changes are anticipated through planned restoration activities. Because changes in water flow and quality have the potential to greatly impact not only the eastern boundary of the Everglades, but also downstream portions of Taylor Slough, several South Florida Natural Resources Center SFNRC studies have been initiated to monitor water quality and ecosystem structure and function near and downstream of water delivery structures. Continuing research shows that alterations in water management practices along the eastern border of the ENP have led to elevated concentrations of phosphorus in periphyton and soils along the periphery of the S-332 water control structures, and repeated elevated inputs (particularly during wet years or overflow events from the L-31W and detention ponds) appear to be causing changes in plant community structure downstream of these structures (Gaiser et al. 2008). Here we examine temporal and spatial patterns in periphyton and plant nutrient content and

abundance to determine whether enrichment trends persist with time and changes in management activities in a distributed set of transects along the eastern ENP boundary.

Methods: Periphyton has been collected annually during the wet season from 0.25 m² quadrats at approximately 20-m intervals along transects extending from the edge of the ENP boundary to approximately ~100 m to the interior. Collections began in 2003 with grab (non-quantitative) samples to estimate total phosphorus (TP, ug/g) content, chlorophyll (chl) *a* content (a measure of algal abundance in periphyton, ug/g) and diatom species composition. In 2003, we sampled only from the edges of the S-332B and C impoundments and the inflow point for water from S-332D into ENP. In 2004, we expanded this effort to include two ‘reference’ transects that did not originate in water management features and in 2005 we added a second transect originating at the spillway of S-332B. In 2006, we began to sample these transects quantitatively, including estimates of periphyton biomass (including ash-free dry mass (AFDM), g/m²) and macrophyte abundance (stems/m²) and TP content (ug/g). In 2009, several additional transects were established in comparative locations, and collection intervals harmonized among sites to 4-20m interval collections. Each year, samples were collected during the wet season from September to December, except in years where sites were dry during this period, in which case we sampled the subsequent January (2006, 2007). In 2008-2010,

plant samples were taken in September and periphyton samples in December when periphyton was most abundant.

Analytical Approach: Periphyton quality, abundance, and composition is highly reflective of both nutrient enrichment and hydrology (Gaiser et al. 2011), and we used several metrics to indicate patterns along the transects. Periphyton TP concentration provides a reliable index of nutrient enrichment (Gaiser et al. 2004) so we used it to provide a measure of P inflow from anthropogenic sources along the boundary of ENP. Periphyton total phosphorus (TP) in excess of 500 ug/g is considered indicative of anthropogenic enrichment in the Everglades in general, and over 200 ug/g is high for the Taylor Slough basin. Periphyton chl *a* content was also assessed to further document enrichment patterns because it typically increases with increasing availability of P in the Everglades (Gaiser et al. 2005), and indicates higher food quality for consumers. Periphyton abundance typically declines with increasing TP content (Gaiser et al. 2005), so ash-free dry mass was added to our sampling protocol to address this consequence of enrichment. Although species composition is cumbersome to estimate, it is the most sensitive metric to changes in enrichment (Gaiser et al. 2011), so it was included at select sites during several sampling years. Macrophyte assessments were added to understand changes in plant community dynamics relative to boundary changes, and to provide estimates of P trends when periphyton was absent (e.g., Gaiser et al. 2005).

Results:

Periphyton TP: In 2003, we found evidence of heightened nutrient levels at the edge of ENP adjacent to the S-332B impoundment and S332D inflow (Fig. V.1A). Sampling at S332D was problematic because no periphyton was present at the inflow point, a possible sign of nutrient enrichment. The gradient of TP concentration noted that year as considered suggestive. Data gathered in 2004 indicated that the patterns in 2003 were indeed the result of persistent nutrient enrichment, primarily because the levels at S-332B and C increased from the previous year; the pattern of decreasing tissue TP concentration with increasing distance into the ENP was retained. No spatial pattern was observed in periphyton-tissue TP at the reference areas. In both 2004 and 2005, no periphyton was present at the inflow point for S-332D, but the more downstream samples were elevated compared to 2003. Periphyton tissue TP decreased with increasing distance downstream from the L-31W inflow associated with the S-332D impoundment. However, the concentration of TP in periphyton tissues was reduced in 2005 compared to those collected at the same location in 2004. The S-332D gradient remained difficult to interpret because it coincided with a marked increase in water flow, which may be suspending existing phosphorus in the area. No flow effect is expected for S-332B and C, though surface flow of water from the S332B impoundment occurred prior to our 2003 sampling, and again prior to our 2005 sampling. In 2005, we added a second transect at

S332B to capture patterns immediately downstream from the cement overflow area of the impoundment. Though infrequent, overflows continued for period extending from days to weeks at this site when they occurred. Periphyton tissue TP was elevated above the 500 ug/g threshold at both transects for at least 20 m into ENP from the S332B impoundment in 2005.

No periphyton was collected in 2006 because of very limited time when the area was inundated, but samples were collected in November of 2007. In 2007, only S332-C displayed the previously common pattern of highest TP adjacent to the impoundment, with decreasing TP with distance into the Park. Transect B displayed an unusual pattern of elevated TP at 40, 60, and 80 m, but not at 0 or 20 m. Very little periphyton was collected at the D transect, and the two reference transects yielded the expected low TP with no pattern extending from the edge of the ecosystem. In 2008, transects B1 and B2 displayed decreasing TP with distance into the Park, while no periphyton was found at the 0 and 20 m points at Site C, and none was collected at the S332D transect. We plotted the TP of periphyton collected at the 0 distance for each year of the study to illustrate how phosphorus enrichment changed over the 6 years are data (Fig. V.4). Only site S332C appeared to be increasing continuously over the course of the study, peaking at approximately 1800 ug/g in 2007, and then with no periphyton present at the edge of the Park at this site in 2008. The TP in periphyton at the S332B impoundment peaked around 1400 ug/g in 2005, before dropping to background levels in 2007 and possibly

increasing again to approximately 500 ug/g in 2008. Site D cannot be evaluated in this way because no periphyton has been consistently available at the 0-m distance at this site.

Transects B1 and B2 were characterized by low levels of periphyton TP (<200 ug/g) in 2009 that were slightly higher in 2010 (200-300 ug/g) but not as high as those observed in prior years (Fig. V.1B). In contrast, transect C had no periphyton at 0 and 20 m in 2009 and TP exceeded 400 ug/g at the 40 m site. These values remained high in 2010. Transect D was excessively enriched from 0-200 m in 2009 (>800 ug/g) and by 2010 had no periphyton at the first two locations and enriched values throughout the remaining sites. Transect E periphyton had low TP content in 2009 and slightly enriched at the boundary site in 2010. Transect F had no periphyton in 2009 except at the furthest interior site where values were enriched above background (252 ug/g). These values returned to prior low levels in 2010. The new transects sampled in 2009 and 2010 showed similar patterns of enrichment near the boundary, especially AE, LB, CA and LC. Transect LA did not have periphyton in either year. Transects CB and AA had relatively low concentrations of periphyton TP in both years.

In summary, periphyton TP is elevated along the eastern boundary, particularly at sites receiving overland flow from the east. Although reference sites (E, F) are less enriched (Fig. V.1C), they, too, show significant boundary influences in some years, possibly indicating subsurface movement of P into the ecosystem (Table V.1; Fig. V.1D).

The steepness of the P gradient appears to be dynamic in time, with transect B1 showing a decrease in slope over time while transect C possibly becoming more enriched.

Periphyton biomass, chlorophyll a, and composition: Periphyton biomass (AFDM) showed a general increase from the boundary to the interior along all transects in 2006-2009, including the “reference” transects (Fig. V.2A). Periphyton biomass was low to zero at boundary sites along the “impact” transects, and this pattern was most visible in 2008 when values increased to expected levels at the interior sites along transects C and D (Fig. V.2B). Biomass was very low, possibly due to low water levels, at all of the new transects in 2009, and was variable across these in 2010, with no apparent trends (Fig. V.2B). The transects are characterized by high variability in biomass from year to year (Fig. V.2C), highlighting the importance of persistent observations to understand long-term trends.

Periphyton chl *a* content followed trends similar to that of the TP availability, but with higher spatial and temporal variability (Fig. V.3A). Chlorophyll *a* content was higher at sites along “impacted” transects (as expected), especially along the length of transect D (reflective of the high TP values also observed there). As for TP, there is some suggestion of a reduction in water quality impacts in 2007-2009, as values were not distinguishable between “impact” and “reference” transects in those years. However, a

steep decrease from the boundary to interior was observed again in 2010, although boundary values were not as high as those observed in earlier years (Fig. V.3B, V.3C).

Diatom assemblages, analyzed in 2003, 2005 and 2008, did not differ significantly between interior locations among transects, but the first and second transect locations at sites B1, B2 and C did differ from those of reference transects E and F in all three years (Fig. V.4A). Diatom assemblages are highly sensitive to enrichment, with characteristic (and in some cases, endemic) Everglades species (*Mastogloia smithii*, *Brachysira neoexilis*, *Encyonema evergladianum*, *Achnanthyrium caledonica*, *Frailaria synegrotesca*) being replaced by circumglobal weedy species (*Nitzschia amphibia*, *Diploneis parva*, *Navicula cryptocephala*) in the presence of enrichment (Fig. V.4B).

Trends in plant TP and biomass: In the 2006 wet season (sampled in Jan 2007), plant stem tissues indicated P enrichment at the edge of ENP downstream from the B, C, and D structures, consistent with periphyton tissue samples (Fig. V.5A). Phosphorus levels in plants living at the marsh edge were significantly above those at the two reference-transects (Fig V.5C); tissue TP dropped toward reference levels at the 20 m distance, though remained significantly elevated at two sites (D and at one of the B transects). By 40 m from the marsh edge, there was no evidence of phosphorus enrichment. The plant stem tissue phosphorus data from 2007 and 2008 are more variable than those from (Fig. V.5A). These data support the pattern of marked nutrient enrichment in a gradient from

the edge of the S332C impoundment (note 2008), but with no clear pattern at the other sites. In 2009, values were elevated at the 0m site along this transect, and throughout the D transect. This trend of plant TP enrichment along transect D was even more noticeable in 2010. In the expanded effort in 2009 and 2010, we did not measure significant trends across the 7 new transects, but values were higher in 2010 than in 2009, mirroring the pattern observed in the periphyton datasets (Fig. V.5B).

Plant stem density was significantly higher in boundary (0m) sites at impact than reference sites in all years, but no influence was seen at interior locations (Fig. V.6C). Species varied in their TP content (TP is measured in the most abundant species in each quadrant), and this influence was not correlated with distance (Fig. V.7).

Conclusions: All transects downstream from impoundments (B, C, and D) display signals of nutrient enrichment 10's of meters into ENP. There is evidence that the gradients expanded into the Park over time, although some transects are showing persistent, but reduced levels, of enrichment along the boundary. The data from periphyton and vascular plant tissues also demonstrate some inter-annual variability, which is probably tied to the amount of water in the system each year and length of time pumping took place in each impoundment.

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- Gaiser, E., L. Scinto, J. Trexler and R. Price. 2008. Phosphorus retention and sub-surface movement through the S-332 detention basins on the eastern boundary of Everglades National Park. *Everglades National Park*. 167 pp.
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Table 1. Regression coefficients and parameter estimates describing the relationship between distance and periphyton total phosphorus (both log transformed) at each transect and date. The column labeled “NS” indicates transects with incomplete data with an astrisk.

Year	Transect	R ²	P	F	Int	Slope	NS
2003	B1	0.96	0.00	367	2.9	-0.5	
2003	C	0.41	0.00	13	2.2	-0.1	
2003	D	0.63	0.00	20	3.0	-0.4	
2004	B1	0.94	0.00	290	3.2	-0.6	
2004	C	0.46	0.00	12	2.9	-0.5	
2004	D	0.18	0.08	4	2.8	-0.1	
2004	E	0.37	0.00	11	2.0	-0.1	
2004	F	0.38	0.00	11	2.1	-0.1	
2005	B1	0.85	0.00	97	3.1	-0.5	
2005	B2	0.71	0.00	42	3.0	-0.4	
2005	C	0.69	0.00	39	2.6	-0.3	
2005	D	0.69	0.00	39	2.1	-0.2	
2005	E	0.33	0.01	8	2.0	-0.2	
2005	F	0.55	0.00	20	2.7	-0.3	
2006	C	0.68	0.00	29	3.0	-0.5	
2006	D	0.94	0.00	75	8.1	-2.5	*
2006	E	0.03	0.51	0	1.9	0.0	
2006	F	0.44	0.00	13	2.4	-0.3	
2007	B1	0.23	0.02	6	2.1	0.3	
2007	B2	0.26	0.11	3	2.3	0.2	*
2007	C	0.64	0.00	21	3.4	-0.4	
2007	D	0.24	0.02	6	2.4	-0.2	
2007	F	0.67	0.00	36	2.2	-0.2	
2008	B1	0.73	0.00	48	2.9	-0.3	
2008	B2	0.75	0.00	25	2.7	-0.2	*
2008	C	0.55	0.00	14	3.5	-0.6	*
2008	D	0.94	0.00	132	7.7	-2.4	*
2008	E	0.10	0.11	3	2.2	0.0	
2009	AA	0.72	0.00	29	1.8	-0.1	
2009	AE	0.93	0.00	155	2.5	-0.3	
2009	B1	0.03	0.55	0	2.1	0.0	*
2009	B2	0.00	0.89	0	2.0	0.0	*
2009	C	0.52	0.06	6	4.6	-1.2	*
2009	CA	0.31	0.04	6	2.3	-0.1	
2009	CB	0.06	0.41	1	2.0	0.0	
2009	CX	0.32	0.03	6	2.2	-0.1	
2009	D	0.05	0.23	3	1.6	0.0	
2009	E	0.57	0.05	8	2.3	-0.1	*
2009	LB	0.88	0.00	79	2.5	-0.3	
2009	LC	0.63	0.00	20	2.0	-0.1	
2010	B1	0.21	0.07	4	2.2	0.1	
2010	AA	0.87	0.00	73	2.2	-0.2	
2010	AE	0.93	0.00	140	2.6	-0.3	
2010	B2	0.10	0.20	2	2.3	-0.1	*
2010	C	0.83	0.00	39	3.0	-0.4	*
2010	CA	0.64	0.01	16	2.0	-0.1	*
2010	CB	0.01	0.79	0	1.7	0.0	
2010	CX	0.00	0.90	0	1.9	0.0	
2010	E	0.38	0.08	5	2.2	-0.1	*
2010	F	0.15	0.11	3	2.3	-0.1	
2010	LB	0.76	0.00	36	2.2	-0.2	
2010	LC	0.81	0.00	47	2.1	-0.2	

