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

Annual Report
Year 2

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Submitted by

Joel C. Trexler
Department of Biological Sciences
Florida International University
Miami, FL 33199

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I. Executive Summary

This is year 2 of an ongoing monitoring initiative of the impacts of the Interim Operating Procedures (IOP) and particularly the new S-332B, C, and D structures. The project also includes a research project to describe the impacts of nutrient enrichment on food webs in short hydroperiod marshes through experimental exclusion of animals of different sizes that act as predators.

This year we noted further nutrient enrichment in gradients downstream from all three S-332 structures. The origin of enrichment at S-332D continues to be difficult to interpret; it could be the result of nutrient inflow from the L-31W or from suspension of nutrients as a result of newly flowing of water over previous static wetlands.

Our field collections are providing baseline data on fish and macroinvertebrate communities at the inflow points of water from the S-332 structures. Macroinvertebrates show a typical pattern associated with hydroperiod, lowest abundance in the Rocky Glades habitats at the eastern edge of ENP, highest abundance in the longer hydroperiod habitats of Shark River Slough, and intermediate abundance at sites in between. The marshes at the S-332D inflow are outliers from this pattern, probably reflecting the greatly lengthened hydroperiod created there by the new sheetflow at this location.

Surprisingly, fish collected by drift fences displayed an opposite pattern to our expectations based on hydroperiod and from throw trap studies. The highest capture rates were at the short-hydroperiod inflow points at the eastern edge of ENP. We hypothesize that this is the result of high migration rates from canals on the eastern edge of the Park and into the newly hydrated Rocky Glades. We will pursue this hypothesis in the coming year.

This year we improved our experimental design for assessing food-web interactions using exclusion cages. This effort led to a research paper submitted to the journal *Hydrobiologia*. The work also demonstrated an important negative impact of predators, probably large fish, on intermediate consumers (small fish and grass shrimp). When large animals are excluded, the density of intermediate consumers increases by immigration into the refuge habitats. Our hypothesis is that the impact of these large predators will be reduced in short-hydroperiod marshes because their densities are lower there, releasing intermediate consumers from one form of population regulation. Adding nutrients may lead to a marked increase in intermediate consumers freed from consumption by larger predators. Our sampling work at the S-332D inflow suggests a large migration of predatory animals (from gar, water snakes, to alligators) into the wetlands downstream from the L-31W canal. This immigration may counter the impact of dry-season mortality of large fish from marsh drying. Immigration and connection to the canal refuge may emerge as a major difference in community responses between the S-332D and S-332B and C structures.

Staff on this project:

Principal Investigator: Joel Trexler

Collaborating Senior Personnel: Evelyn Gaiser, Nathan Dorn, Shawn Liston

Technical Assistants: Brooke Shamblin, Laura Reynolds, Chuck Goss, Myte Ruiz, Arian Avalos, Gary Rodriguez, Alejandro Leon, Veronica Bustabad, Greg Lodin, Betina Hodapp

II. Project Objectives:

1) Gather field data on fish and key macroinvertebrates in IOP-effected and reference areas of ENP. Work will focus on areas downstream from new S-332B and S-332C structures.

2) Use an experimental protocol to parameterize a statistical model of effects of nutrient enrichment and hydroperiod on key components of the aquatic (freshwater) food web in ENP.

3) Use field monitoring data and experimental data to develop Performance Measures of nutrient inputs into short-hydroperiod marshes.

Background

Concern about nutrient enrichment is exacerbated by uncertainty of how to restore the historic ecosystem structure once nutrients are added on a large spatial scale (McCormick et al. 2001). Thus, it is critical for managers to prevent or minimize the impacts of nutrient additions ***before*** they reach levels where ecosystem effects are manifested. Current knowledge suggests that the level of nutrient addition failing to yield long-term ecological impacts is very low, probably near the level of detection above ambient field conditions.

While some satisfaction can be derived from the high level of regulatory attention applied to nutrient impacts in the Everglades, management actions under the Interim Operating Plan (IOP) and the Comprehensive Everglades Restoration Plan (CERP) raise new concerns. These projects seek to improve the hydrological conditions of areas throughout the Everglades watershed, including sensitive areas of the Everglades National Park, by shunting additional water to areas considered too dry at present. However, the prospects of diverting water that is currently transported in canals into sensitive Everglades wetlands raises concern about nutrient inputs, albeit often at low levels, in locations never receiving nutrients before and at a scale exceeding those previously experienced. The IOP, which is already well underway, presents an immediate challenge in the Rocky Glades/Taylor Slough basin. Water is being added into the eastern Everglades at the S332D and S322B structures from the L31W canal that may bear nutrients above the presently very-low levels in that area. These short-hydroperiod marshes differ hydrologically and ecologically from areas previously receiving nutrient enrichment. Past research on nutrient impacts and thresholds has focused on long and intermediate hydroperiod marshes (McCormick et al. 2001), whose ecology is somewhat different from these short-hydroperiod marshes.

A focus of current debate regarding nutrient additions to the Everglades is the propagation of nutrient effects through the food web. Research on nutrient effects

beyond those on vascular plants and algae has lagged, probably because the plant communities provide apparent visual impact, they form the base of the food web, they provide habitat structure in an ecosystem lacking topographic relief, and periphyton mats are particularly sensitive indicators of nutrient addition. However, the extensive knowledge of botanical responses to nutrients has led to questions about their linkage to animal community dynamics. It is clear that the Everglades food web is distinctive, probably in part because of its oligotrophic nature (Turner et al. 1999). Also, we have ample evidence that nutrient addition alters food-web structure in long- and intermediate-hydroperiod Everglades wetlands (Turner et al. 1999; Trexler 2002; Trexler et al. 2001). It is a critical time to build on existing research on nutrient effects on Everglades food webs, and in particular to link that work with studies embracing the full range of hydroperiod conditions where nutrient impacts occur (today and in the future). Here, I propose an experimental protocol that addresses both of those research needs and that will be coupled with a monitoring program of the areas most likely impacted by the IOP.

III. Periphyton TP: Gradients of enrichment

We collected samples of periphyton along transects from the S-332B and C structures and the inflow point for water from S-332D into Everglades National Park for to provide an index of nutrient enrichment from these sources into Everglades National Park (Gaiser et al. 2004). The sampling was conducted in early December in 2003 and at the same locations in December of 2004. We added two reference transects to the sampling in 2004, Context Road and between S332B and C, to provide patterns from the edge of Everglades National Park lacking water structures. In 2003, we found evidence of heightened nutrient levels at S-332B and S332D (Fig. III.1). 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 suggested 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, retaining the pattern of decreasing TP concentration with increasing distance into the ENP. No nutrient pattern was observed at the reference

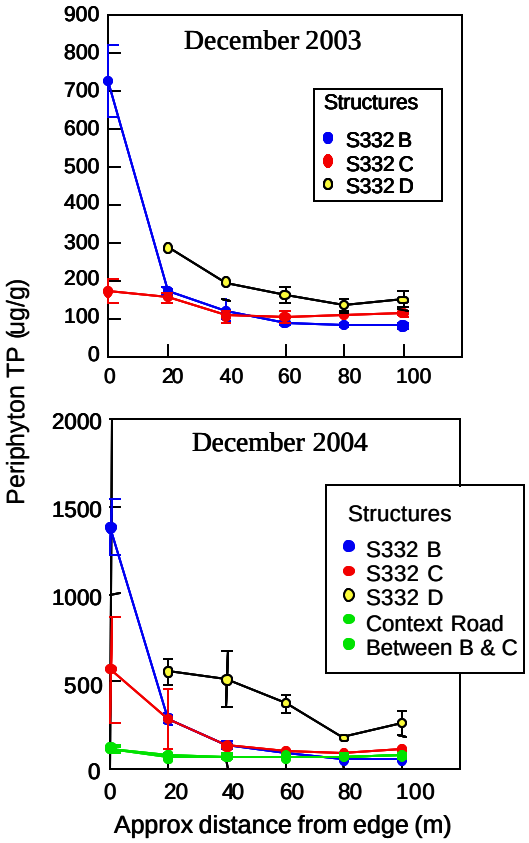

Figure III.1. Total phosphorus in periphyton samples collected from a transect starting at the edge of Everglades National Park.

areas. Again in 2004, no periphyton was present at the inflow point for S-332D, but this year the more downstream samples were elevated compared to 2003 and the downstream gradient pattern was noted. The S-332D gradient remains difficult to interpret as indicative of allochthonous nutrient enrichment because it coincides with marked increase in water flow, which may be suspending existing phosphorus in the area. No flow interpretation is valid for S-332B and C. This project seeks to monitor the response of aquatic animals to encroachment of the nutrient gradient documented here into short-hydroperiod wetlands of the Rocky Glades, Everglades National Park.

Literature cited this section

Gaiser, E. E., L. J. Scinto, J. H. Richards, K. Jayachandran, D. L. Childers, J. C. Trexler, and R. D. Jones. 2004. Phosphorus in periphyton mats provides best metric for detecting low-level P enrichment in an oligotrophic wetland. Water Research 38:507-516

IV. Monitoring impact of water delivery from S-332 structures on aquatic animals

We sampled fishes and macroinvertebrates at 32 sites in seven sampling events between August 30 and December 11, 2004. This period spans much of the time when marshes adjacent to the S-332B, C, and D structures were inundated in 2004. The goals of our work this year focused on continuing to refine our methods for sampling aquatic animals in short-hydroperiod marshes (annual inundation >300 days) and for stabling baseline and early impact conditions associated with the S332 B and S332C structures. We accomplished the latter by documenting spatial and temporal patterns of community structure and abundance of consumers, paying particular attention to comparisons between IOP-impacted and reference sites. The objectives of our work this year were:

Methods development

- To determine whether the exclusion of small macroinvertebrates (< 1 mm maximum dimension) from enumeration of periphyton core infauna (e.g., Liston & Trexler 2005) results in a loss of necessary information pertaining to the community structure and/or abundance of infauna in this study;
- To determine whether it is necessary to install two vertically stratified (stacked) minnow traps in drift fences used to sample fishes when water is deep (> 50 cm);
- To evaluate the use of spatially positioned drift fences to describe spatial and temporal patterns in fish movement at study sites;

Baseline condition descriptions

- To describe spatial variation in macrophyte communities and spatial and temporal variation in water depth among study sites;

- To describe variation in the community structure and abundance of macroinvertebrates and fishes among IOP-impacted and reference sites;
- To examine variation in macroinvertebrate and fish communities as a function of distance from the S332B and S332D water control structures.

METHODS

We continued monitoring macroinvertebrates and fishes continued in Fall 2004 at 10 reference sites (Shark River Slough, the Rocky Glades and eastern Everglades) and 2 IOP-impacted sites (vicinity of S-332B and S-332D structures). Two replicate arrays were constructed at each reference site, and six arrays were constructed at each impacted site (Table IV.1, Figure IV.1). We placed paired drift fences at each reference and impact site, with three pairs at each of three distances from the S 332B and S332D structures: 50-80 m, 210-260 m, and 400-440 m. We sampled in week 35 (August 30-September 01), week 38 (September 20-24), week 41 (October 12-15), week 44 (November 1-4), week 46 (November 15-18), week 48 (November 30-December 3), and week 49 (December 11). Five water depth measurements were made at each drift fence during each sampling event. Macroinvertebrates were only sampled at early and late wet-season sampling events because of the time required for laboratory processing of each sample.

Field sampling

Macrophytes. Emergent vegetation was enumerated at each site in order to characterize the habitat structure. Stem counts of emergent macrophytes were taken at each site during week 38 in five haphazardly thrown 1-m^2 throw-traps (Freeman et al. 1984).

Sweeps and periphyton cores. When early and late in the season when surface water was present, we sampled macroinvertebrates in the vicinity of each drift fence array with sweep nets and periphyton cores. Sweep-net samples were taken by sweeping the water column in a 'U' motion, from the water surface to the top of the sediments and back to the surface with a D-frame net (0.5 cm mesh). Each sweep was ≈1 m in length (Turner and Trexler 1997). Five sweep samples and five 6-cm diameter periphyton cores were collected at each array site. Sweep samples were preserved in 10% formaldehyde and core samples were preserved in 70% ethanol. All samples were brought back to the laboratory for processing.

Sweep net samples were collected three times this year: week 38 ("September"), week 41 ("October"), and week 48 ("December"). Core samples were collected in the October and December sampling events. Frequently (especially in September and October), fewer than five samples were collected because of low water levels and/or the absence of periphyton. Furthermore, analysis of the early wet-season data indicated that three samples were adequate to characterize each site so we cut back to processing a

maximum of three sweep and three core samples from each site for the December collections (Table IV.2).

Drift fences. We constructed drift fences at each site from December 2003-August 2004 (we inherited 6 additional sites from Bill Loftus that were constructed in 2002) to quantify small fish abundance and identify the direction of their movement. Drift fences were constructed of four arms of that intersect to form an X, creating four quadrants (Figure IV.2), and were oriented with the midpoint of each quadrant facing one of the four cardinal compass directions or into the direction of water flow. Each arm of the fences was 12 m long and 0.7 to 1.5 m high (depending on prevailing water depth), and was constructed of greenhouse cloth (impermeable to fishes) attached to and supported by rebar. At the intersection of the four arms, additional cloth was used to create a 1.5 x 1.5 m square with a hole in each quadrant large enough to insert a minnow trap. To sample fishes in drift-fence arrays, a 3-mm wire mesh minnow trap (mouth diameter = 2.5 cm) was inserted into each quadrant of each array. One trap opening faced into the quadrant, and the other (facing the center of the array) was plugged. Minnow traps remained embedded in fences for 24 h. Fishes moving directionally through the marsh intercepted the fences and were corralled into center where they accumulated in the minnow traps.

Data obtained from minnow traps is in units of catch per unit effort (CPUE). CPUE is generally considered an index of abundance, but it must be interpreted as such with caution. CPUE is really an encounter rate (E) of fish arriving at and entering a trap that results from the interaction of local fish density (D) and their movement rate (M), after adjusting for artifacts of the sampling device. This can be modeled similarly to the encounter of prey by a stationary predator (e.g.,):

$$CPUE = E - A - C$$

where $E = D * M$, and artifacts include avoidance of traps because of predators collected previously (A) and consumption of collected animals by predators also in the traps (C). In our analyses, all sampling is conducted for 24 hours; all data are in units of catch day^{-1}. We are working in collaboration with Bill Loftus to estimate A and C.

Drift fences were sampled five times this year: week 38, week 41, week 44, week 46, and week 48. Drift fences can only be sampled when water depth is ≥ 15 cm when minnow trap mouths are fully covered (Table IV.3). When water levels at each site exceeded 50 cm, we inserted a second minnow trap above the first, to capture fishes higher in the water column. Contents of each minnow trap were preserved in 10 % formaldehyde.

Sample processing

Sweep-net samples were rinsed with tap water in a 500-µm sieve. Samples were sorted thoroughly and scanned by eye; all animals were removed and placed in 70%

ethanol. All animals removed from sweep samples were identified under magnification to the lowest feasible taxonomic resolution. Macroinvertebrates collected in sweep nets were quantified as the number sweep^{-1}.

Periphyton core samples were stained with rose Bengal =12 h prior to processing. Each samples was placed in a petri dish and animals were removed from the substrate under a dissecting microscope, identified to the lowest feasible taxonomic level, and preserved in 70% ethanol. The remaining plant material from each sample was dried at 70°C for =48 h and incinerated at 500° C for 3 h to obtain dry mass and ash-free dry mass (AFDM) of the substrate. *Utricularia* spp.(bladderwort) and *Bacopa caroliniana* (water-hyssops) in samples were included in mass measurements. Macroinvertebrates in core samples were quantified as mass densities (no. individuals/g AFDM of periphyton).

Two different periphyton-core processing methods were used this year. The '*group*' method enumerated all macroinvertebrates visible under a dissecting microscope (not distinguishing between sizes), while the '*separate*' method separately enumerated "large" macroinvertebrates (≥ 1 mm maximum dimension) from "small" macroinvertebrates (< 1 mm maximum dimension). The *group* method was used for some samples collected in October, while the *separate* method was used for samples collected in October and December.

Contents of fence-fence minnow traps were identified in the laboratory. Standard length (SL), mass, and sex (when possible) were recorded for fish, and carapace length (CL) and sex were recorded for crayfish. Total wet weight was recorded for all other vertebrates, molluscs, and all other invertebrates. Animals collected in minnow traps were quantified as the number/minnow trap or catch per unit effort (CPUE).

Data analysis

Physical description of sites. We documented spatial and temporal variation in water depth using a factorial analysis of variance (ANOVA) between treatments (reference v. impacted sites), sites, and sampling events (treatment, site(treatment), week). Analysis of emergent macrophytes focused on 11 common taxa (present in ≥10% of samples). We described variation in community structure among reference and impacted sites using a one-way analysis of similarities (ANOSIM). We then used similarity percentage breakdowns (SIMPER) to determine which taxa contributed most to observed variation, and used non-metric multidimensional scaling to visualize latent patterns. We used nested ANOVA (treatment, site(treatment) on common macrophyte taxa to describe variation in abundances.

Comparison of core-processing methods. For work conducted in Shark River Slough, we have found that excluding all animals less than 1-mm in their longest dimension provided a reasonable cut off for analyses of macroinvertebrates inhabiting periphyton mats (Liston and Trexler 2005). However, we felt it was important to re-evaluate that cut off for work on the short-hydroperiod communities that were key to this project. We

enumerated all animals visible under our dissecting scope for all samples collected in October, while separately tallying the animals larger and smaller than the Shark River Slough cutoff (called the *separate* method). We used multivariate techniques to compare the invertebrate community enumerated by this *separate* method to a set of samples enumerated in entirety (*group* method). To ensure *group* and *separate* samples were comparable, one-way ANOSIM was first used to compare the structure of communities enumerated with each method. We then used a one-way ANOSIM to compare the community composition of the community enumerated with the *group* method to that of only the large animals enumerated with the *separate* method in order to delineate the impact of excluding small macroinvertebrates.

Stratification of fish in the water column. We selected all cases where both top (shallow) and bottom (deep) traps were set in a drift fence, and used a combination of multivariate and univariate statistics to examine differences in the communities they captured. We used a two-way ANOSIM (position, week) to compare the community structure of "shallow" and "deep" communities, and SIMPER to determine which taxa were most influential. ANOVA (position, week) was used to characterize variation in CPUE of individual taxa.

Comparison of IOP-impacted and reference sites. We used a combination of multivariate and univaraiate techniques to compare macroinvertebrate and fish communities at IOP-impacted and references sites throughout the 2004 wet season. Analyses focused on common taxa (macroinvertebrates: present in = 10% of samples; fish: present in = 5% of samples): 20 macroinvertebrate taxa in sweep net samples, 26 macroinvertebrate taxa in periphyton core samples and 12 fish taxa in array samples. Fish by-catch in sweep-net samples, macroinvertebrate by-catch in drift-fence samples, and fish collected in "surface" minnow traps (see previous section) were excluded from analyses. We analyzed macroinvertebrate community structure in sweep and core samples using a 2-way crossed ANOSIM (treatment, month), followed by SIMPER to delineate influential taxa. Variation in the abundance of common sweep and core taxa was analyzed with ANOVA (treatment, site(treatment), month). Fish CPUE was analyzed by averaging the catch in each minnow trap at each drift fence, and using a 2-way crossed ANOSIM (treatment, week), followed by SIMPER and then ANOVA of individual taxa (treatment, site(treatment), week). Trends in directional fish movement through arrays were analyzed for each site using ANOVA of individual taxa (direction, week).

Spatial variation at IOP-impacted sites. We analyzed data collected at sites S332B and S332D to describe variation in community structure and CPUE with distance from the water control structures. Sites were located 50-80 m from the structure ("D1"; S332B: A8 & A9; S332D: A0 & A5), 210-260 m from the structure ("D2"; S332B: B1 & B3; S332D: B4 & B8), or 400-440 m from the structure ("D3"; S332B: C1 & D5; S332D: C1 & D2). We used a two-way crossed ANOSIM (site, distance) to examine variation in macroinvertebrate and fish community structure, and SIMPER to determine which taxa were responsible for most community variation. ANOVA (macroinvertebrates: site, distance(site), month; fish: site, distance(site), week) was then used to delineate patterns in individual taxa.

Abundances of macroinvertebrates (no./sweep, no./g AFDM) and fish (CPUE) were ln (y+1) transformed and macrophyte stem densities (no./m2) were $\sqrt{\sqrt{y}}$ transformed to satisfy assumptions of normality. All ANOSIMs were conducted on standardized Bray-Curtis dissimilarity matrices. We report test statistics based on type III sums of squares, as is recommended for designs with unequal sample sizes.

RESULTS

Physical description of sites

We noted significant variation in water depth and vegetation between reference and impacted sites, and among sites within a treatment. Water depth was 1.7x higher at reference sites than IOP-impacted sites ($F_{1,93} = 80.39$, $P < 0.0001$) and varied significantly among sites within each treatment ($F_{10,93} = 45.81$, $P < 0.0001$). Water depth also varied significantly among weeks ($F_{6,93} = 7.62$, $P < 0.0001$), generally highest in October and early-November (Figure IV.3).

We found over 50 species of emergent macrophyhtes within 160 throw-trap samples (32 arrays x 5 throws/array) (Appendix 1). Significant variation was seen in macrophyte community structure between reference and impacted sites (Global R = 0.176, $P = 0.010$; Figure IV.4). SIMPER indicated reference sites were characterized by *Eleocharis cellulosa* (coastal spikerush), *Rhynchospora tracyii* (Tracy's beakrush), *Cladium jamaicense* (sawgrass), and *Muhlenbergia capillaris* (hair grass) (cumulative similarity = 90%), while IOP-impacted sites were characterized by *C. jamaicense*, *Centella asiatica* (coinwort), *R. tracyii*, *M. capillaris*, and *Crinum americanum* (southern swamp-lily) (cumulative similarity = 73%). Density of *E. cellulosa* was 1.5x higher at reference sites and densities of *Andropogon glomeratus* (bushy broom grass), *C. asiatica*, *C. jamaicense*, *Panicum hemitomon* (maidencane), and *Phyla nodiflora* (frog-fruit) were 6.0x, 6.3x, 1.2x, 1.9x, and 118.9x higher at impacted sites (Figure IV.5). *C. americanum* was present only at impacted sites. Site(treat) was significant for 9 of 11 common taxa and total stem density (Table IV.4), but pairwise differences were inconsistent.

Comparison of core processing methods

We found only subtle differences between the macroinvertebrates enumerated in the *group* and *separate* methods. ANOSIM indicated *group* and *separate* samples were comparable, because there was no variation between the techniques in community structure exceeding the within sample-type variation ($P = 0.890$). Furthermore, we found no difference between these two communities when small macroinvertebrates were excluded from *separate* samples ($P = 0.177$). Six taxa, however, were encountered only when small macroinvertebrates were enumerated: Chydoridae, Harpaticoida, *Hydra* spp., Copepoda (nauplii), Platyhelminthes, and Rotifera. While these taxa would be excluded

from samples if small macroinvertebrates were not enumerated, they all have relatively low incidence and relative abundance, with the exception of Chydoridae (Table IV.5).

Stratification of fish in the water column

In 2004 there were a total of 40 cases where water depth at the arrays exceeded 50 cm and we stacked two minnow traps ("shallow" and "deep"). While we saw no variation in fish community structure among sampling events in this data subset ($P = 0.114$), shallow and deep communities were remarkably different (Global $R = 0.427$, $P = 0.001$; Figure IV.6). The shallow fish community was characterized by *Gambusia holbrooki* (eastern mosquitofish) and *Poecilia latipinna* (sailfin mollies) (cumulative dissimilarity = 93.36%), and the deep fish community was characterized by *Lepomis marginatus* (dollar sunfish) and *Lucania goodei* (bluefin killifish) (cumulative similarity = 93.75%). Only CPUE of *G. holbrooki* and *L. goodei* varied significantly (Table IV.6), however, with *G. holbrooki* more abundant in shallow traps and *L. goodei* more abundant in deep traps. CPUE in shallow and deep traps became more different as the season progressed for both taxa (Figure IV.7).

Comparison of IOP-impacted and reference sites

We collected sixty-three macroinvertebrate taxa and six fish taxa in 296 sweep samples collected in September, October and December 2004 (Appendices 2, 3, 4, respectively). We found significant variation in the community structure and abundance of macroinvertebrates among reference and IOP-impacted sites, and throughout the wet season. Multivariate analyses indicated macroinvertebrate community structure in sweep net samples was significantly different at impacted sites (Global $R = 0.256$, $P = 0.001$), driven primarily by *Dasyhelea* spp., Ephemeroptera, *Hyalella azteca*, dipteran pupae, *Physella* spp., Tanypodinae, and Oligochaeta (cumulative dissimilarity = 63.05%). Significant intra-month variation was also seen in sweep net samples (Global $R = 0.092$, $P = 0.006$). Pairwise comparisons indicated variation between September and December ($R = 0.209$, $P = 0.002$), which was driven primarily by Tanytarsus, *Dasyhelea* spp., *Physella* spp., dipteran pupae, Ephemeroptera, *H. azteca*, *Planorbella* spp., and Tanypodinae (cumulative dissimilarity = 61.71%). Abundances of 16 of 20 common taxa varied between reference and impacted sites: 15 taxa and total invertebrates were less abundant at impacted sites, while Ephemeroptera was was more abundant at impacted sites (driven by a high abundance at S332D) (Figure IV.8A, Table IV.7). While we are still working on describing the hydroperiod of each of our study sites, qualitative comparisons of intra-site variation suggest the abundances of *H. azteca*, *Palaemonetes paludosus*, and total abundance are higher at longer-hydroperiod sites (Figure IV.8B).

Fifty-eight macroinvertebrate taxa were collected in 173 periphyton core samples collected in October and December 2004 (Appendices 5 and 6, respectively). Similar trends as those seen in sweep samples were seen in analyses of the community structure and abundance of periphyton mat infauna. Community structure of mat infauna was

significantly different at IOP-impacted sites (Global $R = 0.270$, $P = 0.001$), driven primarily by Chydoridae, Nematoda, Acari, Tanypodinae, *Helicus* spp., Chironomidae, Tanytarsus, Ostracoda, *Dasyhelea* spp., and *H. azteca* (cumulative dissimilarity = 59.35%). We noted variation in mat infauna between October and December samples (Global $R = 0.185$, $P = 0.004$), driven primarily by Chydoridae, Nematoda, Acari, Tanytarsus, Tanypodinae, Chironomidae, *Dasyhelea* spp., Oligochaeta, and Ostracoda (cumulative dissimilarity = 53.97%). Densities of 20 of 26 common taxa varied between reference and impacted sites: 18 taxa and total macroinvertebrates were less abundant at impacted sites, while two coleopteran larvae taxa (*Helicus* spp. and *Berosus* spp.) were more abundant at impacted sites (Figure IV.9A, Table IV.8). Increased density of mat infauna with hydroperiod was also suggested in total macroinvertebrate density and several individual taxa (Figure IV.9B).

We collected thirty-two fish taxa in 546 minnow traps embedded in arrays in five sampling events September through December 2005. Fish community structure did not vary significantly among reference and IOP-impacted sites ($P = 0.194$). While structure of fish communities did vary significantly among sampling events (Global $R = 0.048$, $P = 0.031$), particularly between weeks 38 and 46 ($R = 0.167$, $P = 0.004$), weeks 41 and 46 ($R = 0.173$, $P = 0.002$), weeks 38 and 44 ($R = 0.117$, $P = 0.019$), and weeks 41 and 44 ($R = 0.108$, $P = 0.028$), 'week' explained only a small proportion of the community variation in all cases (all $R < 0.175$). The average CPUE of 8 of 12 common fish taxa and total fish CPUE varied significantly among reference and IOP-impacted sites: 7 taxa and were more abundant at impacted sites, 1 taxa (*L. goodei*) was less abundant at impacted sites (Figure IV.10A, Table IV.9). We observed that the CPUE of most of our common fish taxa (6 of 10), and total fish CPUE, varied significantly among sites within treatment. Overall, CPUE appeared to be higher at sites with longer hydroperiods, but upon further inspection our data suggest that fish CPUE decreased with hydroperiod at slough sites (sites 6, 7, 8, 23, and 50), and were notably higher at the short hydroperiod sites in the east Everglades (sites INT, CKKW, CXTE, and CXTW) that are in relatively close proximity to canals (Figure IV.10B). We also found that fish CPUE often varied among sampling events, but no consistent patterns were evident in pairwise comparisons or among taxa. Analysis of directional patterns of fish movement indicated significant directional movement of some taxa at some sites (Table IV.10), but no consistent patterns were apparent.

