A Survey of Freshwater Fishes in the Hydric Flatwoods of Flint Pen Strand, Lee County, Florida

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ABSTRACT

This study investigated the freshwater fish communities in three isolated, shallow-water hydric flatwood wetlands in the Flint Pen Strand in Lee Co., Florida using clear plastic fish traps (Breder, 1960) The study objectives were to determine fish community structure and evaluate the potential for using wetland fish communities and individual species as indicators of hydrologic alteration and water-level drawdown. Sampling was conducted during February, April, and September-October 1998 to assess seasonal fluctuations in water levels and fish populations and community structure. A total of six fish families, including nine genera, and at least 12 species (11 native fish species and one exotic cichlid) were collected using Breder Traps. The highest fish diversity (H'=1.542 and 1.414) was found in the slash pine dominated canopy that included scattered cypress. Predictive models using stepwise (interactive) multiple linear regression indicated that water depth, habitat type, and sediment type were closely associated with number of species, individual abundance, and species diversity. Several potential indicator species and assemblages were identified that may be useful in monitoring of wetlands for hydrologic disturbance (e.g., water-level drawdown). Study results indicate that hydric pine flatwoods are associated with the overall production and diversity of small forage fish species in Southwest Florida's forested wetlands. Due to their expansive shallow surface waters, it is likely that the hydric pine flatwoods will be the first areas to show biological evidence of water table drawdown. Due to the important linkage that wetland fish serve in the food web of South Florida ecosystems, we recommend that fish community monitoring be included as part of functional assessments and to provide the data necessary for planning future restoration initiatives in hydric flatwoods. Additional research is needed to fully understand: 1) the life history requirements of freshwater, wetland fish species, 2) responses wetland associated fishes make to water level manipulations, and 3) the tolerance that these have to acute and chronic anthropogenic disturbances.

INTRODUCTION

The water supply demands of rapidly increasing coastal populations and extensive agricultural operations in south Florida have challenged water resource managers responsible for maintaining healthy aquatic systems. The increased withdrawal of water from surficial aquifers and the alteration of natural sheet flow from development have direct and indirect effects on the hydrology of natural systems. Hydrology is probably the single most important determinant for establishment and maintenance of the specific types of wetlands and wetland processes yet the effects of hydrologic change or hydrologic disturbance on wetlands are subtle and complex, being influenced by both regional and local processes and impacts (Gosselink et al., 1994). Several authors discuss how hydrologic disturbance and water level drawdown can affect the vegetation changes in south Florida flatwoods marshes (Kushlan, 1990; Mortellaro et al., 1995; Gosselink et al., 1994). However, a great deal remains unknown about the biological communities of wetlands, especially hydric pine flatwoods of southwest Florida (Beever and Dryden, 1993).

Increasing or decreasing wetland hydroperiods and altering the timing of inundation can cause shifts or extirpation of breeding amphibians (Mazzotti et al., 1992). The management of water levels in marshes of the Everglades and Water Conservation Areas has been shown to cause rapid and dramatic changes in fish communities (Loftus and Eklund, 1994; Fury et al., 1995). Reductions in hydroperiods or lowering water tables in ephemeral systems could lead to the extirpation of fish and amphibians before any noticeable change in plant communities is observed. Freshwater fishes are important components of marsh systems, filling niches in the aquatic food web from primary consumers of vegetation and detritus through intermediate levels as predators on aquatic insects, crustaceans and other fish. Fishes, in turn, are prey for a myriad of predators and scavengers (Loftus and Ecklund, 1994). Main et al. (1997) recently described the following three major functional feeding groups and habitats of wetland fish species in the isolated wetlands of the South Florida Water Management District:

1. Small omnivorous fishes – shallow, ephemeral wetlands.
2. Small predatory fishes - wetlands with deepwater refugia.
3. Large predators and open-water fishes - semi-permanent, deepwater wetlands.

Functional feeding groups 1 and 2 include fish that have adapted to the relatively harsh extremes found in natural wetlands of south Florida. When these natural extremes are amplified by anthropogenic disturbances, we can expect to see shifts in fish community structure and possibly the loss of certain species. The loss of small fish and aquatic invertebrates from isolated wetlands will disrupt food chains and affect wading bird populations by reducing forage habitat. For example, the availability and quality of forage, primarily wetland fish and decapod crustaceans (crayfish and prawns), is the limiting factor for successful reproduction in several wading bird species, controlling both nest initiation and abandonment of wood storks and white ibis (Frederick and Spalding, 1994). The objectives of this study were: 1) to survey the fish community structure, species richness and abundance in three isolated hydric flatwood wetland systems using clear plastic fish traps (Breder, 1960) and; 2) to evaluate the potential of wetland fish communities, species assemblages and individual species as indicators of hydrologic disturbance in hydric flatwoods.

STUDY AREA

This study was conducted in Section 33, Township 46S and Range 26E, of Lee County, Florida (Figure 1). Section 33 is located at the northern tip of the Corkscrew Regional Ecosystem Watershed (CREW), a 60,000-acre conservation acquisition area in Lee and Collier Counties. The Lee County portion of CREW is known as the Flint Pen Strand and consists of approximately 15,000 acres. The Flint Pen area is a mosaic of open pine flatwoods, wet prairies, cypress domes and sloughs that was historically used to graze cattle. Habitats in Section 33 include cypress slough, cypress dome, hydric flatwoods, upland pine flatwoods, wet prairie, and flag pond marsh. Four of these cypress dome habitats were surveyed for fish (Main et al., 1997) and macroinvertebrates (Stansly et al., 1997) in 1996. Our study focused on three transects through the habitat gradients between the cypress domes/sloughs and the upland pine flatwoods. For the purposes of this study the habitat gradient is referred to as hydric flatwoods. This gradient consisted of cypress, *Taxodium ascendens*, with scattered slash pine, *Pinus elliottii* var. *densa*, on the deeper side near cypress domes, to pine-cypress mixed in the center, and pine-palmetto on the outer shallow wetland fringes.