Periphyton TP Trends

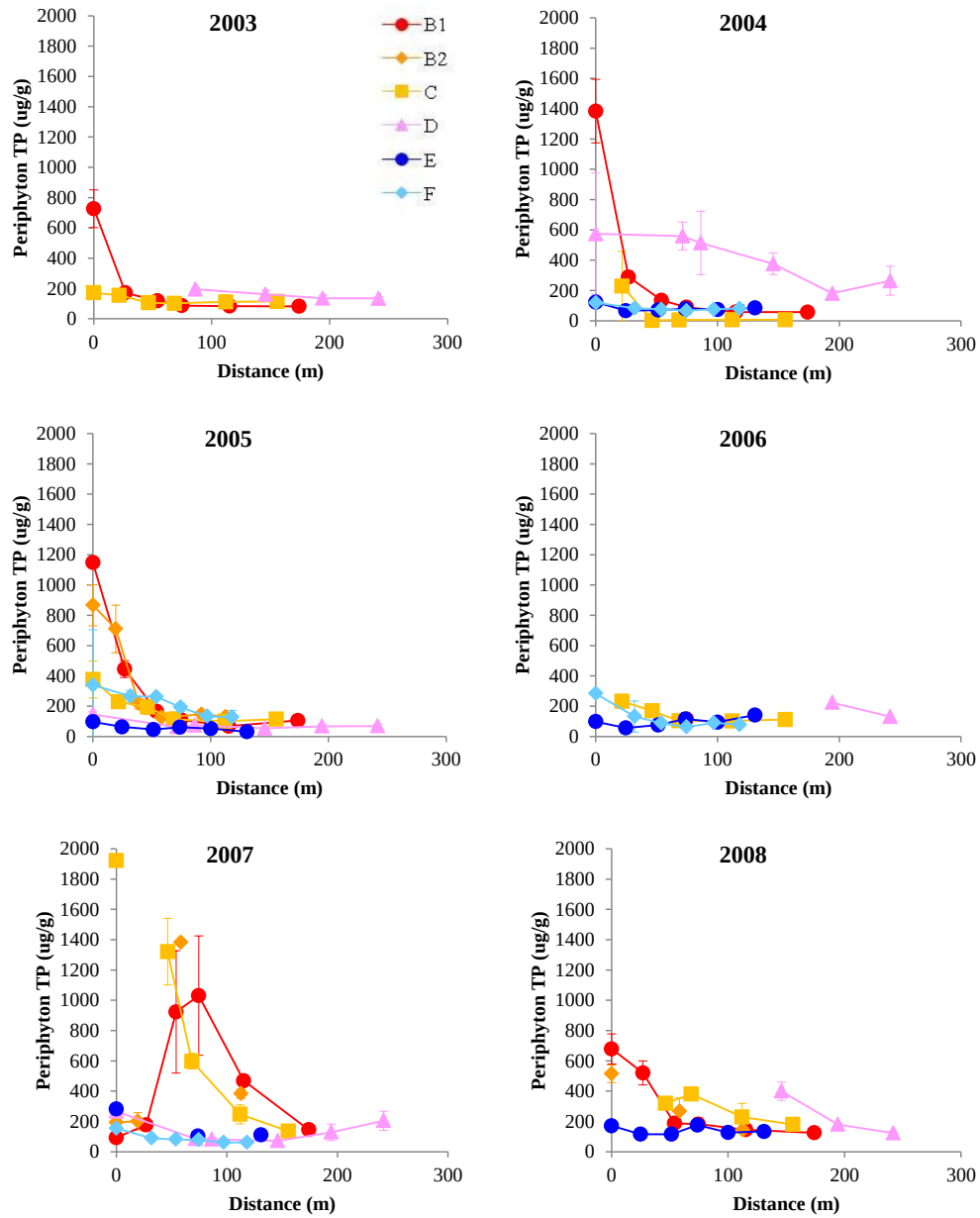


Figure 1A. Trends in total phosphorus (TP) concentration in periphyton with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects).

Periphyton TP Trends

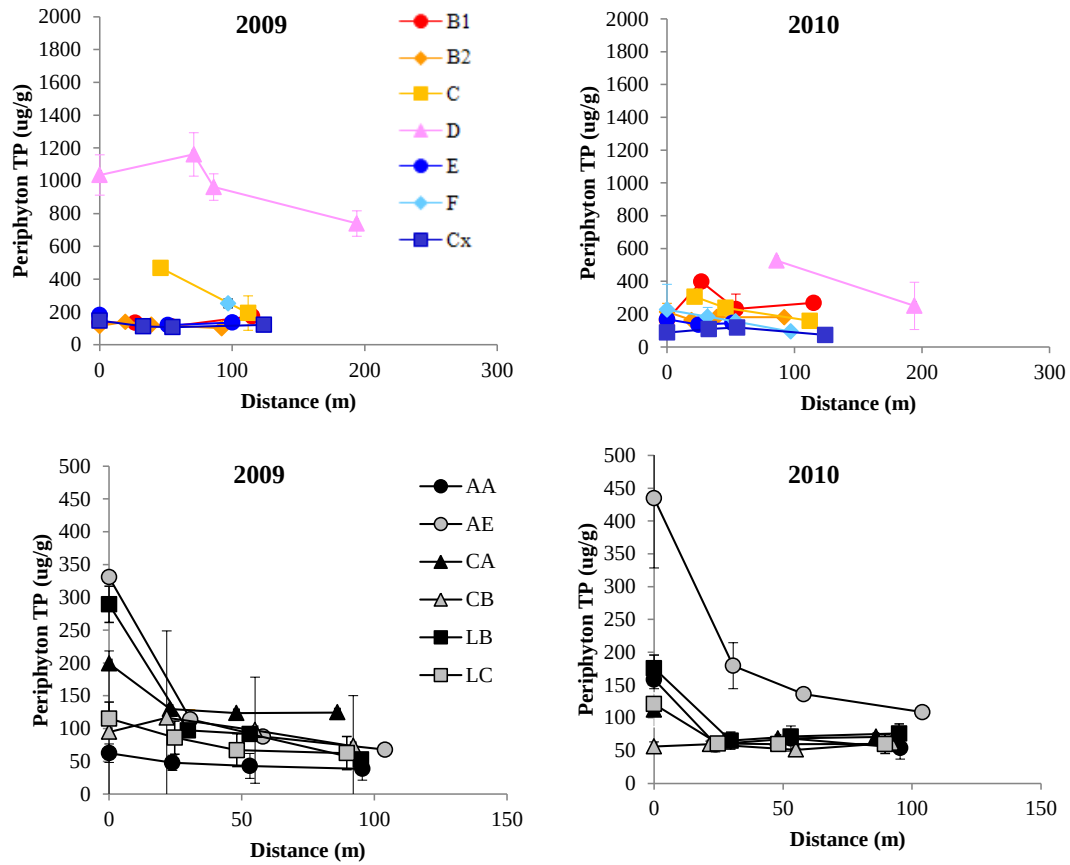


Figure 1B. Trends in total phosphorus (TP) concentration in periphyton with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects; bottom two panels illustrate new transects established in 2009).

Periphyton TP - Temporal Change

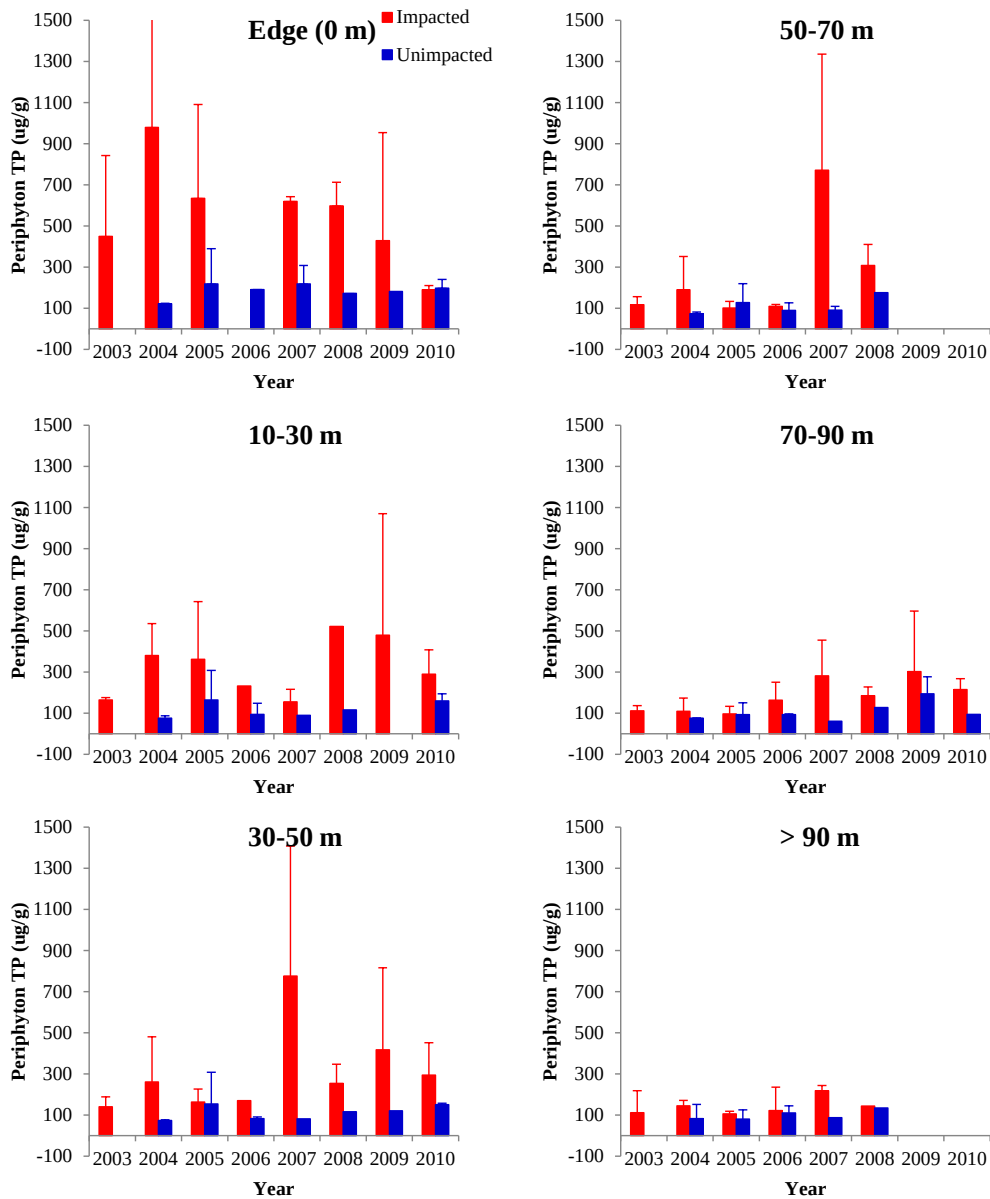


Figure 1C. Differences in total phosphorus (TP) concentration in periphyton over time in “impacted” transects (B1, B2, C and D) and “unimpacted” (reference: E and F) transects at successive distances from the eastern ENP boundary.