Spatial variation at IOP-impacted sites

We found some variation in macroinvertebrate and fish community structure and CPUE with distance from the water control structures, but variation was inconsistent and overall trends were unclear. Community structure of macroinvertebrates collected in sweep nets varied among sites (Global $R = 0.596$, $P = 0.001$) and with distance from the structure (Global $R = 0.308$, $P = 0.002$) (Figure IV.11). Variation among sites was driven primarily by Ephemeroptera, *Dasyhelea* spp., *Physella* spp., Oligochaeta, Tanytarsus, and *Hyalella azteca* (cumulative dissimilarity = 54.8%). Variation in community structure

with distance from the structure was attributed to differences between D1 and D2 (R = 0.299, P = 0.020) and between D1 and D3 (R = 0.544, P = 0.004) (D2 and D3 did not vary: P = 0.219). Intra-site spatial variation resulted primarily from *Dasyhelea* spp., Ephemeroptera, *Hyalella azteca*, Tanytarsus, *Physella* spp., and Oligochaeta (cumulative dissimilarity ≈ 54%). Only abundances of Chironomidae and dipteran pupae varied significantly with distance from structure (Table IV.11). Abundances were low at site S332B (often 0), especially close to the structure, and trends at S332D were inconsistent (Figure IV.12).

Multivariate analysis failed to find site (P = 0.849) or distance (P = 0.200) variation in the community structure of periphyton mat infauna. Densities of 11 of 26 common taxa and total infauna density were generally higher at S332D sites (as seen in previous section, see Figure IV.9B). Eleven of 26 common taxa varied significantly with distance from structure (Table IV.12). While trends were somewhat inconsistent, densities at site S332B tended to be highest closest to the structure (D1) and densities at site S332D tended to be highest at an intermediate distance (D2) (Figure IV.13).

Structure of the fish community did not vary significantly among sites S332B and S332D (P = 0.066) or with distance from the structures (P = 0.063). CPUE of three fish species varied with distance from the water control structure (Table IV.13), but variation was inconsistent and difficult to interpret (Figure IV.14).

DISCUSSION

The data reported here represent our first year of baseline data for assessment of future impacts of water delivery from the new S-332 structures and their operations. For that reason, we have extended our sampling to sites throughout the Shark River Slough to provide a reference point for interpretations of findings in the Rocky Glades. Much of our results this year are methodological

We found that inclusion of small invertebrates in our counts from periphyton cores (less than the 1-mm cut off used for Shark River Slough samples) yielded relatively small returns compared to the added processing time. The exception is that we miss all information on Chydorids by expcluding these smaller animals. Chydorids are the dominant family of cladocerans in the Everglades; in lentic systems, cladocerans are critical organisms both in food webs and ecosystem function. In the Everglades and wetlands in general, their role is not as clear; chironomids and amphipods probably play much more important roles in food web function in wetlands than to cladocerans. Thus, we recommend retaining the 1-mm cutoff for sampling processing in future Rocky Glades sampling.

We also noted a difference in fish collected from surface and bottom samplers when water depths rose above 0.5m. This is not too surprising because of the generally high abundance of eastern mosquitofish, also called topminnows. As surface feeding fishes with upturned mouths, it is not surprising that they dominated in surface traps. More

surprising was the dominance of bluefin killifish in the bottom traps. Its possible that the presence of aggressive mosquitofish at the surface forces bluefin killifish to the bottom. Whatever the reason for this spatial partitioning, we recommend that future use of the drift fence include doubling trapping when water depth exceeds 0.5 m.

Our most surprising result was that fish abundance was greatest in the eastern, short-hydroperiod, sites. This is inconsistent with expectations from throw-trap studies where fish density decreases with shortening hydroperiod (e.g. Loftus and Eklund 1996; Trexler et al. 2001; Ruetz et al. 2005). Macroinvertebrate density decreased in the Rocky Glades compared to longer-hydroperiod sites. Macroinvertebrate density often controlled by top-down forces in temporary aquatic systems (Batzer et al 2004), and our inverse relationship between fish CPUE and macroinvertebrate density is consistent with a similar explanation for the Everglades. However, we believe that the high fish capture rate may have been from high rates of fish movement and encountering the drive fences, rather than high density. This may be because fish are moving from canals in the east and heading into the sloughs on the west. Untangling the rate of movement from density of fishes in the Rocky Glades is an important focus for work in the coming year.

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Table IV.1. List of all reference and impacted array sites in the study, including a description of site location and UTM coordinates.

	#	Array	Site	Site Description	UTM Easting	UTM Northing
Reference Sites	1	6N	Site 6	Adjacent to Plot A, W of trail	0526824	2835470
	2	6S	Site 6	63 m W of Plot B, E of trail	0527824	2835090
	3	7N	Site 7	2.8 km N of Plot C, E of trail	0524165	2829481
	4	7S	Site 7	2.6 km N of Plot C, W of trail (Loftus array 12)	0524008	2829322
	5	8N	Site 8	83 m S of Plot C, W of trail	0517034	2819524
	6	8S	Site 8	124 m N of Plot A, E of trail (Loftus array 13)	0516702	2818798
	7	23N	Site 23	360 m S of Plot A	0538436	2840505
	8	23S	Site 23	150 m W of Plot C	0538334	2839761
	9	50N	Site 50	Adjacent to Plot A	0524178	2841345
	10	50S	Site 50	Adjacent to Plot C	0523961	2840645
	11	INTN	Intermediate	E of Site 8, W of Context Rd (Loftus array 10)	0526032	2820552
	12	INTS	Intermediate	E of Site 8, W of Context Rd	0525839	2820421
	13	CKKEA	East Chekika	S of visitor area, W side of Boundary Rd	0542423	2828885
	14	CKKEB	East Chekika	S of visitor area, W side of Boundary Rd	0542351	2828985
	15	CKKWA	West Chekika	8.6 km W of Boundary Rd, 10 Km E of arrays at Site 7	0533967	2828936
	16	CKKWB	West Chekika			
	17	CXTEA	East Context Rd	100 m NE of gate, N of road	0542611	2820358
	18	CXTEB	East Context Rd	200 m NE of gate, N of road	0542483	2820357
	19	CXTWA	West Context Rd	N of bend at W end of Context Rd	0533847	2820119
	20	CXTWB	West Context Rd			
Impacted Sites	21	A8	S332B	75 m W of retention pond	542660	2825446
	22	A9	S332B	80 m W of retention pond	542623	2825204
	23	B1	S332B	210 m W of retention pond	542474	2824939
	24	B3	S332B	260 m W of retention pond	542464	2825308
	25	C1	S332B	400 m W of retention pond	542291	2825351
	26	D5	S332B	430 m W of retention pond	542275	2824870
	27	A0	S332D	60 m W of L31W	541174	2811983
	28	A5	S332D	50 m W of L31W	541187	2811880
	29	B4	S332D	210 m W of L31W	541026	2812084
	30	B8	S332D	260 m W of L31W	540974	2811915
	31	C1	S332D	410 m W of L31W	540982	2812007
	32	D2	S332D	440 m W of L31W	540803	2811719

Table IV.2. Number of D-frame sweep net and periphyton core samples collected in September (week 38), October (week 41), and December (week 48) 2004 (replicate samples averaged at each array for analyses).

			September		October		December	
	Site	Array	Sweep	Core	Sweep	Core	Sweep	Core
Reference Sites	6	N	5	0	5	5	3	3
		S	5	0	5	5	3	3
	7	N	3	0	5	3	3	3
		S	5	0	5	3	3	3
	8	N	5	0	5	3	3	3
		S	5	0	5	3	3	3
	23	N	5	0	5	3	3	3
		S	5	0	5	3	1	3
	50	N	4	0	5	3	3	3
		S	5	0	5	3	3	3
	CKKE	A	0	0	0	0	0	0
		B	0	0	0	0	0	0
	CKKW	A	5	0	5	5	3	3
		B	5	0	5	5	3	3
	CXTE	A	0	0	0	0	3	3
		B	0	0	0	0	3	3
	CXTW	A	0	0	2	0	3	3
		B	0	0	0	0	3	3
	INT	N	2	0	5	5	3	3
		S	4	0	5	5	3	3
Impacted Sites	S332B	A8	0	0	0	0	3	3
		A9	0	0	3	3	3	3
		B1	0	0	3	5	3	3
		B3	0	0	0	0	3	3
		C1	0	0	5	5	3	3
		D5	0	0	5	5	3	3
	S332D	A0	5	0	5	1	3	0
		A5	5	0	5	0	3	0
		B4	4	0	5	4	3	2
		B8	4	0	5	3	3	3
		C1	4	0	5	5	3	3
		D2	5	0	5	5	3	3
Total samples			90	0	118	90	88	83

Table IV.3. Orientation ("direction") of minnow traps sampled in each array during the five sampling events in 2004. N = north, S = south, E = east, W = west, "---" = no traps set (water depth < 15 cm). Underline indicates 2 traps (shallow and deep) were sampled.

			Week of Sampling				
	Site	Array	38	41	44	46	48
Reference Sites	6	N	SEW	NSEW	EW	NSEW	NSEW
		S	EW	NSEW	NSEW	NSEW	NSEW
	7	N	NSEW	NSEW	NSW	NSEW	NSEW
		S	NSEW	NE	NSEW	NSEW	NSEW
	8	N	SEW	NSEW	NSEW	NSEW	NSEW
		S	NSEW	NSEW	NSEW	NSEW	NSEW
	23	N	NSEW	NSEW	NSEW	NSEW	NSEW
		S	NSE	NSEW	NSEW	NSEW	NSEW
	50	N	NE	---	NSEW	NSEW	NSEW
		S	SEW	SEW	NSEW	---	NSEW
	CKKE	A	---	---	---	---	---
		B	---	---	---	---	---
	CKKW	A	NSEW	SW	NSW	NSEW	NSEW
		B	NSEW	NSEW	NSEW	NSEW	NSEW
	CXTE	A	---	---	---		
		B	---	---	---	---	---
	CXTW	A	---	NSEW	NSEW	NSEW	NSEW
		B	---	---	---	---	---
	INT	N	NSEW	NSEW	NSEW	NSEW	NSEW
		S	NSEW	NSEW	NSEW	NSEW	NSEW
Impacted Sites	S332B	A8	---	---	---	NSEW	---
		A9	---	---	NSEW	NSEW	NSW
		B1	---	---	NSEW	---	---
		B3	---	---	NSEW	NSEW	NSEW
		C1	---	NSEW	NSEW	NSEW	NSEW
		D5	---	---	---	NSEW	NSEW
	S332D	A0	NSEW	N	NSEW	NSEW	---
		A5	NSEW	SW	NSEW	NSEW	---
		B4	NSEW	NSEW	NSEW	NSEW	---
		B8	NSEW	NSEW	NSEW	NSEW	---
		C1	NSEW	---	NSEW	NSEW	---
		D2	NSEW	SEW	NSEW	NSEW	---

Table IV.4. ANOVA of emergent macrophytes sampled with 5 1-m^2 thow-trap samples in the vicinity of each array. 'Treat' = water management treatment (reference v. IOP-impacted). Only common taxa (incidence = 10%) with significant effects ($P = 0.05$) are shown.

	Treatment		Site (Treatment)		
Taxon	$F_{1,20}$	P	$F_{10,20}$	P	R^2
Andropogon glomeratus	15.60	**0.001**	3.00	**0.018**	0.695
Centella asiatica	35.29	**< 0.001**	2.83	**0.023**	0.761
Cladium jamaicense	3.97	0.060	5.91	**< 0.001**	0.759
Crinum americanum	34.88	**< 0.001**	2.83	**0.023**	0.759
Eleocharis cellulosa	9.05	**0.007**	19.38	**< 0.001**	0.910
Muhlenbergia capillaris	5.86	**0.025**	27.01	**< 0.001**	0.932
Panicum hemitomon	5.38	**0.031**	5.13	**0.001**	0.739
Panicum tenerum		0.382	12.22	**< 0.001**	0.860
Phyla nodiflora	14.65	**0.001**	2.42	**0.045**	0.660
Rhyncospora tracyi		0.795	2.32	**0.053**	0.537
Total Stems		0.122	2.99	**0.018**	0.619

Table IV.5. Incidence and relative abundance of small (< 1 mm maximum dimension) macroinvertebrate taxa in periphyton core samples processed with the *separate* method. These taxa would be excluded from collections if samples were processed enumerating only large macroinvertebrates (e.g., Liston and Trexler (2005)).

Taxon	% Incidence	% Relative abundance
Chydoridae	57.7	18.5
Copepod nauplii	11.5	0.2
Harpaticoida	38.5	2.6
Hydra spp.	7.8	< 0.1
Platyhelminthes	57.7	1.0
Rotifera	28.9	0.3

Table IV.6. ANOVA of fish collected in stacked minnow traps in arrays. 'Position' = position in water column (shallow v. deep). Only taxa with significant effects ($P = 0.05$) are shown.

	Week	Position		Week x Position		
Taxon	P	$F_{1,72}$	P	$F_{3,72}$	P	R^2
Gambusia holbrooki	0.219	21.65	0.002	2.73	0.050	0.323
Lucania goodei	0.239	3.95	0.051	3.55	0.019	0.231

Table IV.7. ANOVA of macroinvertebrates collected in D-frame sweep net samples. 'Treat' = water management treatment (reference v. IOP-impacted). Superscripts on insect taxa indicate larval (L) or pupal (P) life stages. Chironomidae includes all members of the family with the exception of Tanypodinae and Tanytarsus, and Ceratopogonidae includes all members of the family with the exception of *Dasyhelea* spp. Only common taxa (incidence = 10%) with significant effects ($P = 0.05$) are shown.

	Treat		Site (Treat)		Month		Treat x Month		Site (Treat) x Month		
Taxon	$F_{1,46}$	P	$F_{9,46}$	P	$F_{2,46}$	P	$F_{2,46}$	P	$F_{14,46}$	P	R^2
Acari	7.70	**0.008**	5.21	< **0.001**		0.924		0.943		0.802	0.595
Ceratopogonidae^{L}	67.65	< **0.001**	18.34	< **0.001**	21.88	< **0.001**	7.58	**0.001**	5.38	< **0.001**	0.891
Chironomidae^{L}*	47.27	< **0.001**	33.79	< **0.001**	10.14	< **0.001**		0.140		0.236	0.895
Coenagrionidae^{L}	5.78	**0.020**	6.44	< **0.001**		0.807	3.63	**0.034**		0.623	0.654
Dasyhelea spp.^{L}	81.45	< **0.001**	10.18	< **0.001**	6.60	**0.003**		0.847		0.513	0.823
Diptera^{P}	44.68	< **0.001**	4.89	< **0.001**		0.192	4.85	**0.012**		0.469	0.742
Ephemeroptera^{L}	36.45	< **0.001**	3.34	**0.003**	3.52	**0.038**	9.53	< **0.001**		0.984	0.737
Gerris^{L}		0.061	5.39	< **0.001**		0.069		0.938		0.206	0.622
Hyalella azteca	39.12	< **0.001**	26.04	< **0.001**	3.76	**0.031**		0.851		0.569	0.867
Lepidoptera^{L}	13.70	**0.001**	13.77	< **0.001**		0.326		0.178		0.074	0.790
Littoridinops monroensis		0.141	42.24	< **0.001**	66.77	< **0.001**	6.48	**0.003**	13.54	< **0.001**	0.943
Oligochaeta	7.68	**0.008**	13.38	< **0.001**	11.35	< **0.001**		0.331		0.193	0.773
Palaemonetes paludosus	64.06	< **0.001**	31.89	< **0.001**	6.22	**0.004**	3.33	**0.045**	6.24	< **0.001**	0.912
Pelocoris femoratus^{A}	8.68	**0.005**	3.68	**0.002**		0.179		0.106		0.575	0.592
Physella spp.	6.03	**0.018**	9.93	< **0.001**		0.333		0.080		0.516	0.737
Planorbella spp.	33.46	< **0.001**	30.47	< **0.001**		0.257		0.091		0.275	0.886
Stratiomyidae^{L}		0.992	2.89	**0.009**	5.35	**0.008**		0.828		0.177	0.572
Tanypodinae^{L}	97.29	< **0.001**	25.03	< **0.001**		0.197		0.561	2.49	**0.010**	0.894
Tanytarsus^{L}	106.84	< **0.001**	50.40	< **0.001**	14.62	< **0.001**		0.128		0.166	0.930
Total Invertebrates	81.21	< **0.001**	38.39	< **0.001**	8.35	**0.001**		0.122		0.458	0.910

Table IV.8. ANOVA of macroinvertebrates collected in 6-cm diameter periphyton mat core samples. 'Treat' = water management treatment (reference v. IOP-impacted). Superscripts on insect taxa indicate adult (A), larval (L) or pupal (P) life stages. Chironomidae includes all members of the family with the exception of Tanypodinae and Tanytarsus, and Ceratopogonidae includes all members of the family with the exception of *Dasyhelea* spp. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*. Only common taxa (incidence = 10%) with significant effects ($P = 0.05$) are shown.

	Treat		Site(Treat)		Month		Treat x Month		Site(Treat) x Month		
Taxon	$F_{1,31}$	P	$F_{9,31}$	P	$F_{1,31}$	P	$F_{1,31}$	P	$F_{8,31}$	P	R^2
Acari	19.28	< **0.001**	5.82	< **0.001**		0.229		0.757	2.47	**0.034**	0.761
Berosus spp.^{L}	33.26	< **0.001**	4.45	< **0.001**		0.471		0.409		0.999	0.703
Ceratopogonidae^{L}	4.67	**0.039**	4.62	**0.001**		0.286		0.985		0.168	0.661
Chironomidae^{L}	27.47	< **0.001**	21.61	< **0.001**	7.49	**0.010**	4.25	**0.048**		0.066	0.896
Chydoridae	39.19	< **0.001**	17.81	< **0.001**	22.89	< **0.001**		0.927	3.52	**0.005**	0.897
Coleoptera^{A}	11.44	**0.002**	10.84	< **0.001**		0.231		0.711	16.00	< **0.001**	0.887
Cyclopoida	30.32	< **0.001**	13.43	< **0.001**	28.62	< **0.001**	5.55	**0.025**	5.52	< **0.001**	0.889
Dasyhelea spp.^{L}	16.16	< **0.001**	15.42	< **0.001**	7.35	**0.011**		0.178		0.210	0.856
Diptera^{P}		0.477	4.88	< **0.001**		0.124	4.01	**0.054**		0.284	0.660
Ephemeroptera^{L}		0.245	2.76	**0.017**		0.072		0.055		0.170	0.615
Harpaticoida	55.07	< **0.001**	21.41	< **0.001**	33.85	< **0.001**	10.24	**0.003**	4.95	**0.001**	0.920
Helicus spp.^{L}	34.18	< **0.001**	3.20	**0.008**	41.49	< **0.001**	47.36	< **0.001**		0.497	0.831
Heteroptera^{A}	34.01	< **0.001**	11.78	< **0.001**	8.20	**0.008**		0.060	4.05	**0.002**	0.864
Hyalella azteca	190.84	< **0.001**	72.97	< **0.001**		0.092		0.805	5.20	< **0.001**	0.968
Macrothricidae	59.10	< **0.001**	29.96	< **0.001**		0.126		0.240		0.687	0.919
Nematoda		0.651	7.90	< **0.001**	19.39	< **0.001**		0.756		0.839	0.775
Oligochaeta	5.50	**0.026**	5.86	< **0.001**	15.31	**0.001**		0.640		0.057	0.766
Ostracoda	8.32	**0.007**	15.06	< **0.001**	7.08	**0.012**		0.630		0.394	0.848
Physella spp.	76.01	< **0.001**	53.97	< **0.001**	7.94	**0.008**	7.29	**0.011**	6.98	< **0.001**	0.956
Platyhelminthes	8.45	**0.007**	5.09	< **0.001**		0.280		0.422		0.340	0.687
Rotifera		0.888	3.17	**0.008**	16.30	< **0.001**		0.995	2.53	**0.030**	0.692
Sididae	7.35	**0.011**	5.71	< **0.001**		0.084		0.398		0.280	0.710
Stratiomyidae^{L}		0.420		0.932	7.80	**0.009**		0.396		0.847	0.381
Tanypodinae^{L}	319.45	< **0.001**	124.27	< **0.001**		0.114	24.67	< **0.001**	5.25	< **0.001**	0.981
Tanytarsus^{L}	60.71	< **0.001**	35.51	< **0.001**		0.288		0.703		0.126	0.929
Total Invertebrates	16.68	< **0.001**	17.58	< **0.001**	12.52	**0.001**		0.997		0.132	0.876

Table IV.9. ANOVA of abundance of fish collected in minnow traps in drift fence arrays. 'Treat' = water management treatment (reference v. IOP-impacted). Analyses were conducted on average CPUE of traps in each cardinal direction at each array, and only fish collected in "bottom" traps were included in analyses. Only common taxa (incidence = 5%) with significant effects ($P = 0.05$) are shown.

	Treat		Site (Treat)		Week		Treat x Week		Site (Treat) x Week		
Taxon	$F_{1,62}$	P	$F_{9,62}$	P	$F_{4,62}$	P	$F_{4,62}$	P	$F_{30,62}$	P	R^2
Gambusia holbrooki	27.42	< **0.001**	5.40	< **0.001**	2.78	**0.035**		0.150		0.080	0.744
Poecilia latipinna	13.81	< **0.001**		0.373		0.364		0.230		> 0.999	0.457
Fundulus confluentus	5.41	**0.023**		0.228	3.26	**0.017**		0.718		0.517	0.559
Lucania goodei	4.74	**0.033**	10.70	< **0.001**		0.537		0.904		0.290	0.704
Fundulus chrysotus	15.25	< **0.001**		0.837	2.57	**0.046**	2.77	**0.035**		0.997	0.570
Lepomis gulosus	7.88	**0.007**	3.27	**0.003**	2.54	**0.049**	3.01	**0.025**		0.916	0.572
Lepomis punctatus		0.379		0.653		0.360	2.97	**0.026**		0.994	0.392
Lepomis marginatus	21.52	< **0.001**	7.66	< **0.001**	3.62	**0.010**		0.093		0.369	0.737
Cichlasoma urophthalmus		0.334	2.25	**0.030**		0.721		0.168		0.908	0.476
Hemichromis letourneuxi	81.62	< **0.001**	12.19	< **0.001**	6.97	< **0.001**	5.97	< **0.001**	2.55	**0.001**	0.807
Total fish	57.21	< **0.001**	6.21	< **0.001**	4.40	**0.003**		0.593		0.396	0.761

Table IV.10. ANOVA of abundance of fish collected in minnow traps in each direction in drift fence arrays. "Direction" = orientation of minnow trap in array (north, south, east, west). Analyses were conducted on CPUE of traps in each cardinal direction at each array, and only fish collected in "bottom" traps were included in analyses. Only common taxa (incidence = 5%) with significant effects ($P = 0.05$) are shown.

		Direction		Week		Direction x Week		
Site	Taxon	$F_{3,16}$	P	$F_{4,16}$	P	$F_{11,16}$	P	R^2
Site 6	*Lepomis marginatus*		0.153	3.68	**0.026**		0.153	0.715
	Total fish	3.22	**0.051**		0.532		0.969	0.487
		$F_{3,21}$	P	$F_{4,21}$	P	$F_{12,21}$	P	R^2
Site 7	*Lucania goodei*	11.72	< **0.001**	3.43	**0.026**	3.43	**0.007**	0.812
	Lepomis marginatus	5.80	**0.005**		0.558		0.841	0.565
	Total fish	3.82	**0.025**		0.385		0.762	0.529
		$F_{3,19}$	P	$F_{4,19}$	P	$F_{12,19}$	P	R^2
Site 8	*Gambusia holbrooki*		0.632	7.52	**0.001**		0.223	0.722
		$F_{3,9}$	P	$F_{4,9}$	P	$F_{12,9}$	P	R^2
Site 50	Total fish		0.577	4.43	0.030		0.426	0.786
		$F_{3,17}$	P	$F_{4,17}$	P	$F_{12,17}$	P	R^2
Site CKKW	*Hemichromis letourneuxi*		0.695	9.13	< **0.001**		0.871	0.726
		$F_{3,19}$	P	$F_{4,19}$	P	$F_{12,19}$	P	R^2
Site INT	*Gambusia holbrooki*		0.471	10.62	< **0.001**	2.80	**0.022**	0.807
	Lepomis gulosus	7.65	**0.002**		0.132	2.37	**0.045**	0.763
	Lepomis marginatus	5.05	**0.010**	5.70	**0.004**		0.154	0.758
	Total fish		0.065	7.68	**0.001**		0.165	0.762
		$F_{3,39}$	P	$F_{3,39}$	P	$F_{9,39}$	P	R^2
Site S332B	*Hemichromis letourneuxi*		0.547	10.01	< **0.001**		0.983	0.474
	Lepomis marginatus	3.18	**0.035**		0.469		0.229	0.392
	Poecilia latipinna		0.632	3.25	**0.032**		0.963	0.300
	Total fish		0.260	4.78	**0.006**		0.405	0.452
		$F_{3,70}$	P	$F_{3,70}$	P	$F_{9,70}$	P	R^2
Site S332D	*Fundulus chrysotus*		0.075	9.94	< **0.001**		0.466	0.383
	Fundulus confluentus		0.087	10.55	< **0.001**		0.458	0.375
	Gambusia holbrooki	3.25	**0.027**	7.41	< **0.001**		0.327	0.376
	Jordanella floridae		0.191	4.00	**0.011**		0.875	0.223
	Lepomis marginatus		0.148	11.21	< **0.001**		0.308	0.430
	Lepomis punctatus	2.70	**0.052**	3.83	**0.013**		0.436	0.284
	Total fish		0.270	7.39	< **0.001**		0.456	0.331

Table IV. 11. ANOVA of macroinvertebrates collected in D-frame sweep net samples at sites S332B and S332D. Sites were located 50-80 m from the structure (S332B: A8 & A9; S332D: A0 & A5), 210-260 m from the structure (S332B: B1 & B3; S332D: B4 & B8), or 400-440 m from the structure (S332B: C1 & D5; S332D: C1 & D2). Only common taxa (incidence = 10%) with significant effects ($P = 0.05$) are shown. Superscripts on insect taxa indicate larval (L) or pupal (P) life stages. Chironomidae includes all members of the family with the exception of Tanypodinae and Tanytarsus.