MATERIALS AND METHODS

Shallow water habitats of three wetlands (FP6, FP7, and FP9) were quantitatively sampled using clear Plexiglas ™ fish traps (Breder, 1960). A Breder trap (Figure 2) consists of two parts, a rectangular funnel, which directs fish into the trap and a box (30 cm x 15 cm x 15 cm), where they are held until collection. Breder traps were selected for this study since they have been effective in shallow water wetlands with dense vegetation, are nondestructive (Main et al., 1997) and have the least amount of sampling bias when compared to other techniques (Sargent and Carlson, 1987).

Three distinct vegetation zones along a gradient were sampled simultaneously within each wetland (FP6, FP7, and FP9) using six traps in each zone. Vegetation zones, from deepest to shallowest, typically consisted of: (A) cypress dominated canopy with scattered pine; (B) slash pine with cypress mix and; (C or D) pine dominated with scattered cypress and/or saw palmetto. This stratified sampling technique was intended to characterize the fish communities of each major vegetative and water depth zone within the flatwoods adjacent to the previously surveyed cypress domes (Main et al., 1997).

Sampling within each zone was conducted within 10 meters of an arbitrarily selected center point, marked with a stake. Six Breder traps were evenly spaced inside this 10 meter circle in an effort to sample microhabitats within each zone. The funnel opening to each trap was placed toward open water to increase catch efficiency. Traps remained in the water for a period of 2 hours then retrieved. Sargent and Carlson (1987) conducted Breder trap "soak time" experiments in salt marsh and mangrove wetlands and suggested 2-3 hours "soak time" for best results. From our experience and from Main et al. (1997),

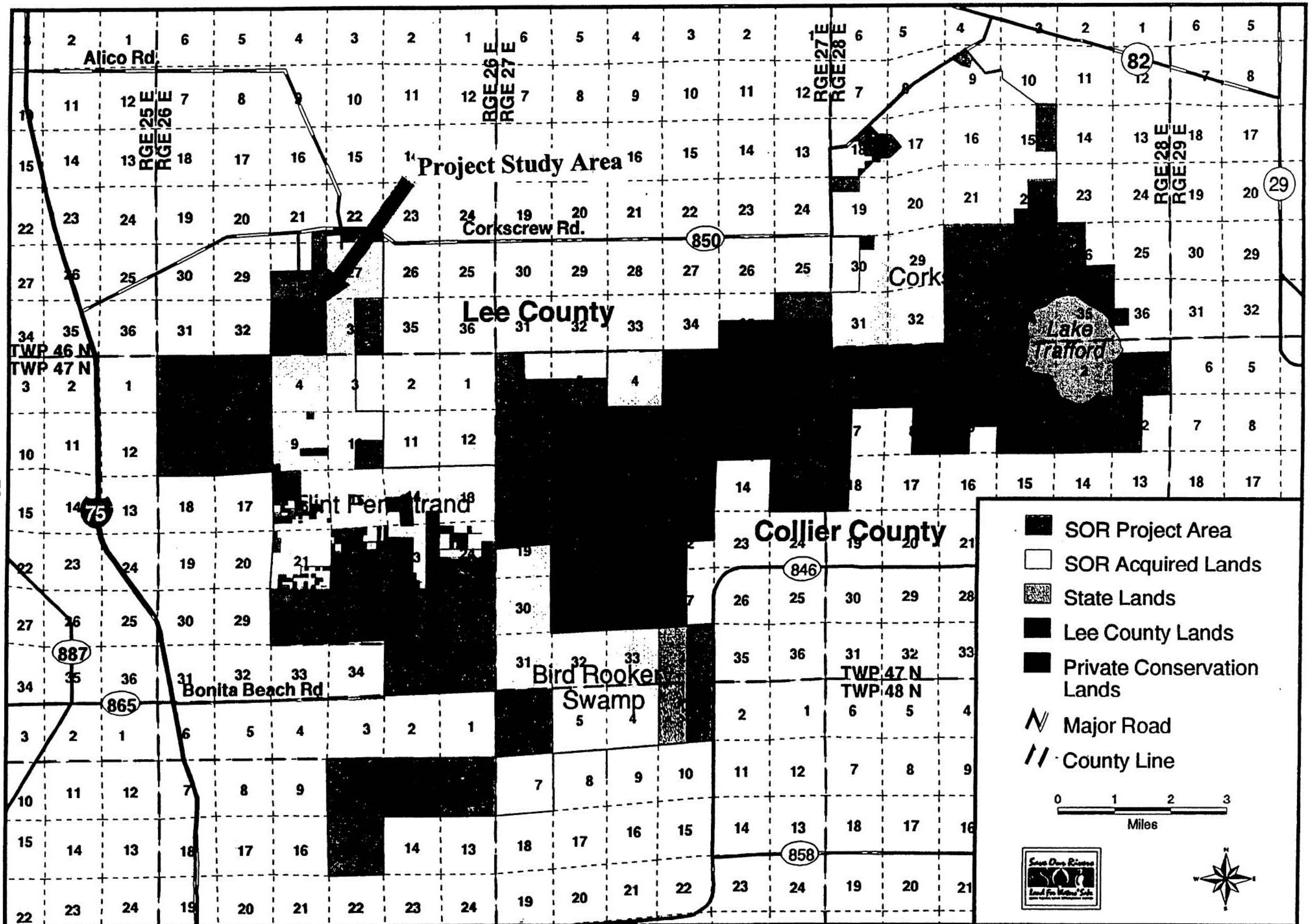


Figure 1. General location map of Section 33 study area (red) in the Flint Pen Strand portion of the Corkscrew Regional Ecosystem Watershed Boundary.

Drawn by P.S.Ellis - 05/29/98

2 hours is sufficient to obtain a representative sample in shallow, non-tidal freshwater marshes. All fish collected were identified to species level, enumerated and most were released. A small number (5-10) of each species were preserved in 10% formalin for voucher specimens and to identify stomach contents. This quantitative sampling was repeated three times during 1998.

