

Effect of aquatic plants and associate microhabitats on early life stages of fish

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Abstract

We examined the effect of aquatic plants and some associate microhabitats on abundance of early life stages of fish in a backwater cove of Aliceville Lake, a reservoir on the Tennessee-Tombigbee Waterway, located on the Alabama-Mississippi border. Abundance of early life stages of fish, along with physicochemical and plant habitat variables were measured from March to August 1998. Biological samples were collected with modified Quatrefoil light traps. Principal component analysis, detrended correspondence analysis, and multiple linear regression were used to detect associations of early life stages of fish with physicochemical and habitat structure variables. We collected 1,388 fish representing 12 genera and 9 families. Evidence from our study demonstrated that aquatic plants can create habitat availability in ways different than structural complexity. We identified different physicochemical structures in the studied cove owing to different levels of plant coverage. Our results suggest that levels of plant coverage of up to 25% create physicochemical conditions that can positively influence habitat availability for spawning and early life stages of fish. Low levels of plant coverage could increase temperature and dissolved oxygen during early spring, triggering fish early spawning. The identification of appropriate levels at which aquatic vegetation provides a good-quality habitat for early life stages of fish is important for successful fisheries and aquatic plant management.

Key words: Early life stages of fish; microhabitat; multivariate statistics; physicochemical structure; plant coverage.

Efecto de plantas acuáticas y sus microhábitats asociados sobre los estadios tempranos de vida de peces

Resumen

Examinamos el efecto de plantas acuáticas y algunos de sus microhábitats asociados sobre la abundancia de estadios tempranos de vida de peces en un área lateral del Lago Aliceville, un reservorio del canal Tennessee-Tombigbee localizado en la frontera de los estados Misisipi y Alabama, Estados Unidos. Se midió la abundancia de estadios tempranos de vida de peces junto con variables físicoquímicas y de hábitat desde marzo hasta agosto de 1998. Las muestras biológicas se colectaron con trampas de luz Quatrefoil modificadas. Se utilizaron análisis de

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componentes principales, análisis de correspondencia sin tendencias y regresión lineal múltiple para detectar la asociación de los estadios tempranos de vida de peces con variables fisicoquímicas y de estructura de hábitat. Colectamos 1.388 peces representando 12 géneros y nueve familias. Evidencias de nuestro estudio demuestran que las plantas acuáticas pueden crear disponibilidad de hábitat en formas diferentes a la complejidad estructural. Identificamos diferentes estructuras fisicoquímicas en el área estudiada debidas a diferentes niveles de cubierta vegetal. Nuestros resultados sugieren que los niveles de cubierta vegetal de hasta 25% crean condiciones fisicoquímicas que pueden influenciar positivamente la disponibilidad de hábitat para el desove de los peces y estadios tempranos de vida. Niveles bajos de cubierta vegetal pudieran incrementar la temperatura y la disponibilidad de oxígeno disuelto al inicio de la primavera, incentivando un desove temprano. Reconocer los niveles apropiados a los cuales la cubierta vegetal provee un hábitat de buena calidad para los estadios tempranos de vida de peces es importante para un manejo exitoso de las pesquerías y de las plantas acuáticas.

Palabras clave: Cubierta vegetal; estadios tempranos de vida de peces; estadística multivariada; estructura fisicoquímica; microhábitat.

Introduction

Aquatic plants have been recognized as important ecological components of aquatic systems and as primary regulators of ecosystem function (1-3), and the role aquatic plants play in freshwater ecosystems has been defined in many ways. Emphasis has been placed on the structural complexity provided by aquatic plants that benefits early life stages and adult fish (4-7), yet this same complexity can negatively affect physicochemical characteristics important to fish. Plant respiration reduces and/or depletes dissolved oxygen during the night, thereby reducing habitat availability (8). From a fishery perspective, adverse effects of overabundant aquatic vegetation include poor access to fishing and slow growing fish populations (9).

Coverage provided by aquatic plants has been recognized as one of the most important determinants of early life stages and adult fish abundance (3, 10). Aquatic plants provide refuge and foraging habitats for early life stages and spawning sites for many fish (1, 11) and affect ecological interactions (12). Along with plant coverage, much effort has been devoted to identify relations between fish population characteristics and

physicochemical variables. However, the approach used has focused on finding correlations among physicochemical and habitat structure variables and fish relative abundance and diversity (3, 10, 13-17). In this study we used principal component analysis (PCA), detrended correspondence analysis (DCA), and multiple linear regression to identify relations among the community structure of the early life stages of fish and the physicochemical and habitat structure characteristics of microhabitats associated with aquatic vegetation in a cove in the Tennessee-Tombigbee Waterway. Our particular interest was to determine whether plant coverage was an important factor to physically characterize the cove and/or in explaining fish catch rates.