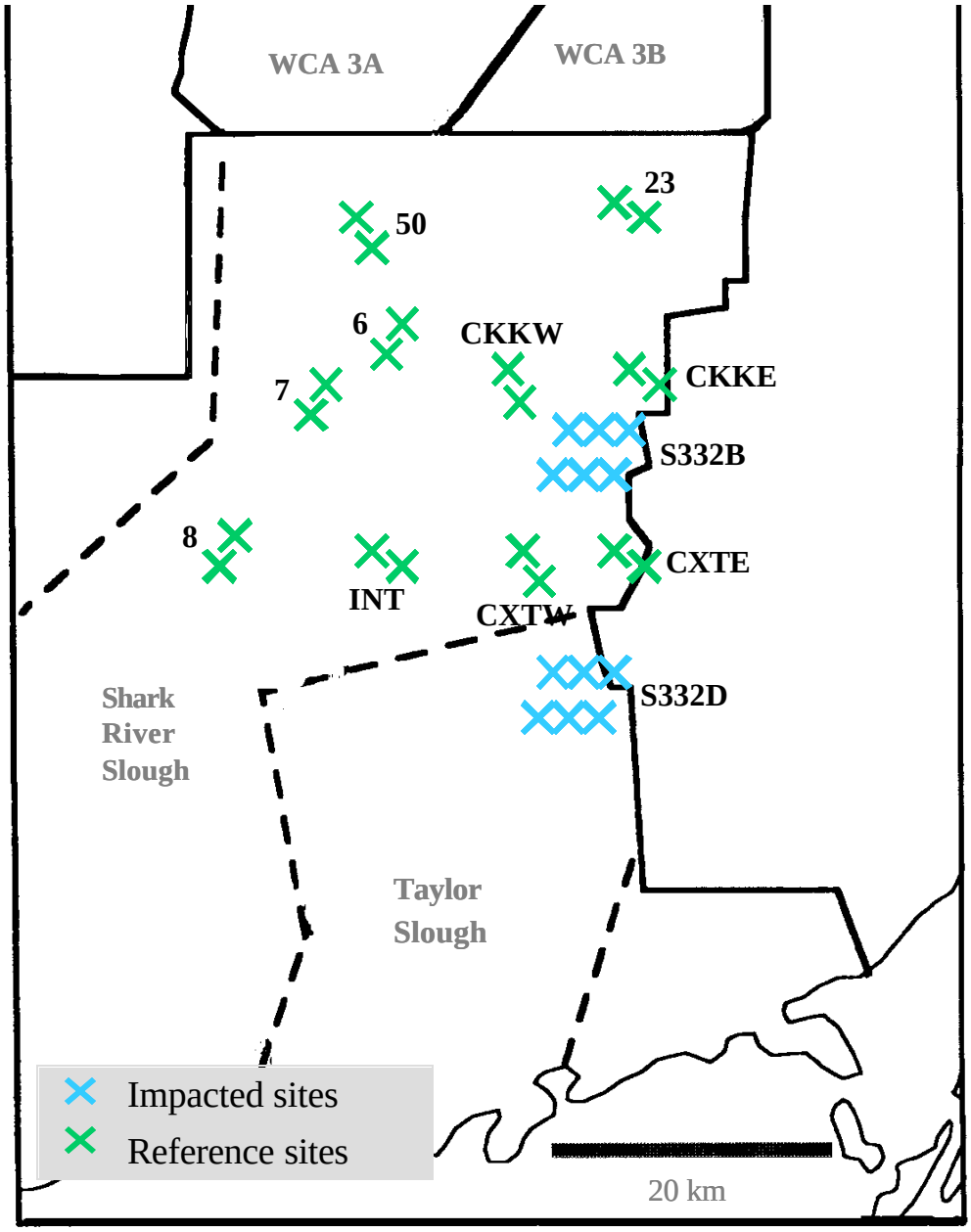
	Site		Distance(Site)		Month		Site x Month		Distance(Site) x Month		
Taxon	$F_{1,13}$	P	$F_{4,13}$	P	$F_{2,13}$	P	$F_{1,13}$	P	$F_{6,13}$	P	R^2
Chironomidae^{L}	5.10	**0.042**	4.00	**0.025**	10.90	**0.002**		0.111		0.330	0.800
Diptera^{P}		> 0.999	4.14	**0.022**	49.65	**< 0.001**		> 0.999	5.51	**0.005**	0.928

Table IV. 12. ANOVA of macroinvertebrates collected in 6-cm diameter periphyton mat core samples at sites S332B and S332D. Sites were located 50-80 m from the structure (S332B: A8 & A9; S332D: A0 & A5), 210-260 m from the structure (S332B: B1 & B3; S332D: B4 & B8), or 400-440 m from the structure (S332B: C1 & D5; S332D: C1 & D2). Superscripts on insect taxa indicate larval (L) life stages. Chironomidae includes all members of the family with the exception of Tanypodinae and Tanytarsus. Only common taxa (incidence = 10%) with significant effects (P = 0.05) are shown.

	Site		Distance(Site)		Month		Site x Month		Distance(Site) x Month		
Taxon	$F_{1,8}$	P	$F_{4,8}$	P	$F_{1,8}$	P	$F_{1,8}$	P	$F_{3,8}$	P	R^2
Acari	6.27	**0.037**	5.35	**0.021**		0.132	8.99	**0.017**		0.192	0.866
Berosus spp.^{L}	19.38	**0.002**	3.76	**0.053**		0.745		0.677		0.584	0.865
Chironomidae^{L}	19.19	**0.002**		0.110		0.813	7.05	**0.029**		0.421	0.825
Chydoridae		0.170		0.067	15.07	**0.005**	13.27	**0.007**		0.987	0.844
Cyclopoida		0.079		0.135	8.53	**0.019**	11.38	**0.010**		0.815	0.819
Dasyhelea spp.^{L}		0.438	11.76	**0.002**	7.63	**0.025**		0.654		0.581	0.868
Ephemeroptera^{L}	20.92	**0.002**	6.15	**0.015**		0.211		0.278		0.814	0.824
Harpaticoida	7.94	**0.023**	10.38	**0.003**	48.03	**< 0.001**	36.28	**< 0.001**		0.116	0.947
Helicus spp.^{L}		0.173		0.652	39.48	**< 0.001**		0.110		0.621	0.866
Nematoda	20.68	**0.002**	23.08	**< 0.001**	72.93	**< 0.001**		0.786		0.331	0.967
Oligochaeta		0.465	9.42	**0.004**	17.41	**0.003**	8.41	**0.020**		0.786	0.886
Ostracoda	51.82	**< 0.001**	20.05	**< 0.001**	17.83	**0.003**	6.93	**0.030**		0.617	0.964
Physella spp.	8.31	**0.020**	4.47	**0.034**		0.499		0.988		0.112	0.853
Platyhelminthes	6.90	**0.030**		0.786		0.533		0.065		0.933	0.759
Rotifera	8.12	**0.022**	6.72	**0.011**	18.48	**0.003**	16.12	**0.004**		0.641	0.905
Tipulidae^{L}	9.14	**0.017**	16.61	**0.001**	22.46	**0.002**	33.38	**< 0.001**	9.68	**0.005**	0.953
Total Invertebrates	29.81	**0.001**	11.57	**0.002**	27.29	**0.001**	8.78	**0.012**		0.419	0.948

Table IV.13. ANOVA of fish collected in minnow traps in arrays at sites S332B and S332D. Sites were located 50-80 m from the structure (S332B: A8 & A9; S332D: A0 & A5), 210-260 m from the structure (S332B: B1 & B3; S332D: B4 & B8), or 400-440 m from the structure (S332B: C1 & D5; S332D: C1 & D2). Only common taxa (incidence = 5%) with significant effects ($P = 0.05$) are shown.

	Site		Distance(Site)		Week		Site x Week		Distance(Site) x Week		
Taxon	$F_{1,15}$	P	$F_{4,15}$	P	$F_{4,15}$	P	$F_{2,15}$	P	$F_{10,15}$	P	R^2
Gambusia holbrooki	4.53	**0.050**	3.22	**0.043**		0.073	3.88	**0.044**		0.566	0.760
Fundulus confluentus		0.494	3.53	**0.032**	4.73	**0.011**	4.40	**0.031**		0.074	0.845
Jordanella floridae	8.22	**0.012**		0.200		0.244		0.214	3.44	**0.015**	0.846
Lepomis gulosus		0.896		0.155	4.14	**0.019**		0.352		0.413	0.719
Lepomis marginatus		0.779	3.98	**0.021**	5.07	**0.009**		0.111		0.691	0.814
Hemichromis letourneauxi	26.33	< **0.001**		0.102	3.68	**0.028**	6.80	**0.008**		0.316	0.854


WCA 3A
WCA 3B
23
50
6
CKKW
7
CKKE
S332B
8
INT
CXTE
CXTW
S332D
Shark
River
Slough
Taylor
Slough
Impacted sites
Reference sites
20 km

Figu
impa

Figure IV.2. Photograph of a typical drift-fence array; this one is located at a short-hydroperiod site.

Figure IV.3. Average water depth at each site during each sampling event in 2004. Error bars represent ±1 SE.

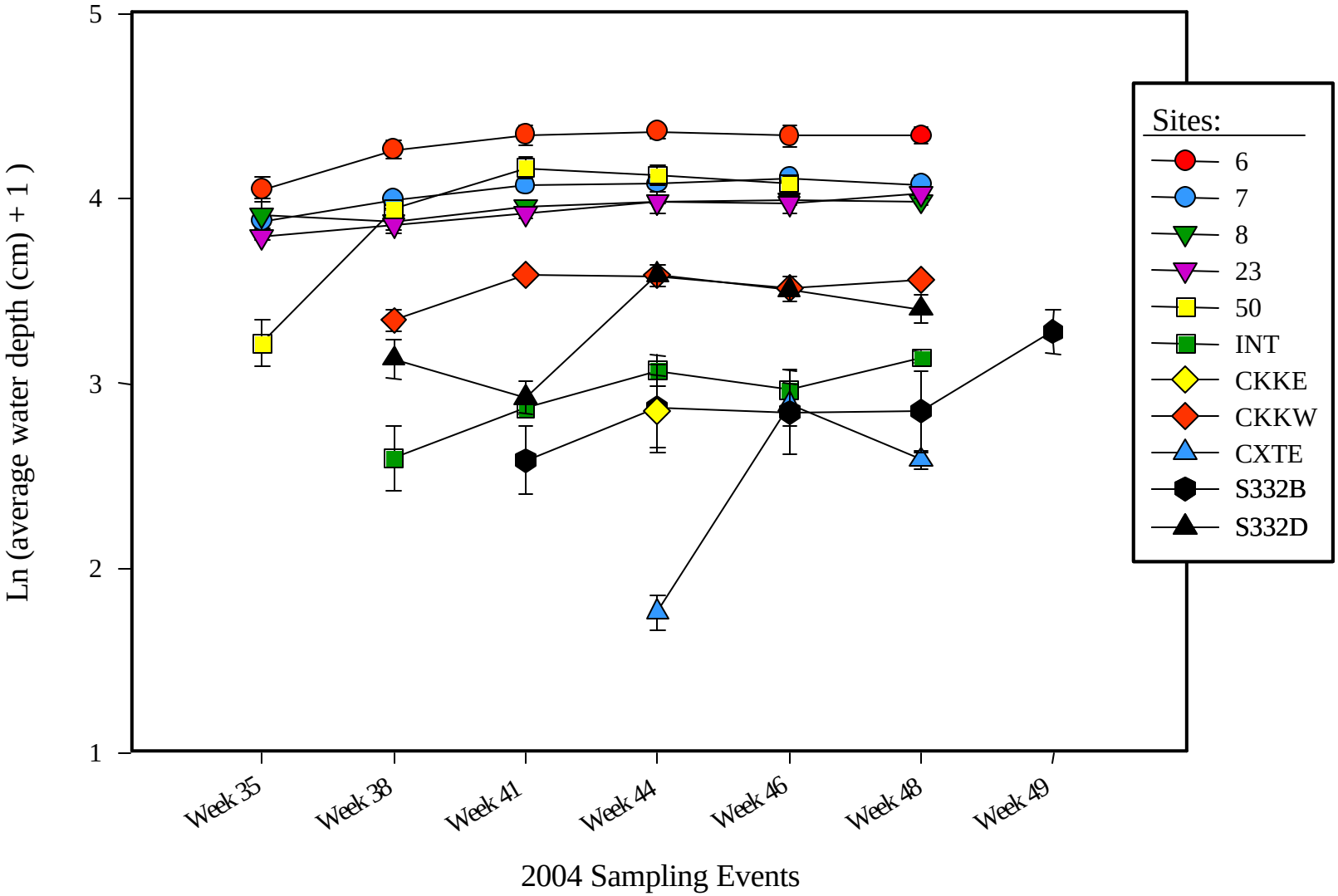


Figure IV.4. NMDS of the community structure of emergent macrophytes sampled with a 1-m^2 throw-trap at reference and IOP-impacted sites (stress = 0.06).

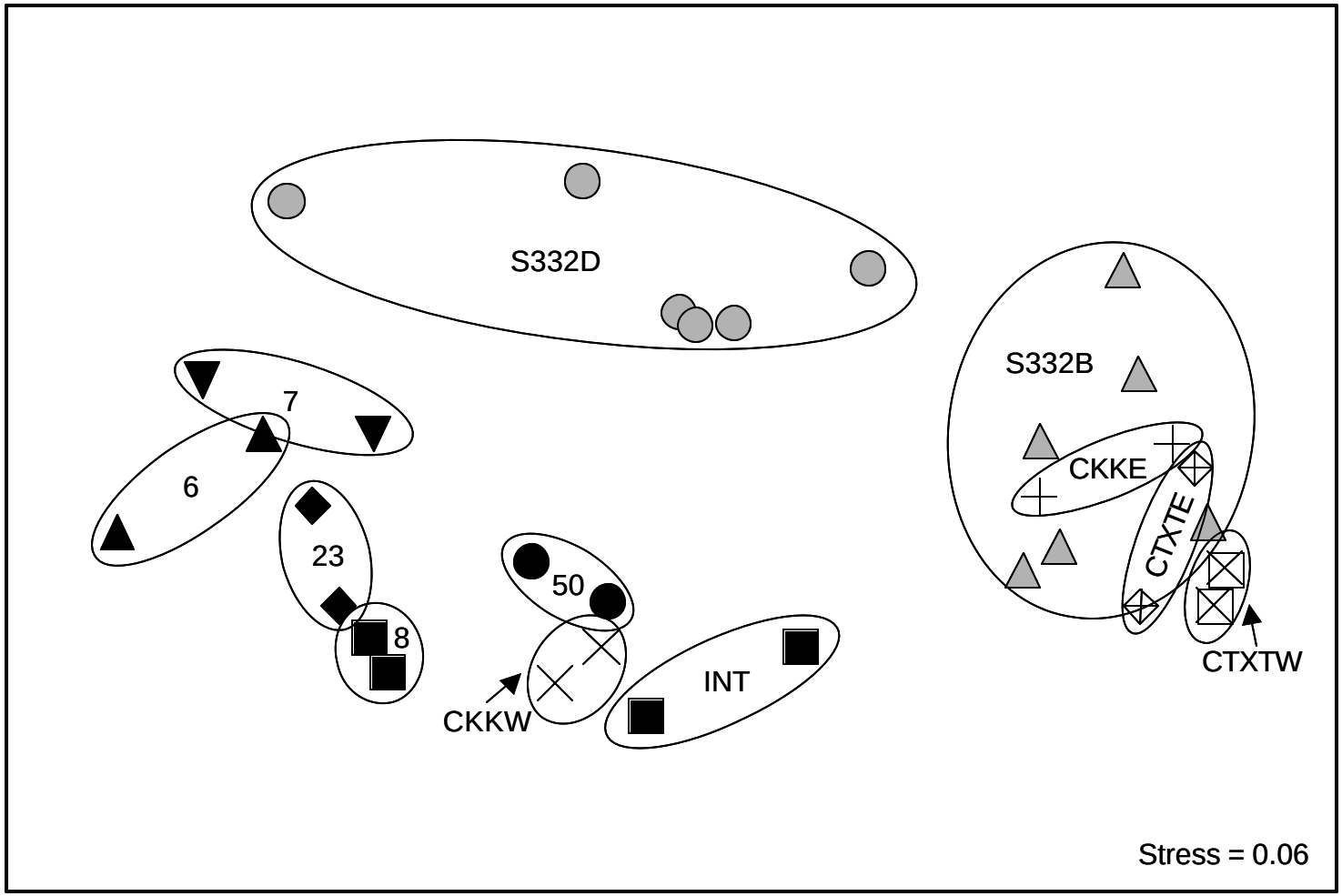


Figure IV.5. Density of emergent macrophytes sampled with a 1-m^2 throw-trap by taxa (common taxa) at reference and IOP-impacted sites (A) and total density among sites (B) (error bars represent ±1 SE).

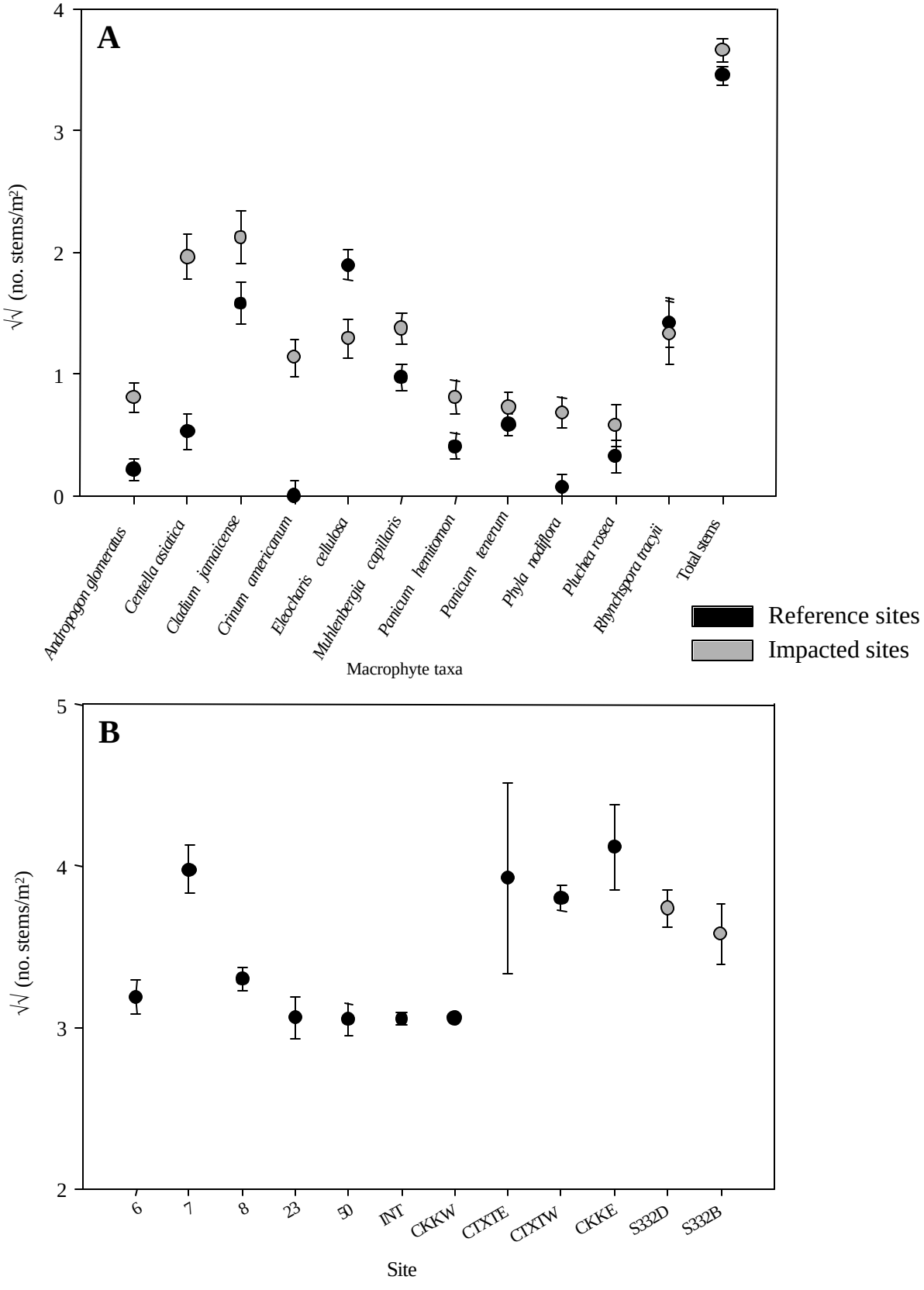


Figure IV.6. NMDS of the community structure of fish sampled in shallow and deep minnow traps at arrays (stress = 0.05).

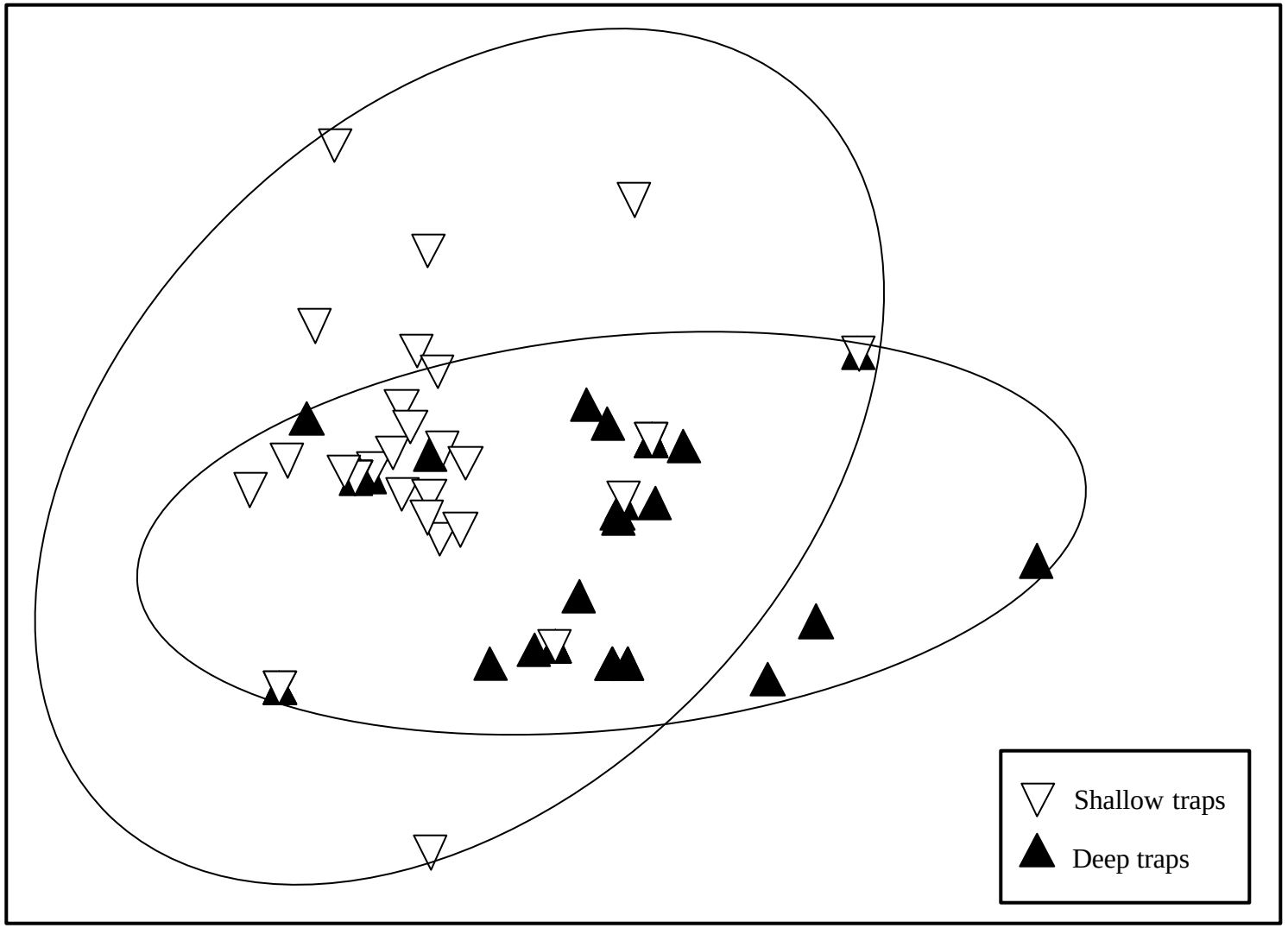


Figure IV.7. Abundance of fish in shallow and deep minnow traps during each sampling event in 2004 (two stacked minnow traps were deployed in arrays when water depth exceeded 50 cm). Only *Gambusia holbrooki* (A) and *Lucania goodei* (B) abundances varied with position in the water column (error bars represent ±1 SE).

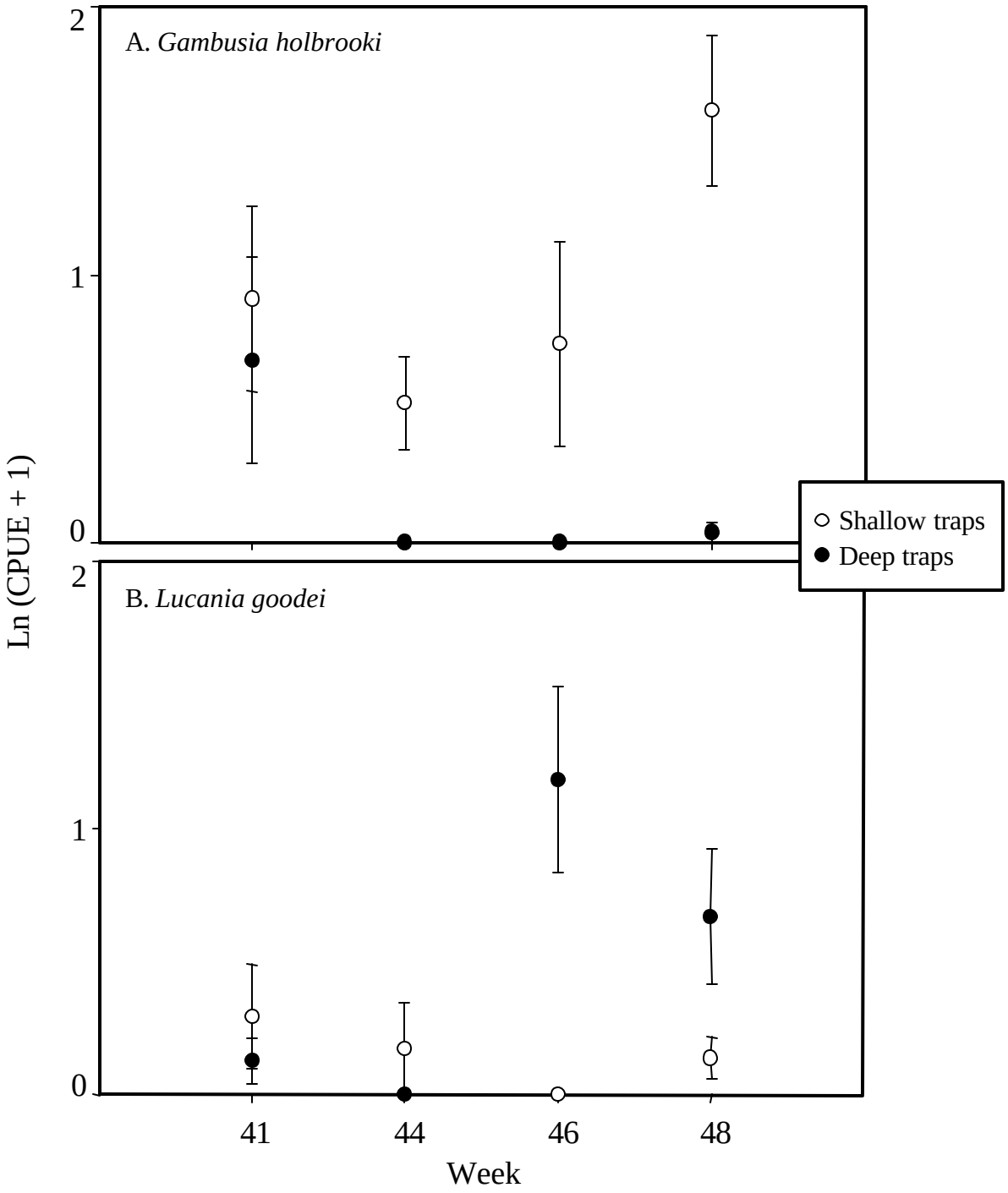


Figure IV.8. Abundance of macroinvertebrates collected in D-frame sweep nets by taxa (10 most common taxa) at reference and IOP-impacted sites (A) and total abundance among sites (B) (error bars represent ±1 SE).