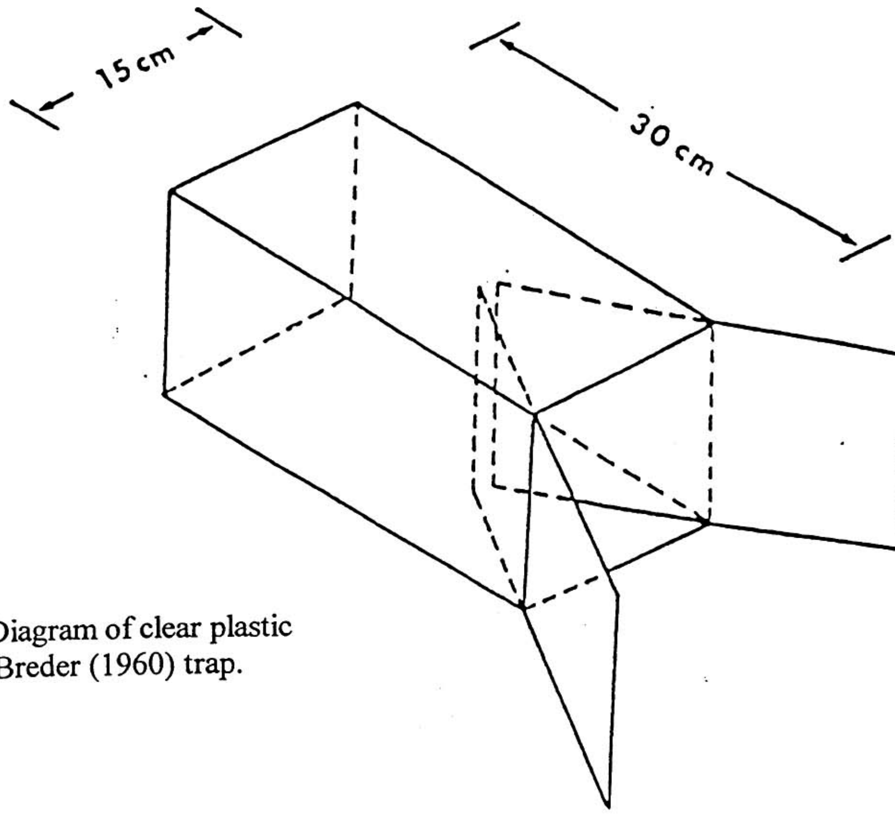


Figure 2. Diagram of clear plastic Breder (1960) trap.

Water quality sampling was conducted using a YSI™ model 57 dissolved oxygen meter and YSI™ model 33 SCT meter. Weather conditions, habitat type (vegetation), sediment type, water temperature, specific conductance, salinity, water depth and dissolved oxygen readings were collected from each sampling zone and recorded on the field data form prior to retrieving traps and were included in the statistical analysis.

Statistical and Graphical Analyses

Field data was entered into "Access 97"™ database management system, downloaded to "Excel" ™ spreadsheet for graphical presentation and statistical analysis using "SYSTAT"™. The six, two-hour Breder trap samples were composited for statistical analysis. Graphical presentation of data included cluster diagrams based on species abundance (standardized and non-standardized) using Pearson's Product Correlation Coefficient (PPC) matrix and Euclidean distance matrix. Both were clustered using Ward's (UPGMA) clustering algorithm. Principal Components Analysis (PCA) and

Common Factor Analysis (iterated principal axis), displaying the first three factor loadings based on species abundance, were graphed for visual interpretation. PCA of the independent variables based on species abundance was also graphed. PPC (r), multiple (interactive) stepwise regression (forward and backward), species diversity (H'), percent similarity, and Jaccard association index were methods used to analyze data in this study.

RESULTS

Unseasonable rainfall events late in 1997 resulted in an extended (or second) "wet season" within the same year. Sampling schedules were adjusted in order to collect fish during the "dry season", after the beginning of the "wet season", and following extended high water levels near the end of the "wet season". In this study, those sampling events were conducted in April, September, and February of 1998, respectively. According to hydrographs provided by the South Florida Water Management District and our field observations, when surface water levels dropped below 16.5 ft. NGVD, the hydric flatwoods were dry. Based on these data and observations the hydroperiod in the "hydric flatwoods" sampling sites ranged between 251 and 267 days during 1998.

Fish sampling began on 6 and 7 February 1998 after the study sites had been continuously flooded for approximately 70 days. During the 17-18 April 1998 sampling trip, water levels had receded and five of the sampling zones (FP6B, FP7B, FP7C, FP9B and FP9C) had no water at the surface to sample. Surface water data indicate that most (or all) sampling sites were dry or only saturated to ground level from late April through late July. The final round of quantitative Breder trap sampling was completed on 1 October, following approximately six weeks of water levels above 16.5 ft. NGVD.

Fish Sampling Results

A total of twelve fish species, representing six families were collected by Breder trap from three wetlands combined (Table 1). Small fish were easily collected, identified, enumerated, and released alive with minimal or no handling to cause stress or mortality. Total species, species richness, and abundance for each wetland zone are presented in Table 2. The most abundant fish was the eastern mosquitofish, *Gambusia holbrooki* (2021 individuals); collected at every site and during each sampling event. Also abundant and widely distributed were flagfish, *Jordanella floridae* (234), least killifish, *Heterandria formosa* (229), and golden topminnows, *Fundulus chrysotus* (184). Sailfin molly, *Poecilia latipinna* (102) were only found in abundance at FP9, with only 3 and 15 individuals collected from wetlands FP6 and FP7 respectively. Marsh killifish, *Fundulus confluentus* (45) were not abundant at any of the wetland sites. However, qualitative dip net sampling of roadway puddles near wetlands FP7 and FP9 produced large numbers of juvenile and adult marsh killifish as water levels dropped in April. Everglades pygmy sunfish, *Elassoma evergladei* (218), were found only at FP6 with the exception of one individual collected at FP7A. An isolated pool at FP6A was all that remained on 17 April 1998 for sampling. A total of 166 *E. evergladei* and 225 *G. holbrooki* were collected from six Breder traps with 82 *E. evergladei* and 73 *G. holbrooki* collected in a single trap.

Centrarchid sunfish species of the genus *Lepomis* were for the most part restricted to deeper water areas of FP7. The dollar sunfish, *Lepomis marginatus* (30), appeared to utilize shallow zones more than other sunfish species. The only non-native fish collected during the study was the black acara, *Cichlasoma bimaculatum* (3), and it was only collected at FP6. Black acara are generally found in deepwater wetlands, ponds and canals in south Florida. Black acara were collected from the cypress dome ponds near FP6 during this study and the study conducted by Main et al. (1997).

