A SURVEY OF THE EFFECTS OF INVASIVE EXOTIC VEGETATION ON WETLAND FUNCTIONS: AQUATIC FAUNA AND WILDLIFE

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TABLE OF CONTENTS

INTRODUCTION

Drainage activity, soil disturbance, fire suppression and other anthropogenic activities have facilitated the spread of invasive non-native trees throughout South Florida, most notably Brazilian pepper (*Schinus terebinthifolius*) and *melaleuca (Melaleuca quinquenervia),* also known as punk trees or paperbark tea trees. As a result of the rapid rate of urban and agricultural development in the region, resource managers, planners, consultants, and engineers are forced to make quick value judgments on the relative quality or "functional value" of wetland habitat types. Often this comes at the expense of what visually appear to be moderate or lower quality wetland habitats, which are subsequently lost to land conversion, fragmentation or dredge and fill. It is routinely argued that the presence or relative dominance of invasive plants in wetland habitats of South Florida severely reduces wetland "functions", yet very little if any scientific data supports such arguments. Although detailed quantitative studies of the ecological effects of invasive species in south Florida have not been performed (Science Sub-group 1994), two recent reports published by DEP and the Exotic Pest Plant Council (Laroche 1994) "provide excellent qualitative summaries of the ecological impacts of *melaleuca*" (Mazotti et al.2002). More recently, O'Hare and Dalrymple (1997) conducted a two-year study of graminoid wetlands with varying degrees of *melaleuca* infestation to assess fish and wildlife utilization in the Southern Everglades.

It is unlikely that exotic plant coverage alone degrades water storage, flood control, or groundwater recharge functions, but what exactly are the effects on native ecosystem components like invertebrates, fish and wildlife? Are these wetland functions degraded or lost permanently? The invasion and dominance of invasive exotic plants in wetlands may be a temporary phenomenon as evidenced by several successful wetland restoration projects and management plans implemented within the CHNEP Study Area. Several hundreds of acres on Sanibel alone have been mechanically cleared of *Schinus* and *Melaleuca* and are now maintained as native marshes and hardwood hammocks through combinations of prescribed fire and selective re-treatment with herbicides. The sites on Sanibel selected for this study include areas that have restored in this manor. In addition, biological control agents for exotic plants like *Melaleuca* are being released, or studied for pending release, every year. The melaleuca weevil (*Oxyops vitiosa*) was released into the study area in Lee County at approximately the time this study was initiated in 2002. The long-term effects of these biological control agents are unknown but short-term visual effects are becoming obvious.

Our current study was intended to provide quantifiable data on the direct effects of pepper and *melaleuca* infestation on resident aquatic fauna, small mammals and other wildlife in Lee County. Of particular interest are the resident aquatic fauna that depend on the localized habitat and hydrology for survival and reproduction. Wetland fishes have recently been used as indicators of hydroperiod and habitat conditions (Ceilley et al. 2000, Main et al. 1997). Aquatic beetles have long been regarded as transient visitors to wetlands and other water bodies, but recent studies suggest strong environmental influences on distribution and thus the potential for using beetles as bioindicators of habitat quality (Fairchild et al. 2003). Previous technical reports from the region indicate that macroinvertebrate and fish diversity is suppressed in both brackish and freshwater wetlands (Ceilley 1995 and Ceilley and Cox 1995).

This project quantitatively evaluated the effects of invasive exotic *Melaleuca* and Brazilian pepper on wetland faunal groups and wildlife utilization. We intended to document habitat utilization from an aquatic, trophic level and a terrestrial, structural level. We attempted to employ the most practical, standardized, cost-effective and repeatable sampling methods for each taxonomic group to document species richness, abundance and diversity for comparison between habitats. Public lands within the Tidal Caloosahatchee River Watershed drainage basin (invaded by *Melaleuca*) and private conservation lands in the Pine Island/Barrier Islands region (invaded by Brazilian pepper) served as two distinct study sites for this research and restoration project.

MATERIALS AND METHODS

Study Areas

The Lee County Conservation 2020 Program was instituted in 1996 as a land acquisition program based on a citizen referendum to purchase sensitive lands with property taxes. Subsequent action by the Board of County Commissioners has resulted in more than 7,460 acres being purchased since 1997. Two wetland habitat types (a marsh and a wet prairie) were sampled within the largest of these conservation areas, 2,400± acres known as the Prairie Pines Preserve, situated North of the Caloosahatchee River along the Lee and Charlotte County line. Within each wetland type, sites were selected that were free of exotic plants (<1%), adjacent areas that are moderately infested with *Melaleuca* (40% -60%), and areas that were completed dominated (>90%) by this invasive exotic species. Patch size for this study was limited by site constraints and the need to sample sites that were hydrologically connected and had the same water depths as other treatments.

The project provides a comprehensive inventory of fishes, aquatic macroinvertebrates, amphibians, wading birds and other wildlife using the Prairie Pines Wildlife Preserve. The results of this project will assist the Conservation 2020 Program in developing land management plans to appropriately restore, manage and maintain fish and wildlife habitats purchased with public funds. The project provides additional information on how native wetland plant and wildlife communities have responded to *Melaleuca* and at what levels of infestation may produce significant differences.

Three areas were selected along the Sanibel River Corridor consisting of rare and unique barrier island freshwater wetlands that were once contiguous along the Sanibel River Slough. Each of the three areas has been invaded by invasive non-native vegetation, especially Brazilian pepper and to a lesser extent Australian pine (*Casuarina* sp.) where spoil material has been deposited. Two of the study areas have been cleared of invasive exotics, one in 1994 (Johnston Swale) and one in 2000/01 (Frannie's Preserve), while the third area is un-restored (Periwinkle-Casa Ybel River Preserve or "PCRP"). The study results from these areas will provide information on their habitat value for fish, macroinvertebrates, and wildlife species. It will also provide a deeper understanding of trophic linkages that may be altered by the presence or abundance of exotic plants. Numerous listed species are documented as foraging, nesting or frequenting the interior freshwater wetlands on Sanibel Island. The data obtained from this project will be used to evaluate the functional impairment of coastal wetlands and uplands due to the invasion and domination by the invasive exotic plant, Brazilian pepper. It will also provide baseline taxonomic inventories for several groups in this unique system for future reference and post-restoration evaluations currently planned by SCCF.

Methods for Data Collection

The purpose of this study was to quantitatively evaluate the effects of invasive exotic *Melaleuca* and Brazilian pepper (*Schinus* terebinthefolius on wetland faunal groups, plant community structure, and wildlife utilization within the CHNEP Study Area. Two wetland habitat types (a marsh and a wet prairie) were sampled within the Prairie Pines Wildlife Preserve, and, within each wetland type, sites were selected that were free of exotic plants (<1%), adjacent areas that are moderately infested with *Melaleuca* (10% - 50%), and areas that were completed dominated (>90%) by this invasive exotic species. Three freshwater wetland areas were selected on Sanibel Island and each of the areas has been invaded by invasive non-native vegetation, especially Brazilian pepper, and to a lesser extent Australian pine (*Casuarina* sp.). Two of the study areas have been cleared of invasive exotics, one in 1994 (Frannie's Preserve) and one in 2000/01 (Johnston Swale), while the third area is unrestored (Periwinkle-Casa Ybel-River Preserve or "PCRP").

Standardized and repeatable sampling methods were used to document species richness, abundance, and diversity of fish, macroinvertebrates, small mammals, amphibians, and other wildlife at each of the sampling sites within the respective study areas. Fish sampling was conducted using the non-destructive sampling methods recommended for South Florida wetlands (Main et al., 1997; Ceilley et al., 2000). Eight clear plastic traps (Breder, 1960) were set in shallow waters (< 40 cm) at each sampling site and retrieved after a 1-hour soak time. Fish were collected live, identified, and enumerated with sub-samples preserved as vouchers. Water quality data were collected using a YSI model 85 D.O./Temp./Salinity meter and recorded on fish sampling data sheets.

Macroinvertebrate samples were collected from each site using a 1,400 micron mesh D-frame dip-net with a width of 30 cm along the bottom and a height of 22 cm at the tallest point. Samples were collected by sweeping the net through vegetation and benthic substrates and, in the presence of flowing water, kicking an area immediately upstream of the net. Individual rocks and snags were picked up, and attached macroinvertebrates were removed and placed in the sample. Snags were sampled by scraping them with the net and matted vegetation was shaken directly over the net. Sampling was performed until no new macroinvertebrates were collected in three attempts or, in areas of low macro-invertebrate abundance, until the person or persons sampling had been collecting for a total of 0.5 combined person hours with no new results. This typically represents the asymptote of the species accumulation curve where all common and most uncommon or occasional species are collected. Macroinvertebrates were field-sorted using forceps, eyedroppers, and white sorting pans, and preserved in 70% ethanol for later identification to the lowest practical taxonomic level. Macroinvertebrate and fish sampling were conducted during the wet season of 2002 and twice each day, early morning and late afternoon.

Small mammal surveys were conducted simultaneously along each habitat transect using twenty-five Sherman traps set at each site. The trapping array consisted of 1 trap at the midpoint of the array and 3 traps spaced 10 m apart along transects at 45º compass headings from the midpoint. Unshelled peanuts and oats were used as bait and traps were set for four consecutive days at each site. During all sampling events in Prairie Pines Preserve, wildlife use was determined by directly observing animals or indirectly observing tracks, scat, calls, or food acquisition.

Drift fence and funnel trap sampling was employed to enhance capture rates for several taxa of wetland fauna in the Southern Everglades with relative success (O'Hare and Dalrymple 1997). However, drift fence trap methods for herpetofauna (turtles, lizards, snakes and amphibians) were abandoned at the Prairie Pines Preserve after it was observed that unauthorized public access, including off-road vehicles, hunting, and horseback riding was a common occurrence. Audible anuran amphibian surveys were conducted at Prairie Pines during the summer of 2002 and 2003 following rain events using methods based on those developed by the for "Frogwatch USA" (NWF and USGS. 2001).

Sampling for amphibians and reptiles (Sanibel only) was done using drift fencing, which consisted of 20" aluminum flashing buried approximately 2-4" in the ground and held up using rebar stakes. Buckets were buried flush with the ground at each end of a fence section and mesh funnel traps were placed in the middle of each section of fencing. PVC pipes of approximately 4' in length were also placed in the ground at approximate 45° angles on each end of a fence section. Fences were arrayed in an "H" shape with one section ran perpendicular to the ridge and four sections placed parallel to the same ridge. On Sanibel, both the Frannie's and Johnston preserve two sights were chosen for these "H" arrays each on homologous ridges. Due to constraints of edge effects on the PCRP site, only one fence array was established on a ridge homologous to one of the two arrays on the Frannie's and Johnston preserve. To compensate for the lack of a second sampling site, the "H" array on the PCRP consisted of two sections of fence perpendicular to the ridge and six sections parallel to it and all data were adjusted for the total length of fence at each location. Traps were checked on one to two day intervals without marking individuals.