More holistic perspectives based on ecological applications of multivariate statistics have expanded widely in the last few years because of the ability to identify and assess intercorrelations among variables of interest and the urgency of making wise ecologically based decisions in management (18-19). Principal component analysis and DCA are valuable techniques for identifying relations between the structure of fish communities and characteristics of physical habitats and are conceptually similar, com-

plementary, multivariate ordination techniques (18, 20). Defining and understanding these relations is important for the management of fish and aquatic plant populations.

Materials and Methods

The study was conducted in a backwater cove of Aliceville Lake (33° 26' N, 88° 31' W; Figure 1), a reservoir on the Tennessee-Tombigbee Waterway, located on the Alabama-Mississippi Border. The cove selected contained various aquatic plant coverages, and had a surface area of approximately 7.6 ha and a mean depth of 0.6 m (3). Emerged, submersed, and floating vegetation covered 88% of the cove surface from 1993 to 1994 (3), and 85 to 95% in 1997 (E. Dibble and S. Harrel, Department of Wildlife and Fisheries, Mississippi State University, unpublished data). The predominant emerged plants in the cove were waterprimrose (*Ludwigia hexapetala* Hook and Arn. and *L. peploides* Kunth), smartweed (*Polygonum* spp. L.), and alligatorweed (*Althernanthera philoxeroides* Mart). Submersed plants included Eurasian watermilfoil (*Myriophyllum spicatum* L.), coontail (*Ceratophyllum demersum* L.), curlyleaf

pondweed (*Potamogeton crispus* Poiret), and hydrilla (*Hydrilla verticillata* L.f.). The predominant floating plant was water hyacinth (*Eichhornia crassipes* Mart).

We sampled early life stages of fish from March to August 1998. Criteria used to distinguish early life stages of fish from juveniles were total lengths for early life stages as reported in the literature and prevalence of a yolk sac. When no specific references on early life stages were found in the literature (e.g., banded pygmy sunfish *Elassoma zonatum* Jordan, mosquitofish *Gambusia affinis* Baird and Girard), only specimens with evidence of yolk sac were reported. The sampling schedule was based on peak spawning time for most fish reported previously for Aliceville Lake (21). Sampling was conducted twice in May, July and August, and once in March, April and June. We used a light trap modified from the original design of Floyd *et al.* (22) as the sampling gear. The trap consisted of a slotted trapping apparatus having four, 150-mm long, 5-mm wide entrance slots that allowed early life stages of fish to enter the trap's inner chamber.

A total of 102 light traps was set during the whole sampling period. Twelve traps

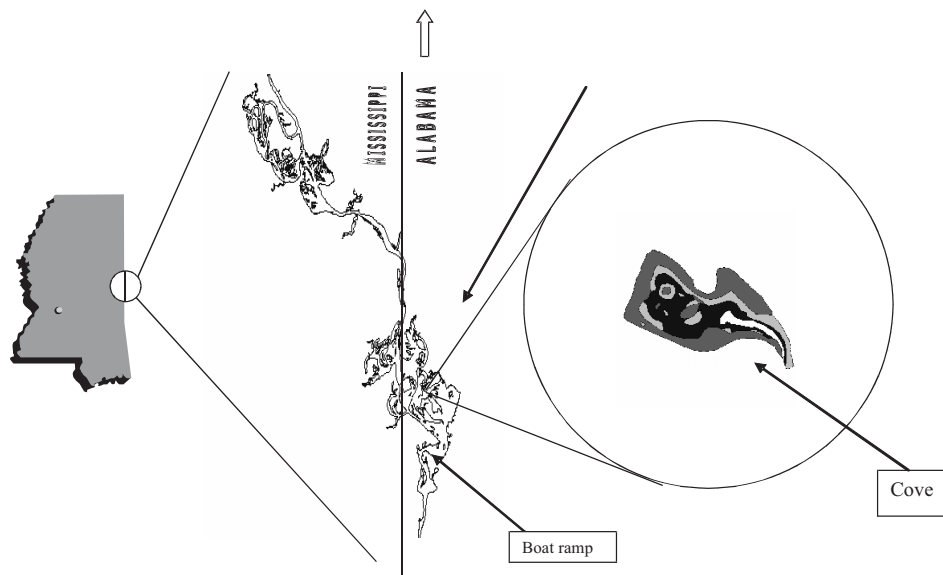


Figure 1. Map of Aliceville Lake, Mississippi-Alabama, and relative position of the studied cove.