Table 1. Fish Species Collected by Breder Trap, Flint Pen Strand Wetland Sites.

Family	Scientific Name	Common Name
Cyprinodontidae		
Pupfishes	*Jordanella floridae*	flagfish
Fundulidae		
Topminnows	*Fundulus chrysotus*	golden topminnow
& Killifish	*Fundulus confluentus*	marsh killifish
	Lucania goodei	bluefin killifish
Poeciliidae		
Livebearers	*Gambusia holbrooki*	eastern mosquitofish
	Heterandria formosa	least killifish
	Poecilia latipinna	sailfin molly
Centrarchidae		
Sunfishes	*Lepomis gulosus*	warmouth
	Lepomis marginatus	dollar sunfish
	Lepomis punctatus	spotted sunfish
	Lepomis sp. (juvenile)	
Elassomatidae		
Pygmy sunfish	*Elassoma evergladei*	everglades pygmy sunfish
Cichlidae		
Cichlids	*Cichlasoma bimaculatum**	black acara

* = Non-native, introduced species

Fish species diversity was calculated using the natural logarithm of the Shannon diversity index (H') and based on species abundance in each sample by date and site. The diversity (H') values in this study were from 0.261 to 1.542. The highest H' values, 1.542 and 1.414 were at FP6B (8 species) and FP7C (7 species) on 30 September. The two sites with the highest fish diversity represent the middle and outer fringe of hydric pine flatwoods respectively. Both of these sites were completely dry during the April sampling event and were not re-flooded until approximately six weeks prior to the final sampling. Mean water depths at during this September sampling event were 16.8 cm (6.6 inches) and 9.8 cm (3.8 inches) for sites FP6B and FP7C respectively.

	Combined Fish Sampling Results by Site, Breder Trap								
	Wetland FP6			Wetland FP7			Wetland FP9		
Fish Species	**FP6A**	**FP6B**	**FP6D**	**FP7A**	**FP7B**	**FP7C**	**FP9A**	**FP9B**	**FP9C**
Jordanella floridae	14	25	28	33	12	40	23	28	31
Fundulus chrysotus	25	20	13	49	24	26	17	2	8
Fundulus confluentus			3	10	2	7	5	5	13
Lucania goodei				1					
Gambusia holbrooki	486	261	51	298	198	125	318	136	148
Heterandria formosa	66	28	18		8	20	25	44	20
Poecilia latipinna		1	2	6		9	10	55	19
Elassoma evergladei	166	1	50	1					
Lepomis gulosus				3		1	1	1	
Lepomis marginatus				18	11		1		
Lepomis punctatus			1						
Lepomis sp. (juv.)		1		3					
Cichlasoma bimaculatum		1	2						
Species Richness/Site	5	8	9	10	6	7	8	7	6
Total Species Richness	10			11			8		

Table 2. Summary of Breder Trap sampling results for Wetlands FP6, FP7 & FP9

Stepwise (interactive) multiple linear regressions were used to construct predictive models of a dependent variable (number of species, number of individuals, and species diversity) using one or more independent variables. Forward selection procedures indicated that about 24% (r^2=0.236) of the variance in the number of species collected at each site could be attributed to habitat type/vegetation. Specific conductance (12%), temperature (8%), sediment (4%), and dissolved oxygen (DO)(3%) appear to be less associated with the number of species collected, but when combined account for 51% of the variance in the predictive model of number of species. In a predictive model of number of individuals collected, water depth (r^2=0.178) combined with sediment, time of day, DO, and conductance explained approximately 50% (r^2=0.498) of the variance. In a predictive model of species diversity (H') sediment type (r^2=0.200), DO, water depth, time, and habitat type contributed to explaining about 38% (r^2=0.375) of the variance. The results of these regressions indicate that habitat type/vegetation, water depth, sediment type and to a lesser extent conductance are some primary factors that are associated with number of species, number of individuals, and species diversity.

The Pearson Product Correlation Coefficient (r) between all variables (both dependent and independent) is presented in the form of a matrix (Appendix). In this data set there are few strong associations as evidenced by this analysis, however, there are some notable exceptions. A high, positive correlation (r = 0.892) existed between the abundance of *Gambusia holbrooki* and the total number of individuals of all species. This is to be expected, as *G. holbrooki* was the most abundant fish present and clearly contributed to the total number of fish collected at each site. Between species there was high positive correlation (r = 0.703) between *Elassoma evergladei* and *Heterandria formosa*. This may reflect their similar habitat preference for waters containing dense vegetation. Several (weak) negative correlations were calculated between both *G. holbrooki* and *H. formosa,* and several other fish species abundance, most of which were sunfishes. This might indicate that *G. holbrooki* and *H. formosa* were often not present when other species were abundant due to predation. Similarly, it could indicate that the shallowest habitats were suitable for *G. holbrooki* and *H. formosa* but unsuitable for other species.

Graphical presentations of the data were used to help visualize associations between and among dependent and independent variables. Two-dimensional cluster analysis was used to help depict fish species and habitat attribute associations (Figure 2). A graph of Principal Components Analysis (PCA) using the first three factor loadings provides a three dimensional view that illustrates how the first three independent variables interact with or, are associated with, fish species abundance (Figure 3).

Lepomis marginatus, Lepomis gulosus, Lepomis sp. and *Lucania goodei* cluster together which is to be expected. *L. gulosus* and *L. marginatus* are the most common sunfish in freshwater wetlands of southwest Florida (Cox and Ceilley, 1995; Main et al., 1997). While only one *L. goodei* was collected in this study, Kushlan (1980) found in the Everglades that *L. goodei* populations increased along with several species of *Lepomis* during a period of extended high water. There is a close association between *Elassoma evergladei, Heterandria formosa, Gambusia holbrooki,* and *Fundulus chrysotus*.