Data Analysis

The total number of operational taxonomic units (OTUs) and number of individuals was determined for fish, macroinvertebrates, small mammals, amphibians, and other wildlife at the sampling sites of each study area. Species richness was calculated as the total number of species and abundance was calculated as the total number of individuals. A series of diversity indices were calculated for each sample site using PRIMER statistical software (Clarke and Gorley, 2001). These indices include: Margalef richness index (d), Pielou evenness index (J'), Simpson's evenness index ($1-\lambda$), Shannon diversity index (H'), and Hill numbers N_1 and N_2, where N_1 is a transform of Shannon diversity [$N_1 = \exp(H')$] and N_2 is the reciprocal of Simpson's λ [$N_2 = 1/\Sigma p_i^2$]. Standardization of the abundance of macroinvertebrate and wildlife taxa was necessary given the qualitative sampling methods. OTUs for these two groups were categorized as rare (n=1), occasional (n=2-9), common (n= 10-24), or abundant ($n \geq 25$), and rank values of 1, 6, 17, or 25 were applied to the respective categories (Main et al., 1997).

RESULTS

Prairie Pines Wildlife Preserve

Fishes

A total of 5 families of fish and at least 8 species were collected from the wetland habitat types in Prairie Pines Wildlife Preserve (Table 1). Eight species of fish, including a non-native cichlid, were collected from the marsh habitat, while only 4 species were collected from the wet prairie habitat. The mosquitofish (*Gambusia holbrooki*) was the most abundant species in both habitats, followed by the flagfish (*Jordanella floridae*). The number of fish families collected in the wet prairie habitat decreased at the sites moderately infested and dominated by *Melaleuca* (Fig. 1). The number of fish families in the moderately infested marsh site increased owing to the collection of a non-native cichlid (Table 1), but the number decreased at the marsh site dominated by *Melaleuca*. Fish species richness decreased with increasing exotic infestation of the wet prairie sites (Fig.1). Fish species richness was the same for the exotic free and moderately infested marsh sites, but decreased at the *Melaleuca* dominated site. Fish abundance decreased with increasing *Melaleuca* infestation at both habitat types and fish abundance was higher in the corresponding marsh sites (Fig. 1).

With the exception of the Margalef's index, the diversity indices indicated a decrease in fish family diversity with increasing *Melaleuca* infestation in the marsh habitat types (Table 2). Margalef's index is a measure of richness and, as such, the values calculated for the fish families in the marsh habitat follow the same distribution as the family richness (Fig. 1). The moderately infested marsh site had higher fish species diversity than the exotic free marsh site, and both of these sites had higher diversity than the marsh site dominated by *Melaleuca* (Table 3). Both the exotic free and moderately infested marsh sites have equal fish species richness (n=7; Fig.1), and therefore similar Margalef's indices, but this diversity index does not discriminate situations when evenness (equal abundance of species) varies. The moderately infested marsh site had fewer "rare" fish species (n=1) and less abundance of most other species (Table 1), giving this site greater evenness. The remaining diversity indices incorporate information on the proportional abundance of species and therefore assign a higher value to the site with greater species evenness (Magurran, 1988). With the exception of Pielou's index, diversity indices in the wet prairie habitat indicated greatest diversity in the exotic free site for both fish families and species (Table 3). There was less range in abundance for flagfish and mosquitofish in the *Melaleuca* dominated wet prairie site (Table 1), giving a greater evenness, and therefore higher Pielou's index, to the respective families and species at this site. The greater evenness of the exotic dominated wet prairie site also influenced the remaining diversity indices by giving higher values for this site than the moderately infested site, but not high enough to offset the greater richness in the OTUs of the exotic free site (Fig. 1). At Prairie Pines Preserve, fish species richness was the same for the exotic free and moderately infested marsh sites, but decreased at the *Melaleuca* dominated site.

Fish species richness decreased with increasing exotic infestation of the wet prairie sites. Fish abundance decreased with increasing *Melaleuca* infestation at both habitat types and fish abundance was higher in the corresponding marsh sites. The moderately infested marsh site had higher fish species diversity than the exotic free marsh site, and both of these sites had higher diversity than the marsh site dominated by *Melaleuca*. Diversity indices in the wet prairie habitat indicated greatest fish species diversity in the exotic free site.

<u>Macroinvertebrates</u>

A total of 5 classes, 12 orders, 29 families, and at least 48 genera of macroinvertebrates were collected from the wetland habitat types in Prairie Pines Wildlife Preserve (Table 4). Insects were the most abundant in both habitat types and had the highest number of OTUs (6 orders, 21 families, and at least 42 genera). The damselfly *Ischnura hastata* (*n*=35) was the most abundant macroinvertebrate species in the marsh habitat followed by the mayfly *Callibaetis sp.* (*n*=34). The mayfly *Callibaetis sp.* (*n*=72 in exotic free and *n*=60 in moderate *Melaleuca* sites) was the most abundant in the wet prairie habitat followed by the damselfly *Ischnura sp.* (*n*=58) and an unidentified ostracod (*n*=54). Abundance in the insect orders decreased with increasing *Melaleuca* infestation (Fig. 2). Similarly, macroinvertebrate family and species richness decreased with increasing proportions of *Melaleuca*, and there was a substantial decrease in overall macroinvertebrate abundance with increasing exotic vegetation (Fig. 3).

With the exception of Pielou's index for the marsh habitat, the diversity indices indicated a decrease in macroinvertebrate family diversity (Table 5) and species diversity (Table 6) with increasing infestation of *Melaleuca* in both habitat types. The *Melaleuca* dominated marsh site did not have any "common" or "abundant" rankings relative to the other marsh sites. Therefore, the slightly greater Pielou's index for the families and species at this site indicated more evenness of abundance rankings. Values for the macroinvertebrate diversity indices were considerably higher than those calculated for fish (Tables 2 and 3) indicating greater richness and, owing to the standardization, greater evenness among macroinvertebrate OTUs.

<u>Small mammals</u>

Three species of small mammals were collected from the Prairie Pines Preserve wetland habitat types (Table 7). The cotton mouse (*Peromyscus gossypinus*) was the most abundant small mammal in the marsh habitat and was primarily captured in the site moderately infested with *Melaleuca*. The hispid cotton rat (*Sigmodon hispidus*) was the only small mammal collected in the wet prairie and was captured in the moderately infested site for this habitat type. Small mammal abundance was relatively low in both habitat types (Fig. 4). Diversity indices were not calculated for this group given the low species richness and abundance.

<u>Amphibians and Reptiles</u>

Audible anuran surveys were conducted on three occasions within Prairie Pines Preserve but the results were difficult to quantify between habitats due to close proximity of treatments. It was clear that no native tree frogs were observed or audibly recorded from the *melaleuca* dominated habitats. Only the non-native Cuban tree frog (Osteopilus septentrionalis) was audibly detected within the 100% *melaleuca* sites. Pig frogs (*Rana grylio*), green and squirrel tree frogs (*Hyla cinerea* and *H. squirella*) and narrow-mouth frogs (*Gastrophryne carolinensis*) were all commonly observed and audibly recorded from the native marsh habitat. Pinewoods tree frogs (Hyla femoralis) were detected chorusing in the wet prairie transect during 2002 and 2003. The chorusing males appeared to be fairly common in both the 50% *melaleuca* and the native wet prairie early in the rainy season. Later in the summer, as water levels rose pinewoods tree frogs were calling from the adjacent mesic pine flatwoods to the west. Green tree frogs and squirrel tree frogs were also observed calling from a small marsh within the wet prairie next to our study plots. On several occasions driving at night to and from our sites we observed southern toads (*Quercus terrestris*) and southern leopard frogs (*Rana utricularia*) along the roads in upland habitats that consisted of slash pine and *melaleuca*.

<u>Wildlife observations</u>

A total of 4 classes of wildlife were observed in the wetland habitats of the Prairie Pines Wildlife Preserve, including 37 avian, 9 amphibian, 7 mammalian, and 5 reptilian species (Table 8). Of these totals, 33 avian, 6 amphibian, 7 mammalian, and 4 reptilian species were observed in the marsh habitat, while 19 avian, 9 amphibian, 4 mammalian, and 3 reptilian species were observed in the wet prairie habitat. White ibis (*Eudocimus albus*) were the most abundant wildlife species at both habitat types (*n*=326 for marsh and *n*=173 for wet prairie) followed by glossy ibis (*Plegadis falcinellus*) at the marsh habitat (*n*=134). Wildlife classes decreased from the exotic free marsh site to the moderately infested marsh site (Fig. 5), but increased in the exotic dominant marsh site due to the presence of deer tracks. Wildlife classes in the wet prairie habitat decreased with increasing *Melaleuca* infestation. Species richness decreased from 45 species in the exotic free marsh site to 1 avian and 1 amphibian in the moderately infested site, but increased to 3 avian, 3 amphibian, and 1 mammalian species in the *Melaleuca* dominated marsh site (Fig. 5). Species richness in the wet prairie habitat decreased with increasing *Melaleuca* infestation. There were substantial declines in abundance for both habitat types from exotic free sites to sites with moderate and dominant *Melaleuca* infestation (Fig. 5).

With the exception of Margalef's index, the exotic free site had the largest diversity indices for wildlife classes in the marsh habitat (Table 9). The exotic free marsh site had more wildlife classes (*n*=4) than the *Melaleuca* dominated site (*n*=3), but the Margalef's richness index was slightly larger in the latter site. This discrepancy was due to the relatively small number of wildlife classes at both sites and the proportionally larger denominator when calculating Margalef's index (no. of wildlife classes/natural log of the ranking total) for the exotic dominated site. The *Melaleuca* dominated marsh site also exhibited greater diversity indices than the moderately infested site owing to the greater richness and evenness among the wildlife classes. With the exception of Pielou's index, there was decreasing wildlife class diversity with increasing *Melaleuca* infestation in the wet prairie habitat. The *Melaleuca* dominated wet prairie site had 2 wildlife classes with equal ranking and therefore had the greatest evenness among the sites. The diversity indices indicated greater wildlife species diversity in the exotic free sites of both habitats and decreasing species diversity with increasing *Melaleuca* infestation (Table 10).

While diversity was generally low in the *Melaleuca* dominated sites in Prairie Pines Preserve, wildlife observations included a small group of woodstorks foraging in pools of water withing the 90-100% *Melaleuca* and several observations of a resident pair Florida mottled ducks dabbling in a road cut through the *Melaleuca* treatment. We also encountered the scattered remains of wading bird in dense *Melaleuca* that apparently was killed by a bobcat, fox, or other predator.