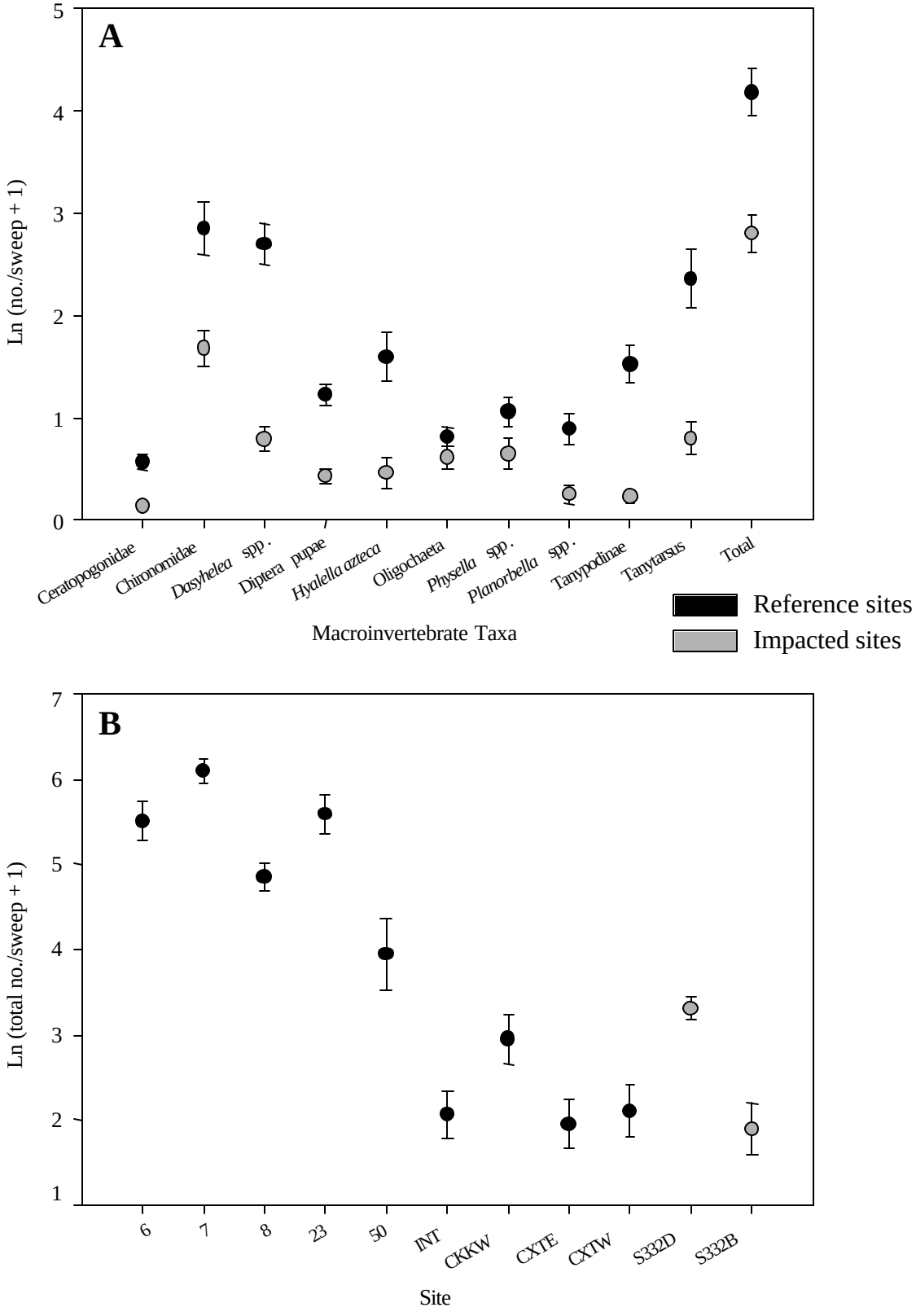


Figure IV.9. Density of macroinvertebrates collected in periphyton cores by taxa (12 most common taxa) at reference and IOP-impacted sites (A) and total density among sites (B) (error bars represent ±1 SE).

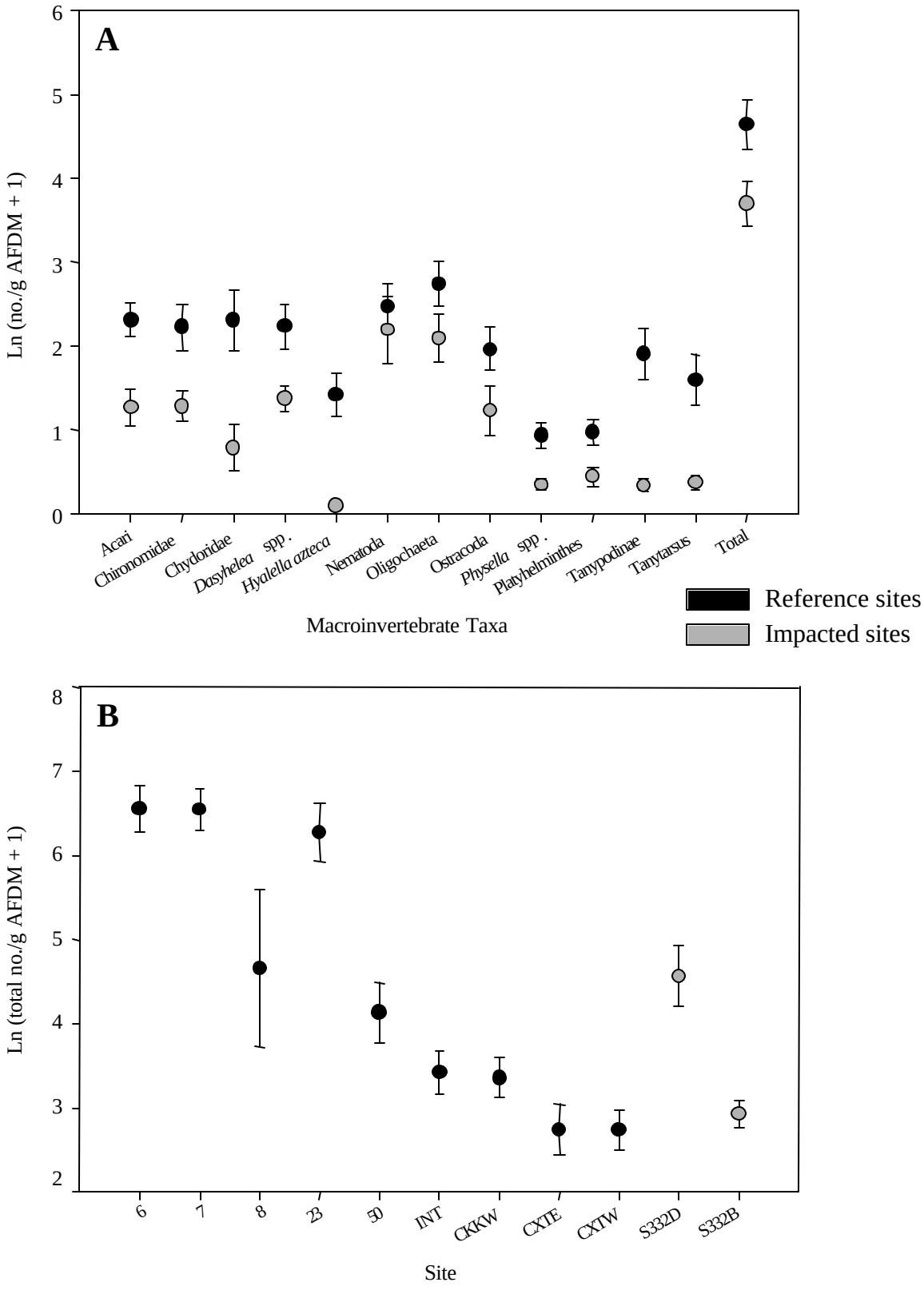
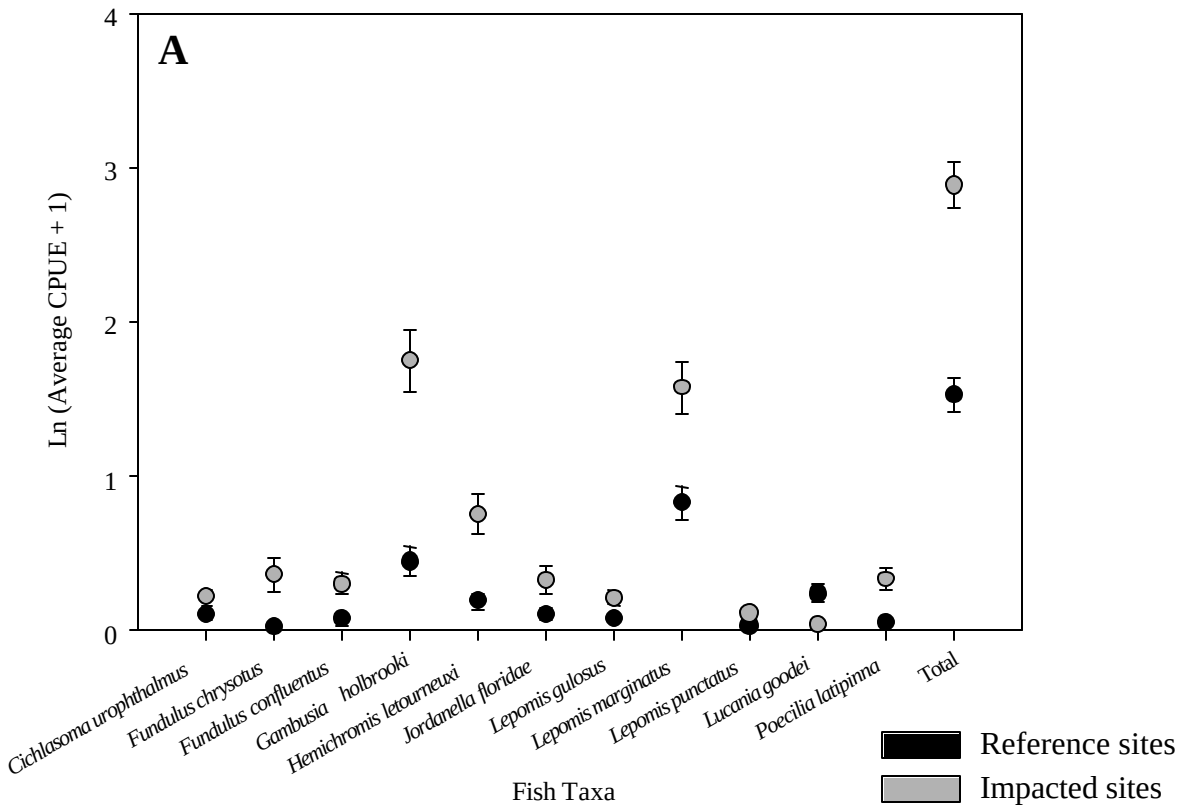


Figure IV.10. Abundance of fish collected in arrays by taxa (11 common taxa) at reference and IOP-impacted sites (A) and total abundance among sites (B) (error bars represent ±1 SE).



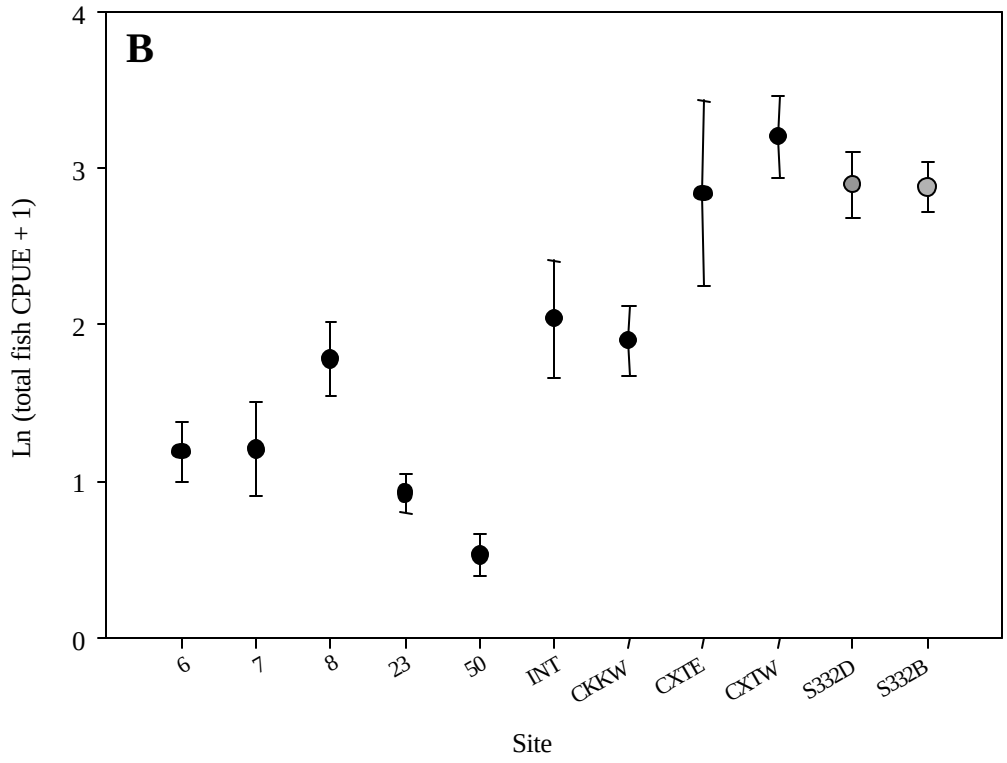


Figure IV.11. NMDS of community structure of macroinvertebrates sampled in D-frame sweep nets with distance from water control structure at sites S332B and S332D (stress = 0.12).

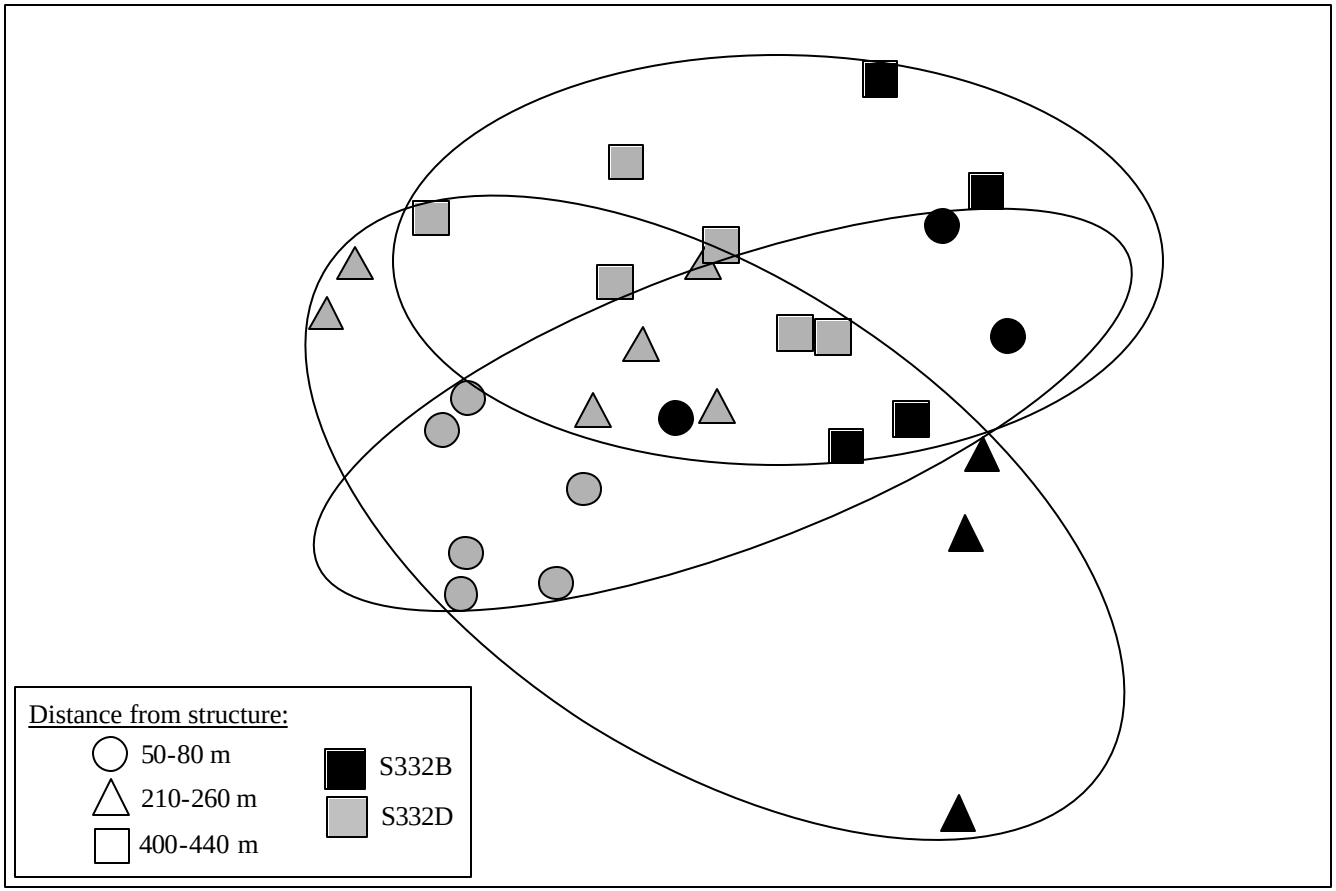


Figure IV.12. Abundance of macroinvertebrates sampled in D-frame sweep nets with distance from water control structure at sites S332B and S332D. Chironomidae includes all members of the family with the exception of Tanypodinae and Tanytarsus. Only common taxa (incidence ≥ 10%) with significant effects (P ≤ 0.05) are shown.

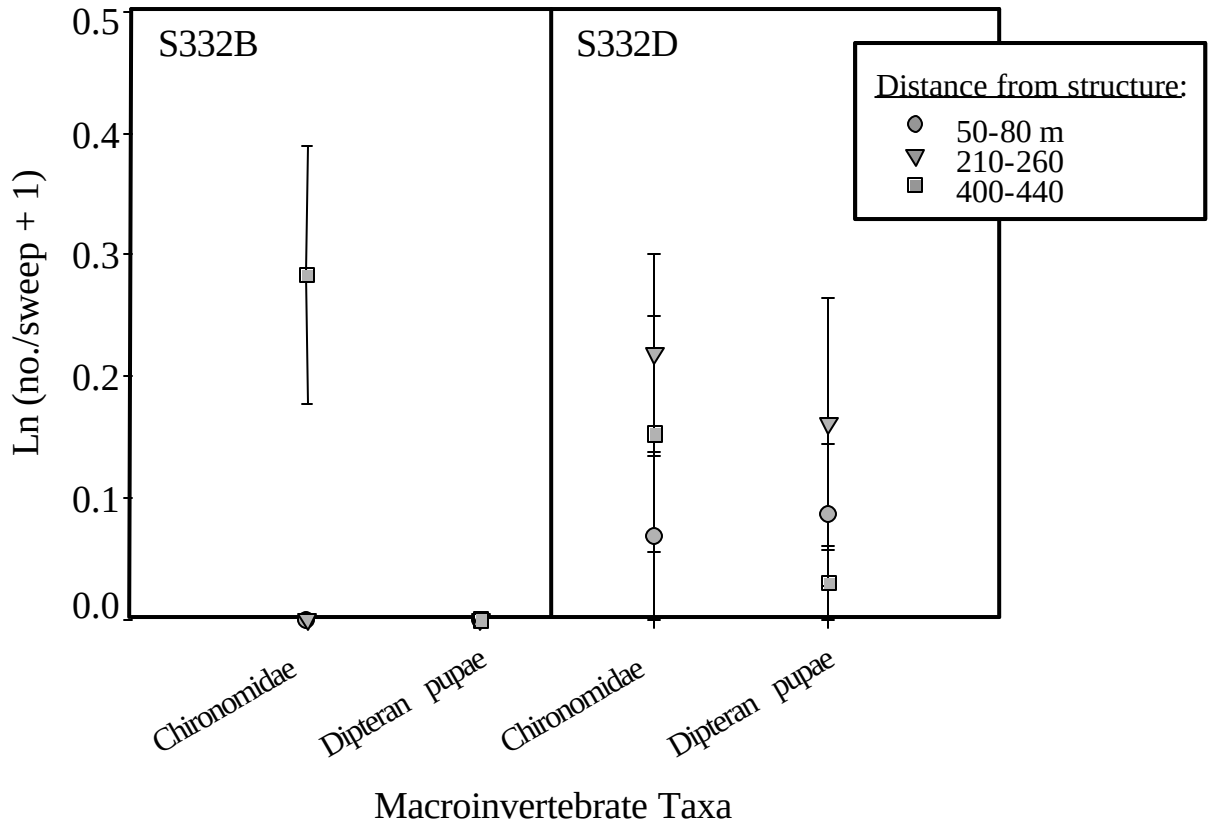


Figure IV.13. Abundance of macroinvertebrates sampled in periphyton cores with distance from water control structure at sites S332B and S332D. Only common taxa (incidence ≥ 10%) with significant effects ($P \leq 0.05$) are shown.

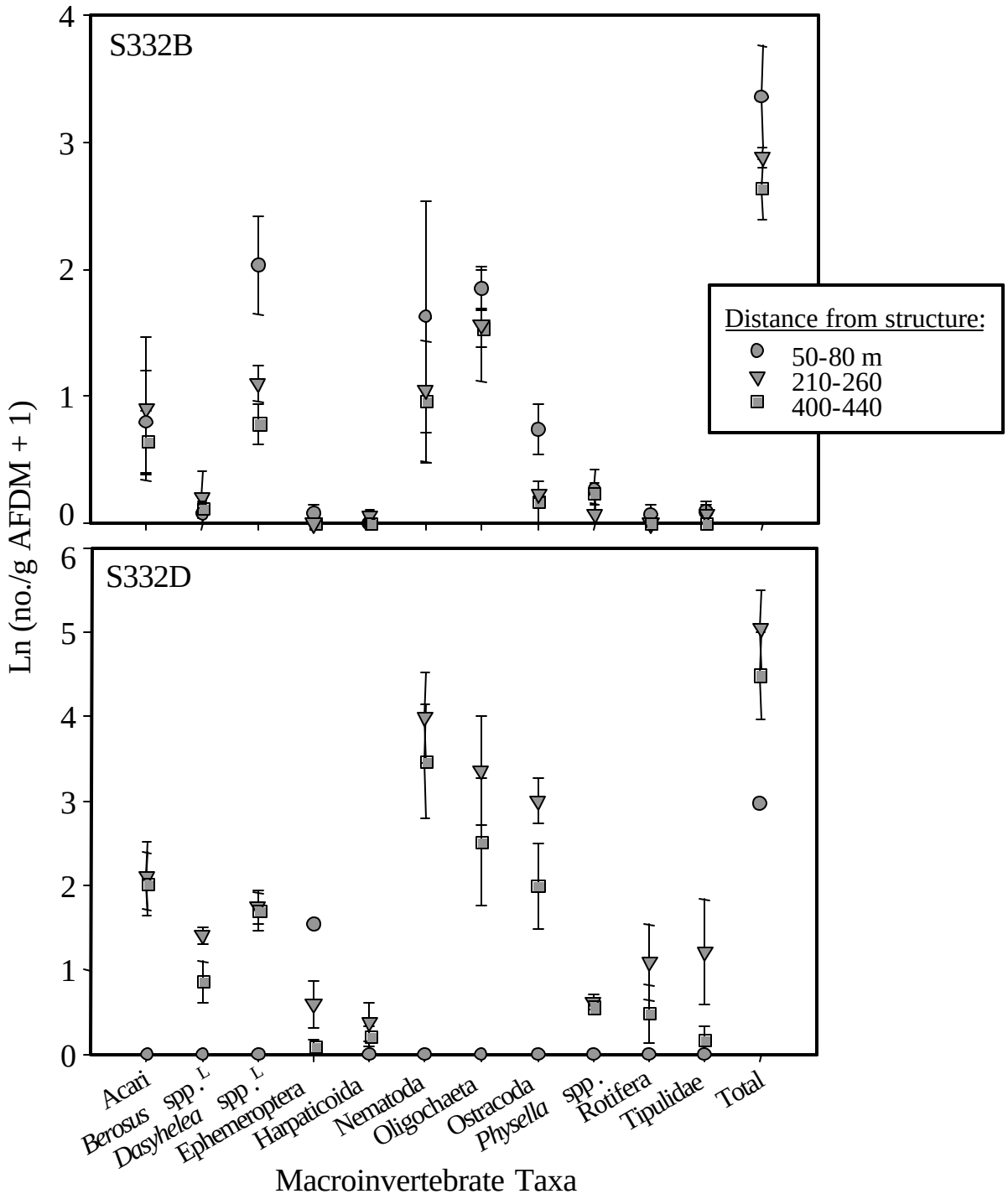
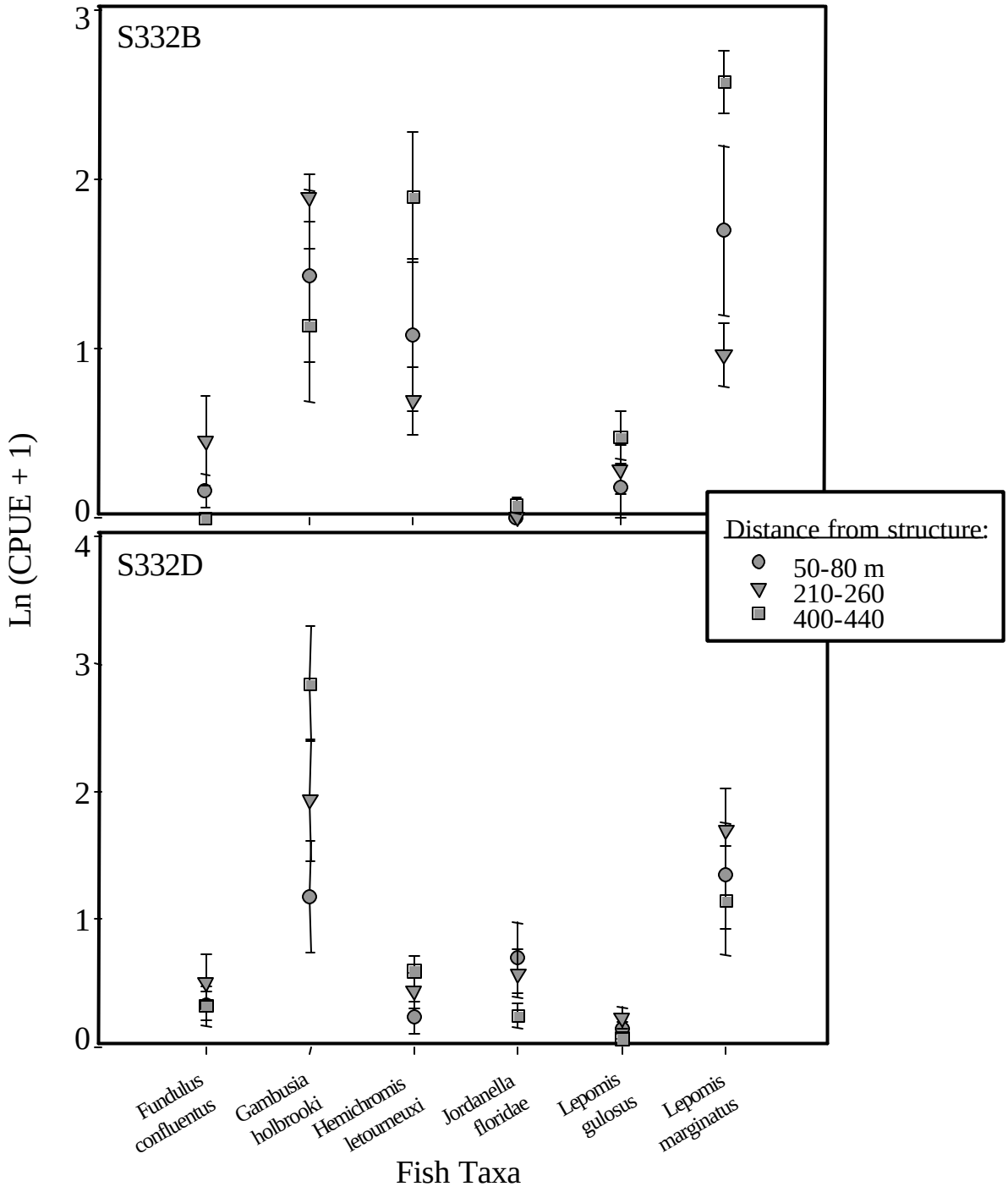


Figure IV.14. Abundance of fish sampled in arrays with distance from water control structure at sites S332B and S332D. Only common taxa (incidence ≥ 5%) with significant effects ($P \leq 0.05$) are shown.



Appendices

Appendix 1. Total incidence and average density (no./m^2 ±SE) of emergent macrophyte stems enumerated in 1-m^2 throw-traps at each site in September 2004 (N = number of arrays/site; 5 replicate samples collected at each array and averaged; "0" indicates species was not encountered).