Periphyton Ash-Free Dry Mass Trends

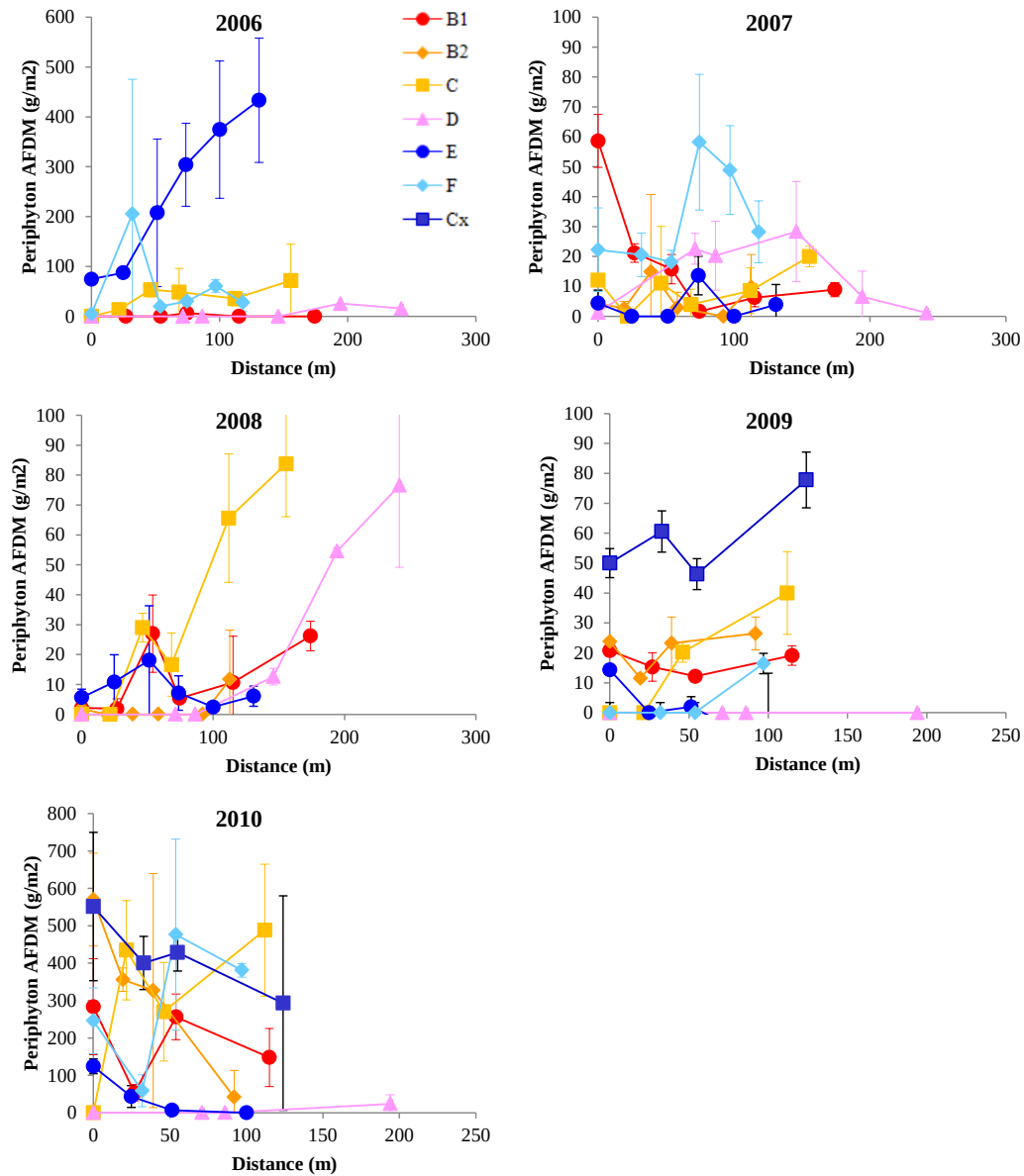


Figure 2A. Trends in periphyton ash-free dry biomass with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects).

Periphyton Ash-Free Dry Mass Trends

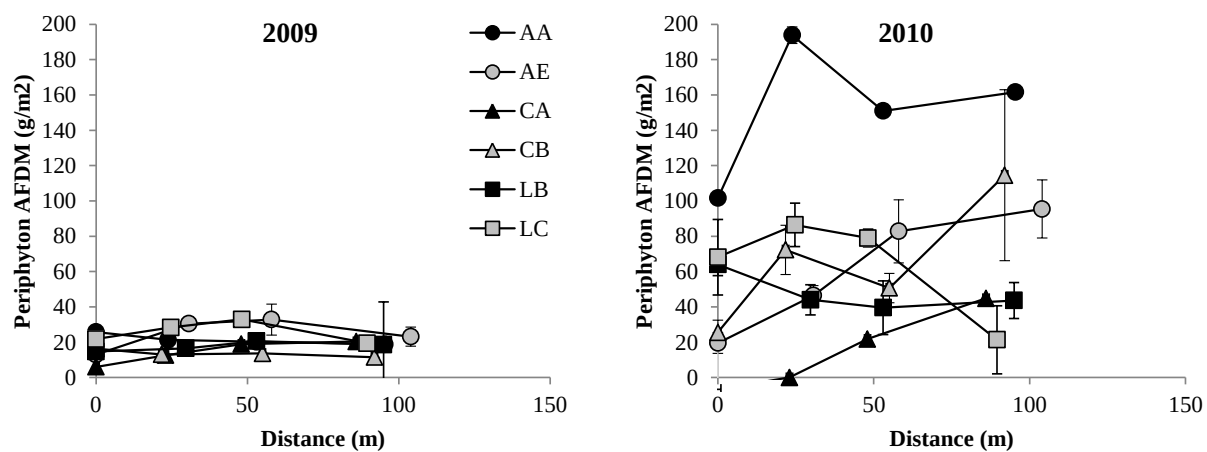


Figure 2B. Trends in periphyton ash-free dry biomass with distance from eastern ENP boundary for each year of wet-season sampling at new transects established in 2009.

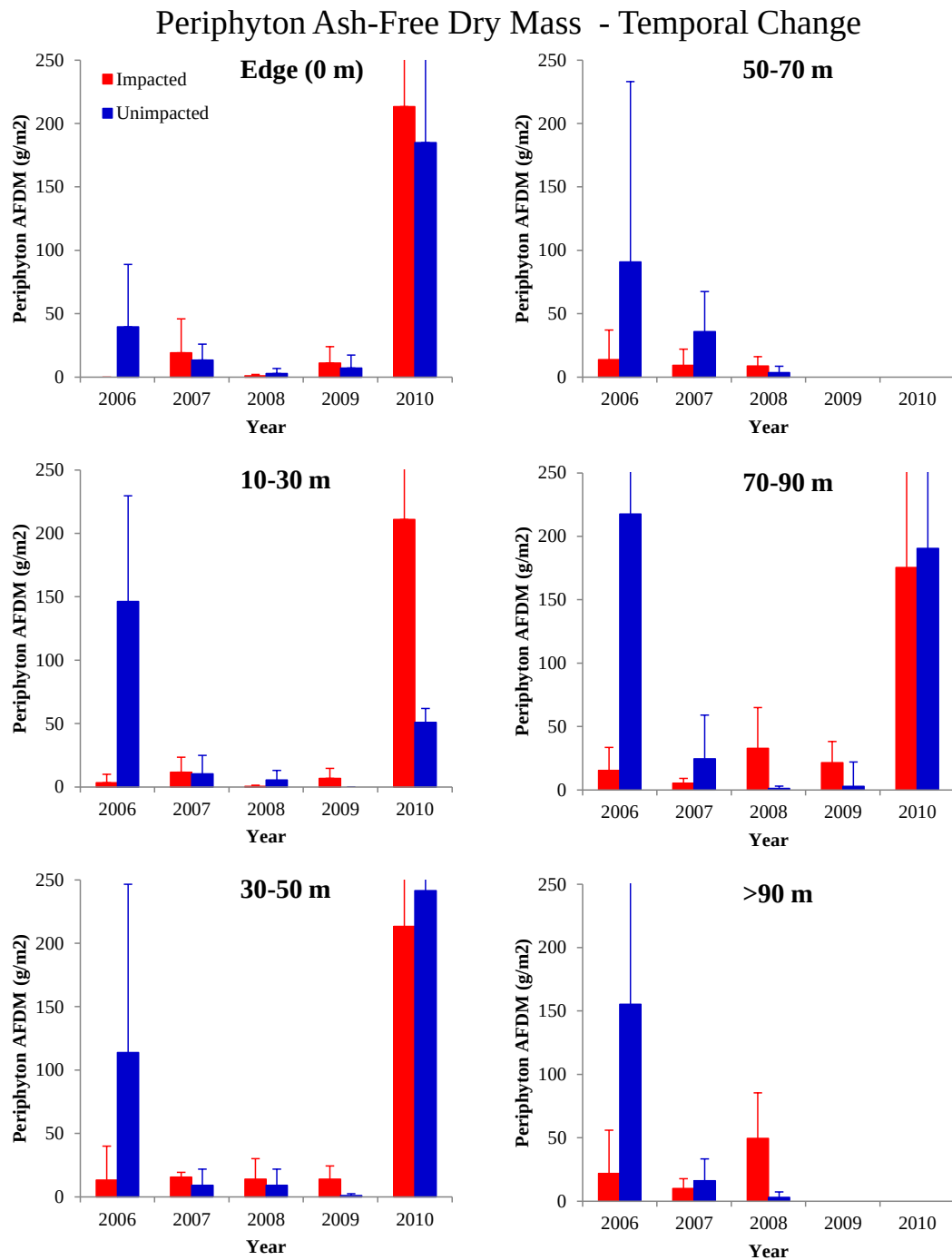


Figure 2C. Differences in periphyton ash-free dry biomass over time in “impacted” transects (B1, B2, C and D) and “unimpacted” (reference: E and F) transects at successive distances from the eastern ENP boundary.

Periphyton Chlorophyll *a* Trends

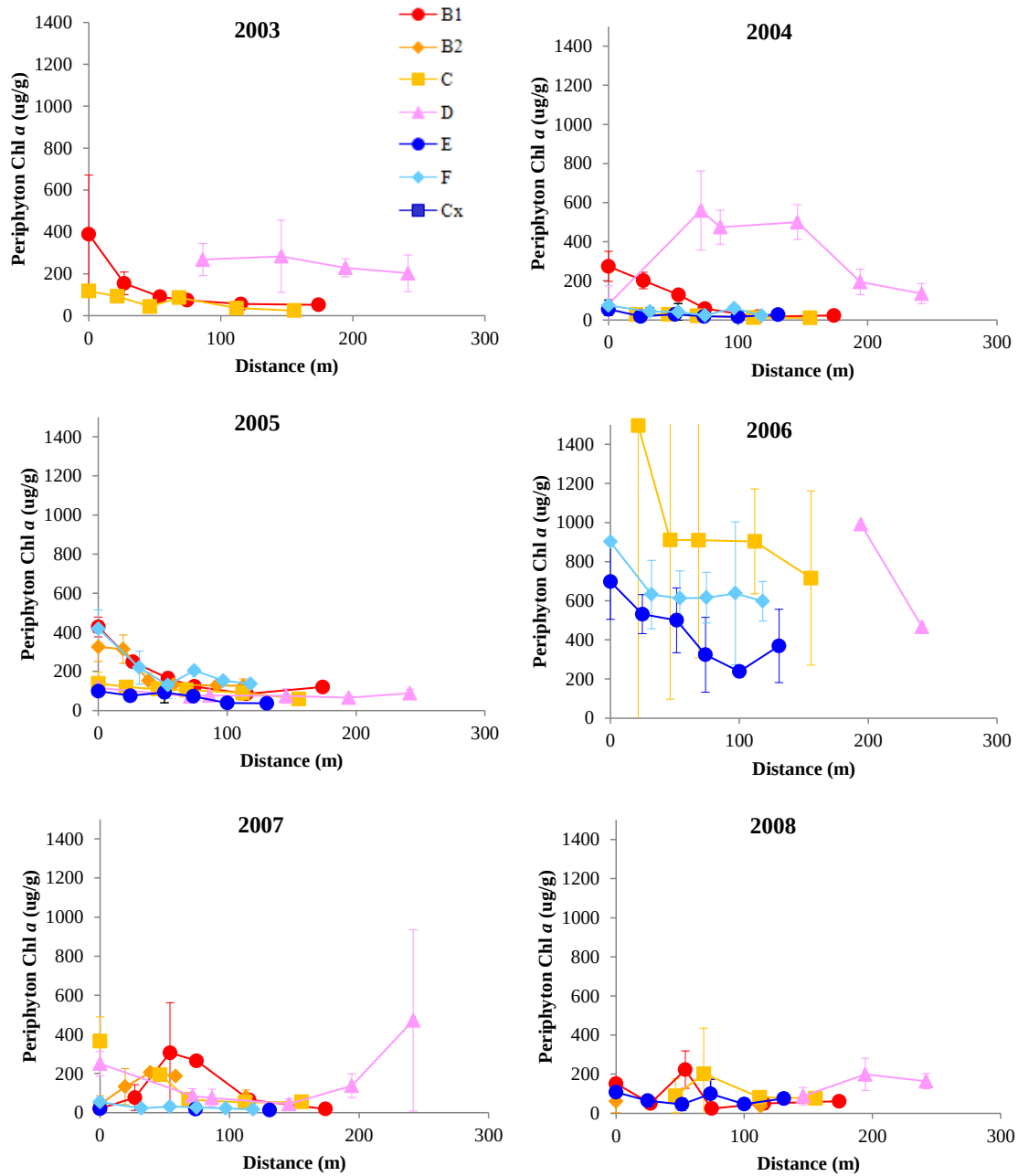


Figure 3A. Trends in periphyton chlorophyll *a* content with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects).