were placed randomly in the selected cove using a grid superimposed on an aerial photo of the cove. Traps were set for one night from approximately 3 h before sunset to 3 h after sunrise for an approximated soak time of 16 h. Traps were illuminated by 12-h Cyalume chemical sticks. Fish were preserved in 5% buffered formalin and identified and enumerated in the laboratory. Primary references for fish identification included Hogue *et al.* (23), Auer (24), and Holland-Bartels *et al.* (25).

Surface coverage of aquatic plants was estimated using three randomly tossed 0.25 m² PVC plastic quadrats within a 1-m radius of each trap site. Total percent coverage within each quadrat was visually estimated, averaged across the three samples and expressed as means for total plant coverage, and emersed, submersed, and floating fractions. Plants were identified based on standard methodologies (e.g., 26). From one of the three sampled quadrats, all plants were harvested and dried at 60°C for 24-h to obtain dry weight (DW) (27). These variables are referred as habitat structure variables.

Several physicochemical variables were determined at each trap site to describe microhabitats associated with abundance of early life stages of fish. Water temperature (°C), dissolved oxygen (DO; mg/L), and pH were measured when traps were set in the evening and following morning when traps were checked. Turbidity (Nephelometric Turbidity Units), depth (m), and distance from the shore (DS; m) were determined during mornings when traps were checked. Water samples were collected for the analysis of turbidity in the laboratory using a HACH DR/2000 spectrophotometer. Water temperature and DO were measured with a YSI 55 DO-meter, and pH with a HANNA System pH-conductivity meter. Water depth was measured with a stadia rod and DS was measured with a range finder. All readings were taken at subsurface depth (approximately 15 cm). Three sets of variables were

created for data analyses, a set consisting of all individual and averaged physicochemical variables, a set consisting of all mentioned variables plus habitat structure variables, and another set consisting of all fish taxa.

Data analyses

Principal component analysis and DCA were done with PC-ORD V.3.15 (28) and the rest of statistical analyses with Statistical Analysis System (SAS), Version 7.00 (29). Principal component analysis combines a large number of correlated variables to generate axes (principal components, PCs) representing types or groups of variables, and DCA uses two-way or reciprocal averaging and also provides ordination of sampling sites along axes (30, 18). Guidelines for application and interpretation of PCA and DCA vary and are available at different levels of resolution (18, 31). Linear regression analysis is useful for the description of relations between, and prediction of future values of, measurable variables (32).

We first conducted PCA on the correlation matrix for all individual and averaged physicochemical variables from all trap sites (102 × 12 matrix: 102 trap sites, 12 physicochemical variables). Each trap site was categorized according to one of the following four categories of plant coverage: C1 (0 to 25%), C2 (25 to 50%), C3 (50 to 75%) and C4 (75 to 100%). The broken-stick model (33) was used to evaluate the relative interpretability of the ordination results. Site scores of the PC1 were tested for normality (PROC UNIVARIATE, SAS) and then used in a one-way ANOVA (PROC GLM, SAS) for site categories differences. The Tukey's HSD method was used for post hoc means separation test.

Detrended correspondence analysis was conducted on the fish taxa data matrix (102 × 12 matrix: 102 trap sites, 12 fish taxa). Site scores generated in this analysis were used, along with sites scores generated by a second PCA done on the physicochemi-

cal and habitat structure variables (102×18 matrix: 102 trap sites, 18 physicochemical and habitat structure variables), for testing the null hypothesis: H_0 , that no relation between ordination axes scores based on early life stages of fish matrix, and scores based on physicochemical and habitat structure variables exists. Product moment correlation was used for testing this null hypothesis, and significance was declared at $P \leq 0.01$.