Sanibel Island

<u>Fishes</u>

A total of 4 families of fish and 10 species were collected from the wetland areas on Sanibel Island (Table 11). Eight species of fish were collected from Frannie's Preserve, while only 6 species were collected from the Johnston Swale area. No fish were collected from PCRP, the unrestored area dominated by Brazilian pepper. The mosquitofish (*Gambusia holbrooki*) was the most abundant fish species (Table 11), followed by the sailfin molly (*Poecilila latipinna*). Fish family richness, species richness, and abundance in the more recently restored Frannie's wetland was substantially greater than that of the Johnston Swale (Fig. 6).

Diversity indices indicated higher fish family diversity in the Frannie's restoration area than in the Johnston area (Table 12). Margalef's index indicated higher fish species diversity for Frannie's (Table 13), given the greater species richness in this area (Fig. 6). However, the remaining species diversity indices were slightly higher for Johnston, probably due to the less range of abundance (Table 11) and therefore greater evenness for the fish species in this area.

<u>Macroinvertebrates</u>

A total of 3 classes, 9 orders, 26 families, and at least 34 genera of macroinvertebrates were collected from the wetland areas on Sanibel Island (Table 14). Insects were the most abundant and had the highest number of OTUs (6 orders, 21 families, and at least 31 genera). Water scavenger beetles of the genus *Tropisternus* were the most abundant macroinvertebrate (*n*=33 at Johnston, 36% larval, and *n*=32 at Frannie's, 84% larval), followed by larval mosquitoes *Culex* sp. (*n*=22 at PCRP), water bugs (Hemiptera) of the genus *Belostoma* (*n*=21 at Frannie's), and larval chironomids (*n*=19 at PCRP). Hemipterans had relatively higher abundance in the restored Frannie's and Johnston areas (Fig. 7), whereas dipterans had higher relative abundance in PCRP area infested with exotic vegetation. Odonates were much less abundant in Sanibel Island wetlands compared to the marsh and wet prairie habitats in Prairie Pines Preserve (Fig. 2).

Margalef's index indicated higher macroinvertebrate family and species diversity at Frannie's (Tables 15 and 16), given the higher taxonomic richness in this restored area (Fig. 8), and both restored areas had higher diversity than the exotic infested PCRP area. However, Pielou's index indicated slightly greater evennness for macroinvertebrate families in the PCRP area and for macroinvertebrate species in the Johnston area. The remaining indices indicted slightly higher macroinvertebrate family diversity for Johnston and slightly higher species diversity at Frannie's (Table 15), and both restored areas had higher diversity than PCRP.

<u>Small mammals</u>

The hispid cotton rat (*Sigmodon hispidus*) was the most abundant small mammal at Sanibel wetland sites (Table 17). Relatively large numbers of this species were captured at the restored areas (Johnston and Frannie's), but not the exotic infested area (PCRP). The black rat was primarily captured in the PCRP area. The restored areas had greater small mammal abundance (Fig. 9) given the dominance by the hispid cotton rat. Diversity indices were not calculated for this group because of the low species richness.

Amphibians and Reptiles

Drift fence data for both families and species showed higher values in restored sites for all indices except Pielou’s (Tables 19 and 20). Evenness (J’) was highest at the exotic infested area (PCRP) in both the alalysis of family and species. The preserve with the longest time interval since removal of exotics (Johnston) showed the highest values only in the family analysis for Simpson and Hill's N_2 (Table 19). In all other cases, the site most recently cleared of exotics (Frannie's) exhibited the highest values.

DISCUSSION

While a consistent pattern of higher diversity in native (exotic-free) wetlands is not apparent in all taxa across all indices, the trend toward decreased diversity and abundance in exotic dominated areas is apparent. It can also be said from the data that dominance by exotics does not increase richness and abundance for any taxa as a whole. The dense (90-100%) pepper and *Melaleuca* sampling sites were nearly devoid of herbaceous ground cover and filamentous algae. The *Melaleuca* stands are characterized by a forest floor with adventitious root mats and a layer of *Melaleuca* leaf litter that appears resistant to decay.

The dramatic differences between study treatments in some taxa indicate considerable disruption of ecosystem functions in areas dominated by monocultures of exotic vegetation. However, the data from Sanibel also indicate that these functions are not permanently lost and can be restored to some extent by simply eliminating the dominance of exotic vegetation. The extent to which Sanibel's wetlands have recovered compared to a pristine condition cannot be determined since no such areas exist on the island for comparison.

Mazzotti *et al.* (1981) and Ostrenko & Mazzotti (1981) trapped small mammals in a variety of habitats in the east Everglades, including areas contaminated to varying degrees by *Melaleuca* and *Casuarina*. Within this region, *Melaleuca* habitats had fewer small mammals than native hammock communities trapped previously by Smith & Vrieze (1979). *Melaleuca* habitats had *higher* numbers when compared to *Casuarina* habitats or to the sawgrass prairies being invaded. Ostrenko & Mazzotti (1981) observed predators of small mammals (including a barn owl and an endangered indigo snake) in *Melaleuca* habitats. Based on these observations, the authors concluded that although non-native plant communities were not good habitats for wildlife, they should not be classified as biological deserts. More recent work conducted in the Southern Everglades indicates that small patches of *melaleuca* can increase structural diversity in graminoid wetlands and not negatively effect fish and wildlife diversity with moderate levels of infestation (O'Hare and Dalrymple 1997).

Data from Prairie Pines, while not offering an indication of the ability to restore lost functions does give us an idea of the extent to which exotics can alter the functionality of a pristine system. The data suggest that overall faunal diversity, and therefore corresponding wetland function declines in a linear fashion with an increase in exotic infestation. However, our observations and data suggest that moderately *Melaleuca* infested (40%-60%) wetlands retain relatively high faunal diversity. These sites may provide structural shelter from predators and storm events, as well as shade and cooler waters that may attract fishes and other wildlife from adjacent open wet prairie wetlands during hot sunny days when water temperatures approach 40 ˚ Celsius. With respect to aquatic macroinvertebrates, there are often specific microhabitat requirements for certain taxonomic groups and species. Even the habitats dominated by *Melaleuca* retained some taxonomic richness of macroinvertebrates including crustaceans (crayfish and shrimp), ostracods, diptera (flies), ephemeroptera (mayflies) and coleoptera (water beetles) and the most common forage fishes, mosquitofish (*Gambusi)* and the endemic Florida flagfish *(Jordanella floridae).* Interestingly, one species of Aeshnid dragonfly larva, *Gynacantha* *nervosa,* was only collected from the 90-100% *Melaleuca* dominated site (along the wet prairie transect) and from PCRP, the Brazilian pepper dominated site on Sanibel. This same species has been collected from relatively pristine, cypress-strand swamp within Fakahatchee Strand State Preserve (Ceilley et al. 2004). The Fakahatchee Strand study sites have a canopy that consists mainly of cypress (*Taxodium*), popash (*Fraxinus*) and pond apple (*Annona glabra*). Common elements to these three very different habitats (*Melaleuca*, *Schinus* and *Taxodium*) are a closed canopy with shaded understory, relatively cool waters, low D.O., leaf litter in the benthos, and an abundance of mosquitoes (Diptera: Culicidae) and/or backswimmers (Hemiptera: Notonectidae). Both mosquitoes and backswimmers are air-breathers that are relatively tolerant of low dissolved oxygen and seem to be associated with detritus and dead leaf litter. The dragonfly (*Gynacantha nervosa*) is entirely predacious and is likely preying on these other aquatic insects.

This study was conducted in relatively small patches of habitat that were contiguous with, or adjacent to other treatments in Prairie Pines Preserve or Sanibel River Corridor respectively. The PCRP site has now been cleared of Brazilain pepper and other exotic plants and is being managed with other preservation lands within the Sanibel River Corridor. The only variable considered at Prairie Pines Preserve was melalueca coverage. To assess landscape level effects of 90-100% *Melaleuca* on fish and wildlife we would recommend evaluating larger patches of each treatment which was not possible at this site. It will be important to also monitor the short-term and long-term effects of the newly introduced biological control agents such as the melaleuca weevil, *Oxyops vitiosa*. The immediate effects of this introduction were not quantified as a part of this study. Our observations indicate that *Oxyops* has become well established at Prairie Pines and larvae and adults are widespread and foraging on the apical growth of *Melaleuca*.

It is clear that while overall faunal diversity was lower in the exotic plant dominated sites but these sites are by no means void of fish and wildlife. We would generally agree with Ostrenko & Mazzotti (1981) that these areas are not biological deserts. Furthermore, in some situations the structural diversity and sheltering effects of small patches of *Melaleuca* may increase diversity in herbaceous wetlands (O'Hare and Dalrymple 1997) and seem to provide thermal refugia for certain aquatic fauna.

LITERATURE CITED

Baker, Donald P. 1997 "USDA's latest weapon has a nose for noxious weeds," Washington Post, April 26, 1997.

Breder, C.M. 1960. Design for a fish fry trap. Zoologica 45:155-160.

Ceilley, D.W., D.E. Ceilley and S.A. Bortone. 2000. A survey of freshwater fishes in the hydric flatwoods of Flint Pen Strand, Lee Co., FL. Proceedings of 27th Annual Conference on Ecosystem creation and Restoration, Hillsborough Community College, Tampa FL.

Ceilley, D.W., I. Bartoszek, and M. Schuman. 2004. Interim Report to the US Fish and Wildlife Service on Enhancing the Recovery of Threatened and Endangered Species in the South Florida Ecosystem through Aquatic Refugia. USFWS, Vero Beach, FL.

Ceilley, D.W. and W.R. Cox. 1995. Biological Integrity, Florida Gulf Coast University Phases 1B, 1C, and 1D Baseline Wetland Monitoring Report. KLECE Inc. Ft. Myers, Florida.

Ceilley, D.W. 1995 Support of Food Chains Assessment, Appendix D of Little Pine Island Wetland Mitigation Bank Assessment. Mariner Properties, Inc., Fort Myers, Florida.

Clarke, K.R. and R.N. Gorley. 2001. PRIMER User Manual/Tutorial, Version 5. PRIMER-E Ltd., Plymouth, United Kingdom. 91 p.

Fairchild, W.G, J. Cruz, A.M. Faulds, A.E.Z. Short., and J.F. Matta. 2003. Microhabitat and landscape influences on aquatic beetle assemblages in a cluster of temporary and permanent ponds. J. N. Am. Benthol. Soc., 22(2): 224-240.

O'Hare, N.K. and Dalrymple, G.H**.** 1997. Wildlife in southern Everglades wetlands invaded by melaleuca (Melaleuca quinquenervia). Bulletin of the Florida Museum of Natural History 41(1): 1-68.