Periphyton Chlorophyll *a* Trends

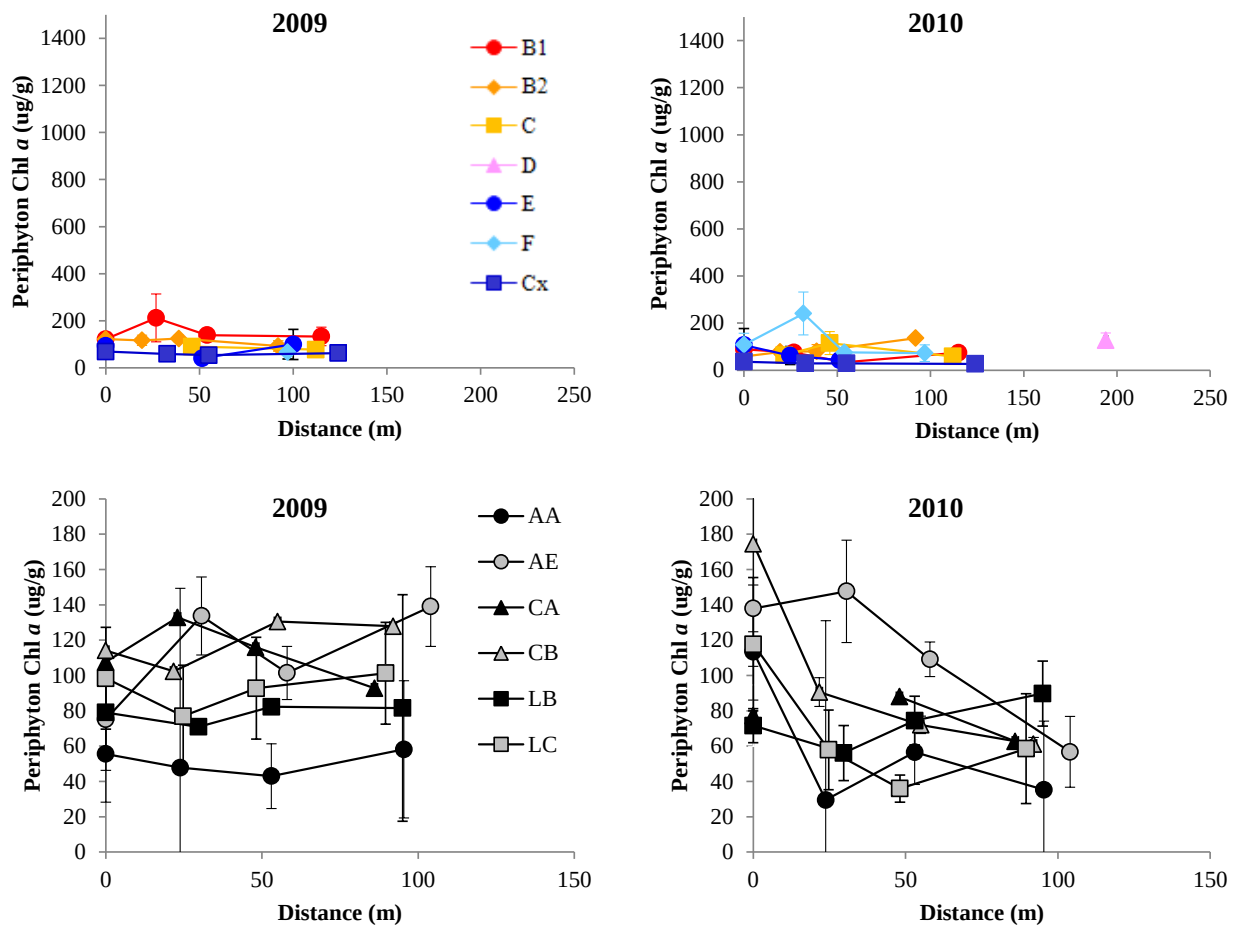


Figure 3B. Trends in periphyton chlorophyll *a* content with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects; bottom two panels illustrate new transects established in 2009).

Periphyton Chlorophyll *a* – Temporal Change

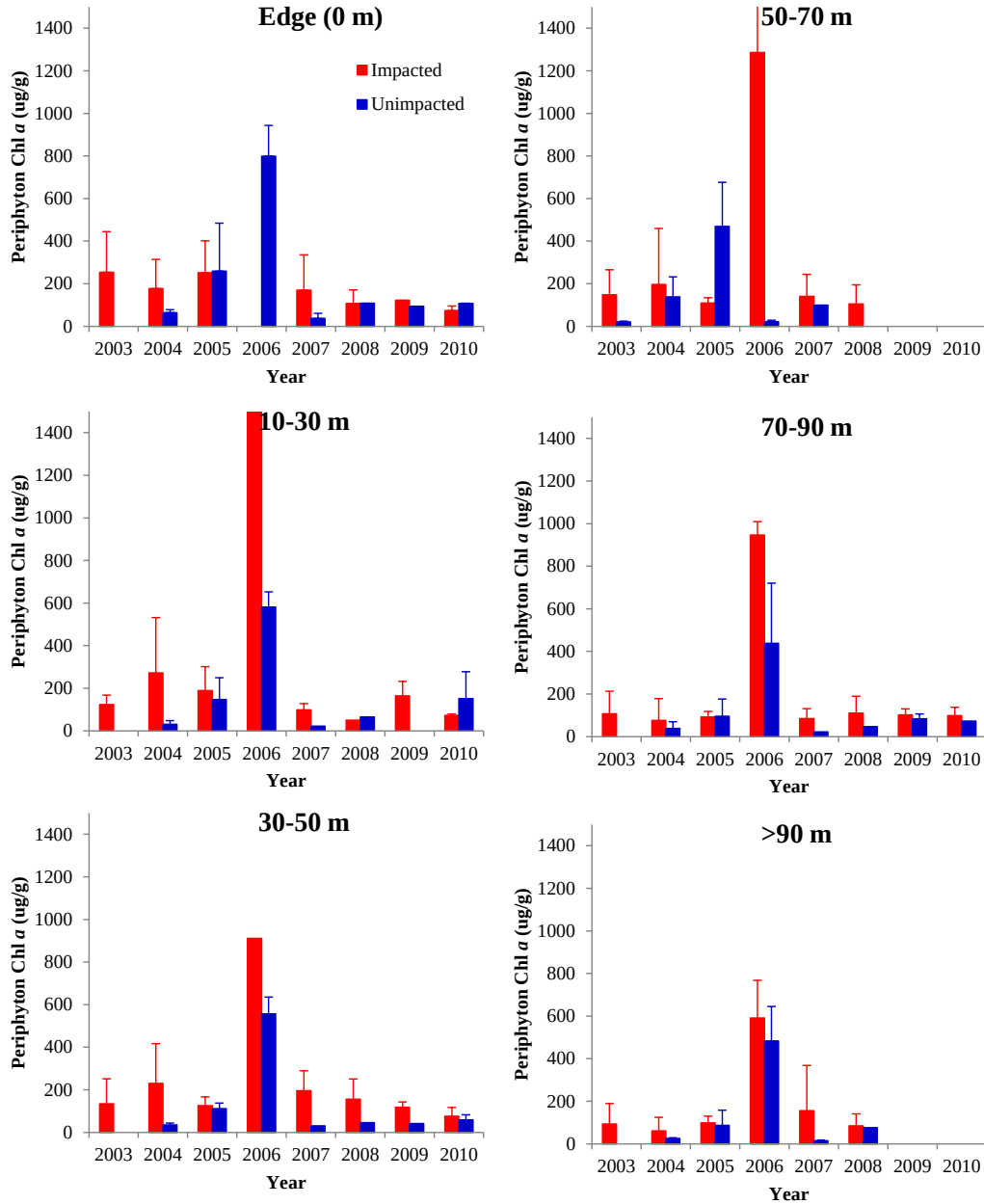


Figure 3C. Differences in periphyton chlorophyll *a* content over time in “impacted” transects (B1, B2, C and D) and “unimpacted” (reference: E and F) transects at successive distances from the eastern ENP boundary.

Site Differences in Diatom Species Relative Abundances (2D Non-Metric Multidimensional Scaling Ordination)

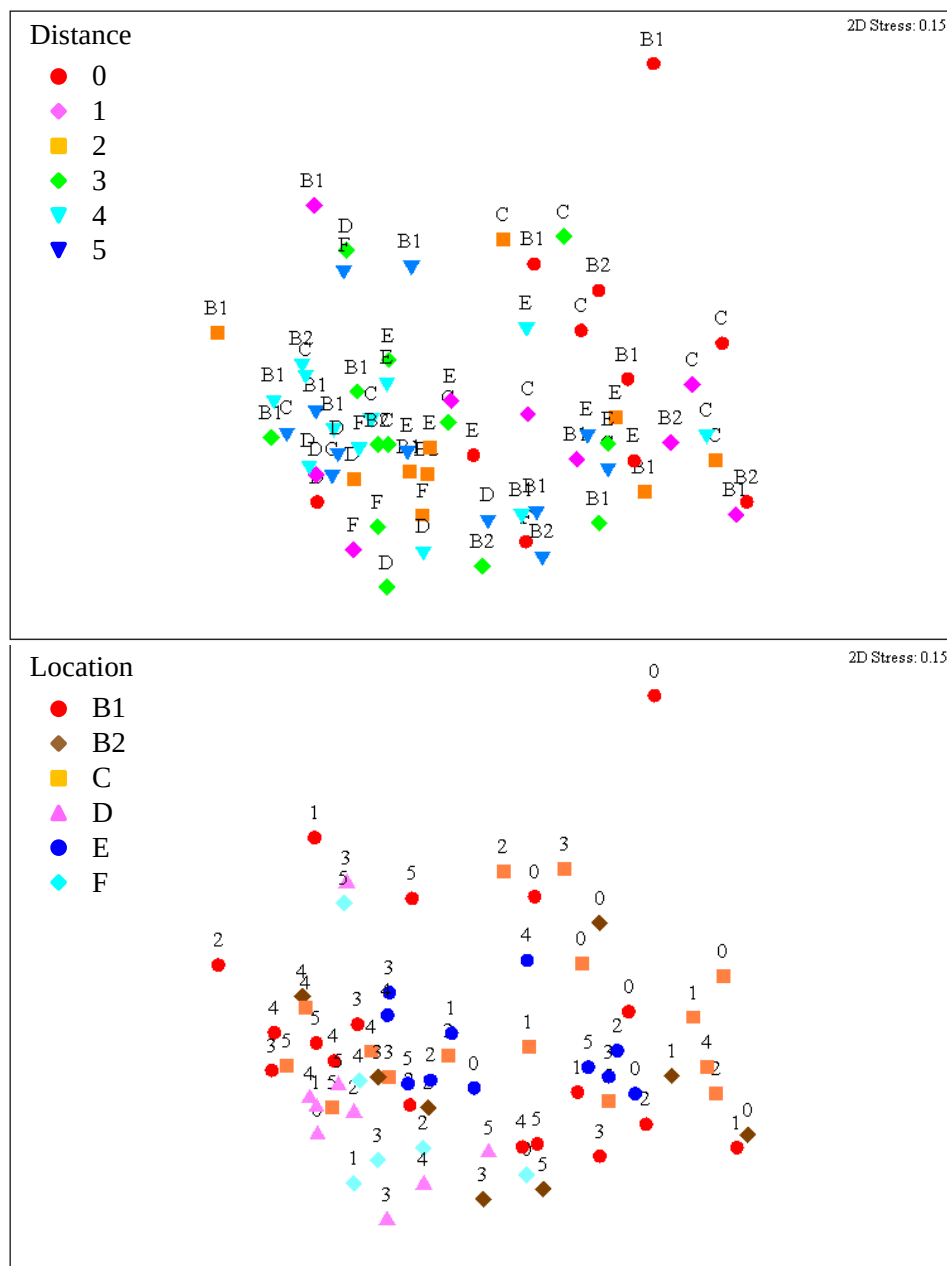


Figure 4A. Differences among sites based on dissimilarity in diatom species relative abundances represented in 2-dimensional non-metric multidimensional scaling ordination space, with sites coded by distance category (above) and location (below).

Abundance Patterns of Common Diatom Species (2D Non-Metric Multidimensional Scaling Ordination)

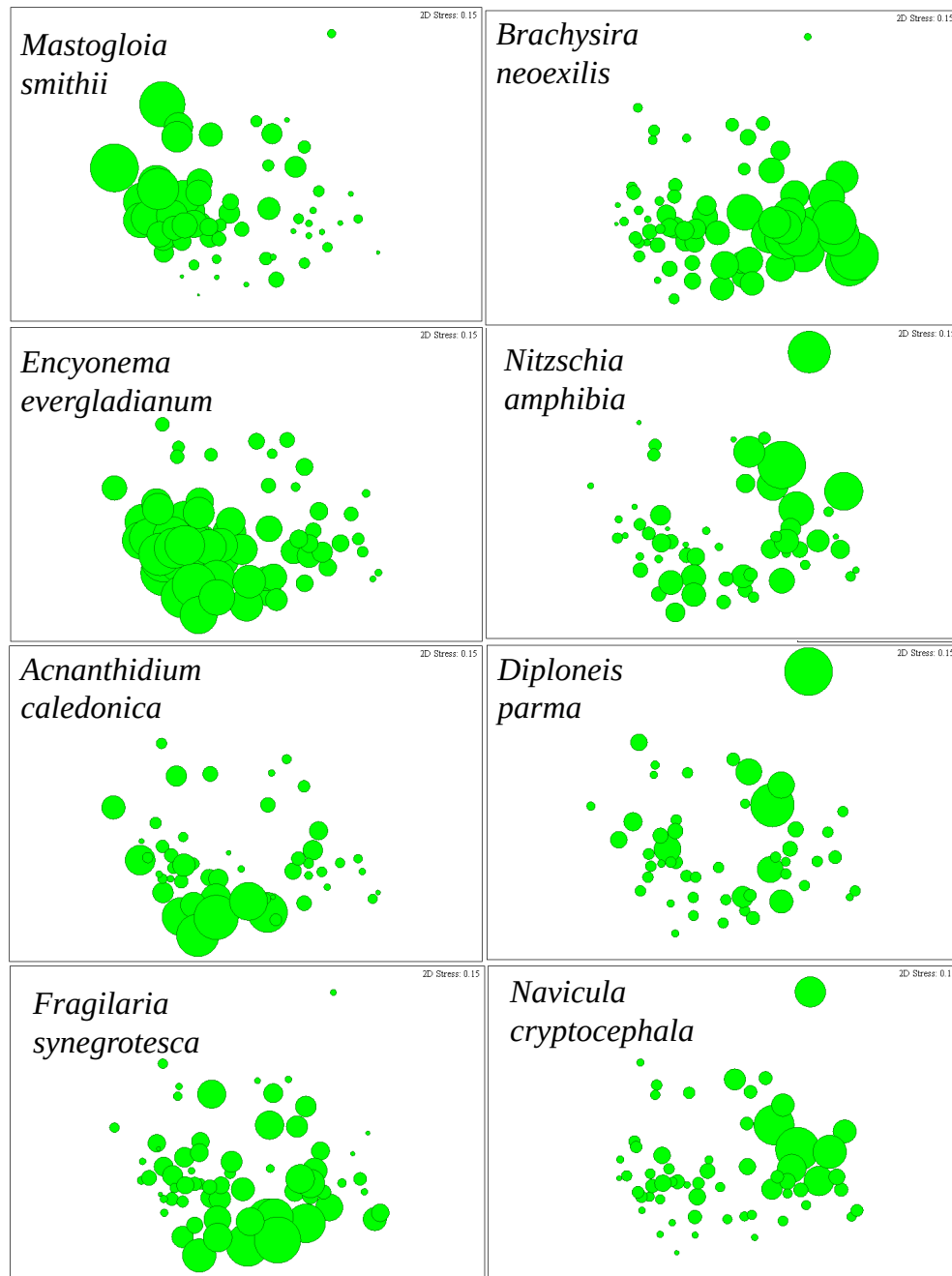


Figure 4B. Patterns in abundance of 8 common diatom species influencing site distribution in ordination space, with bubbles size scaled to relative abundance.