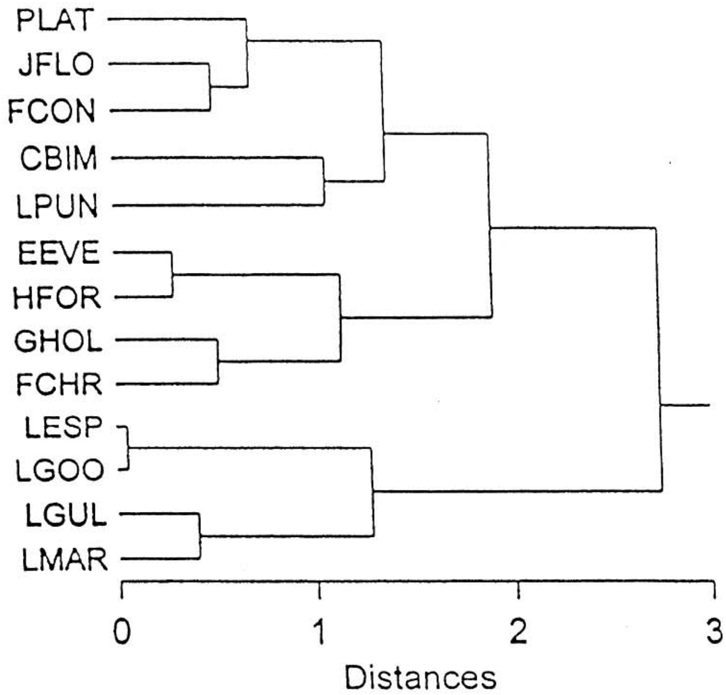
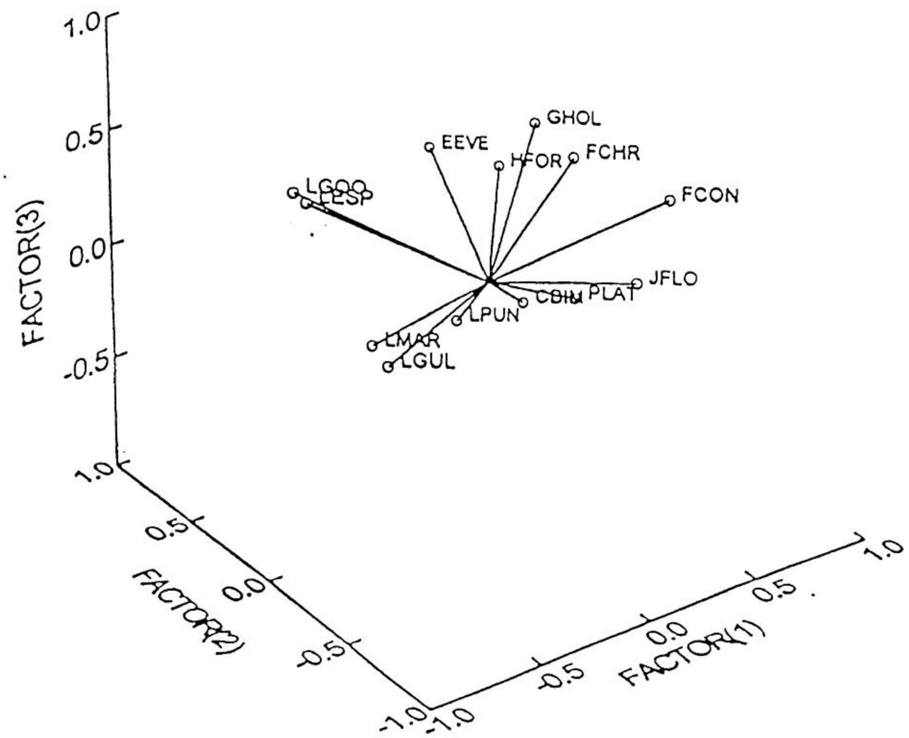


Figure 3. A species cluster diagram based on the standardized species abundance using the Pearson Product Correlation Coefficient matrix and using Ward's (UPGMA) clustering algorithm.

Figure 4. Factor Loading Plot using Principal Components Analysis based on species abundance displaying the first three factor loadings.



However, *E. evergladei* populations respond positively to extended periods of high water while *G. holbrooki, H. formosa*, and *F. chrysotus* typically decrease in number following such periods (Kushlan, 1980; Fury et al., 1995). The *G. holbrooki, H. formosa*, and *F. chrysotus* association is supported by observations in other areas of southwest Florida where these species dominate wetland fish collections (Cox and Ceilley, 1995: Main et al., 1997) along with *Jordanella* (Carlson and Duever, 1977). *Cichlasoma bimaculatum* and *Lepomis punctatus* are loosely associated with each other. Both species prefer deepwater habitats of ponds, canals or large marshes and are uncommon or rare in flatwoods. *C. bimaculatum* is an exotic species that is intolerant of cold water and therefore, limited in distribution to subtropical areas in Florida. *Poecilia latipinna* clustered closely with *Fundulus confluentus* and *Jordanella floridae*. This might be explained by the fact that *P. latipinna* and *F. confluentus* are eurihaline species, considered by some authors to be estuarine species (Dunson et al., 1997; Robins et al., 1986). *J. floridae* is primarily a freshwater pupfish species but enters brackish water (Page and Burr, 1991). In addition, *F. confluentus* and *J. floridae* both have eggs that can withstand some periods of desiccation or severely reduced moisture (Lee et al., 1980)

Water Quality

Water quality parameters measured in this study appeared to have little effect on fish species distribution or abundance. Specific conductance ranged broadly from 30 to 410 µS/cm between sites and seasons. Conductance was lowest during the February monitoring event after recent heavy rains when water levels were highest. Conductance was highest during the April event when receding water concentrated dissolved cations. Daytime dissolved oxygen (DO) concentrations ranged from 1.0 to 17.5 mg/l (supersaturated). DO concentrations were not correlated with fish species presence/absence or abundance. Surprisingly, low DO concentrations did not appear to effect survival of larger predatory sunfish; for example, warmouth (*Lepomis gulosus*) were collected from areas with the lowest DO concentrations.