Laroche, F.B. 1994. *Melaleuca Management Plan for Florida.* Exotic Pest Plant Council. 88pp.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Princeton University Press, New Jersey. 179 p.

Main, M.B., D.W. Ceilley, and P.A. Stansly. 1997. Bionventory of Freshwater Fish: South Florida Water Management District-Isolated Wetland Monitoring Program. Research Contract #C-7950, Technical Report of the South Florida Water Management District, West Palm Bch., FL.

Mazzotti, F.J., W. Ostrenko and A.T. Smith. 1981. Effects of the exotic plants *Melaleuca quinquenervia* and *Casuarina equisetifolia* on small mammal populations in the Eastern Florida Everglades. *Fla. Sci.* 44(2):65-71.

Mazzotti, F.J. T. D. Center, F. A. Dray, and D. Thayer. 2002. Ecological Consequences of Invasion by *Melaleuca Quinquenervia* in South Florida Wetlands: Paradise Damaged, not Lost. IFAS Publ. SSWEC #123, Univ. of Florida, Gainesville, FL.

National Wildlife Federation and U.S. Geological Survey. 2001. http://www.nwf.org/frogwatchUSA

Ostrenko, W., and F.J. Mazzotti. 1981. Small mammal populations in *Melaleuca quinquenervia* communities in the Eastern Florida Everglades. Pp. 91-98. In: Geiger, R.K. (ed.). *Proc. Melaleuca Symp.* Sept. 23-24, 1980, Edison Comm. Coll., Ft. Myers. Fla. Dept. Agric. & Cons. Serv., Div. Forestry, Tallahassee.

Schortemeyer, J.L., R.E. Johnson, and J.D. West. 1981. A preliminary report on wildlife occurrence in *melaleuca* heads in the Everglades Wildlife Management Area. Pp. 81-89. In: Geiger, R.K. (ed.). *Proc. Melaleuca Symp.* Sept. 23-24, 1980, Edison Comm. Coll., Ft. Myers. Fla. Dept. Agric. & Cons. Serv., Div. Forestry, Tallahassee.

Science Sub-group. 1994. South Florida ecosystem restoration: scientific information needs. Draft. Management and Coordination Working Group, Interagency Task Force on the South Florida Ecosystem. 536pp.

Smith, A.T. and J. M. Vrieze. 1978. Population structure of Everglades rodents: responses to a patchy environment. *J. Mammol* . 60:778-794.

APPENDIX

List of Tables

Table 1. Fish species and numbers collected by Breder traps in Prairie Pines Preserve wetland habitat types.

		Marsh			Wet Prairie		
Family	Species	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Centrarchidae	*Lepomis marginatus* (dollar sunfish)	1	0	0	0	0	0
	Lepomis sp. (juvenile)	0	1	0	1	0	0
Cichlidae	*Cichlasoma urophthalmus* (Mayan cichlid)*	0	2	0	0	0	0
Cyprinodontidae	*Jordanella floridae* (Flagfish)	108	60	12	74	17	11
Fundulidae	*Fundulus chrysotus* (golden topminnow)	1	0	0	0	0	0
	Fundulus confluentus (marsh killifish)	23	3	0	3	0	0
Poeciliidae	*Gambusia holbrooki* (mosquitofish)	576	302	370	379	213	92
	Heterandria formosa (least killifish)	7	5	0	2	1	0
	Poecilia latipinna (sailfin molly)	17	108	2	0	0	0

* Non-native, introduced species

Table 2. Diversity indices for fish families collected in Prairie Pines Preserve wetlands. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	0.4547	**0.6477**	0.1681	**0.4895**	0.1837	0.2158
Pielou (J')	**0.4090**	0.2823	0.2006	0.3571	0.3792	**0.4902**
Shannon (H')	**0.5670**	0.4543	0.1391	**0.4951**	0.2628	0.3398
Simpson	**0.3076**	0.2405	0.0607	**0.2856**	0.1369	0.1927
Hill (N_1)	**1.7630**	1.5751	1.1492	**1.6406**	1.3006	1.4046
Hill (N_2)	**1.4434**	1.3158	1.0644	**1.3985**	1.1579	1.2358

Table 3. Diversity indices for fish species collected in Prairie Pines Preserve wetlands. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	0.9095	**0.9715**	0.3361	**0.6526**	0.3675	0.2158
Pielou (J')	0.3751	**0.5150**	0.1561	0.3245	0.2643	**0.4902**
Shannon (H')	0.7299	**1.0020**	0.1715	**0.5223**	0.2904	0.3398
Simpson	0.3597	**0.5408**	0.0708	**0.2928**	0.1450	0.1927
Hill (N_1)	2.0749	**2.7238**	1.1871	**1.6859**	1.3369	1.4046
Hill (N_2)	1.5605	**2.1723**	1.0759	**1.4127**	1.1687	1.2358

Table 4. Macroinvertebrate taxa and numbers collected at Prairie Pines Preserve wetland sites.

				Marsh			Wet prairie		
Class	Order	Family	Species	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Arachnida	Hydracarina			0	0	0	1	0	0
Crustacea	Amphipoda	Hyalella	*Azteca sp.*	0	0	0	1	0	0
	Cladocera	Daphnidae	*Daphnia sp.*	0	1	0	1	0	0
	Decapoda	Cambaridae	*Procambarus alleni*	0	0	0	1	0	1
			Procambarus sp.	1	1	1	3	3	2
		Palaemonidae	*Palaemonetes sp.*	1	0	0	1	0	1
	Ostracoda	Cypridae		15	2	2	54	0	6
Hirudinae				1	0	1	0	0	0
Insecta	Coleoptera			0	0	0	0	0	1
		Dytiscidae		0	0	1	0	0	0
			Cybister fimbriolatus	1	0	0	3	1	0
			Cybister sp.	5	0	0	1	0	0
			Hydrovatus sp.	0	1	0	0	0	0
			Laccodytes sp.	0	3	0	3	0	0
			Laccophilus sp.	0	0	0	3	2	0
			Pachydrus princeps	0	0	3	0	0	0
			Pachydrus sp.	0	0	1	0	0	0
			Thermonectes agabates	0	0	0	0	0	1
			Thermonectes basillaris	0	0	0	0	1	1
			Thermonectes sp.	1	0	0	0	1	1
		Gyrinidae	*Dineutus sp.*	0	0	0	7	2	0
		Haliplidae	*Haliplus sp.*	1	0	0	0	0	0

Table 4. continued.

Class	Order	Family	Species	Marsh			Wet prairie		
				Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Insecta	Coleoptera	Hydrophilidae	*Enochrus sp.*	3	2	0	0	0	0
			Helobata larvalis	0	0	0	2	0	0
			Hydrochus sp.	0	0	0	2	0	0
			Tropisternus sp.	15	7	0	3	0	0
		Noteridae	*Hydrocanthus regius*	2	0	0	5	0	0
			Hydrocanthus sp.	17	8	0	15	9	0
			Suphis sp.	1	0	0	0	0	0
			Suphisellus sp.	8	3	0	6	5	0
		Scirtidae		0	0	0	0	1	0
			Cyphon sp.	0	0	3	0	0	0
	Diptera	Culicidae	Unidentified spp.	7	2	8	10	6	13
			Anopheles sp.	0	0	0	0	0	1
			Culex sp.	1	0	0	0	0	0
			Uranotaenia sp.	0	0	0	0	1	0
	Ephemeroptera	Baetidae	*Callibaetis sp.*	34	15	2	72	60	17
		Caenidae	*Caenis dimunita*	7	0	0	0	0	0
			Caenis sp.	2	7	0	4	2	0
	Hemiptera	Belostomatidae		10	0	0	2	0	0
			Belostoma sp.	7	0	5	1	4	3
			Lethocerus griseus	0	0	0	1	0	0
			Lethocerus sp.	0	0	0	0	1	0
			Pelocoris sp.	2	0	0	0	0	0

Table 4. continued.

Class	Order	Family	Species	Marsh Exotic free	Marsh Moderate	Marsh Dominant	Wet prairie Exotic free	Wet prairie Moderate	Wet prairie Dominant
Insecta	Hemiptera	Pleidae	*Neoplea*	1	0	0	0	0	0
	Hemiptera	Corixidae		0	0	0	24	19	0
		Gerridae		0	0	0	4	0	0
			Neogerris sp.	0	0	0	2	0	0
			Trepobates sp.	0	0	0	2	0	0
		Hebridae	*Lipogomphus sp.*	0	0	0	2	0	0
		Hydrmetridae	*Hydrometra sp.*	2	0	0	4	0	0
		Mesoveliidae	*Mesovelia sp.*	2	3	0	0	0	0
			Mesovelia amoena	0	1	0	0	0	0
			Mesovelia mulsanti	0	0	0	1	0	0
		Nepidae	*Ranatra sp.*	5	0	0	4	0	0
		Notonectidae		0	0	0	0	1	0
			Buenoa sp.	0	0	0	2	0	9
		Veliidae	*Microvelia sp.*	0	0	0	3	0	0
	Lepidoptera			0	1	0	0	0	0
	Odonata	Aeshnidae	*Anax junius*	2	0	0	3	0	0
			Anax longipes	2	0	0	0	0	0
			Coryphaeschna ingens	1	0	0	0	0	0
			Coryphaeschna sp.	1	1	0	0	0	0
			Gomphaeschna sp.	0	0	0	2	0	0
			Gynacantha nervosa	0	0	0	0	0	1
		Coenagrionidae		0	4	0	0	0	1

Table 4. continued.