Plant TP Trends

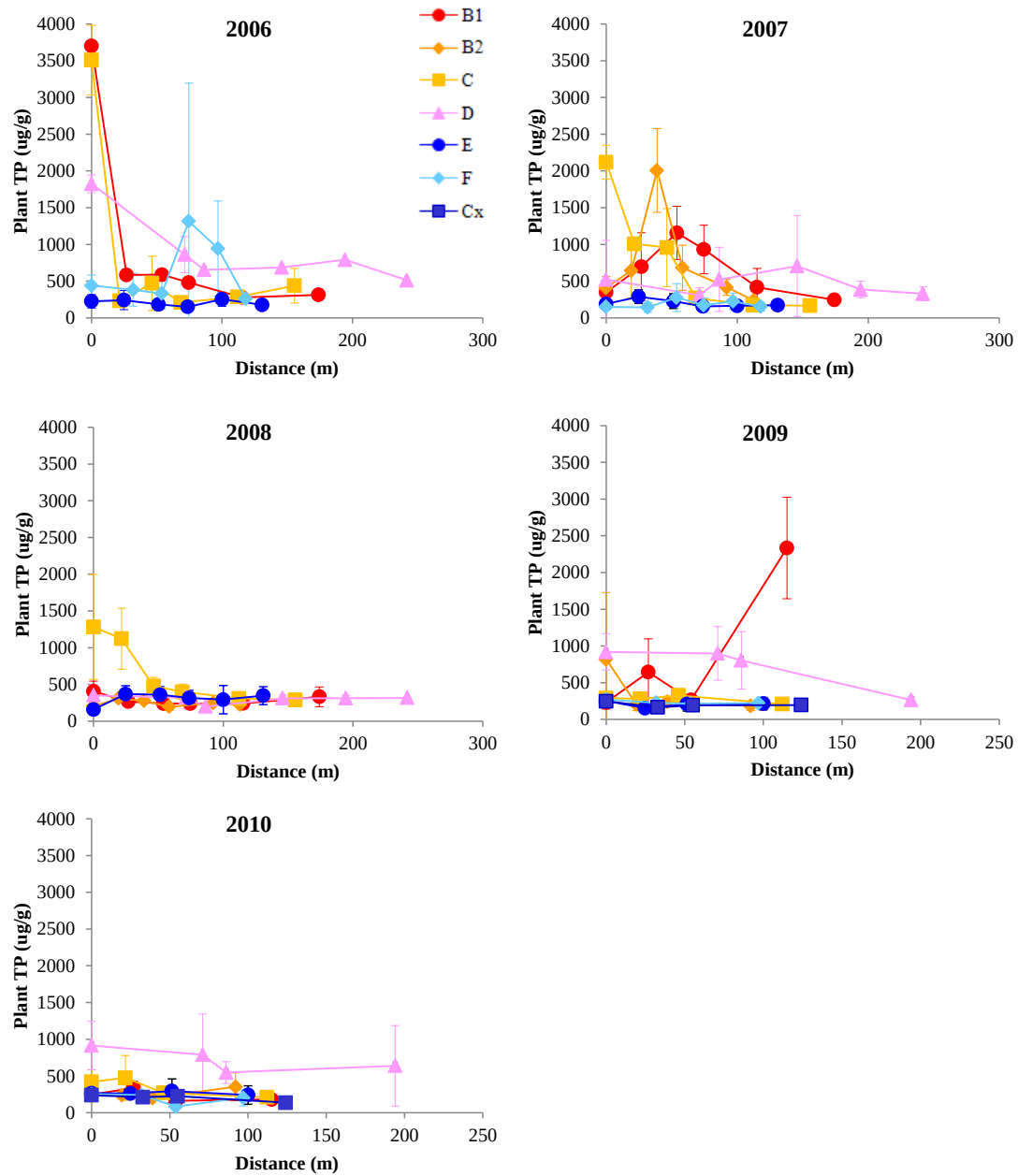


Figure 5A. Trends in total phosphorus (TP) content in plant tissue with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects).

Plant TP Trends

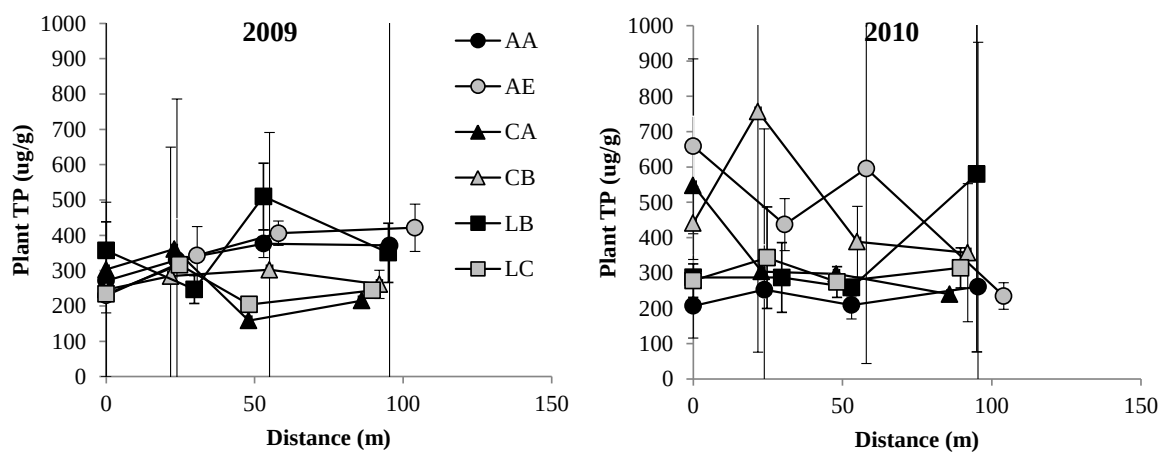


Figure 5B. Trends in plant TP content with distance from eastern ENP boundary for each year of wet-season sampling at new transects established in 2009.

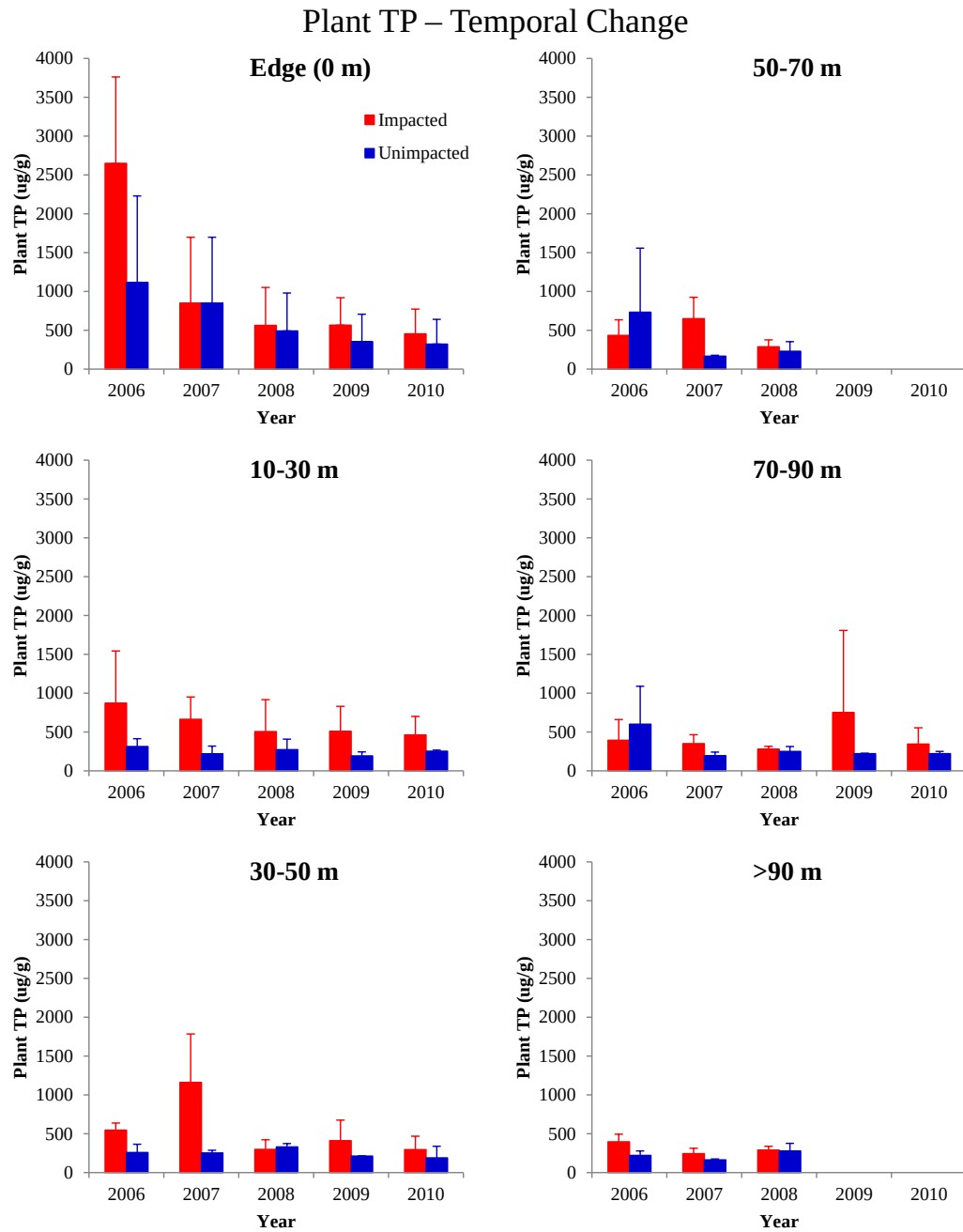


Figure 5C. Differences in plant TP content over time in “impacted” transects (B1, B2, C and D) and “unimpacted” (reference: E and F) transects at successive distances from the eastern ENP boundary.

Plant Stem Density Trends

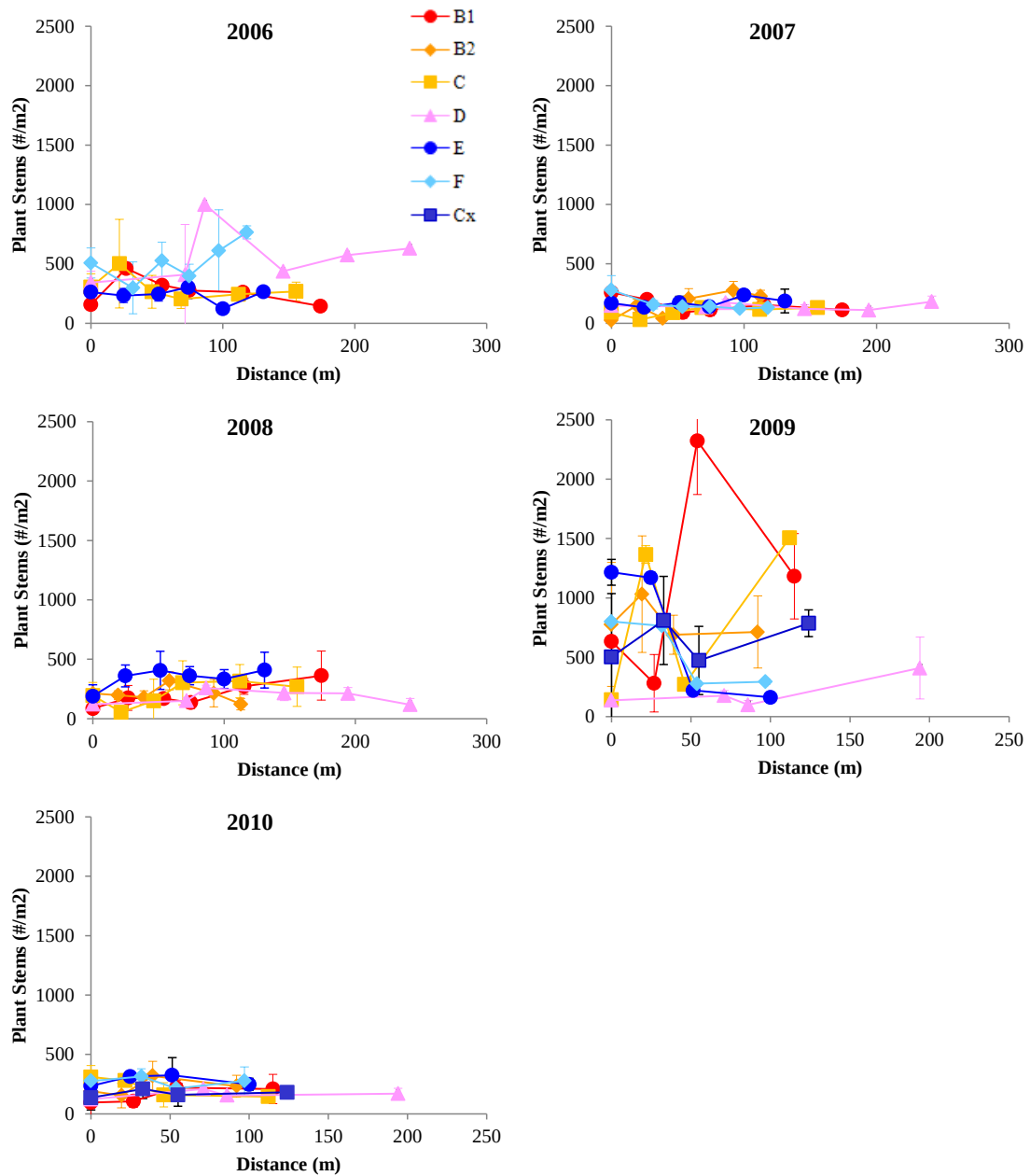


Figure 6A. Trends plant stem density with distance from eastern ENP boundary for each year of wet-season sampling (sites B1, B2, C and D considered “impacted” while E and F are “reference” (“unimpacted”) transects).