DISCUSSION AND CONCLUSIONS

The distribution of fishes in aquatic environments in south Florida is dependent on several factors including water chemistry, protective cover, connectivity to other bodies of water, and hydrology (Carlson and Duever, 1977; Hoyer and Canfield, 1994; Kushlan, 1973; 1980; Dunson, 1997). In south Florida's isolated wetlands, hydrologic patterns are considered to be the most important factor influencing fish community composition (Main et al., 1997; Kushlan, 1980). Based on our observations and grab samples of water quality, water temperature and DO did not appear to limit species richness or abundance at any of the sites. Diurnal temperature and DO fluctuations are dramatic in these shallow wetlands, yet several small fishes thrive there. Water depth, hydroperiod duration, and connection to deep-water refugia appear to be more important in determining fish community structure. Each of these may be negatively affected by water table drawdown. Habitat type, water depth, sediment type, and specific conductance appeared to be the primary factors associated with species presence/absence, abundance and diversity in this study. Taken together, these independent variables are descriptive of ecological zones or microhabitats within the flatwoods complex that are directly influenced by hydrology, climate, and geology.

Cypress Domes and Hydric Flatwoods Fishes

Table 3 compares the fish communities found in the cypress domes (Main et al., 1997) with those collected in this study from the adjacent hydric flatwoods. None of the fishes from functional group 3 were collected from the flatwoods sampling sites while representatives of all three functional groups were collected from the adjacent cypress dome, FP6. This FP6 cypress dome contained a gator hole that contains water year round and apparently serves as a local dry season refugia for many fish species.

During the wet season hydric flatwoods wetlands were shallow (4-20cm deep) and broad, but contiguous with and surrounding much smaller and deeper (50-180± cm) cypress dome wetlands. The high diversity and abundance of fish collected from the shallow hydric pine flatwoods is somewhat surprising when compared to other wetland sites in the SFWMD. Overall fish species richness, family richness (Table 2), and diversity (H') were highest in the pine and mixed pine-cypress canopy habitats than in the deeper cypress dominated fringes sampled in this study. Generally speaking, the shallowest zones sampled contained a high proportion of small juveniles (especially *G. holbrooki, H. Formosa, J. floridae*, and *F. chrysotus*) and few mature adults while deeper zones contained mature adults and few small juveniles. This habitat partitioning by size may be a function of foraging, predation, predator avoidance, and reproductive strategies or most likely combinations thereof. Under normal hydrologic conditions, cypress domes and strands are not biologically isolated in terms of aquatic fauna from surrounding habitats especially the hydric flatwoods of south Florida. As water levels rise during the rainy season and hydric flatwoods re-flood, fishes migrate from dry season refugia into adjacent habitats. Kushlan (1980) stated that this movement probably represents spawning migrations for many species. In addition, certain species like the marsh killifish (*F. confluentus*) and flagfish (*J. floridae*) have unique reproductive strategies including egg stages that are adapted to survive some periods of desiccation (Harrington, 1959; Lee et al., 1980). This allows these species to re-colonize ephemeral wetlands or systems that experience dry periods then become re-hydrated during the rainy season. Additional research will be needed to determine the minimum hydroperiod required for survival or how long these eggs can survive in sediments without inundation.

The severance of this seasonal aquatic continuum near the cypress dominated edge by ditches and dikes, agriculture, and development disrupts the seasonal movement of several small fish species (functional groups 1 and 2) into the shallow flatwoods where many would normally live and propagate during much of the year. This results in the direct loss of important feeding, nesting, and nursery habitat for numerous native fishes. In addition, by confining small forage fish to deepwater zones (cypress domes) year-round we may expect increased mortality through predation by large piscivorous fish and other fauna.

	Functional Group	Cypress Domes*		Hydric Flatwoods		
Fish Species		**FP6**	**FP7**	**FP6**	**FP7**	**FP9**
Fundulus confluentus	1	X	X	X	X	X
Gambusia holbrooki	1	X	X	X	X	X
Heterandria formosa	1	X	X	X	X	X
Jordanella floridae	1	X	X	X	X	X
Poecilia latipinna	1	X	X	X	X	X
Enneacanthus gloriosus	2	X	X			
Elassoma evergladei	2	X	X	X	X	
Fundulus chrysotus	2	X	X	X	X	X
Lepomis gulosus	2	X	X		X	X
Lepomis marginatus	2	X			X	X
Lepomis punctatus	2			X		
Lepomis sp. (juv.)	2			X	X	
Lucania goodei	2	X	X		X	
Ameiurus nebulosus	3	X				
Labidesthes sicculus	3	X				
Lepisosteus platyrhincus	3	X				
Lepomis microlophus	3	X				
Cichlasoma bimaculatum	NA	X	X	X		
Species Richness	18	16	11	10	11	8
Functional Grps. Present	1,2,3	1,2,3	1,2	1,2	1,2	1,2

Table 3. A Comparison of Fish Collections from Cypress Domes* and adjacent Hydric Flatwoods in the Flint Pen Strand, Lee County, Florida.

Functional Feeding Groups and Associated Habitats*

1. Small omnivorous fishes – shallow, ephemeral wetlands.
2. Small predatory fishes – wetlands with deepwater refugia.
3. Large predators and open-water fishes – semi-permanent, deepwater wetlands.

* Main et al. (1997)

Potential Indicator Species

Assessing the fish community structure of wetland habitats is a cost-effective method of measuring functional attributes and may serve as a valuable tool for monitoring hydrologic alteration over time. Main et al. (1997) suggested using the "functional group" approach to evaluate hydrologic conditions of wetlands throughout the South Florida Water Management District. These functional groups are helpful for identifying general hydrologic conditions of wetland habitat types and gross changes in hydroperiods over time. For evaluating regional wetlands and specific habitat types (e.g. southwest Florida flatwoods) we recommend using individual fish species presence/absence, relative abundance, and community assemblages to detect more subtle changes in hydrology.
Fishes within a single functional group have a variety of adaptations and strategies to survive in the dynamic conditions of Florida's freshwater wetlands. With monitoring information on fish community structure, rainfall, topography, and climate these specific adaptations can be used by wetland scientists to evaluate hydrologic conditions and identify levels of disturbance.