Class	Order	Family	Species	Marsh			Wet prairie		
				Exotic	Moderate	Dominant	Exotic	Moderate	Dominant
Insecta	Odonata	Coenagrionidae	*Enallagma sp.*	0	2	0	0	0	0
			Ischnura hastata	35	0	0	4	0	0
			Ischnura ramburii	0	0	0	2	0	0
			Ischnura sp.	0	1	0	58	12	0
		Libellulidae		5	0	0	5	1	0
			Erythemis sp.	5	1	0	4	0	0
			Erythrodiplax sp.	0	2	0	0	2	0
			Pachydiplax longipennis	1	0	0	1	0	0
Gastropoda	Basommatophora	Ancylidae		0	0	0	1	0	0
		Physidae		0	0	0	0	0	1
			Physella sp.	1	0	0	1	0	0
		Planorbidae		5	0	0	3	1	0
			Planorbella sp.	3	0	0	1	0	0

Table 5. Diversity indices for standardized macroinvertebrate families collected in Prairie Pines Preserve wetlands. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	**3.2116**	2.7011	1.6616	**4.7021**	2.7107	2.3699
Pielou (*J′*)	0.9085	0.8957	**0.9597**	**0.8899**	0.8771	0.8392
Shannon (*H′*)	**2.6258**	2.2975	1.8676	**2.9330**	2.3146	2.0124
Simpson	**0.9199**	0.8902	0.8649	**0.9387**	0.8880	0.8477
Hill (N_1)	**13.8159**	9.9498	6.4726	**18.7837**	10.1212	7.4814
Hill (N_2)	**11.7965**	8.3142	6.3088	**15.3763**	8.3807	6.0682

Table 6. Diversity indices for standardized macroinvertebrate species collected in Prairie Pines Preserve wetlands. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	**5.7408**	3.6725	1.5346	**6.6973**	3.0743	2.6755
Pielou (*J′*)	0.8665	0.8820	**0.8953**	**0.9035**	0.8473	0.7602
Shannon (*H′*)	**2.9756**	2.4988	1.6042	**3.2624**	2.2945	1.8230
Simpson	**0.9362**	0.9098	0.8154	**0.9534**	0.8755	0.7898
Hill (N_1)	**19.6009**	12.1675	4.9737	**26.1134**	9.9195	6.1904
Hill (N_2)	**14.5361**	9.8129	4.6301	**19.6198**	7.4772	4.3663

Table 7. Small mammal species and numbers collected in Prairie Pines Preserve wetland habitat types.

	Marsh			Wet Prairie		
Species	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Mus musculus (house mouse)*	1	0	1	0	0	0
Peromyscus gossypinus (cotton mouse)	1	3	1	0	0	0
Sigmodon hispidus (hispid cotton rat)	0	0	1	0	2	0

* Non-native, introduced species

Table 8. Wildlife species and numbers observed at Prairie Pines Preserve wetland sites.

		Marsh			Wet Prairie		
Classes	Species	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Aves	*Agelaius phoeniceus* (red-winged blackbird)	0	0	1	2	0	0
	Anas discors (blue-winged teal)	31	0	0	0	0	0
	Anas fulvigula (mottled duck)	50	0	0	0	0	0
	Anhinga anhinga (anhinga)	9	0	0	0	0	0
	Aramus guarauna (limpkin)	1	0	0	0	0	0
	Ardea herodias (great blue heron)	10	0	0	0	0	0
	Bubulcus ibis (cattle egret)	11	0	0	0	0	0
	Buteo lineatus (red-shouldered hawk)	0	0	0	1	0	0
	Butorides striatus (green heron)	1	0	0	0	0	0
	Cairina moschata (domestic muscovy)	4	0	0	0	0	0
	Calidris alba (sanderling)	70	0	0	0	0	0
	Cardinalis cardinalis (northern cardinal)	2	1	0	4	0	0
	Casmerodius albus (great egret)	18	0	0	2	0	0
	Cathartes aura (turkey vulture)	10	0	0	1	0	0
	Ceryle alcyon (belted kingfisher)	1	0	0	4	0	0
	Charadrius vociferus (killdeer)	27	0	0	0	0	0
	Contopus virens (eastern wood-pewee)	0	0	1	0	0	3
	Cyanocitta cristata (blue jay)	3	0	0	0	1	0
	Dumetella carolinensis (gray catbird)	0	0	1	1	0	0
	Egretta caerulea (little blue heron)	20	0	0	5	0	0
	Egretta thula (snowy egret)	8	0	0	5	0	0
	Egretta tricolor (tricolored heron)	19	0	0	1	0	0

Table 8. continued.

Classes	Species	Marsh			Wet Prairie		
		Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Aves	*Eudocimus albus* (white ibis)	326	0	0	169	3	1
	Fulica americana (American coot)	3	0	0	0	0	0
	Gallinula chloropus (common moorhen)	13	0	0	0	0	0
	Geothlypis trichas (common yellowthroat)	2	0	0	2	0	0
	Melanerpes carolinus (red-bellied woodpecker)	1	0	0	1	0	0
	Meleagris gallopavo (wild turkey)	0	0	0	1	0	0
	Mycteria americana (wood stork)	17	0	0	0	0	0
	Nyctanassa violacea (yellow-crowned night heron)	0	0	0	1	0	0
	Picoides pubescens (downy woodpecker)	0	0	0	3	2	0
	Pipilo erythrophthalmus (eastern towhee)	0	0	0	1	0	0
	Plegadis falcinellus (glossy ibis)	134	0	0	0	0	0
	Quiscalus major (boat-tailed grackle)	1	0	0	0	0	0
	Quiscalus quiscula (common grackle)	76	0	0	0	0	0
	Tringa melanoleuca (greater yellowlegs)	9	0	0	0	0	0
	Tyrannus tyrannus (eastern kingbird)	1	0	0	0	0	0
	Vireo griseus (white-eyed vireo)	1	0	0	0	0	0
Amphibia	*Amphiuma means* (two-toed amphiuma)	1	0	0	0	0	1
	Bufo quercicus (oak toad)	24	0	3	31	3	0
	Bufo terrestris (southern toad)	3	0	0	1	0	0
	Eleutherodactylus planirostris (greenhouse frog)	0	0	0	1	0	0
	Gastrophryne carolinensis (narrow-mouthed toad)	0	0	0	1	0	0
	Hyla cinerea (green treefrog)	5	10	0	2	0	0

Table 8. continued.

Classes	Species	Marsh			Wet Prairie		
		Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Amphibia	*Osteopilus septentrionalis* (Cuban treefrog)*	0	0	1	0	2	1
	Pseudacris nigrita verrucosa (Florida chorus frog)	0	0	0	1	0	0
	Rana sphenocephala (southern leopard frog)	1	0	2	2	10	0
Mammalia	*Canus domesticus* (dog)	1	0	0	1	0	0
	Didelphis marsupialis (opossum)	1	0	0	0	0	0
	Lutra canadensis (river otter)	1	0	0	0	0	0
	Lynx rufus (bobcat)	2	0	0	1	0	0
	Odocoileus virginianus (white-tailed deer)	0	0	1	0	0	0
	Procyon lotor (raccoon)	1	0	0	2	0	0
	Sus scrofa (feral pig)	1	0	0	1	0	0
Reptilia	*Anolis carolinensis* (green anole)	1	0	0	2	1	0
	Coluber constrictor (black racer)	2	0	0	4	0	0
	Ophisaurus ventralis (eastern glass lizard)	1	0	0	0	0	0
	Sistrurus miliarius barbouri (pigmy rattlesnake)	1	0	0	0	0	0
	Thamnophis sirtalis sirtalis (eastern garter snake)	0	0	0	0	1	0

* Non-native, introduced species

Table 9. Diversity indices for standardized wildlife class observations in Prairie Pines Preserve wetland sites. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	0.7269	0.3460	**0.7797**	**0.7269**	0.5939	0.4024
Pielou (J')	**0.8544**	0.3095	0.8292	0.8544	0.8784	**1.0000**
Shannon (H')	**1.1845**	0.2146	0.9110	**1.1845**	0.9650	0.6931
Simpson	**0.6668**	0.1111	0.6154	**0.6668**	0.5911	0.5455
Hill (N1)	**3.2690**	1.2393	2.4869	**3.2690**	2.6249	2.0000
Hill (N2)	**2.9077**	1.1172	2.3151	**2.9077**	2.3296	2.0000

Table 10. Diversity indices for standardized wildlife species observations in Prairie Pines Preserve wetland sites. Highest values for a given habitat are shown in bold.

	Marsh			Wet Prairie		
	Exotic free	Moderate	Dominant	Exotic free	Moderate	Dominant
Margalef	**7.2931**	0.3460	2.1177	**5.8434**	1.8498	1.3654
Pielou (J')	**0.8757**	0.3095	0.8060	**0.8409**	0.8234	0.7233
Shannon (H')	**3.3333**	0.2146	1.5684	**2.8600**	1.7122	1.0027
Simpson	**0.9596**	0.1111	0.7794	**0.9217**	0.7928	0.5833
Hill (N1)	**28.0320**	1.2393	4.7992	**17.4622**	5.5412	2.7257
Hill (N2)	**23.4194**	1.1172	3.7532	**11.7998**	4.4404	2.0769

Table 11. Fish species and numbers collected by Breder traps in Sanibel Island wetlands.

Family	Species	Johnston	Frannie's	PCRP
Centrarchidae	*Lepomis gulosus* (warmouth)	2	0	0
	Lepomis macrochirus (bluegill)	0	3	0
	Micropterus salmoides (largemouth bass)	2	0	0
Cyprinodontidae	*Jordanella floridae* (flagfish)	0	4	0
Fundulidae	*Fundulus chrysotus* (golden topminnow)	0	2	0
	Fundulus confluentus (marsh killifish)	1	7	0
	Lucania goodie (bluefin killifish)	0	18	0
Poeciliidae	*Gambusia holbrooki* (mosquitofish)	345	1066	0
	Heterandria formosa (least killifish)	16	21	0
	Poecilia latipinna (sailfin molly)	161	312	0

Table 12. Diversity indices for fish families collected in Sanibel Island wetlands. Highest values for a given area are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	0.3191	**0.4128**	-
Pielou (J')	0.0531	**0.0920**	-
Shannon (H')	0.0584	**0.1276**	0.0000
Simpson	0.0189	**0.0466**	-
Hill (N_1)	1.0601	**1.1361**	1.0000
Hill (N_2)	1.0192	**1.0488**	-

Table 13. Diversity indices for fish species collected in Sanibel Island wetlands. Highest values for a given area are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	0.7978	**0.9632**	-
Pielou (J')	**0.4464**	0.3527	-
Shannon (H')	**0.7999**	0.7334	0.0000
Simpson	**0.4781**	0.3991	-
Hill (N_1)	**2.2253**	2.0821	1.0000
Hill (N_2)	**1.9126**	1.6634	-

Table 14. Macroinvertebrate taxa and numbers collected at Sanibel Island wetland sites.

Class	Order	Family	Species	Johnston	Frannie's	PCRP
Crustacea	Amphipoda	Talitridae	*Hyalella azteca*	0	7	0
			Hyalella sp.	0	1	0
	Decapoda	Cambaridae	*Procambarus alleni*	2	3	0
		Palaemonidae	*Palaemonetes* sp.	0	1	0
Gastropoda	Basommatophora	Planorbidae		1	1	0
		Physidae	*Physella* sp.	2	0	0
		Physidae	*Planorbella* sp.	1	0	0
Insecta	Coleoptera	Dytiscidae		0	0	2
			Cybister fimbriolatus	0	1	0
			Cybister sp.	0	7	0
			Hydaticus sp.	0	0	4
			Lacophilus sp.	2	0	0
			Thermonectes bassilaris	0	0	1
			Thermonectes sp.	3	0	1
		Haliplidae	*Peltodytes* sp.	3	1	0
		Hydrophilidae		2	0	0
			Berosus sp.	1	5	0
			Berosus youngi	1	0	0
			Enochrus sp.	1	0	1
			Tropisternus lateralis nimbatus	12	1	0
			Tropisternus sp.	21	31	2
		Noteridae	*Hydrocanthus* sp.	1	1	0
		Scirtidae	*Scirtes* sp.	0	2	2

Table 14. continued.