Plant Stem Density Trends

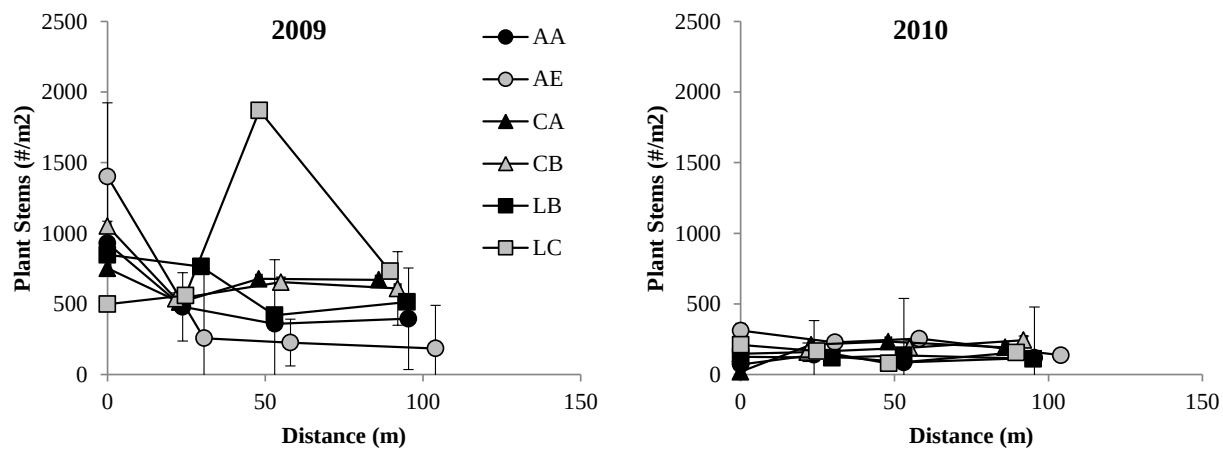


Figure 6B. Trends in plant stem density with distance from eastern ENP boundary for each year of wet-season sampling at new transects established in 2009.

Plant Stem Density – Temporal Changes

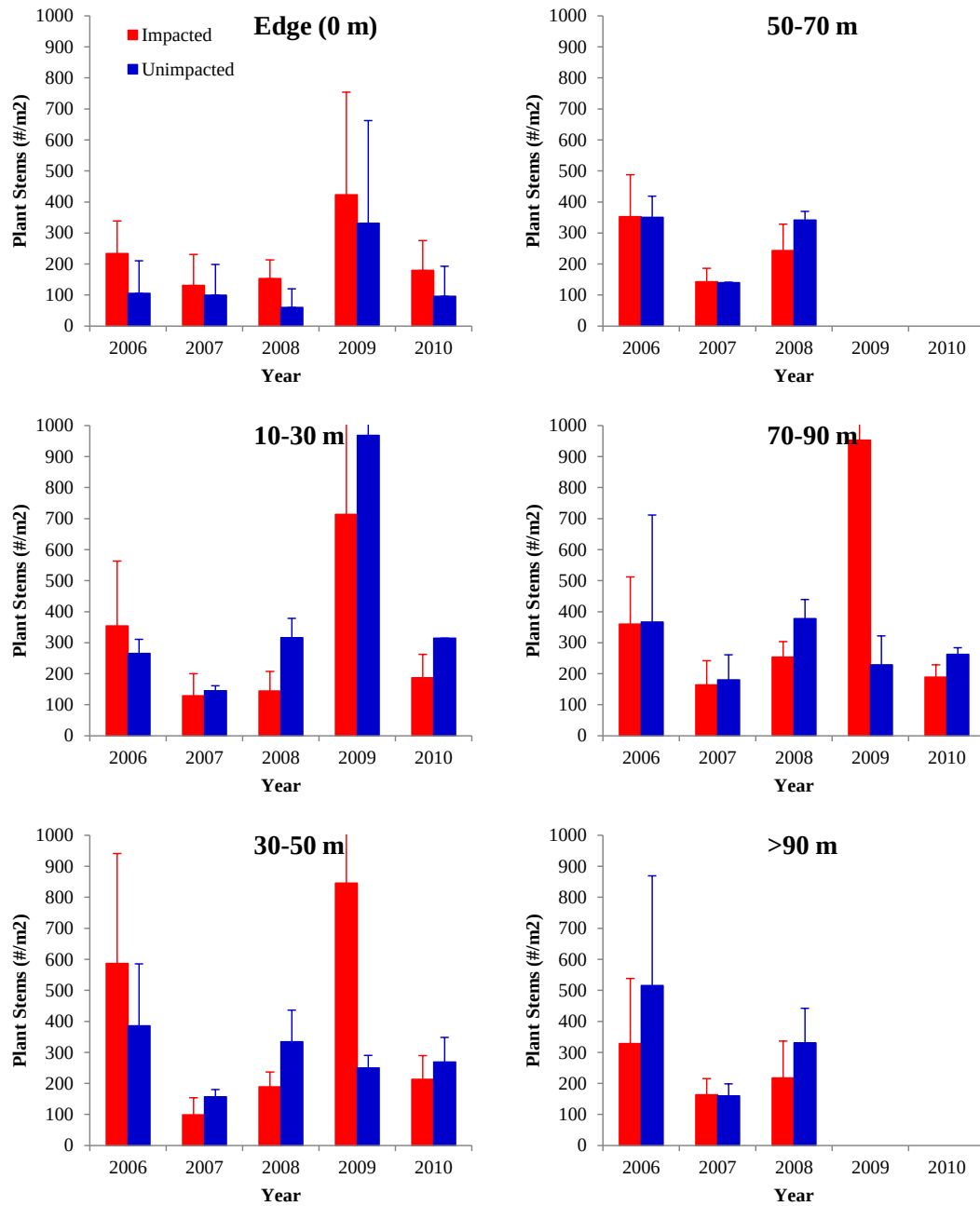
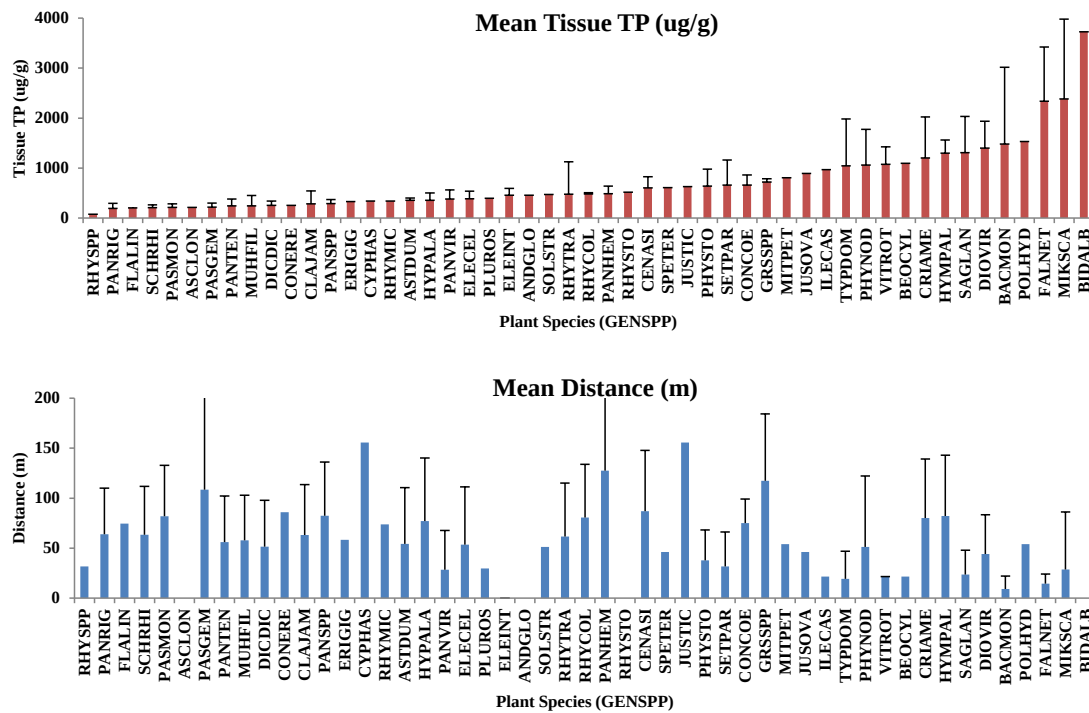


Figure 6C. Differences in plant stem density over time in “impacted” transects (B1, B2, C and D) and “unimpacted” (reference: E and F) transects at successive distances from the eastern ENP boundary.

Plant Species – Mean TP and Distance



CODE	Plant species name	CODE	Plant species name	CODE	Plant species name
ANDGLO	<i>Andropogon glomeratus</i>	GRSSPP	<i>Grass spp.</i>	POLHYD	<i>Polygonum hydropiperoides</i>
ASCLON	<i>Asclepias longifolia</i>	HYPAL	<i>Hymenocallis palidosus</i>	RHYCOL	<i>Rhynchospora colorata</i>
ASTDUM	<i>Aster dumosum</i>	HYPALA	<i>Hyptis alata</i>	RHYMIC	<i>Rhynchospora microcarpa</i>
BACMON	<i>Bacopa monnieri</i>	ILECAS	<i>Ilex cassine</i>	RHYSPP	<i>Rhynchospora spp.</i>
BEOCYL	<i>Boehmeria cylindrica</i>	JUSOVA	<i>Justicia ovata</i>	RHYSTO	<i>Rhynchospora sp. 2</i>
BIDALB	<i>Bidens sp.</i>	JUSTIC	<i>Justicia spp.</i>	RHYTRA	<i>Rhynchospora tricii</i>
CENASI	<i>Centella asiatica</i>	MIKSCA	<i>Mikania scandens</i>	SAGLAN	<i>Sagittaria lancifolia</i>
CLAJAM	<i>Cladium jamaicense</i>	MITPET	<i>Mitreola petiolata</i>	SCHRHI	<i>Schizachyrium rhizomatum</i>
CONCOE	<i>Conoclinium coelestinum</i>	MUHFIL	<i>Muhlenbergia filipes</i>	SETPAR	<i>Setaria parviflora</i>
CONERE	<i>Conoclinium sp.</i>	PANHEM	<i>Panicum hemitomon</i>	SOLSTR	<i>Solanum stramonifolium</i>
CRAME	<i>Crinum americanum</i>	PANRIG	<i>Panicum rigidulum</i>	SPETER	<i>Spermacoce terminalis</i>
CYPHAS	<i>Cyperus spp.</i>	PANSPP	<i>Panicum spp.</i>	TYPDOM	<i>Typha domingensis</i>
DICDIC	<i>Dicanthelium dichotomiflorum</i>	PANTEN	<i>Panicum tenerum</i>	VITROT	<i>Vitis rotundifolia</i>
DIOVIR	<i>Diodia virginiana</i>	PANVIR	<i>Panicum virginicum</i>		
ELECEL	<i>Eleocharis cellulosa</i>	PASGEM	<i>Paspalidium geminatum</i>		
ELEINT	<i>Eleocharis interstincta</i>	PASMON	<i>Paspalum monostachyum</i>		
ERIGIG	<i>Erianthus giganthus</i>	PHYNOD	<i>Phyla nodiflora</i>		
FALNET	<i>False nettle</i>	PHYSTO	<i>Phyla stoechadifolia</i>		
FLALIN	<i>Flaveria linearis</i>	PLUROS	<i>Pluchea rosea</i>		

Figure 7. Differences in tissue total phosphorus (TP) concentration in the dominant plant species collected across all sites, and their mean distance of occurrence along the transects.

VIA. Large fish moving from canals

Note: This section reports results from a complementary CESI-funded project and is included here because of its relevance for interpreting patterns reported in other sections of this report

Animal movement between habitats plays an important role in ecological processes such as flow of materials (e.g., biomass, nutrients, energy) between different systems, food web structure, and spatial fluctuations in population size (metapopulation dynamics) and community structure (community assembly, metacommunity dynamics). Canals bordering the Florida Everglades contain many large, predatory fishes that are also found at low densities in Everglades marshes. When there are connections between these two habitats, canals may act as a source pool of abundant predators that spread their predatory influence into adjacent marshes. Evidence already exists that there is a spatial gradient of predator abundance from canal edges into the interior of the Everglades (Trexler et al. 2002; Rehage and Trexler 2006) and that proximity to canals affects dry-season use of alligator ponds (Parkos et al. 2011). It is not currently known to what degree these patterns result from movement of fish between canals and marshes.

Canals in south Florida may also be pathways of invasion for exotic fish species. Canal environments allow exotic species to persist by providing deep water during the dry season and thermal refuge during winter conditions. Similar to native fishes, exotic species may spread into neighboring marshes when connections exist between canals and

the Everglades. Assessment of exotic species movement between canals and marshes will contribute to evaluating the role, if any, of canals in facilitating spread of invasive species into the Florida Everglades.