Due to their unique life history requirements the following (common and widely distributed) species may serve as indicators of hydrologic conditions or disturbance in SW Florida wetlands:

1. The most abundant centrarchid in the hydric flatwoods was the dollar sunfish, *Lepomis marginatus*. Dollar sunfish have been observed constructing and defending nest sites in the slash pine-*Hypericum* zones of flatwoods during the wet season in southwest Florida (Ceilley and Cox, 1995). The dollar sunfish appeared to thrive in these shallow zones where no other *Lepomis* species are found. The use of shallow hydric pine flatwoods and wet prairies by dollar sunfish indicates that populations could be negatively affected by surface water drawdown especially if deepwater refugia nearby is also impacted by draw-down or contains high concentrations of other fish competitors and predators. The dollar sunfish, by virtue of it's preference for shallow wetland systems (Main et al., 1997; Fury et al., 1995; Kushlan and Lodge, 1974), wide distribution, and life history (Lee et al., 1980), may have value as an indicator of hydroperiod conditions in many southwest Florida wetlands (i.e., cypress domes with flatwoods).

2. The golden topminnow (*F. chrysotus*) and the marsh killifish (*F. confluentus*) have similar habitat requirements in terms of vegetation, water depth, and sediment and appear to prey on similar items (ostracods, dipterans, small snails). However, the reproductive strategies of these species are quite different. *F. chrysotus* requires permanent water to survive, lays eggs in submergent vegetation, and colonizes very shallow zones after inundation as they migrate out of deepwater refugia. Conversely, *F. confluentus* adults appear to breed in shallow water as water levels recede, laying eggs in muddy pools, with delayed hatching after the dry season as water levels rise. Excessive desiccation from drought or water table drawdown would likely inhibit reproductive success of *F. confluentus*.

3. Flagfish , *Jordanella floridae*, are endemic to peninsular Florida and seem to prefer heavily vegetated ephemeral waters (Lee et al., 1980). Their reproductive strategy is similar to that of *F. confluentus*. However, *F. confluentus* is mainly limited to the Everglades and freshwater and brackish coastal areas of Florida (Lee et al., 1980) while *J. floridae* is more widely distributed throughout Florida's freshwater wetlands and lakes with an affinity for alkaline, low nutrient waters with abundant vegetation (Hoyer and Canfield, 1994). In the wet prairie habitats of Corkscrew Swamp Sanctuary, Carlson and Duever (1977) found that *J. floridae* dominated collections (25-60% by number and 20-85% by weight). Both *F. confluentus* and *J. floridae* appear to have great potential as hydroperiod indicators due to their habitat preferences for shallow systems and reproductive strategies that are dependent on natural water cycles (i.e., seasonal flooding and drying of wetlands). Their reproductive success is directly affected by water level fluctuations that regulate both egg deposition and delayed hatching.

4. Everglades pygmy sunfish (*E. evergladei*), bluefin killifish (*Lucania goodei*), and warmouth (*Lepomis gulosus*) populations responded favorably to extended periods of high water in the Everglades water conservation areas indicating that they may prefer longer hydroperiods and higher water levels (Fury et al., 1995). This is supported by our observations and other wetland fish studies (Main et al., 1997). Together these species may serve as indicators of hydroperiod conditions in other wetlands of south Florida.

5. Eastern mosquitofish (G. holbrooki) is the most ubiquitous and abundant fish in south Florida wetlands. Mosquitofish may have value in evaluating hydroperiod condition since they tend to dominate collections, in terms of total numbers of fish collected, following periods of drought (Fury et al., 1995).

Additional investigation into the seasonal use of hydric pine flatwoods by small omnivorous fish species is warranted. In order to develop better predictive models we recommend larger quantitative samples be taken in the future. By evaluating wetland fish species presence/absence, overall diversity, and community structure, we should be able to detect subtle changes in hydroperiods rather quickly. Alternate seasons (or cycles) of flood and drought conditions are normal in the flatwoods and typically follow the summer/fall wet season and winter/spring dry season, respectively. In this relatively harsh environment for aquatic fauna, many fish species are adapted in a variety of ways to survive, and thrive under, these extremes. However, anthropogenic manipulations of hydroperiod cycles and resultant extremes of either flood or drought can exceed the tolerances of even these hardy fish species. Due to their expansive shallow surface waters, it is likely that the hydric flatwood habitats will be the first areas to show biological evidence of water table drawdown when it exceeds natural seasonal fluctuations. Fish species presence/absence and relative abundance (diversity) and community composition may therefore be an effective indicator of annual hydroperiod and whether or not conditions have been impaired or degraded to the point that wetland functions are lost (e.g. extirpation of species, disruption of food chains).

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APPENDIX

Statistical Tables & Matrices

Table 6. Summary of stepwise (interactive) multiple linear regression

Summary of Forward Selection Procedure for Dependent Variable: Number of Species (NO_SP)

Step	Variable Entered	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	HAB_CODE	1	0.2356	0.2356	4.5437	6.1651	0.0220
2	CD	2	0.1198	0.3554	3.0116	3.5299	0.0757
3	T	3	0.0802	0.4356	2.6463	2.5576	0.1272
4	DO	4	0.0321	0.4677	3.6989	1.0259	0.3253
5	SED_CODE	5	0.0382	0.5059	4.5724	1.2369	0.2825

Summary of Forward Selection Procedure for Dependent Variable: Number of Individuals (NO_IN)

Step	Variable Entered	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	WD	1	0.1780	0.1780	5.1843	4.3318	0.0505
2	SED_CODE	2	0.1458	0.3238	3.0727	4.0960	0.0573
3	ST	3	0.0642	0.3880	3.2627	1.8872	0.1864
4	DO	4	0.0851	0.4731	2.8629	2.7449	0.1159
5	CD	5	0.0245	0.4976	4.1720	0.7801	0.3902

Summary of Forward Selection Procedure for Dependent Variable: Species Diversity (H_PRI)

Step	Variable Entered	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	SED_CODE	1	0.2004	0.2004	0.0354	5.0110	0.0367
2	ST	2	0.0357	0.2361	1.2300	0.8881	0.3578
3	WD	3	0.0424	0.2784	2.2742	1.0572	0.3175
4	DO	4	0.0718	0.3503	2.6544	1.8791	0.1883
5	HAB_CODE	5	0.0249	0.3752	4.0923	0.6382	0.4360