		REFERENCE SITES					
Species	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)	Site INT (*N* = 2)
Abdilgaardia ovata	1.9	0	0	0	0	0	0
Aeschynomene pratensis	0.6	0	0	0	0	0.10 (±0.10)	0
Andropogon glomeratus	11.9	0	0	0	0	0	0
Angadenia berteroi	3.8	0	0	0	0	0	0
Annona glabra	0.6	0	0	0	0	0	0
Aristida affinis	2.5	0	0	0	0	0	0
Baccharis halimifolia	0.6	0	0	0	0	0	0
Boehmeria cylindrica	3.1	0	0	0	0	0	0
Carphephorus odoratissimus	1.3	0	0	0	0	0	0
Cassytha filiformis	3.8	0	0	0	0	0	0
Centella asiatica	33.8	0	0	0	0	0	0.60 (±0.60)
Chiococca alba	5.6	0	0	0	0	0	0
Cirsium horridulum	3.1	0	0	0	0	0	0
Cladium jamaicense	59.4	0	0.40 (±0.40)	0	0	27.50 (±14.1)	29.00 (±8.20)
Coelorachis spp.	3.1	0	0	0	0	0	0
Crinum americanum	14.4	0	0	0	0	0	0
Cyperus spp.	1.3	0	0	0	0	0	0
Eleocharis baldwinii	0.6	0	0	0	0	0	0
Eleocharis cellulosa	53.1	93.90 (±5.90)	233.50 (±42.70)	74.80 (±15.00)	73.00 (±20.60)	28.00 (±17.60)	6.40 (±0.20)
Eragrostis spp.	7.5	0	0	0	0	0	0
Erigeron vernus	3.8	0	0	0	0	0	0
Eupatorium capillifolium	5.6	0	0	0	0	0	0
Eupatorium mikanioides	1.3	0	0	0	0	0	0
Flaveria linearis	3.8	0	0	0	0	0	0
Galium tinctorium	0.6	0	0	0	0	0	0
Hymenocallis latifolia	1.9	0	0	0	0	0	0
Hyptis alata	6.3	0	0	0	0	0	0
Ipomea sagittata	3.1	0	0	0	0	0	0
Iva frutescens	6.9	0	0	0	0	0	0
Justicia ovata	7.5	0	0	0	0	0	0
Lamiaceae (unidentified)	1.3	0	0	0	0	0	0
Lobelia glandulosa	0.6	0	0	0	0	0	0

(Appendix 1 continued)

Species	Incidence (%)	REFERENCE SITES					
		Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)	Site INT (*N* = 2)
Ludwigia microcarpa	1.3	0	0	0	0	0	0.10 (±0.10)
Mikania scandens	5.0	0	0	0	0	0	0
Muhlenbergia capillaris	30.6	0	0	0	0	0	0.70 (±0.70)
Nymphaea odorata	1.3	0.90 (±0.90)	0	0	0	0	0
Nymphoides aquatica	1.3	5.00 (±5.00)	0	0	0	0	0
Oxypolis filiformis	2.5	0	0	0	0	0	0
Panicum hemitomon	20.0	1.50 (±1.50)	15.50 (±3.30)	0	0.30 (±0.30)	1.00 (±0.40)	0
Panicum tenerum	18.1	0	0	0	0	0	0
Paspalidium geminatum	7.5	1.00 (±1.00)	0.40 (±0.40)	0	0	0.20 (±0.20)	0
Phragmites australis	1.3	0	0	0	0	0	0
Phyla nodiflora	11.9	0	0	0	0	0	0
Phyllanthus carolinensis	3.8	0	0	0	0	0	0
Pluchea rosea	15.0	0	0	0	0	0	1.60 (±1.60)
Polygola grandiflora	1.3	0	0	0	0	0	0
Polygonum spp.	2.5	0	0	0	0	0	0
Pontederia cordata	0.6	0	0	0	0	0	0
Potamogeton illinoiensis	5.0	0	0	1.70 (±0.10)	6.50 (±6.50)	0	0
Rhynchospora inundata	1.3	0	0	0	0	0	0
Rhyncospora colorata	0.6	0	0	0	0	0	0
Rhyncospora tracyi	38.1	0.20 (±0.20)	2.10 (±2.10)	42.20 (±5.00)	6.10 (±2.10)	27.60 (±9.20)	47.60 (±10.80)
Sacciolepis spp.	8.1	0	0	0	0	0.40 (±0.40)	0
Sagittaria lancifolia	6.3	1.30 (±1.30)	0	0	2.40 (±2.40)	1.90 (±1.90)	0.80 (±0.80)
Salix caroliniana	1.9	0	0	0	0	0	0
Setaria spp.	3.1	0	0	0	0	0	0
Solidago spp.	5.0	0	0	0	0	0	0
Solidago stricta	3.1	0	0	0	0	0	0
Spermacoce prostrata	0.6	0	0	0	0	0	0
Stillingia aquatica	0.6	0	0	0	0	0	0
Typha spp.	1.9	0	0	0	0.20 (±0.20)	0	0
Unidentified grasses	16.3	0	0	0	0	0	0
Unidentified seedlings	6.3	0	0	0	0	0	0
Unidentified (other)	4.4	0	0	0	0	0	0
Total		103.80 (±14.00)	251.90 (±37.30)	118.70 (±9.90)	88.50 (±14.90)	86.70 (±10.90)	86.80 (±4.60)

(Appendix 1 continued)

Species	Incidence (%)	REFERENCE SITES Site CKKE (*N* = 2)	Site CKKW (*N* = 2)	Site CXTE (*N* = 2)	Site CXTW (*N* = 2)	IMPACTED SITES Site S332B (*N* = 6)	Site S332D (*N* = 6)
Abdilgaardia ovata	1.9	0	0	13.80 (±5.80)	0	2.90 (±2.90)	0
Aeschynomene pratensis	0.6	0	0	0	0	0	0
Andropogon glomeratus	11.9	0.40 (±0.20)	0	3.80 (±1.80)	0	0.27 (±0.12)	4.73 (±3.47)
Angadenia berteroi	3.8	0.40 (±0.40)	0	0.10 (±0.10)	0	0.23 (±0.13)	0
Annona glabra	0.6	0	0	0	0.10 (±0.10)	0	0
Aristida affinis	2.5	0.90 (±0.90)	0	0.30 (±0.30)	0.20 (±0.20)	0	0
Baccharis halimifolia	0.6	0	0	0	0	0.03 (±0.03)	0
Boehmeria cylindrica	3.1	0	0	0	0	0.23 (±0.23)	0.93 (±0.93)
Carphephorus odoratissimus	1.3	0	0	0.40 (±0.40)	0	0	0
Cassytha filiformis	3.8	0.10 (±0.10)	0	0.50 (±0.50)	0	0.03 (±0.03)	0
Centella asiatica	33.8	42.10 (±28.70)	0	1.50 (±0.30)	2.80 (±0.60)	37.00 (±27.02)	22.40 (±5.95)
Chiococca alba	5.6	0	0	17.60 (±16.60)	0	0.23 (±0.23)	0
Cirsium horridulum	3.1	0	0	0.50 (±0.50)	0	0.13 (±0.10)	0
Cladium jamaicense	59.4	103.30 (±12.70)	21.70 (±18.10)	40.90 (±17.90)	102.10 (±10.50)	42.50 (±8.09)	32.13 (±11.70)
Coelorachis spp.	3.1	0	0	0	0	0	0.40 (±0.19)
Crinum americanum	14.4	0	0	0	0	2.50 (±2.50)	22.57 (±8.42)
Cyperus spp.	1.3	0	0	0	0	0	0.13 (±0.08)
Eleocharis baldwinii	0.6	0	3.20 (±3.20)	0	0	0	0
Eleocharis cellulosa	53.1	0	28.50 (±3.90)	0	0	0	73.67 (±24.05)
Eragrostis spp.	7.5	0	0	10.50 (±0.30)	0	1.30 (±0.59)	0
Erigeron vernus	3.8	0	0	0.80 (±0.80)	0	0.07 (±0.04)	0
Eupatorium capillifolium	5.6	0.10 (±0.10)	0	0.20 (±0.20)	0	1.10 (±0.76)	0.03 (±0.03)
Eupatorium mikanioides	1.3	0	0	0	0.20 (±0.20)	0.07 (±0.07)	0
Flaveria linearis	3.8	0.60 (±0.60)	0	1.20 (±1.20)	0	0	0
Galium tinctorium	0.6	0	0	0	0	0.23 (±0.23)	0
Hymenocallis latifolia	1.9	0	0	0	0	0.17 (±0.08)	0
Hyptis alata	6.3	0	0	0.40 (±0.40)	0	0.13 (±0.13)	1.07 (±0.95)
Ipomea sagittata	3.1	0	0	0	0.40 (±0.40)	0.07 (±0.07)	0.03 (±0.03)
Iva frutescens	6.9	0.50 (±0.10)	0	5.80 (±2.60)	0	0.03 (±0.03)	0
Justicia ovata	7.5	0	0	0	0.70 (±0.70)	0.30 (±0.30)	0.47 (±0.16)
Lamiaceae (unidentified)	1.3	0	0	0	0	0.07 (±0.04)	0
Lobelia glandulosa	0.6	0.10 (±0.10)	0	0	0	0	0
Ludwigia microcarpa	1.3	0	0	0.10 (±0.10)	0	0	0

(Appendix 1 continued)

Species	Incidence (%)	REFERENCE SITES Site CKKE (*N* = 2)	Site CKKW (*N* = 2)	Site CXTE (*N* = 2)	Site CXTW (*N* = 2)	IMPACTED SITES Site S332B (*N* = 6)	Site S332D (*N* = 6)
Mikania scandens	5.0	0.10 (±0.10)	0	0.30 (±0.30)	0.10 (±0.10)	0.13 (±0.10)	0.07 (±0.07)
Muhlenbergia capillaris	30.6	106.20 (±45.20)	0	152.80 (±113.20)	61.90 (±31.90)	58.90 (±17.12)	0.03 (±0.03)
Nymphaea odorata	1.3	0	0	0	0	0	0
Nymphoides aquatica	1.3	0	0	0	0	0	0
Oxypolis filiformis	2.5	0	0	0	0	0.03 (±0.03)	0.17 (±0.13)
Panicum hemitomon	20.0	0	0	0	0	0.10 (±0.07)	6.70 (±2.15)
Panicum tenerum	18.1	12.00 (±3.40)	0	8.80 (±4.60)	38.00 (±27.00)	9.20 (±3.20)	0
Paspalidium geminatum	7.5	0.40 (±0.40)	0	0	0	0.07 (±0.07)	0.27 (±0.14)
Phragmites australis	1.3	0	0	0	0	0	0.23 (±0.15)
Phyla nodiflora	11.9	0.30 (±0.10)	0	0	0	0.07 (±0.07)	7.07 (±3.34)
Phyllanthus carolinensis	3.8	0.60 (±0.60)	0	0.30 (±0.10)	0	0	0
Pluchea rosea	15.0	2.50 (±1.10)	0.40 (±0.40)	0.70 (±0.70)	0.10 (±0.10)	2.13 (±1.35)	0.77 (±0.46)
Polygola grandiflora	1.3	0	0	0	0	0.07 (±0.04)	0
Polygonum spp.	2.5	0	0	0	0	0	1.00 (±0.92)
Pontederia cordata	0.6	0	0	0	0	0	0.20 (±0.20)
Potamogeton illinoiensis	5.0	0	0	0	0	0	0
Rhynchospora inundata	1.3	0	0	0	0	0	0.20 (±0.20)
Rhyncospora colorata	0.6	0	0	0	0	0.03 (±0.03)	0
Rhyncospora tracyi	38.1	15.90 (±15.90)	33.20 (±14.00)	0.70 (±0.70)	0.10 (±0.10)	11.20 (±7.61)	15.43 (±5.21)
Sacciolepis spp.	8.1	0	0	1.10 (±0.10)	0.30 (±0.30)	2.03 (±1.30)	3.27 (±3.27)
Sagittaria lancifolia	6.3	0	0.30 (±0.30)	0	0	0	0.90 (±0.72)
Salix caroliniana	1.9	0	0	0	0	0	1.27 (±1.19)
Setaria spp.	3.1	0	0	0	0.50 (±0.30)	0	0.43 (±0.43)
Solidago spp.	5.0	0.30 (±0.30)	0	0.20 (±0.20)	0	0.40 (±0.33)	0
Solidago stricta	3.1	0.40 (±0.20)	0	1.20 (±0.40)	0	0	0
Spermacoce prostrata	0.6	0	0	0.40 (±0.40)	0	0	0
Stillingia aquatica	0.6	0	0	0	0	0	0.03 (±0.03)
Typha spp.	1.9	0	0	0	0	0	0.80 (±0.80)
Unidentified grasses	16.3	3.70 (±2.30)	0	3.50 (±0.70)	1.20 (±1.20)	2.17 (±1.57)	3.17 (±1.74)
Unidentified seedlings	6.3	2.60 (±2.60)	0	0	0	0.80 (±0.65)	0
Unidentified (other)	4.4	0	0	0.20 (±0.20)	0	0.43 (±0.24)	0
Total		299.80 (±77.20)	87.30 (±2.70)	272.30 (±144.90)	209.80 (±17.60)	180.77 (±35.50)	203.73 (±24.74)

Appendix 2. Total incidence and average abundance (no./sweep ±SE) of macroinvertebrates and fish collected in D-frame sweep net samples at each site in September 2004 (N = number of arrays/site; 1-5 replicate samples collected at each array (see Table D) and averaged; "0" indicates species was not collected). Superscripts indicate insect adult (A), larval or nymph (L), and pupal (P) life stages. Chironomidae includes all members of the family except Tanypodinae and Tanytarsus. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*.

		REFERENCE SITES				
Macroinvertebrate taxa	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Acari	14.3	0	0.27 (±0.07)	0	1.30 (±0.10)	0.23 (±0.03)
Belostoma spp.^{A}	12.1	0	0.67 (±0.33)	0	0.20 (±0.20)	0
Berosus spp.^{L}	4.4	0.10 (±0.10)	0	0	0	0
Brachymesia gravida^{L}	2.2	0.20 (±0.20)	0	0	0	0
Celina spp.^{L}	2.2	0	0	0	0.40 (±0.40)	0
Celithemis eponina^{L}	9.9	0.50 (±0.50)	0	0	0.70 (±0.10)	0
Ceratopogonidae^{L}	25.3	0.10 (±0.10)	1.63 (±0.97)	1.20 (±0.00)	0.20 (±0.20)	0.33 (±0.08)
Chironomidae^{L}	78.0	52.00 (±15.20)	54.30 (±0.70)	38.70 (±7.30)	75.30 (±9.10)	4.95 (±1.55)
Coenagrionidae^{L}	16.5	0.60 (±0.00)	0.40 (±0.40)	0	0.20 (±0.00)	0.10 (±0.10)
Coleoptera^{A}	17.6	0	0.43 (±0.23)	0	0.90 (±0.90)	0.10 (±0.10)
Collembola	2.2	0	0	0	0	0
Corixidae^{L}	1.1	0	0	0	0.10 (±0.10)	0
Daphniidae	1.1	0	0.10 (±0.10)	0	0	0
Dasyhelea spp.^{L}	67.0	33.30 (±31.70)	76.37 (±16.03)	21.50 (±5.30)	26.00 (±19.40)	14.23 (±7.98)
Diptera^{A}	1.1	0	0	0	0	0
Diptera^{P}	63.7	4.90 (±4.30)	6.77 (±1.43)	2.60 (±0.60)	4.40 (±2.60)	1.80 (±0.20)
Enochrus spp.^{L}	13.2	0	1.00 (±0.00)	0	0.30 (±0.30)	0
Ephemeroptera^{L}	38.5	0.30 (±0.10)	0.20 (±0.20)	0.20 (±0.20)	0.80 (±0.00)	0.10 (±0.10)
Erythemis simplicicollis^{L}	3.3	0	0.70 (±0.70)	0	0	0
Gerris spp.	14.3	0.30 (±0.30)	0.57 (±0.23)	0	0.10 (±0.10)	0
Heteroptera^{A}	7.7	0	0.27 (±0.07)	0	0.10 (±0.10)	0
Hyalella azteca	47.3	16.50 (±6.30)	28.00 (±12.00)	0.60 (±0.40)	34.70 (±9.50)	0
Laevapex peninsulae	1.1	0	0	0	0	0
Lepidoptera	12.1	0.20 (±0.20)	0.37 (±0.03)	0	0.70 (±0.10)	0
Lethocerus spp.^{A}	1.1	0	0	0	0	0
Libellula needemi^{L}	2.2	0.10 (±0.10)	0.10 (±0.10)	0	0	0

(Appendix 2 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Littoridinops monroensis	46.2	1.00 (±0.20)	0.57 (±0.23)	0.40 (±0.20)	15.30 (±3.50)	0.45 (±0.05)
Macrothricidae	1.1	0.10 (±0.10)	0	0	0	0
Micromentus dilatatus avus	9.9	0	0	0	0.50 (±0.30)	0
Nematoda	1.1	0	0.10 (±0.10)	0	0	0
Oligochaeta	40.7	1.00 (±0.20)	2.57 (±0.23)	1.90 (±0.70)	0.80 (±0.40)	1.03 (±0.23)
Orthoptera	4.4	0	0	0	0.10 (±0.10)	0
Ostracoda	2.2	0	0.17 (±0.17)	0.10 (±0.10)	0	0
Palaemonetes paludosus	23.1	2.10 (±1.50)	1.30 (±0.30)	0.10 (±0.10)	1.30 (±0.70)	0
Pelocoris femoratus[A]	22.0	0.60 (±0.60)	1.30 (±0.30)	0.50 (±0.10)	0.60 (±0.60)	0.33 (±0.08)
Physella spp.	67.0	3.10 (±2.30)	6.83 (±3.17)	1.10 (±0.70)	22.60 (±15.00)	1.80 (±0.80)
Planorbella spp.	44.0	4.80 (±3.20)	3.80 (±1.80)	0.40 (±0.40)	17.60 (±4.20)	0
Planorbella trivolvis	12.1	0	0	0	1.40 (±1.40)	0
Platyhelminthes	1.1	0	0	0	0	0.10 (±0.10)
Pomacea paludosa	3.3	0	0	0	0	0
Procambarus alleni	5.5	0	0	0	0	0
Pseudosuccinea columella	1.1	0	0	0	0	0.20 (±0.20)
Sphaeriidae	6.6	0.10 (±0.10)	0	0	1.50 (±0.70)	
Stratiomyidae	18.7	0.30 (±0.30)	0.90 (±0.10)	0.30 (±0.10)	0.30 (±0.30)	
Tabanidae	1.1	0	0	0	0.10 (±0.10)	
Tanypodinae	46.2	16.40 (±9.60)	30.53 (±9.87)	6.20 (±3.40)	14.70 (±2.10)	0.80 (±0.20)
Tanytarsus	57.1	102.40 (±45.00)	69.83 (±17.83)	8.70 (±3.10)	56.30 (±28.10)	0.70 (±0.30)
Taphromysis louisianae	1.1	0.30 (±0.30)	0	0	0	0
Trichoptera	8.8	0.10 (±0.10)	0.20 (±0.20)	0.10 (±0.10)	0.30 (±0.10)	0.10 (±0.10)
Unidentified invertebrates	1.1	0	0	0.10 (±0.10)	0	0
Total invertebrates		241.40 (±117.00)	290.23 (±29.57)	84.70 (±11.10)	280.00 (±33.60)	27.33 (±7.08)
Fish taxa						
Fundulus chrysotus	7.7	0	0	0	0	0
Gambusia holbrooki	16.5	0.10 (±0.10)	0.43 (±0.23)	1.50 (±0.90)	0.70 (±0.10)	0
Heterandria formosa	3.3	0	0.17 (±0.17)	0	0.10 (±0.10)	0
Jordanella floridae	1.1	0	0	0	0	0
Lepomis spp.	1.1	0	0	0	0.10 (±0.10)	0
Lucania goodei	13.2	1.00 (±0.00)	0.27 (±0.07)	0	0.40 (±0.00)	0
Unidentified fishes	6.6	0	0.10 (±0.10)	0	0.50 (±0.50)	0

(Appendix 2 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	REFERENCE SITES Site INT (*N* = 2)	IMPACTED SITES Site S332D (*N* = 6)
Acari	14.3	0.20 (±0.20)	0	0.03 (±0.03)
Belostoma spp.[A]	12.1	0	0	0.26 (±0.08)
Berosus spp.[L]	4.4	0	0	0.11 (±0.07)
Brachymesia gravida[L]	2.2	0	0	0
Celina spp.[L]	2.2	0	0	0
Celithemis eponina[L]	9.9	0	0	0
Ceratopogonidae[L]	25.3	0	0	0
Chironomidae[L]	78.0	0.33 (±0.08)	0.75 (±0.75)	5.74 (±2.95)
Coenagrionidae[L]	16.5	0	0	0.26 (±0.07)
Coleoptera[A]	17.6	0	0	0.74 (±0.34)
Collembola	2.2	0.10 (±0.10)	0.25 (±0.25)	0
Corixidae[L]	1.1	0	0	0
Daphniidae	1.1	0	0	0
Dasyhelea spp.[L]	67.0	1.90 (±0.10)	0.25 (±0.25)	0.50 (±0.26)
Diptera[A]	1.1	0	0	0.04 (±0.04)
Diptera[P]	63.7	4.65 (±0.85)	0.38 (±0.38)	0.58 (±0.20)
Enochrus spp.[L]	13.2	0	0	0.17 (±0.13)
Ephemeroptera[L]	38.5	0	0	7.15 (±2.10)
Erythemis simplicicollis[L]	3.3	0	0	0
Gerris spp.	14.3	0.40 (±0.40)	0.25 (±0.25)	0.11 (±0.05)
Heteroptera[A]	7.7	0.10 (±0.10)	0	0.10 (±0.10)
Hyalella azteca	47.3	0	0	0.74 (±0.39)
Laevapex peninsulae	1.1	0	0	0.04 (±0.04)
Lepidoptera	12.1	0	0	0.12 (±0.08)
Lethocerus spp.[A]	1.1	0	0	0.03 (±0.03)
Libellula needemi[L]	2.2	0	0	0
Littoridinops monroensis	46.2	0	0	1.37 (±0.23)
Macrothricidae	1.1	0	0	0
Micromentus dilatatus avus	9.9	0	0	1.32 (±1.22)
Nematoda	1.1	0	0	0

(Appendix 2 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	REFERENCE SITES Site INT (*N* = 2)	IMPACTED SITES Site S332D (*N* = 6)
Oligochaeta	40.7	0.13 (±0.13)	0	0.81 (±0.27)
Orthoptera	4.4	0.13 (±0.13)	0	0.08 (±0.05)
Ostracoda	2.2	0	0	0
Palaemonetes paludosus	23.1	0	0	0
Pelocoris femoratus[A]	22.0	0	0	0.03 (±0.03)
Physella spp.	67.0	0.10 (±0.10)	0.13 (±0.13)	3.97 (±0.92)
Planorbella spp.	44.0	0.25 (±0.25)	0.63 (±0.38)	1.65 (±1.14)
Planorbella trivolvis	12.1	0	0	0.34 (±0.11)
Platyhelminthes	1.1	0	0	0
Pomacea paludosa	3.3	0	0	0.11 (±0.07)
Procambarus alleni	5.5	0	0	0.20 (±0.13)
Pseudosuccinea columella	1.1	0	0	0
Sphaeriidae	6.6	0	0	0.03 (±0.03)
Stratiomyidae	18.7	0	0	0.28 (±0.11)
Tabanidae	1.1	0	0	0
Tanypodinae	46.2	0	0	0
Tanytarsus	57.1	0.30 (±0.30)	0	0.61 (±0.39)
Taphromysis louisianae	1.1	0	0	0
Trichoptera	8.8	0	0	0
Unidentified invertebrates	1.1	0	0	0
Total invertebrates		8.58 (±0.18)	2.63 (±0.88)	27.83 (±6.46)
Fish taxa				
Fundulus chrysotus	7.7	0	0	0.34 (±0.11)
Gambusia holbrooki	16.5	0	0	0.03 (±0.03)
Heterandria formosa	3.3	0	0	0.07 (±0.07)
Jordanella floridae	1.1	0	0	0.04 (±0.04)
Lepomis spp.	1.1	0	0	0
Lucania goodei	13.2	0	0	0
Unidentified fishes	6.6	0	0	0.08 (±0.05)

Appendix 3. Total incidence and average abundance (no./sweep ±SE) of macroinvertebrates and fish collected in D-frame sweep net samples at each site in October 2004 (N = number of arrays/site; 1-5 replicate samples collected at each array (see Table D) and averaged; "0" indicates species was not collected). Superscripts indicate insect adult (A), larval or nymph (L), and pupal (P) life stages. Chironomidae includes all members of the family except Tanypodinae and Tanytarsus. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*.