We conducted a radio telemetry study to investigate patterns of native and non-native fish movement between canals and neighboring marshes. Mayan cichlids and largemouth bass were tagged prior to onset of the wet season in two segments of the L-31W canal adjoining Everglades National Park (southern portion of Figure 1 in the Project Overview section). Fish locations were determined on the ground by use of a handheld antenna and receiver, and from the air by use of H-antennae attached to a fixed-wing aircraft. Attempts were made to locate fish from once to twice weekly on the ground and once a week from the air. Tagging and tracking was conducted from 2009 to 2011. On average, individual fish were tracked for 94 days. In total for the period 2009-2011, 18-23 fish were tracked per species for each canal segment.

More Mayan cichlids than largemouth bass crossed from canals into neighboring marshes (Table VI.1). On average, 81% of tagged Mayan cichlids and 44% of tagged largemouth bass moved into marshes from canals during rising water levels. Of the fish that dispersed from canals, more largemouth bass than Mayan cichlids returned to the canals at least once during the wet season (Table VI.1). Date of dispersal from canal habitat into adjacent marshes varied among years and species. Mayan cichlids usually entered marshes earlier in the wet season than largemouth bass, and all fish dispersed

from canals earlier in 2009 and 2010 than in 2011 (Figure VI.1). Later dispersal in 2011 relative to the other two years was associated with the later timing of water level rise in 2011 (Figure VI.2). Mayan cichlids that crossed from canal to marsh habitat dispersed deeper into the Everglades than largemouth bass (Table VI.1). On average, Mayan cichlids usually moved greater than 1 km into the Everglades while largemouth bass usually moved less than 1 km from their canal of origin (Table VI.1).

Table VI.1. Summary data on movement of Mayan cichlids (*Cic uro*) and largemouth bass (*Mic sal*) in two canal segments (L-31W-north and L-31W-south) during 2009-2011. The number of fish dispersing from canals to marshes, total number of tagged fish (N), % dispersing from canals to marshes, % dispersers returning to canal at least once during wet season, and distance moved from canal border into marshes (mean $\pm$ 1 SE).

Species	Location	Year	Number dispersing to marsh	N	% dispersing	% returning dispersers	Distance from canal border (m)
<i>Cic uro</i>	L31W-north	2009	3	3	100	33	701 (534)
<i>Cic uro</i>	L31W-north	2010	6	7	86	17	1422 (426)
<i>Cic uro</i>	L31W-north	2011	6	10	60	50	1989 (518)
<i>Cic uro</i>	L31W-south	2009	8	10	80	38	4014 (2695)
<i>Cic uro</i>	L31W-south	2011	8	10	80	13	3414 (1111)
<i>Mic sal</i>	L31W-north	2009	5	13	39	60	368 (135)
<i>Mic sal</i>	L31W-north	2011	4	10	40	75	1069 (492)
<i>Mic sal</i>	L31W-south	2009	2	2	100	100	50
<i>Mic sal</i>	L31W-south	2010	0	6	0	.	.
<i>Mic sal</i>	L31W-south	2011	4	10	40	50	338 (158)

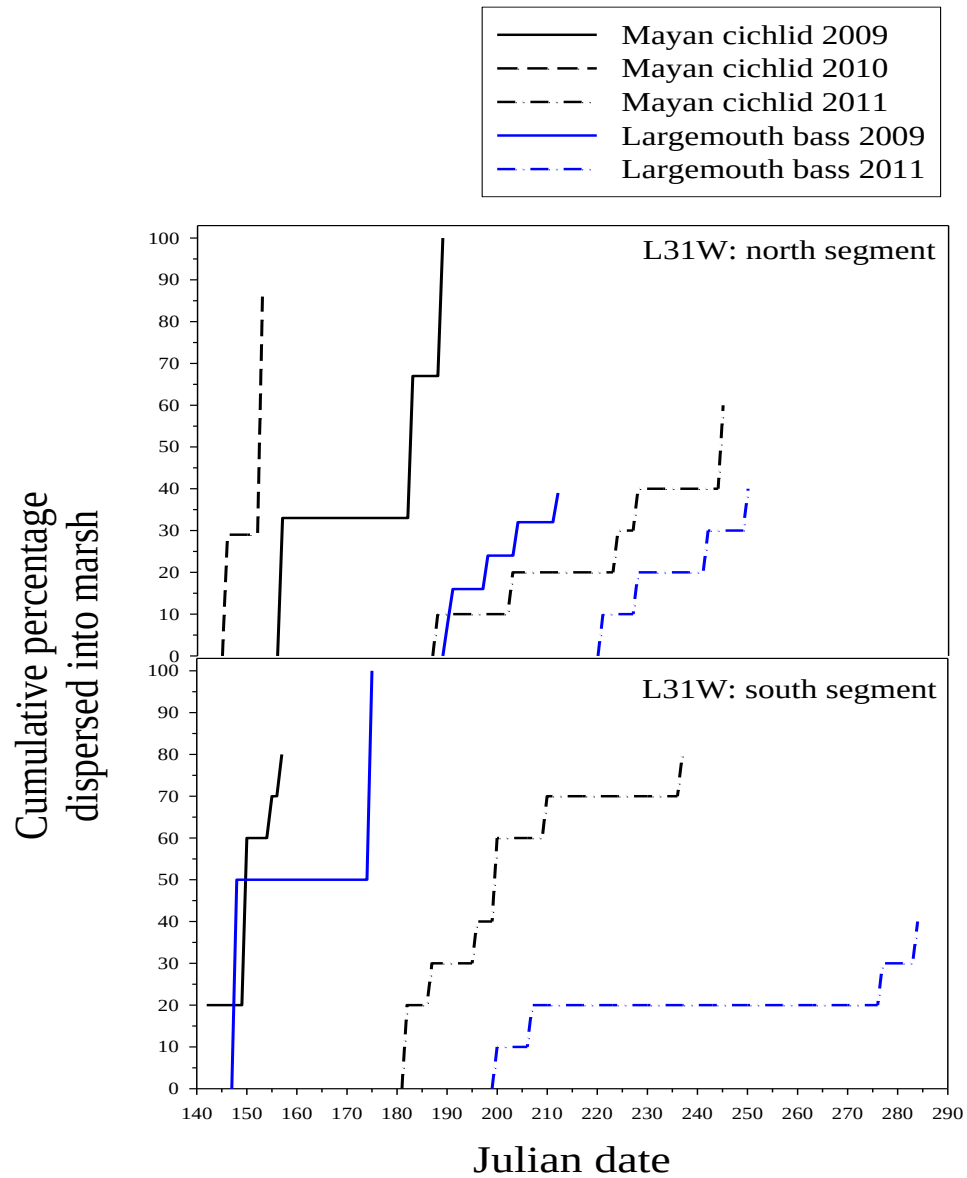


Figure 1. Cumulative percentage of fish dispersing over time from two canal segments into adjacent marshes.

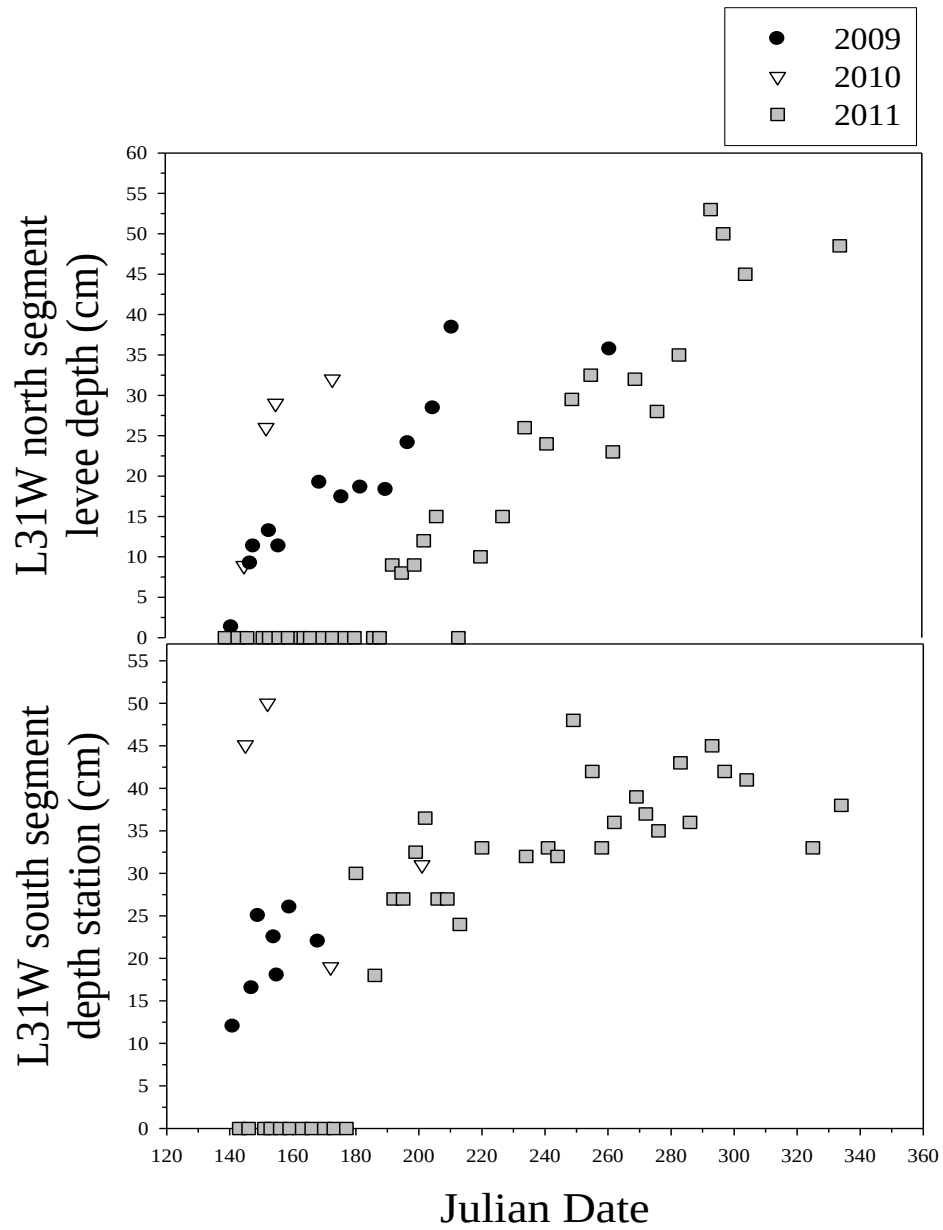


Figure 2. Water depth measurements over time at levee stations in two canal segments of the L31W.

VIB. Fish Use of the L-31W Canal

In order to better understand the role of canals in affecting ecology of the adjacent wetlands, we surveyed fish use of the L-31W adjacent to some of our marsh monitoring sites. Our goal was to document the change in fish density in the canal linked to our independent analysis of movement within the canal and between the canal and marsh. We used a sonar device that permits quantitative assessment of both large and small fish in the canal, relevant to large fishes whose movement we tracked directly and small ones that we sample with drift fences as they move into the marshes.

We conducted monthly surveys of fish in the L-31W and L67C canals from May through October 2011 using a Dual-Frequency Identification Sonar (DIDSON). The DIDSON is a multi-beam sonar capable of recording video-like images underwater. In high-frequency mode (1.8 MHz), it transmits 96 beams to produce a fan-shaped image spanning 29° in the horizontal axis and 14° in the vertical axis. Each beam is longitudinally sectioned into 512 pixels, creating an image of 96 x 512 pixels (Figure VI.3). The resolution of the image is a function of the window length (i.e., distance from the sonar) and varies depending on the range of interest, such that objects further away are viewed at a lower resolution than those closer. We selected a window length of 5 m to maximize resolution of small fishes. The DIDSON was deployed to record acoustic videos of the canal-marsh edge near the surface of the water and then rotated to record the deeper, middle portion of the canal. Within the L67C canal, three marsh-edge and two middle-of-canal acoustic videos were recorded at each of the three Decomp Physical Model canal sites (Figure VI.4A). Sampling design was similar in the L-31W except one of the three sites consisted of five marsh-edge videos (Figure VI.4A). Over the course of

this period, 79 and 90 5-minute acoustic videos were collected in the L67C and L-31W, respectively (Table VI.2). Based on these data, we modified our sampling regime starting in December 2011. The new protocol entailed collection of two 15-minute acoustic videos at six new sites in each canal (Figures VI.4B and VI.5B). Samples were collected during the day and at night. Beginning in February 2012 we changed the window length to 10 m to maximize the area sampled while still maintaining good resolution. A total of 60 videos in the L67C and 72 in the L-31W were collected from December 2011 to March 2012 (Table VI.2). January sampling did not occur because boating operations were shut down temporarily. In March, we did not sample at night in the L67C because of inclement weather.

The DIDSON malfunctioned during July 2011 and needed to be shipped back to manufacturer for repair for the month. As a result, only 5 videos were collected in July instead of the usual 15 per sampling event. Weather delays in March 2012 prevented night sampling.

Post-Processing of Acoustic Videos

Each video was reviewed using DIDSON Software V5.25 and the following metrics were calculated: fish density, fish length, number of fish schools, number of fish in each school, and average length of fish in the school. A school was defined as the aggregation of fish that were observed swimming uniformly and changes in speed or direction occurred in rhythm. The data were then exported as a comma-delimited file and merged with site information to be analyzed using statistical software. Analysis of videos required 15-30 minutes per 5-minute video. Videos containing large densities of fish (>

50) and numerous schools can take longer and require more intensive analysis. Progress is being made to use acoustics software that will speed up analysis for future data collecting.

Fish density, fish length, and presence of fish schools have been calculated for May through August sampling events in both canals. Additional analysis is needed to determine school size and average length of fish in each school. May and June data were analyzed with data from Dec 2010 – April 2011 and are reported below. July and August are still in the DIDSON file format and have been not been exported to a comma-delimited file. All post-processing of the 5-minute videos should be completed by the end of April. Post-processing of the 15-minute acoustic videos will not begin until May.