Legend for Independent Variables

CD = Specific Conductance
DO = Dissolved Oxygen
HAB_CODE = Habitat Type/Dominant Vegetation
SED_CODE = Sediment Type
ST = Start Time
T = Temperature
WD = Water Depth

Pearson correlation matrix

	M	WD	DO	T	CD
M	1.000				
WD	0.216	1.000			
DO	-0.525	-0.284	1.000		
T	0.842	0.105	-0.199	1.000	
CD	0.279	-0.280	-0.324	0.002	1.000
NOSP	0.464	0.053	-0.155	0.397	0.208
NOIN	-0.229	-0.422	0.195	-0.070	0.023
H	0.080	-0.261	0.018	0.101	0.066
CBIM	0.320	-0.057	-0.114	0.539	-0.186
EEVE	-0.112	-0.150	-0.290	-0.045	-0.052
FCHR	0.015	-0.344	0.555	0.348	-0.084
FCON	-0.235	-0.527	0.506	-0.199	0.306
GHOL	-0.213	-0.310	0.323	-0.044	0.031
HFOR	-0.398	-0.453	-0.072	-0.405	-0.075
JFLO	0.223	-0.305	0.189	0.258	0.041
LESP	0.300	0.404	-0.220	0.246	-0.048
LGOO	0.234	0.401	-0.213	0.097	0.008
LGUL	0.245	0.455	-0.089	0.103	-0.074
LMAR	-0.200	0.501	0.196	-0.154	-0.137
LPUN	-0.088	0.302	-0.272	-0.160	-0.082
PLAT	0.146	-0.397	-0.008	-0.076	0.418

	NOSP	NOIN	H	CBIM	EEVE
NOSP	1.000				
NOIN	-0.343	1.000			
H	0.578	-0.219	1.000		
CBIM	0.303	-0.231	0.388	1.000	
EEVE	-0.230	0.667	0.056	-0.081	1.000
FCHR	0.191	0.526	0.092	0.128	0.229
FCON	0.210	0.200	0.237	-0.005	-0.187
GHOL	-0.437	0.892	-0.521	-0.287	0.326
HFOR	-0.278	0.641	0.236	-0.174	0.703
JFLO	0.542	-0.053	0.469	0.273	-0.317
LESP	0.421	-0.179	0.087	0.070	-0.076
LGOO	0.282	-0.125	-0.028	-0.065	-0.061
LGUL	0.231	-0.309	0.277	-0.151	-0.142
LMAR	-0.007	-0.236	0.154	-0.120	-0.112
LPUN	0.100	-0.175	-0.131	-0.065	0.234
PLAT	0.170	0.021	0.305	-0.111	-0.161

	FCHR	FCON	GHOL	HFOR	JFLO
FCHR	1.000				
FCON	0.469	1.000			
GHOL	0.480	0.198	1.000		
HFOR	0.020	0.028	0.337	1.000	
JFLO	0.216	0.492	-0.097	-0.082	1.000
LESP	-0.072	-0.191	-0.162	-0.169	-0.048
LGOO	-0.127	-0.149	-0.091	-0.146	-0.099
LGUL	-0.212	-0.290	-0.330	-0.258	0.044
LMAR	-0.093	-0.265	-0.211	-0.214	-0.241
LPUN	-0.151	-0.149	-0.286	-0.118	-0.126
PLAT	-0.156	0.298	-0.063	0.158	0.397

	LESP	LGOO	LGUL	LMAR	LPUN
LESP	1.000				
LGOO	0.947	1.000			
LGUL	0.249	0.295	1.000		
LMAR	0.196	0.233	0.591	1.000	
LPUN	-0.061	-0.048	-0.111	-0.087	1.000
PLAT	-0.154	-0.127	0.118	-0.228	-0.127

	PLAT
PLAT	1.000

Number of observations: 22

Pearson correlation matrix

	CBIM	EEVE	FCHR	FCON	GHOL
CBIM	1.000				
EEVE	-0.081	1.000			
FCHR	0.128	0.229	1.000		
FCON	-0.005	-0.187	0.469	1.000	
GHOL	-0.287	0.326	0.480	0.198	1.000
HFOR	-0.174	0.703	0.020	0.028	0.337
JFLO	0.273	-0.317	0.216	0.492	-0.097
LESP	0.070	-0.076	-0.072	-0.191	-0.162
LGOO	-0.065	-0.061	-0.127	-0.149	-0.091
LGUL	-0.151	-0.142	-0.212	-0.290	-0.330
LMAR	-0.120	-0.112	-0.093	-0.265	-0.211
LPUN	-0.065	0.234	-0.151	-0.149	-0.286
PLAT	-0.111	-0.161	-0.156	0.298	-0.063

	HFOR	JFLO	LESP	LGOO	LGUL
HFOR	1.000				
JFLO	-0.082	1.000			
LESP	-0.169	-0.048	1.000		
LGOO	-0.146	-0.099	0.947	1.000	
LGUL	-0.258	0.044	0.249	0.295	1.000
LMAR	-0.214	-0.241	0.196	0.233	0.591
LPUN	-0.118	-0.126	-0.061	-0.048	-0.111
PLAT	0.158	0.397	-0.154	-0.127	0.118

	LMAR	LPUN	PLAT
LMAR	1.000		
LPUN	-0.087	1.000	
PLAT	-0.228	-0.127	1.000

Number of observations: 22

Appendix 3 Legend for Abbreviations

Fish Species Codes

CBIM = *Cichlasoma bimaculatum*
EEVE = *Elassoma evergladei*
FCHR = *Fundulus chrysotus*
FCON = *Fundulus confluentus*
GHOL = *Gambusia holbrooki*
HFOR = *Heterandria formosa*
JFLO = *Jordanella floridae*
LESP = *Lepomis sp. (juv.)*
LGOO = *Lucania goodei*
LGUL = *Lepomis gulosus*
LMAR = *Lepomis marginatus*
LPUN = *Lepomis punctatus*
PLAT = *Poecilia latipinna*

Independent Variables

M = Date
WD = Water Depth
DO = Dissolved Oxygen
T = Temperature
CD = Specific Conductance

Dependent Variables

NOSP = Number of Species
NOIN = Number of Individuals
H = Species Diversity