		REFERENCE SITES				
Macroinvertebrate taxa	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Acari	11.9	0.10 (±0.10)	0.20 (±0.20)	0.20 (±0.00)	0.60 (±0.40)	0
Anisoptera^{L}	0.8	0	0	0	0.20 (±0.20)	0
Belostoma spp.^{A}	2.5	0	0.10 (±0.10)	0	0	0
Berosus spp.L	7.6	0	0	0	0	0.10 (±0.10)
Celithemis eponina^{L}	7.6	0.10 (±0.10)	0.20 (±0.20)	0.10 (±0.10)	1.00 (±0.20)	0
Ceratopogonidae^{L}	34.7	2.60 (±1.00)	5.20 (±0.80)	3.00 (±0.20)	1.80 (±0.20)	0.50 (±0.30)
Chironomidae^{L}	83.1	87.80 (±3.20)	193.80 (±55.40)	86.50 (±3.10)	74.30 (±2.10)	24.40 (±16.60)
Chydoridae	4.2	0.10 (±0.10)	0	0.60 (±0.60)	0.40 (±0.40)	0
Coenagrionidae^{L}	16.9	0.60 (±0.60)	1.10 (±0.30)	0.40 (±0.40)	0.30 (±0.10)	0.10 (±0.10)
Coleoptera^{A}	14.4	0.30 (±0.30)	0.90 (±0.30)	0.70 (±0.70)	0.10 (±0.10)	
Collembola	3.4	0	0	0	0	0
Corixidae^{L}	11.9	0.40 (±0.20)	1.20 (±0.20)	0.20 (±0.20)	0	0
Dasyhelea spp.^{L}	72.0	40.70 (±22.90)	70.70 (±16.10)	60.70 (±10.30)	30.50 (±6.70)	11.70 (±7.70)
Diptera^{P}	55.9	5.30 (±3.30)	10.80 (±2.00)	6.80 (±2.20)	3.20 (±0.40)	1.60 (±0.60)
Enochrus spp.^{L}	6.8	0.10 (±0.10)	0.50 (±0.30)	0	0.10 (0.10)	0
Ephemeroptera^{L}	33.9	0.30 (±0.30)	1.70 (±0.50)	0.50 (±0.10)	0.70 (0.10)	0.30 (0.10)
Erythemis simplicicollis^{L}	4.2	0.10 (±0.10)	0.50 (±0.50)	0	0.30 (0.30)	0
Gerris spp.	14.4	0	2.00 (±0.80)	0.20 (±0.20)	0.90 (±0.50)	0.10 (±0.10)
Helicus spp.^{L}	5.9	0	0	0	0	0
Heteroptera^{A}	4.2	0	0.40 (±0.20)	0.10 (±0.10)	0.10 (±0.10)	0
Hirudinea	0.8	0	0	0	0.10 (±0.10)	0
Hyalella azteca	40.7	14.30 (±1.70)	60.90 (±9.90)	4.00 (±0.40)	34.50 (±1.50)	0.50 (±0.50)
Laevapex peninsulae	0.8	0	0	0	0	0
Lepidoptera	14.4	0.90 (±0.50)	0.40 (±0.20)	0	1.30 (±0.70)	0
Libellula needemi^{L}	2.5	0.10 (±0.10)	0.20 (±0.20)	0	0.10 (±0.10)	0

(Appendix 3 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Littoridinops monroensis	17.8	0.30 (±0.30)	0.80 (±0.40)	0.20 (±0.20)	6.60 (±2.00)	0
Micromentus dilatatus avus	4.2	0	0	0	0	0
Nematoda	3.4	0	0	0.10 (±0.10)	0.30 (±0.10)	0
Oligochaeta	50.8	1.60 (±1.40)	4.30 (±2.30)	3.40 (±1.60)	1.10 (±0.30)	1.10 (±0.50)
Orthoptera	0.8	0.10 (±0.10)	0	0	0	0
Ostracoda	9.3	0.10 (±0.10)	0.90 (±0.10)	0	0.30 (±0.10)	0
Palaemonetes paludosus	27.1	4.80 (±2.40)	6.20 (±0.40)	0.20 (±0.20)	2.10 (±0.30)	0.10 (±0.10)
Pelocoris femoratus[A]	16.9	0.30 (±0.30)	1.60 (±1.40)	0.90 (±0.70)	0.60 (±0.20)	0
Physella spp.	46.6	5.80 (±0.20)	12.10 (±3.10)	2.30 (±1.10)	17.20 (±11.40)	0.30 (±0.30)
Planorbella spp.	32.2	10.80 (±6.40)	8.00 (±2.40)	0.70 (±0.50)	18.30 (±0.50)	0
Platyhelminthes	0.8	0	0	0	0	0
Polychaeta	0.8	0	0	0	0	0
Pomacea paludosa	0.8	0	0	0	0	0
Procambarus alleni	1.7	0	0	0	0	0
Procambarus spp.	0.8	0	0	0	0	0
Sphaeriidae	4.2	0.30 (±0.30)	0	0	0.60 (±0.40)	0
Stratiomyidae[L]	19.5	0.10 (±0.10)	0.40 (±0.20)	0.80 (±0.40)	0.20 (±0.00)	0
Tabanidae[L]	4.2	0	0	0	0.10 (±0.10)	0.10 (±0.10)
Tanypodinae[L]	56.8	14.30 (±0.70)	41.20 (±2.00)	6.50 (±1.10)	16.50 (±3.70)	0.70 (±0.70)
Tanytarsus[L]	57.6	104.40 (±3.20)	190.00 (±6.60)	15.90 (±3.30)	94.30 (±13.10)	1.00 (±0.80)
Tipulidae[L]	2.5	0	0	0	0	0
Trichoptera[L]	6.8	0.40 (±0.40)	0.20 (±0.20)	0.10 (±0.10)	0.10 (±0.10)	
Unidentified invertebrates	1.7	0	0	0	0	0
Total invertebrates		297.10 (±15.10)	616.50 (±71.50)	195.20 (±10.20)	308.80 (±29.20)	42.60 (±28.20)
Fish taxa						
Fundulus chrysotus	5.9	0	0.10 (±0.10)	0	0.20 (±0.00)	0.10 (±0.10)
Gambusia holbrooki	21.2	0.10 (±0.10)	0.50 (±0.50)	1.30 (±0.10)	0.50 (±0.30)	0
Heterandria formosa	5.1	0.20 (±0.20)	0.30 (±0.10)	0	0.20 (±0.20)	0
Lepomis spp.	0.8	0	0	0	0.10 (±0.10)	0
Lucania goodei	8.5	0.60 (±0.20)	0.70 (±0.50)	0	0.20 (±0.00)	0
Unidentified fishes	4.2	0.30 (±0.10)	0.30 (±0.10)	0	0	0

(Appendix 3 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTW (*N* = 1)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	Site S332D (*N* = 6)
Acari	11.9	0.50 (±0.30)	0	0	0	0
Anisoptera[L]	0.8	0	0	0	0	0
Belostoma spp.[A]	2.5	0	0	0	0	0.07 (±0.04)
Berosus spp.L	7.6	0.10 (±0.10)	0	0	0.08 (±0.08)	0.20 (±0.07)
Celithemis eponina[L]	7.6	1.30 (±1.30)	0	0	0	0
Ceratopogonidae[L]	34.7	0.40 (±0.20)	0	0.20 (±0.20)	0.10 (±0.10)	0.10 (±0.07)
Chironomidae[L]	83.1	2.70 (±2.10)	0	1.90 (±0.90)	1.08 (±0.65)	6.40 (±1.81)
Chydoridae	4.2	0	0	0	0	0
Coenagrionidae[L]	16.9	0	0	0.10 (±0.10)	0	0.03 (±0.03)
Coleoptera[A]	14.4	0	0	0	0.08 (±0.08)	0.37 (±0.15)
Collembola	3.4	0	1.00	0	0	0.10 (±0.07)
Corixidae[L]	11.9	0	0	0	0	0.03 (±0.03)
Dasyhelea spp.[L]	72.0	7.00 (±0.60)	0	1.30 (±0.10)	1.28 (±0.48)	1.47 (0.56)
Diptera[P]	55.9	3.40 (±1.00)	2.00	2.70 (±1.70)	0.47 (±0.18)	0.37 (±0.21)
Enochrus spp.[L]	6.8	0	0	0	0	0.10 (±0.07)
Ephemeroptera[L]	33.9	0.10 (0.10)	0	0.10 (0.10)	0	1.60 (±0.53)
Erythemis simplicicollis[L]	4.2	0	0	0	0	0
Gerris spp.	14.4	0	0	0	0.05 (±0.05)	0.07 (±0.04)
Helicus spp.[L]	5.9	0	0	0.10 (±0.10)	0.05 (±0.05)	0.50 (±0.31)
Heteroptera[A]	4.2	0	0	0	0	0
Hirudinea	0.8	0	0	0	0	0
Hyalella azteca	40.7	0.20 (±0.20)	0	0	0.05 (±0.05)	2.30 (±1.46)
Laevapex peninsulae	0.8	0	0	0	0	0.03 (±0.03)
Lepidoptera	14.4	0	0	0	0	0.07 (±0.04)
Libellula needemi[L]	2.5	0	0	0	0	0
Littoridinops monroensis	17.8	0	0	0	0	0.27 (±0.12)
Micromentus dilatatus avus	4.2	0	0	0	0	0.47 (±0.39)
Nematoda	3.4	0	0	0	0	0
Oligochaeta	50.8	0.60 (±0.00)	0	0.30 (±0.10)	0.05 (±0.05)	2.23 (±0.54)
Orthoptera	0.8	0	0	0	0	0

(Appendix 3 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTW (*N* = 1)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	Site S332D (*N* = 6)
Ostracoda	9.3	0	0	0	0	0.30 (±0.30)
Palaemonetes paludosus	27.1	0.10 (±0.10)	0	0	0	0
Pelocoris femoratus[A]	16.9	0.20 (±0.00)	0	0	0	0.10 (±0.07)
Physella spp.	46.6	1.20 (±1.00)	0.50	0	0	1.33 (±0.61)
Planorbella spp.	32.2	0	0	0	0	0.23 (±0.13)
Platyhelminthes	0.8	0	0	0	0	0.03 (±0.03)
Polychaeta	0.8	0	0	0	0	0.03 (±0.03)
Pomacea paludosa	0.8	0	0	0	0	0.10 (±0.10)
Procambarus alleni	1.7	0	0	0	0	0.10 (±0.07)
Procambarus spp.	0.8	0	0	0	0	0.07 (±0.07)
Sphaeriidae	4.2	0	0	0	0	0.03 (±0.03)
Stratiomyidae[L]	19.5	0.20 (±0.20)	0	0.20 (±0.20)	0.18 (±0.07)	0.17 (±0.06)
Tabanidae[L]	4.2	0.20 (±0.00)	0	0	0	0.03 (±0.03)
Tanypodinae[L]	56.8	0.40 (±0.20)	0	1.60 (±0.40)	0.28 (±0.19)	0.60 (±0.25)
Tanytarsus[L]	57.6	0.40 (±0.40)	0	0.50 (±0.10)	0	1.47 (±0.56)
Tipulidae[L]	2.5	0	0	0	0	0.10 (±0.07)
Trichoptera[L]	6.8	0	0	0	0	0.07 (±0.07)
Unidentified invertebrates	1.7	0	0	0	0.05 (±0.05)	0.03 (±0.03)
Total invertebrates		19.20 (±0.40)	3.50	9.00 (±0.20)	3.82 (±1.49)	21.57 (±4.93)
Fish taxa						
Fundulus chrysotus	5.9	0	0	0	0.05 (±0.05)	0.10 (±0.10)
Gambusia holbrooki	21.2	0.20 (±0.00)	0	0.10 (±0.10)	0.30 (±0.14)	0.23 (±0.10)
Heterandria formosa	5.1	0	0	0	0	0
Lepomis spp.	0.8	0	0	0	0	0
Lucania goodei	8.5	0	0	0	0	0
Unidentified fishes	4.2	0	0	0	0.05 (±0.05)	0

Appendix 4. Total incidence and average abundance (no./sweep ±SE) of macroinvertebrates and fish collected in D-frame sweep net samples at each site in December 2004 (N = number of arrays/site; 1-5 replicate samples collected at each array (see Table D) and averaged; "0" indicates species was not collected). Superscripts indicate insect adult (A), larval or nymph (L), and pupal (P) life stages. Chironomidae includes all members of the family except Tanypodinae and Tanytarsus. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*.

		REFERENCE SITES				
Macroinvertebrate taxa	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Acari	4.5	0.33 (±0.33)	0.17 (±0.17)	0	2.50 (±2.50)	0
Belostoma spp.^{A}	1.1	0	0	0	0	0
Berosus spp.^{L}	11.2	0	0	0	0	0
Celithemis eponina^{L}	4.5	0	0.67 (±0.33)	0	0.17 (±0.17)	0
Ceratopogonidae^{L}	39.3	0.50 (±0.17)	1.33 (±0.00)	1.50 (±0.50)	0.33 (±0.33)	2.67 (±1.00)
Chironomidae^{L}	80.9	121.50 (±67.50)	162.50 (±2.83)	26.33 (±10.00)	44.00 (±10.00)	84.67 (±38.33)
Chydoridae	6.7	1.33 (±0.33)	2.83 (±2.83)	0	3.83 (±3.17)	0
Coenagrionidae^{L}	16.9	0.50 (±0.17)	1.33 (±0.00)	0.33 (±0.33)	0.17 (±0.17)	0
Coleoptera^{A}	13.5	0	0.17 (±0.17)	0.67 (±0.67)	0	0.17 (±0.17)
Collembola	4.5	0	0	0	0	0
Corixidae^{A}	7.9	0	2.50 (±0.17)	0.33 (±0.33)	0.17 (±0.17)	0
Coryphaeschna ingens^{L}	1.1	0	0	0	0	0
Dasyhelea spp.^{L}	73.0	40.00 (±25.00)	47.17 (±16.17)	39.33 (±27.67)	75.83 (±69.17)	43.33 (±20.00)
Diptera^{P}	52.8	2.50 (±1.17)	4.33 (±0.33)	2.33 (±1.67)	1.50 (±1.50)	3.17 (±0.50)
Enochrus spp.^{L}	1.1	0	0	0	0	0
Ephemeroptera^{L}	21.3	0.17 (±0.17)	0.50 (±0.17)	0	0	0.17 (±0.17)
Gerris spp.^{A}	22.5	0.50 (±0.17)	1.67 (±1.00)	0.33 (±0.33)	2.17 (±1.83)	0
Helicus spp.^{L}	12.4	0	0	0	0	0
Heteroptera^{A}	6.7	0	0.33 (±0.33)	0	0	0
Hyalella azteca	38.2	14.67 (±8.33)	65.50 (±14.83)	16.67 (±7.33)	87.00 (±80.00)	6.33 (±5.67)
Laevapex peninsulae	2.2	0	0	0	0	0
Lepidoptera^{L}	11.2	0.17 (±0.17)	1.17 (±0.50)	0.33 (±0.33)	1.00 (±0.00)	0
Littoridinops monroensis	3.4	0	0.33 (±0.33)	0	0.17 (±0.17)	0
Nematoda	9.0	1.50 (±1.50)	1.50 (±0.17)	0	1.50 (±1.50)	0
Oligochaeta	43.8	2.50 (±0.83)	4.17 (±0.83)	2.33 (±1.33)	2.83 (±0.83)	9.50 (±2.17)
Ostracoda	6.7	0.17 (±0.17)	1.50 (±1.17)	0	6.67 (±6.33)	0
Palaemonetes paludosus	18.0	3.33 (±1.67)	9.50 (±1.83)	6.83 (±5.17)	0.33 (±0.33)	0
Pelocoris femoratus^{A}	6.7	0	0.50 (±0.50)	0	0	0.33 (±0.33)

(Appendix 4 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Physella spp.	38.2	1.83 (±1.17)	3.00 (±1.67)	3.00 (±0.33)	9.00 (±6.00)	1.00 (±1.00)
Planorbella spp.	30.3	3.00 (±1.00)	2.50 (±0.17)	1.33 (±0.67)	8.17 (±0.83)	0.17 (±0.17)
Pomacea paludosa	4.5	0	0.17 (±0.17)	0	0.83 (±0.83)	0
Procambarus alleni	2.2	0	0.17 (±0.17)	0	0	0
Stratiomyidae[L]	4.5	0	0	0.33 (±0.33)	0	0
Tanypodinae[L]	50.6	6.17 (±4.17)	19.50 (±3.83)	1.17 (±1.17)	19.33 (±18.67)	4.67 (±1.67)
Tanytarsus[L]	67.4	89.67 (±60.33)	152.50 (±22.50)	20.83 (±10.17)	36.17 (±14.83)	16.17 (±12.17)
Taphromysis louisianae	2.2	0.50 (±0.50)	0	0	0	0
Tipulidae[L]	12.4	0	0.50 (±0.50)	0.17 (±0.17)	0	0
Trichoptera[L]	12.4	0	1.17 (±0.17)	0	0	0.33 (±0.00)
Unidentified invertebrates	14.6	0.33 (±0.00)	0	0	3.00 (±3.00)	0.50 (±0.17)
Total invertebrates		291.17 (±172.17)	489.17 (±11.83)	124.17 (±2.17)	306.67 (±210.33)	173.17 (±81.83)
Fish taxa						
Fundulus chrysotus	2.2	0	0.50 (±0.17)	0	0	0
Gambusia holbrooki	21.3	0.33 (±0.00)	0.83 (±0.50)	8.17 (±2.17)	0	0
Heterandria formosa	2.2	0	0.67 (±0.33)	0	0	0
Jordanella florida	1.1	0	0	0.17 (±0.17)	0	0
Lucania goodei	10.1	0.83 (±0.17)	1.00 (±0.67)	0	2.00 (±2.00)	0

(Appendix 4 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTE (*N* = 2)	Site CXTW (*N* = 2)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 6)	Site S332D (*N* = 6)
Acari	4.5	0.33 (±0.33)	0	0	0	0	0
Belostoma spp.[A]	1.1	0	0	0	0	0	0.06 (±0.06)
Berosus spp.[L]	11.2	0.17 (±0.17)	0	0	0	0	0.69 (±0.24)
Celithemis eponina[L]	4.5	0	0	0	0	0	0
Ceratopogonidae[L]	39.3	0.50 (±0.17)	0.17 (±0.17)	0.17 (±0.17)	0.33 (±0.00)	0.17 (±0.11)	0.44 (±0.10)
Chironomidae[L]	80.9	3.17 (±1.17)	1.33 (±0.00)	0.67 (±0.67)	2.17 (±0.83)	5.83 (±2.11)	13.69 (±3.66)
Chydoridae	6.7	0	0	0	0	0	0
Coenagrionidae[L]	16.9	0.17 (±0.17)	0.17 (±0.17)	0	0.17 (±0.17)	0.06 (±0.06)	0.11 (±0.11)
Coleoptera[A]	13.5	0.33 (±0.00)	0.33 (±0.33)	0	0	0.06 (±0.06)	0.17 (±0.07)
Collembola	4.5	0	0.17 (±0.17)	0	0	0.06 (±0.06)	0.06 (±0.06)
Corixidae[A]	7.9	0	0	0	0	0.06 (±0.06)	0
Coryphaeschna ingens[L]	1.1	0	0	0	0	0	0.06 (0.06)
Dasyhelea spp.[L]	73.0	27.50 (±19.17)	3.00 (±1.33)	5.00 (±0.67)	6.83 (±2.50)	2.22 (±0.70)	2.92 (±1.31)
Diptera[P]	52.8	2.00 (±1.00)	0.17 (±0.17)	0.33 (±0.33)	0.33 (±0.33)	0.44 (±0.25)	1.44 (±0.56)
Enochrus spp.[L]	1.1	0	0	0	0	0	0.06 (±0.06)
Ephemeroptera[L]	21.3	0	0.17 (±0.17)	0	0	0.28 (±0.22)	3.44 (±2.22)
Gerris spp.[A]	22.5	0.17 (±0.17)	0	0.17 (±0.17)	0	0.06 (±0.06)	0.50 (±0.27)
Helicus spp.[L]	12.4	0	0.17 (±0.17)	0.33 (±0.33)	0	0.06 (±0.06)	0.56 (±0.16)
Heteroptera[A]	6.7	0	0.33 (±0.00)	0	0	0	0.06 (±0.06)
Hyalella azteca	38.2	0.33 (±0.33)	0	0	0	0	3.36 (±2.03)
Laevapex peninsulae	2.2	0	0	0.33 (±0.33)	0	0	0.28 (±0.28)
Lepidoptera[L]	11.2	0.17 (±0.17)	0	0	0	0	0.06 (±0.06)
Littoridinops monroensis	3.4	0	0	0	0.17 (±0.17)	0	0
Nematoda	9.0	0	0	0	0	0	0
Oligochaeta	43.8	0.50 (±0.50)	0.33 (±0.33)	0	0.67 (±0.33)	0.11 (±0.07)	2.31 (±0.51)
Ostracoda	6.7	0	0	0	0	0	0.22 (±0.22)
Palaemonetes paludosus	18.0	0	0	0	0	0	0
Pelocoris femoratus[A]	6.7	0	0	0	0	0	0.14 (±0.09)
Physella spp.	38.2	2.00 (±0.67)	0	0.33 (±0.00)	0	0.06 (±0.06)	2.97 (±2.23)
Planorbella spp.	30.3	0	0	0	0.33 (±0.00)	0	0.44 (±0.24)
Pomacea paludosa	4.5	0	0	0	0	0	0.08 (±0.08)
Procambarus alleni	2.2	0	0	0.17 (±0.17)	0	0	0

(Appendix 4 continued)

Macroinvertebrate taxa	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTE (*N* = 2)	Site CXTW (*N* = 2)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 6)	Site S332D (*N* = 6)
Stratiomyidae[L]	4.5	0	0	0	0.17 (±0.17)	0	0.11 (±0.11)
Tanypodinae[L]	50.6	1.83 (±0.50)	0	0.67 (±0.00)	1.17 (±0.17)	0.17 (±0.07)	0.58 (±0.36)
Tanytarsus[L]	67.4	2.67 (±2.33)	0	1.83 (±0.17)	1.50 (±0.83)	2.00 (±1.24)	6.89 (±3.03)
Taphromysis louisianae	2.2	0	0	0	0	0	0
Tipulidae[L]	12.4	0.67 (±0.00)	0	0	0	0	0.56 (±0.37)
Trichoptera[L]	12.4	0	0	0	0	0.06 (±0.06)	0.28 (±0.13)
Unidentified invertebrates	14.6	0	0	0.17 (±0.17)	0	0.22 (±0.16)	0.19 (±0.12)
Total invertebrates		42.67 (±24.67)	6.33 (±2.00)	10.17 (±0.83)	13.83 (±4.83)	11.89 (±4.02)	42.72 (±9.10)
Fish taxa							
Fundulus chrysotus	2.2	0	0	0	0	0	0
Gambusia holbrooki	21.3	0.17 (±0.17)	0.17 (±0.17)	0.17 (±0.17)	0.17 (±0.17)	0	0.33 (±0.07)
Heterandria formosa	2.2	0	0	0	0	0	0
Jordanella florida	1.1	0	0	0	0	0	0
Lucania goodei	10.1	0	0	0	0	0	0

Appendix 5. Total incidence and average abundance (no./g AFDM periphyton ±SE) of macroinvertebrates collected in 6-cm diameter core samples at each site in October 2004 (N = number of arrays/site; 1-5 replicate samples collected at each array (see Table D) and averaged). Most samples were sorted enumerating both "small" (< 1 mm max. dimension) and "large" (≥1 mm max. dimension) individuals of each taxon ("All" = small + large). "0" indicates species was not collected and "0" indicates samples were not sorted by size. Superscripts indicate insect adult (A), larval or nymph (L), and pupal (P) life stages. Chironomidae includes all members of the family except Tanypodinae and Tanytarsus. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*.

			REFERENCE SITES				
Macoinvertebrate taxa	Size	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site50 (*N* = 2)
Acari	Small		0	60.47 (±4.35)	28.04 (±13.37)	64.14 (±11.25)	4.74 (±3.01)
	Large		0	0	0.57 (±0.57)	0	0
	All		15.06 (±3.81)	60.47 (±4.35)	28.60 (±13.93)	64.14 (±11.25)	4.74 (±3.01)
Anisoptera	(All large)		0	1.18 (±1.18)	0	0	0
Berosus spp.^{L}	(All large)		0	0	0.23 (±0.23)	0	0
Calanoida	Small		0	0	0.53 (±0.53)	0.87 (±0.87)	0
	Large		0	0	0.84 (±0.84)	1.98 (±1.37)	0
	All		0	0	1.37 (±1.37)	2.85 (±2.25)	0
Celithemis eponina	(All large)		0.22 (±0.22)	0	0	0	0
Ceratopogonidae^{L}	(All large)		0	0.90 (±0.01)	1.55 (±1.12)	0.80 (±0.80)	0
Chironomidae^{L}	Small		0	2.67 (±0.49)	3.07 (±2.35)	17.10 (±15.75)	0.65 (±0.65)
	Large		0	74.55 (±21.83)	32.36 (±4.98)	56.71 (±38.36)	4.68 (±1.85)
	All		121.28 (±22.25)	77.23 (±21.34)	35.43 (±2.63)	73.81 (±54.11)	5.33 (±1.21)
Chydoridae	(All small)		210.09 (±145.37)	241.93 (±19.46)	100.47 (±3.72)	154.95 (±111.27)	2.30 (±0.53)
Coenagrionidae^{L}	(All large)		2.14 (±0.40)	1.50 (±1.50)	0.83 (±0.21)	0	0
Coleoptera^{A}	(All large)		0.34 (±0.09)	4.62 (±1.24)	0.44 (±0.44)	0	0
Collembola	(All small)		0.90 (±0.90)	1.02 (±0.11)	0	0	0
Copepoda (nauplii)	(All small)		4.89 (±4.89)	0.38 (±0.38)	0.75 (±0.75)	3.24 (±3.24)	0

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES				
			Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site50 (*N* = 2)
Cyclopoida	Small		0	24.88 (±1.14)	9.24 (±2.42)	27.98 (±14.90)	1.68 (±0.70)
	Large		0	1.13 (±1.13)	0	0	0
	All		4.40 (±4.40)	26.01 (±2.27)	9.24 (±2.42)	27.98 (±14.90)	1.68 (±0.70)
Daphniidae	(All small)		0	0	0	0.29 (±0.29)	0
Dasyhelea spp.[L]	Small		0	1.13 (±1.13)	1.11 (±0.39)	18.27 (±12.05)	0
	Large		0	72.16 (±4.75)	40.91 (±17.34)	84.86 (±7.07)	5.14 (±0.83)
	All		64.71 (±0.57)	73.28 (±3.62)	42.02 (±16.96)	103.12 (±19.12)	5.14 (±0.83)
Diptera[P]	(All large)		1.81 (±0.99)	1.55 (±0.80)	1.93 (±1.47)	2.22 (±0.02)	0
Dytiscidae	(All large)		0	0	0	0	0
Enochrus spp.[L]	(All large)		1.45 (±0.86)	4.77 (±1.36)	0	1.94 (±0.58)	0
EphemeropteraL	Small		0	1.60 (±1.60)	3.66 (±2.49)	0.29 (±0.29)	0.22 (±0.22)
	Large		0	2.51 (±1.39)	1.19 (±0.05)	0.73 (±0.73)	0.22 (±0.22)
	All		2.73 (±2.22)	4.12 (±2.99)	4.84 (±2.44)	1.02 (±0.45)	0.43 (±0.43)
Erythemis simplicicollis	(All large)		0.54 (±0.11)	0	0.73 (±0.73)	0	0
Harpaticoida	(All small)		42.93 (±35.11)	43.68 (±4.25)	14.91 (±0.66)	11.54 (±2.45)	1.00 (±0.14)
Helicus spp.[L]	(All large)		0	0	0	0	0
Heteroptera[A]	Small		0	2.99 (±0.63)	0.44 (±0.44)	0.29 (±0.29)	0
	Large		0	6.51 (±1.97)	2.04 (±0.09)	2.75 (±1.14)	0
	All		5.56 (±2.17)	9.50 (±2.61)	2.48 (±0.35)	3.04 (±1.43)	0
Hyalella azteca	(All large)		12.98 (±1.36)	21.08 (±1.86)	10.55 (±7.10)	9.40 (±1.30)	0.92 (±0.92)
Hydra spp.	(All small)		0	0	0.43 (±0.01)	0	0.24 (±0.24)
Isopoda	(All large)		0	0	0	0	0
Laevapex peninsulae	All		0	0	0	0	0
Lepidoptera[L]	(All large)		0	0.38 (±0.38)	0.22 (±0.22)	0	0

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES				
			Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site50 (*N* = 2)
Macrothricidae	Small		0	13.67 (±3.59)	1.71 (±0.47)	12.89 (±12.14)	0.83 (±0.83)
	Large		0	1.36 (±0.24)	0.97 (±0.97)	1.05 (±1.05)	0
	All		93.38 (±59.03)	15.03 (±3.36)	2.68 (±0.50)	13.94 (±11.08)	0.83 (±0.83)
Nematoda	Small		0	43.97 (±3.87)	6.72 (±0.97)	103.35 (±88.06)	2.04 (±0.19)
	Large		0	56.04 (±11.10)	21.90 (±0.81)	60.91 (±29.01)	9.41 (±4.74)
	All		199.90 (±139.73)	100.01 (±7.23)	28.62 (±1.79)	164.25 (±117.07)	11.44 (±4.93)
Oligochaeta	Small		0	10.97 (±5.31)	13.89 (±11.77)	18.55 (±18.55)	3.85 (±3.30)
	Large		0	67.81 (±25.03)	104.08 (±26.80)	92.97 (±56.01)	30.26 (±6.86)
	All		100.16 (±37.77)	78.78 (±19.72)	117.97 (±15.03)	111.52 (±74.56)	34.12 (±10.17)
Ostracoda	Small		0	86.04 (±0.80)	17.50 (±3.13)	74.80 (±2.38)	5.68 (±1.01)
	Large		0	1.20 (±0.31)	0.50 (±0.50)	1.10 (±0.23)	0.35 (±0.35)
	All		31.07 (±0.99)	87.24 (±0.49)	17.99 (±2.64)	75.90 (±2.61)	6.04 (±1.37)
Pelocoris femoratus	(All large)		0.25 (±0.25)	0.85 (±0.85)	1.81 (±0.67)	0	0
Physella spp.	Small		0	0	0	0.90 (±0.90)	0
	Large		0	8.42 (±0.39)	4.67 (±0.66)	5.97 (±0.46)	0.32 (±0.32)
	All		4.97 (±0.06)	8.42 (±0.39)	4.67 (±0.66)	6.87 (±1.35)	0.32 (±0.32)
Planorbella spp.	Small		0	0	0	0.61 (±0.61)	0.39 (±0.39)
	Large		0	0.38 (±0.38)	0	0	0
	All		0.88 (±0.38)	0.38 (±0.38)	0	0.61 (±0.61)	0.39 (±0.39)
Platyhelminthes	(All small)		11.25 (±9.35)	7.45 (±5.94)	4.32 (±0.59)	9.82 (±9.24)	2.91 (±0.02)
Procambarus spp.	(All large)		0	0	0	0	0
Rotifera	(All small)		2.32 (±2.32)	1.87 (±0.74)	2.43 (±1.36)	4.07 (±1.76)	0.43 (±0.43)
Sididae	Small		0	0	0	4.11 (±4.11)	0
	Large		0	0.36 (±0.36)	0.31 (±0.31)	2.22 (±0.72)	0
	All		3.95 (±1.84)	0.36 (±0.36)	0.31 (±0.31)	6.32 (±4.83)	0
Sphaeriidae	(All large)		0	0	0	0	0
Stratiomyidae[L]	(All large)		0.31 (±0.31)	1.28 (±1.28)	0.28 (±0.28)	0.37 (±0.37)	0.28 (±0.28)