For all taxa of early life stages of fish collected, catch-per-unit-effort (CPUE) was calculated as the number of fish per sampling time (fish/h). To examine relations between early life stages of fish CPUE and the 18 physicochemical and habitat structure variables, a stepwise multiple linear regression (PROC GLM, SAS) was done. Response and predictor variables were examined to determine the need for data transformations, and many were $\log_e(x+1)$ transformed prior to analyses to meet criteria of normality, to homogenize variance and to linearize relations. Percentage of plant coverage and pH were not transformed. The variance inflation factor (VIF) was used to detect multicollinearity. Alpha = 0.1 was selected as the significance level for entry into the model. Residuals were checked for model suitability and deviation from linearity.

Results

We collected 1,388 fish representing 12 genera and nine families (Table 1). These nine families represented 60% of the families previously reported in Aliceville Lake. Centrarchidae was the most abundant family, contributing 65% to the total number of fish. The family Poeciliidae accounted for 24% of the sample and was represented by mosquitofish (*Gambusia affinis*). The family Atherinidae, represented by brook silverside (*Labidesthes sicculus*), accounted for 7% of the fish collected. The other families collected were Percidae, Cyprinodontidae, Cyprinidae, Belontiidae, Catostomidae and Clupeidae.

Eleven plant species were identified in the cove, with water hyacinth and hydrilla as the most abundant (Table 2). Values for physicochemical and habitat structure variables measured varied during the sampling period (Table 3). Catch-per-unit-effort varied temporally and spatially (Table 4). Mean total CPUE was greatest in late May and was consistently less before and after this sample period. The peak catches in late May were mainly *Lepomis* spp. and *G. affinis*.

The first PCA produced two PCs with eigenvalues that exceeded those of the broken-stick model. The first PC, explaining 44.3% of the variation, was a composite axis consisting of mean DO, mean pH, evening pH and evening DO; and the second PC explained an additional 17.6% of the variation and was represented by mean and evening water temperature (Table 3). Scores of the PC1 were normally distributed, and the one-way ANOVA revealed a significant effect for site categories. The Tukey's test indicated that sites with low plant coverage (0 to 25%) scored significantly higher for PC1 scores than did sites with intermediate and high plant coverage. There were no significant differences between intermediate and high plant coverage site categories (Table 4).

The second PCA also produced two PCs with eigenvalues exceeding those of the broken-stick model. The first PC explained 32.7% of the variation and consisted of DO, mean pH, evening pH, and evening DO; and the second PC explained 16% of the variation and was represented by DW (Table 5). Eigenvalues generated by the DCA on the fish taxa matrix showed that the first two axes were relevant (Table 6). Product moment correlation indicated that scores of the first axis of the DCA were positively correlated ($r = 0.281$; $P < 0.01$) with scores of the PC1 based on physicochemical and habitat structure variables. There was no significant relation between DCA axis 1 and PC2 ($r = -0.163$; $P > 0.01$). Thus, the null hypothesis of no relation between ordination axis scores based on early life stages of fish

Table 1
Total number, percentage, and length range (L.R.) of larval fishes collected with light traps from Aliceville Lake, March-August 1998

	Mar 28	Apr 29	May 14	May 26	Jun 27	Jul 08	Jul 24	Aug 07	Aug 21	Total	%	L.R (mm)
Catostomidae	0	2	0	0	0	0	0	0	0	2	0.14	8-9
Cyprinidae	0	7	2	0	0	0	0	0	1	10	0.72	9-17
Clupeidae	0	0	0	0	0	0	0	0	2	2	0.14	7-12
<i>Elassoma zonatum</i>	16	10	9	51	5	0	0	0	0	91	6.56	4-18
Cyprinodontidae	2	6	2	6	3	3	1	0	0	23	1.66	6-8
<i>Gambusia affinis</i>	5	9	23	199	67	9	9	9	3	333	23.90	7-9
<i>Labidesthes sicculus</i>	4	5	27	31	25	2	0	0	2	96	6.92	12-15
<i>Lepomis</i> spp.	1	1	276	276	71	50	51	33	23	782	56.30	6-13
<i>Micropterus</i> spp.	0	3	0	14	1	0	0	0	0	18	1.29	5-15
<i>Strongylura marina</i>	0	0	7	0	0	0	0	0	0	7	0.50	17-21
Percidae	2	0	1	1	4	3	0	0	0	11	0.79	11-14
<i>Pomoxis</i> spp.	0	0	0	13	0	0	0	0	0	13	0.94	9-14
Total	30	43	347	591	176	67	61	42	31	1388		

Catostomidae = *Ictiobus* spp./Carpoides spp.; Cyprinidae = not identified; Clupeidae = Dorosoma spp.; Cyprinodontidae = Fundulus olivaceus/Fundulus notatus; Percidae = Percina spp.