Class	Order	Family	Species	Johnston	Frannie's	PCR P
Insecta	Diptera	Chironomidae		3	14	19
		Culicidae		11	0	0
			Aedes sp.	0	0	1
			Anopheles sp.	0	2	0
			Culex sp.	0	1	22
			Psorophora sp.	0	0	1
			Uranotaenia sp.	0	0	1
		Stratiomyidae		0	5	0
		Stratiomyidae	*Odontomyia* sp.	4	0	0
	Ephemeroptera	Baetidae	Callibaetis sp.	2	0	0
	Hemiptera			2	0	0
		Belostomatidae		2	8	0
			Belostoma lutarium	0	3	0
			Belostoma sp.	5	18	0
			Lethocerus sp.	13	9	0
		Corixidae		2	13	0
		Hydrometridae	*Hydrometra australis*	0	1	0
		Mesoveliidae	*Mesovelia* sp.	0	1	0
		Naucoridae	*Pelocoris femoralus*	1	0	0
			Pelocoris sp.	3	0	0
		Nepidae	*Ranatra* sp.	0	1	0
		Notonectidae		1	0	0

	Veliidae	*Microvelia* sp.	0	0	6

Table 14. continued.

Class	Order	Family	Species	Johnston	Frannie's	PCR P
Insecta	Lepidoptera	Noctuidae	*Archanara* sp.	1	0	0
	Odanata	Aeshnidae	*Anax junius*	0	4	0
			Gynacantha nervosa	0	0	1
			Gynacantha nervosa	0	0	1
			Triacanthagyna trifida	0	0	1
		Coenagrionidae		0	2	0
			Ischnura hastata	0	1	0
			Ischnura ramburii	0	2	0
			Ischnura sp.	0	10	0

Table 15. Diversity indices for standardized macroinvertebrate families collected in Sanibel Island wetlands. Highest values for a given habitat are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	3.3249	**3.5924**	1.4030
Pielou (J')	0.8827	0.8398	**0.8960**
Shannon (H')	**2.5007**	2.4727	1.7435
Simpson	**0.9038**	0.9004	0.8001
Hill (N_1)	**12.1916**	11.8543	5.7172
Hill (N_2)	**9.6548**	9.4697	4.7386

Table 16. Diversity indices for standardized macroinvertebrate species collected in Sanibel Island wetlands. Highest values for a given habitat are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	3.8148	**4.7252**	3.0834
Pielou (J')	**0.8710**	0.8435	0.7919
Shannon (H')	2.5645	**2.6806**	2.0313
Simpson	0.9126	**0.9139**	0.8333
Hill (N_1)	12.9940	**14.5933**	7.6238
Hill (N_2)	10.4708	**10.7370**	5.4444

Table 17. Small mammal species and numbers collected from Sanibel Island wetland areas.

Species	Johnston	Frannie's	PCRP
Sigmodon hispidus (hispid cotton rat)	39	30	0
Rattus rattus (black rat)*	0	1	5

* Non-native, introduced species

Table 18. Amphibian and reptile taxa and numbers collected from Sanibel Island wetland areas.

Order	Family	Species	Johnston	Frannie's	PCRP
Anura	Bufonidae	*Bufo terrestris* (southern toad)	15	39	0
	Hylidae	*Osteopilus septentrionalis* (Cuban treefrog)*	276	223	80
	Leptodactylidae	*Eleutherodactylus planirostris* (greenhouse frog)	2	2	0
	Microhylidae	*Gastrophryne carolinensis* (eastern narrow-mouthed toad)	80	119	22
	Ranidae	*Rana sphenocephala* (southern leopard frog)	4	4	3
Squamata	Colubridae	*Coluber constrictor priapus* (southern black racer)	77	55	10
		Diadophis punctatus (ringneck snake)	8	3	0
		Elaphe guttata (corn snake)	1	6	0
		Elaphe obsoleta quadrivittata (yellow rat snake)	1	4	0
		Nerodia fasciata pictiventris (Florida water snake)	0	3	0
		Thamnophis sauritus sackeni (peninsula ribbon snake)	0	1	0
	Polychridae	*Anolis sagrei* (brown anole)*	53	27	56
	Scincidae	*Eumeces inexpectatus* (southeastern five-lined skink)	62	4	0
		Scincella lateralis (ground skink)	7	0	0
	Teiidae	*Cnemidophorus sexlineatus* (six-lined racerunner)	6	23	0

* Non-native, introduced species

Table 19. Diversity indices for amphibian and reptile families collected in Sanibel Island wetlands. Highest values for a given habitat are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	1.2252	**1.2804**	0.7327
Pielou (J')	0.7127	0.7132	**0.7937**
Shannon (H')	1.566	**1.5671**	1.2773
Simpson	**0.7376**	0.7295	0.6983
Hill (N_1)	4.7876	**4.7928**	3.5871
Hill (N_2)	**3.7957**	3.6779	3.2819

Table 20. Diversity indices for amphibian and reptile species collected in Sanibel Island wetlands. Highest values for a given habitat are shown in bold.

	Johnston	Frannie's	PCRP
Margalef	1.8798	**2.0832**	0.7780
Pielou (J')	0.6506	0.6404	**0.7591**
Shannon (H')	1.6688	**1.6901**	1.2217
Simpson	0.7286	**0.7362**	0.6574
Hill (N_1)	5.3056	**5.4198**	3.3931
Hill (N_2)	3.6677	**3.7703**	2.8869

List of Figures

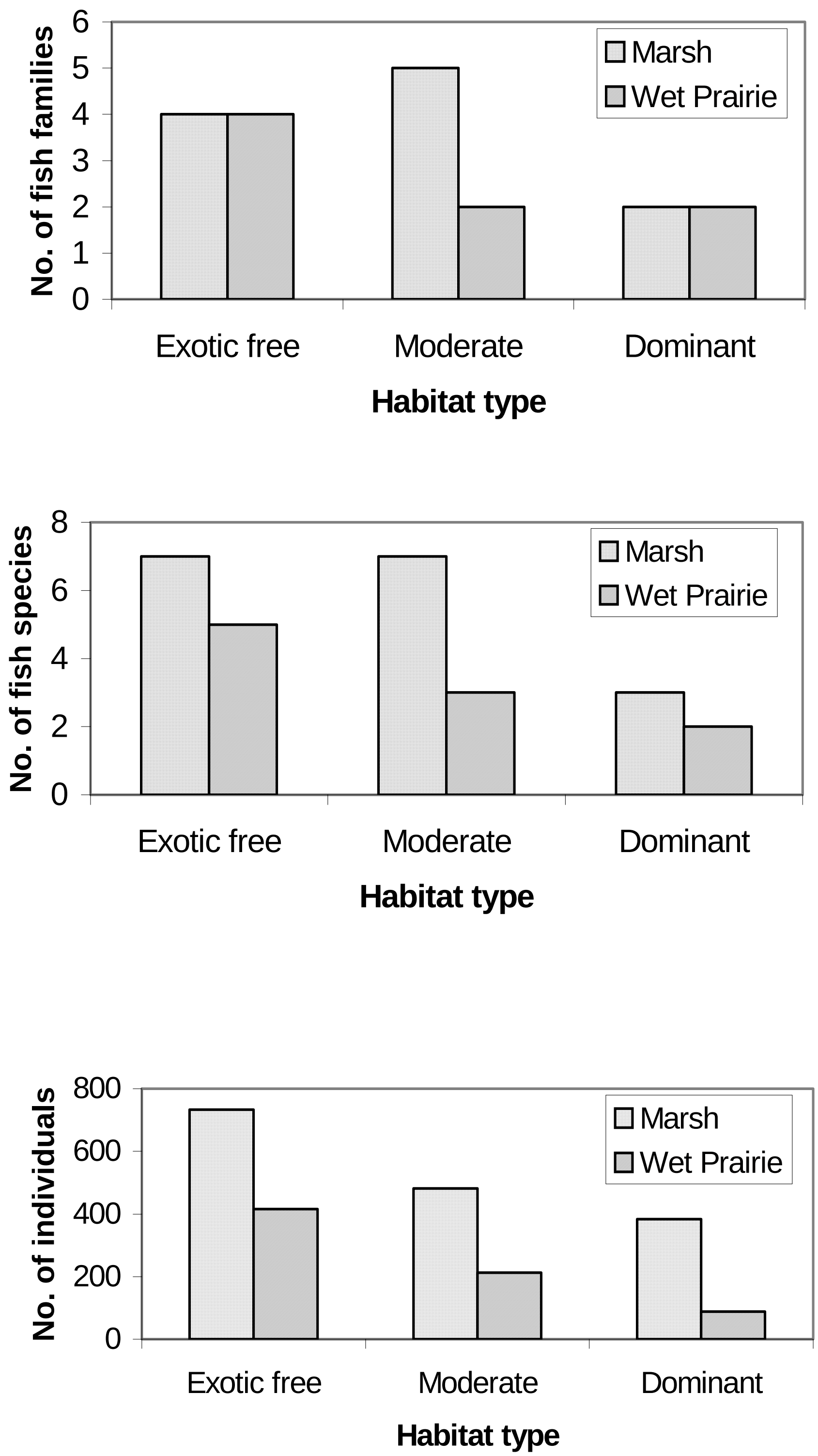


Figure 1. Fish family richness, species richness, and abundance for wetland habitat types in Prairie Pines Preserve.