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES				
			Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site50 (*N* = 2)
Tabanidae[L]	(All large)		0	0	0.22 (±0.22)	0	0
Tanypodinae[L]	Small		0	6.88 (±3.64)	0	21.71 (±18.89)	0.43 (±0.43)
	Large		0	94.49 (±25.41)	8.85 (±2.27)	47.95 (±8.26)	0.75 (±0.75)
	All		67.74 (±30.81)	101.37 (±21.78)	8.85 (±2.27)	69.66 (±27.15)	1.18 (±0.32)
Tanytarsus[L]	Small		0	2.70 (±2.70)	0.31 (±0.31)	0.73 (±0.73)	0
	Large		0	69.35 (±41.77)	6.16 (±3.14)	23.32 (±16.83)	0.43 (±0.43)
	All		28.41 (±22.75)	72.05 (±44.47)	6.47 (±2.83)	24.06 (±17.56)	0.43 (±0.43)
Tipulidae[L]	(All large)		0	0.45 (±0.45)	0.28 (±0.28)	0	0
Trichoptera[L]	(All large)		0	0	0	0	0
Unidentified Gastropoda	(All large)		0	0	0	0	0
Total invertebrates	Large		7.07 (±0.09)	494.84 (±42.00)	244.42 (±61.70)	397.27 (±158.69)	52.77 (±15.92)
	All		1036.63 (±527.89)	1049.13 (±52.67)	453.95 (±29.44)	947.75 (±476.09)	80.14 (±24.32)

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	REFERENCE SITES Site CXTW (*N* = 1)	REFERENCE SITES Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	IMPACTED SITES Site S332D (*N* = 5)
Acari	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		5.28 (±1.16)	0.28	9.94 (±7.62)	1.10 (±0.70)	11.06 (±2.90)
Anisoptera	(All large)		0	0	0	0	0
Berosus spp.[L]	(All large)		0	0	0	0.078 (±0.08)	1.95 (±0.80)
Calanoida	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0	0	0	0	0.18 (±0.10)
Celithemis eponina	(All large)		0	0	0	0	0
Ceratopogonidae[L]	(All large)		0.19 (±0.19)	0	0.48 (±0.10)	0	0.24 (±0.13)
Chironomidae[L]	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		1.55 (±0.47)	1.70	2.29 (±1.74)	0.84 (±0.43)	9.41 (±4.10)
Chydoridae	(All small)		1.71 (±0.16)	0	4.80 (±4.36)	0.63 (±0.38)	18.20 (±9.20)
Coenagrionidae[L]	(All large)		0	0	0	0	0
Coleoptera[A]	(All large)		0	0	0	0.06 (±0.06)	0.13 (±0.10)
Collembola	(All small)		0	0	0	0	0.88 (±0.43)
Copepoda (nauplii)	(All small)		0	0	0	0	0.20 (±0.12)
Cyclopoida	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0.23 (±0.23)	0	0.35 (±0.21)	0	1.42 (±0.54)
Daphniidae	(All small)		0.46 (±0.46)	0	0.07 (±0.07)	0	0
Dasyhelea spp.[L]	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		5.15 (±2.73)	0.22	0.26 (±0.26)	5.16 (±3.18)	4.93 (±1.58)

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTW (*N* = 1)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	Site S332D (*N* = 5)
Diptera[P]	(All large)		0	0	0	0.19 (±0.19)	0.28 (±0.28)
Dytiscidae	(All large)		0	0.12	0	0	0.048 (±0.05)
Enochrus spp.[L]	(All large)		0	0	0	0	0
EphemeropteraL	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0	0	0	0	0.91 (±0.71)
Erythemis simplicicollis	(All large)		0	0	0	0	0
Harpaticoida	(All small)		0	0	0.16 (±0.16)	0.05 (±0.05)	0.68 (±0.25)
Helicus spp.[L]	(All large)		0	0.24	0	0.04 (±0.04)	0
Heteroptera[A]	Small		0	0	0	0	0
	Large		0	0.	0	0	0
	All		0.13 (±0.13)	0	0.22 (±0.22)	0.06 (±0.06)	0.07 (±0.07)
Hyalella azteca	(All large)		0	0	0.14 (±0.14)	0.04 (±0.04)	0.06 (±0.06)
Hydra spp.	(All small)		0	0	0	0	0
Isopoda	(All large)		0	0	0	0.16 (±0.16)	0.03 (±0.03)
Laevapex peninsulae	All		0.06 (±0.06)	0	0	0	0
Lepidoptera[L]	(All large)		0	0	0	0	1.50 (±1.46)
Macrothricidae	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0	0	0	0	0.10 (±0.07)
Nematoda	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		11.41 (±7.91)	3.89	3.12 (±1.76)	11.83 (±6.17)	93.05 (±26.68)

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTW (*N* = 1)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	Site S332D (*N* = 5)
Oligochaeta	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		4.44 (±4.23)	7.16	8.02 (±0.27)	5.69 (±1.11)	46.93 (±14.78)
Ostracoda	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0.70 (±0.70)	0	2.72 (±2.59)	0.80 (±0.43)	19.48 (±6.53)
Pelocoris femoratus	(All large)		0	0	0	0	0
Physella spp.	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0.76 (±0.14)	0	0.34 (±0.34)	0.27 (±0.18)	0.69 (±0.21)
Planorbella spp.	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0	0	0	0	0.63 (±0.43)
Platyhelminthes	(All small)		0.08 (±0.08)	0	0.51 (±0.51)	0	1.96 (±0.80)
Procambarus spp.	(All large)		0.08 (±0.08)	0	0	0	0
Rotifera	(All small)		0	0	0	0.06 (±0.06)	3.00 (±1.36)
Sididae	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0	0	0.17 (±0.17)	0	0.20 (±0.13)
Sphaeriidae	(All large)		0	0	0	0.04 (±0.04)	0
Stratiomyidae[L]	(All large)		0.19 (±0.19)	0.14	0.53 (±0.38)	0.23 (±0.09)	0.15 (±0.15)
Tabanidae[L]	(All large)		0	0	0	0	0
Tanypodinae[L]	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0.66 (±0.15)	0	1.84 (±0.07)	0.12 (±0.12)	0.32 (±0.12)

(Appendix 5 continued)

Macoinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES Site CKKW (*N* = 2)	Site CXTW (*N* = 1)	Site INT (*N* = 2)	IMPACTED SITES Site S332B (*N* = 4)	Site S332D (*N* = 5)
Tanytarsus[L]	Small		0	0	0	0	0
	Large		0	0	0	0	0
	All		0.25 (±0.12)	0	0.30 (±0.30)	0.28 (±0.28)	0.51 (±0.40)
Tipulidae[L]	(All large)		0.08 (±0.08)	0	0	0	3.74 (±2.19)
Trichoptera[L]	(All large)		0	0	0.16 (±0.16)	0.06 (±0.06)	0.07 (±0.07)
Unidentified Gastropoda	(All large)		0	0	0	0.04 (±0.04)	0
Total invertebrates	Large		0.54 (±0.23)	0.50	1.17 (±0.32)	0.90 (±0.24)	8.15 (±2.95)
	All		33.42 (±17.17)	13.76	36.41 (±17.89)	27.84 (±11.39)	223.01 (±64.84)

Appendix 6. Total incidence and average abundance (no./g AFDM periphyton ±SE) of macroinvertebrates collected in 6-cm diameter core samples at each site in October 2004 (N = number of arrays/site; 1-5 replicate samples collected at each array (see Table D) and averaged). Most samples were sorted enumerating both "small" (< 1 mm max. dimension) and "large" (≥1 mm max. dimension) individuals of each taxon ("All" = small + large). "0" indicates species was not collected and "0" indicates samples were not sorted by size. Superscripts indicate insect adult (A), larval or nymph (L), and pupal (P) life stages. Chironomidae includes all members of the family except Tanypodinae and Tanytarsus. Heteroptera includes all members of the suborder with the exception of Corixidae, *Belostoma*, *Lethocerus*, *Pelocoris*, and *Gerris*.

			REFERENCE SITES				
Macroinvertebrate taxa	Size	Incidence (%)	Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Acari	Small		4.65 (±1.35)	7.69 (±1.86)	5.37 (±4.80)	41.15 (±8.23)	3.83 (±2.95)
	Large		0	0.13 (±0.13)	0	0	0
	All		4.65 (±1.35)	7.82 (±1.73)	5.37 (±4.80)	41.15 (±8.23)	3.83 (±2.95)
Anisoptera	(All large)		0	0	0	0.74 (±0.74)	0
Berosus spp.^{L}	(All large)		0	0	0	0	0
Calanoida	Small		0	0	0	0	0.11 (±0.11)
	Large		0	0.18 (±0.18)	0	2.35 (±2.35)	0
	All		0	0.18 (±0.18)	0	2.35 (±2.35)	0.11 (±0.11)
Celithemis eponina	(All large)		0	0	0	0	0
Ceratopogonidae^{L}	(All large)		0.33 (±0.33)	3.52 (±0.72)	0.35 (±0.35)	1.57 (±1.57)	0
Chironomidae^{L}	Small		0.75 (±0.75)	7.21 (±1.08)	0.11 (±0.11)	0.69 (±0.69)	0
	Large		45.96 (±20.14)	89.54 (±12.80)	5.52 (±3.66)	6.65 (±4.00)	3.27 (±1.13)
	All		46.71 (±19.39)	96.75 (±13.88)	5.63 (±3.77)	7.34 (±4.68)	3.27 (±1.13)
Chydoridae	(All small)		96.19 (±38.22)	46.01 (±10.26)	0.65 (±0.65)	28.80 (±4.53)	4.75 (±4.75)
Coenagrionidae^{L}	(All large)		0.33 (±0.33)	1.21 (±0.47)	0	0	0.10 (±0.10)
Coleoptera^{A}	(All large)		0	0.18 (±0.18)	0	0.58 (±0.58)	1.88 (±0.02)
Collembola	(All small)		0	0	0	0	0
Copepoda (nauplii)	(All small)		0.27 (±0.27)	0	0	0	0

(Appendix 6 continued)

Macroinvertebrate taxa	Size	Incidence (%)	REFERENCE SITES Site 6 (*N* = 2)	Site 7 (*N* = 2)	Site 8 (*N* = 2)	Site 23 (*N* = 2)	Site 50 (*N* = 2)
Cyclopoida	Small		1.09 (±0.00)	0.98 (±0.45)	0	5.88 (±3.03)	0.24 (±0.24)
	Large		0.27 (±0.27)	0	0	0	0
	All		1.36 (±0.27)	0.98 (±0.45)	0	5.88 (±3.03)	0.24 (±0.24)
Daphniidae	(All small)		0	0.16 (±0.16)	0	0	0
Dasyhelea spp.[L]	Small		0	0.19 (±0.19)	0	0	0
	Large		29.26 (±15.93)	30.66 (±1.37)	8.48 (±8.20)	21.76 (±0.14)	1.14 (±0.52)
	All		29.26 (±15.93)	30.84 (±1.55)	8.48 (±8.20)	21.76 (±0.14)	1.14 (±0.52)
Diptera[A]	(All large)		0	0	0	0	0
Diptera[P]	(All large)		0.56 (±0.56)	2.11 (±0.71)	0.25 (±0.25)	3.40 (±2.51)	0.32 (±0.32)
Enochrus spp.[L]	(All large)		0	0	0	0.58 (±0.58)	0
Ephemeroptera[L]	Small		0.33 (±0.33)	0	0	0	0.10 (±0.10)
	Large		0.80 (±0.80)	0.13 (±0.13)	0.17 (±0.17)	0.45 (±0.45)	0.08 (±0.08)
	All		1.13 (±1.13)	0.13 (±0.13)	0.17 (±0.17)	0.45 (±0.45)	0.18 (±0.01)
Harpaticoida	(All small)		6.51 (±3.20)	3.55 (±0.61)	0.11 (±0.11)	3.69 (±3.69)	0
Helicus spp.[L]	(All large)		0	0	0	0	0
Heteroptera[A]	(All large)		1.22 (±1.22)	1.63 (±1.63)	0.11 (±0.11)	5.59 (±3.80)	0.20 (±0.20)
Hirudinea	(All large)		0	0	0	0	0.11 (±0.11)
Hyalella azteca	Small		1.48 (±0.39)	0.18 (±0.18)	0	0.44 (±0.44)	0
	Large		46.73 (±2.82)	36.49 (±6.61)	1.67 (±0.71)	18.59 (±3.03)	1.33 (±1.10)
	All		48.21 (±3.21)	36.67 (±6.43)	1.67 (±0.71)	19.03 (±2.59)	1.33 (±1.10)
Hydra spp.	(All small)		0.33 (±0.33)	0	0	0	0
Laevapex peninsulae	Small		0	0.31 (±0.04)	0	0	0
	Large		0	0.22 (±0.22)	0	0	0
	All		0	0.53 (±0.26)	0	0	0

V. Experimental Analysis of Community Structure

This year we worked on improving our experimental design for analysis of the impact of nutrients and hydroperiod on food-web structure. The following manuscript describes the results of our past year's efforts. In the coming year we will replicate this experimental design in the Rocky Glades, and along hydroperiod and nutrient gradients throughout the Everglades. The results of this research will improve our ability to disentangle the impact of these two environmental drivers in shaping patterns of fish and macroinvertebrate density in areas where water is added to formerly short-hydroperiod marshes for restoration under IOP and CERP.

Primary Research Paper

Exploring the role of large predators in marsh food webs: evidence for a behaviorally-mediated trophic cascade.

Nathan J. Dorn[1], Joel C. Trexler, and Evelyn E. Gaiser

Department of Biological Sciences, Florida International University, Miami, FL 33199 USA

[1]*Present Address: Department of Biological Sciences, Florida Atlantic University, Davie, FL 33314* Contact: ndorn1@fau.edu

Keywords: effect size, food web, grass shrimp, macroinvertebrates, predation, trophic cascade, wetland

Abstract

The importance of large predators in oligotrophic, complex, and frequently disturbed aquatic environments is generally thought to be weak. We looked for effects of large predators in 2 semi-permanent, low nutrient, spikerush marshes by excluding large fish (> 12-mm body depth) and similar-sized herpetofauna from 1-m^2 cages (exclosures) for 2 weeks. The exclosures allowed for colonization of intermediate (-sized) consumers (small fish, shrimp, and crayfish). At the end of the experiment intermediate-consumer densities were significantly higher in exclosures than in controls at both sites. Decapod crustaceans, especially the grass shrimp (*Palaemonetes paludosus*), accounted for the majority of the response. Small primary consumers (mostly small snails, amphipods, and midges) living on the floating periphyton mats and in the flocculent organic matter were less abundant in the exclosures, indicative of a trophic cascade. Periphyton mat characteristics (i.e., biomass, chlorophyll *a*, TP) were not clearly or consistently affected by the exclosure while TP in the floc declined in the exclosures. Densities of intermediate consumers in our exclosures were similar to marsh densities, while the open controls had lower densities. This suggests that, relative to the surrounding environment, our experimental controls were risky/avoided while the exclosures were neither avoided nor preferred. Although illuminating about the dynamics of open-cage experiments, this finding does not influence the main results of the study. The collective cascading effects of large predators were consistent at both sites despite differences in drought frequency, stem density, and productivity. Effects of large fish on shrimp were generally consistent across sites, but per-capita effects were sensitive to estimates of predator abundance.

Introduction

Aquatic populations and communities are often assumed to be limited and/or structured by large-bodied fish and other consumers (e.g., Carpenter and Kitchell 1993, Persson 1999). The manifestation of top-down effects, however, may be influenced by ecosystem type (Shurin et al. 2002), system productivity (Benndorf et al. 2002, Pace et al. 1999), disturbance frequency (Menge & Olson 1990, Wellborn et al. 1996), food-web structure (Mittelbach et al. 1995, Vander Zanden et. al. 2005), and habitat complexity (Diehl 1992). Models and empirical studies indicate that top-down influences of large predators should be weakest in oligotrophic, stressful (highly disturbed), and structurally complex environments (Menge & Olson 1990, Diehl 1992, Power 1992, Wellborn et al. 1996).

The oligotrophic freshwater marshes of the Everglades have annual wetting and drying cycles and dense emergent vegetation. The trophic structure of the Everglades is unique in that fish and invertebrate densities are quite low relative to the abundance of periphyton mats (Turner et al. 1999). The effect of large aquatic predators (i.e., large fish and herpetofauna) on Everglades' prey communities is currently unresolved, and has been debated in the literature (Kushlan 1987, Loftus & Eklund 1994, Trexler et al. 2005). Effects of large fish (> 8 cm standard length, SL) on prey assemblages might be weak because of the abundant vegetation (high stem density), or the oligotrophic conditions and repeated droughts that limit densities of small- and large-bodied fish (Loftus & Eklund 1994, Chick et al. 2004, Trexler et al. 2005).

Here we report results from a manipulation designed to measure the influence of large predators at a 1-m^2 scale. Because the Everglades food web is populated by many

omnivores, we used a size-based manipulation that simplified the food web under the assumption that most similarly-sized large animals function as predators or omnivores that prey upon smaller animals. This assumption is reasonable given the intractable nature of understanding species-rich food webs via pairwise interactions (Polis and Strong 1996), and because body-size relationships are generally good predictors of predator-prey relations in aquatic communities (Diehl 1993, Layman & Winemiller 2004). For example, fish predators do not discriminate between potential prey based on prey diets (e.g., carnivorous vs. herbivorous invertebrates), but rather on the size of the prey relative to their own gape (Diehl 1993).

We looked for effects of large predators on intermediate consumers and lower trophic levels by excluding all animals larger than 1 cm body depth (i.e., most fish > 8 cm SL) from 1-m^2 areas for 2 weeks. At the end of the experiment we collected all intermediate consumers (mostly small fish and decapods), and sampled primary consumers (smaller invertebrates), and basal resources (periphyton and flocculent detritus) from exclosures and controls. Differences in intermediate consumer densities could have been caused by differential migration or survival in the experimental arenas, but we assumed that over these spatial and temporal scales the primary mechanism would most likely be migration and habitat choice (see Englund 1997, Englund et al. 2001). We first report cascading effects in the aggregated food web and then return to explore the response of the intermediate consumers in greater detail.

Methods

Study Sites and Food-Web Description

We initiated a food-web experiment in March 2004 in two marshes near SRS 2 and 3 in Shark River Slough (Everglades National Park, Figure V.1). Site 2 is upstream and north of 3, has lower productivity (Williams 2004) and dries less frequently. The sites are characterized by high densities of emergent spikerush (mostly *Eleocharis* spp.), with site 3 having especially high densities (Table V.1). Water depths typically vary annually between 0 and 80cm deep. Site 3 dried (depth < 5cm) in 6 of the previous 10 years while site 2 dried only once (2001) during the same period. The fish and invertebrate communities found at each site are similar, however densities tend to be greater at the naturally productive site 3 (Table V.1, Turner et al. 1999). While catch-per-unit-effort (CPUE) of large fish is seasonally and spatially variable (Chick et al. 2004), CPUE was similar at the two sites prior to the experiment (Table V.1).

A conceptual (simplified) Everglades size-based food web can be seen in Figure V.2. Large fish assemblages consist mainly of several sunfishes (*Lepomis* spp. and *Micropterus salmoides* Lacepede), Florida gar (*Lepisosteus platyrhincus* De Kay), lake chubsucker (*Erimyzon sucetta* Lacepede), pickerel (*Esox* spp.), yellow bullhead (*Ameiurus natalis* Lesueur) and the non-indigenous Mayan cichlid (*Cichlasoma uropthalmus* Gunther) and blue tilapia (*Oreochromis aureus* Steincachner). Large-bodied herpetofauna such as alligators (*Alligator mississippiensis* Daudin), greater siren (*Siren lacertina* Linnaeus), and pig frogs (*Rana grylio* Stejneger) were also excluded from our experimental cages. Although alligators and pig frogs are known to decapod crustaceans (T. Ugarte, personal communication) their importance in the food web is largely unknown. We will hereafter refer to the excluded animals as “large predators” or “large fish,” and will discuss the impacts of “large fish” in the discussion.

Intermediate consumers in this food web are both intermediate in size and in trophic position. They consist primarily of small fish, crayfish, and grass shrimp (Figure V.2). A few individuals of other similar-sized intermediate consumer taxa (e.g., dragonfly naiads) colonized the cages but their numbers were low and we excluded them from the analyses. The assemblage of small fishes (*Gambusia holbrooki* Girard, *Heterandria formosa* Agassiz, *Lucania goodie* Jordan, *Fundulus chrysotus* Günther, *Erymizon sucetta*, *Noturus gyrinus* Mitchill, *Lepomis marginatus* Holbrook, *Lepomis punctatus* Valenciennes, and *Aphrododerus sayanus* Gilliams) that colonized the enclosures included mostly carnivores and omnivores (Gunderson and Loftus 1993) while the crayfish (*Procambarus fallax* Hagen) and grass shrimp (*Palaemonetes paludosus* Gibbes) are omnivores.

This simplified Everglades food web has basal resources of periphyton mats and flocculent detritus (Figure V.2). The periphyton mats are a complex of live and dead algae, *Utricularia* spp., heterotrophic bacteria, and detritus, and they can form large floating mats (Turner et al. 1999). The mats and flocculent sediments have distinct invertebrate communities (Liston & Trexler 2005). For the purposes of this paper, we have lumped all of the small invertebrates residing in or on each of the basal resources into 2 response variables; primary consumers (mostly small gastropods, amphipods, chironomids, and oligochaetes). Although there may be some carnivorous members of these groups, we assume that the most are herbivores/detritivores (Figure V.2).

Cage experiment

The experimental cages measured 1-m^2 in area with walls and floors of 2-mm mesh. Each cage contained artificial vegetation (50 black plastic strips, 2.5 cm wide and

50 cm long) to provide cover for the animals. Treatments consisted of two cage types: a cage control (hereafter "control") with one open side that allowed all consumers, including large predatory fish and herpetofauna, to move in and out and an exclosure cage (hereafter "exclosure") with 1-cm mesh on one side that allowed small fish, shrimp, crayfish and other invertebrates to move freely in and out, while excluding large predators.

The experiments were started on consecutive dates (site 37 on March 8, and site 6 on March 9). At this time of year water depths were 37 and 39 cm at the two sites, but site 37 dried completely a month after our experiment was completed while site 6 remained wet throughout the dry season. The cages were arranged perpendicular to the flow of water in 3 blocks (1 replicate per block) at each site. We scored the experiment after 14 days.

We added periphyton mat to each cage at densities similar to densities in the marsh (2 kg wet mass per cage). Large invertebrates and small fish were removed from the periphyton mat prior to addition. To measure the effects of these treatments on nutrients and invertebrates in the flocculent organic sediments (hereafter "floc"), we also added a single tray (170 cm^2) with floc (~350 ml) to each cage. Large animals (e.g., shrimp) were removed from the floc prior to placing it in the trays and the trays were open on top so that consumers could forage on the organic material or invertebrates residing therein.

The cages were sealed off when we scored the experiment, to capture the mobile animals in the cages. After sealing each cage we used bar seines and aquarium nets to recover the fish, invertebrates, and benthic algae. After 4-8 bar seines per cage, we

tipped the cage on a corner to remove the remaining algae and animals by hand and/or aquarium net. We passed our hands through the corners of the cage (through any accumulated sediments) to feel for snails and other remaining animals. Fish, crayfish, shrimp, and other large invertebrates were preserved in 10% formalin (fish were first anesthetized with MS222). All fish and large invertebrates were counted in the lab.

At the termination of the experiment, all algae was removed from the cages, placed in a plastic bag on ice, and transported back to the lab. After draining excess water from the mat samples, we recorded the wet mass of each sample and removed a subsample for further analysis. We first picked out, counted, and identified macroinvertebrates under a dissecting scope. Invertebrates were identified to orders (e.g., gastopoda) or families (e.g., chironomidae), but for this paper all animals (< 1 cm length) were lumped together and analyzed as density of primary consumers per unit dry mass (g) of periphyton mat. The remaining sample of algae and detritus was homogenized in a blender and subsamples were taken for total phosphorous (TP, 120 mL), chlorophyll *a* (1 mL), and measurements of dry/ash weights (40 mL). For chlorophyll analysis, we filtered 1 mL samples onto 25-mm glass fiber filters, placed them in microvials, and extracted chlorophyll with 1.5 mL 90% acetone in a dark freezer for 20 hours. After centrifuging the samples, we used narrow-band fluorometry (Welschmeyer 1994) to quantify chlorophyll *a* concentration.

We also removed the trays of floc at the end of the experiment. From each tray we removed one aliquot (~1.5g after drying) for TP analysis and a second aliquot for invertebrate processing (all animals < 1 cm length). Invertebrate communities were primarily composed of midges (families Chironomidae and Tanypodinae), Oligochaetes,

and Ostracods. Invertebrate densities were expressed as density per unit ash-free dry mass of floc.

Statistics

Response variables for the two sites were analyzed together with site and block nested within site treated as two fixed effects. Where block(site) was non-significant ($p > 0.45$), it was dropped from the final analysis. Intermediate consumer densities were analyzed with ANOVA (total density of decapods and fish together).

Analyses of primary consumers were performed with individual ANOVAs (floc and periphyton mat invertebrates), and responses of the two basal resources were analyzed separately with 2 tests; MANOVA was used for the 3 periphyton response variables and floc TP was analyzed with ANOVA. Response variables were $\log_{10}$ or square-root transformed when necessary to normalize residuals.

We looked for treatment effects and site*treatment interactions the three intermediate-consumer taxa (fish, shrimp, and crayfish) separately with multivariate ANOVA (MANOVA). We also calculated effect sizes of large predators on grass shrimp (the most abundant intermediate consumer) at each block, to test for inter-site variation in predator effects. We used 2 indices reviewed by Berlow et al. (1999), the dynamic index [$DI = \ln(N_c/N_e)$, see also Osenberg et al. 1997] and the raw difference ($RD = N_c - N_e$; where N_c = density in control and N_e = density in exclosure), and compared collective effects and per-capita effects (dividing each effect by large fish abundance at each site). Large-fish abundance can be estimated different ways, and the calculation of per capita effects is sensitive to the quality of the estimates (Berlow et al. 1999). We estimated large-fish abundance with the raw CPUE (Table V.1) and by estimation of density (#/0.1

ha) (extricated from the CPUE vs. density relationship in Chick et al. 1999; 8/ha at site 2 vs. 18/ha at site 3). Because the relationship between CPUE and density is not proportional (density rises proportionally faster than CPUE), differences in predator abundance between the sites were greater when converted to density. Effect sizes measured with DI are probably the most appropriate measure for such a short-term colonization experiment, with populations starting far from equilibrium (zero at beginning of this study)(Berlow et al. 1999). For each index we used univariate tests to look for site variation.

We also compared the total intermediate consumer densities in our cages to natural densities in the marsh (samples taken before and after the experiment; see methods in Trexler et al. 2005, Dorn et al. 2005), to examine the general assumption that exclosures act as refuges in the natural environment. We assumed a linear relationship would best describe the dynamics of total intermediate consumer densities at site 2 and estimated a 95% confidence window for total animal density from February through April. Because site 3 was dry in April, we could only compare cage densities to marsh densities from February.

Results

We captured two large (> 10 cm SL) carnivorous fish (pike killifish, *Belenesox belizanus,* and Mayan cichlid, *Cichlasoma urophthalmus*) in two of the control cages at site 3. At site 2, one of the floc trays placed in a control cage was removed, presumably by an alligator (as evidenced by tooth marks), and deposited more than 20 m away. These observations indicated that large predators in the marsh used our control cages as

foraging areas and that exclosures provided a different environment with lower predation risk.