Table 2
Relative importance of plant species identified
in the studied cove, Aliceville Lake,
March-August 1998

Plant species	Relative percentage
Water hyacinth (<i>Eichhornia crassipes</i>)	64.27
Giant duckweed (<i>Spirodela polyrhiza</i>)	0.55
Alligatorweed (<i>Althernanthera philoxeroides</i>)	5.51
Waterprimrose (<i>Ludwigia hexapetala</i>)	3.84
Hydrilla (<i>Hydrilla verticillata</i>)	14.27
Conespur bladderwort (<i>Utricularia gibba</i>)	1.21
Curlyleaf pondweed (<i>Potamogeton crispus</i>)	2.43
Najas (<i>Najas</i> spp.)	0.05
Eurasian watermilfoil (<i>Myriophyllum spicatum</i>)	0.72
Fanwort (<i>Cabomba caroliniana</i>)	0.27
Coontail (<i>Ceratophyllum demersum</i>)	3.02
Filamentous algae	4.40

matrix and scores based on physicochemical and habitat structure variables was rejected.

Only four fish taxa were sufficiently well represented in all months to render reliable regression models. The stepwise multiple linear regression suggested that only physicochemical variables were significantly correlated with abundance of more than one taxon (Table 7). Depth and distance from the shore appeared as the most important single components of habitat

Table 3
Mean (\pm SE) of physicochemical and habitat
structure variables measured at trap sites
(N = 102) in Aliceville Lake, March-August 1998

Microhabitat variable	Mean \pm SE
Depth (m)	0.77 \pm 0.03
Distance from the shore (m)	26.09 \pm 1.77
Dissolved oxygen (mean, mg/L)	5.56 \pm 0.25
Dissolved oxygen (evening, mg/L)	6.65 \pm 0.36
Dissolved oxygen (morning, mg/L)	4.49 \pm 0.29
pH (mean)	7.21 \pm 0.02
pH (evening)	7.25 \pm 0.02
pH (morning)	7.17 \pm 0.02
Temperature (mean, °C)	29.03 \pm 0.47
Temperature (evening, °C)	29.70 \pm 0.45
Temperature (morning, °C)	28.39 \pm 0.55
Turbidity (NTU)	15.84 \pm 2.25
Aquatic vegetation dry weight (g/m ²)	158.72 \pm 21.72
Emergent vegetation (%)	5.45 \pm 1.64
Floating vegetation (%)	39.19 \pm 3.88
Submergent vegetation (%)	13.47 \pm 2.44
Filamentous algae (%)	2.68 \pm 0.87
Plant coverage (%)	61.10 \pm 3.79

structure. Plant coverage was not significantly related to total or any individual taxa CPUEs.

Discussion

Rejection of the null hypothesis of no relation between ordination axis scores generated by DCA based on the fish matrix, and scores generated by the PCA based on the physicochemical and habitat structure variables, confirmed a significant association between fish abundance and physicochemi-

Table 4
 Mean CPUE (fish/h) for larval fishes collected from Aliceville Lake, March-August 1998.
 The standard error of the mean is in parentheses