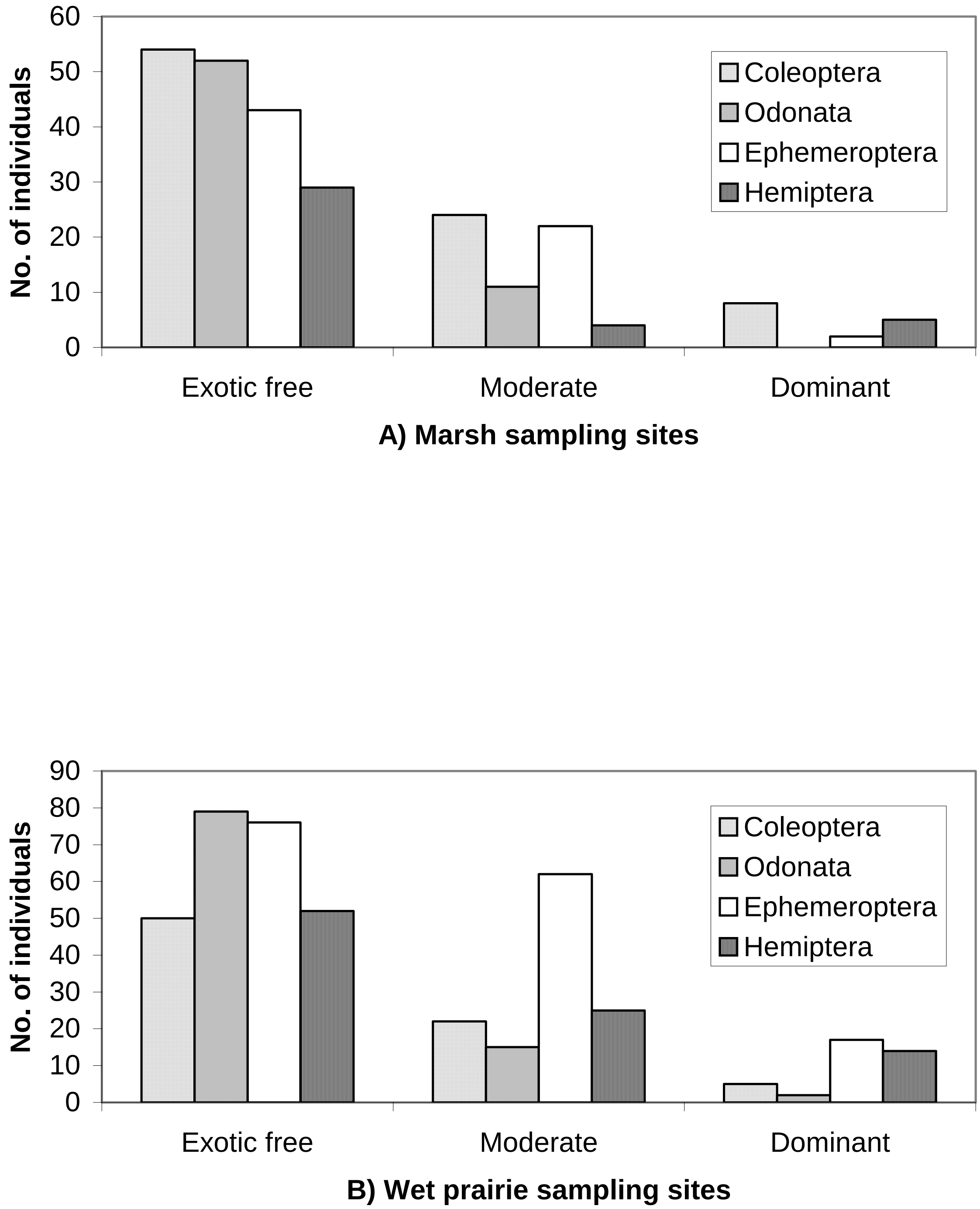


Figure 2. Abundance for insect orders collected from the (a) marsh and (b) wet prairie sampling sites in Prairie Pines Preserve.

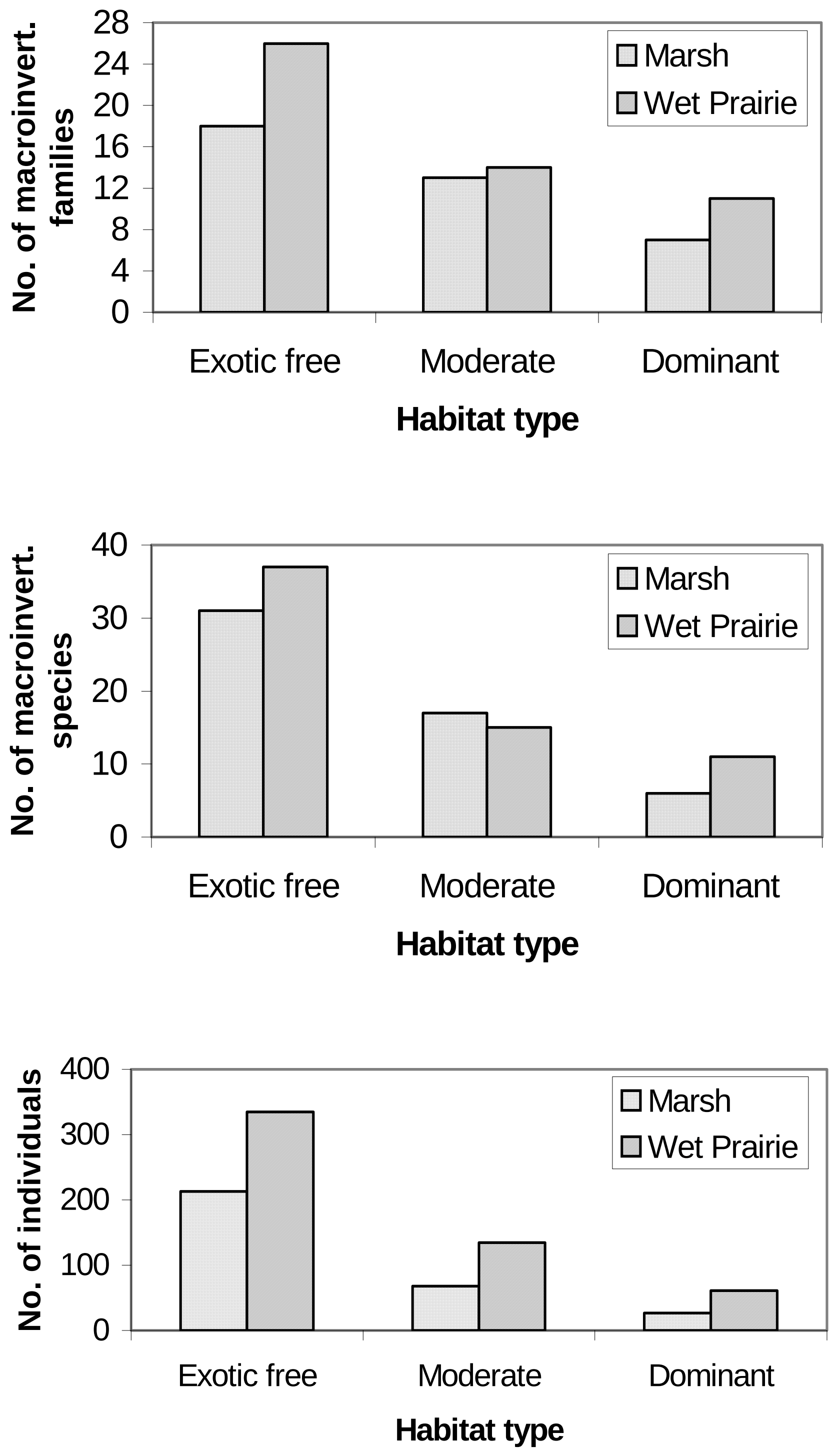


Figure 3. Macroinvertebrate family richness, species richness, and abundance for wetland sampling sites in Prairie Pines Preserve.

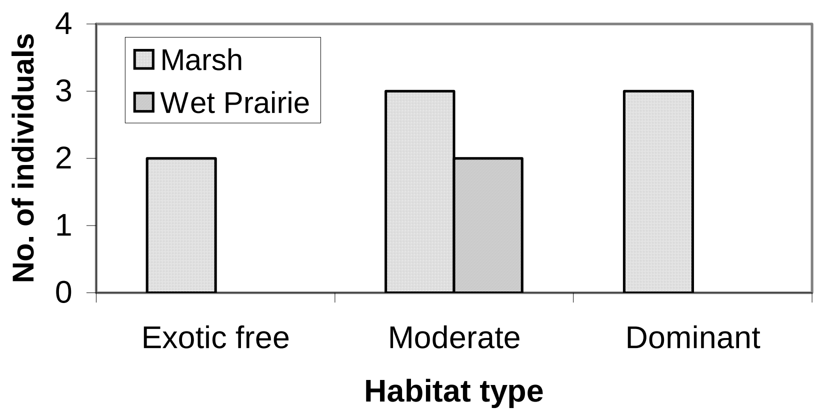
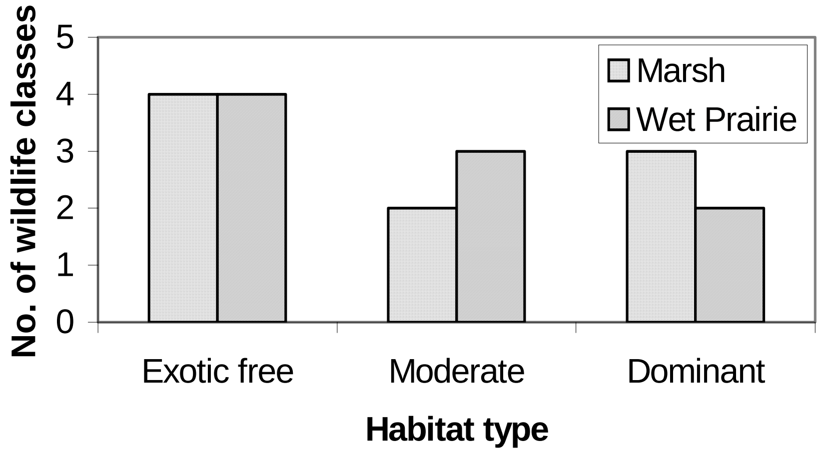
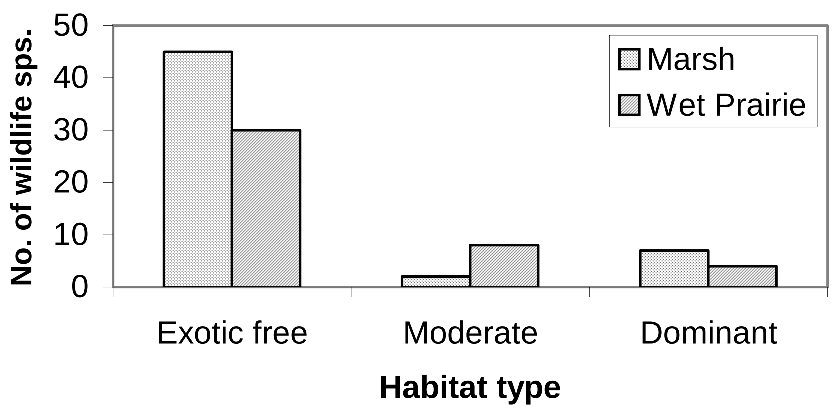


Figure 4. Small mammal abundance for wetland habitat types in Prairie Pines Preserve.