Results

Marsh water levels dropped considerably during this time and by May water levels in the marsh surrounding the L67C were near zero, while marsh water levels dropped earlier in the year at L-31W and were below ground for the entire study period (Figure 4). Small fish density increased in both canals as the dry-season progressed, peaking a month earlier in the L-31W than in the L67C (Figure VI.7). Prior to marsh drying, fish densities in both canals were low ($\sim 1 \text{ fish m}^{-2}$). With the decline of marsh water levels, densities of both large- and small-bodied fishes increased dramatically (7-10 fish m^{-2} ; Figure 5), indicating these habitats were functioning as dry-season refuges. Large fish showed the most marked dry-season increase in density in the L67C, possibly because water depth had already dropped in the L-31W area when this study began.

The increase in fish density also coincided with an increase in the frequency of

schools of small fish (< 8 cm). Although schooling behavior was observed prior to marsh drying, they were more frequent during months when there was limited connectivity to the marsh surface. Month had a significant effect on the likelihood of detecting a schooling event ($p = 0.001$), with schooling events becoming more prevalent in June (Figure VI.8). School sizes ranged from < 10 individuals to > 100 individuals. Schooling may be a response to the observed increase in large-bodied fishes, and future work will explore how this pattern changes seasonally and diurnally.

These data support the flux of fish to and from the canal with seasonal fluctuation in canal depth and connection the marsh. The L-31W south of the S175 structure is a confined water body with limited connection to the C-111 system at the southern end. When coupled with other data in this report, it is apparent that fish are actively moving between the canal and the marsh habitats in this area as the water table rises and falls with the seasons.

Table VII.2. Number of samples (acoustic videos) collected at each sampling event in the L67C and L-31W canals. The DIDSON malfunctioned in July and only a few videos were able to be collected before sending back to manufacturer for repair. Weather delays in March prevented a night sampling event in the L67C.

Date	# Samples	
	L67C	L-31W
May 2011	15	17
June 2011	15	17
July 2011	5	4
August 2011	15	17
September 2011	15	17
October 2011	15	17
December 2011 (day)	12	12
December 2011 (night)	12	12
February 2012 (day)	12	12
February 2012 (night)	12	12
March 2012 (day)	12	12
March 2012 (night)	0	12

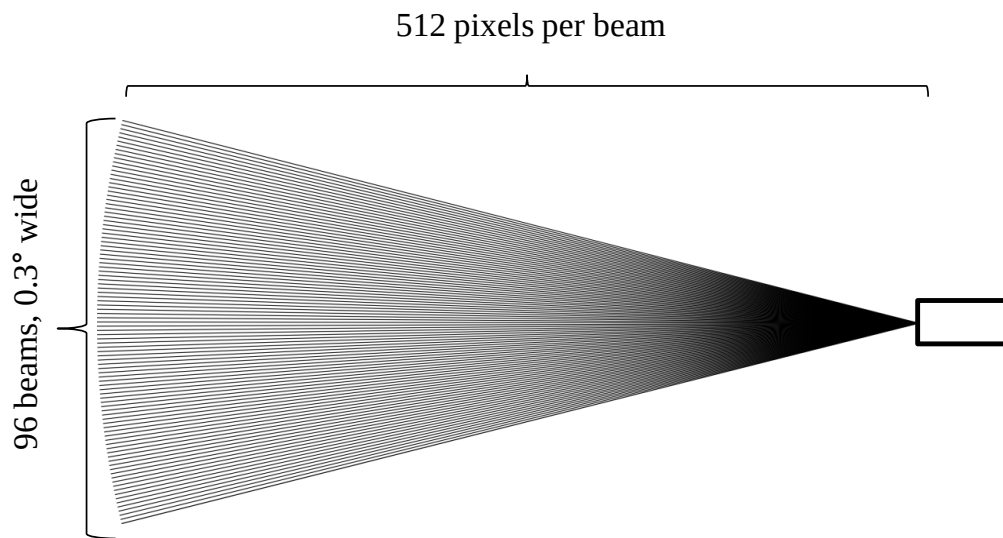


Figure VII.3. Diagram of fan-shaped image produced by the DIDSON.

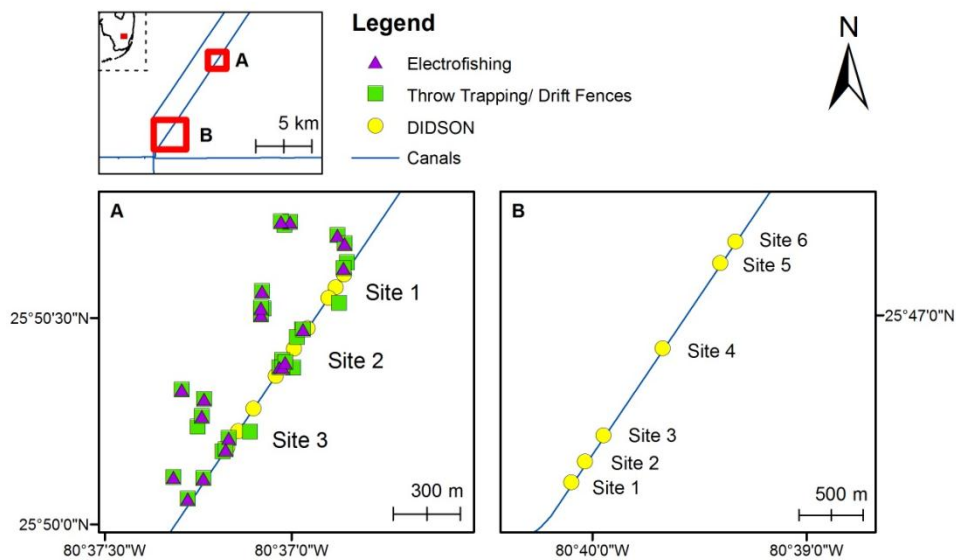


Figure VII.4. Decomp sampling locations within the L67C canal: A) Site locations from May – October 2011, and B) site locations from December 2011 – March 2012.

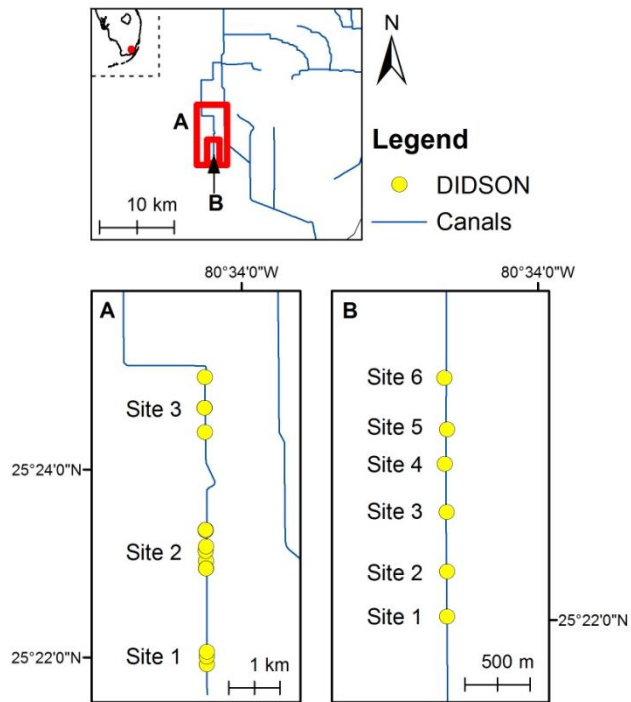


Figure VII.5. Sampling locations within the L-31W: A) Site locations from May – October 2011, and B) site locations from December 2011- March 2012.

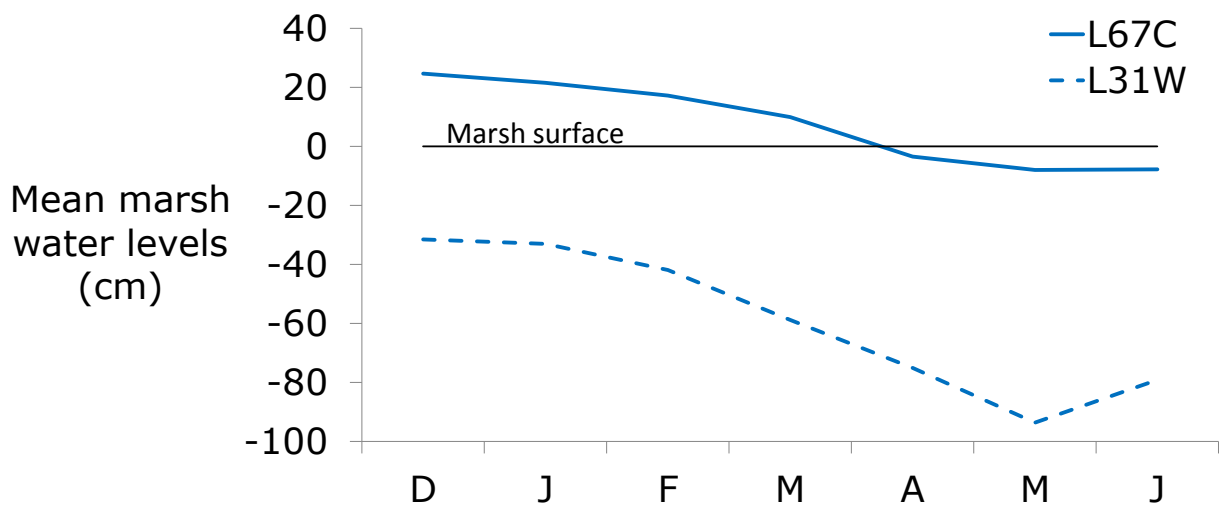


Figure VII.6. Mean monthly marsh water levels for the L-31W and L67C canals from December 2010 to June 2011.

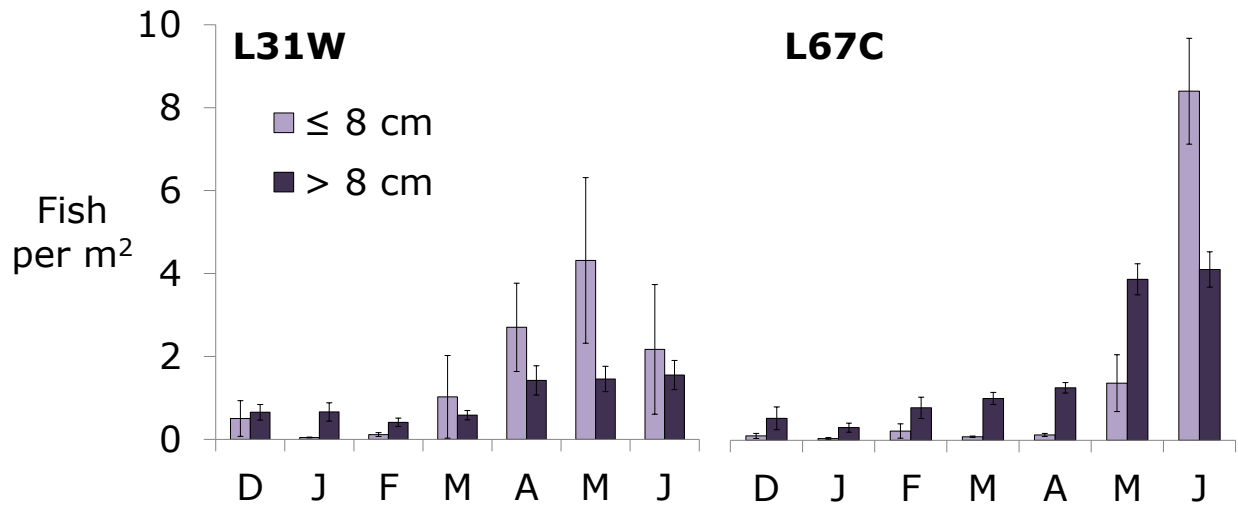


Figure VII.7. Mean fish density per 5-minute video from December 2010 to June 2011.

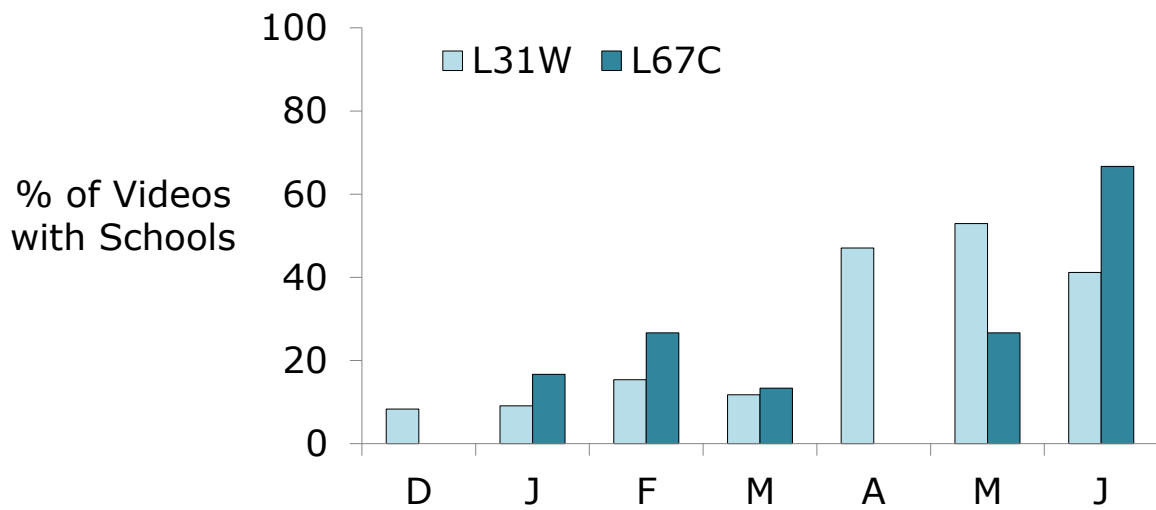


Figure VII.8. Percent of samples (each 5-minute video is one sample) with at least one schooling behavior from December 2010 to June 2011.