	Mar 28	Apr 29	May 14	May 26	Jun 27	Jul 08	Jul 24	Aug 07	Aug 21
Catostomidae	0.00	0.01 (0.01)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.03 (0.03)	0.01 (0.01)	0.00	0.00	0.00	0.00	0.00	0.01 (0.01)
Clupeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01 (0.01)
<i>Elasoma zonatum</i>	0.11 (0.10)	0.05 (0.03)	0.05 (0.02)	0.27 (0.12)	0.03 (0.02)	0.00	0.00	0.00	0.00
Cyprinodontidae	0.01 (0.01)	0.03 (0.01)	0.01 (0.01)	0.03 (0.01)	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00	0.00
<i>Gambusia affinis</i>	0.03 (0.01)	0.04 (0.02)	0.12 (0.04)	1.04 (0.28)	0.35 (0.15)	0.05 (0.02)	0.05 (0.03)	0.05 (0.02)	0.02 (0.01)
<i>Labidesthes sicculus</i>	0.02 (0.01)	0.02 (0.01)	0.14 (0.08)	0.16 (0.08)	0.14 (0.05)	0.01 (0.01)	0.00	0.00	0.01 (0.01)
<i>Lepomis</i> spp.	0.01 (0.01)	0.01 (0.01)	1.44 (0.99)	1.47 (1.01)	0.39 (0.16)	0.28 (0.10)	0.30 (0.05)	0.18 (0.07)	0.12 (0.04)
<i>Micropterus</i> spp.	0.00	0.02 (0.01)	0.00	0.07 (0.02)	0.01 (0.01)	0.00	0.00	0.00	0.00
<i>Strongylura marina</i>	0.00	0.00	0.04 (0.03)	0.00	0.00	0.00	0.00	0.00	0.00
Percidae	0.01 (0.01)	0.00	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.02 (0.01)	0.00	0.00	0.00
<i>Pomoxis</i> spp.	0.00	0.00	0.00	0.07 (0.04)	0.00	0.00	0.00	0.00	0.00

Table 5
Loadings of principal components (PC1 and PC2) for the principal component analysis on all individual and averaged physicochemical variables, Aliceville Lake, March-August 1998

Variable	PC1	PC2
Depth (m)	-0.1778	0.3397
Distance from shore (m)	0.0355	0.2012
Mean temperature (°C)	0.3240	-0.4269
Mean dissolved oxygen (mg/L)	-0.3842	-0.1988
Mean pH	-0.3745	-0.2926
Turbidity (NTU)	0.0784	-0.0367
Dissolved oxygen in the morning (mg/L)	-0.2139	-0.2224
pH in the morning	-0.3094	-0.3435
Temperature in the morning (°C)	0.3158	-0.3891
Dissolved oxygen in the evening (mg/L)	-0.3470	-0.0929
pH in the evening	-0.3499	-0.1880
Temperature in the evening (°C)	0.2900	-0.4154

Table 6
Results of the Tukey's HSD test on scores of the first principal component for the principal component analysis on all individual and averaged physicochemical variables, Aliceville Lake, March-August 1998. Site category (C1 = 0-25%, C2 = 25-50%, C3 = 50-75%, C4 = 75-100%) represents plant coverage categories. Asterisk means no significant differences. F for the model = 15.98, P < 0.01

Mean	N	Site Category
2.2458	26	C1
0.0967*	8	C3
-0.1993*	9	C2
-0.9724*	59	C4

cal and habitat structure variables. This approach has been used by others (e.g., 20, 34), and it is based on the philosophy that environmental variables likely operated in concert with each other as a multivariate system, and not as isolated variables (14, 35). However, further analyses (PCA, multiple linear regression) failed to identify plant coverage as an important variable to physically characterize the cove or to explain variability in fish catch rates.

Regression analysis confirmed that no single variable accounted for a significant amount of variation in either total or individual fish CPUE, and that the community structure of fish early life stages in Aliceville Lake was only correlated with combinations of variables. Some measurements related to habitat structure, particularly depth and distance from the shore, and factors related to productivity, particularly pH, were detected as significantly related to CPUE, al-

Table 7
 Loadings of principal components (PC1 and PC2) for the principal component analysis on all individual and averaged physicochemical variables plus habitat structure variables, Aliceville Lake, March-August 1998

Variable	PC1	PC2
Depth (m)	-0.1706	0.1093
Distance from shore (m)	0.0409	-0.0084
Mean Temperature (°C)	0.2871	-0.3599
Mean dissolved oxygen (mg/L)	-0.3724	-0.1260
Mean pH	-0.3571	-0.1054
Turbidity (NTU)	0.0747	0.0833
Dissolved oxygen in the morning	-0.2163	-0.2365
pH in the morning	-0.2966	-0.1408
Temperature in the morning (°C)	0.2787	-0.3606
Dissolved oxygen in the evening	-0.3308	0.0101
pH in the evening	-0.3339	-0.0581
Temperature in the evening	0.2573	-0.3147
Plant coverage (%)	0.2479	0.3212
Filamentous algae	-0.0957	0.1995
Floating vegetation	0.1545	0.3206
Submergent vegetation	0.1234	-0.2176
Emergent vegetation	0.0742	0.2096
Aquatic vegetation dry weight (g/m ²)	0.0122	0.4233

though the total variation explained by these models was low. For example, mosquitofish inhabited near shore and turbid waters, whereas sunfish (*Lepomis* spp.) inhabited warm waters and brook silverside and banded pygmy sunfish inhabited shallow waters (Table 7). Nevertheless, evidences from our study demonstrate that aquatic plants modify and create habitat availability in ways different than structural complexity.