Exclosures contained a greater total density of intermediate consumers than controls at both sites, and intermediate consumer densities were higher at site 3 (Table V.2, Figure V.3A). Exclosures had lower densities of small primary consumers inhabiting the periphyton mat and floc (Table V.2, Figure V.3B). Despite the lower density of primary consumers, the treatment had an inconsistent and/or weaker influence on periphyton (MANOVA on three response variables: $F_{3,2} = 17.75$, $p = 0.054$)(univariate statistics in Table V.2, Figure V.3C). Total phosphorous content of the periphyton mat was generally lower in exclosures (Figure V.3C, $p = 0.092$), but biomass and chlorophyll *a* did not differ (Table V.2). Total phosphorous content (both sites) of the benthic floc was lower in exclosures (exclosure effect: $p = 0.008$, Table V.2, Figure V.3C).

The three taxa of intermediate consumers responsed to the exclosures (MANOVA $F_{3,2} = 32.77$, $p = 0.03$), by increasing overall densities, but univariate tests indicated that only grass shrimp and crayfish responded to the exclosures (Figure V.4, Table V.3). Fish and crayfish were both more abundant at site 3 than at site 2 (Figure V.4, Table V.3), and there were no significant interactions between site and treatment (Table V.3).

Analyses of most effect sizes were consistent with tests of raw densities (Table V.4); the collective effects and per-capita effects calculated using CPUE did not differ between sites. The per-capita effect sizes were smaller at site 3 (both DI and RD) when we used the estimates of large-fish density (Table V.4).

Densities of these animals in the exclosures at site 2 were near the estimated (interpolated) mean density of intermediate consumers in the marsh, while density in the

controls were 65-70% less than densities in the marsh. Densities in exclosure cages at site 3 (Figure V.5B) were closest to the densities in the natural marsh in February, while densities in the controls were below the densities in the marsh.

Discussion

The response of the decapods to these treatments demonstrates that these animals discriminated between the environments with different predation risk, and that the response was consistent across 2 sites with different productivity, stem density, and disturbance frequency. Several other studies indicate that decapod crustaceans seek shelter from large predatory fish (Ruiz et al. 1993, Garvey et al. 1994, Jordan et al. 1996). Similar size-based exclosure experiments have been used successfully to measure behavioral responses of small- and medium-sized prey fish to the exclusion of large piscivores in neotropical rivers (Layman & Winemiller 2004), and responses of invertebrate communities to exclusion of benthivorous fish in littoral zones and cattail marshes (Batzer 1998, Mancinelli et al. 2002). When exclosures are small relative to the daily movement rates of the prey taxa, models indicate that dynamics in the cages will be dominated by migration (i.e., refuging behavior) (Englund 1997, Englund et al. 2001). We believe this was the most likely case in this study; shrimp and crayfish with body lengths of 1-5 cm probably move more than one length of the cage (1 m) per day.

While the differences in colonization of our cages most likely represented a behavioral response to a safer environment (i.e., exclosures were safer than controls), comparisons of the densities with natural densities in the marsh suggests there was also a cage effect; open cages were avoided relative to the natural marsh (Figure V.4). Shrimp

may have considered the open/control cages to be risky because they had different habitat structure (i.e., plastic stems), or it is possible that cages attracted predators, creating killing stations. We cannot address these explanations directly, but we captured predatory fish in 2 of 6 open cages indicates predatory fish used them at least intermittently. This observation undermines the expectation that exclosure cages operate as refuges relative to the surrounding environment (i.e., exclosures appear to be refuges in many stream experiments, Englund et al. 2001, and in one river study, Layman & Winemiller 2004). Although this observation was illuminating about the function of our cages relative to the marsh, the observation also indicates that the cascading effects on primary consumers was not driven by exorbitant (unnatural) shrimp densities in the exclosure cages. Instead, primary consumers were sustained at higher densities in the control environment where intermediate consumer densities were experimentally lowered. Because natural densities range widely in the field we have some confidence that mat-dwelling invertebrates will be released from predation in areas with fewer shrimp. We expect that densities of primary consumers in the undisturbed marsh would have been similar to densities in the exclosures. Unfortunately we did not collect invertebrates from undisturbed mat during the study and could not check this hypothesis further.

Earlier work by Geddes & Trexler (2003) found a positive relationship between intermediate consumer (shrimp and fish) density and periphyton mat growth (TP, AFDM, etc.). This contrasts with the lack of responses in our study. However, in their paper, Geddes & Trexler (2003) reported from three separate experiments and in the experiment most similar to our study (late dry season in Shark River Slough), they found no net

positive effects of intermediate consumers on the periphyton mat. It is also likely that there is significant spatial and seasonal variation (e.g., the dry season is dominated by algal senescence) in consumer effects on the algal mat, underscoring the importance or replicating experiments in space and time.

In general, predator effects attenuate as they move through the food web (Shurin et al. 2002) and this could explain weak/inconsistent responses by the algal mat in this study. The intermediate consumers in this study, which are plant-animal omnivores, may complicate the predictions of trophic cascades by feeding on both primary producers and the periphyton mat (Polis & Strong 1996, Geddes & Trexler 2003, Dorn & Wojdak 2004). The direction of the floc TP response indicates that the decapods may have been milling through the benthic sediments and selectively ingesting high-quality (P rich) food. This explanation is consistent with several other studies that indicate decapods play a significant role in organic matter processing (Crowl et al. 2001, Usio and Townsend 2002).

Effects of large predators in Everglades' marshes

Food web theory suggests that oligotrophic and frequently disturbed environments should have fewer top predators, and weaker top-down effects, than more permanent environments (Menge & Olson 1990). While the Everglades' marshes are naturally oligotrophic and have annual drying cycles, we do not currently know where these Everglades' freshwater marshes fall along this continuum. Kushlan (1987) argued that the current altered ecosystem has more large fish predators (and a larger effect of piscivores) than the historic system, but Loftus & Eklund (1994) refuted the earlier work and argued that both small and large fish are limited by drought. Trexler et al. (2005) re-

analyzed the historic data and developed a conceptual model suggesting that predator effects will begin to outweigh effects of disturbance on small fish density after 5-8 years of constant inundation. Based on that model, fish communities at most sites in the Everglades' sloughs should be in recovery (population growth) phases most of the time. The sites where we performed this experiment had only been wet for 2-3 years, suggesting that the lack of response by fish in these experiments could have been caused by a paucity of large fish. The significant responses by shrimp and crayfish suggests that decapods are more sensitive to large fish than the contemporaneous fish assemblage. Collective predator effects, whether by comparisons of actual densities or effect sizes (DI or RD) indicated the same basic story; there were no differences in predator impacts between the sites, despite differences in hydrology, vegetation, and productivity. However, when we computed per-capita effects, a different result emerged. The effects per predator on shrimp at site 3 were less than those at site 2 when we used density estimates but not when we used CPUE. Given the high variation in density estimates possible for these CPUE values (Chick et al. 1999), we hesitate to discuss the difference between the sites. Nevertheless, the contradictory results highlight the importance of obtaining robust density estimates in order to make meaningful conclusions about per-capita effect sizes.

Conclusion

In spite of the oligotrophic conditions, high stem densities, and annual drying cycles, we found evidence for large-fish effects on Everglades' intermediate consumers. The effect of large fish indirectly reduced small primary consumers dwelling in the periphyton mats (presumably a linear cascade) and lowered TP in the flocculent

sediments. The influences of large predators and intermediate consumers in freshwater Everglades' marshes are not fully appreciated and will require greater attention to predict effects of hydro-management and restoration scenarios.

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Table V. 1. Physical and biological parameters (mean + S.E.) at the experimental sites.

	Site 2		Site 3	
Parameter	February	April	February	April
Water Depth (cm)	46.5 (1)	36.4 (1)	41.3 (3)	DRY
Periphyton biovolume (ml)	2667 (135)	2900 (438)	1133 (446)	0
Stem density (no. / m^2)	138 (5.5)	158 (11)	770 (218)	NA
Large fish[a] CPUE (no. / 5 min. bout)	1 (0.4)	1.67 (0.9)	1.44 (0.9)	0
Small fish[b] density (no. / m^2)	11.3 (1.7)	9.7 (2.1)	28 (4.5)	0
Density of large invertebrates (no. / m^2)	16.3 (3.6)	52.9 (7.0)	89.6 (6.7)	0
(shrimp density)	13.1 (3.2)	44.9 (5.8)	62.6 (6.6)	0
(crayfish density)	0.6 (0.2)	1.1 (0.6)	5 (1.4)	0

[a] greater than 8 cm Standard length, [b] less than 8 cm Standard length

Table V.2. Effects of predator exclosures on intermediate consumers, primary producers, and basal resources (periphyton and floc) as detected by ANOVA (F-statistics and error degrees of freedom shown). Error degrees of freedom differ depending upon whether or not the nested block term was included in the analysis (removed when $p > 0.45$).

Source	Intermediate consumers[a]	Periphyton 1^{o} Consumers	Floc 1^{o} Consumers[b]	Periphyton TP	Periphyton AFDM	Periphyton chl a	Floc TP[b]
Treatment	47.2***	195.7***	68.0*	4.9[‡]	3.2	0.4	13.2**
Site	11.9**	0.8	6.6	1.0	7.8*	12.1*	20.8**
Site * Treatment	0.5	0.3	1.0	0.0	1.5	2.3	0.7
Block (Site)	-	64.1***	22.7*	2.9	2.1	4.7[‡]	-
Error d.f.	8	4	3	4	4	4	7

[‡] $0.05 < p < 0.1$, * significant at $p < 0.05$, ** significant at $p < 0.01$, *** significant at $p < 0.005$

[a] fish, shrimp, and crayfish combined.

[b] replicates were lost from the control cages for these response variables

Table V.3. Effects of large predator exclosures on densities of three intermediate consumer taxa as revealed by ANOVA (F-statistics shown).

Source	d.f.	Fish	Shrimp	Crayfish
Treatment	1	1.5	115.7***	7.1*
Site	1	20.6**	1.0	12.3**
Site * Treatment	1	1.0	0.7	1.9
Error	8			

‡ $0.05 < p < 0.1$, * significant at $p < 0.05$, ** significant at $p < 0.01$, *** significant at $p < 0.005$

Table V.4. Mean (S. E.) collective and per-capita effect sizes of large fish on shrimp. DI = ln(Nc/Ne) and RD= (Nc-Ne). Statistical results from ANOVA.

	Site			
measure	2	3	$F_{1,4}$	*p*
DI	-1.36 (0.2)	-1.47 (0.3)	0.1	0.73
DI/cpue	-1.36 (0.2)	-1.03 (0.2)	1.6	0.28
DI/density	-0.18 (0.02)	-0.08 (0.02)	10.6	0.03
RD	-27.0 (2.1)	-33.7 (6.9)	0.9	0.41
RD/cpue	-27.0 (2.1)	-23.4 (4.8)	0.5	0.53
RD/density	-3.4 (0.3)	-1.9 (0.4)	10.6	0.03

Figure Legends

Figure V.1. Map of experimental sites (LTER sites SRS 2 and 3) in the Florida Everglades. These sites are also known as sites 6 and 37 (in Trexler et al. 2002).

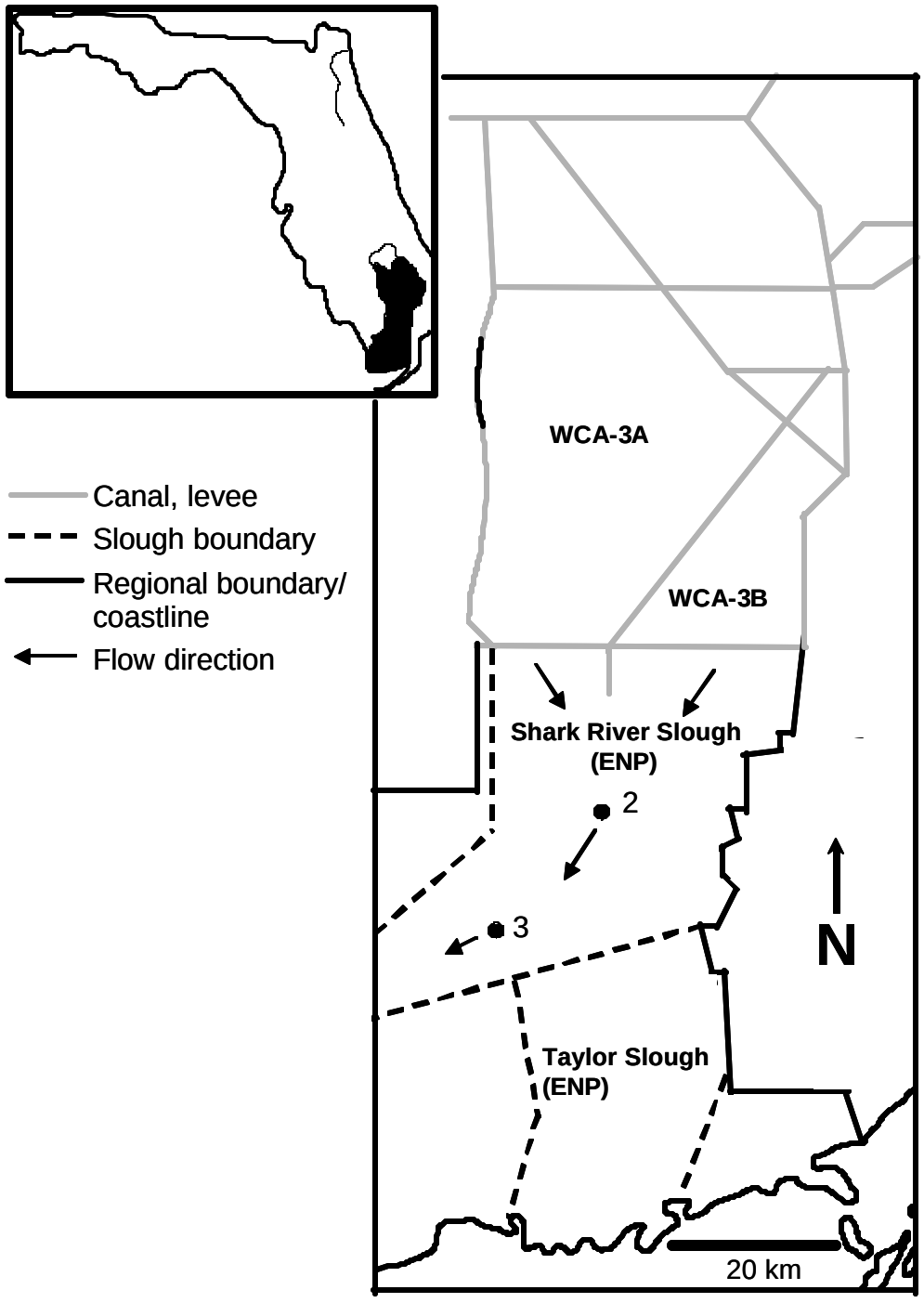
Figure V.2. Schematic size-based food web for Everglades marshes. Arrows indicate the flow of energy and plant-animal omnivory between size-based trophic groupings.

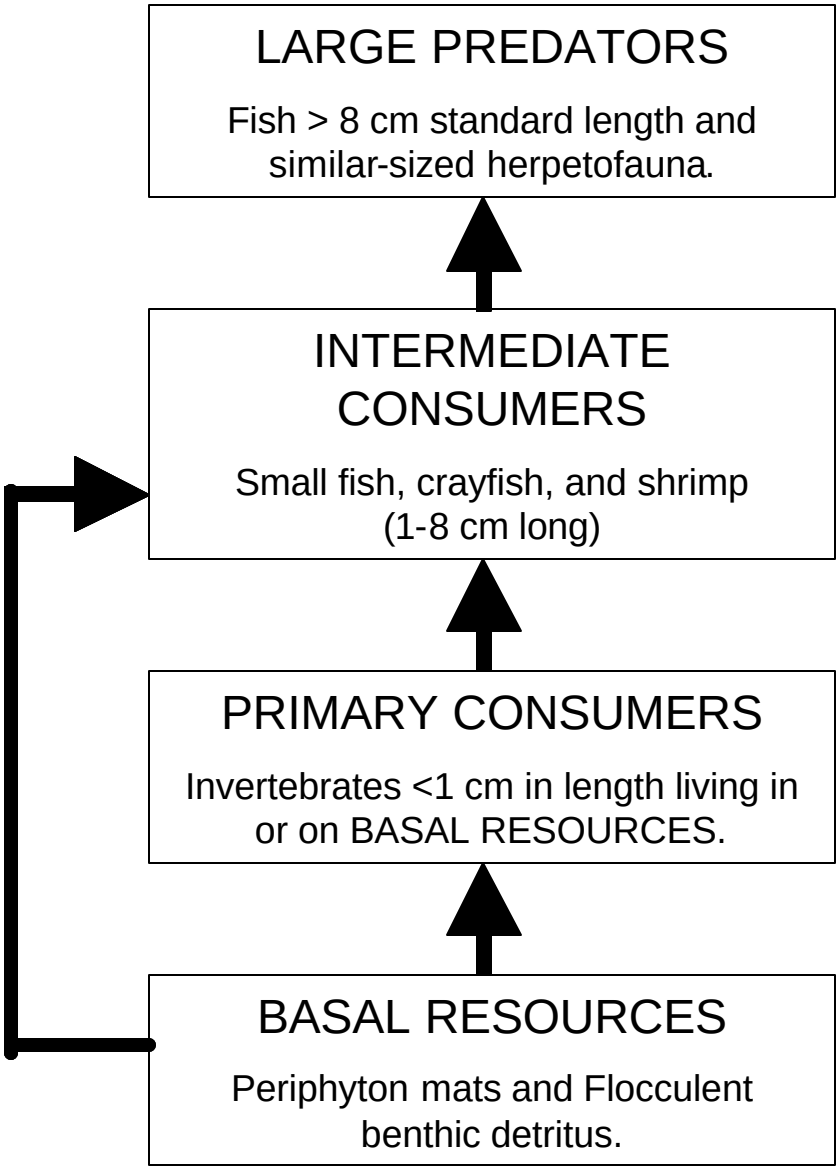
Figure V.3. Responses of three trophic levels to manipulation of large predators in Everglades marshes. A) Densities of total intermediate-sized consumers (fish, shrimp, and crayfish). B) Densities of primary consumers (amphipods, midges, and snails) living in floc (filled circles) and periphyton mats (open circles). C) Phosphorous content of floc (filled circles) and periphyton mats (open circles). Error bars represent 1 S.E.

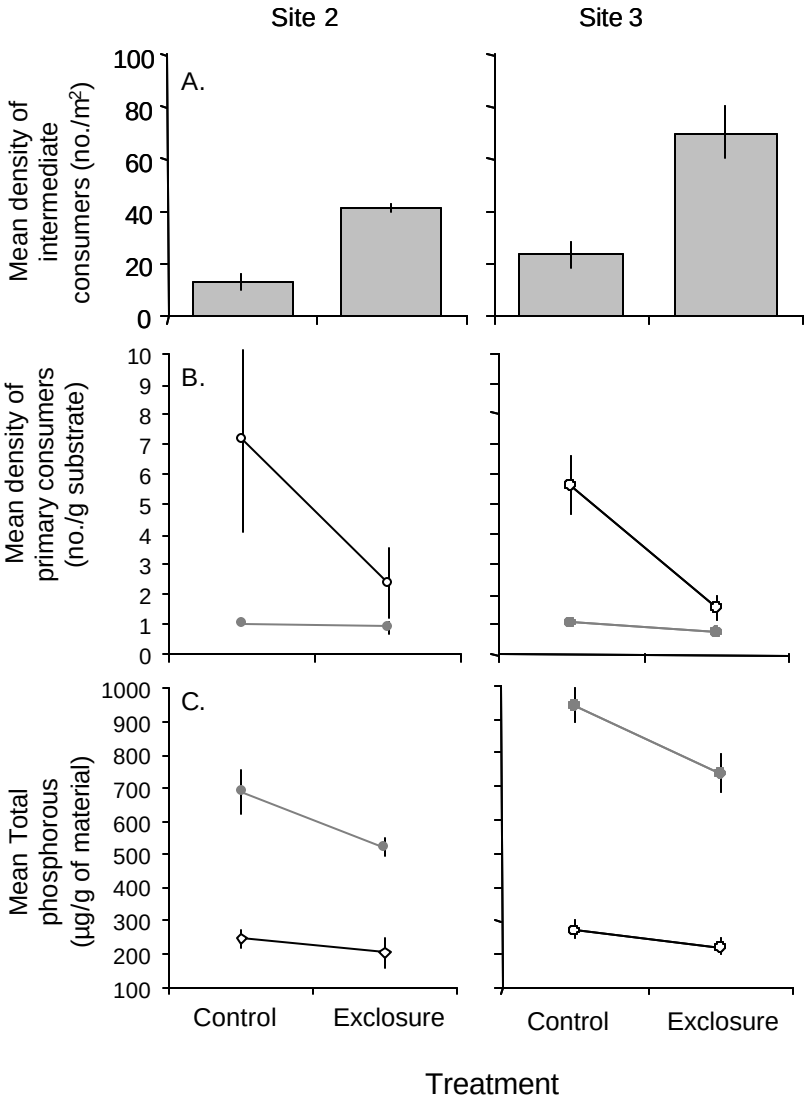
Figure V.4. Mean number of the 3 most common intermediate-sized consumer groups recovered from cage controls and exclosure cages at A. Site 2 and B. Site 3 (Everglades National Park). Error bars represent 1 S.E.

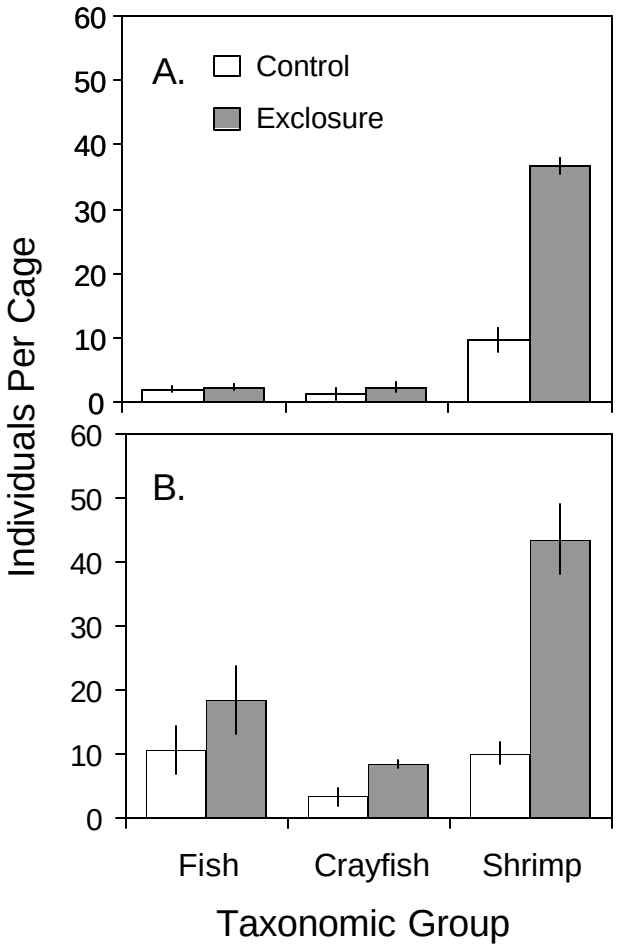
Figure V.5. Densities of intermediate consumers (all fish, crayfish, and shrimp combined) in the marsh (¦) (both February and April for site 6) and exclosures (?) and control (?) cages (all data points plotted) at A) Site 2 and B) Site 3. Marsh densities are averages and error bars represent 95% confidence intervals (n = 7 estimates). Independent measurements of density were not available for site 37 in April because the marsh was

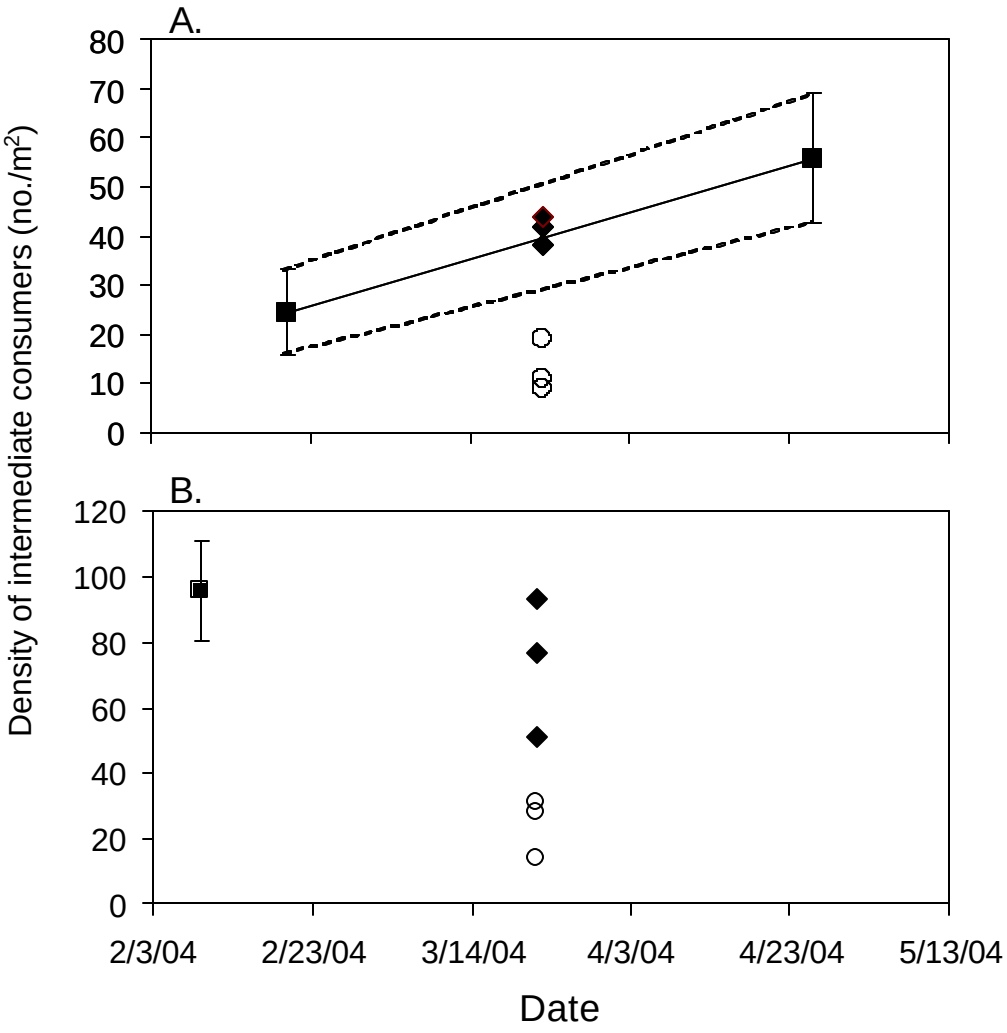
dry. Trend lines were added to panel A to indicate probable changes in animal density over the time period.


Canal, levee
Slough boundary
Regional boundary/ coastline
Flow direction
WCA-3A
WCA-3B
Shark River Slough (ENP)
2
3
N
Taylor Slough (ENP)
20 km


LARGE PREDATORS
Fish > 8 cm standard length and similar-sized herpetofauna.
INTERMEDIATE CONSUMERS
Small fish, crayfish, and shrimp (1-8 cm long)
PRIMARY CONSUMERS
Invertebrates <1 cm in length living in or on BASAL RESOURCES.
BASAL RESOURCES
Periphyton mats and Flocculent benthic detritus.


Site 2
Site 3
A.
B.
C.
Mean density of intermediate consumers (no./m²)
Mean density of primary consumers (no./g substrate)
Mean Total phosphorous (µg/g of material)
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
1000
900
800
700
600
500
400
300
200
100
Control
Exclosure
Control
Exclosure
Treatment


A.
Control
Exclosure
B.
Individuals Per Cage
0
10
20
30
40
50
60
Fish
Crayfish
Shrimp
Taxonomic Group


A.
B.
Density of intermediate consumers (no./m2)
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
2/3/04
2/23/04
3/14/04
4/3/04
4/23/04
5/13/04
Date