5
4
3
2
1
0
No. of wildlife classes
Marsh
Wet Prairie
Exotic free
Moderate
Dominant
Habitat type


50
40
30
20
10
0
No. of wildlife sps.
Marsh
Wet Prairie
Exotic free
Moderate
Dominant
Habitat type

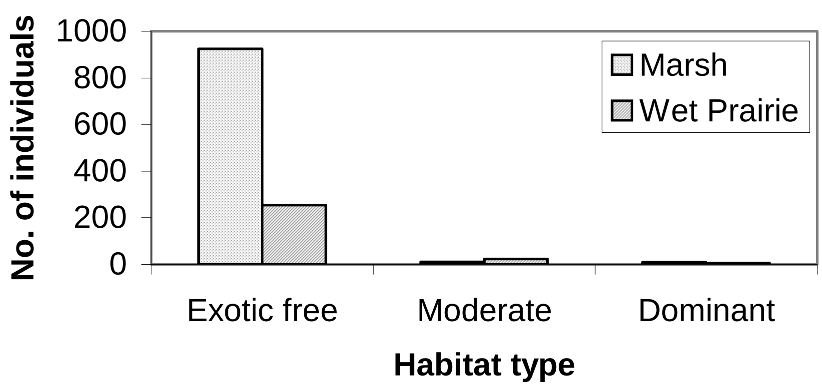
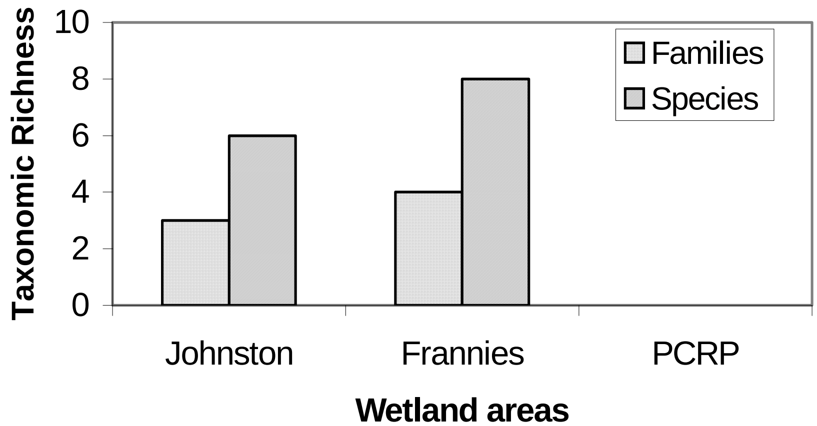

1000
800
600
400
200
0
No. of individuals
Marsh
Wet Prairie
Exotic free
Moderate
Dominant
Habitat type

Figure 5. Wildlife class richness, species richness, and abundance for wetland sampling sites in Prairie Pines Preserve.



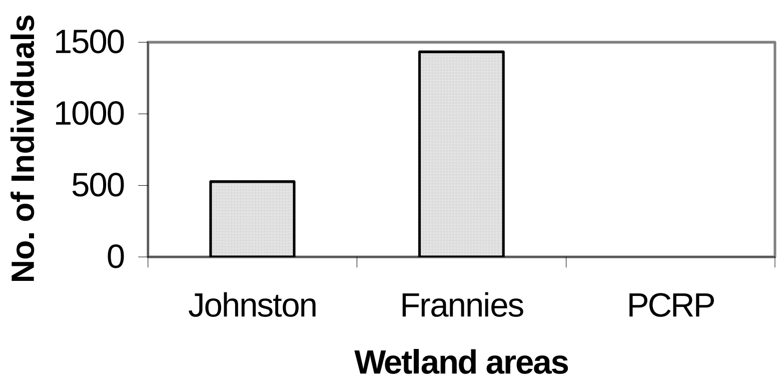


Figure 6. Fish family richness, species richness, and abundance for wetland areas on Sanibel Island.

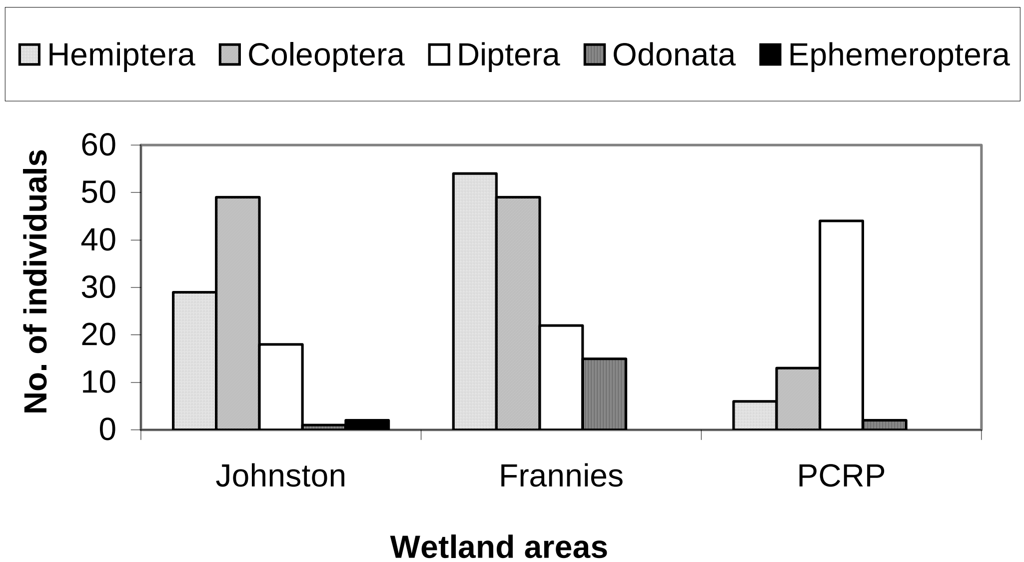


Figure 7. Abundance for insect orders collected from wetland areas on Sanibel Island.

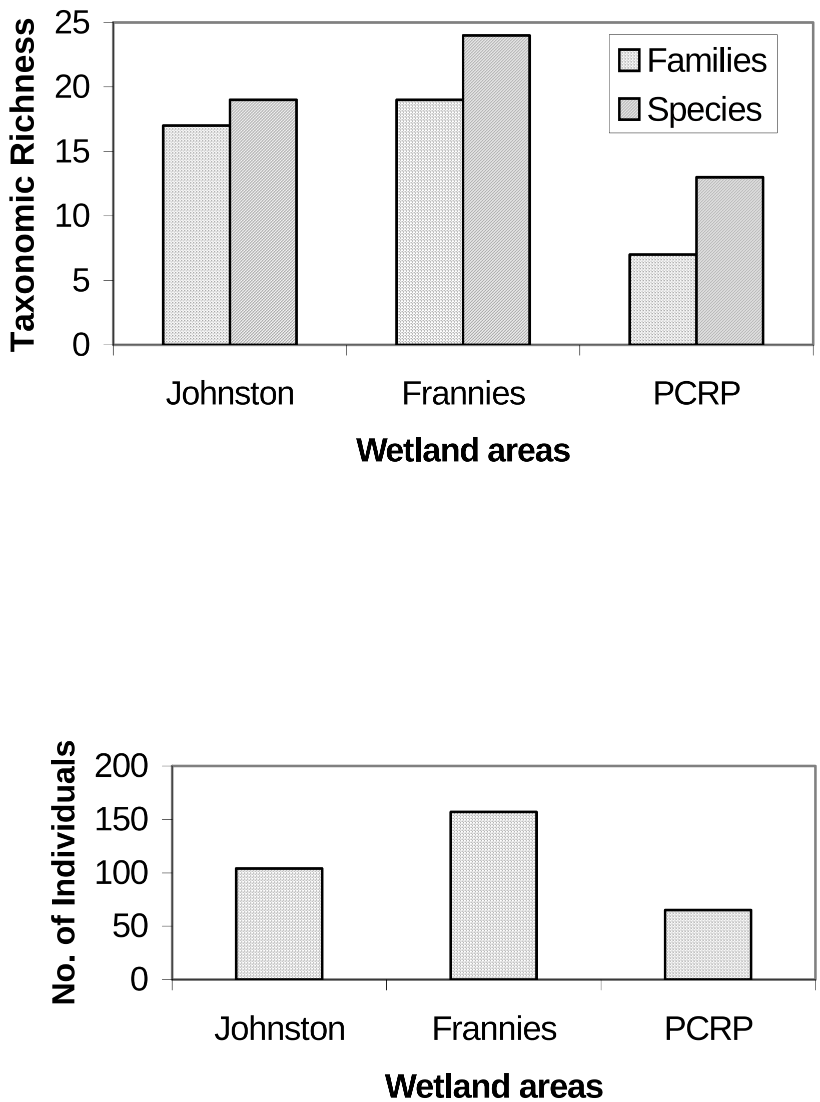


Figure 8. Family richness, species richness, and abundance for macroinvertebrates collected from Sanibel Island wetland areas.

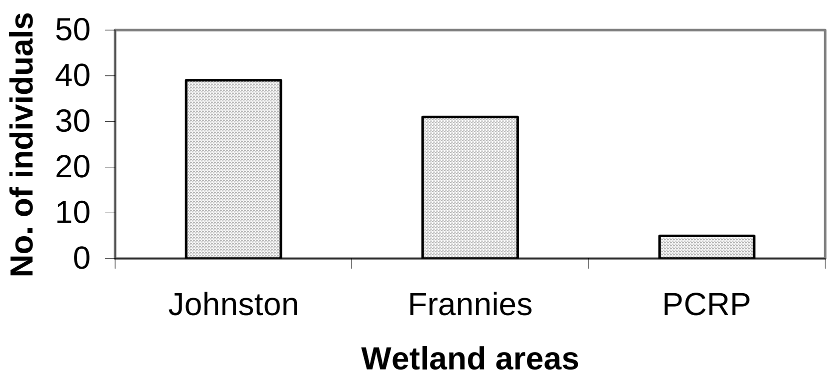


Figure 9. Abundance for small mammals collected from Sanibel Island wetland areas.

The Charlotte Harbor National Estuary Program is a partnership of citizens, elected officials, resource managers and commercial and recreational resource users working to improve the water quality and ecological integrity of the greater Charlotte Harbor watershed. A cooperative decision-making process is used within the program to address diverse resource management concerns in the 4,400 square mile study area. Many of these partners also financially support the Program, which, in turn, affords the Program opportunities to fund projects such as this. The entities that have financially supported the program include the following:

U.S. Environmental Protection Agency
Southwest Florida Water Management District
South Florida Water Management District
Florida Department of Environmental Protection
Florida Coastal Zone Management Program
Peace River/Manasota Regional Water Supply Authority
Polk, Sarasota, Manatee, Lee, Charlotte, DeSoto and Hardee Counties
Cities of Sanibel, Cape Coral, Fort Myers, Punta Gorda, North Port, Venice and Fort Myers Beach
and the Southwest Florida Regional Planning Council.