Different physicochemical environments associated to the different levels of plant coverage were effectively detected by PCA. Trap sites characterized by low plant coverage scored higher means than sites

with intermediate and high plant coverage, suggesting that plant coverage affected the physicochemical structure of the water in the cove. Once plant coverage reached a level of 25%, no discernible differences in the physicochemical structure were detected thereafter. This suggested that the indirect effect plants have on habitat may be more important than the direct effects of plant structure. The structure of aquatic plants affects physical environment and fish habitat by altering velocity of waves and currents, and sedimentation patterns and substrates (36-37). Submersed vegetation may also establish gradients in water clarity (38) and other physical parameters, including light and temperature. Available light at the

Table 8
Scores of detrended correspondence analysis axes (DCA1 and DCA2) for larval fish taxa collected from Aliceville Lake, March-August 1998 (λ represents eigenvalues)

Taxa	DCA1 ($\lambda = 0.751$)	DCA2 ($\lambda = 0.276$)
<i>Elassoma zonatum</i>	403	156
<i>Micropterus</i> spp.	289	223
<i>Gambusia affinis</i>	287	0
Cyprinodontidae ¹	277	293
Catostomidae ²	273	390
<i>Pomoxis</i> spp.	209	185
<i>Strongylura marina</i>	173	-79
<i>Labidesthes sicculus</i>	160	186
Percidae ³	126	40
<i>Lepomis</i> spp.	112	96
Clupeidae ⁴	-8	122
Cyprinidae ⁵	-38	101

¹Cyprinodontidae: *Fundulus* spp. ²Catostomidae: *Ictiobus* spp. ³Percidae: *Percina* spp. ⁴Clupeidae: *Dorosoma* spp. ⁵Cyprinidae: unidentified.

Table 9
Multiple regression models among physicochemical and habitat structure variables and log_e-transformed CPUE of selected and total larval fish collected from Aliceville Lake, March-August 1998

<i>Lepomis</i> spp.	= -4.326 + 0.494 pHe ¹ + 0.032 Te ²	R ² = 0.130	P < 0.01
<i>Labidesthes sicculus</i>	= -1.259 - 0.099 D ³ + 0.005 Tm ⁴ + 0.166 pHe	R ² = 0.201	P < 0.01
<i>Gambusia affinis</i>	= 0.173 - 0.004 DS ⁵ + 0.005 TUR ⁶	R ² = 0.249	P < 0.01
<i>Elassoma zonatum</i>	= 0.102 - 0.002 D	R ² = 0.075	P < 0.01
Total	= -4.467 - 0.022 DS + 0.121 Te	R ² = 0.340	P < 0.01

¹pHe = evening pH. ²Te = evening temperature. ³D = depth. ⁴Tm = morning temperature. ⁵DS = distance from the shore. ⁶TUR = turbidity.

bottom of plant beds may be reduced to as little as 0.01% of surface levels (39). Dale and Gillespie (40) observed that the daily cycle and distributions of temperatures in Lake Opinicon, Ontario were greatly influenced by submersed vegetation.

Our data suggest that low levels of plant coverage modify physicochemical characteristics within vegetated microhabitats by increasing temperature and DO. This may positively influence and provide habitat for spawning and early life stages of

fish. In early spring when water is still cool, the increase in water temperature and DO may encourage and prolong spawning. Fish in Aliceville Lake tend to spawn earlier than reported in other systems (21), which could be a consequence of high water temperatures owing to low plant coverage. At this point, further investigation is necessary to better understand these complex relations.

Although discussing roles of physicochemical factors and aquatic plants on fish recruitment regulation is beyond the objective of this paper, we believe our results contribute to gain some insight on this subject. Our analyses provide information concerning effects of aquatic vegetation on the physicochemical characteristics within microhabitats important to spawning and young fish. Although the direct effect of plant coverage was not detected by the statistical techniques we used, our data suggest low plant coverage provide early life stages of fish with a good quality habitat. The identification of appropriate level at which aquatic vegetation provides quality habitat for early life stages of fish is important for successful fisheries and aquatic plant management.

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